EXHIBIT 10

PR NA270Z0347-01 1992/93

Nonpoint-Source Pollution at the Fajardo River Basin, Puerto Rico

Félix A. Grana-Raffucci
Mayra T. García-Pérez

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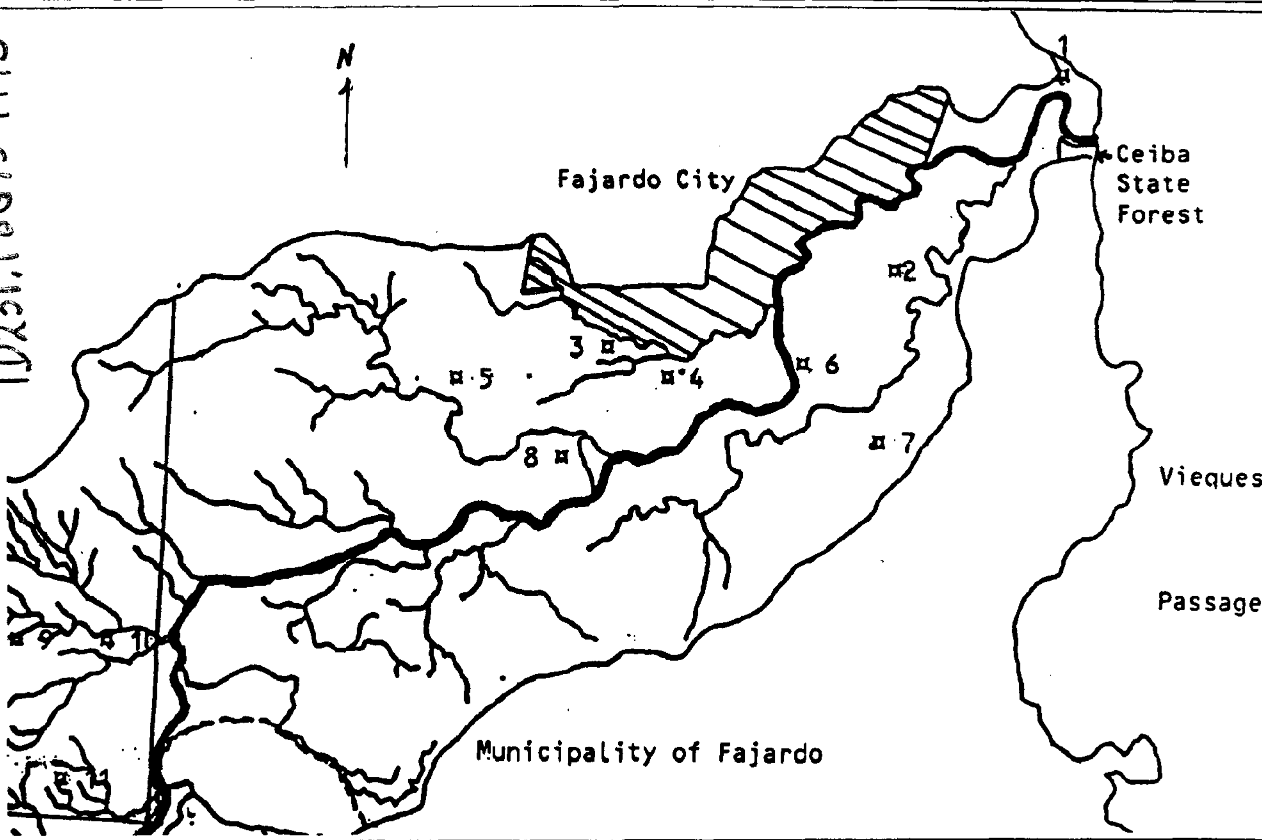

Final Report Task 7.2
Coastal Zone Management Program
Scientific Research Area
Department of Natural Resources
San Juan, Puerto Rico

A report of Puerto Rico Department of Natural Resources to the National Oceanic and Atmospheric Administration pursuant to NOAA Award No. NA270Z0347-01

Un informe del Departamento de Recursos Naturales de Puerto Rico a la Administración Oceánica y Atmosférica Nacional conducente al Fondo NOAA No. NA270Z0347-01

Nonpoint-Source Pollution at the Fajardo River Basin, Puerto Rico

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EXECUTIVE SUMMARY

During the last thirty years, at least, surface and ground water resources in Puerto Rico have been impacted by large quantities of various kinds of pollutants of both the point-source and nonpoint-source varieties. Nonpoint source pollutants are diffuse, both in terms of origins and in the ways they reach water bodies. These pollutants originates mostly from different human activities: landfills, crop and animal farms, urban and rural communities' runoff and waste leakage, soil movement and extraction, construction projects, deforestation, marinas, etc. The Fajardo River basin, though relatively small, is representative of the development of hydrological basins in Puerto Rico and the impact this development brought. Geology and soil type, land use, water management practices, biodiversity, and water quality history for the basin were researched and are discussed. Field interviews to parties involved in one way or another in nonpoint source pollution in the basin were done. Based on the information presented, a series of recommendations leading to control nonpoint source pollution at the basin is offered.

ACKNOWLEDGEMENTS

We wish to thank the following persons whose help resulted indispensable for the succesful completion of this project: Ms. Ileana Pérez and the staff from DNR Laboratory; Mr. Carlos Padín (CZMP), Mr. Paulino Laguna (DNR-Water Resources), Mr. Eric Morales (EQB-Water Quality), Ms. Nitza Massini (DNR-Scientific Inventory), Mr. Israel Díaz, Mr. James Timber, Mr. Miguel Miranda, Mr. José Colón, (DNR-Marine Resources) and the staff of Consultations and Endorsements (DNR).

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I. INTRODUCTION

Point-source pollution is clearly identified with a well-defined location or place. Gross pollution of this kind have, in large part, been brought under control. Government, by requiring permits and impact evaluations, has created mechanisms whereby technology to treat these polluters can be mandated, and the effect of such technology can be monitored. This success is at best a partial one; water pollution remains a serious problems. Sediment, nutrients, pathogenic organisms, and toxins still find their way into our waters, where thy degrade the ecosystem, pose health hazards, and impair the full use of aquatic resources.

Nonpoint-source pollution or NPSP (unlike pollution from point sources) is diffuse, both in terms of its origin and in the manner in which it enters ground and surface waters. It results from a variety of human activities that take place over a wide geographic area. Pollutants from nonpoint sources usually find their way into water bodies in sudden surges associated with rainfall, in addition to constant slow percolation from other sources. The most significant sources of NPSP are:

1. Agricultural activities: Including sediments from eroded croplands and overgrazed pastures, fertilizers, animal wastes, pesticides, etc.
2. Runoff: From roads, sewers, and urban areas. Industrial stormwater discharges and runoff from sewers serving populations of 100,000 or more are considered point sources.
3. Hydromodification: Reservoir or dam construction, stream channelization, flood prevention projects, etc.

4. Abandoned mines and other resource-extraction operations: Active mines are considered point sources.
5. Forestry operations
6. Construction: Produces toxic materials and huge sediment loads. Construction activities disturbing five acres or more are considered point sources.
7. Waste disposal on land: Largely leakage form septic tanks and the spreading of sewage sludge.
8. Marinas: Responsible for important spills of oils, greases, paints, metals, wastewaters, and others.

Often, the full effect of NPSP cannot be measured in terms of water contamination alone: loss of topsoil due to erosion has a negative impact on agricultural productivity and damages structures, roads and ditches. Sediments can destroy breeding grounds for fish and other wildlife. Carried all the way to the sea, sediments kill entire marine communities, such as coral reefs and seagrass prairies. Increased levels of sediment mean increased costs for dredging harbors and treating wastewaters.

Unfortunately, there is no practical way to write a permit for every agricultural field because NPSP is not affected by discharge controls of individual pipes or outfalls. Further, NPSP occurs as a direct result of land use planning and zoning. Control strategies for NPSP proceed from two basic principles involving land use practices:

1. Measures can be taken to increase the ability of land to retain water, thereby reducing runoff to streams, lakes, and the sea.
2. The kinds and amounts of pollutants swept away in runoff can be minimized.

Puerto Rico has 100 hydrological basins, all showing signs of NPSP. In fact, the Environmental Quality Board of Puerto Rico (EQB) considers that NPSP currently presents "a serious threat to the quality of surface and groundwaters, risking human health and the environment". As a result of these and other human activities, EQB recently determined that impairment of designated uses in rivers amounts to 73% of total area for aquatic life, 71% for swimming, 69% for drinking water, and 63% for secondary contact recreation. At estuaries, impairment for designated uses were determined as 64% of total area for aquatic life, 66% for swimming, and 58% for secondary contact recreation. The main sources to which these results were related included for rivers: land disposal, agriculture, urban runoff, and natural sources (intermittence of streams, soil types, rains, etc.); and for estuaries: urban runoff, storm sewer discharges, and land disposal. This document reports on the Fajardo River Basin, a small basin chosen because it was considered representative, at a small scale, of problems with NPSP throughout Puerto Rico.

II. OVERVIEW OF EXISTING GOVERNMENT EFFORTS IN PUERTO RICO TO CONTROL NONPOINT SOURCE POLLUTION

1. Federal level

Federal agencies expect that state nonpoint source programs build on and complement, rather than duplicate and conflict with, other Federal statutory requirements and state implemented programs. State nonpoint source agencies are encouraged to work with these programs in implementing their programs.

Environmental Protection Agency (EPA)

1. Clean Water Act Section 319 - Nonpoint Source Program

A number of local, state and Federal programs have been implemented over time to address nonpoint source pollution. However, the first national program to authorize Federal funding for the control of nonpoint sources began in 1987 when Congress passed the Water Quality Act of 1987, enacting section 319 of the Clean Water Act, which established a national program to control nonpoint sources of water pollution. Section 319 requires that, in order to be eligible for federal funding, states develop an assessment report detailing the extent of nonpoint pollution, and a management program specifying nonpoint source controls. Section 319 authorizes EPA to issue grants to states to assist them in implementing their nonpoint source management programs or portions of management programs that have been approved by EPA.

2. Clean Water Act Section 320 - National Estuary Program

EPA also administers the National Estuary Program under section 320 of the Clean Water Act. This program focuses on point and nonpoint pollution in geographically targeted, high-priority estuarine waters. Under this program, EPA assists state, regional and local governments in developing estuary-specific comprehensive conservation and management plans that recommend corrective actions to restore and maintain estuarine water quality and to protect fish populations and other designated uses of these targeted waters. In Puerto Rico, one estuarine system (San Juan Bay) has been designated as part of the National Estuary Program.

3. Near Coastal Waters Program

The Near Coastal Waters (NCW) Program serves as a primary vehicle for implementing environmental protection in coastal areas under a variety of programs and authorities. It is also the framework for coastal regions for carrying-out Agency directives, strategic themes, and other initiatives not specifically related to distinct program issues. Examples of these cross-cutting themes include geographic targeting for management attention; pollution prevention; and setting priorities based on the expected efficacy of preventive measures as well as the magnitude of ecological or human health risks.

4. Ground-Water Protection Programs

EPA has a number of programs, in addition to section 319, to control nonpoint source pollution of ground-water. Since at least 1984, ground-water protection programs have provided technical and financial assistance to states for the development of state ground-water strategies and, more recently, Groundwater Protection Programs. Under the Safe Drinking Water Act, EPA may designate sole source aquifers. These are aquifers that are the sole or principal of drinking water source for an area. At EPA's discretion, no commitment for federal funds can be made for projects that will contaminate these aquifers. In addition, the 1986 amendments to the Safe Drinking Water Act established a Wellhead Protection program. This program was created to protect ground waters that supply wells and wellfields that contribute to public drinking water supply systems. USDA and EPA are also cooperating under a program to assess private drinking water wells on farmsteads.

5. Pesticides Program

EPA's pesticides program under the Federal Insecticide, Fungicide, and Rodenticide Act addresses some forms of nonpoint pollution. Among other things, this statute authorizes EPA to control pesticides that may threaten ground water and surface waters. Pesticide State Management Plans will be developed by state agriculture, water/environment, and health agencies and will prescribe pesticide application measures to protect ground water that is vulnerable to pesticide contamination. Required components of these Plans will include: state philosophy and goals, state roles and responsibilities, legal authority, resources, assessment and planning, monitoring, prevention, response, enforcement, public awareness and participation,information dissemination, and records and reporting.

6. Wetlands Protection Program

EPA's wetlands program also has undertaken a number of projects to increase awareness of the relationship between the protection and restoration of wetlands and nonpoint source control. In 1990, the agency developed guidance to encourage coordination of nonpoint sources and wetlands programs, both within EPA and the states, to attain water quality goals shared by the two programs. In addition, EPA has released technical guidance on how to ensure effective application of water quality standards to wetlands.

The Wetlands Division is working with several agencies to develop methods and transfer information on protecting and restoring wetlands in ways which can be expected to provide nonpoint source abatement benefits. EPA is providing support for the development of criteria to address the many types of nonpoint source pollutants including nutrients, clean sediment, and organic contaminants (e.g., pesticides). The Wetlands Division is assisting in the development of wildlife criteria applicable to all waterbody types and biological criteria for wetlands.

National Oceanic and Atmospheric Administration (NOAA)

Coastal Zone Management Program

The Coastal Zone Management Act of 1972 established a program for states and territories to voluntarily develop comprehensive programs to protect and manage coastal resources. In order to receive Federal approval and implementation funding, states and territories must demonstrate that they have programs, including enforceable policies that are sufficiently comprehensive and specific to regulate land uses, water uses, and coastal development; and to resolve conflicts among competing uses. In addition, they must have the authority to implement the enforceable policies. The programs operates within a coastal zone bound any which includes coastal waters and those which have a direct one significant impact on coastal waters.

This program must protect and manage important coastal resources, including: wetlands, estuaries, beaches, dunes, barrier islands, coral reefs, and fish and wildlife and their habitats. Resource management and protection is accomplished in a number of ways through state laws, regulations, permits, and local plans and zoning ordinances. While water quality protection is integral to the management of many coastal resources, it was not specifically cited as a purpose or policy of the original statute. The Coastal Zone Act Reauthorization Amendments of 1990 specifically charged state coastal programs, as well as state nonpoint source programs, with addressing nonpoint source pollution affecting coastal water quality.

United States Department of Agriculture (USDA)

USDA's Agricultural Stabilization and Conservation Service (ASCS), Soil Conservation Service (SCS) and Extension Service administer a number of programs that contribute to reducing nonpoint pollution from agricultural production.

1. Agricultural Conservation Program

The Agricultural Conservation Program, administered by ASCS, provides cost-share funds to farmers and ranchers to install conservation practices. The program has several goals including: conserving soil and water, improving water quality, protecting and maintaining productive farm and ranch land, and preserving and developing wildlife habitat. ASCS also administers the Conservation Reserve Program (CRP), designed to protect the most highly erodible land and to protect and improve water quality. Under the CRP, farmers are reimbursed for retiring highly erodible and environmentally sensitive croplands from production under ten year contracts. Water quality improvements occur as lands are taken out of production because of-lower fertilizer and pesticide applications and because reductions in soil erosion decrease sediment loadings to water. Land enrolled in the reserve program also provides habitat and other environmental benefits. Criteria for the conservation reserve program have been expanded to include environmentally sensitive lands such as filter strips, wetlands and wellhead protection areas.

2. Soil Conservation Service

The Soil Conservation Services (SCS) is the technical arm of USDA. SCS provides technical assistance to conservation districts throughout the U. S. and Puerto Rico. Under the President's Water Quality Initiative, started in 1989, SCS is focusing some of its technical assistance on a number of demonstration projects to address water quality problems. SCS staff are also located in many of EPA's Regional Offices to provide technical assistance and support to the States and EPA. SCS is also providing accelerated technical assistance to multi-state, regional projects such as the National Estuary Program.

3. Nonpoint Source Hydrologic Unit Areas

In selected agricultural watersheds and aquifer recharge areas, SCS, Extension Service, and cooperating federal, state and local agencies will provide technical assistance and conservation planning to help farmers and ranchers meet state water quality goals without undue economic hardship. These hydrologic units are selected based on: significance of the agricultural sources of pollution, relative predominance of pollutants such as pesticides, nutrients, and animal wastes; and conformance with other water quality efforts. Findings on the water quality effects of selected conservation practices will provide a basis for expanding applications of such practices to other areas with similar water quality problems.

4. Forest Service

In Puerto Rico, the Forest Service manages approximately 14,400 acres of public lands at the Caribbean National Forest, part of the National Forest System. This agency shows increased concern regarding the potential impacts of sediment production from forest management activities on water quality and aquatic life. . It currently requires the implementation of Best

Management Practices Plans (BMPs) to any project carried out or proposed within Forest boundaries. These BMPs include provisions to prevent possible sources of NPSP.

5. President's Water Quality Initiative

In 1989, President Bush launched an initiative to protect ground and surface water from contamination of fertilizers and pesticides. Congress has funded the initiative in the past several years. USDA, EPA, USGS, and NOAA are all working together on this initiative through a series of work groups. Through this initiative, a number of watershed projects have begun to address fertilizer and pesticides problems. The agencies are tracking the implementation progress in these watersheds.

United States Geological Survey (USGS)

EPA and the U.S. Geological Survey have signed a memorandum of understanding (MOU) pledging cooperation and collaboration on water quality monitoring and assessment activities. Both agencies expend much effort on monitoring and assessment activities and the MOU is a tool to coordinate these efforts. USGS has a similar agreement with Puerto Rico's Environmental Quality Board.

Related Federal laws and regulations

a. The Clean Water Act (CWA) (33 USC 1251, et seq.)

b. The Rivers and Harbours Act (RHA) (33 USC 401 et seq.).

c. Endangered Species Act (ESA) - 1973

d. Act for the Protection of Marine Mammals (1972) (16 USC 1361 et seq.).

e. Food Security Act, 1986 (16 USC 3821, et seq.).

f. Emergency Wetlands Resources Act of 1986 (PL-99-645).

g. Executive order Num. 11990, emitted by President J. Carter on May 24, 1977 (42 CFR 26961).

h. Coastal Areas Management Act (1972) (16 USC 1451 et seq.).

2. Commonwealth level

Environmental Quality Board (EQB)

EQB is the local government agency with the legal responsibility to implement federal and state laws and regulations concerning pollution in Puerto Rico, it is the local "Lead Agency" concerning all types of pollution. It has designated a Nonpoint Source Division under the Water Quality Area with the main objective of controlling nonpoint source pollution from livestock farms, and from sewage disposal in small communities. They address the first by requiring livestock farms to implement Best Management Plans (BMPs). By agreement with Puerto Rico's Department of Agriculture (PRDA) and the federal Department of Agriculture (USDA), farms found in violation of their BMPs can loose subsidies and services offered by PRDA and USDA. The implementation of these Plans is monitored by both EQB and PRDA personnel. To address the second, EQB may provide financial assistance for the construction of wastewater treatment works in rural communities. Estuaries and wetlands conservation and management is another concern of this Division, and EQB may also provide financial assistance to deal with these problems.

As part of this Division tasks, EQB collects surface and ground water quality data both from its own Water Quality Monitoring Network and from monitoring stations operated by the United States Geological Survey (USGS). This data, together with information provided by BMPs and other permits applications (like is analyzed to pinpoint probable sources of NPSP in Puerto Rico's major river basins.

Certain EQB programs related to point-source pollution, like requiring *Erosion and Sedimentation Control Plans* to major construction projects, and the emission of *National Pollutant Discharge and Emission System* (NPDES) permits, are a source of useful data for evaluating the impact of non-point source pollution at specific areas.

Related laws and regulations:

-Act 9 of 1970 (Environmental Public Policy Act)
Established the Environmental Quality Board as the agency in charge of the surveillance, management and conservation of the quality of air, waters and soils in Puerto Rico.

-Regulation of Environmental Impact Statements (1984).
EQB fulfill this mandate through the evaluation of Environmental Impact Statements and other environmental documents.

- Water Quality Standards Regulation (1990).
Based on current EPA water quality standards, this regulation established similar standards for Puerto Rico. Currently it does not include standards or use classifications for wetlands, but includes an anti-degradation statement applicable to wetlands.

- Regulation for Hazardous and Non-Hazardous Solid Waste Control (1983).

Department of Natural Resources (DNR)

The Department of Natural Resources is responsible for regulating the extraction of water, soil and minerals through the emission of corresponding permits. It evaluates any project which includes the above-mentioned activities, and potential for non-point source pollution is one of the elements considered. DNR is also responsible for ensuring the conservation of natural aquatic and terrestrial ecosystems. Extraordinary episodes , like fuel spills and fish kills, are monitored by DNR.

Though not an integral part of DNR, the *Coastal Zone Management Program of Puerto Rico (CZMP)* is ascribed to this agency. CZMP regulates development activities within the coastal zone of Puerto Rico by proposing to the Planning Board the designation of natural reserves and areas "of special planning", in which certain human activities are restricted.

Related laws and regulations:

-Act 23 of 1972 (Organic Act of the Department of Natural Resources)
Established the Department of Natural Resources as the state agency in charge of the protection, surveillance and conservation of all natural resources of Puerto Rico, including water resources and aquatic biota.

-Act 83 of 1936, as amended (Fishing Act)
For fishing conservation; conservation of aquatic habitats is required since they are fundamental for the life cycle of many fish species.

-Act 6 of 1968 (pursuant to flood prevention and conservation of beaches and rivers). DNR is responsible for providing surveillance and protection to swamps, beaches, and rivers of the Commonwealth of Puerto Rico.

-Act 133 of 1975 (Forests Act).
DNR is responsible for the conservation, protection, and management of the forests of the Commonwealth of Puerto Rico.

-Act 70 of 1976 (Wildlife Act).
For the protection of wildlife and its habitats.

-Act 1 of 1977 (DNR Corps of Rangers Act).
Establishes the Corps of Rangers as the law-enforcement division of PRDNR and its statutes.

-Act 6 of 1961, as amended.
Stipulates that PRDNR is responsible for the surveillance and conservation of the Commonwealth's mangrove swamps.

-Act 144 of 1976 (Act for the Control of Excavation and Extraction of Land).

-Spanish Act of Harbors and Rivers of 1896.
Established the maritime-terrestrial zone as a public domain, including mangrove swamps.

-Regulation for the Protection of Endangered Species and Critical Wildlife Management Areas in the Commonwealth of Puerto Rico (1985).

-Regulation for the Development, Use, Conservation and Management of the Waters of Puerto Rico (1992).
Regulates the extraction of ground and surface water in Puerto Rico.

-Regulation for the Development, Surveillance, Conservation and Management of the Territorial Waters, the Lands Under Them and the Maritime-Terrestrial Zone (1992).
It establishes zones of special concern or value in the maritime-terrestrial zone and territorial waters and regulates construction and extraction projects within those areas.

Planning Board (PB)

PB is in charge of establishing land zoning and designating corresponding planning objectives. As such, it is the PB the lead agency in the evaluation of development projects. It is also the state organism with legal power to designate state forests and reserves and other areas of special planning.

Related laws and regulations:

-Act 75 of 1975, as amended (Organic Act of the Planning Board of Puerto Rico)
Established the Planning Board as the agency in charge of preparing public policies and objectives regarding land use and zonification.

-Act 9 of 1970 (Environmental Public Policy Act)
Designated the Planning Board as the agency in charge of preparing public policies regarding environmental protection.

-Land Use Plan of Puerto Rico (1977)

-Integral Development Plan of Puerto Rico (1979)

Regulation 17, Regulation of Coastal Area Zonification and Beach and Coast Entrance.

Regulation 13, Regulation for Floodable Areas.

Regulation 4, Zoning Regulation (1989)

Regulation for Special Zoning of Non-urban Areas for the Municipalities Surrounding the Caribbean National Forest (1983).

Resolution Num. 74-21 (1974) to Preserve, Protect and Restore Mangrove Swamps in Puerto Rico.

Puerto Rico Department of Agriculture (PRDA)

PRDA is the local agency in charge of the development of agriculture and commercial fishing in Puerto Rico, including assignment of state and federal subsidies for agricultural production and other support services for farmers. Agreements signed by PRDA, USDA, and EQB give PRDA the joint responsibility (with EQB) of monitoring the implementation of Best Management Plans (BMPs) for livestock farms and for the suspension of all financial and technical support to farms found in violation of BMPs.

PRDA is also in charge of the application in Puerto Rico of all USDA programs.

Aqueducts and Sewers Authority (ASA)

ASA is in charge of developing sources of drinking and irrigation waters, of delivering these waters and of treating and disposing wastewaters according to federal and state laws and regulations. ASA is required NPDES permit for discharges from its wastewater and drinking water treatment plants and has been found in violation of these permits repeatedly by EPA. As a result, it has not only been forced to pay heavy fines, but also several of its plants had been temporarily arrested.

Regulations and Permits Administration (REPA)

-Act 76 of 1975, as amended.
Established REPA as the agency in charge of the enforcement of planning regulations promulgated by the Planning Board by reviewing applications for the necessary permits for regulated activities, land use and construction projects.

Solid Wastes Management Administration (SWMA)

-Act 70 of 1978, as amended.
Established SWMA as the agency in charge of assisting Commonwealth and local (municipal) governments in the development of infrastructure at the local and intermunicipal levels for the disposal and recycling of solid wastes.

Other applicable local legislation:

- Article IV of the Constitution of the Commonwealth of Puerto Rico (1952)
Established the use and conservation of Puerto Rico's natural resources as a constitutional right.

III. THE FAJARDO RIVER BASIN

The Fajardo River basin, located in northeastern Puerto Rico, covers some 118 km^2 mostly within the municipalities of Fajardo and Ceiba, from the Luquillo Sierra to the Vieques Passage, an arm of the Caribbean Sea (Figure 1). This is the definition of the basin used by the United States Geological Survey (USGS); the Department of Natural Resources (DNR) has used traditionally a wider definition which we did not agree with. The Basin, (as defined by USGS) contains the southern part of a small city (Fajardo; 40,000 people), rural neighborhoods, farms, a small local airport, one marina and a significant portion of the Caribbean National Forest, one of the few tropical montane rainforests within the National Forest Service system. The southern shoreline at the river mouth is covered by a small mangrove forest which is part of the Ceiba State Forest, managed by DNR.

Although development in the area concentrates immediately north of the basin. government and private interest in the basin *per se* is growing, as evidenced by projects under way for flood control measures at the Fajardo River mouth, enlargement of the local airport, an increasing number of commercial farms, and residential and road construction projects. Between 1989 and 1993, DNR approved 99 development projects' permits and endorsements (Figure 2) for the municipalities of Fajardo and Ceiba. 38.38% of them were for the reconstruction of public infrastructure, such as roads, docks and sewers. The Fajardo River has even been mentioned as the site of a possible new reservoir. There is already significant concern among environmentalists and community groups for the increase in silting of the River estuary and flooding along the river shore, and a reduction of fish stocks, allegedly due to past and current development within the basin.

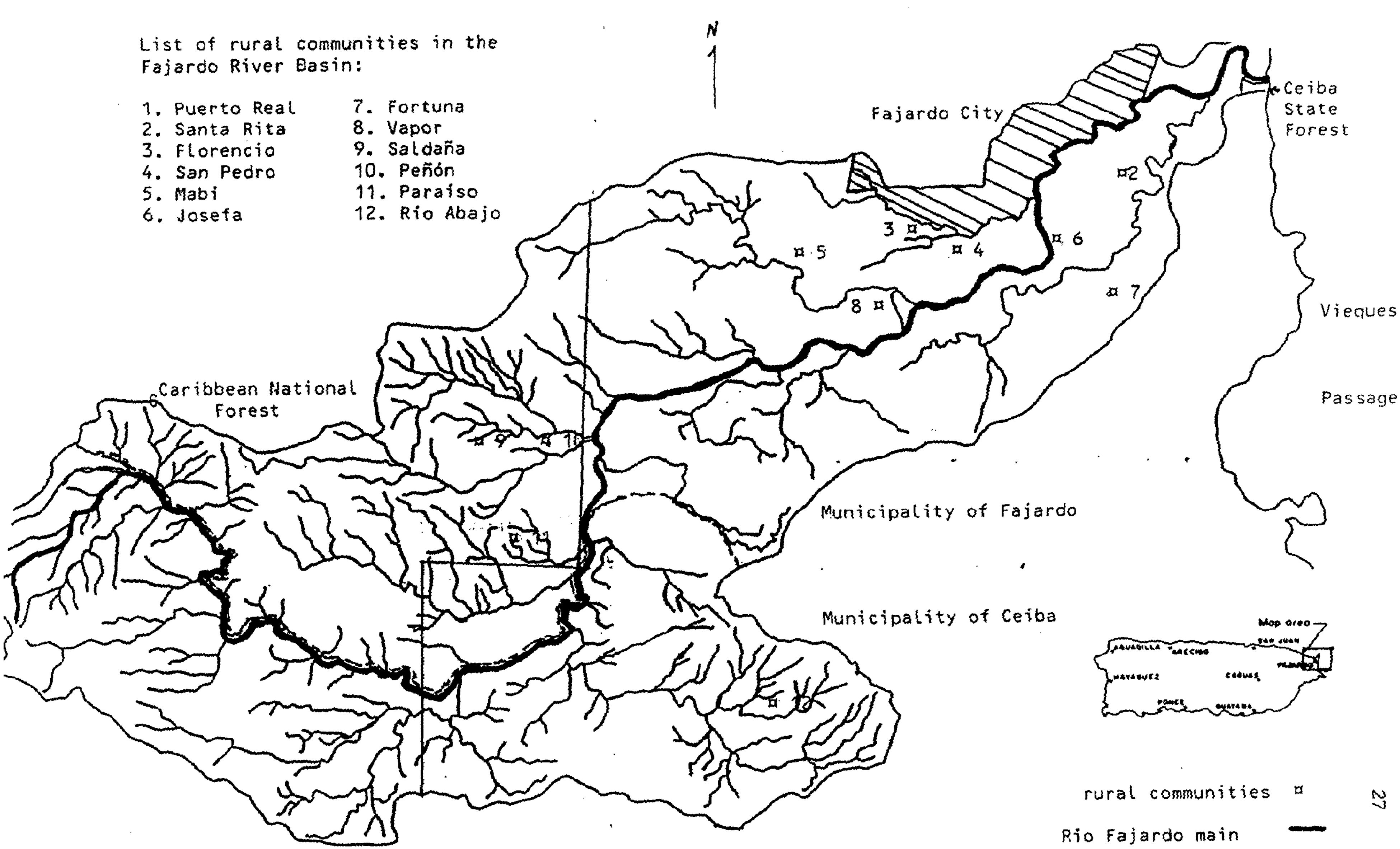

FIGURE 1: The Fajardo River Basin.

FIGURE : DNR-approved permits and indorsements; municipalities of Fajardo and Ceiba (1989-1993).
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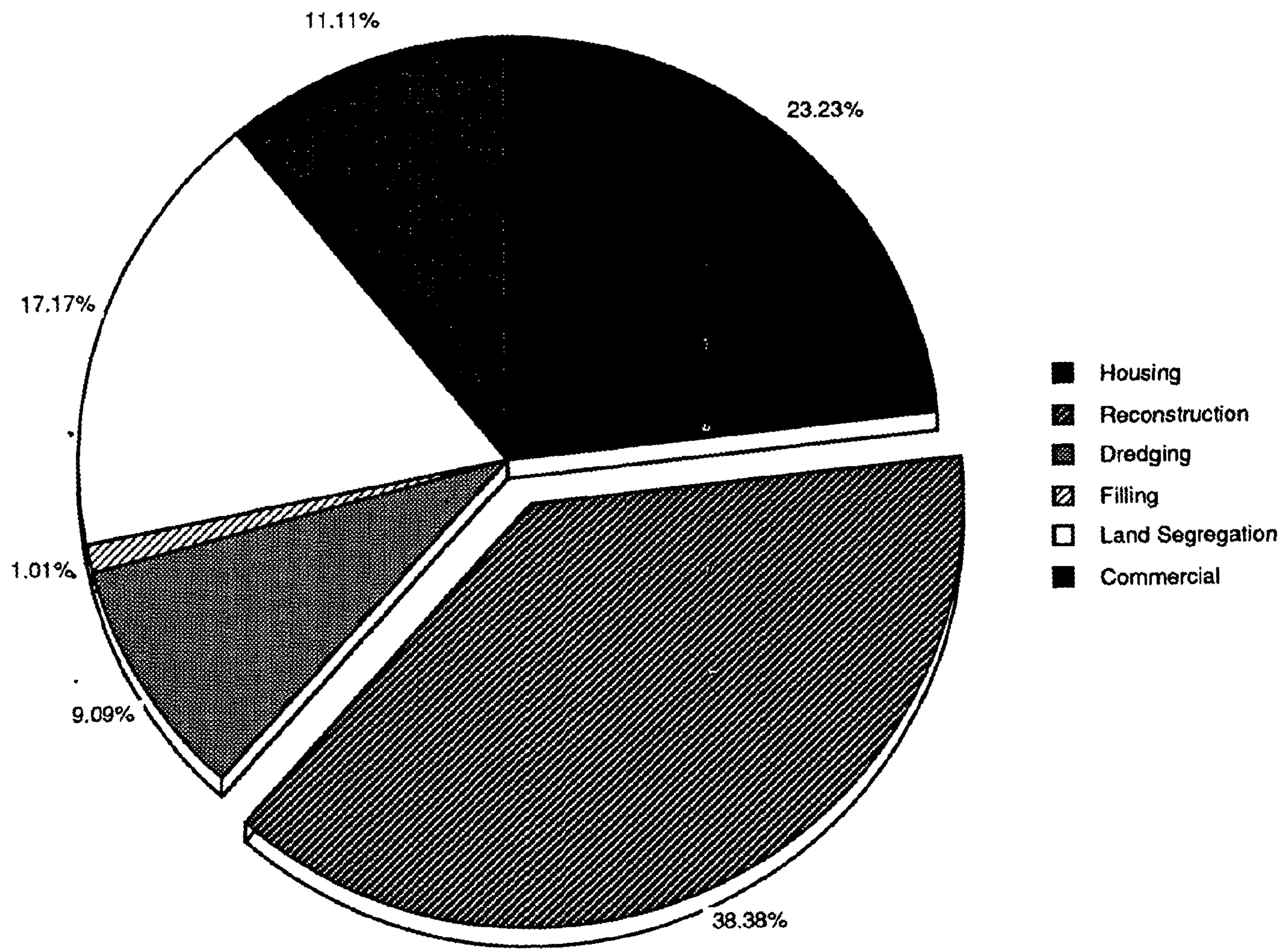


Goenaga and Cintrón (1979), and Goenaga *et al.* (1990) cited possible increased discharge of freshwater and sediment from the Fajardo River as one cause for degradation of coral reefs and seagrass communities located off the Fajardo coast and at the nearby Cordillera Keys.

The Fajardo River Basin is a typical Antillean mountain river basin. In its headwater it flows in narrow valleys, have steep gradients, and transport and deposit coarse sediments. The rural areas of the basin are forested in its western third, the Caribbean National Forest having most of this. The rest is used mainly by farms with a splash of growing rural communities. Cow farms are present throughout the basin. In the lowlands, multiple channels and depositional surfaces occur within the valley floor. Sugar cane is still heavily planted in the alluvial valley next to the city of Fajardo. Throughout the basin, there are many small plantain (a fruit closely related to bananas) farms, and also a few small farms dedicated to pigs, chicken, fruits (limes, papayas, grapefruits, oranges) or cassavas.

Land use

Available data on land use at the Fajardo River basin, obtained at the Scientific Inventory Division of DNR, came from aerial photographs on the area dating from 1971 and 1979, and was organized in thirteen zoning categories and compared (see Table 1). Categories that showed the largest increases in percentage of change during that period were: transportation (+67.00%), communications (+50.00%), and forests (+38.39%). In terms of absolute measurements, though, only the category of forests presented considerable increase (+8.76 km^2). On the other hand, the largest decreases in percentage of change corresponded to agriculture (-36.09%), and wetlands (-31.03%), while the largest decrease in area was also in agriculture (-19.62 km^2).

From this data one would expect that during the period 1971-1979, due to a reduction in agricultural lands and increases in forest area, and construction of transportation and communications projects, the generation of pollutants related to agricultural activities (fecal streptococci and coliforms, phosphates and nitrates, among others) would have decreased. An increase in forests would mean a larger capacity of soils to retain water, so measurements of water discharge would show diminished amounts. Finally, an increase in construction projects could have generated larger sediment loads in the river. While visiting the area working on this project (1992), the authors received the impression that significant portions of land were being cleared to be used for rural and urban construction, and for livestock farming.

TABLE 1: Comparison of land zoning categories for 1971 and 1979 at the Fajardo River Basin.

LAND USE	AREA 1971 (km^2)	PERCENTAGE (%)	AREA 1979 (km^2)	PERCENTAGE (%)	NET CHANGE (km^2)	% OF CHANGE
Agriculture	54.46	46.15	34.84	29.53	-19.62	-36.07
Forests	52.85	44.79	72.70	61.61	+8.76	+38.39
Wetlands	0.68	0.58	0.47	0.40	-0.28	-31.03
Non-productive	0.78	0.66	0.78	0.66	none	none
Residential, Urban	4.12	3.49	4.00	3.38	-0.74	-3.15
Residential, Rural	3.46	2.93	3.34	2.83	-0.63	-3.41
Recreational	0.58	0.49	0.50	0.42	-0.26	-2.00
Public Uses	0.40	0.31	0.44	0.37	-0.03	-8.38
Commercial	0.21	0.18	0.20	0.17	-0.04	-5.66
Industrial	0.28	0.24	0.30	0.25	+0.01	-4.00
Extractions	0.07	0.06	0.08	0.07	+0.01	+14.29
Transport	0.10	0.08	0.28	0.24	+0.14	+67.00
Communications	0.01	0.01	0.02	0.02	+0.01	+50.00
TOTAL	118.00	100.00	118.00	100.00	-----	-----

Geology, hydrology, geography and soils

More than a dozen geological faults cross the area of the Fajardo River basin. Most of them have a northwest-southeast orientation, although many also run from east to west. The western third of the basin, part of the Luquillo Sierra, comprises mostly mountains (some of them more than 670 m high) with steep slopes, and formed basicly from poorly cemented volcanic rock, sandstone and mudstone. Formations in these areas include cupric minerals and ferruginous clays. Soils here are thin, highly erodible, and highly acidic.

The other two thirds comprise of and alluvial plain of sand, clays and rock-and-pebble fields that broadens towards the river mouth, and then nears the mouth narrows again. To the west, north and south, this plain is bordered by hills formed of sandstone and mudstone. The alluvial plain is separated from the sea by mangrove swamp deposits. As one goes from west to east, soils gradually turn from thin to thick, from highly acidic to slightly acidic, and from highly erodible to erodible.

The area is within the "rain mantle" of the Luquillo Mountains, the first geographical stfucture in Puerto Rico that encounters moist-ladden trade winds blowing in a northeast-to-southwest direction from the Atlantic Ocean most of the year. When trade winds make contact with the warm surface of the mountains, most of their humidity condenses into rain. As a result, the Sierra receives an annual rainfall that ranges from 70 to 500 cm. Sudden, heavy rains has been held responsible for constant bleaching of soil minerals, frequent natural landslides and sudden large increases of water discharge of the Fajardo River and its tributary creeks which causes, among other things, significant erosion of riverbanks in periodic episodes. It is possible that these episodes of sudden, large water discharges serve as a flushing mechanism for, at least, some of the pollutants that percolates or fall into the Fajardo River. However, this mechanism's action probably stops at the very moment that freshwater coming down the river meets the saltier, denser water mass at the estuary.

Water management at the basin:

The Environmental Quality Board maintains a database of possible sources of NPSP in Puerto Rican rivers (we found, that for the Fajardo River, it needed updating). EQB, throughout its 1992 monitoring of point and nonpoint source pollution on Puerto Rican surface waters, found in the Fajardo River Basin high levels of pesticides, metals, and phenolic substances and attributed them to the Fajardo Drinking Water Plant, the Fajardo Wastewater Treatment Plant, the Ceiba Municipal Landfill, urban runoff, road construction, soil extraction operations, and local produce and livestock farms, as well as to natural causes (Figures 3, 7 & 8). In terms of use potential, EQB divides the river into five segments: estuary segment, recharge area segment, unclassified area segment, drinking water area segment, and

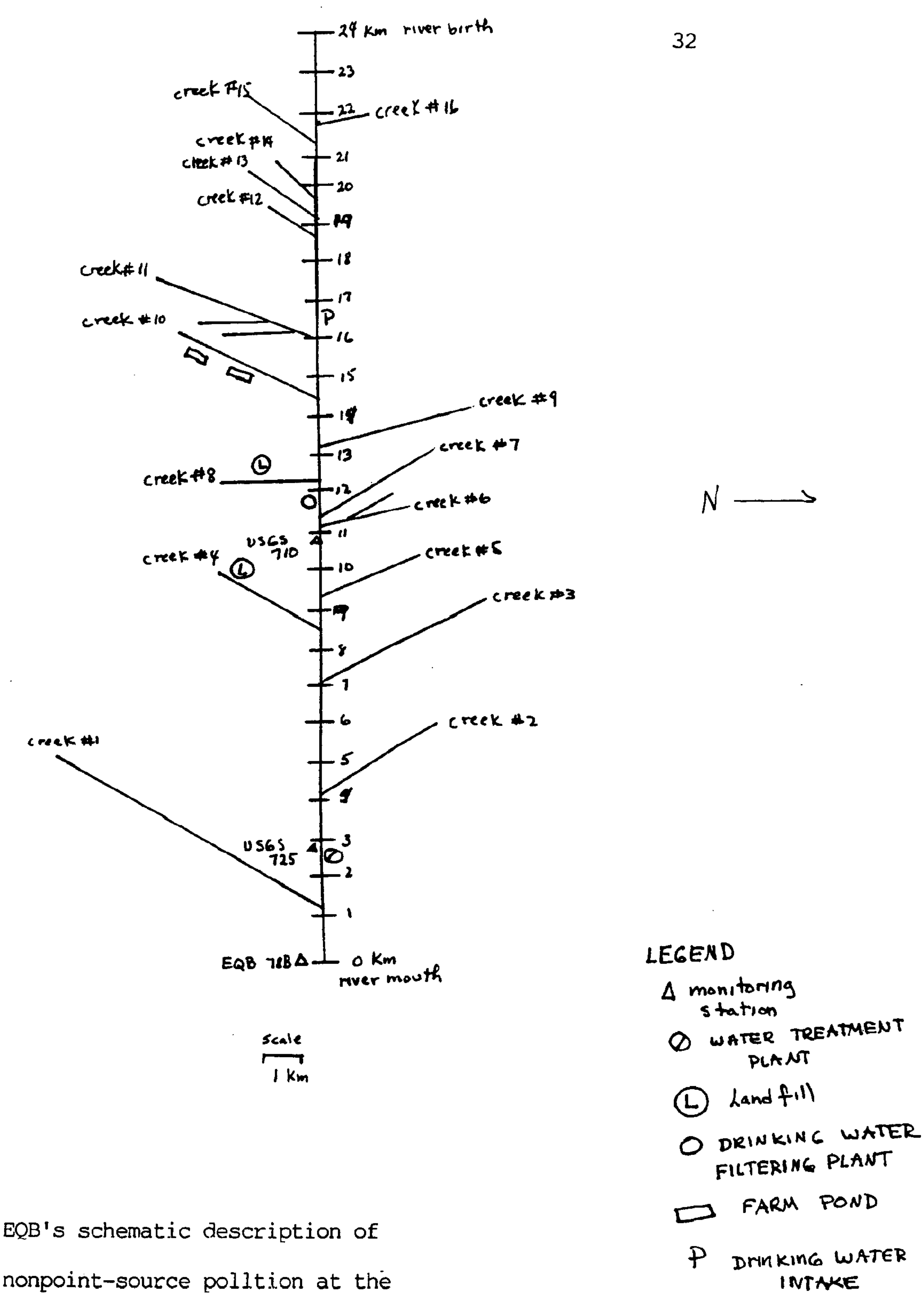


FIGURE 3: EQB's schematic description of nonpoint-source polltion at the Fajardo River.

ecologically sensitive area segment (Table 2). An EQB description of the estuary segment (the only segment description available) is shown in Table 3.

TABLE 2: EQB's use clasification of the Fajardo River.

SEGMENT	CLASSIFICATION	TRIBUTARIES INCLUDED
1. From the river mouth to 2.2 km upstream (Fajardo).	Estuary	
2. From the river mouth to Km 10.8 HW 976 upstream (Fajardo).	Recharge area	Redonda Creek
3. From the end of segment #2 upstream to Km 11.4 HW 976 (Fajardo).	Unclassified segment	
4. From the end of segment #3 (Fajardo) upstream to river's birthplace (Ceiba).	Drinking water area	Aguas Buenas Creek, Rincón Creek, Juan Diego Creek, Sonadora Creek
5. From Km 18.0 HW 976 (Fajardo) upstream to river's birthplace (Ceiba).	Ecologically sensitive area	

TABLE 3: EQB's use description of the estuary segment of the Fajardo River.

Water body name	Fajardo River
Water body segment type	Estuary
Water body segment size	2.0 miles
Segment evaluation	Estuarine
Aquatic life support	Partially supporting
Swimming	Partially supporting
Secondary contact	2.0 miles. Threatened by wastewaters.
Drinking Water Supply	Unfit for drinking
Overall	Partially supporting
Comments	Presence of urban runoff.

In terms of water properties and water quality parameters, EQB divides the river in two categories: "SC" (coastal-estuarine segment), and "SD" (all other surface waters). The Aqueducts and Sewers Authority has a Drinking Water Plant at , and a Wastewater Treatment Plant (Figures 7 & 8). This last plant discharges filter backwash to the river under a NPDES (National Pollutant Discharge and Elimination System) permit issued by EQB. Frequently, it has been found in violation of permit specifications (Table 4)

TABLE 4: NPDES permit limits imposedby EQB on ASA's wastewater plant filter backwash discharges unto the Fajardo R.

Rows	Parameters	NPDES Limits	Jan 1991	Feb 1991	Mar 1991	Apr 1991	May 1991
1	DO	>5 mg/l	•	•	•	•	•
2	Total Coliforms	10,000/100 ml	•	•	•	•	•
3	Fecal Coliforms	4,000/100 ml	•	•	•	•	•
4	Color	10 STU	•	•	•	•	•
5	Surfactants	100 µg/l	•	•	•	•	•
6	Flow	2.2 MGD	•	•	•	•	•
7	TSS	30-45 mg/l	•	•	•	•	•
8	Residual Chlorine	0.5 mg/l	•	•	1.2	•	1.2
9	Turbidity	50 NTU	1300	750	•	•	•
10	Phosphorus, total	1 mg/l	•	2.39	1.91	1.96	•
11	Copper	40 µg/l	80	•	•	60	•
12	Lead	50 µg/l	•	•	•	•	•
13	Zinc	50 µg/l	70	•	•	•	•
14	Fluoride	700 µg/l	•	•	•	•	•
15	Iron, total	300 µg/l	27000	2500	3800	3800	8910

Rows	Jul 1991	Aug 1991	Sep 1991	Oct 1991	Nov 1991	Dic 1991	Jan 1992
1	•	•	•	•	•	•	•
2	•	•	•	•	•	•	230000
3	•	•	•	•	•	•	230000
4	•	•	•	•	•	•	30
5	•	•	•	•	•	•	•
6	•	•	•	•	•	•	2.8
7	•	•	•	•	•	•	•
8	•	1.9	1.7	3	1.3	1.3	2.5
9	•	•	•	•	•	390	•
10	•	•	•	•	•	•	3.57
11	•	•	80	•	•	•	•
12	•	•	•	•	•	•	70
13	•	•	•	•	•	•	90
14	•	•	•	•	•	•	•
15	1200	6000	9000	5900	6450	6800	10000

Rows	Feb 1992	Mar 1992	Abr 1992	May 1992	Jun 1992	Jul 1992	Aug 1992
1	•	•	•	•	•	•	•
2	11000	70000	50000	23000000	13000000	•	•
3	•	30000	30000	13000000	3000000	•	•
4	25	50	45	35	30	45	30
5	1640	•	•	•	•	800	1000
6	2.54	•	3.25	4.26	2.91	•	3.09
7	•	•	82	79	35	40	•
8	2.6	3	2.8	2	2	4	8
9	•	•	•	315	850	•	55
10	2.87	5.45	5.09	4.46	3.35	•	4.41
11	•	•	125	•	70	•	70
12	•	•	•	•	•	•	•
13	•	•	70	220	130	140	•
14	•	•	•	•	•	•	•
15	38000	•	9855	2600	20000	700	1400

Rows	Sep 1992	Oct 1992	Nov 1992	Dec 1992
1	•	4.9	4	4.4
2	•	2100000	•	•
3	•	1700000	5000000	300000
4	50	40	30	30
5	3750	950	1000	2200
6	3.68	3.6	4.97	4.05
7	•	48	35	35
8	2.2	2.2	3	4
9	600	•	•	•
10	4.18	4.22	4.66	3.04
11	•	•	•	•
12	•	•	•	•
13	•	•	•	•
14	•	•	•	•
15	7900	6100	3100	5800

creating a point-source pollution (turbidity, fecal bacteria, metals, nitrogen, phosphorus, etc.) that is difficult to pinpoint as separate from NPSP in the Fajardo River.

Natural biota and biodiversity:

USGS assessed phytoplankton populations in the Fajardo River from 1977 to 1981 at monitoring station #USGS 710. It also monitored, at the same station, benthic invertebrates from 1980 to 1982. During those periods, 39 species of microalgae (Table 5), and 37 species of benthic invertebrates (Table 6) were collected and identified. An analyses of the river's phytoplankton standing crop, defined as the amount of microalgal cells *per* milliliter of sampled water, is shown on Figure 4. It fluctuated from 0 to 2,000 cells/ml with an extraordinary peak in 1978 of around 11,000 cells/ml. While the number of different species compares favorably with similar, nearby rivers like the Mameyes, species diversity was very low, as demonstrated by the fact that only two or three species of phytoplankton or invertebrates were dominant on any single sampling day (Figures 5 & 6). Low biodiversity may be induced by the frequent entrance to the river system of external tensors, such as pollutants.

It has been reported that the Fajardo River is frequently visited by recreational fishermen looking for tarpon (*Megalops atlantica*), and snooks (*Centropomus* sp.). In addition, the authors of this report observed green macroalgae of the genus *Chara* growing in some sections of the river passing through the city of Fajardo, as well as needlefishes (Belonidae) and mullets (Mugilidae) swimming in the estuary segment.

ROWS *	DIVISION	CLASS	ORDER	FAMILY	GENUS	COMMENTS
1	Chlorophyta**	Chlorophyceae	Chlorococcales	Ooscystaceae	*Ankistrodesmus*	Common in pools & ponds.
2					*Chlorella*	Widespread in organically rich & polluted waters.
3					*Gloeoactinium*	
4					*Kirchneriella*	Usually an open-water group.
5					*Oocystis*	Common.
6					*Selenastrum*	Common in shallow waters.
7				Scenedesmaceae	*Scenedesmus*	Common in pools & ponds.
8			Oedogoniales	Oedogoniaceae	*Oedogonium*	
9			Volvocales	Chlamydomonadaceae	*Chlamydomonas*	Very common, specially in barnyard pools and water throughs.
10			Zygnematales	Desmidiaceae	*Closterium*	Found in soft-water habitats.
11					*Cosmarium*	Found in soft-water habitats.
12					*Staurastrum*	Usually found in acid or soft-water habitats.
13	Chrysophyta	Bacillariophyceae	Achnantales	Achnantaceae	*Achnantes*	
14					*Cocconeis*	
15			Bacillariales	Nitzchiaceae	*Denticula*	
16					*Nitzchia*	
17				Surirellaceae	*Surirella*	
18			Eupodiscales	Coscinodiscaceae	*Cyclotella*	Found on hard or alkaline water habitats.
19					*Melosira*	Common.
20			Naviculales	Cymbellaceae	*Cymbella*	
21				Diatomaceae	*Diatoma*	
22				Eunotiaceae	*Eunotia*	Found in soft or acid water habitats.
23				Fragilariaceae	*Fragilaria*	
24					*Synedra*	
25				Gomphonemataceae	*Gomphonema*	
26				Naviculaceae	*Frustulia*	
27					*Gyrosigma*	Common.

TABLE 5: Phytoplankton identified from samples taken at station USGS 710, Fajardo River.

28					*Navicula*	
29					*Pinnularia*	
30	Cyanophyta**	Cyanophyaceae	Chroococcales	Chroococcaceae	*Anacystis*	
31			Hormogonales	Nostocaceae	*Anabaena*	
32					*Anabaenopsis*	Found only in nitrogen-rich waters.
33					*Aphanizomenon*	
34				Oscillatoriaceae	*Lyngbya*	Common in lakes & streams.
35					*Oscillatoria*	
36					*Schizothrix*	
37					*Spirulina*	
38				Rivulariaceae	*Rachidiopsis*	
39	Euglenophyta**	Euglenophyceae	Euglenales	Euglenaceae	*Trachelomonas*	

NOTES:

* Row numbers are the same as those used in Figure 5

** Usually, **Chlorophyta** is more abundant in freshwater habitats than all other algal groups combined.
Cyanophyta is most abundant in lotic waters rich in organic matter.
Euglenophyta are almost always found in ponds rich in organic matter.

ROWS *	PHYLUM	CLASS	ORDER	FAMILY	GENUS	COMMENTS
1	Annelida	Oligochaeta	Plesiopora	Tubificidae	unknown	
2			Prosopora	unknown	unknown	
3	Arthropoda	Crustacea	Decapoda	Palaemonidae	*Macrobrachium*	
4					*Palaemonetes*	
5		Insecta	Coleoptera	Elmidae	*Stenelmis*	
6			Diptera	Chironomidae	*Ablabesmya*	
7					*Chironomus*	
8					*Conchapelopia*	
9					*Cricotopus*	
10					*Eukiefferiella*	
11					*Labrundinia*	
12					*Larsia*	
13					*Limnochironomus*	
14					*Paramerina*	
15					*Pentaneura*	
16					*Polypedilum*	
17					*Tanytarsus*	
18					*Thienemanniella*	
19				Empididae	unknown	
20			Ephemenoptera	Baetidae	*Baetis*	
21					unknown	
22				Caenidae	*Caenis*	
23				Ephemerellidae	*Ephemerella*	
24				Heptageniidae	*Stenonema*	
25				Leptophlebiidae	*Hermanellopsis*	
26					*Leptophlebia*	
27					unknown	
28			Lepidoptera	Pyralididae	*Paragyactis*	
29			Odonata	Coenagrionidae	*Emallagma*	
30					unknown	
31			Trichoptera	Calanoceratidae	*Phylloicus*	
32				Hydroptilidae	*Hydroptila*	
33					*Oxyethira*	

TABLE 6: Benthic invertebrates identified from samples taken from station USGs 710, Fajardo River.

34	Mollusca	Gastropoda	Basommatophora	Ancylidae	*Ferrissia*	
35			Mesogastropoda	Pleuroceridae	*Goniobasis*	
36					*Pleurocera*	
37	Platyhelminthes	Turbellaria	Tricladida	Planariidae	unknown	
39						

* Row numbers are the same as those used in Figure 7.

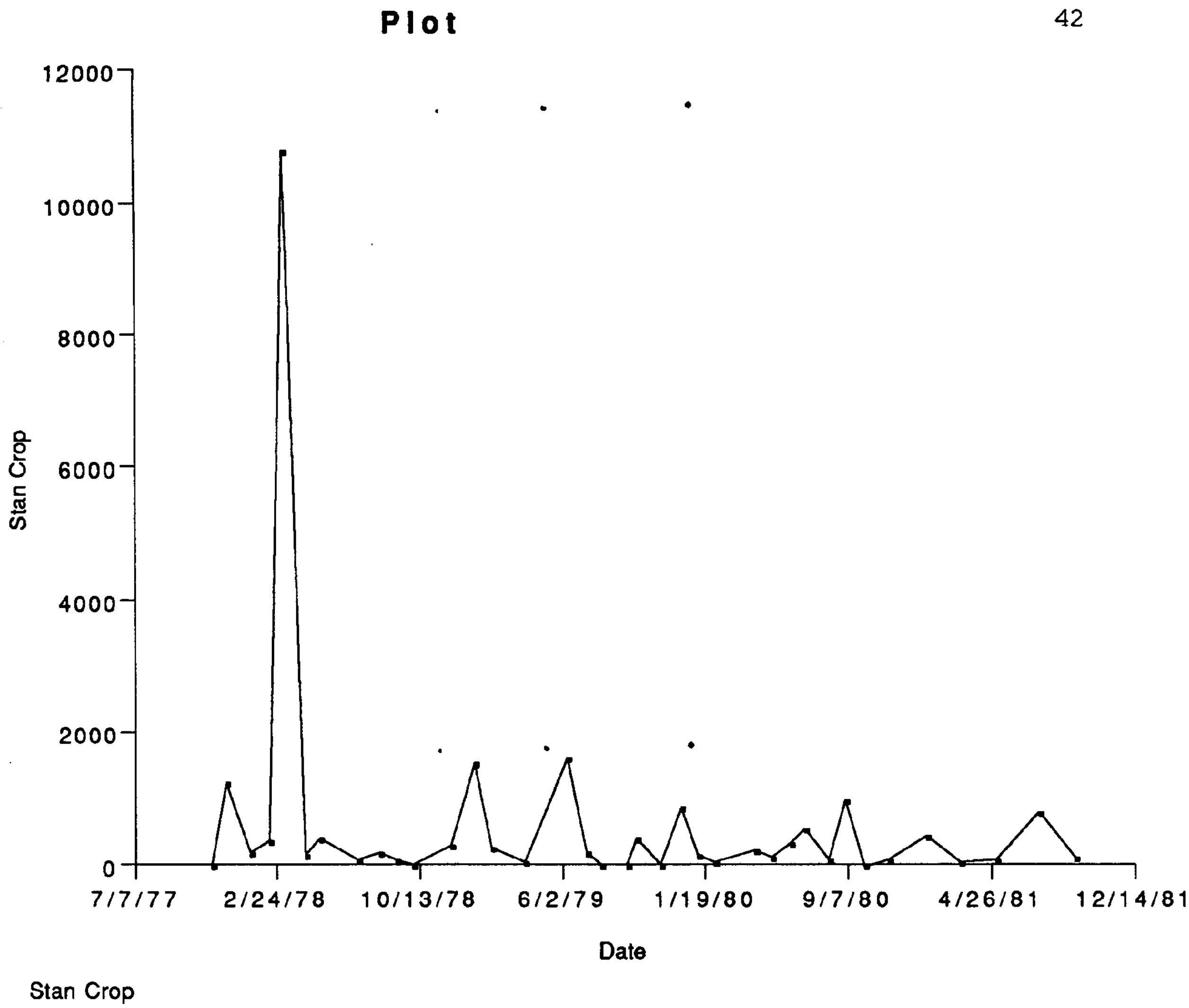


FIGURE 4: Phytoplankton standing crop from the Fajardo River.

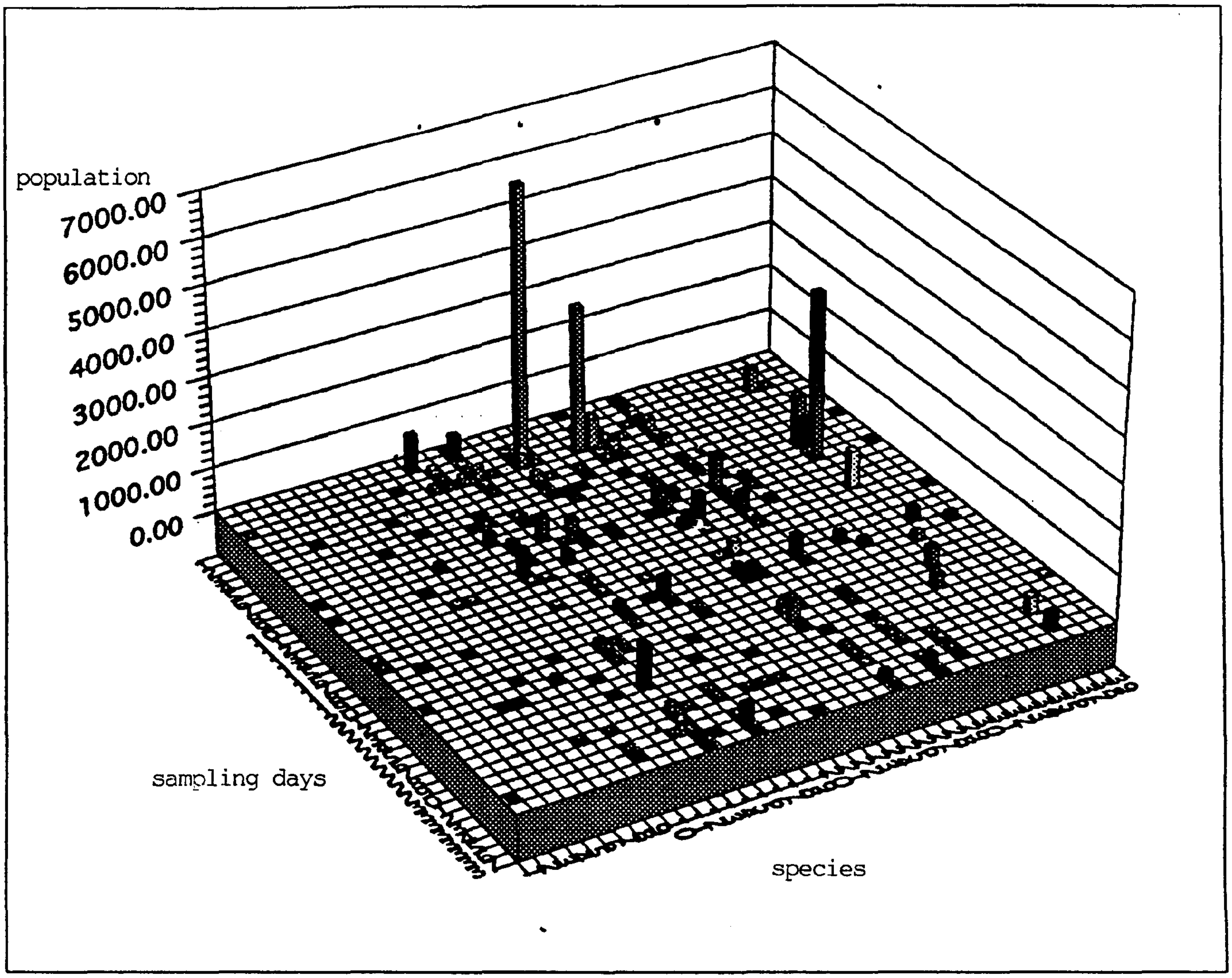


FIGURE 5: Phytoplankton biodiversity at the Fajardo River.

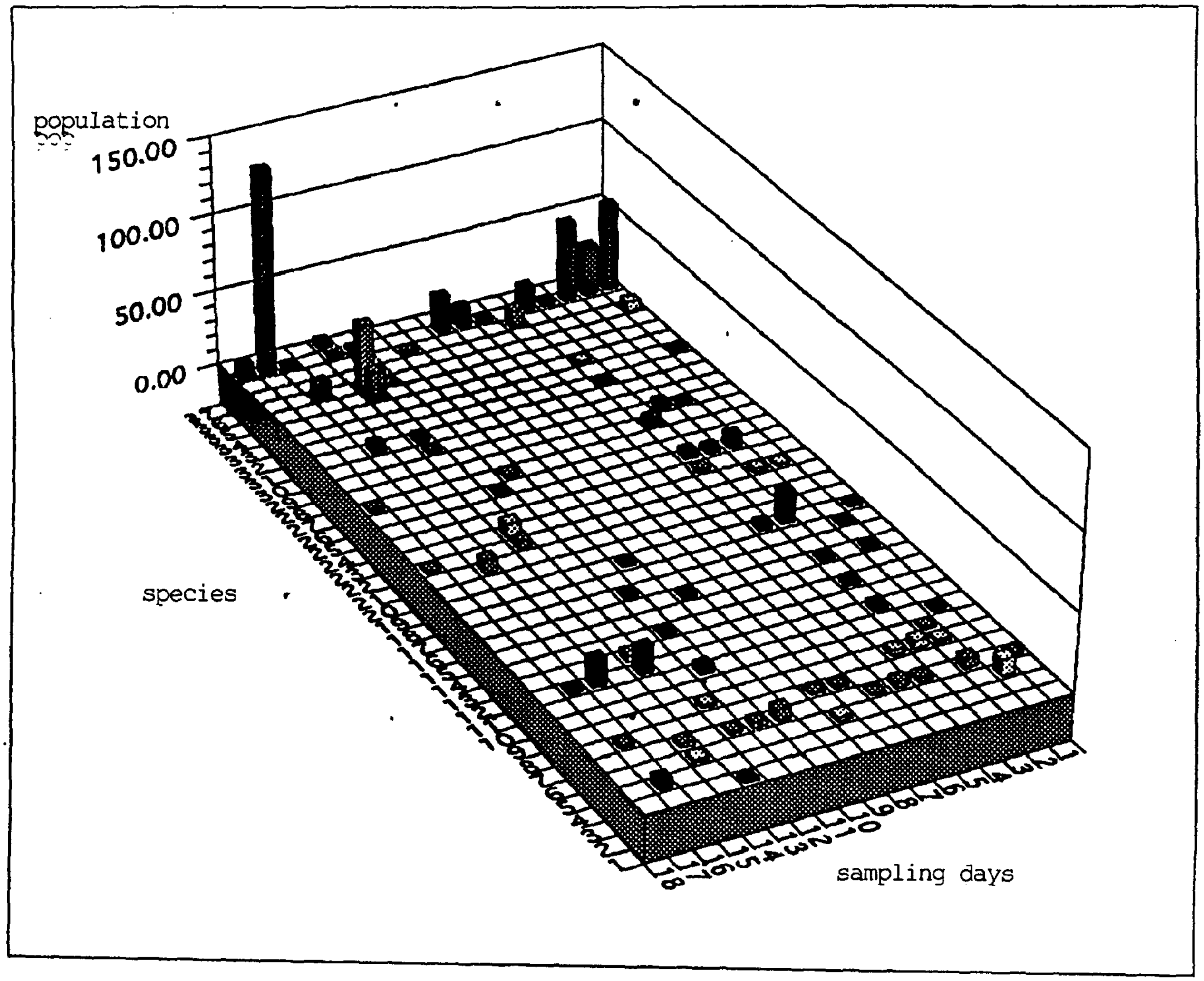


FIGURE 6: Benthic invertebrate biodiversity at the Fajardo River.

IV. WATER QUALITY HISTORY OF THE FAJARDO RIVER

Sampling stations

EQB only established one monitoring station on the Fajardo River Basin (EQB 78B). It is a coastal marine station located in estuarine waters immediately north of the Fajardo River mouth that receive freshwater aport from the river (EQB classification "SC"). EQB has contracted USGS to monitor the river *per se* (EQB classification "SD"). USGS has three stations along the river: USGS 710, 720 and 725. The locations of these stations is described in Table 7 and shown in Figures 7 & 8. An analysis of relevant historical data gathered by EQB and USGS is presented in Table 9. Figures 9-70 are plots of this data for each station.

TABLE 7: Water quality monitoring stations located at the Fajardo River Basin.

Station #	Monitoring Agency	Location	Period Monitored
USGS 710	U. S. Geological Survey	On left bank, HW 976, 5.3 km sw of Fajardo.	1960-1992
USGS 720	U. S. Geological Survey	At bridge on HW 3, 0.8 km south of Fajardo.	1958-1967, 1974
USGS 725	U. S. Geological Survey	1.9 km sw of Playa Fajardo.	1974-1992
EQB 78B	P. R. Environmental Quality Board	Coastal marine station located at Isleta Marina dock, 1.5 km nw of river mouth.	1986-1990

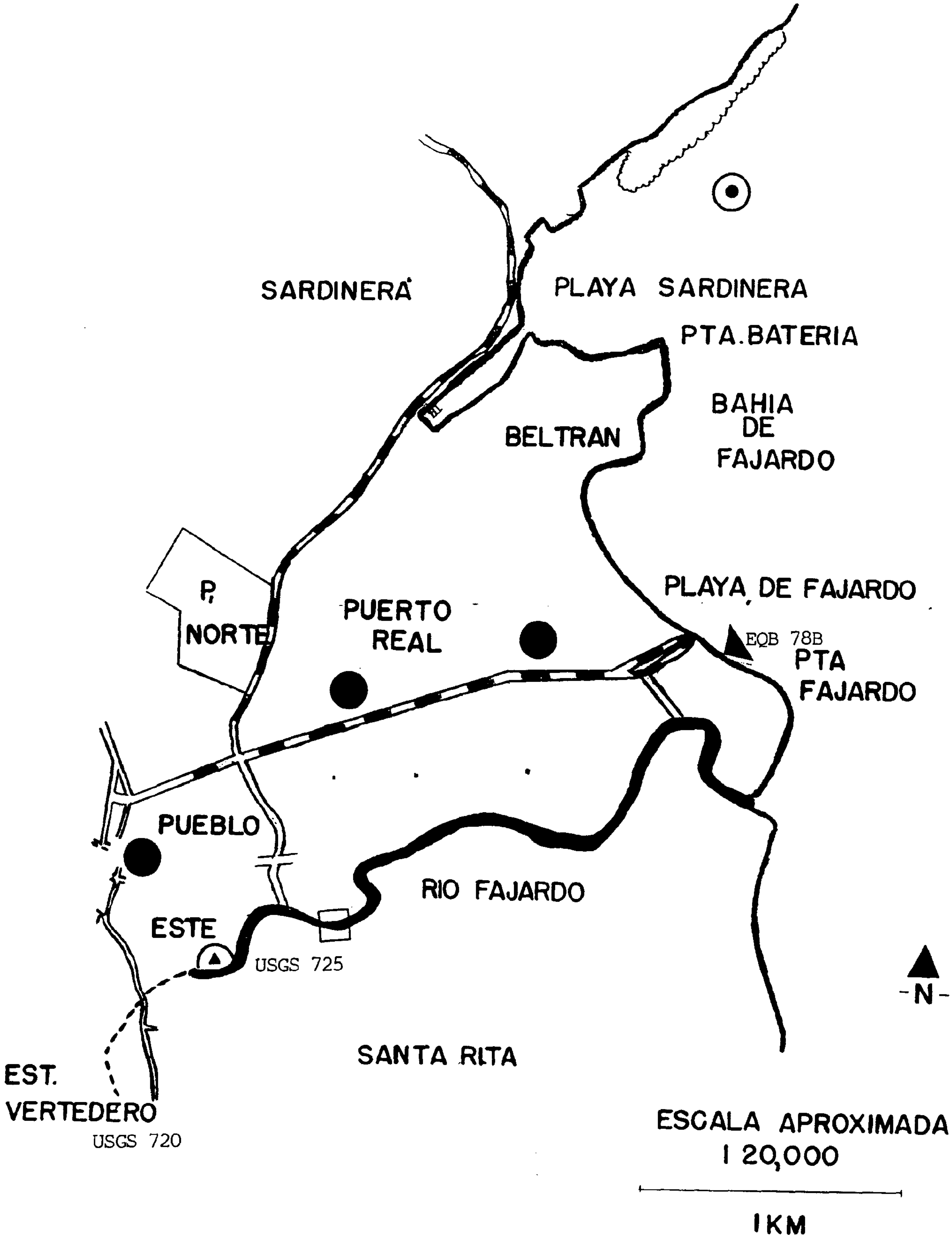


FIGURE 7: Water quality monitoring stations and nonpoint sources, as identified by EQB, along the Fajardo River.

MAPA AREAS IDENTIFICADAS DE FUENTES DE CONTAMINACION NO PRECISADAS

LEYENDA

LEGEND FOR FIGURE 7

Mapa 1. Areas identificadas de fuentes de contaminación no precisadas.

● Estaciones de Bombas - Autoridad de Acueductos y Alcantarillados.
Pump stations-ASA

Estación de Monitoreo - Servicio Geológico de E.U.
USGS water quality monitoring stations

⊙ Sistema de Uso Nacional de Eliminación de Descargas Contaminantes (Privadas).
Private NPDES discharge systems

□ Sistema de Uso Nacional de Eliminacion de Descargas Contaminantes (Públicas).
Public NPDES discharge systems

▲ Estación de Monitoreo Junta de Calidad Ambiental.
EQB water quality monitoring station

☆ Estaciones de Muestreo Departamento de Recursos Naturales.

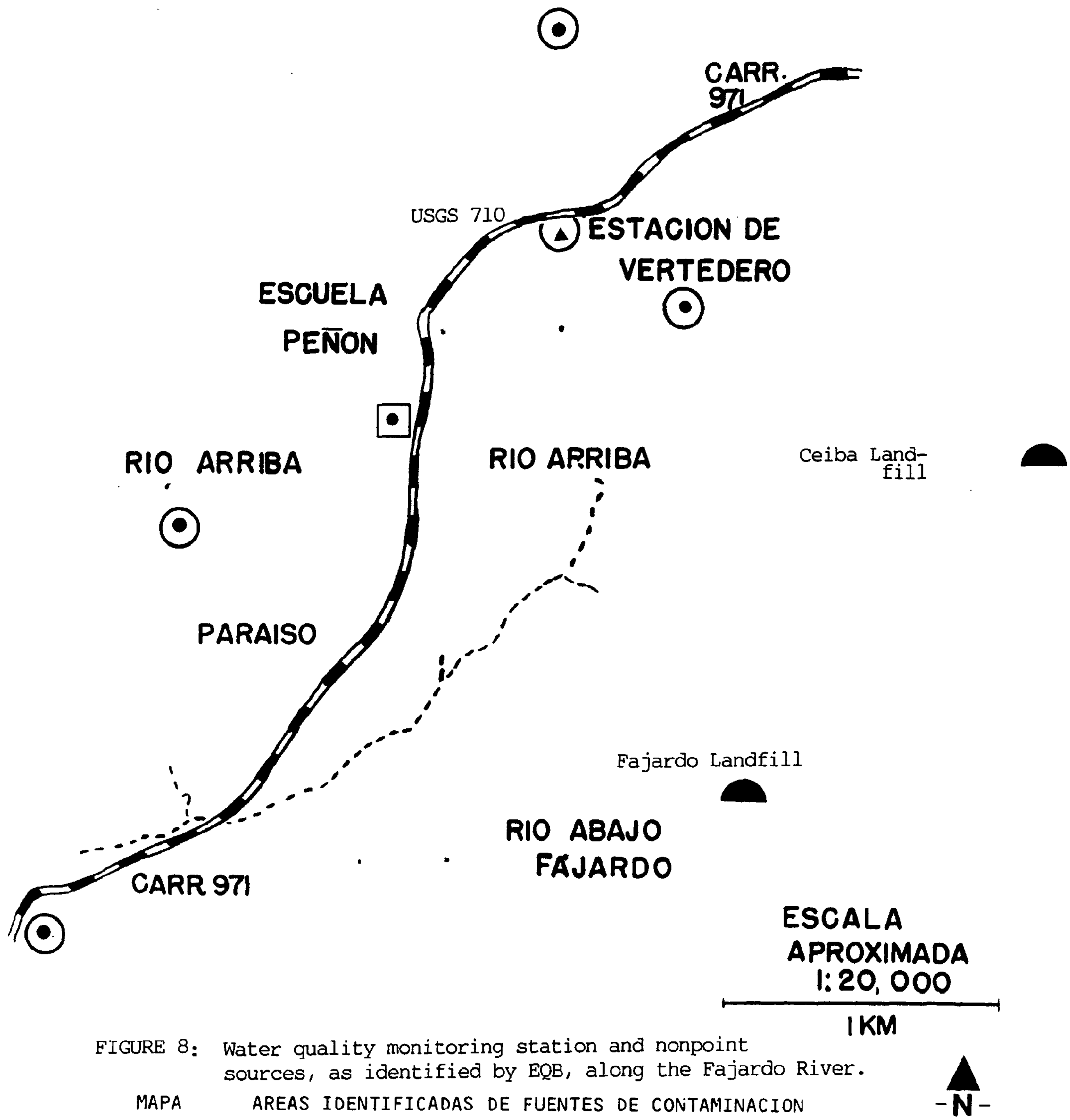


FIGURE 8: Water quality monitoring station and nonpoint sources, as identified by EQB, along the Fajardo River.

MAPA AREAS IDENTIFICADAS DE FUENTES DE CONTAMINACION NO PRECISADAS

LEYENDA

LEGEND FOR FIGURE 8

Iapa 2. Areas identificadas de fuentes de contaminación no precisadas.

- Vertederos de relleno sanitarios
  Municipal landfills
- Pozos de oxidación
  oxydation ponds
- Estación de monitoreo (JCA)
- Sistema de uso nacional de eliminación de descargas contaminantes.
  NPDES discharge system

------ Fajardo River main course

Table 4 shows data from the monitoring of backwash discharges during 1991-1992 from the Fajardo Water Treatment Plant into the Fajardo River. Though a point-source type of pollution that requires a NPDES, since these discharges goes directly into the river, such data is needed to compare with water quality data from the river's monitoring stations as an attempt to separe pollution from point sources from pollution from non-point sources.

Water discharge

Water discharges from the Fajardo River are typical (in volume and behavior) of northeastern Puerto Rico mountain rivers born at the Luquillo Sierra (Table 9: parameters #1 & 2; Figures 9 & 10). The fact that these parameter has not shown significant change over time indicates that those factors which may affect water retention capabilities of the basin's soils (like significant vegetation cover loss, excessive water extraction from the river, channelization, construction of dams, dikes or some other sort of flood-control or water-retention project) are still absent from the basin.

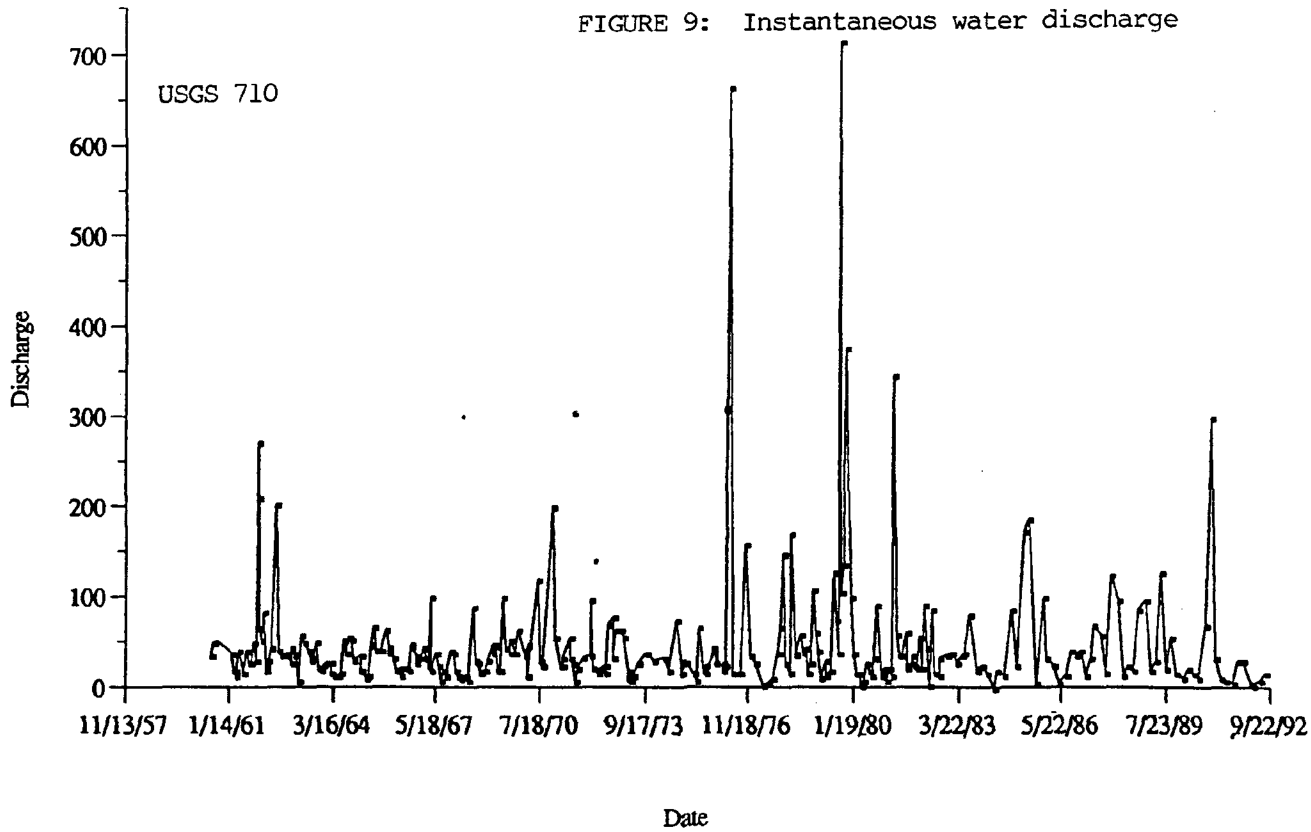
Temperature

Temperature is a measure of heat. The physical properties of water are dependant to a large degree on heat, since cool waters are capable of dissolving more gases, salts, and minerals than warm waters. Aquatic organisms adapt themselves to the natural heat fluctuations of the body of water which they inhabit. Sudden extreme temperature changes can kill these organisms as well as cause significant changes in the physical and chemical properties of water. Temperatures in surface waters in Puerto Rico usually fluctuate at around 30°C. Abnormally high temperatures may be due to warm water discharges or decomposition of huge amounts of organic matter.

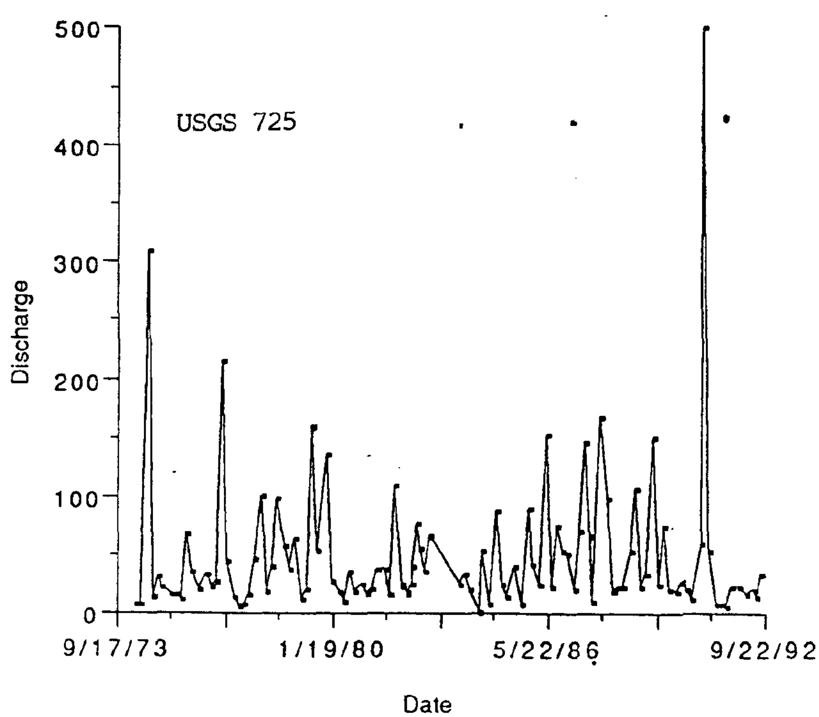
Temperature surges reflected in data from the Fajardo River (Table 9: parameter #3; Figure 11) coincide with peaks in other parameters like BOD (parameter #17; USGS 725: 1973, 1977), total organic nitrogen (parameter #37; USGS 725: 1973, 1974), and valleys in DO (parameter #15; USGS 710 & 725: 1973-1974), suggesting that decomposition of abnormally high amounts of organic matter throughout the river is the likely cause.

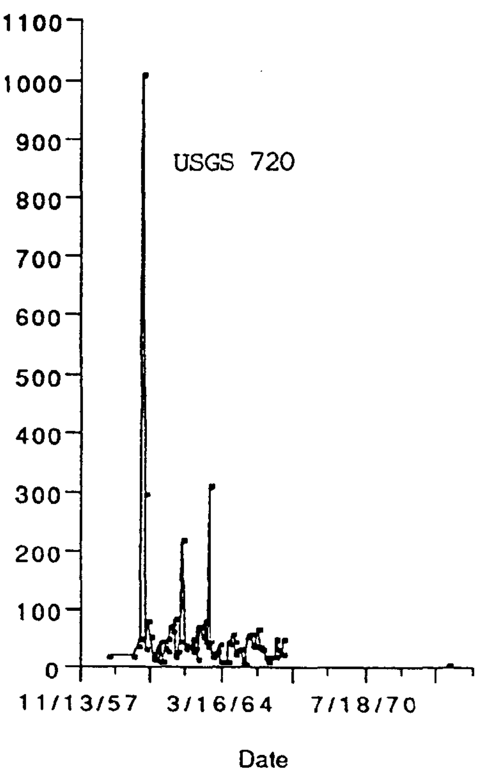
Plot

FIGURE 9: Instantaneous water discharge



Plot





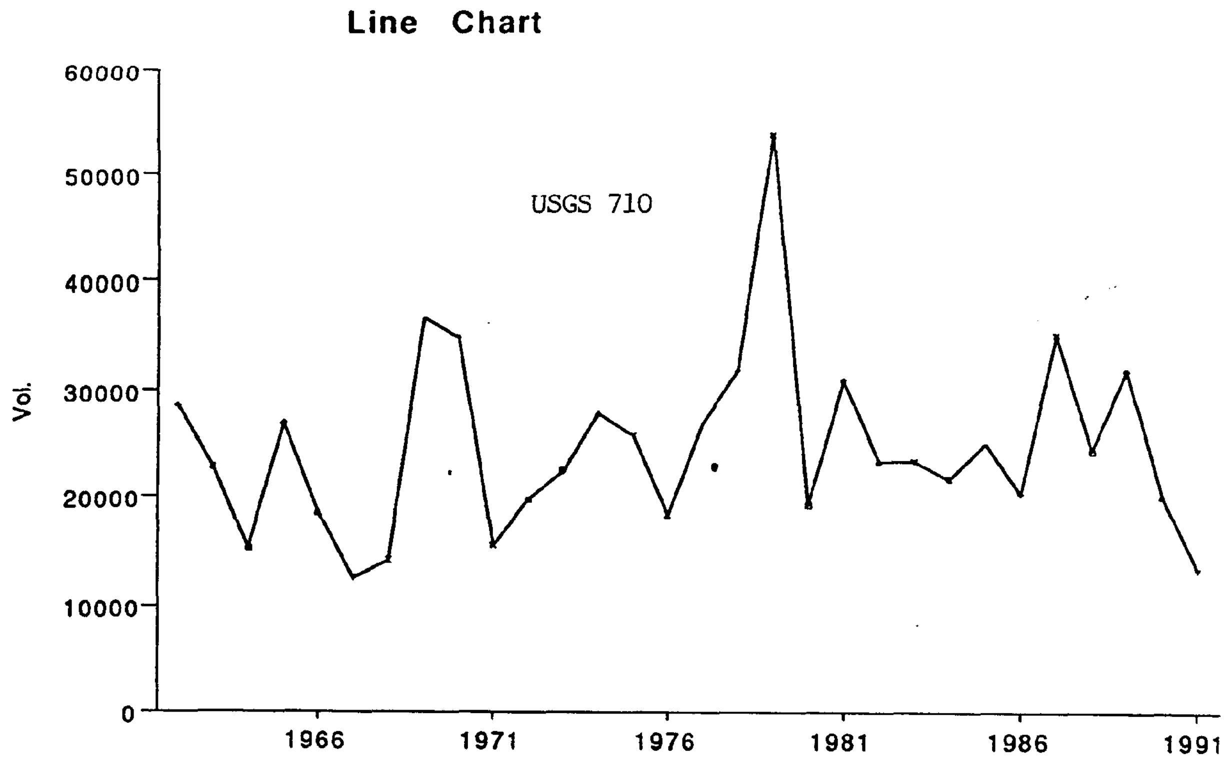
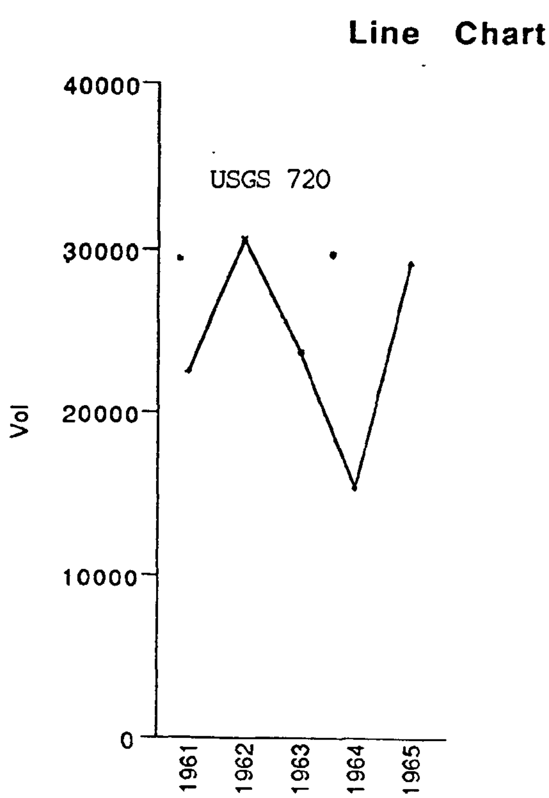
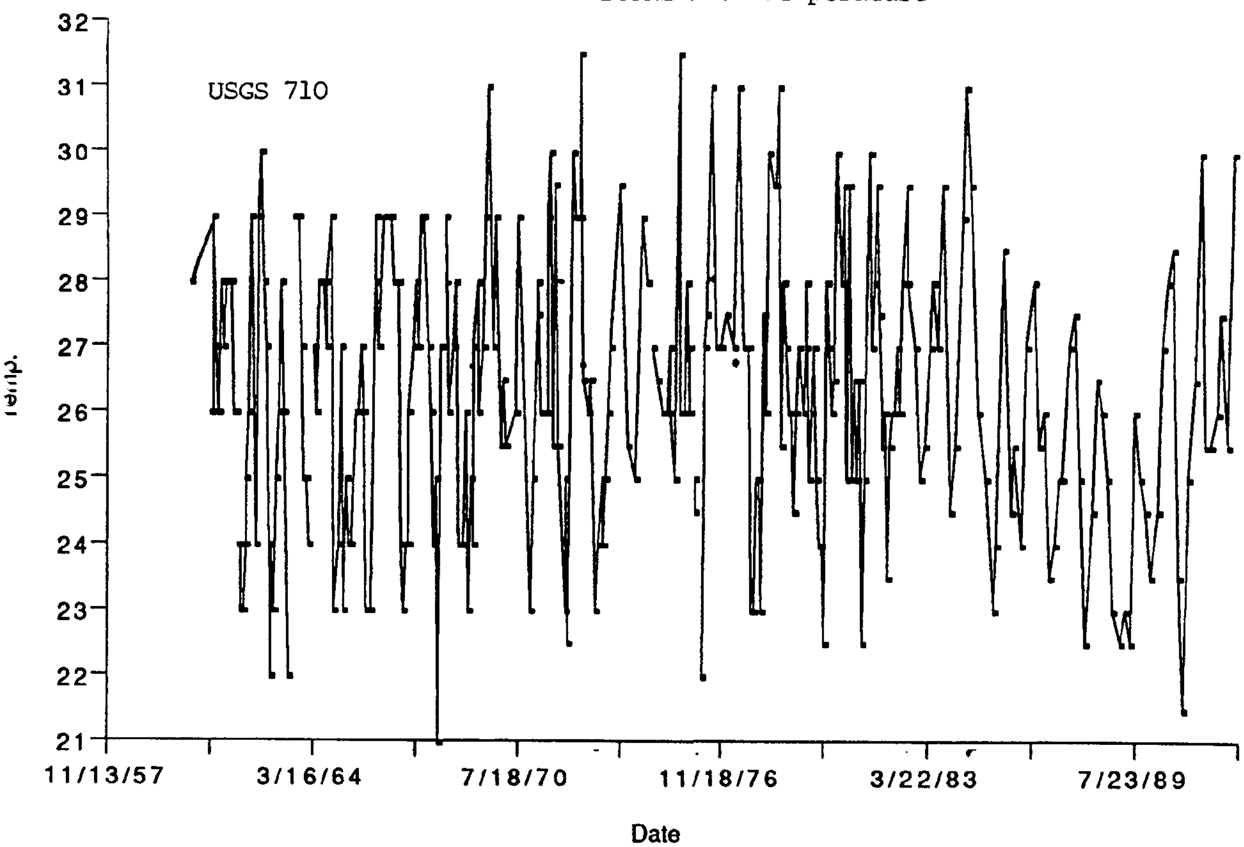


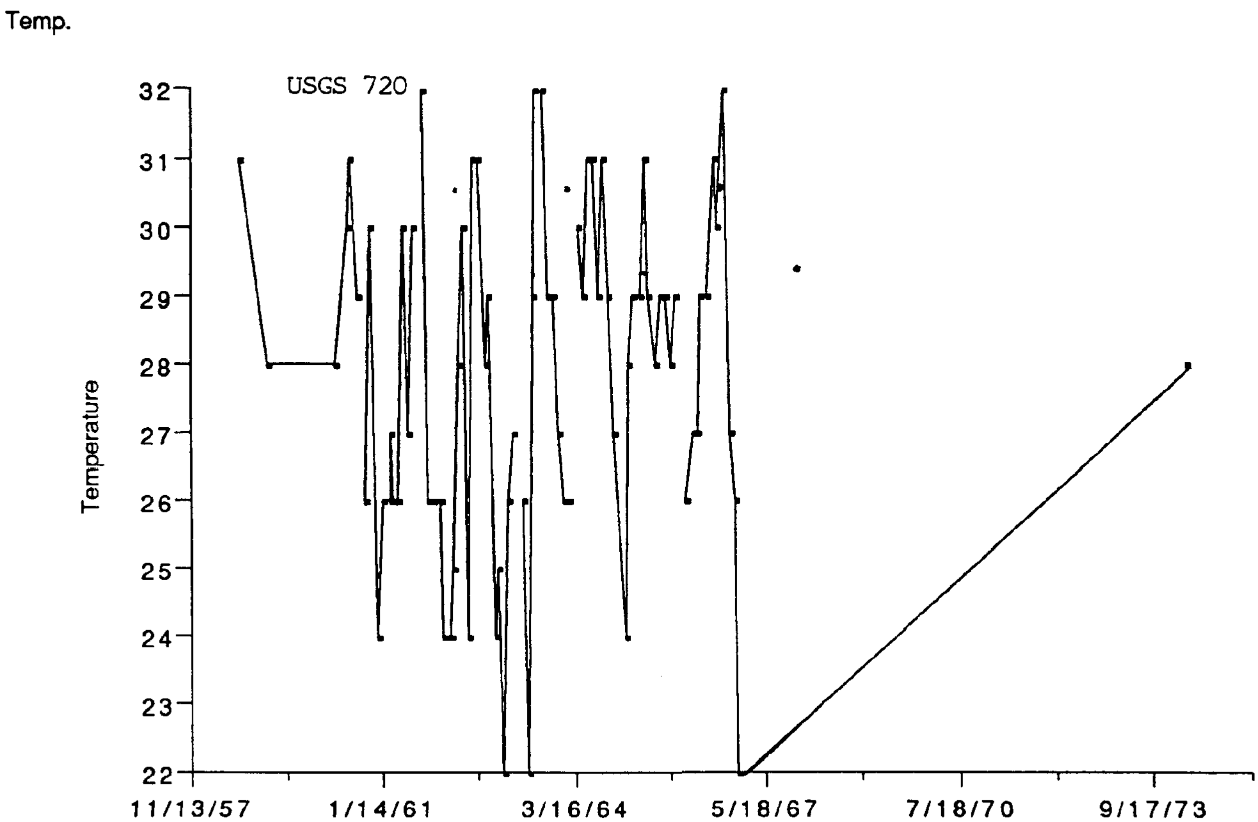
FIGURE 10: Annual water discharge



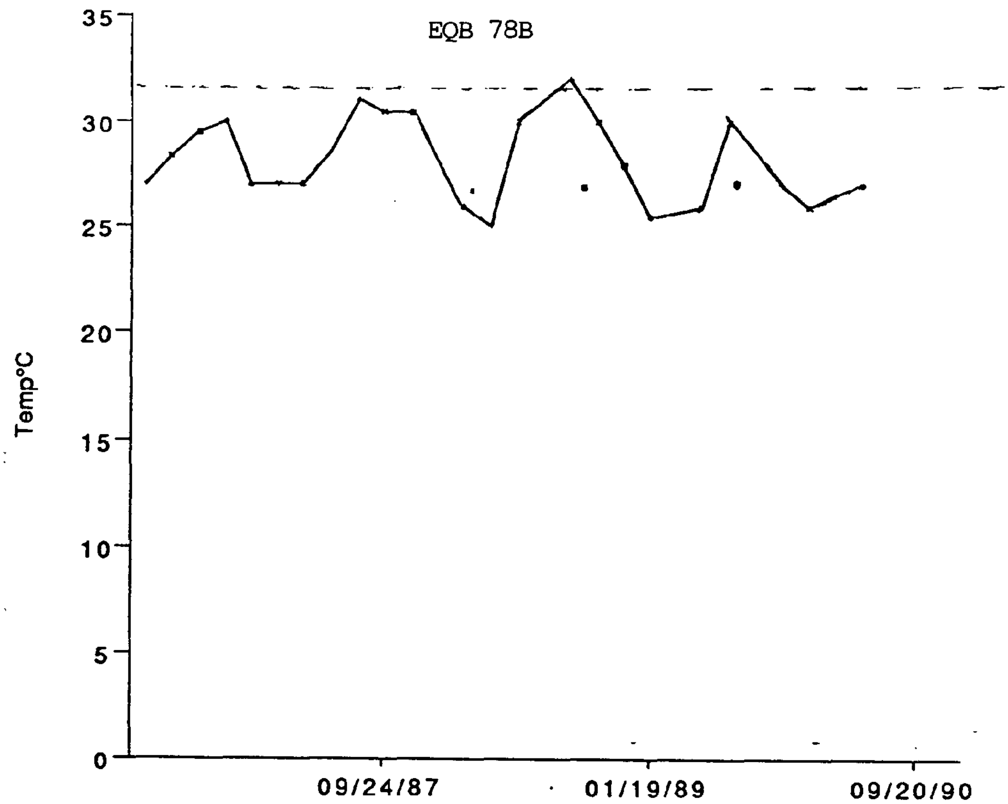
Plot

FIGURE 11: Temperature

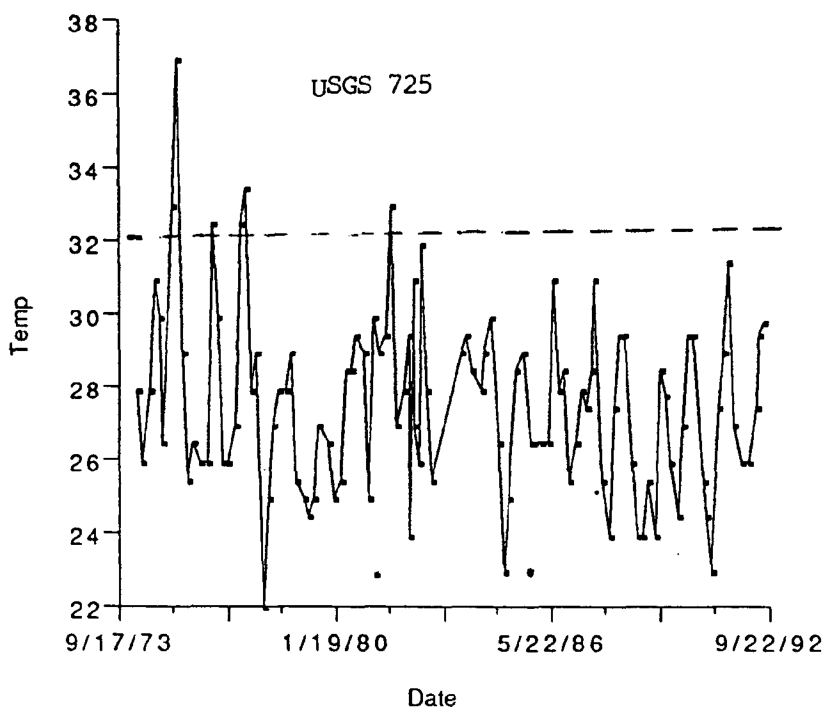




Line Chart



Plot



Conductance, salinity, dissolved solids

Conductance is a measure of the speed with which an electric current is transported through water (conductivity of water). As the concentration of ions in water increases, so does conductance. Marine waters show conductance values of more than 200 µs/cm, freshwaters usually show less than 100 µs/cm, and estuarine waters has values anywhere in between. Conductance is sometimes used as indirect measurements of water salinity and amount of dissolved solids.

Salinity, to use the simplest possible definition, is a measure of the amount of dissolved salts in water. Marine waters have salinity values of 30-40 ppt. Freshwaters have a value of 0 ppt. Estuarine waters measure anywhere in between. *Dissolved solids* is a measurement somewhat similar to salinity but it is more general because it includes any solids in water that can precipitate, not just salts.

All three parameters vary with freshwater inputs, sea water intrusions, droughts, temperature changes, sedimentation, and inputs of any ion-producing substance.

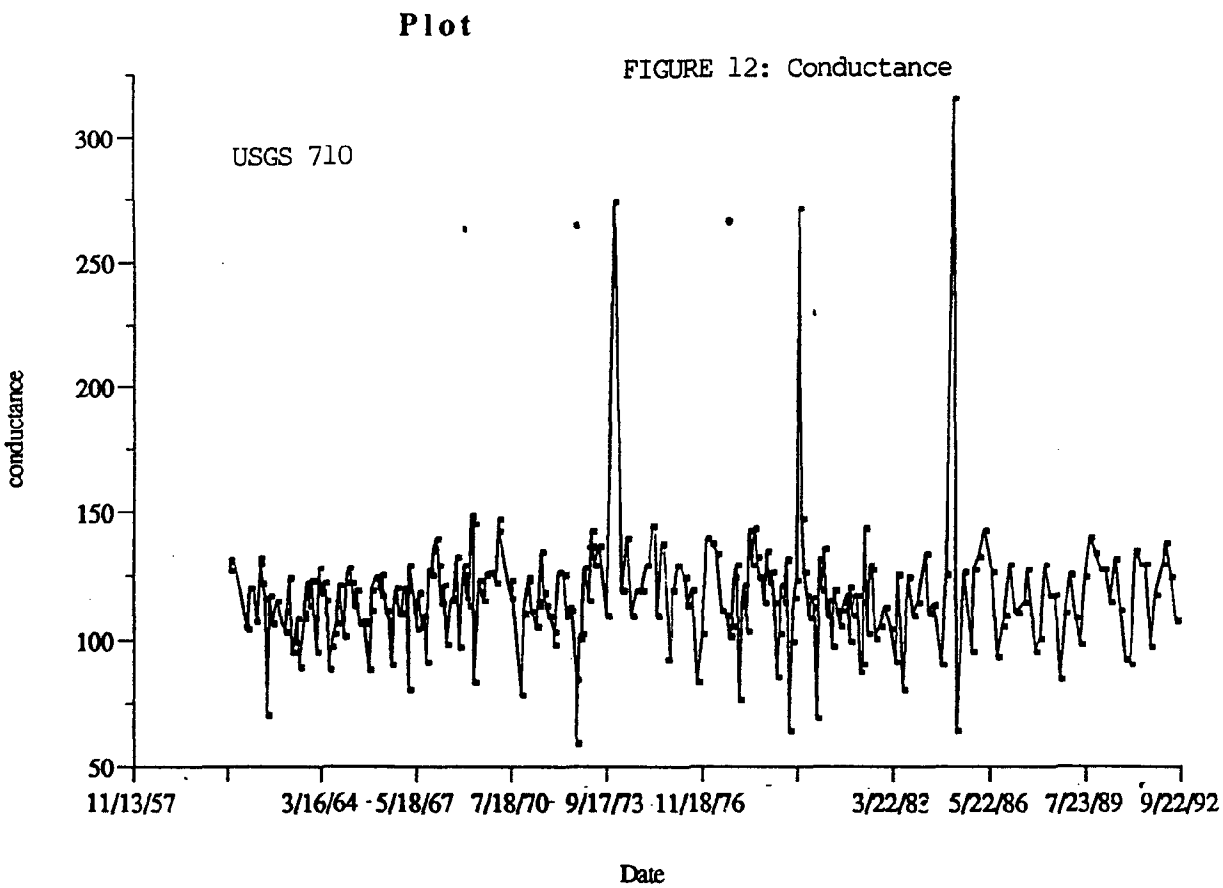
Conductance level fluctuations of over 150 µm/cm on stations USGS 720 & 725 may reflect periodic saltwater intrusions from the river estuary (Table 9: parameter #4; Figure 12). However, peaks in 1973 and 1980 appearing also at station USGS 710 (upriver) may signal episodes of NPSP occurring along the river.

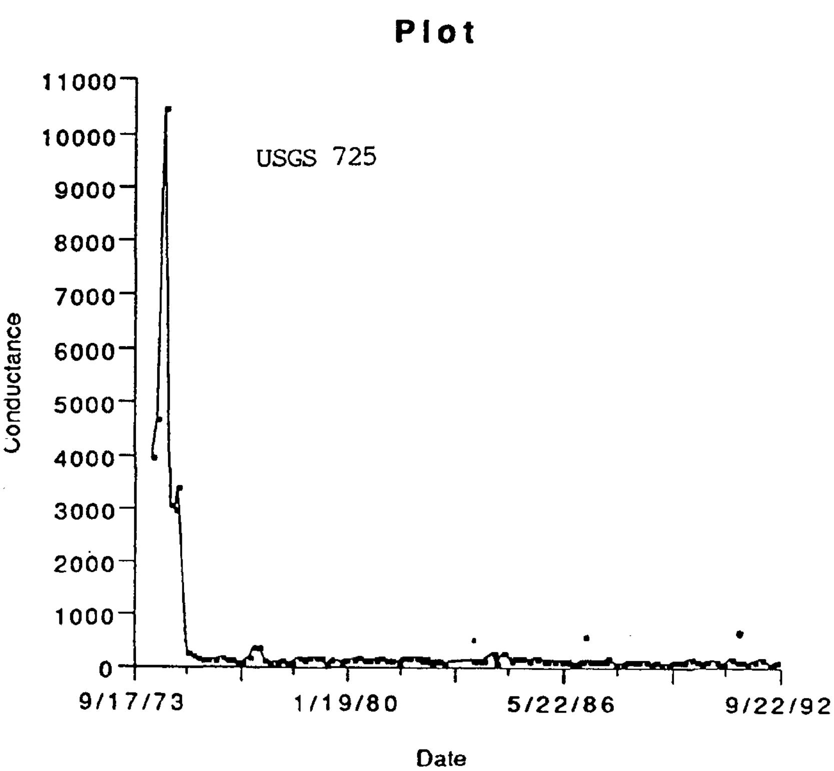
Salinity, measured at station EQB 78B, is normal for coastal estuarine situations (Table 9; parameter #5; Figure 13). Dissolved solids show a declining tendency (Table 9: parameters #10 & 11; Figures 14 &15).

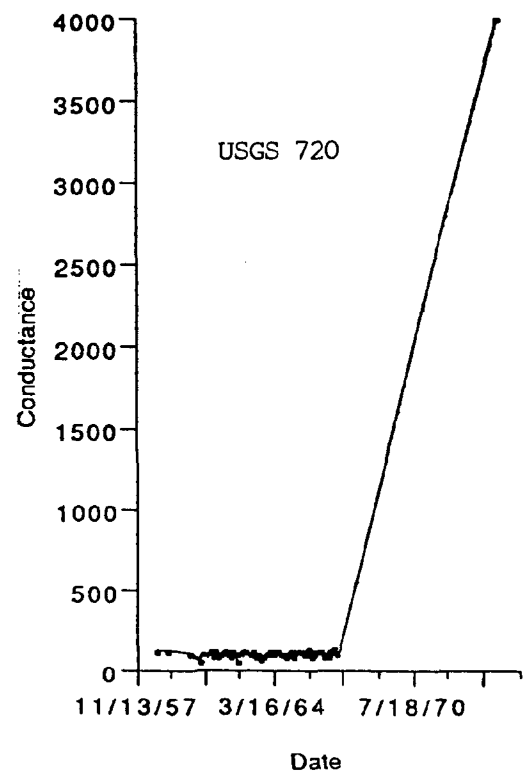
Fecal bacteria

Bacteria are microscopic, unicellular, autotrophic organisms assigned by biologists to the Kingdom Monera. Typically they are either spherical (cocci), rodlike (bacilli) or threadlike (spirilli). They often clump together to form colonies. Many bacteria are found naturally in the soil or in surface waters. However, bacteria that transmit waterborne diseases do not multiply in natural waters or even in heavily polluted waters. Water and wastewaters are not good media for their growth. Water serves primarily as a mechanical

FIGURE 12: Conductance







Conductance

FIGURE 13: Salinity

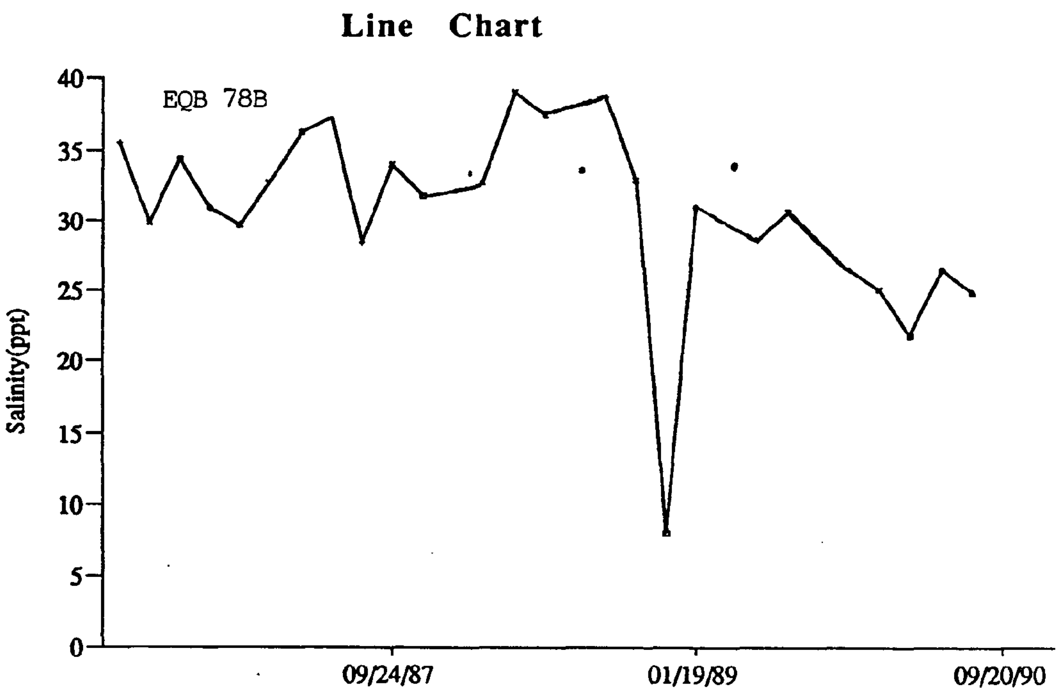
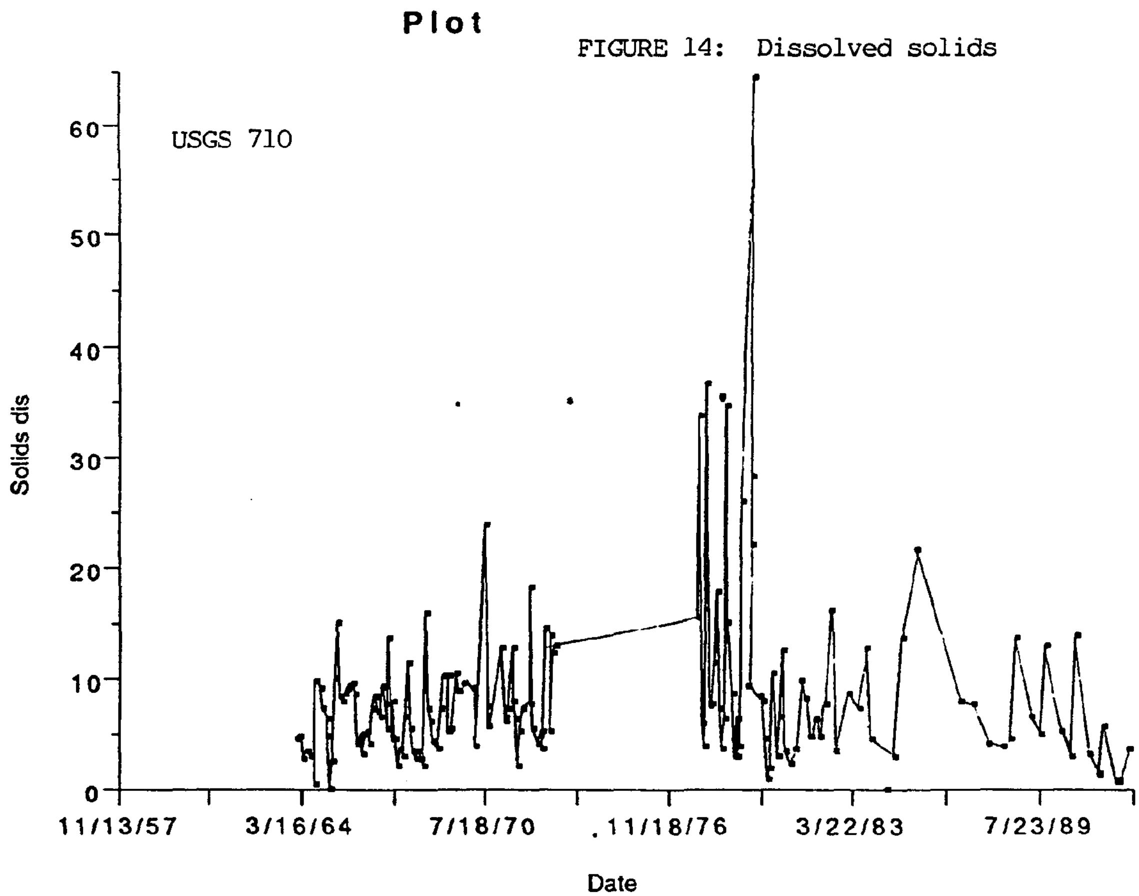


FIGURE 14: Dissolved solids



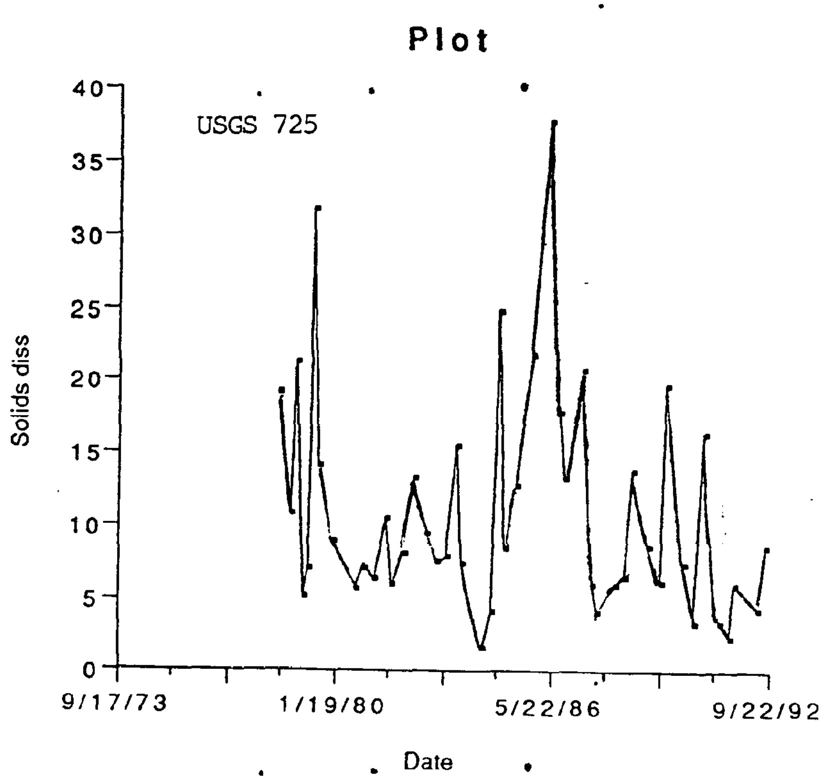
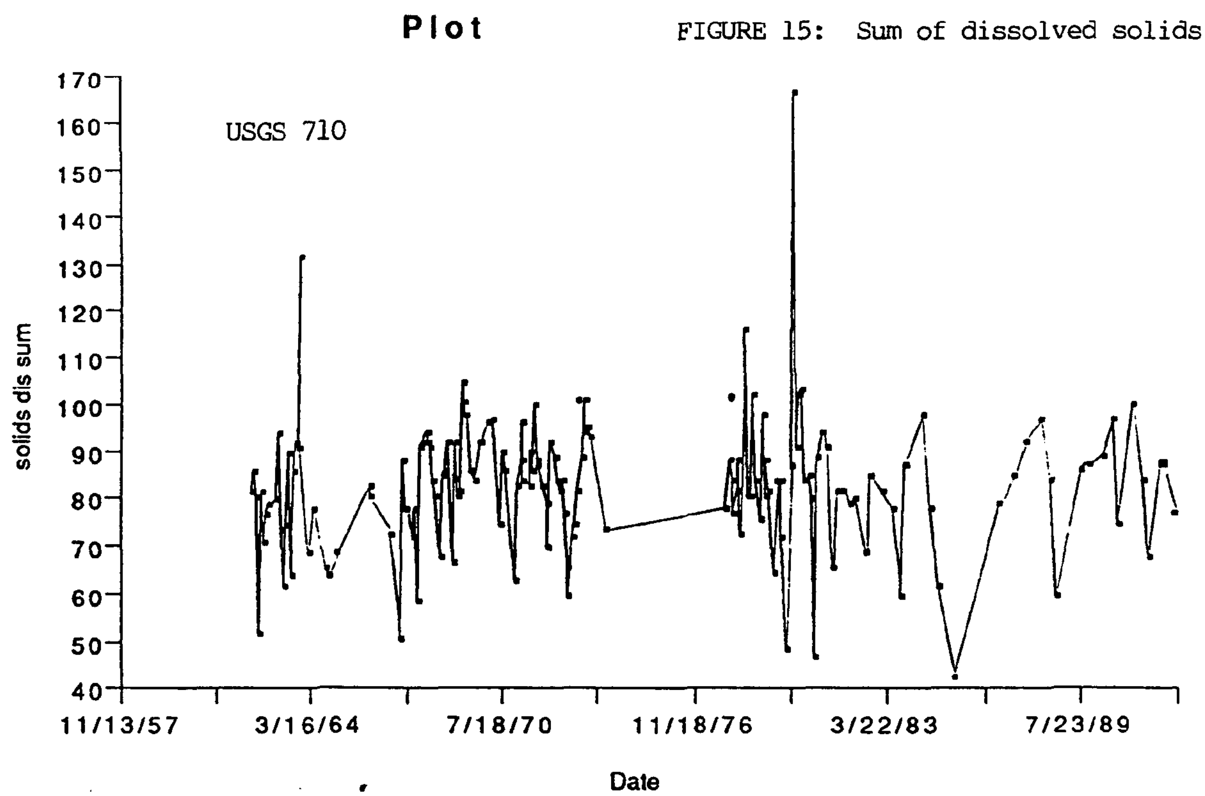
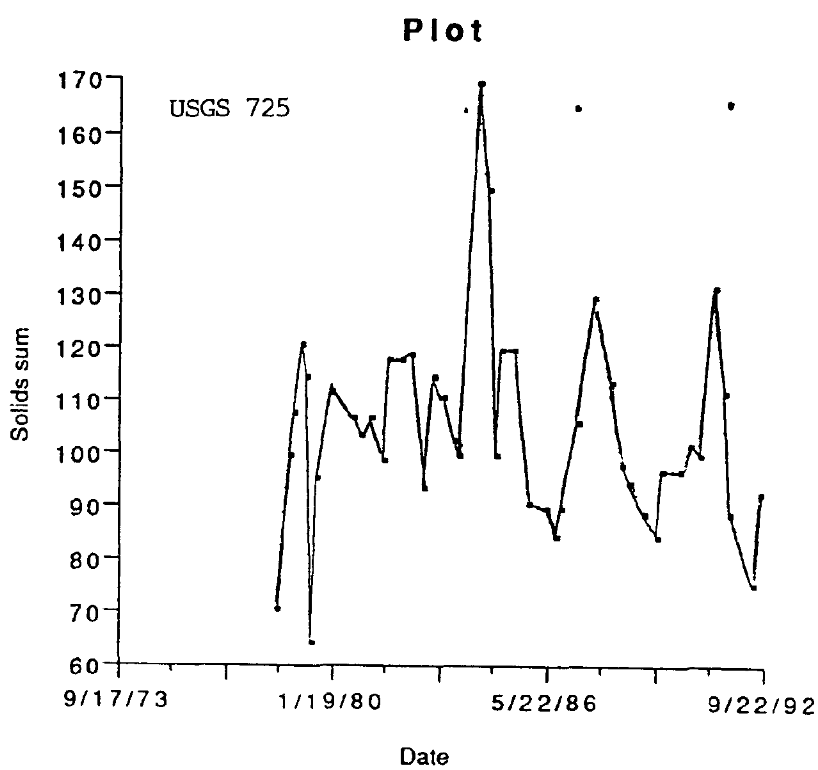
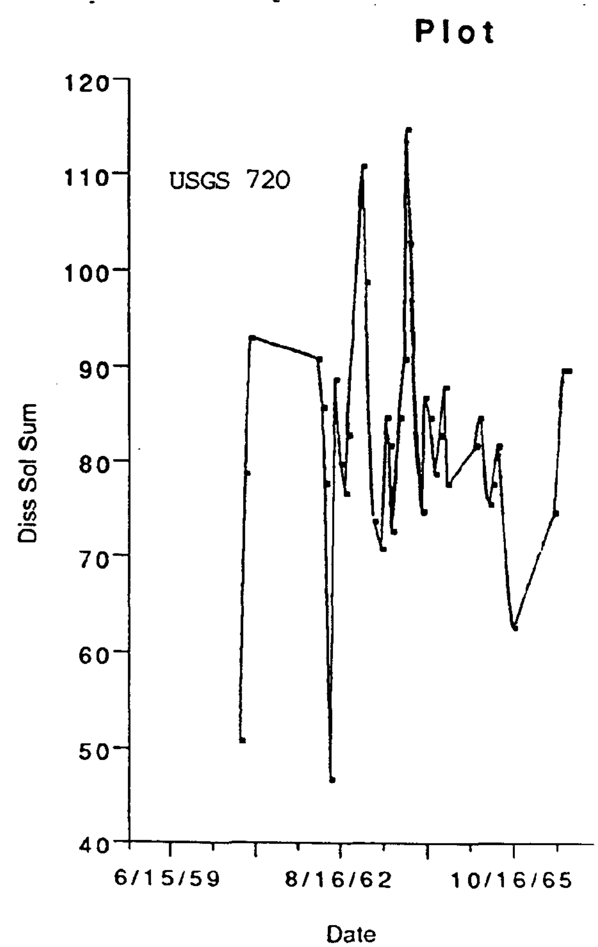


FIGURE 15: Sum of dissolved solids







medium for transmission of disease organisms, and most of the natural processes that go in water decrease the likelihood of transmittance. Pathogenic bacteria usually originates in the intestines and feces of warm-blooded animals. Consequently, water borne outbreaks are associated with recent, gross pollution.

One of the measures used as an indicator of possible sewage pollution is *Total Coliform Bacteria Count*. Coliform bacteria are a kind of aerobic or facultative anaerobic bacillus. However, general bacterial counts, such as this are not the best indicators because natural microbial flora is also present. As a result, *Fecal Coliforms* are frequently separated and censused. Fecal coliforms are mostly associated to human fecal material. *Fecal Streptococci*, bacteria usually associated with farm animals' fecal material, are also commonly counted in surface waters.

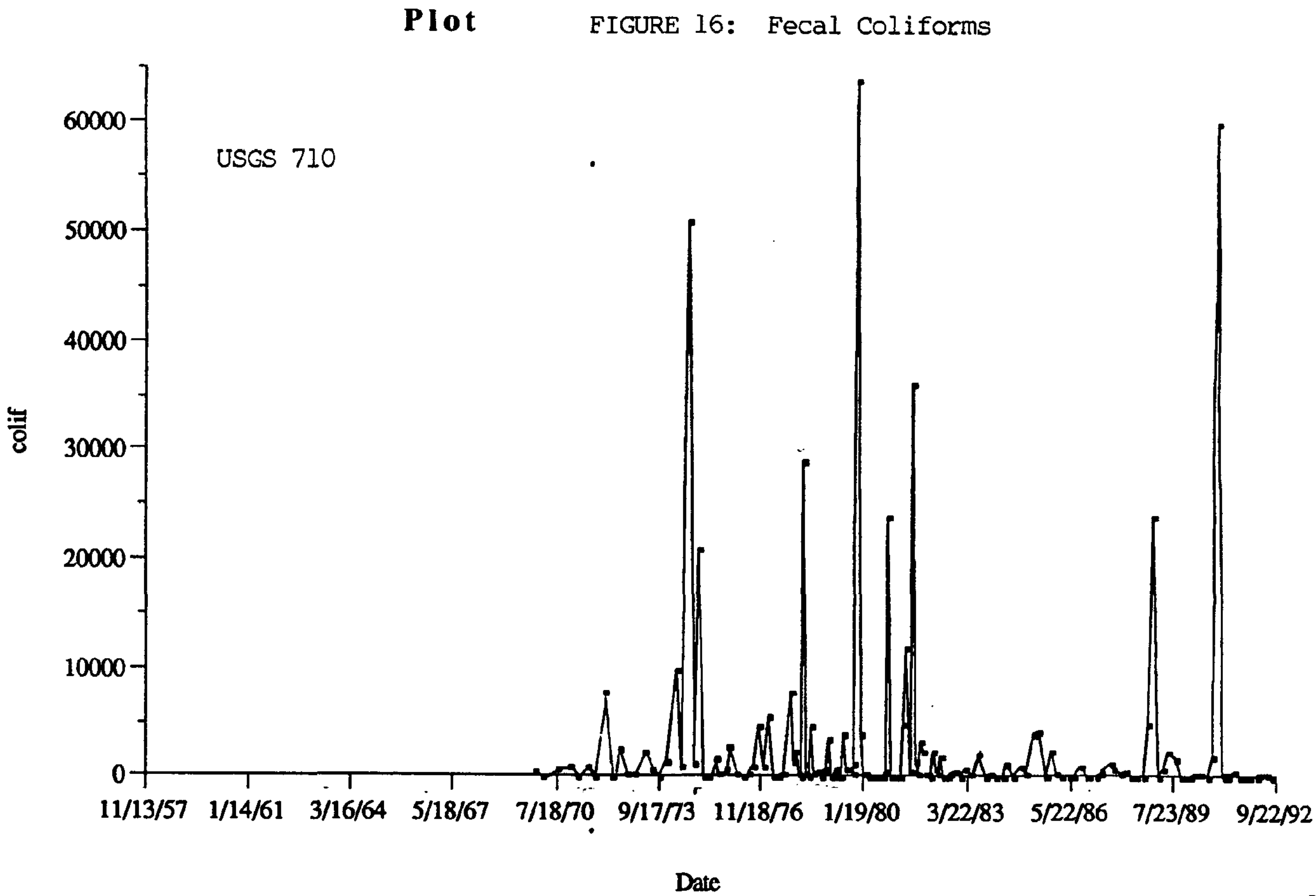
The Fajardo River Basin has a history of coliforms outbreaks (Table 9: parameters #42 & 43; Figures 16 & 17). Its many cattle farms allow their animals free access to the river, there are many rural houses that still spill their wastewater to the river and the Fajardo Wastewater Treatment Plant discharges its filters backwash into the river. From a high peak in 1973, reflected at all stations, the situation has gotten better but its still unsatisfactory.

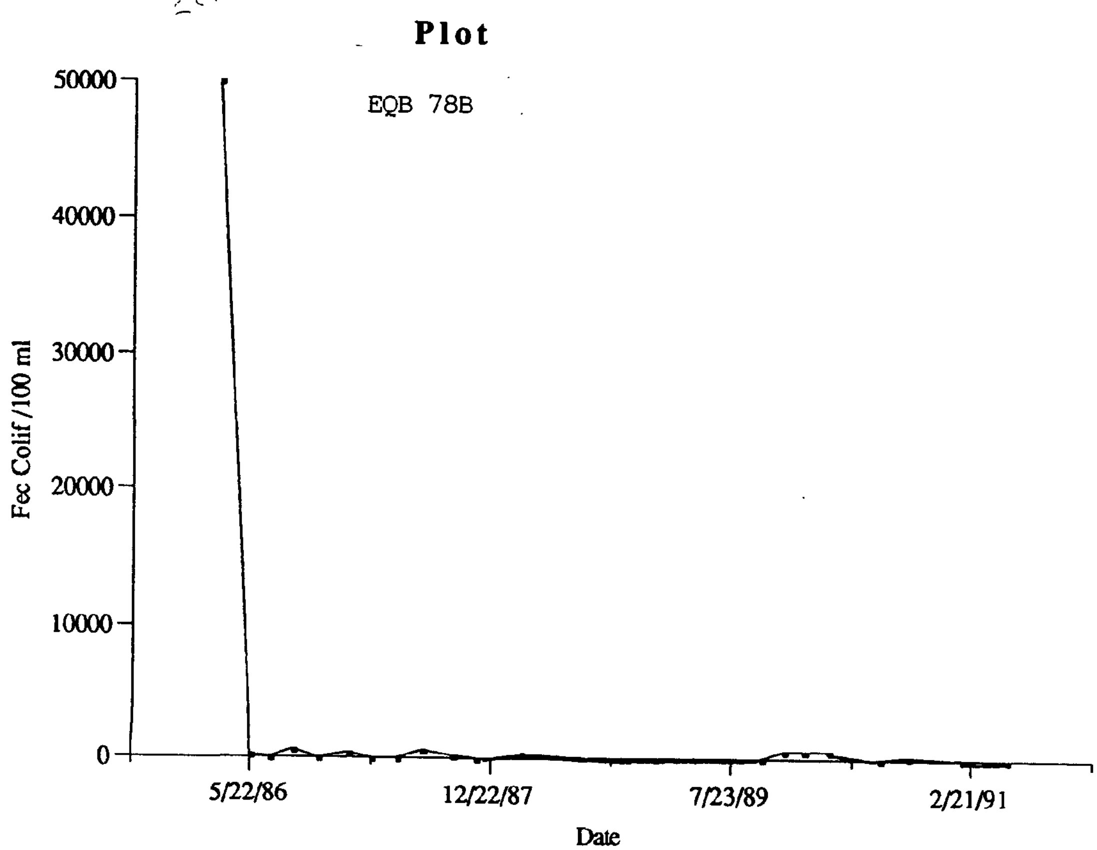
Turbidity, color, suspended materials

Turbidity is a measure of the concentration of suspended material in water. *Color* is an estimate of the amount of organic matter in water whose decomposition process produces dark-colored substances. *Suspended sediments* is a measure of the amount of suspended material in water. An excess of suspended materials in water produces a significant reduction in light penetration, which affects photosynthetic organisms and, eventually, their production of oxygen and consumption of carbon dioxide (CO_2). Sediments also clog the gills of aquatic animals, asphyxiating them.

Except for a peak in 1981 (USGS 710 & 725), turbidity fluctuations appear to be localized episodes (Table 9: parameter #8 ; Figure 18). Suspended sediments may be able to precipitate or settle between stations. Sediment fluctuations at station EQB 78B are high and may be due to the vicinity of this

FIGURE 16: Fecal Coliforms





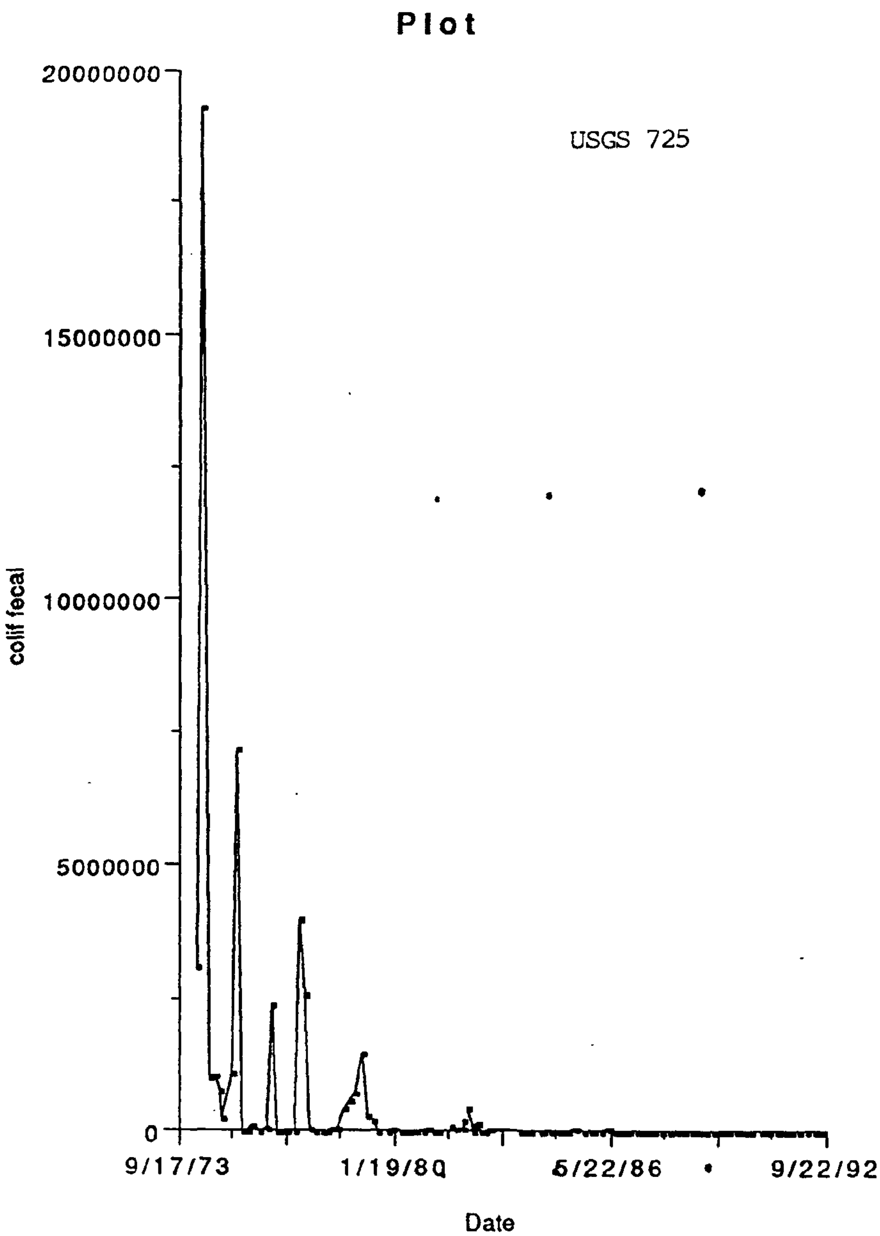
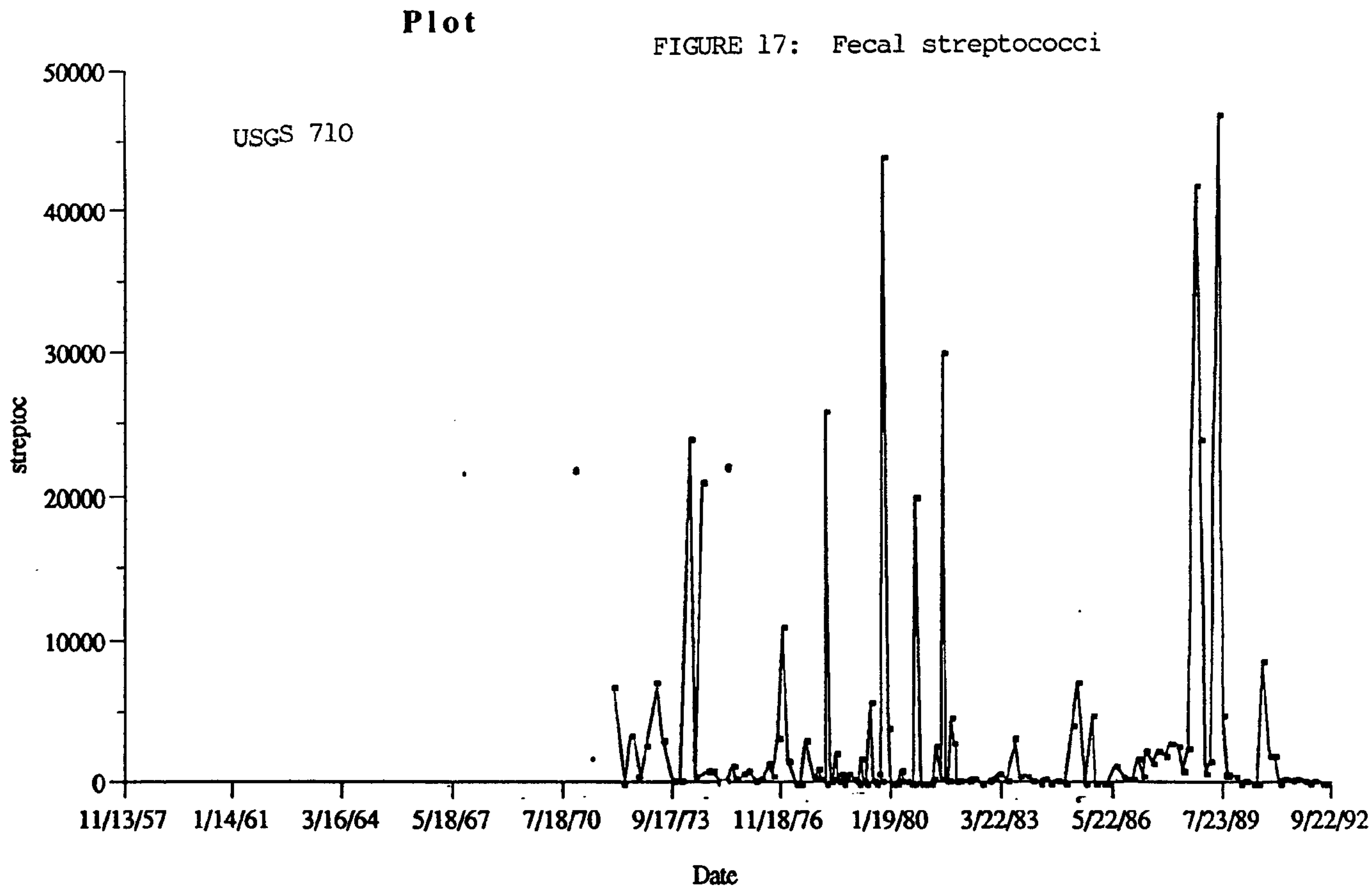

Plot
USGS 725
20000000
15000000
10000000
5000000
0
colif fecal
9/17/73
1/19/80
6/22/86
9/22/92
Date

FIGURE 17: Fecal streptococci



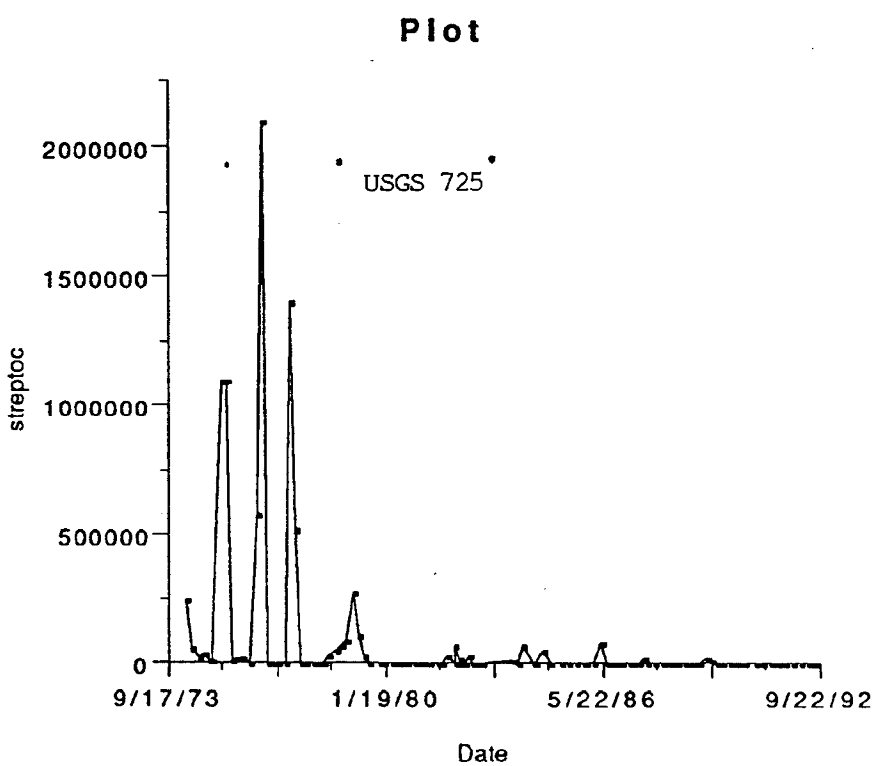
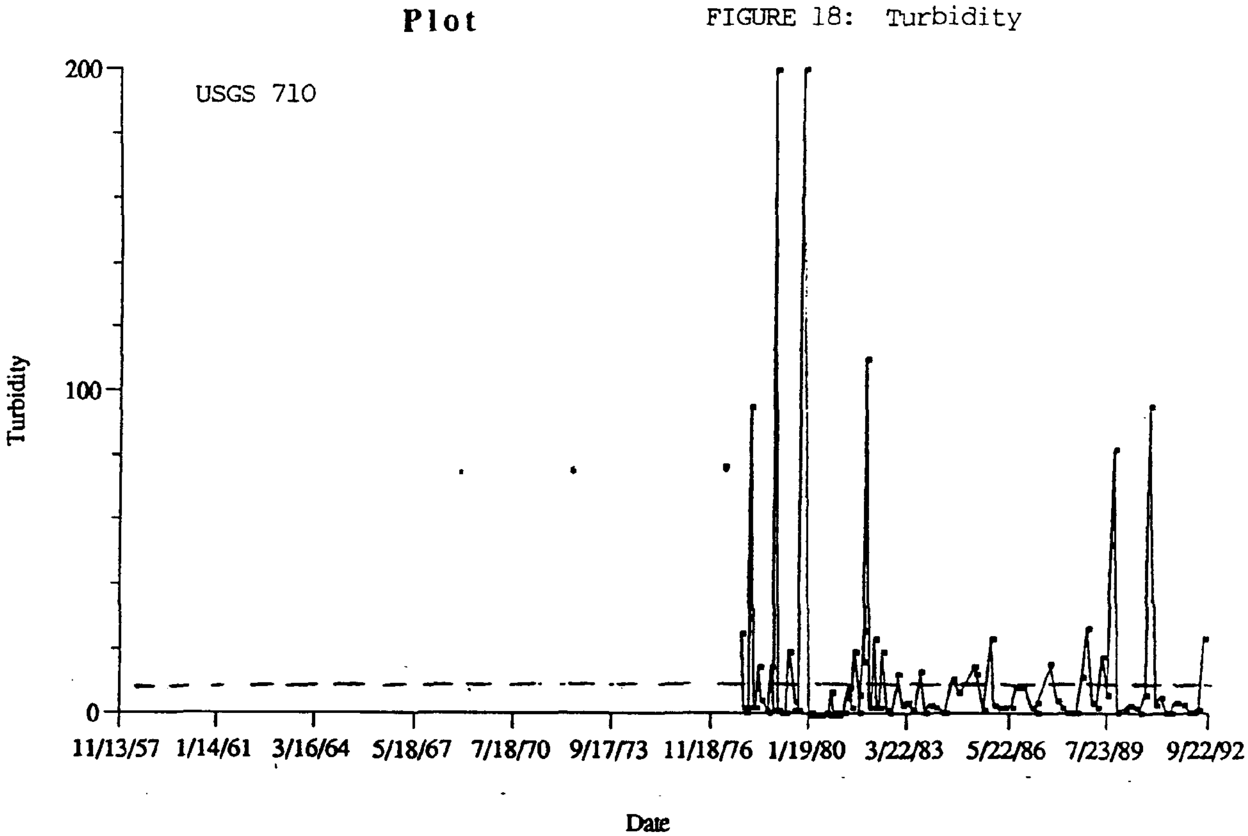
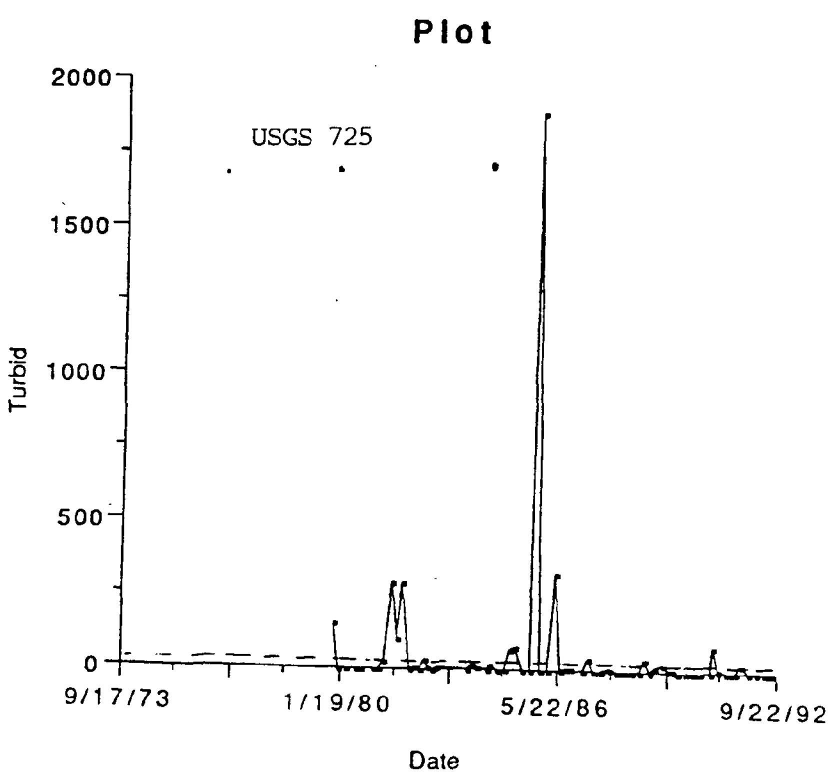
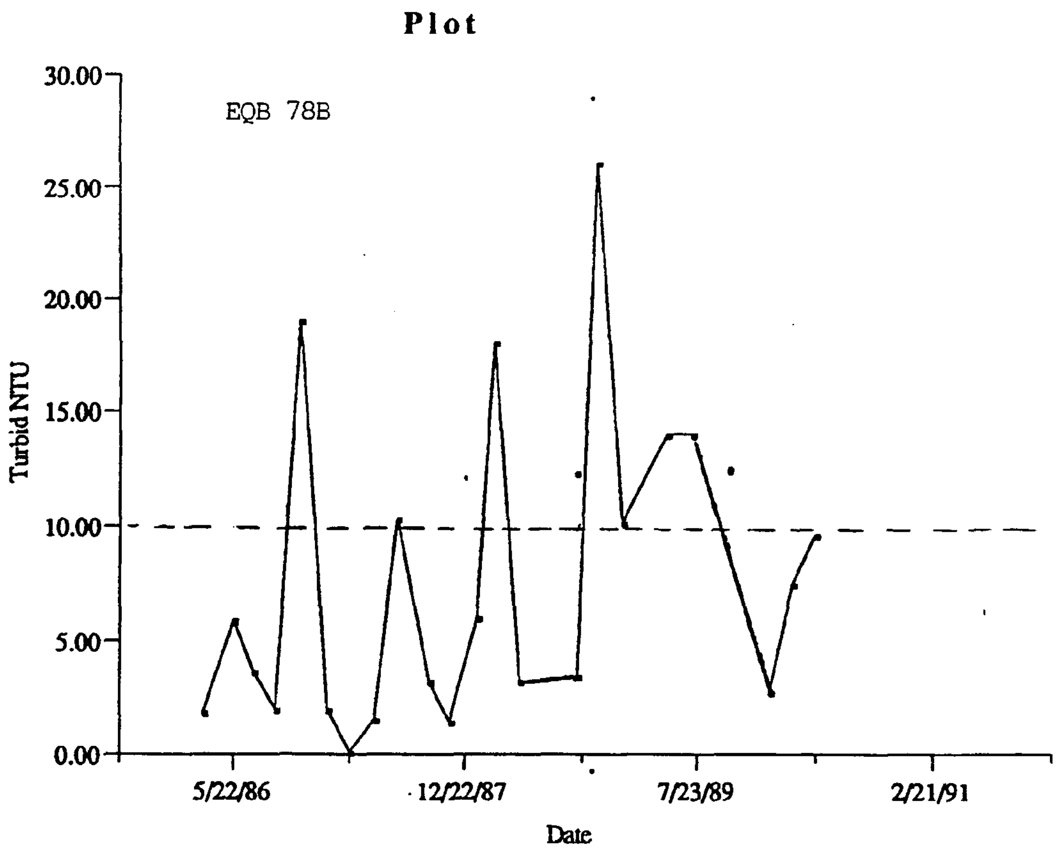


FIGURE 18: Turbidity






Plot
EQB 78B
Turbid NTU
30.00
25.00
20.00
15.00
10.00
5.00
0.00
5/22/86
12/22/87
7/23/89
2/21/91
Date

station to a marina whose boat motors lift bottom sediments continually (Table 9: parameters #7 & 9; Figures 19, 20 & 21).

Suspended oils and greases, measured at EQB 78B, show frequent peaks which may be due to frequent small spills from boats at the marina (Table 9: parameter #14; Figure 22).

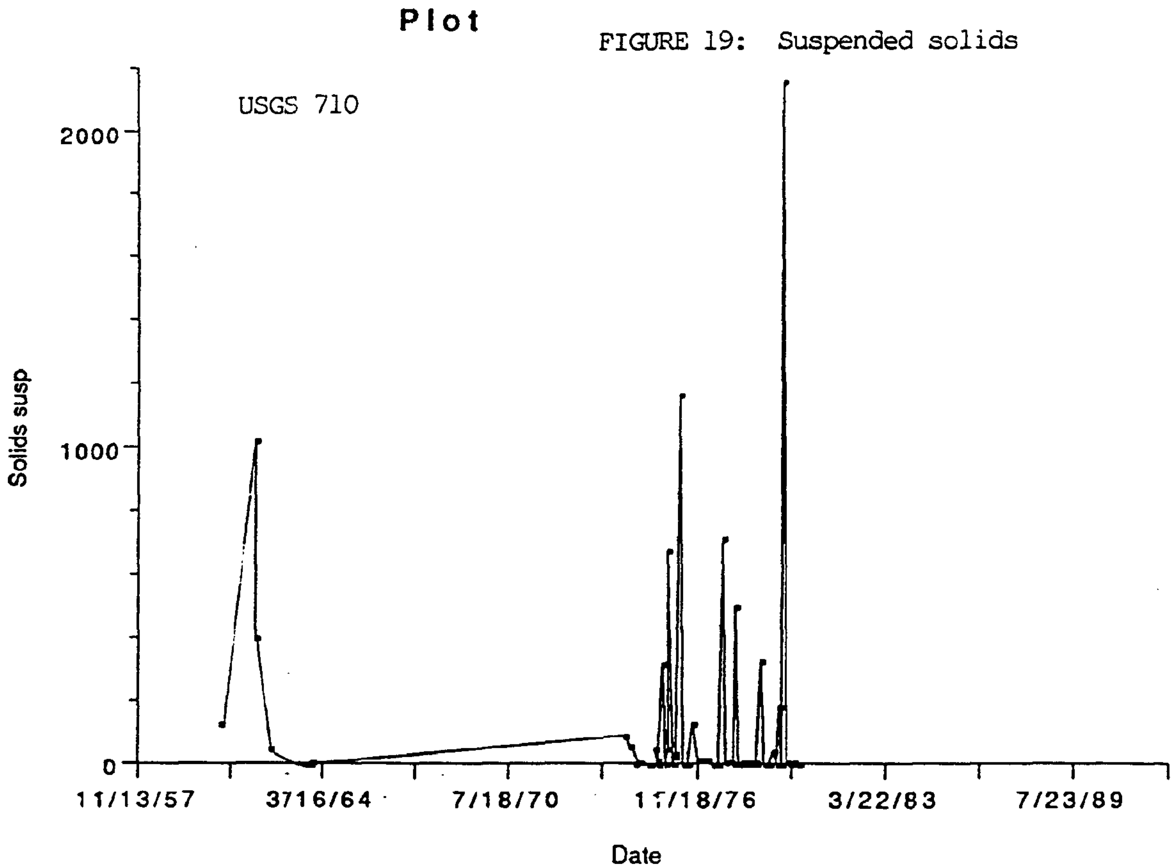
Oxygen requirements

Oxygen concentrations determine the kinds of living activities that can go on in water. It is determined mostly by water temperature, salinity, pressure, and the interaction between water and atmosphere. Cool, clear, fast-moving, over-oxygenated mountains streams support a small variety of specialized organisms. As water slows and organic matter accumulates, these organisms are replaced by a larger variety of more tolerant types. However, if the concentration of organic wastes continue increasing, it could reach the level in which oxygen is completely depleted by decomposition (water turns anaerobic). Most organisms will be wiped out, bacteria will begin obtaining oxygen from nitrite, nitrate, or sulfate in that order. Nitrite and nitrate will be reduced to nitrogen gas which will show as bubbles. Sulfate will be reduced to hydrogen sulfide. Sulfides react with metals in water to form a black suspension that darken polluted waters. Metals will also be reduced. Soluble ferric and manganic compounds will turn into insoluble ferrous and manganous ones. Organic matter decomposition will grind to a halt without oxygen, leaving in the water organic acids, alcohols, and aldehydes, as well as CO_2, that normally are just transitional products in the breakdown of organic matter.

Chemical Oxygen Demand (COD) is a measurement of the amount of dissolved oxygen required to convert organic waste compounds in the water to stable, inoffensive, and harmless compounds (preferably, water and carbon dioxide). As such, it is an indirect measurement of the amount of organic and reducing material present. Determined values may correlate with water color or organic pollution.

Biochemical Oxygen Demand (BOD) is the most popular measurement of the likely behavior of organic wastes as oxygen consumers. It measures the oxygen levels needed for the biochemical oxidation of organic matter.

FIGURE 19: Suspended solids



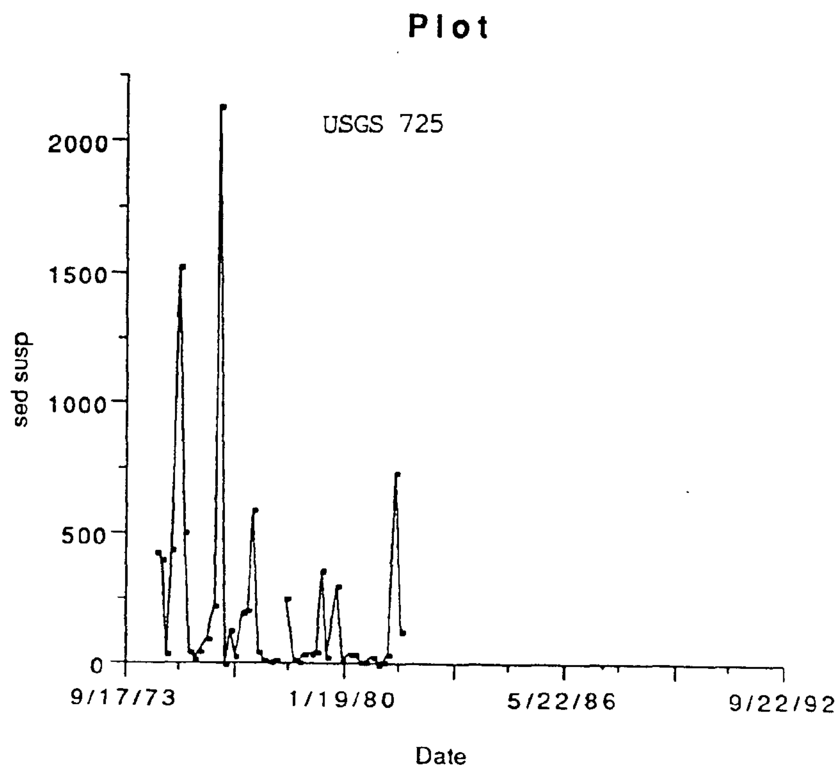
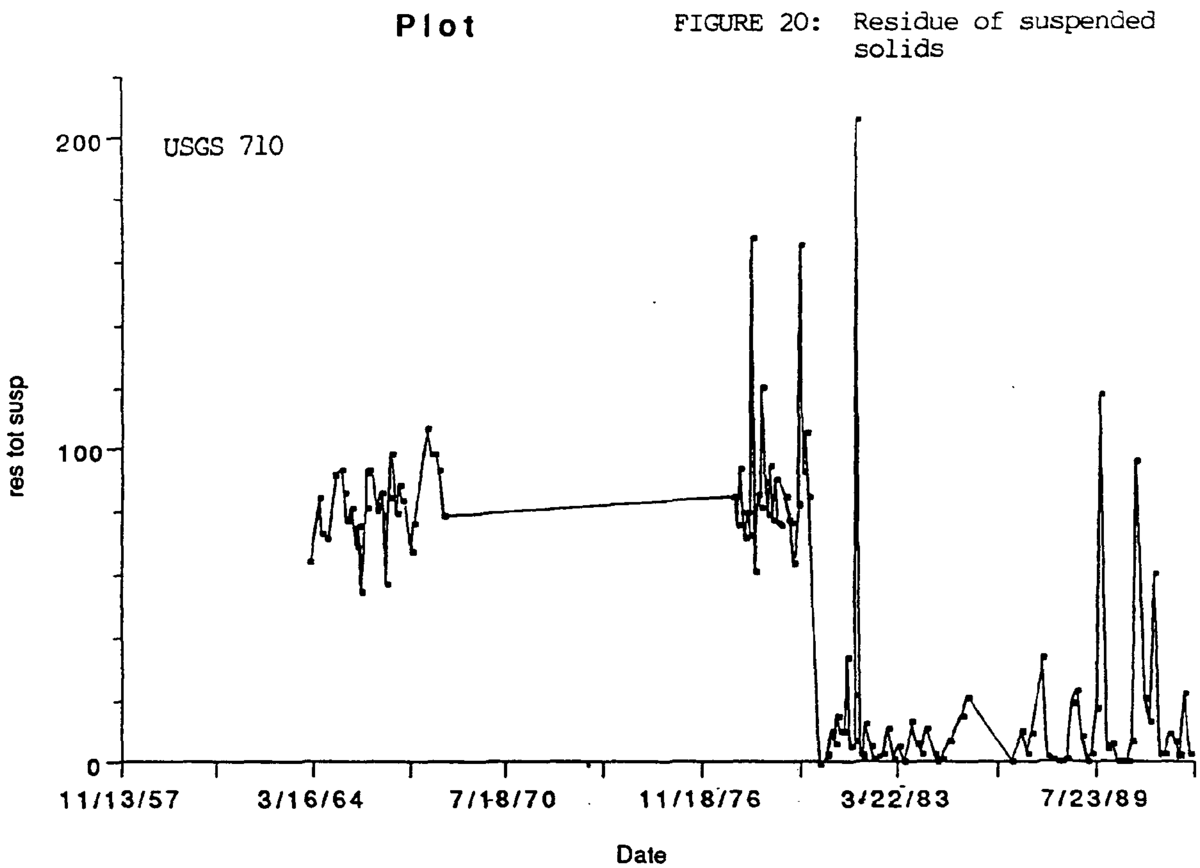
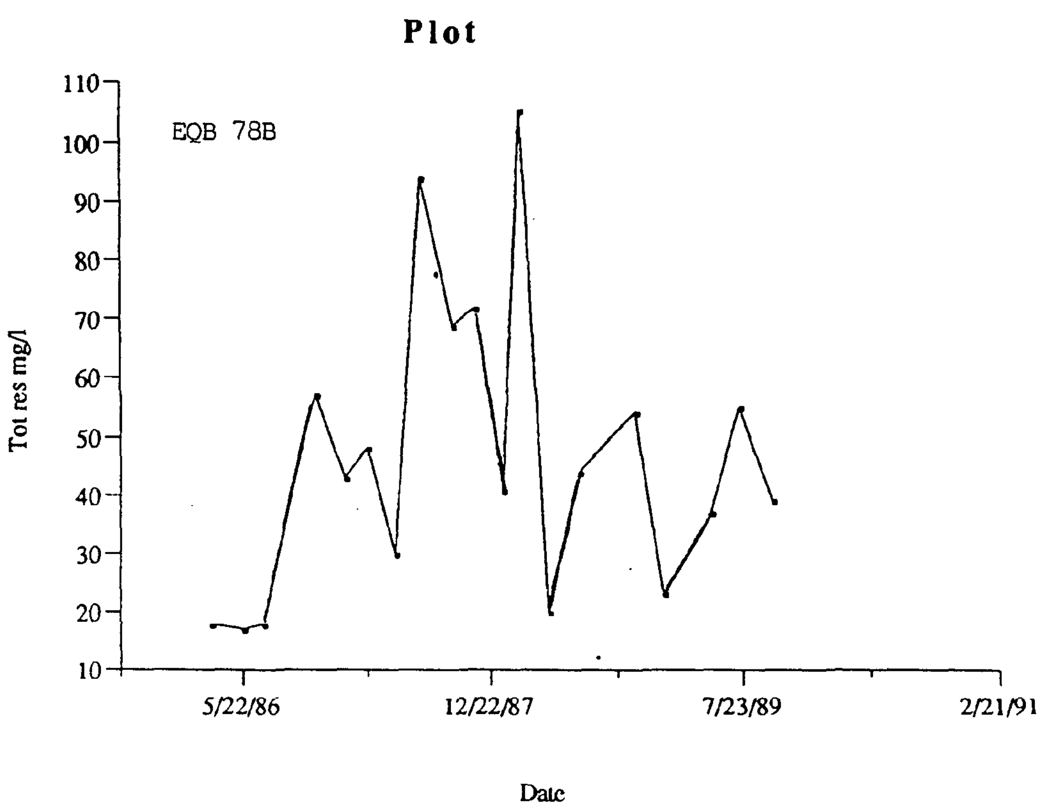
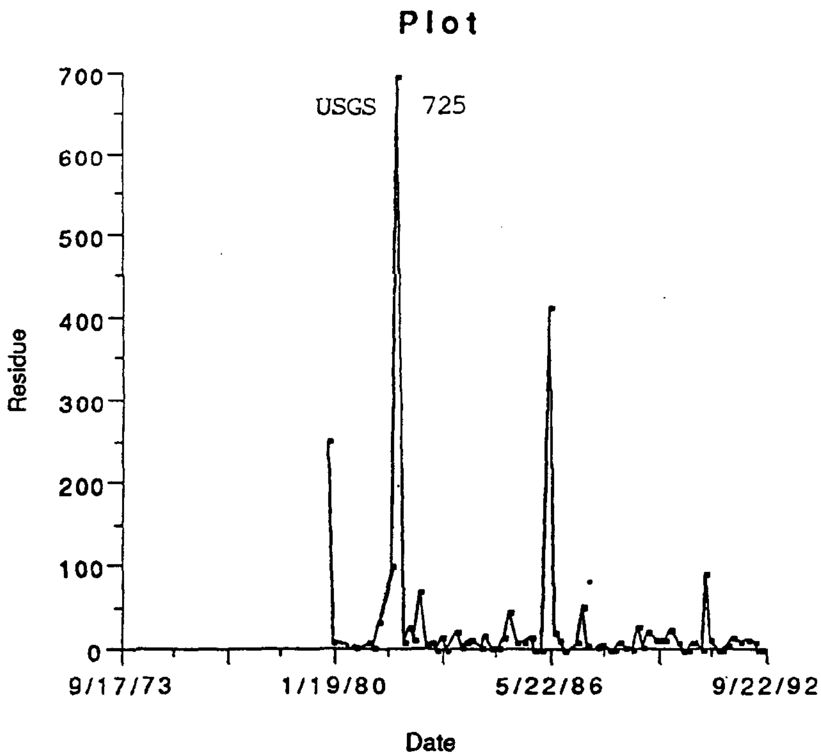


FIGURE 20: Residue of suspended solids






Plot
USGS 725
Residue
0
100
200
300
400
500
600
700
9/17/73
1/19/80
5/22/86
9/22/92
Date

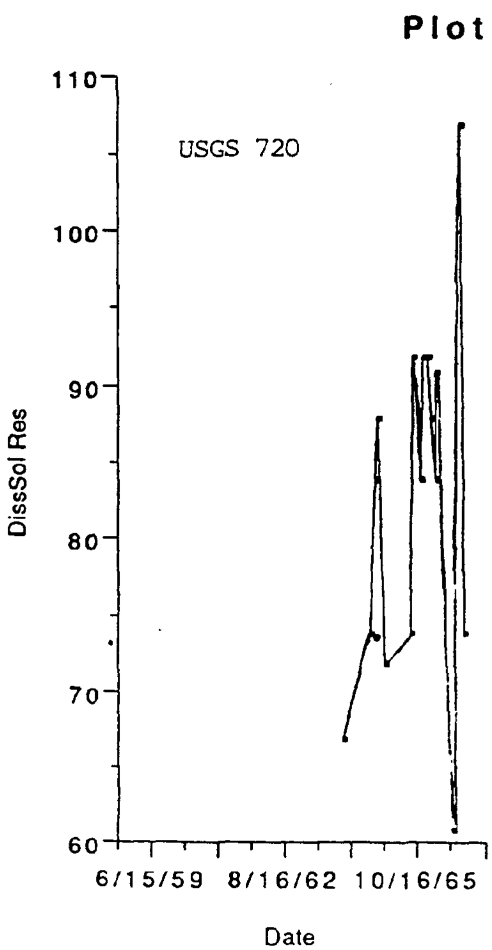
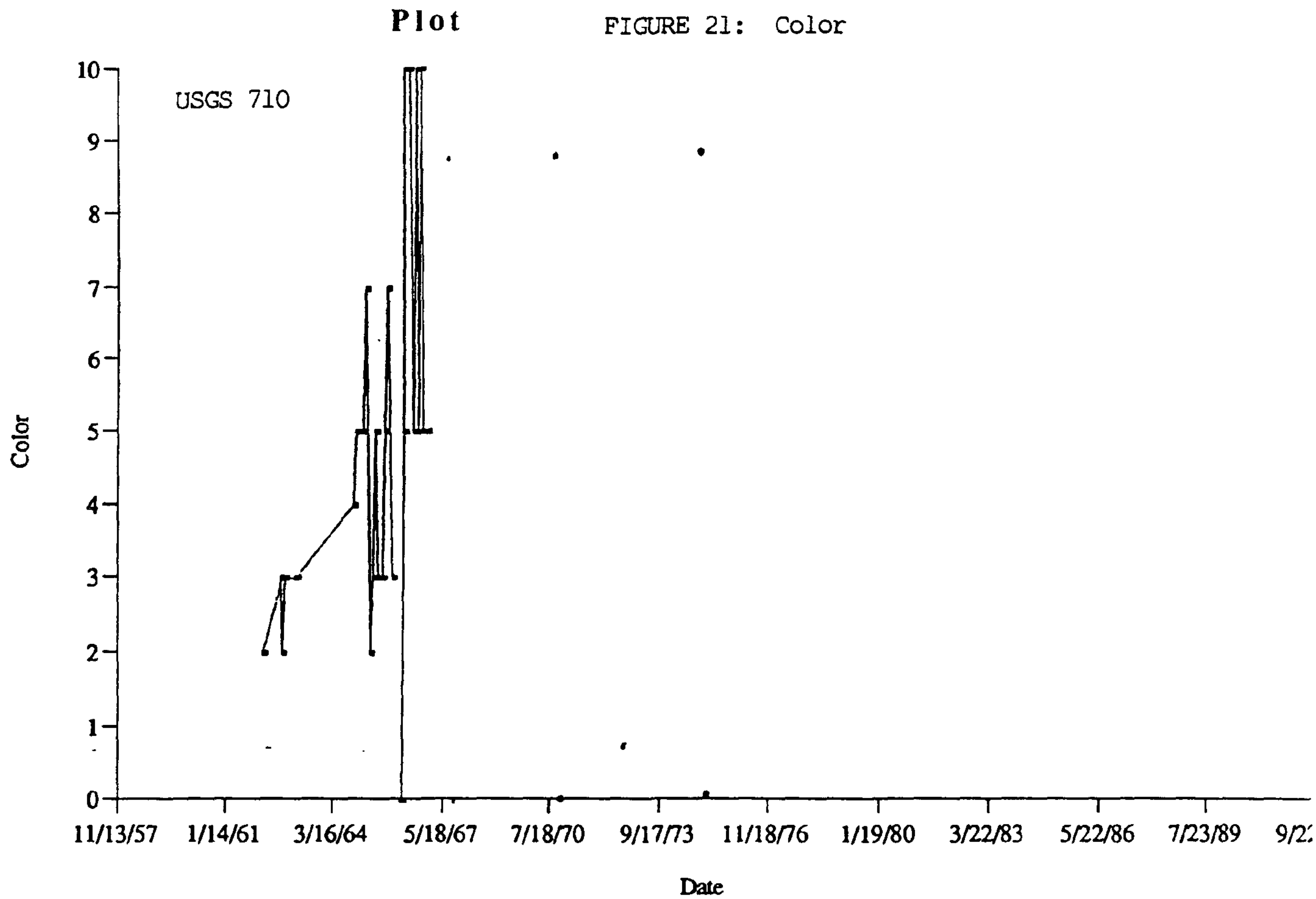
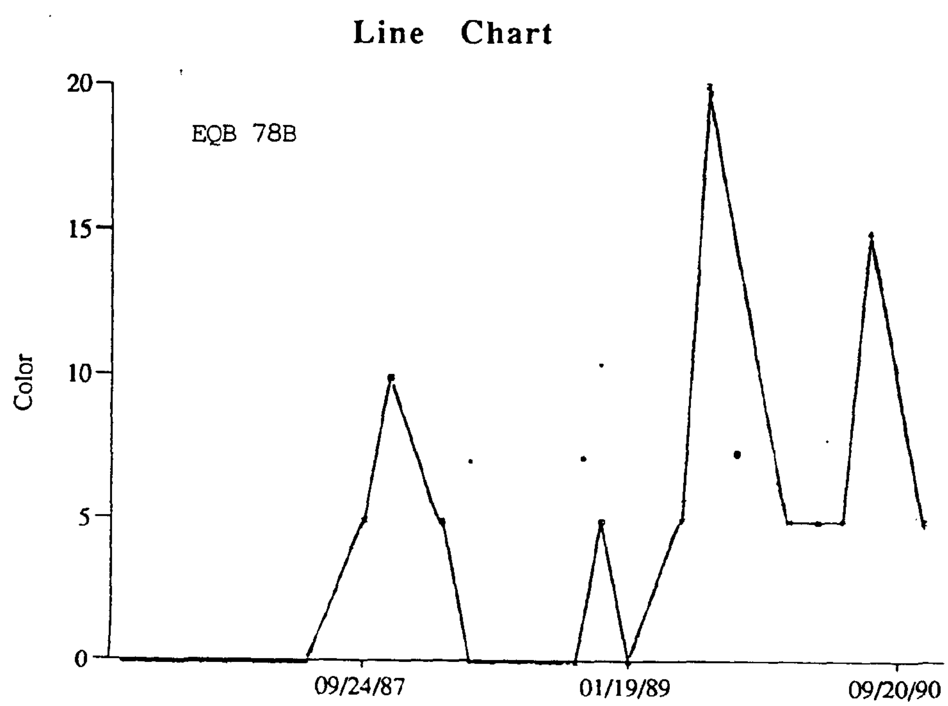
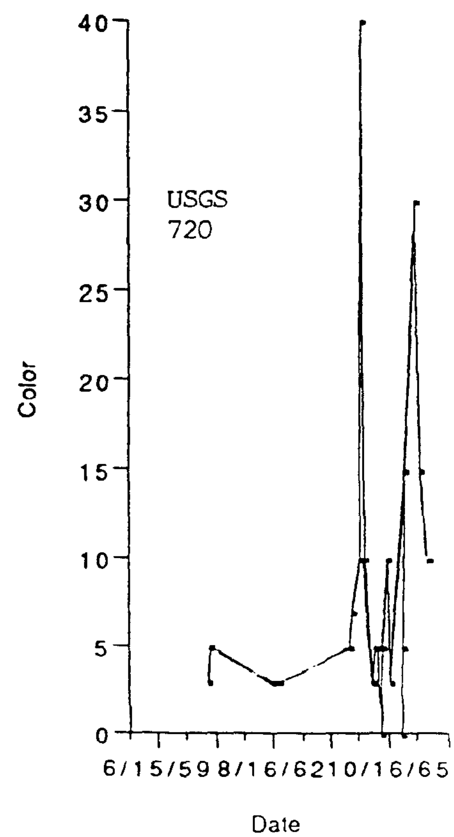
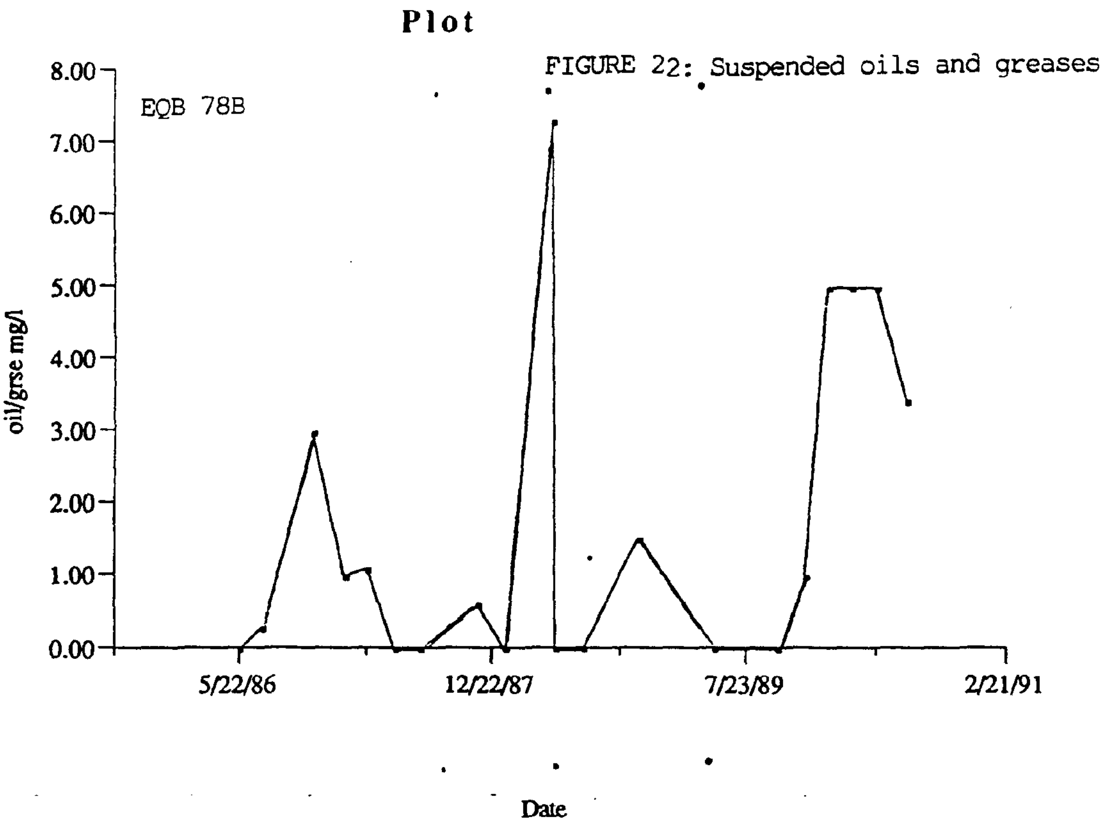

Plot
USGS 720
DissSol Res
60
70
80
90
100
110
6/15/59
8/16/62
10/16/65
Date

FIGURE 21: Color








Plot
FIGURE 22: Suspended oils and greases
EQB 78B
8.00
7.00
6.00
5.00
4.00
3.00
2.00
1.00
0.00
oil/grse mg/l
5/22/86
12/22/87
7/23/89
2/21/91
Date

One way of estimating the requirements for oxygen in a body of water is to study the pattern of oxygen uptake in the water itself using various oxygen measurements along with COD and BOD over time. Several conditions combine together to determine oxygen requirement: First, oxygen is more soluble in cold water than in warm water, and in clear water than in water with high levels of suspended sediments. Second, organic matter consumes oxygen slower in cold water than in warm water. Third, decomposition of organic matter in water increases CO_2 content and reduces pH. Fourth, some aquatic animals (like fish), cannot take up oxygen as fast in low pH waters with high CO_2 as in high pH waters with low CO_2.

Data from the Fajardo River show critical oxygen situations for 1973-74 (DO valley in 1974 at USGS 725; BOD peaks in 1973-74 at USGS 710). Although such problem levels fell significantly to normal fluctuations, BOD, COD and *% of oxygen saturation* data signals to an descending tendency in available oxygen (Table 9: parameters # 15, 16, 17 &18; Figures 23, 24, 25 & 26).

Hardness and alkalinity

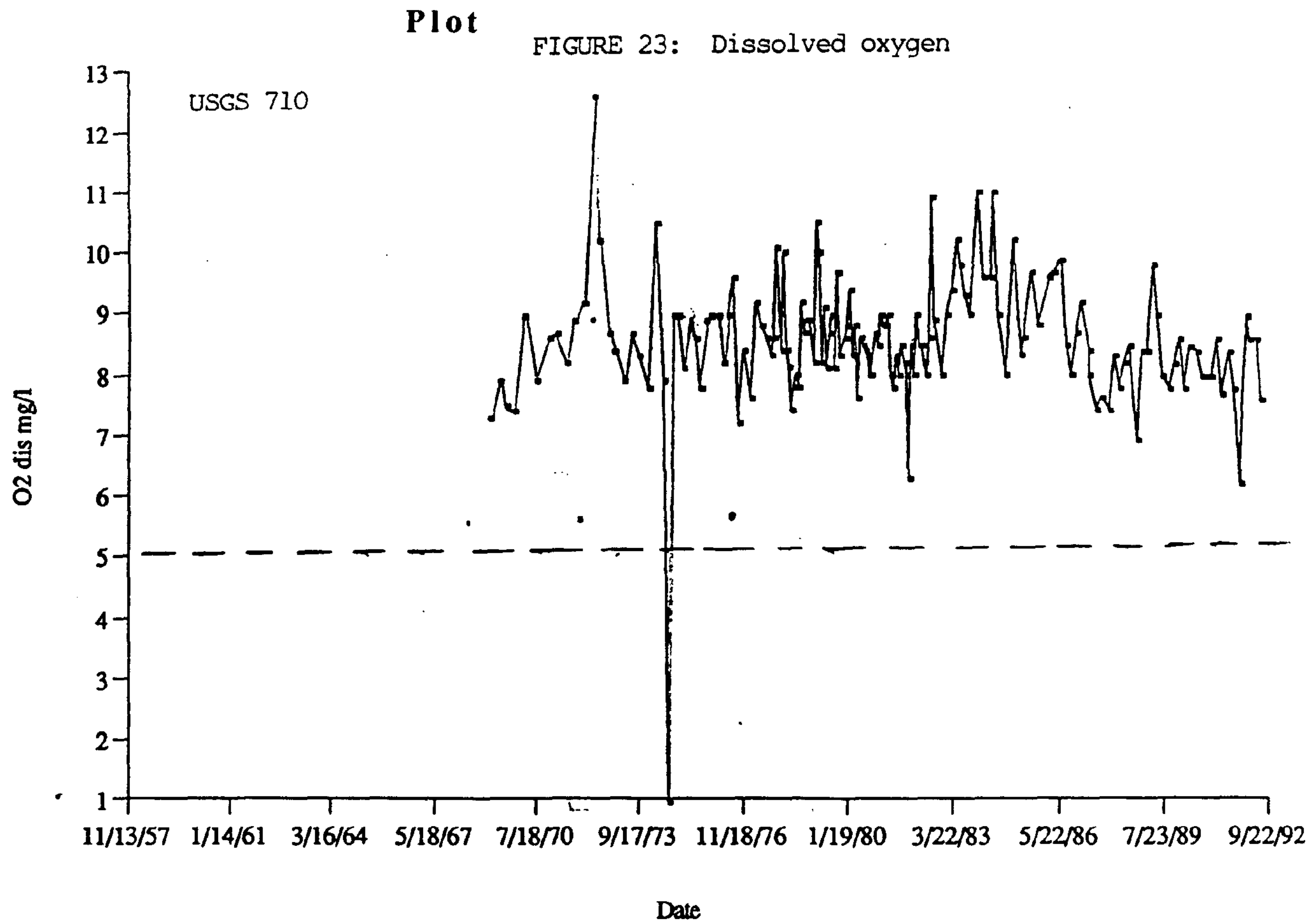
Hardness is the amount of dissolved alkaline metals in water. "Hard" waters are waters high in such materials, particularly calcium and magnesium; these waters are present in areas of limestone or other alkaline type of soils. "Soft" waters, like those of the Fajardo River, are low in such components.

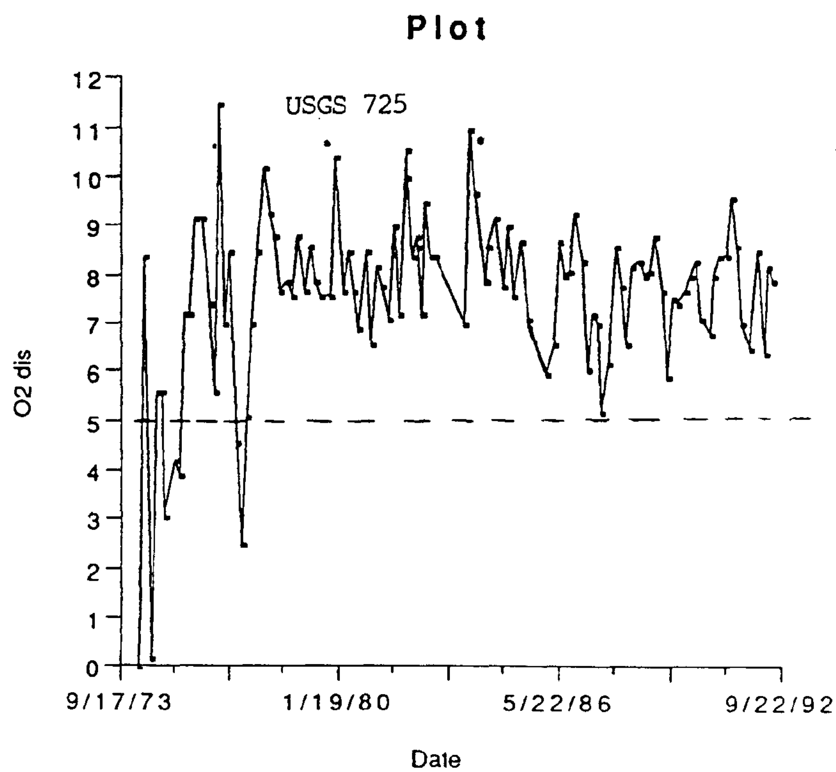
Historical data from the Fajardo River show a declining tendency in hardness, though periodical peaks occur. These peaks may be due to intensive use of fertilizers, which tend to be alkaline (Table 9: parameters #19 & 20; Figures 27 & 28).

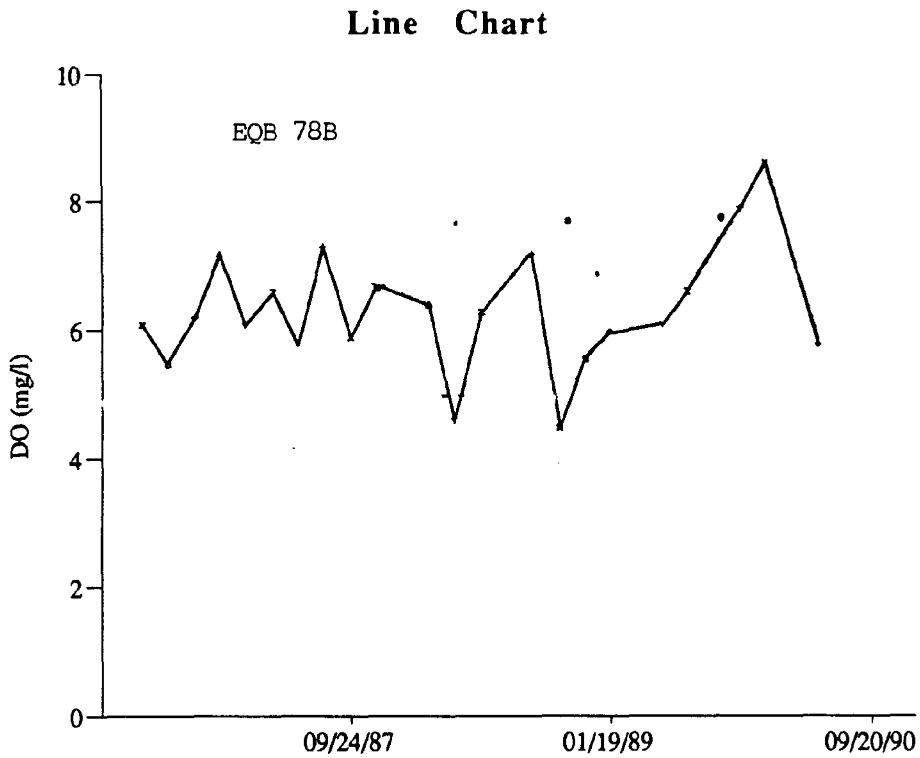
Alkalinity is an estimate of the amount of negative ions (anions) dissolved in water (anions react with water to form alkaline materials). In the Fajardo basin, alkalinity as such shows a decrease, but amounts of alkaline materials: sodium (Na), calcium (Ca), magnesium (Mg), potassium (K), and sulfates (SO_4^{-2}), all show increasing tendencies (Table 9: parameters #21, 22, 23, 24, 25 & 32; Figures 29, 30, 31, 32, 33 & 34).

SO_4^{-2} besides its alkaline properties, is a nutrient formed by decomposition of organic matter.

FIGURE 23: Dissolved oxygen

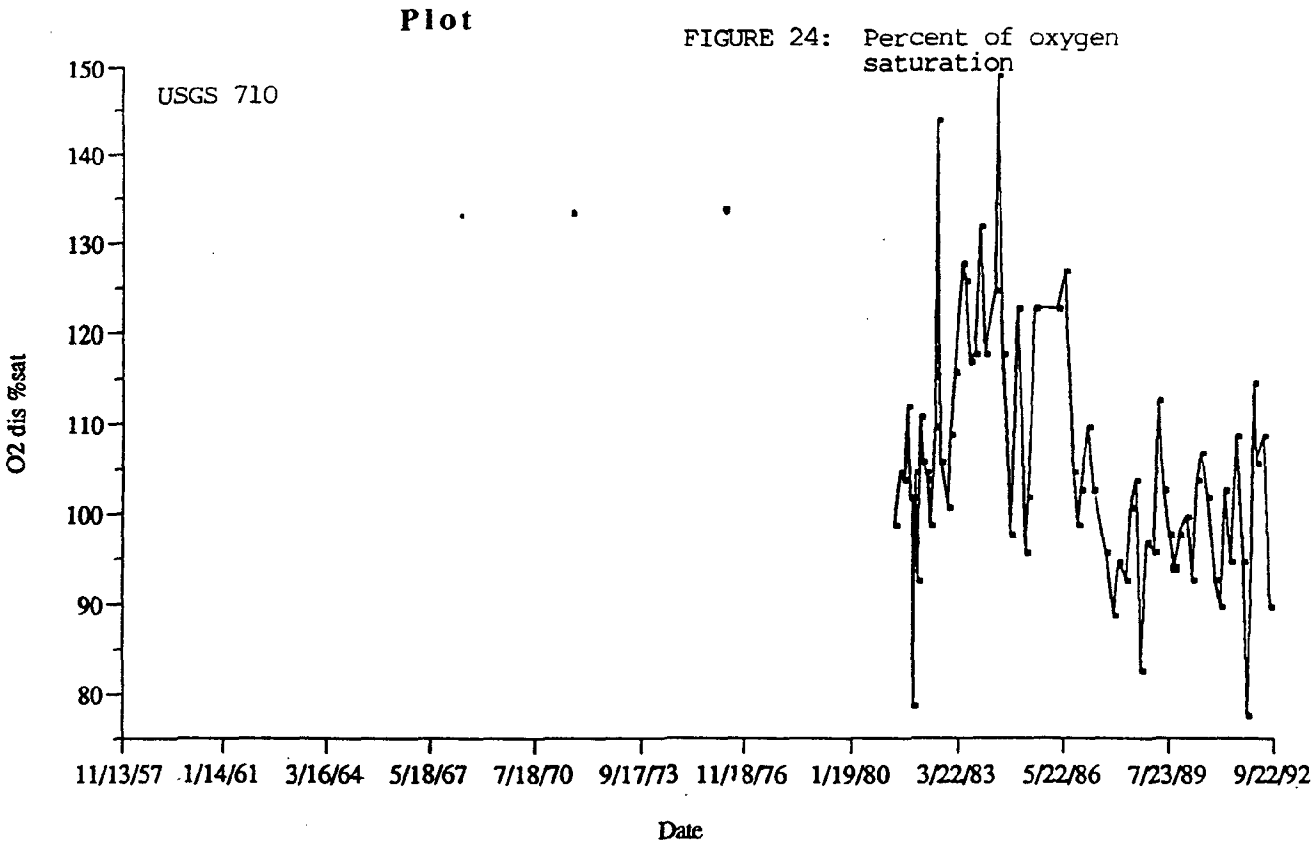


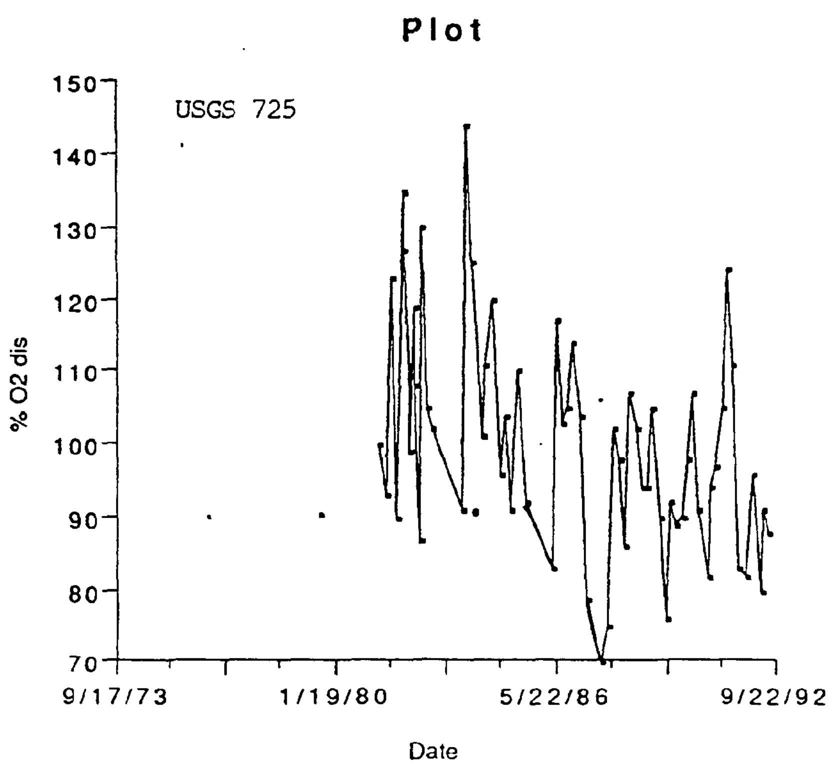




DO (mg/l)

FIGURE 24: Percent of oxygen saturation





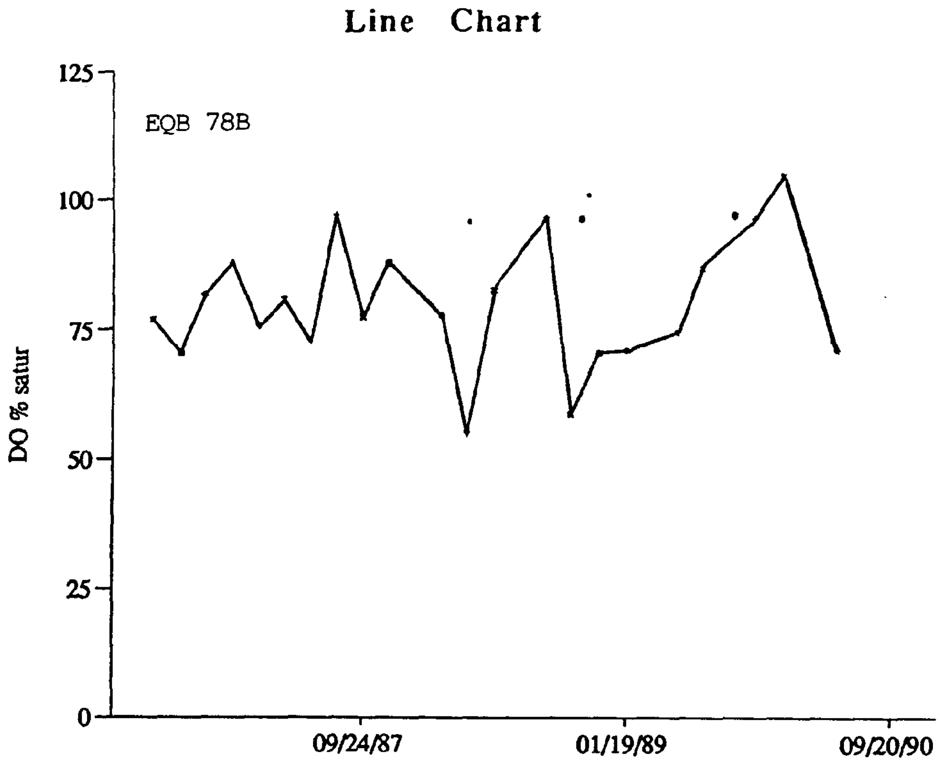
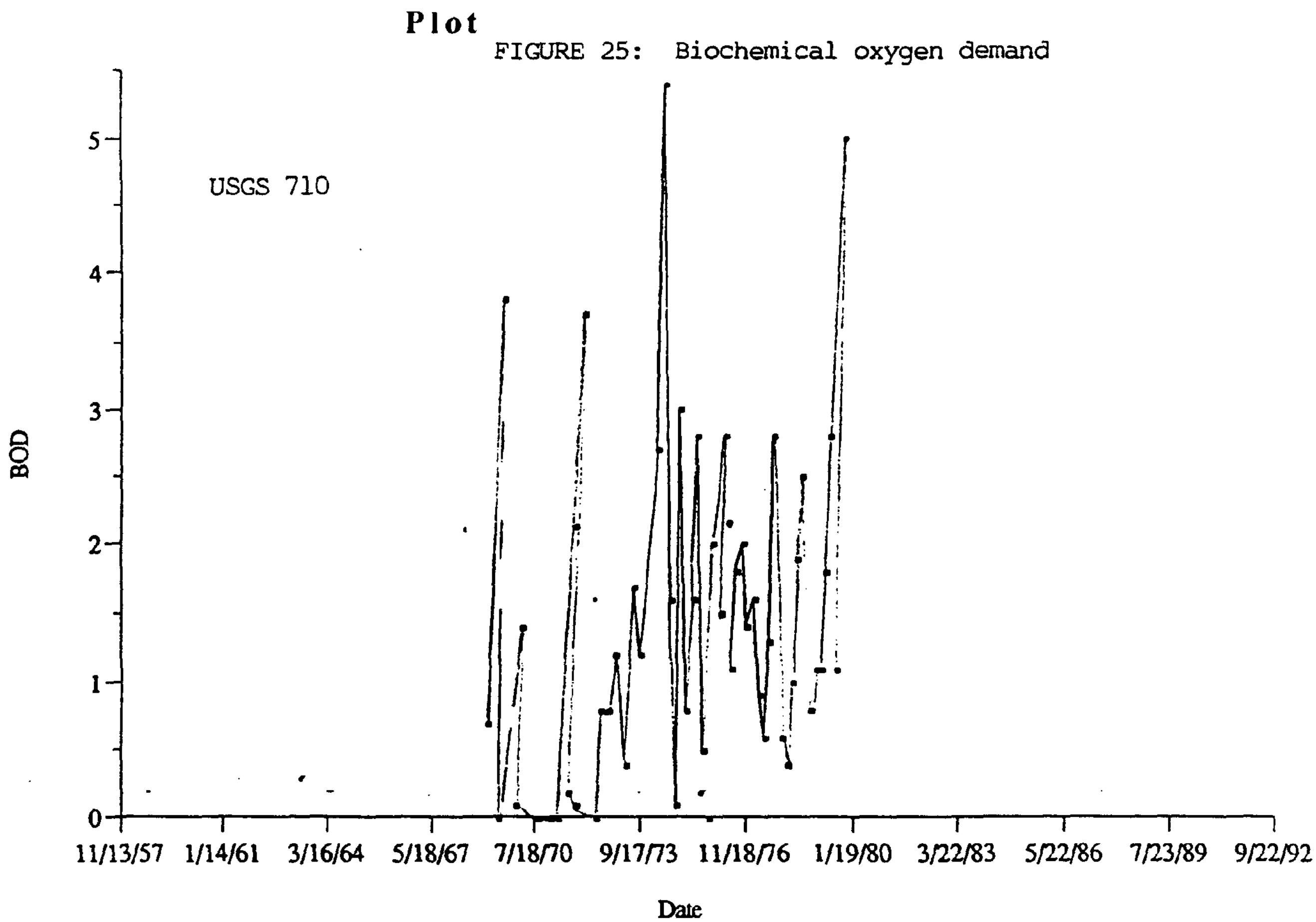

Line Chart
EQB 78B
DO % satur
125
100
75
50
25
0
09/24/87
01/19/89
09/20/90

FIGURE 25: Biochemical oxygen demand



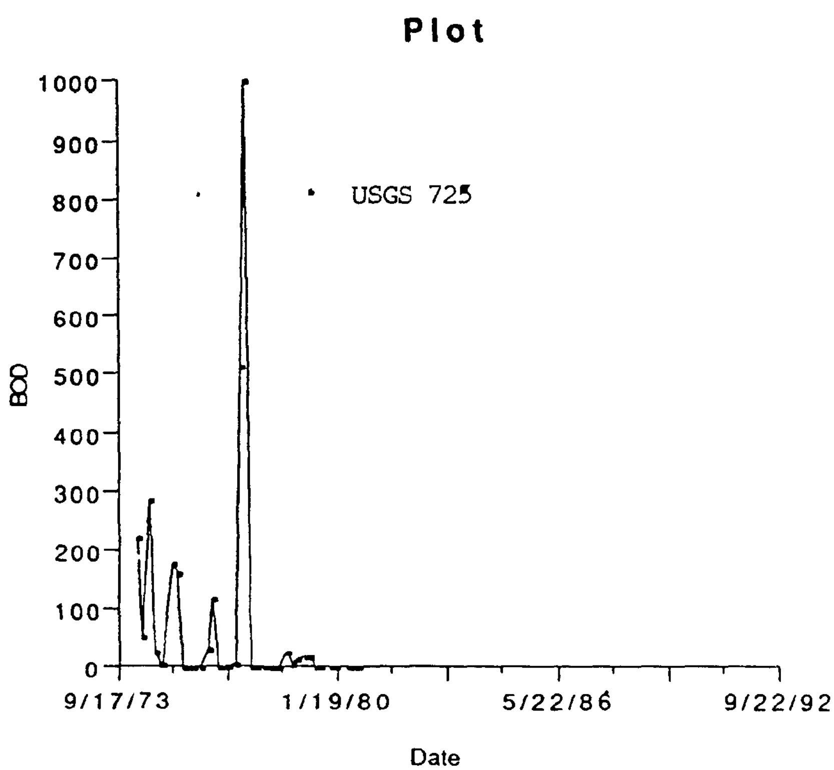
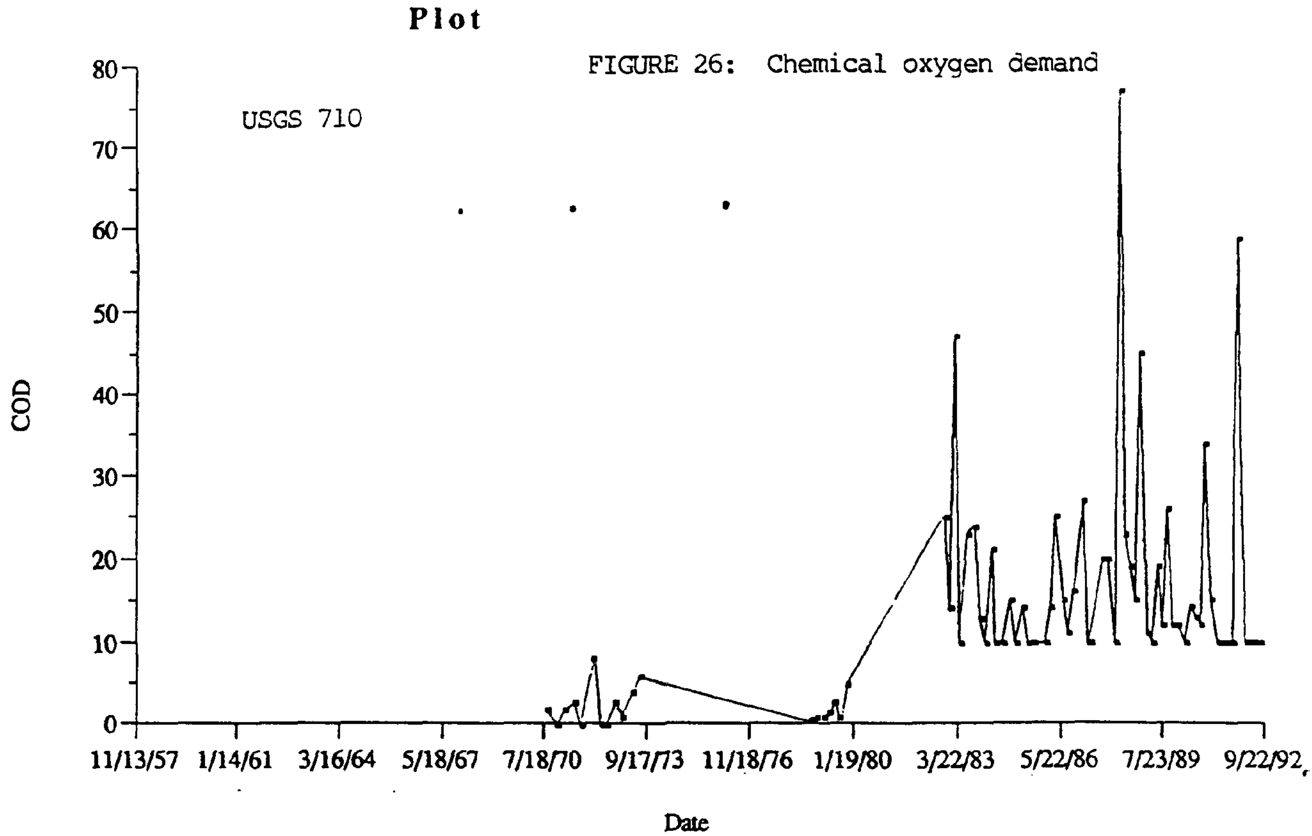


FIGURE 26: Chemical oxygen demand



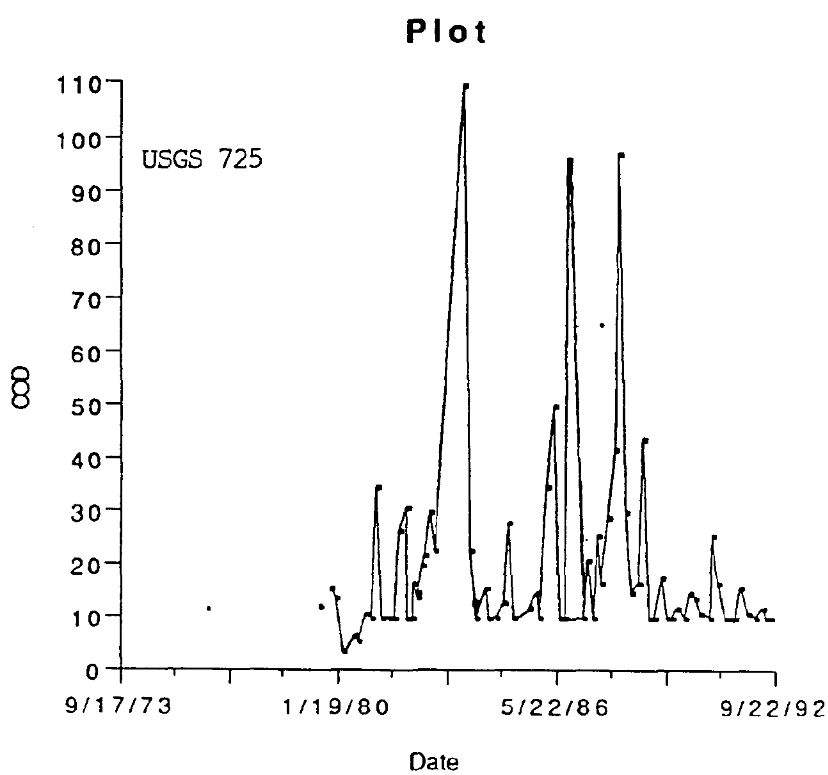
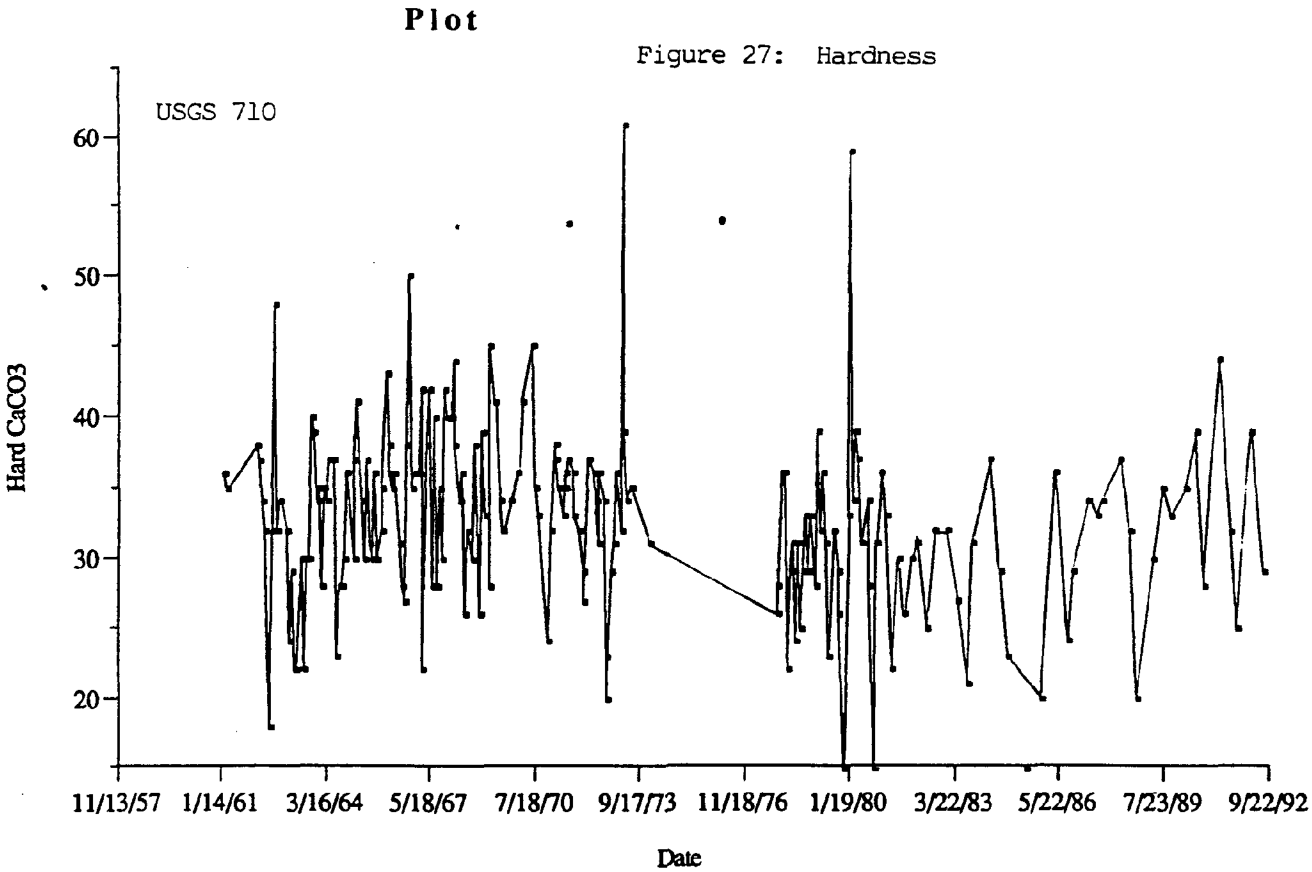
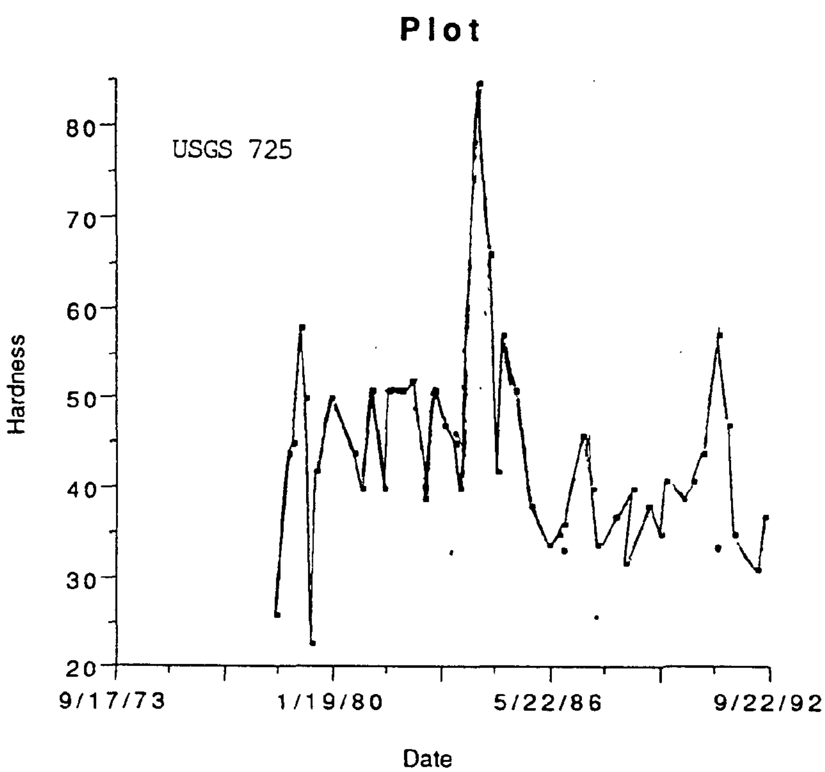


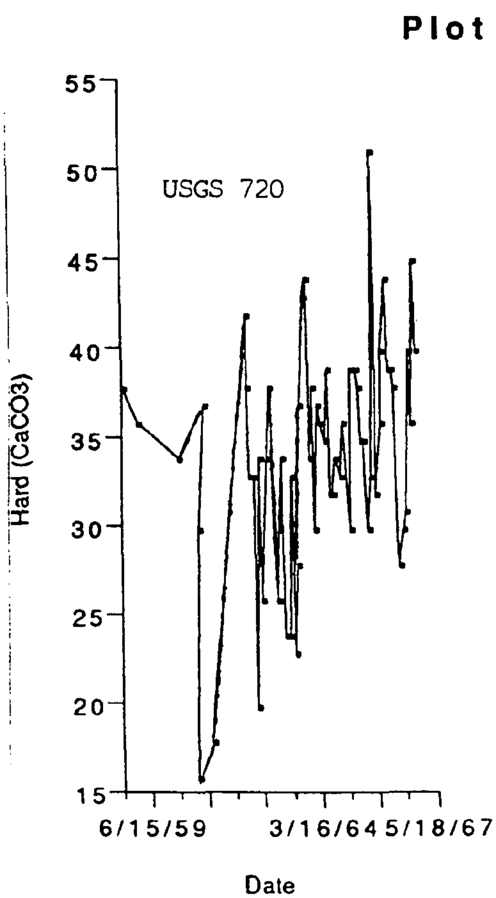
Figure 27: Hardness



Hard CaCO3

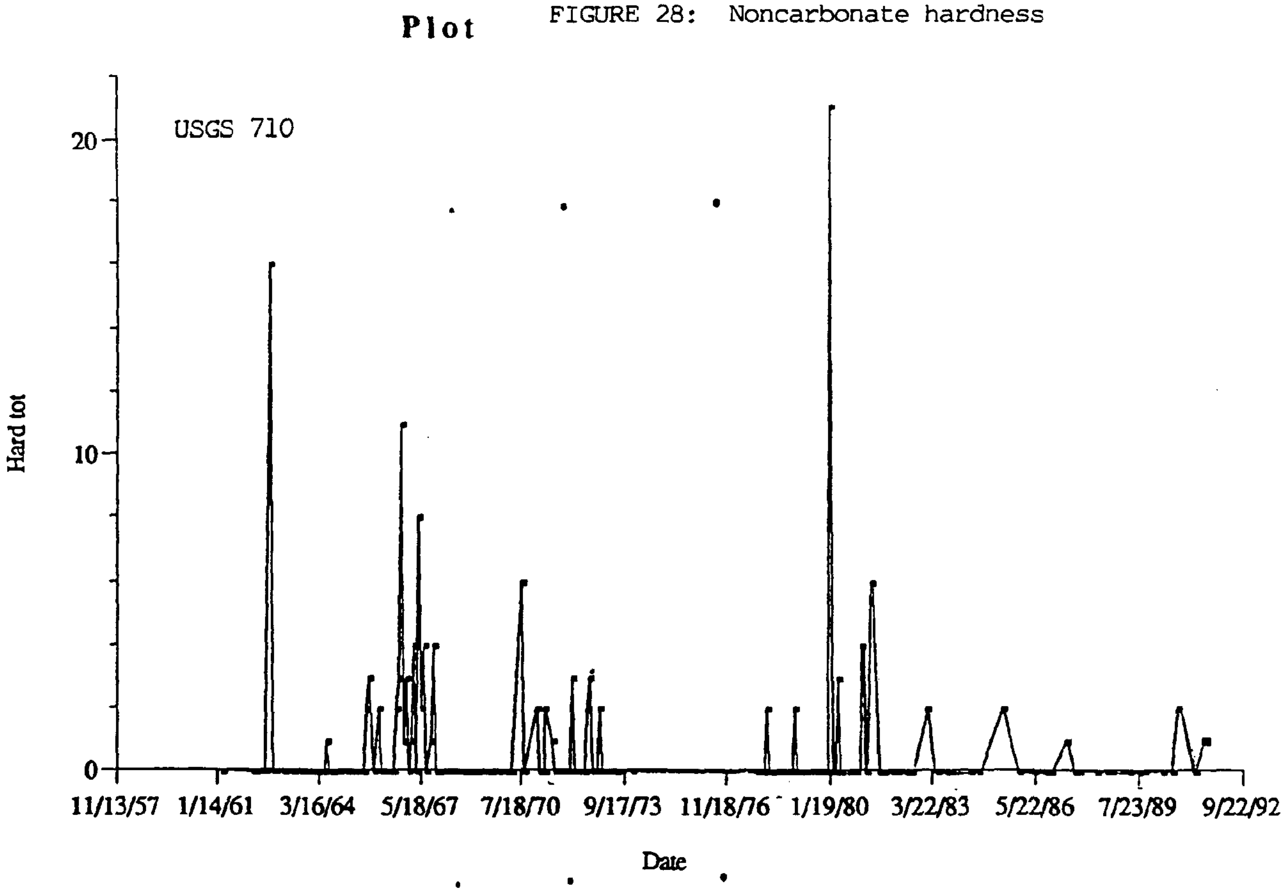


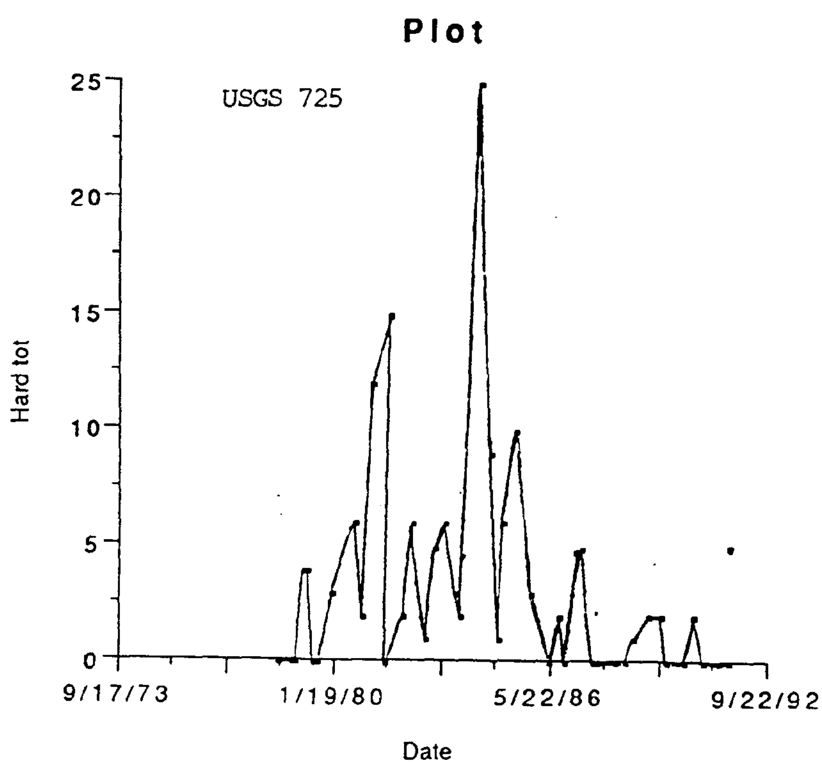
Hardness



Hard (CaCO3)

FIGURE 28: Noncarbonate hardness





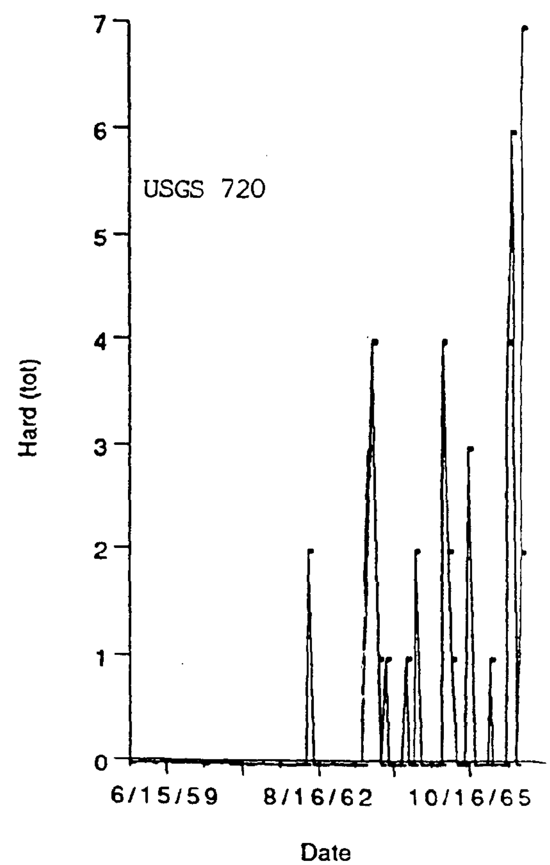
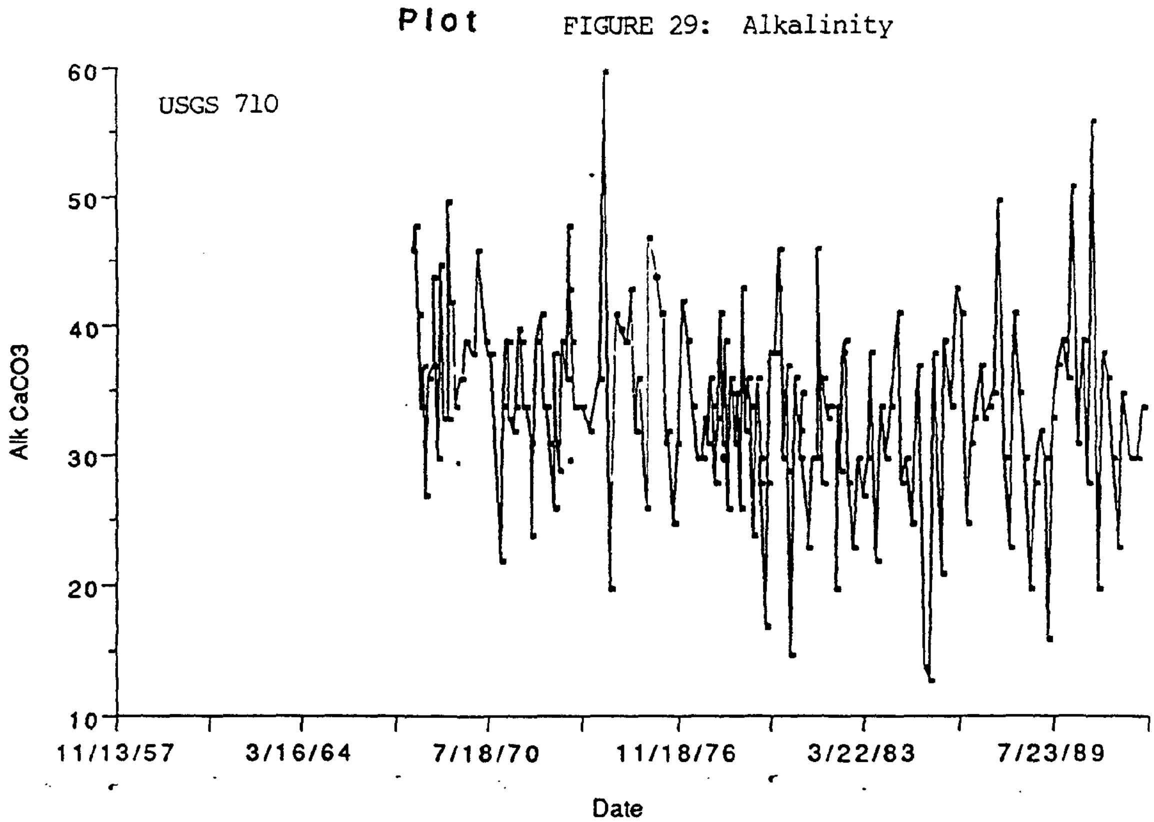


FIGURE 29: Alkalinity



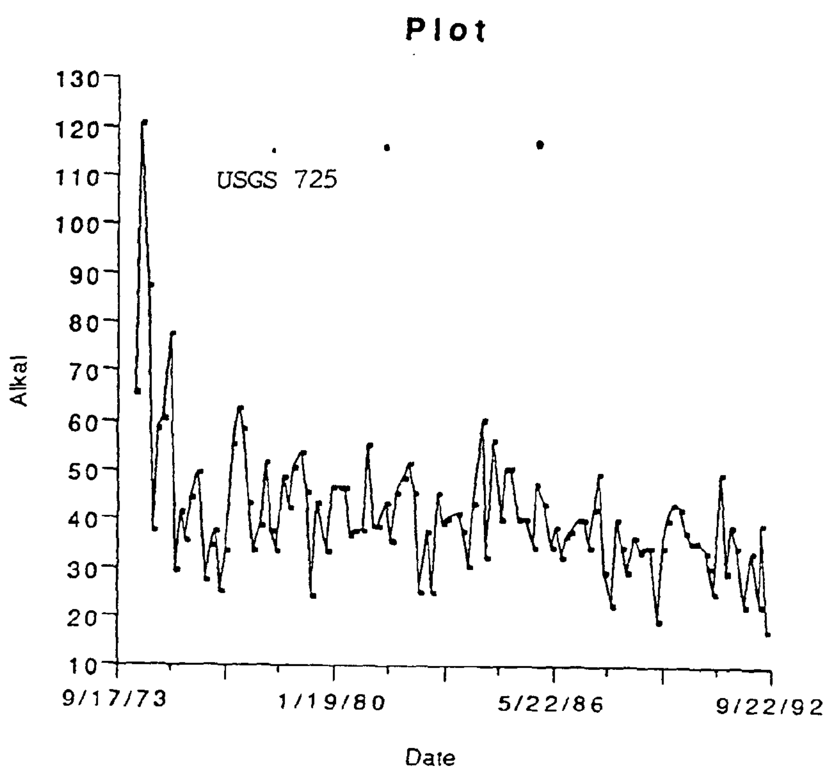
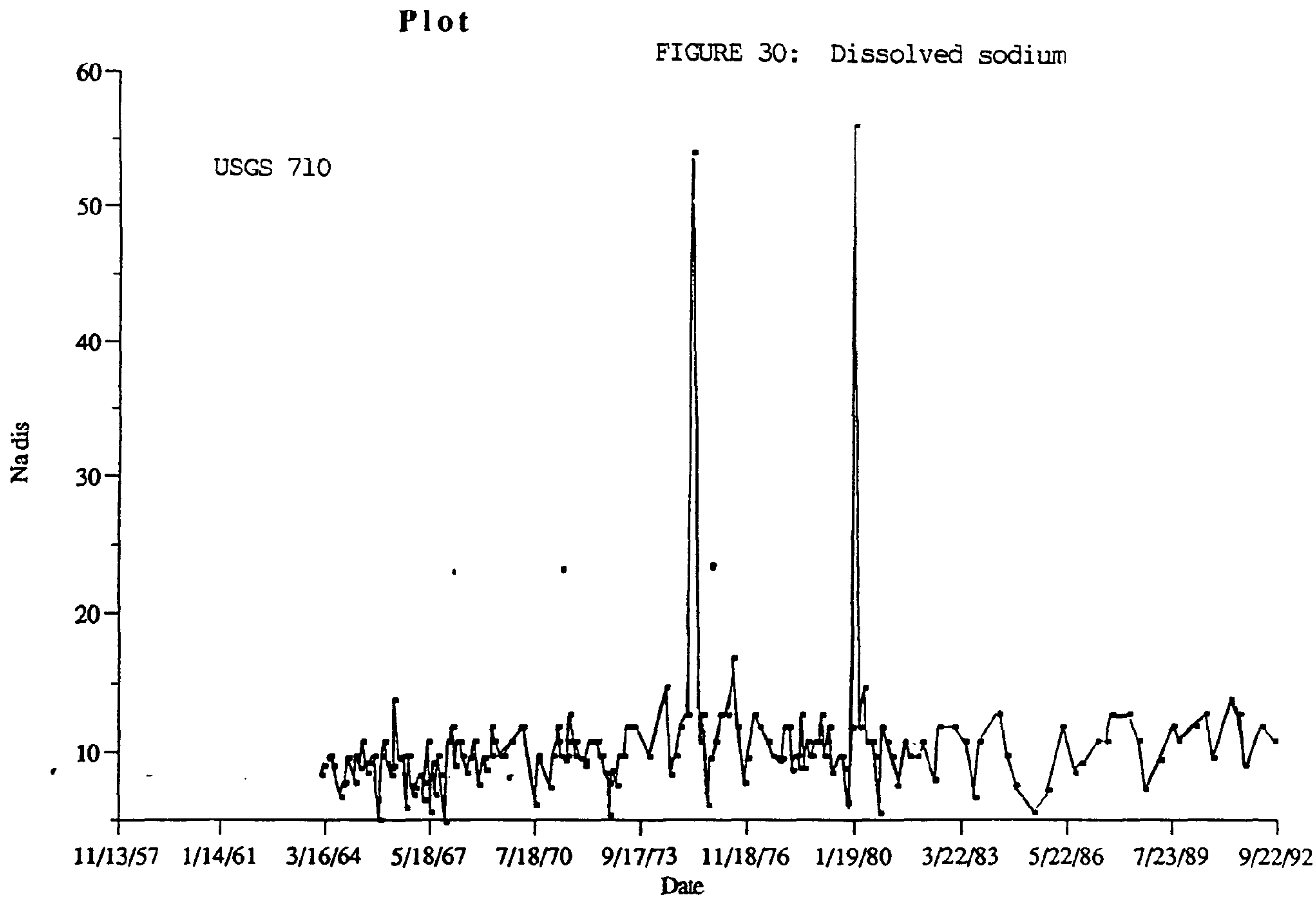
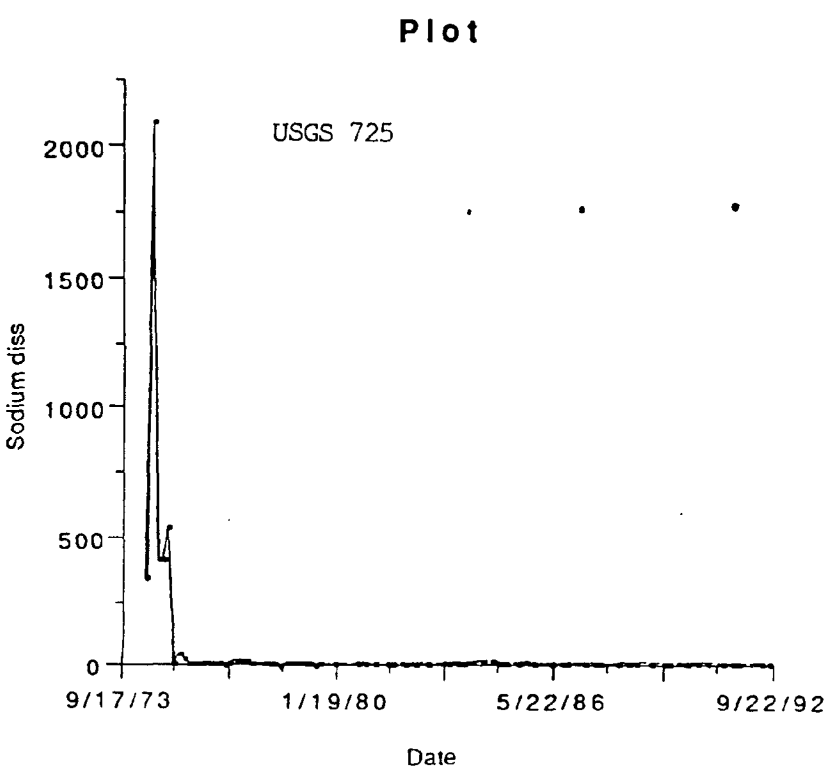


FIGURE 30: Dissolved sodium





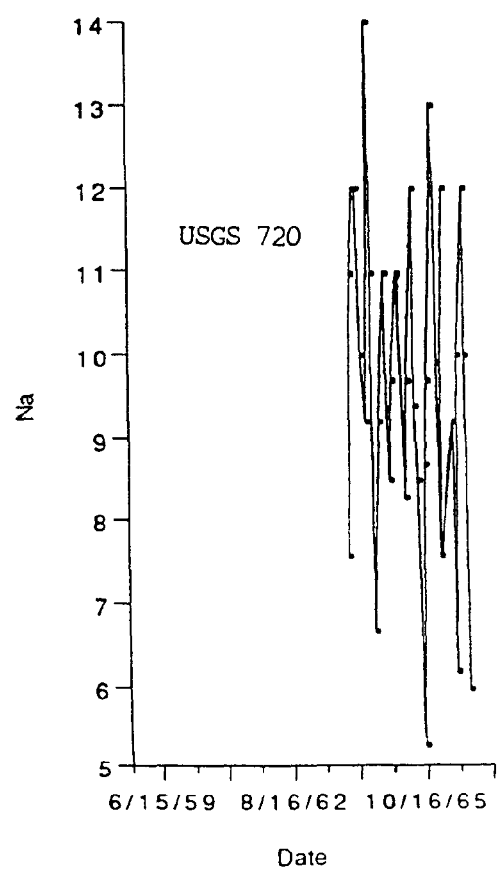
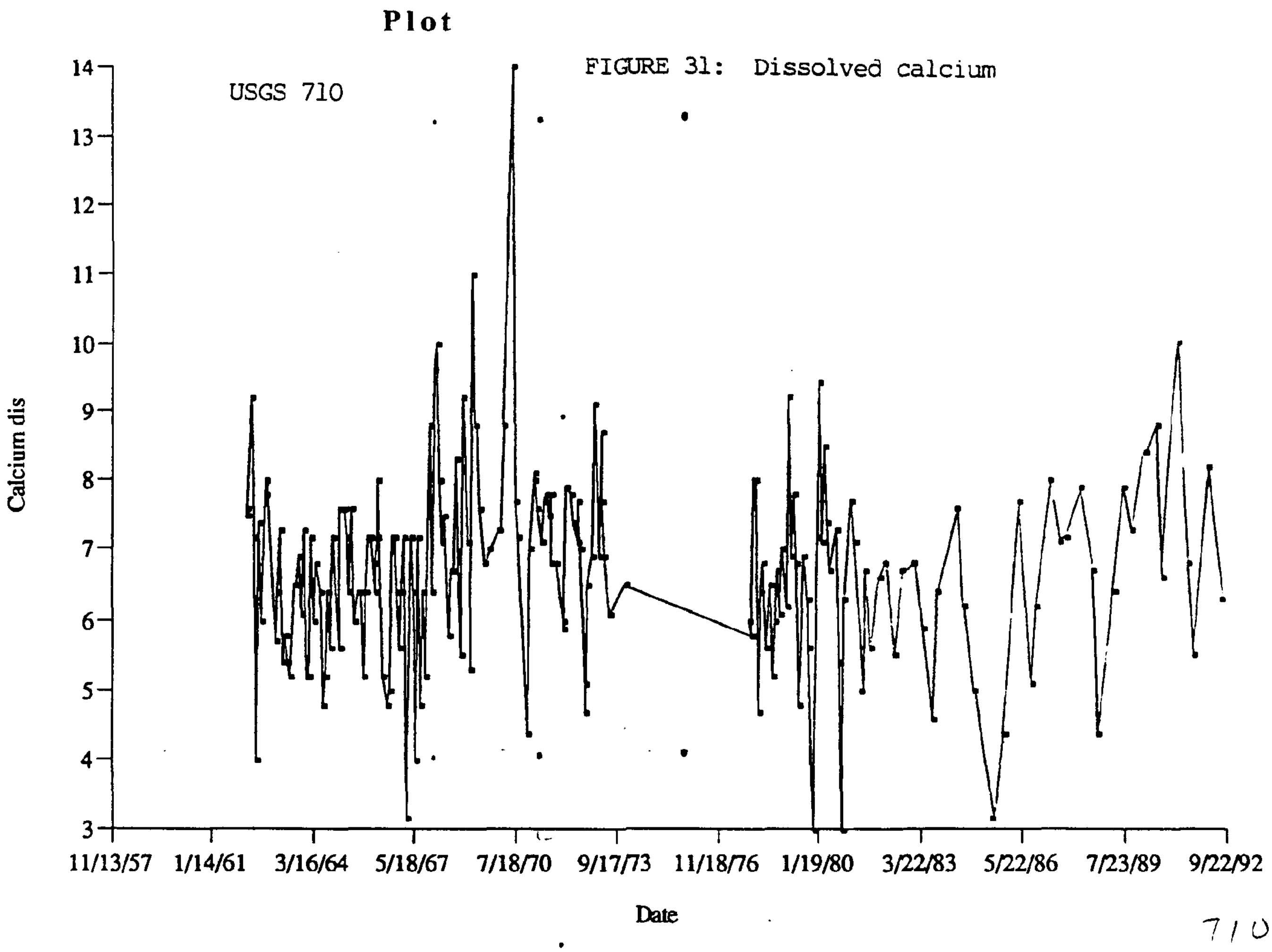
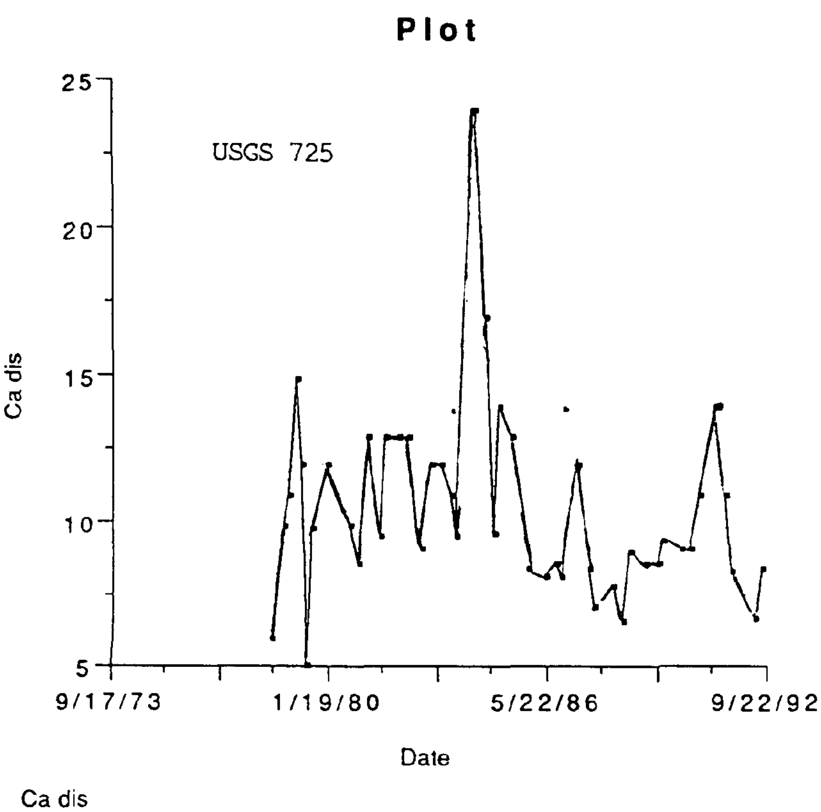


FIGURE 31: Dissolved calcium





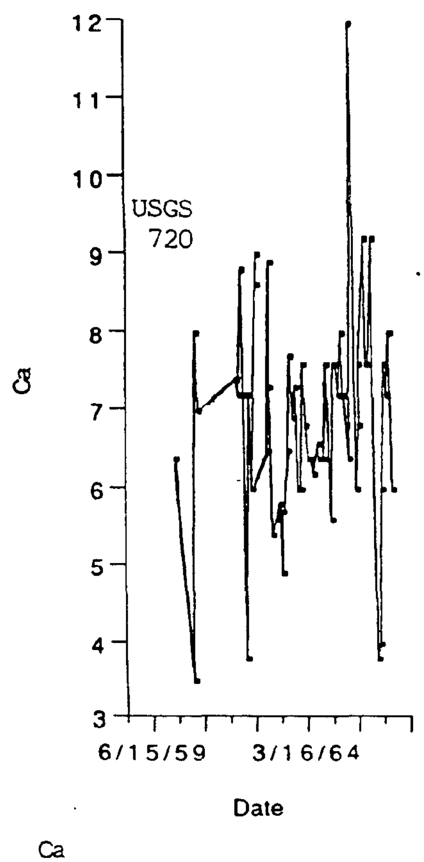
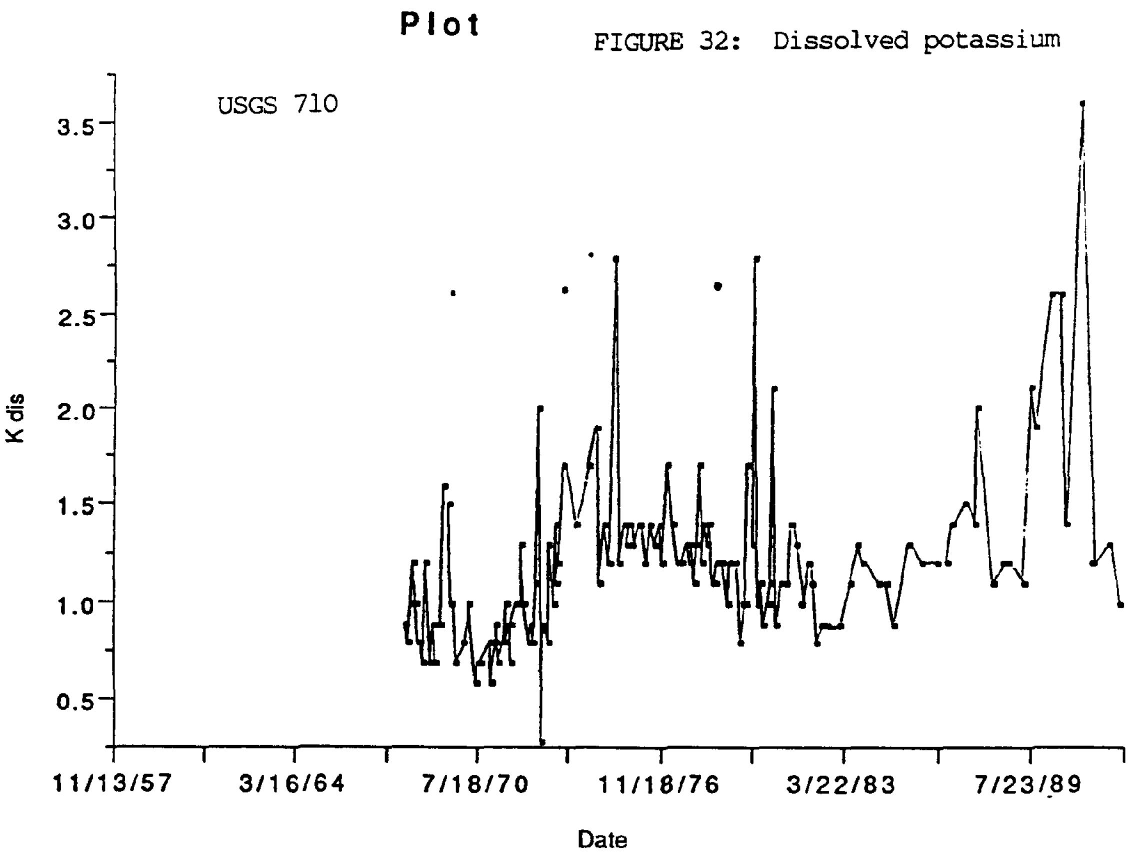


FIGURE 32: Dissolved potassium



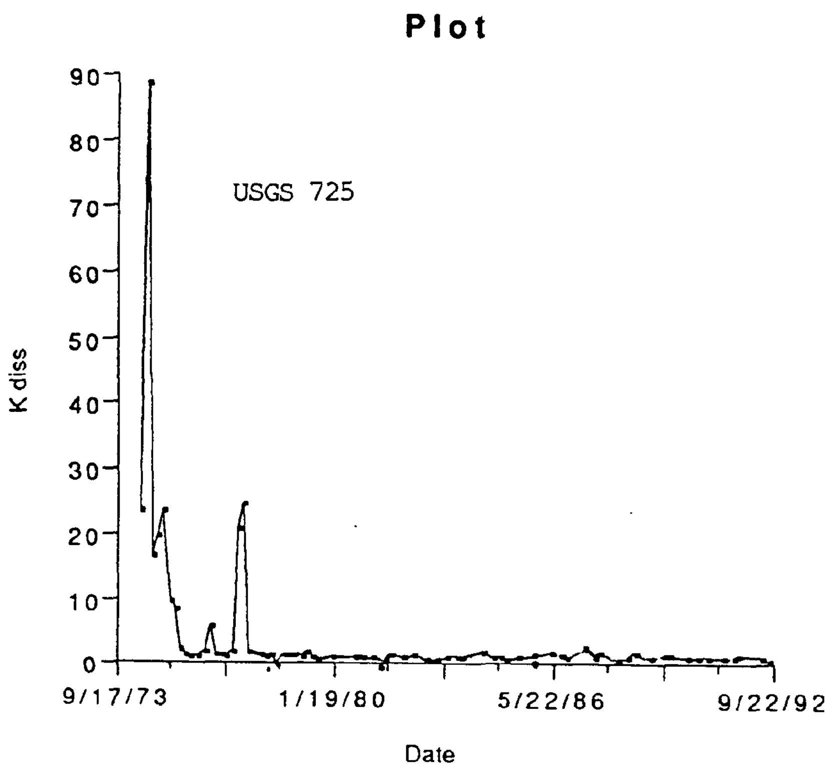
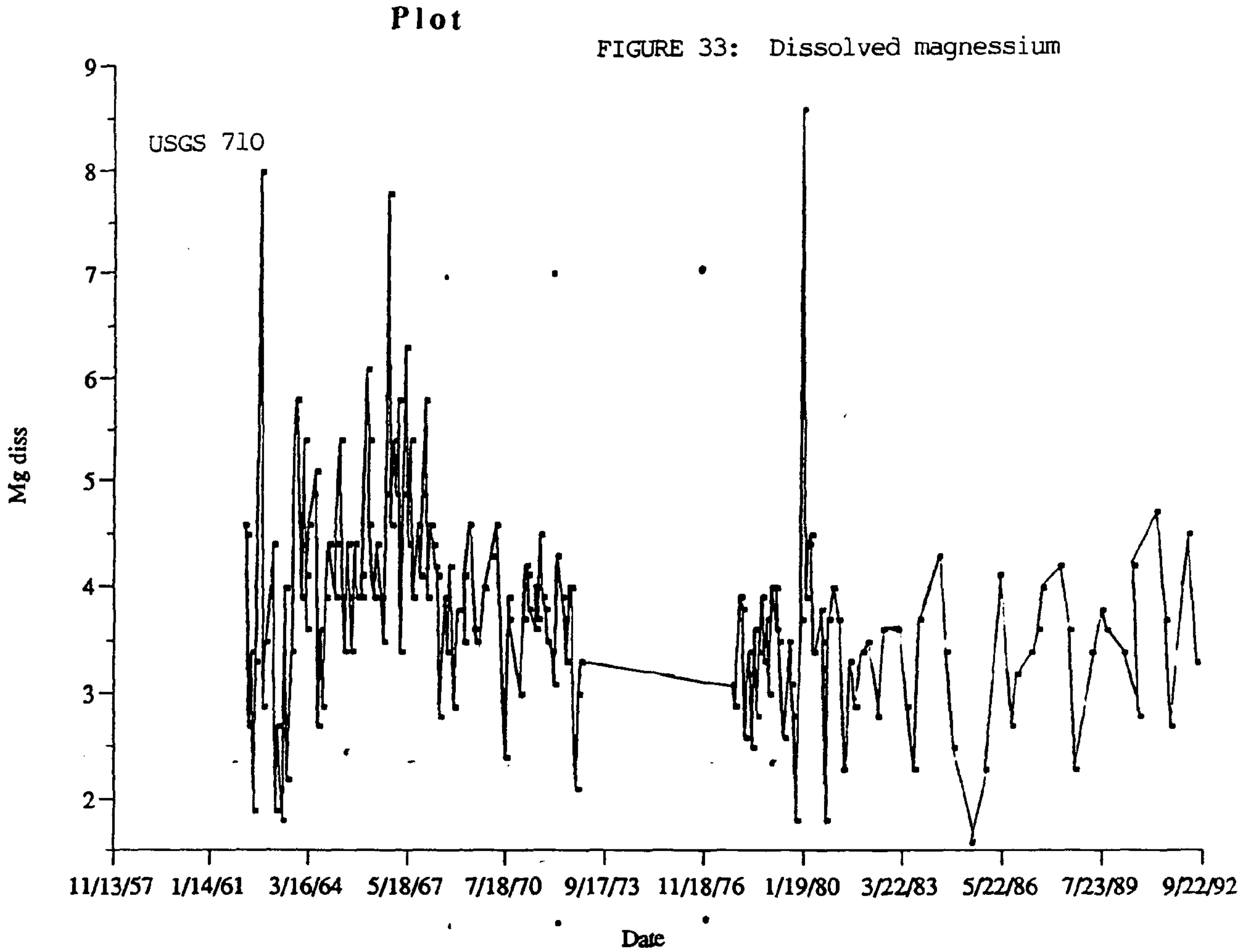
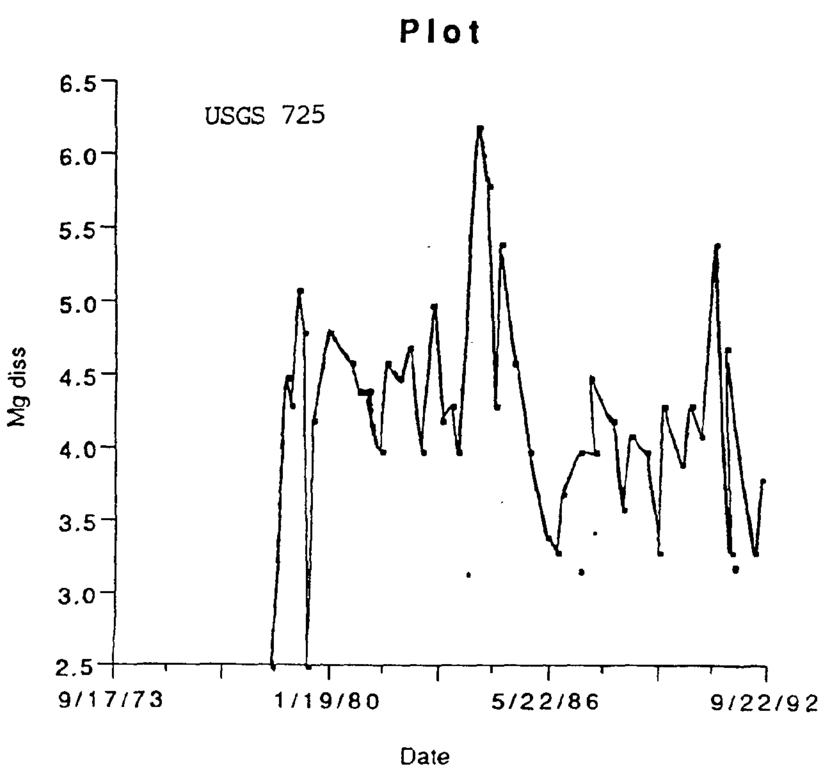


FIGURE 33: Dissolved magnesium





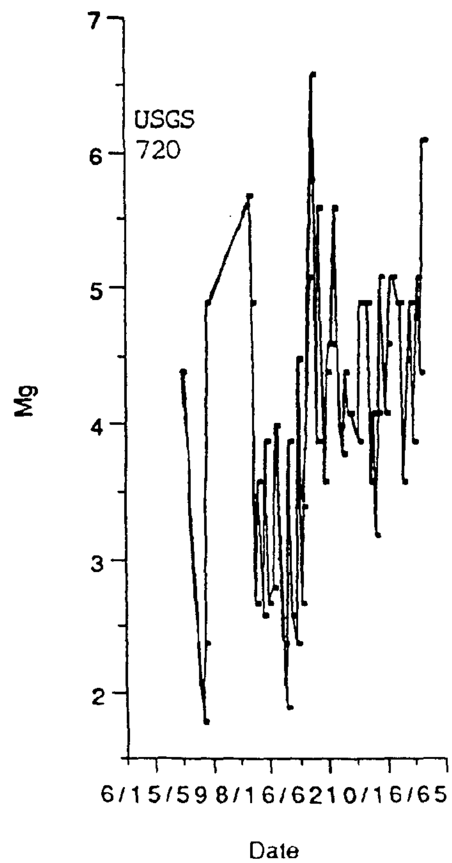
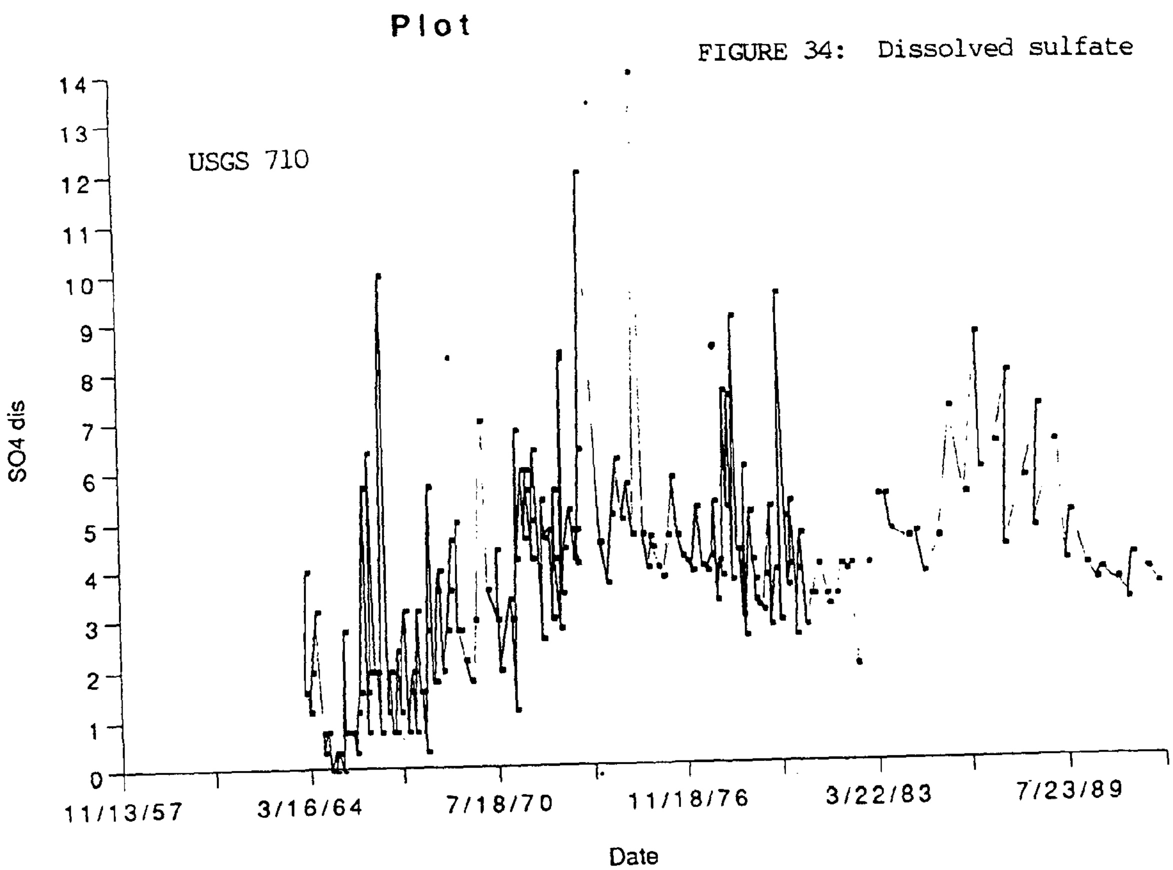
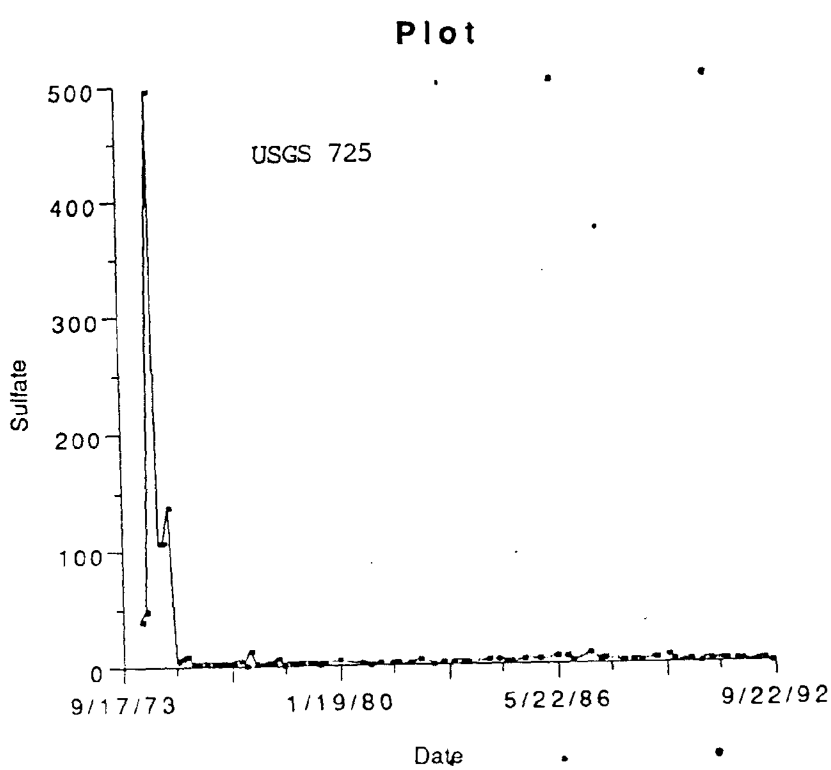
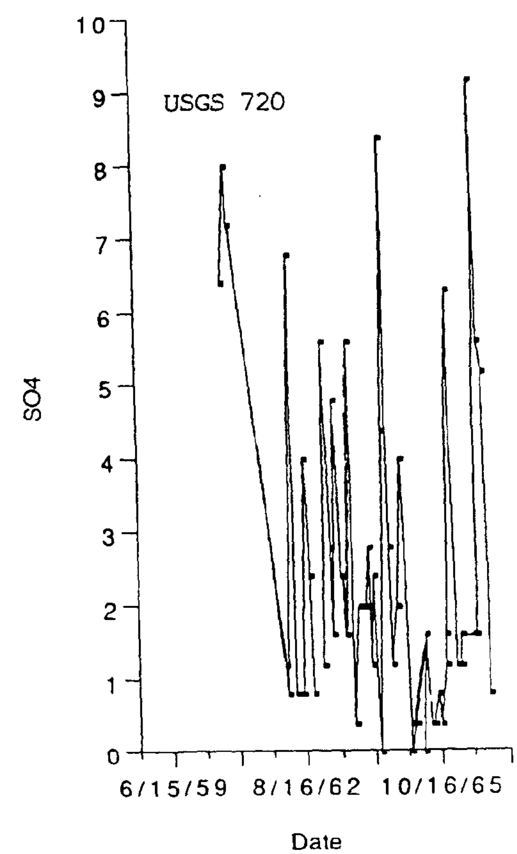


FIGURE 34: Dissolved sulfate







Sulfate

Substances reactive to Methylene Blue

Methylene Blue is a chemical dye which changes color in the presence of anions dissolved in water. So, the dye is used as an indirect method of estimating alkalinity and hardness. In the data from the Fajardo River it shows a declining tendency (Table 9: parameter #61; Figure 35).

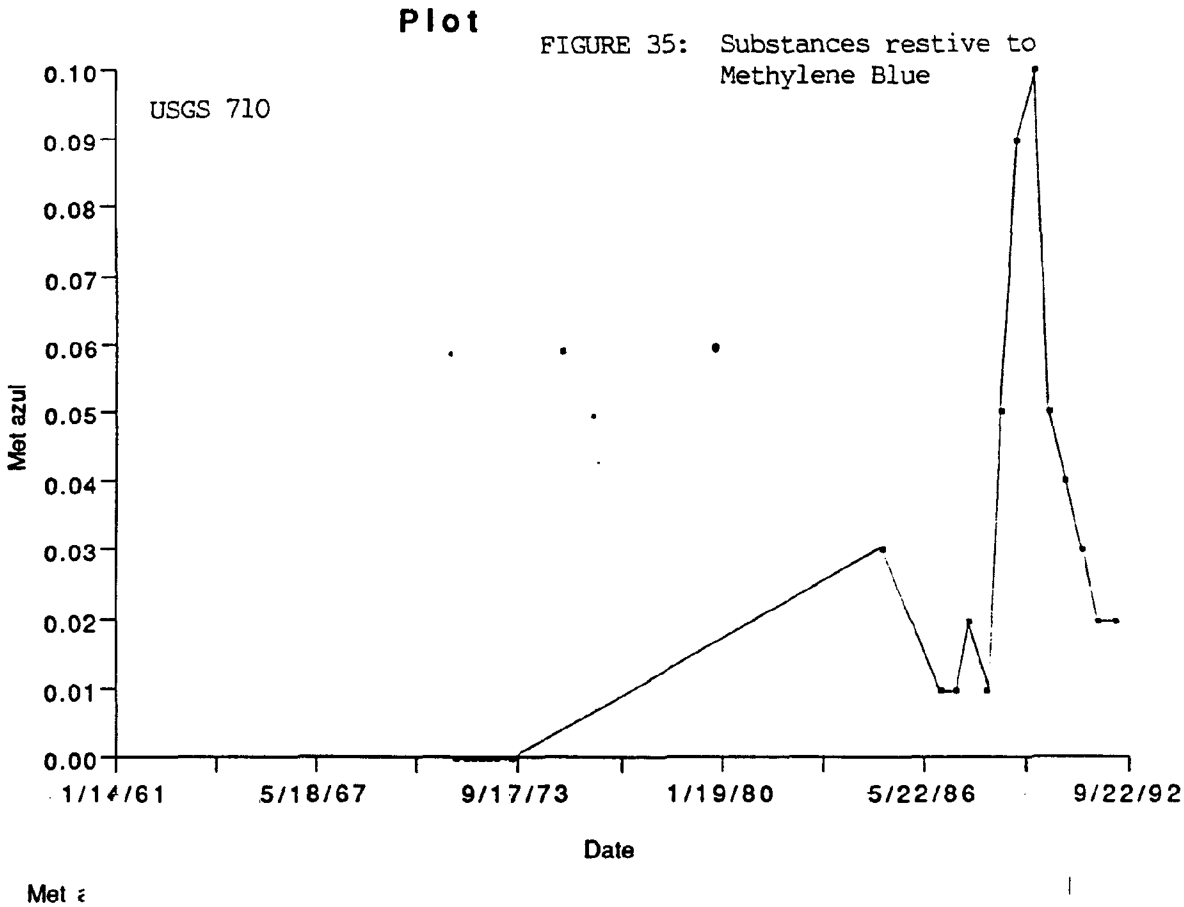
Chlorine and Fluoride

Chlorine and fluoride are cheap, effective disinfectants added to treated waters. Their presence in natural water bodies indicates waste water discharges. Chlorine is also illegally used, in concentrated form, by fishermen to kill and capture freshwater shrimp. Chlorine showed a very high peak in the Fajardo River data for 1973-74 at station USGS 725 and an increase tendency at USGS 720. Fluoride has fluctuated within acceptable levels (Table 9: parameters #26 & 27; Figures 36 & 37). Anions formed from both elements also contribute to water's hardness and alkalinity.

Nitrogen and phosphorus

Nitrogen, phosphorus and soluble materials composed of them are the most important sources of nutrients in aquatic systems (see Table 8). What we call *organic nitrogen* is the sum of the amounts of nitrates (NO_3), nitrites (NO_2) and ammonia (NH_4) in water. Clean natural waters rarely contain more than a tenth of a milligram of ammonia nitrogen per liter (0.1 ppm N), while community sewages commonly contain 15-50 ppm N. Most of this ammonia rises from the hydrolysis of urea in urine, but additional ammonia is generated by decomposition of other nitrogenous materials in sewage. Sudden increases in the concentrations of ammonia found in streams indicates that sewage, barnyard wastes, or other high energy nitrogen additions are being added. Other changes commonly accompanies added nitrogen from sewage: slime growth in shallow surfaces of the stream, algal blooms, turbidity due to bacteria and colloids, fish kills, and sewage odors. Ammonia measurements are used because they afford a rough quantitative measurement of the relative concentration of sewage in the water, even at very low levels of pollution. If dissolved oxygen is available in the water,

FIGURE 35: Substances restive to Methylene Blue



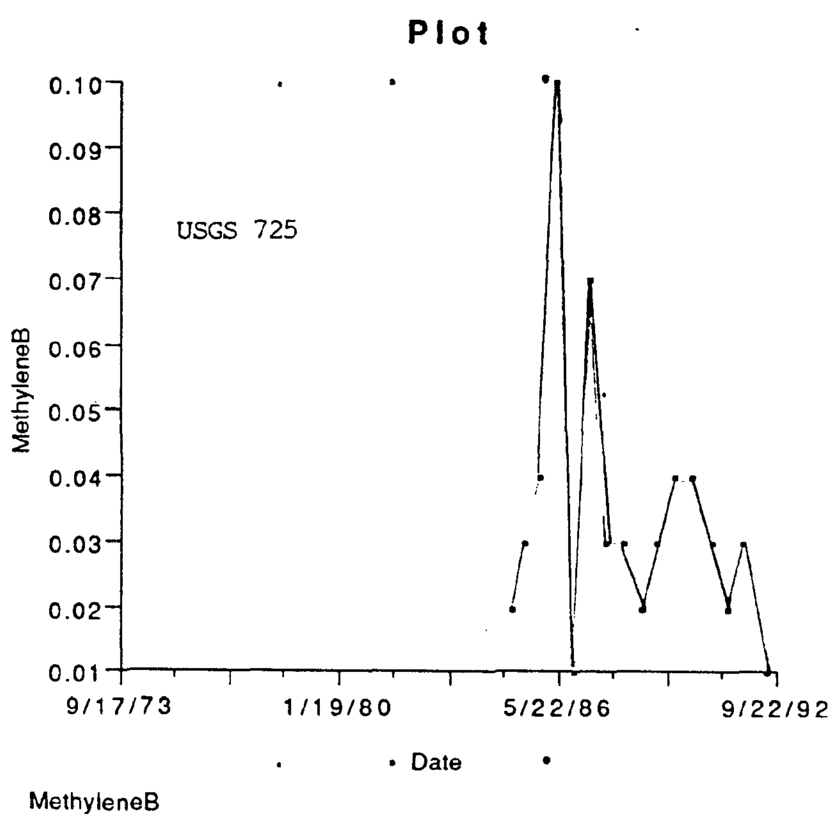
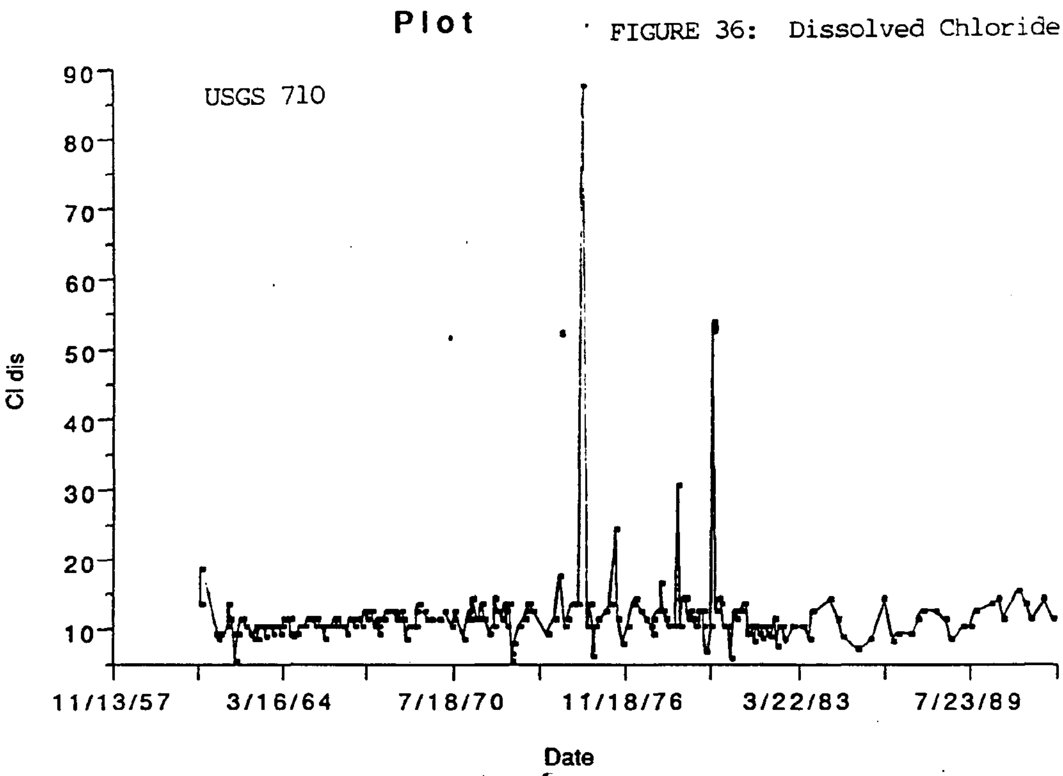
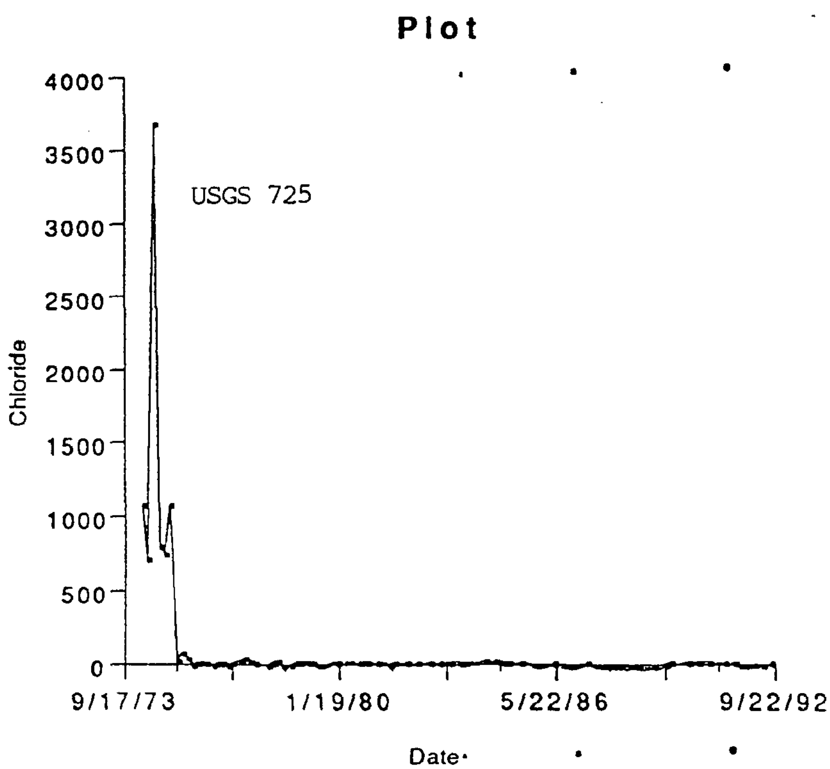
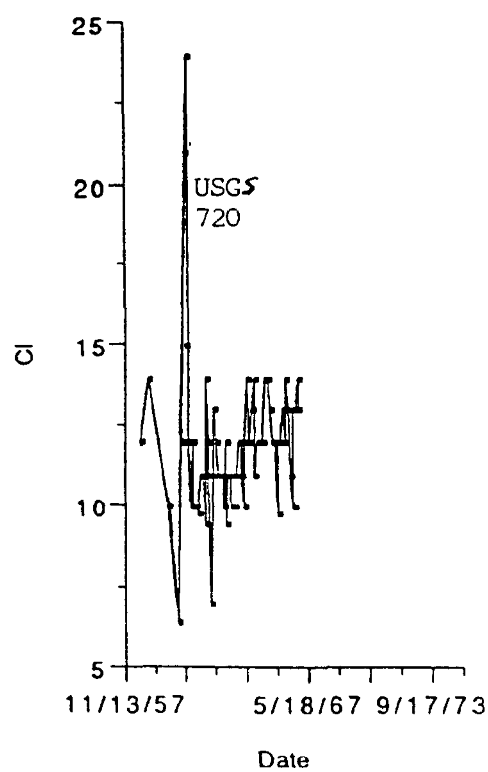


FIGURE 36: Dissolved Chloride

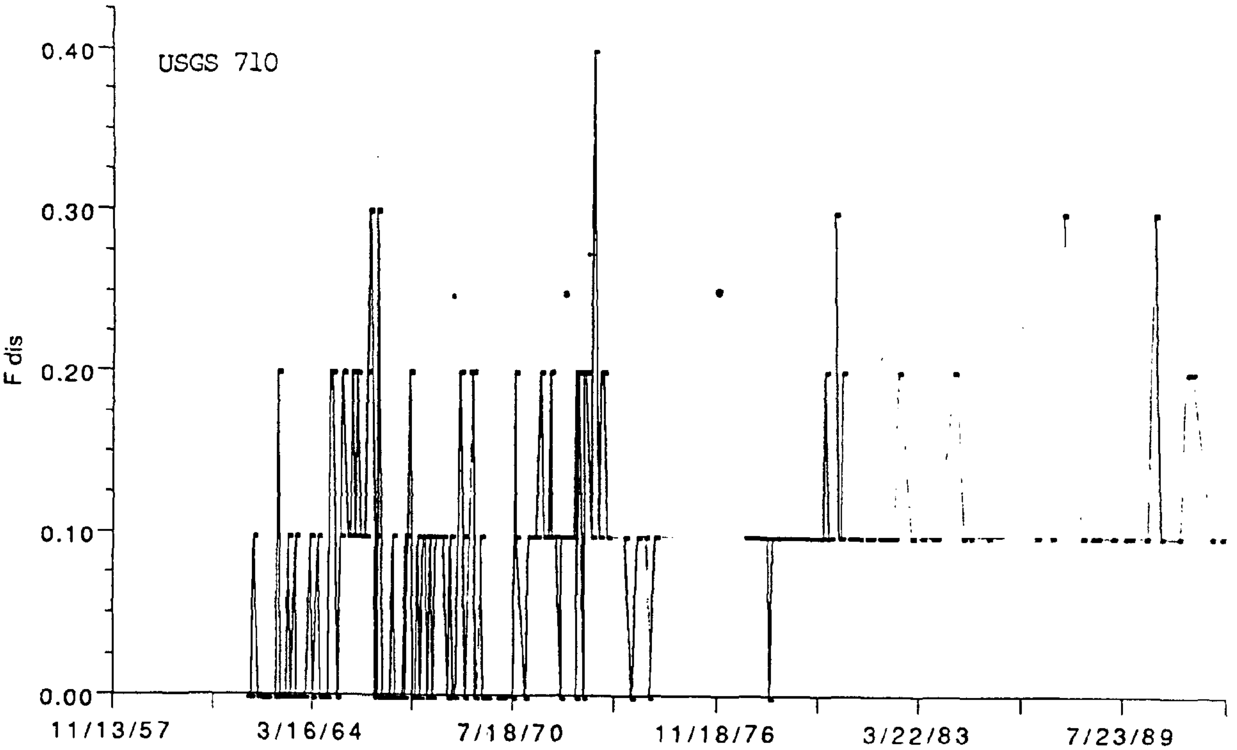


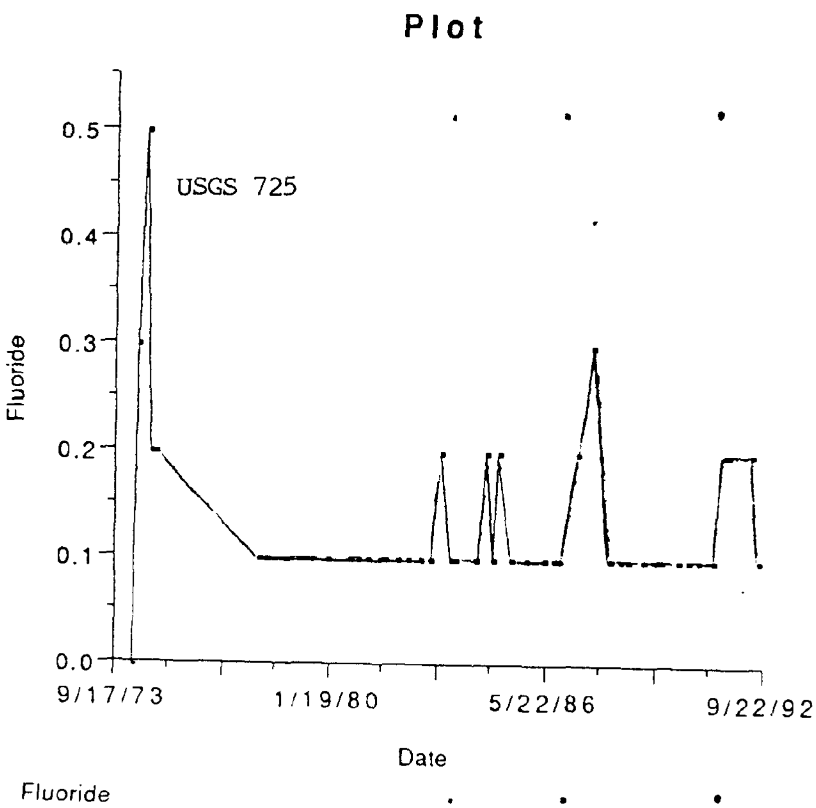


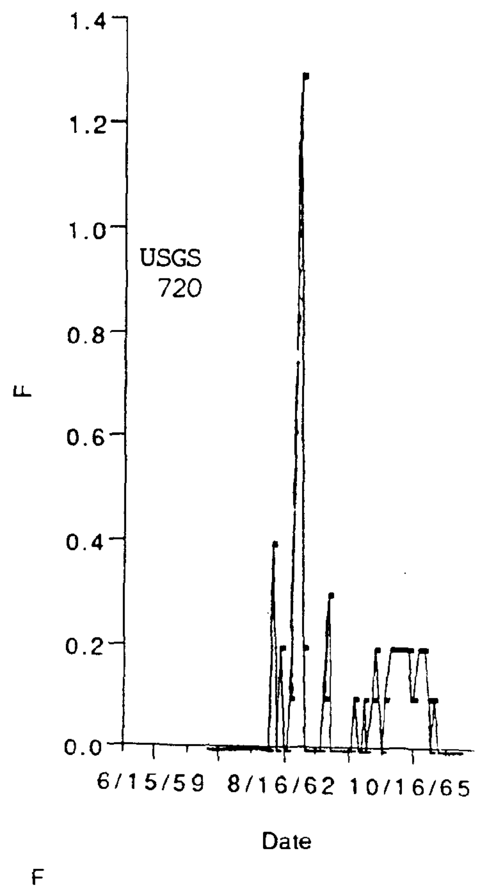


Plot

FIGURE 37: Dissolved Fluoride







highly toxic ammonia is eventually oxidized by some bacteria into nitrites, which are, in turn, oxidized into nitrates (which are fertilizers for aquatic plants). The presence of significant concentration of nitrites and nitrates is an indicator of older waste or pollution further up stream. It is also an indirect way of determining the presence of adequate amounts of dissolved oxygen in the water. Ammonia, nitrite, and nitrate can also enter water from sources other than sewage, like fertilizers and industrial wastes. Reported cases in scientific literature have revealed that nitrates in concentrations above 10 mg/l can be fatal to small infants and to the elderly.

TABLE 8: Macro- and micronutrients essential for aquatic biota.

Macronutrients	Micronutrients
carbon, hydrogen, oxygen, phosphorus, sulfur, potassium, magnessium, calcium (except for algae)	calcium (for algae), iron, manganese, copper, zinc, molibdenum, vanadium, boron, chloride, cobalt, silica

From the data gathered from the Fajardo River, it is obvious that periodic episodes of peak levels of organic nitrogen in all its from have been happening since 1973 and continue (Table 9: parameters #33, 34, 35, 36, 37, 38 & 39; Figures 38, 39, 40, 41, 42, 43, 44 & 45).

Phosphates, which are soluble phosphorus derivatives, like nitrogenous materials, are a normal component of sewage, but inclusion of phosphates from detergents has multiplied phosphate coming from treatment plants. Intensive fertilization of farm lands with fertilizers containing high phosphorus concentrations also raises the phosphate contents of runoff waters. High phosphate levels in water produces heavy algal blooms which disrupts the oxygen content of the water as well as the balance of the food chain. Phosphorus levels reached a high peak in 1973 at USGS 710 but have been showing a declining tendency since 1975 at USGS 725 (Table 9: parameters #40 & 41; Figures 46 & 47).

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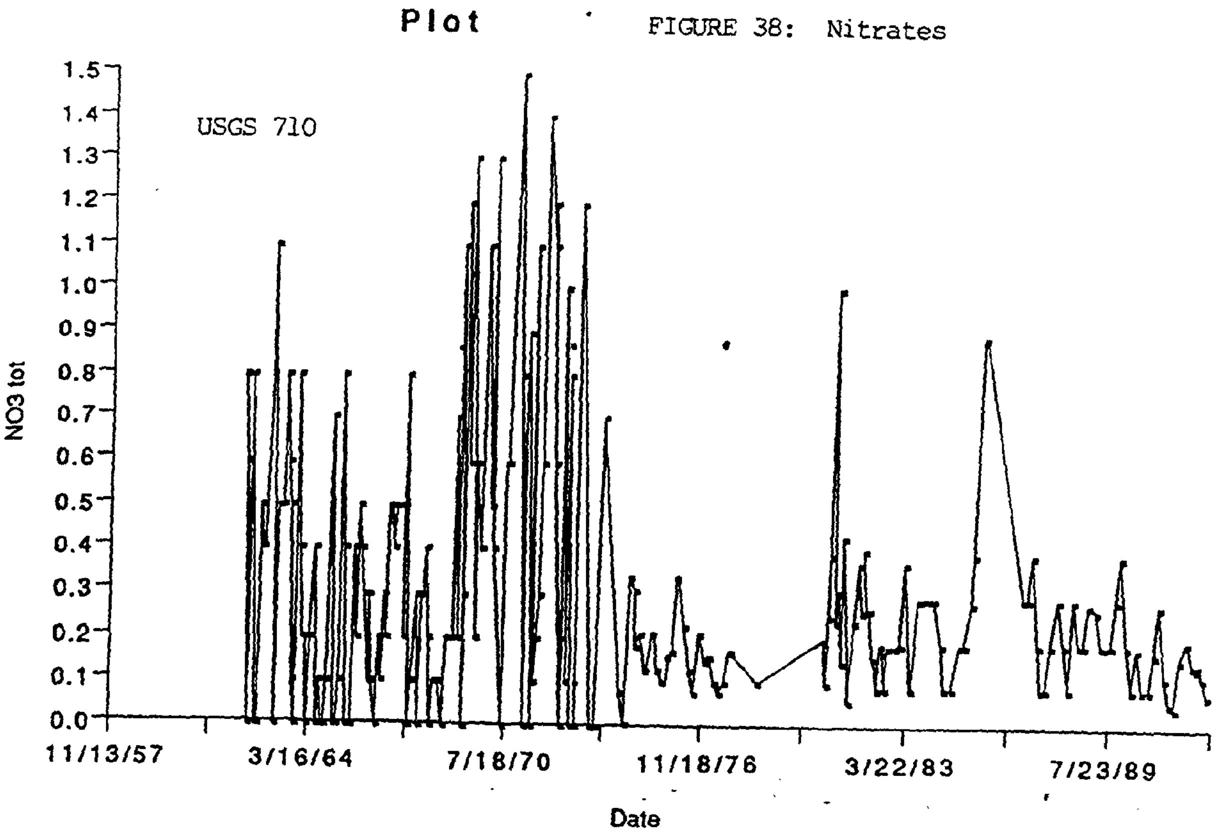
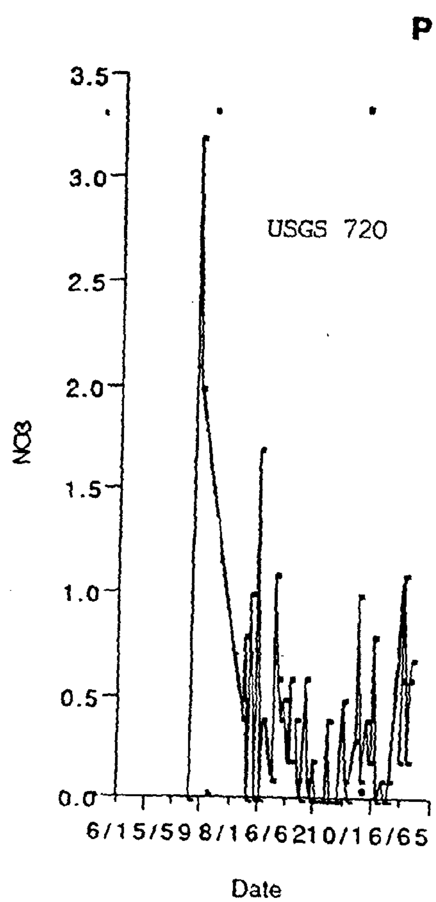
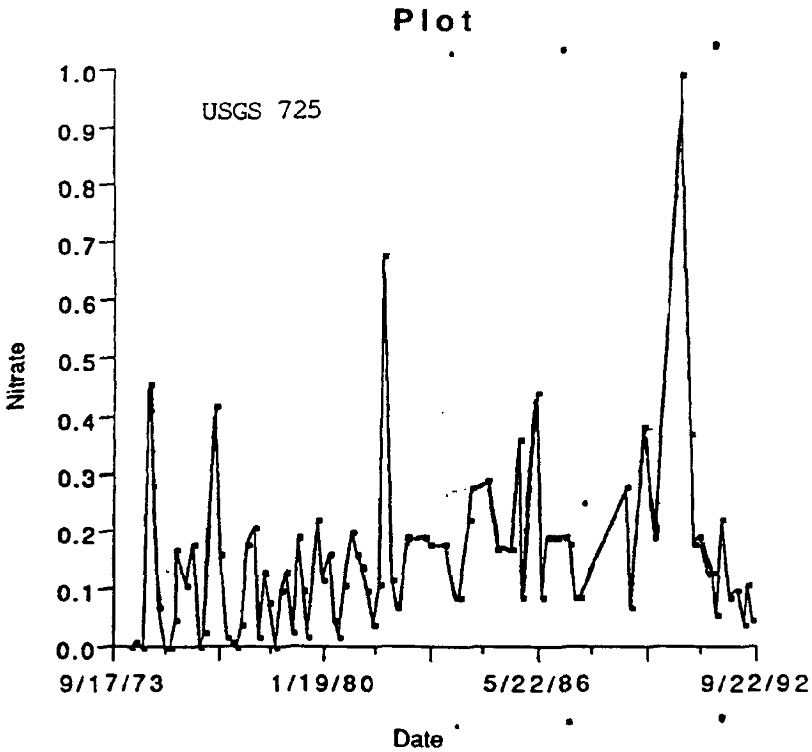
. . .

FIGURE 38: Nitrates






Plot
USGS 725
Nitrate
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
9/17/73
1/19/80
5/22/86
9/22/92
Date

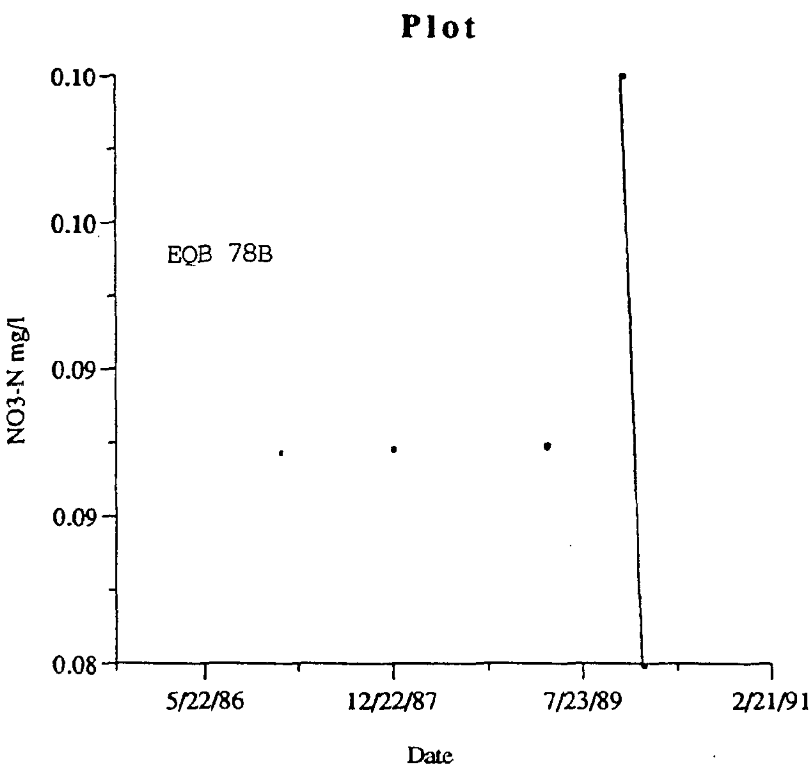
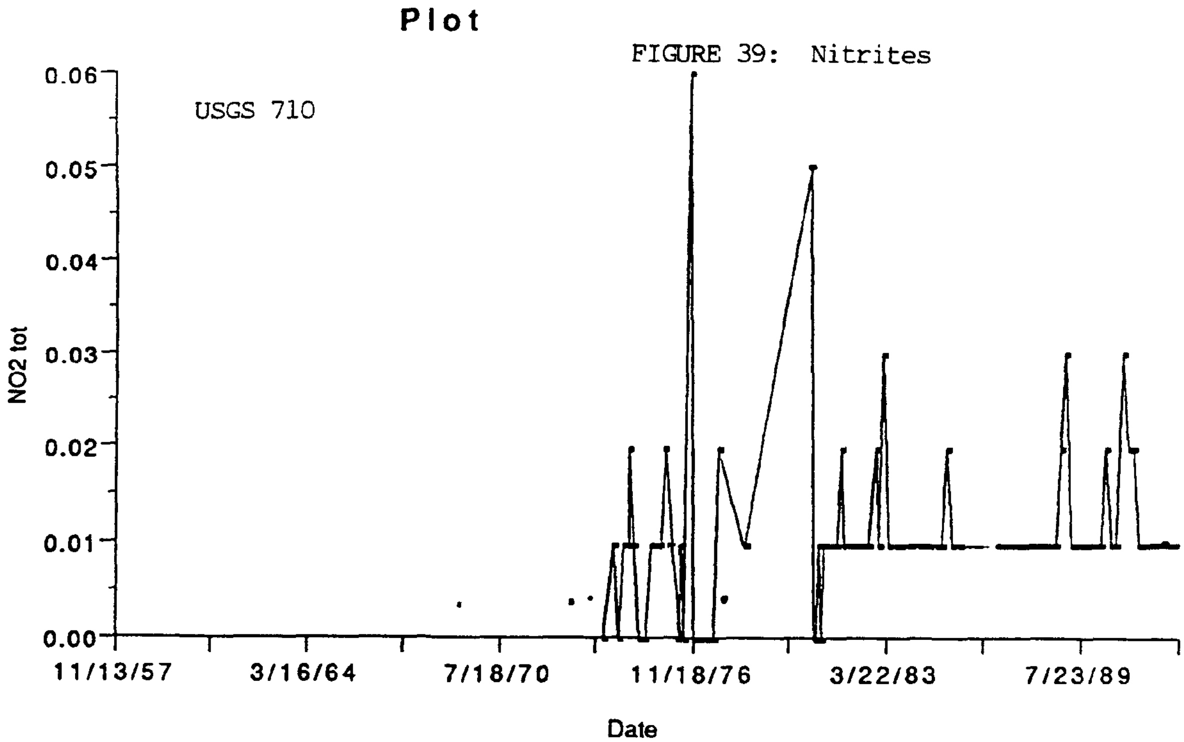

Plot
EQB 78B
NO3-N mg/l
0.10
0.10
0.09
0.09
0.08
5/22/86
12/22/87
7/23/89
2/21/91
Date

FIGURE 39: Nitrites



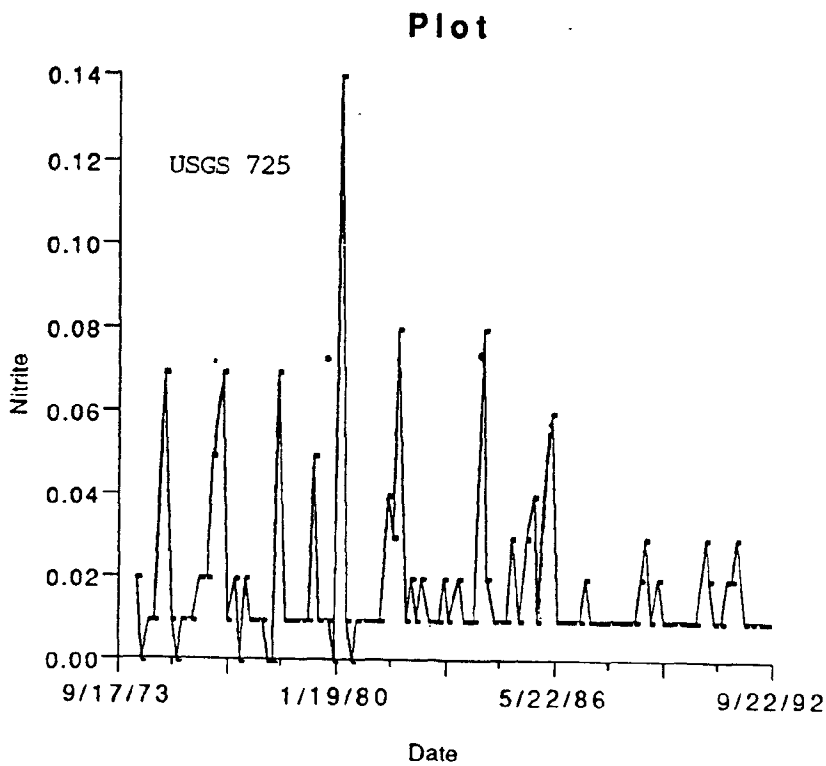
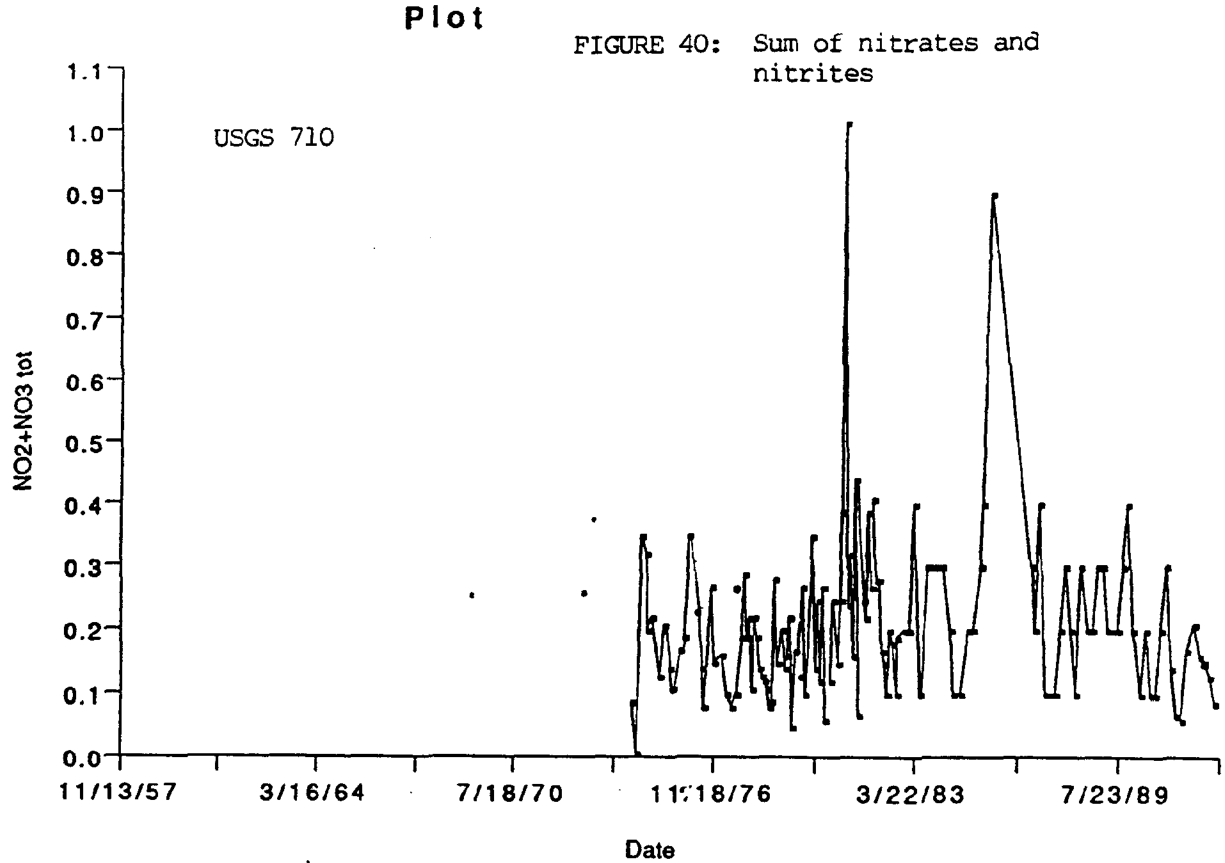
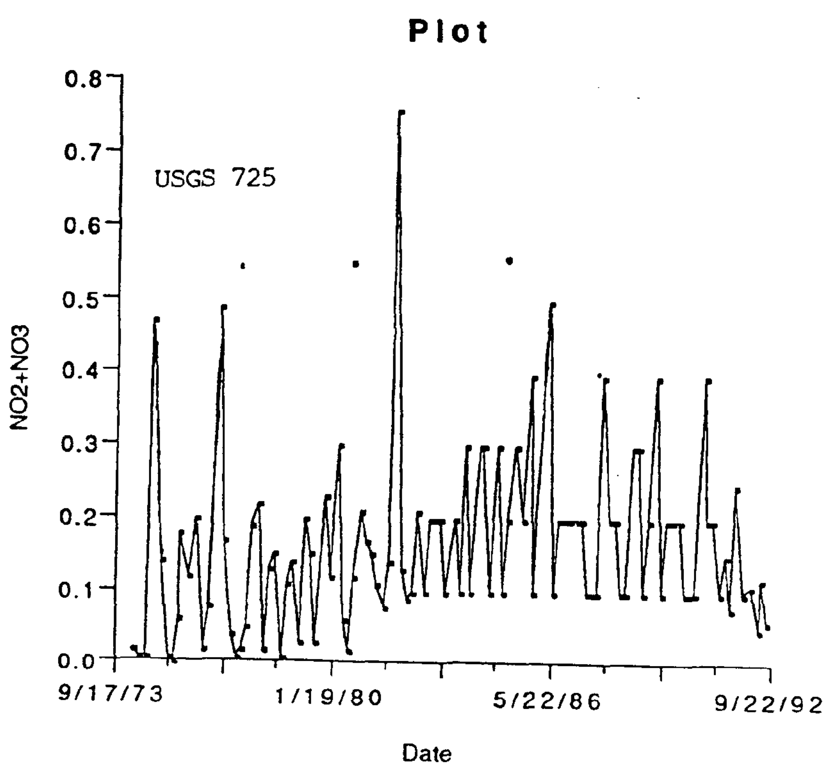


FIGURE 40: Sum of nitrates and nitrites





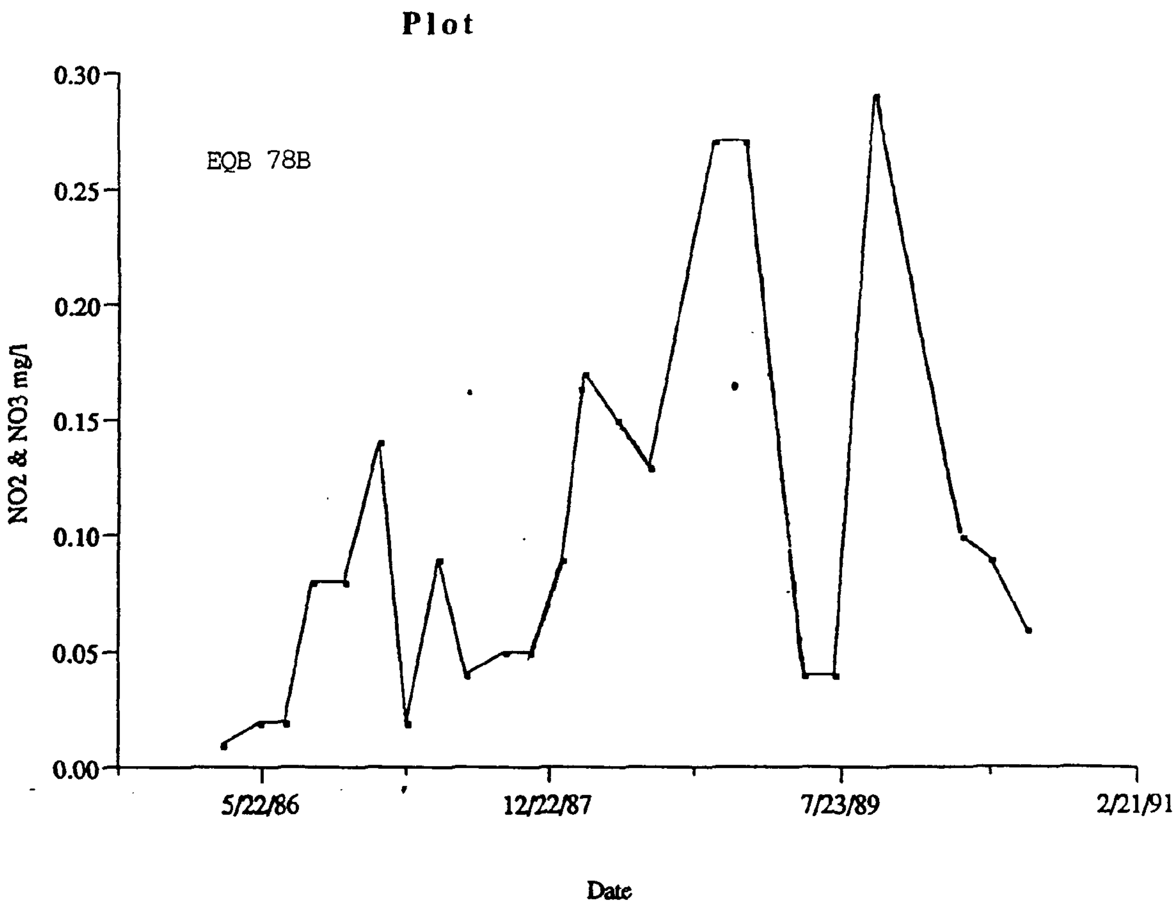
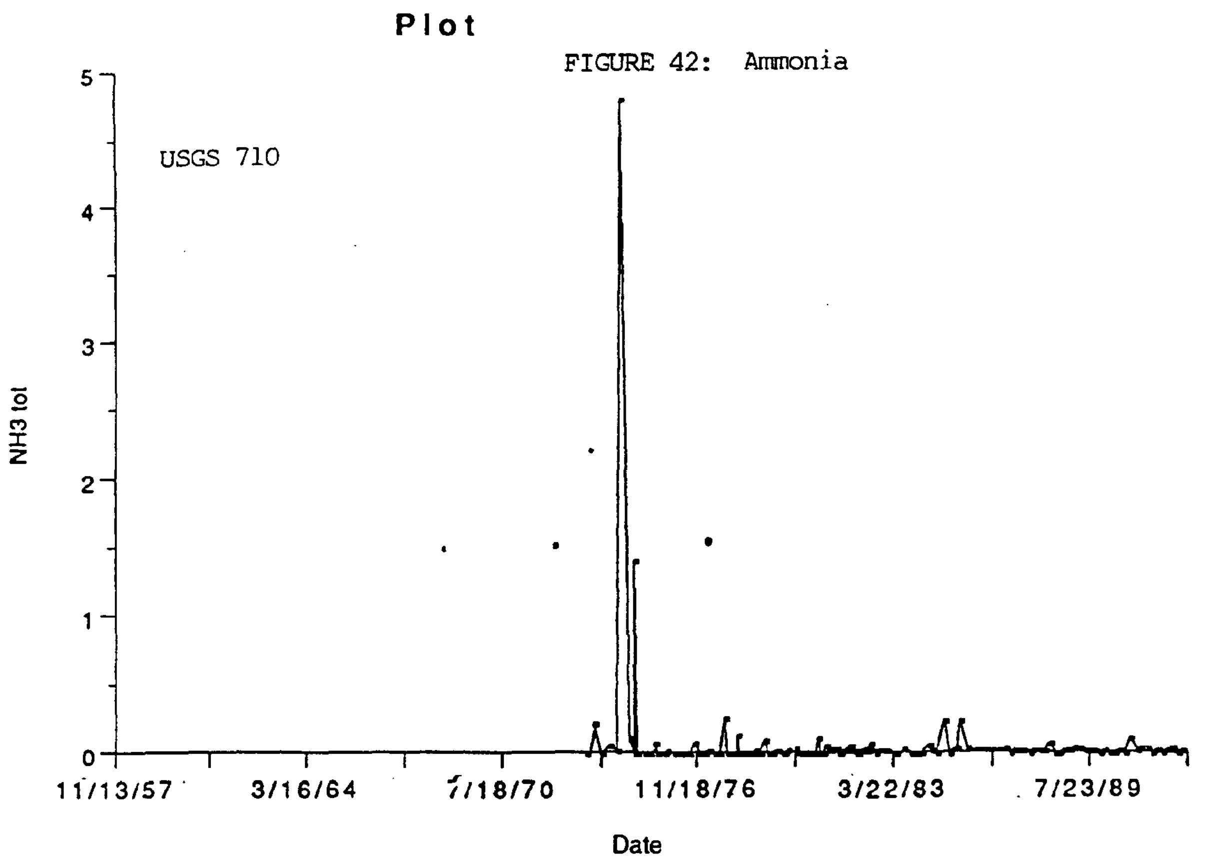
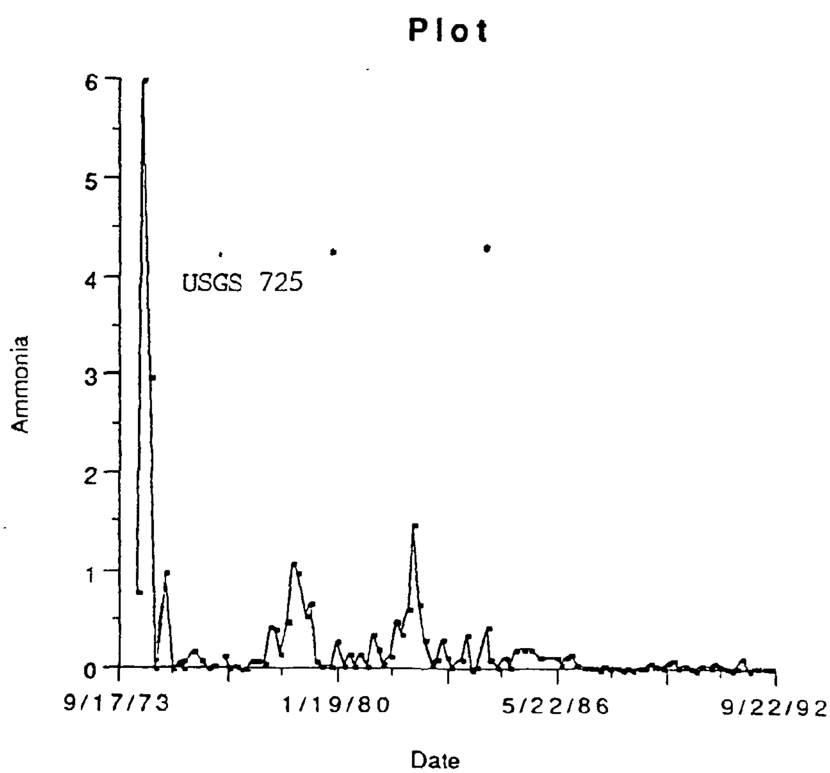
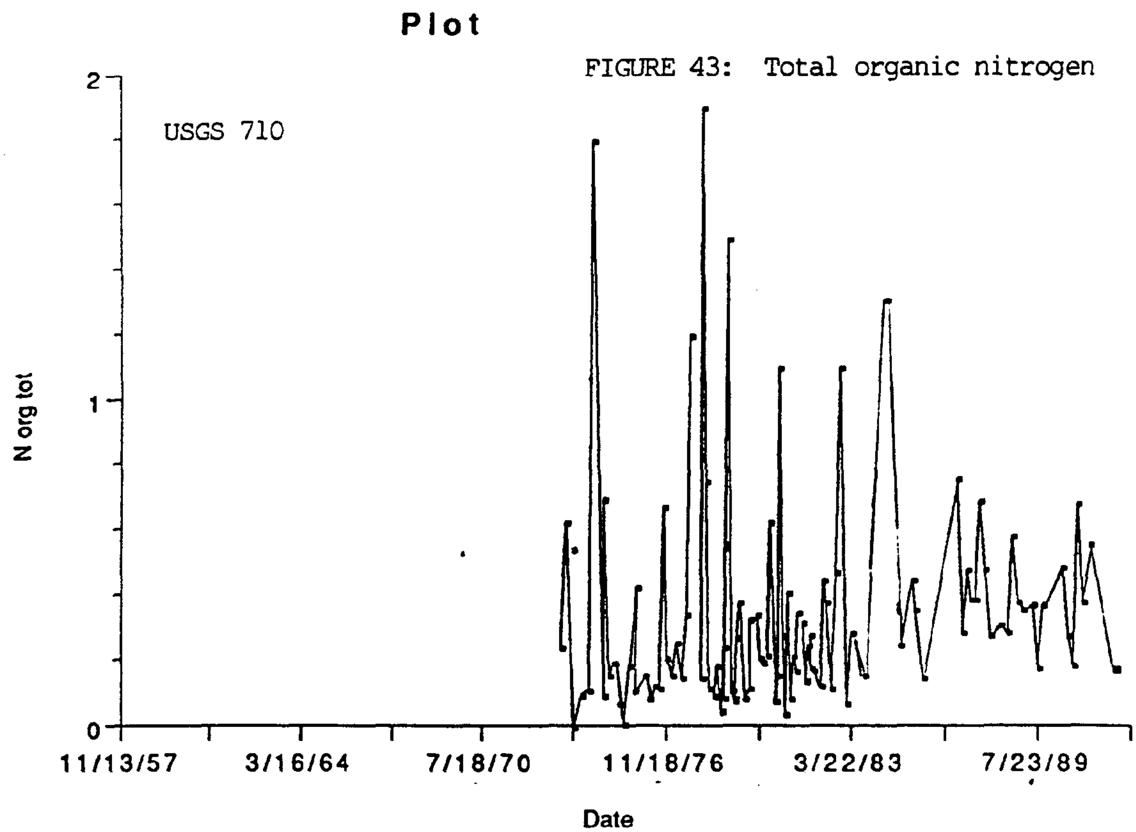
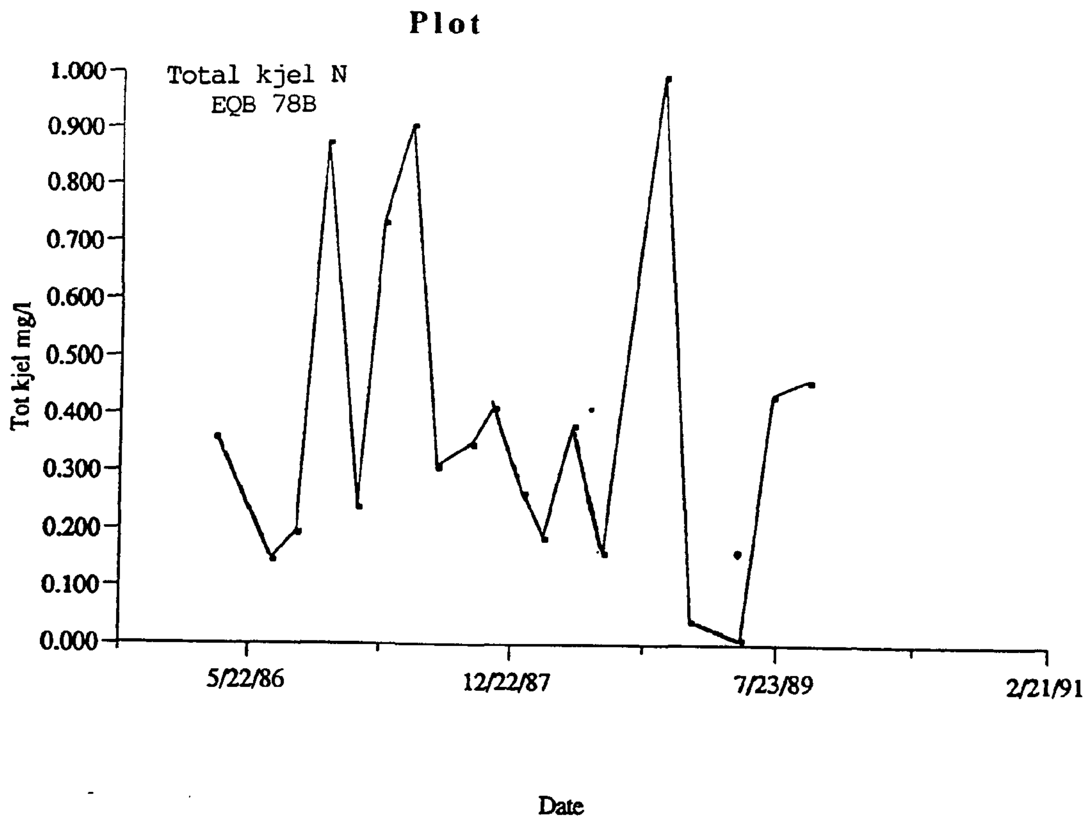

Plot
EQB 78B
0.30
0.25
0.20
0.15
0.10
0.05
0.00
NO2 & NO3 mg/l
5/22/86
12/22/87
7/23/89
2/21/91
Date

FIGURE 42: Ammonia






Plot
FIGURE 43: Total organic nitrogen
USGS 710
N org tot
2
1
0
11/13/57
3/16/64
7/18/70
11/18/76
3/22/83
7/23/89
Date


Plot
Total kjel N
EQB 78B
Tot kjel mg/l
1.000
0.900
0.800
0.700
0.600
0.500
0.400
0.300
0.200
0.100
0.000
5/22/86
12/22/87
7/23/89
2/21/91
Date

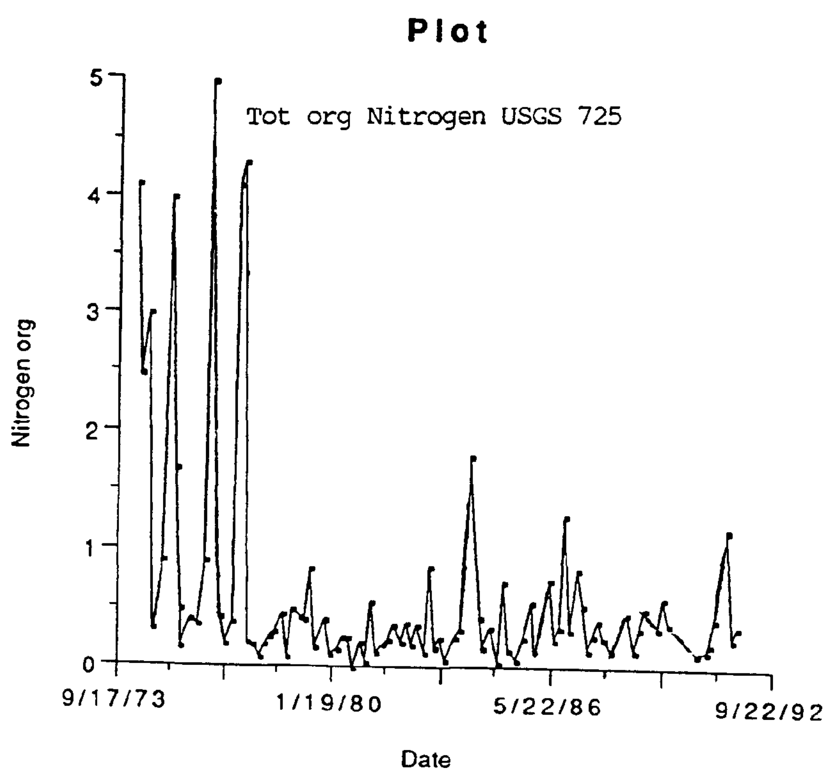
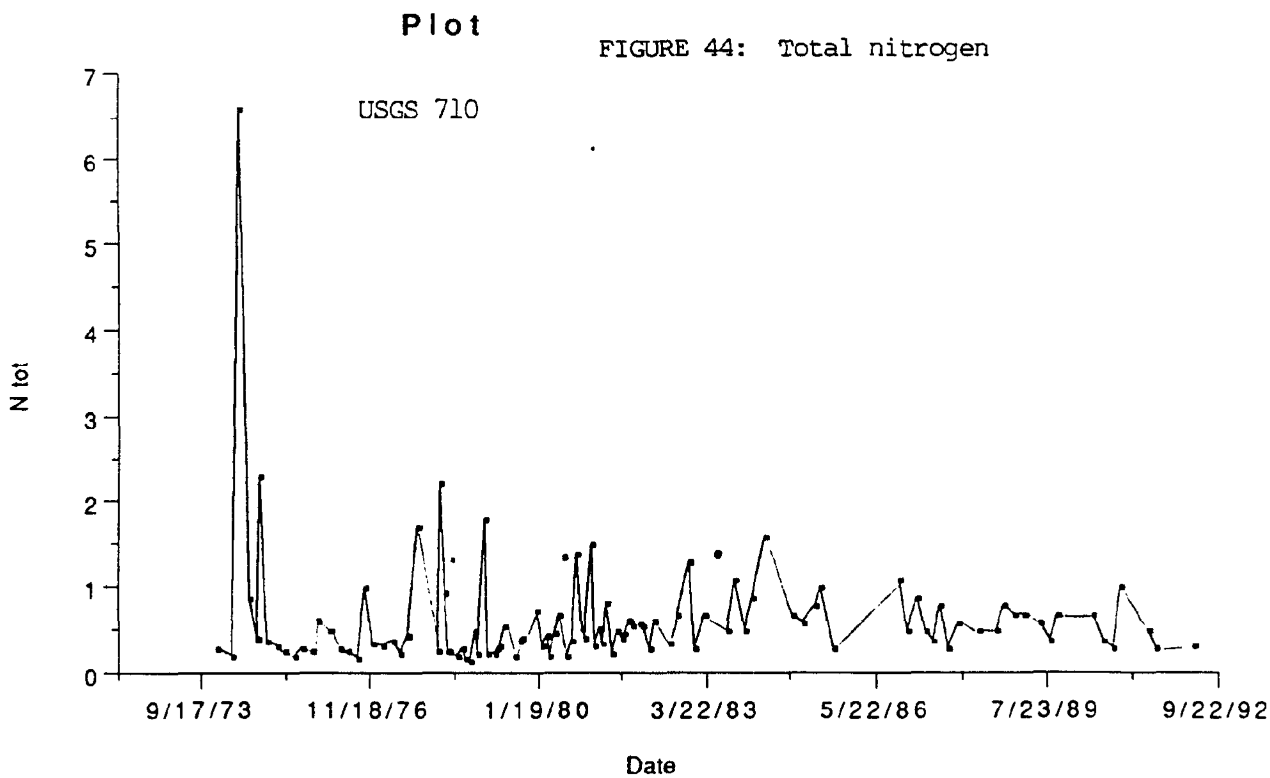
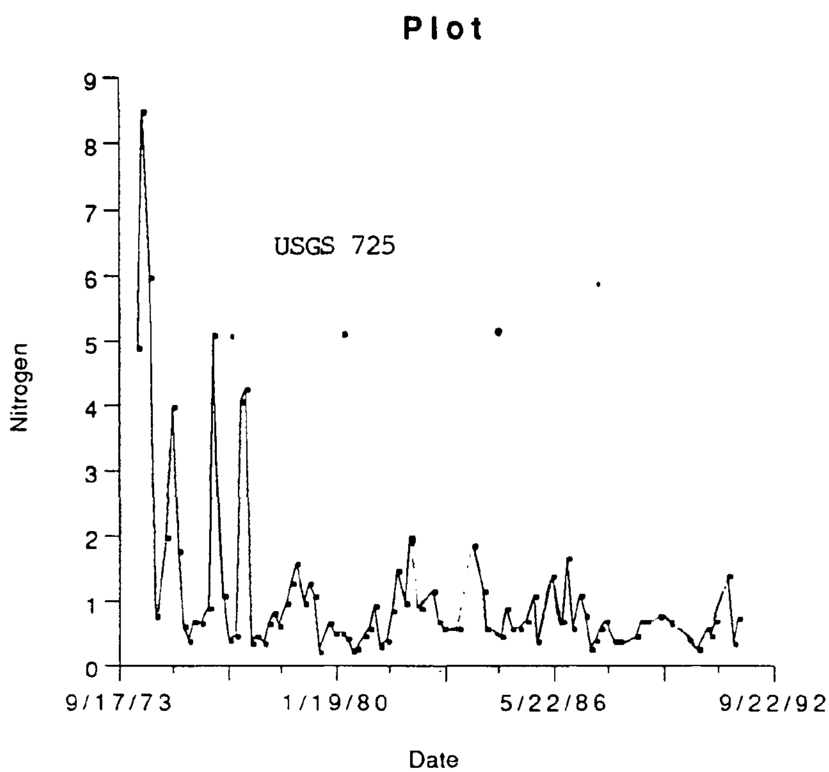

Plot
Tot org Nitrogen USGS 725
Nitrogen org
5
4
3
2
1
0
9/17/73
1/19/80
5/22/86
9/22/92
Date

FIGURE 44: Total nitrogen

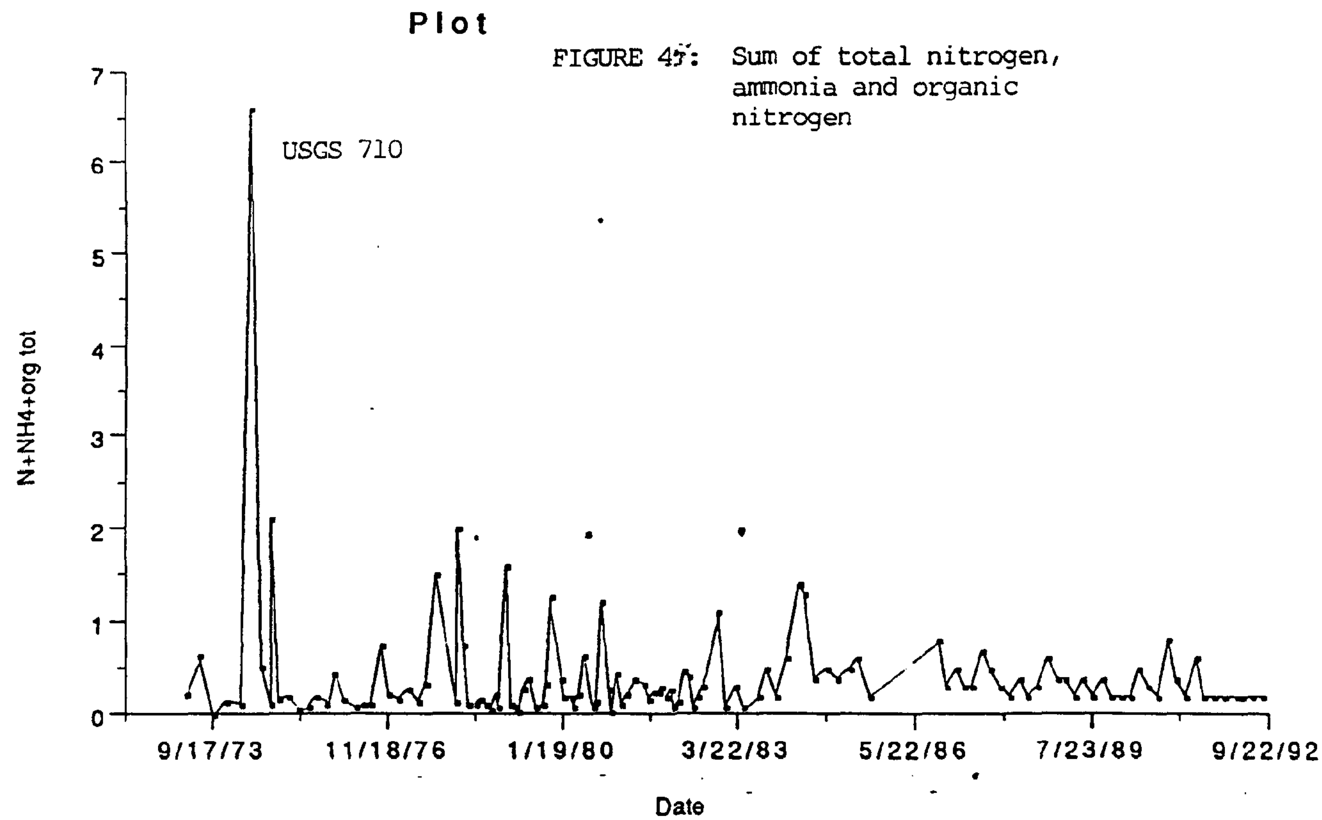


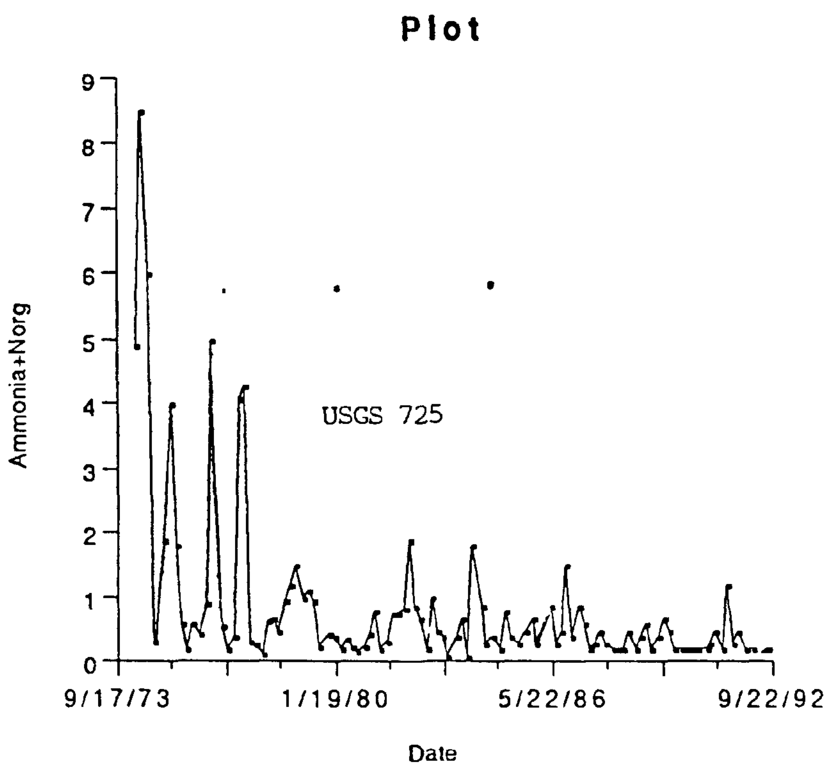
N tot



Nitrogen

FIGURE 45: Sum of total nitrogen, ammonia and organic nitrogen





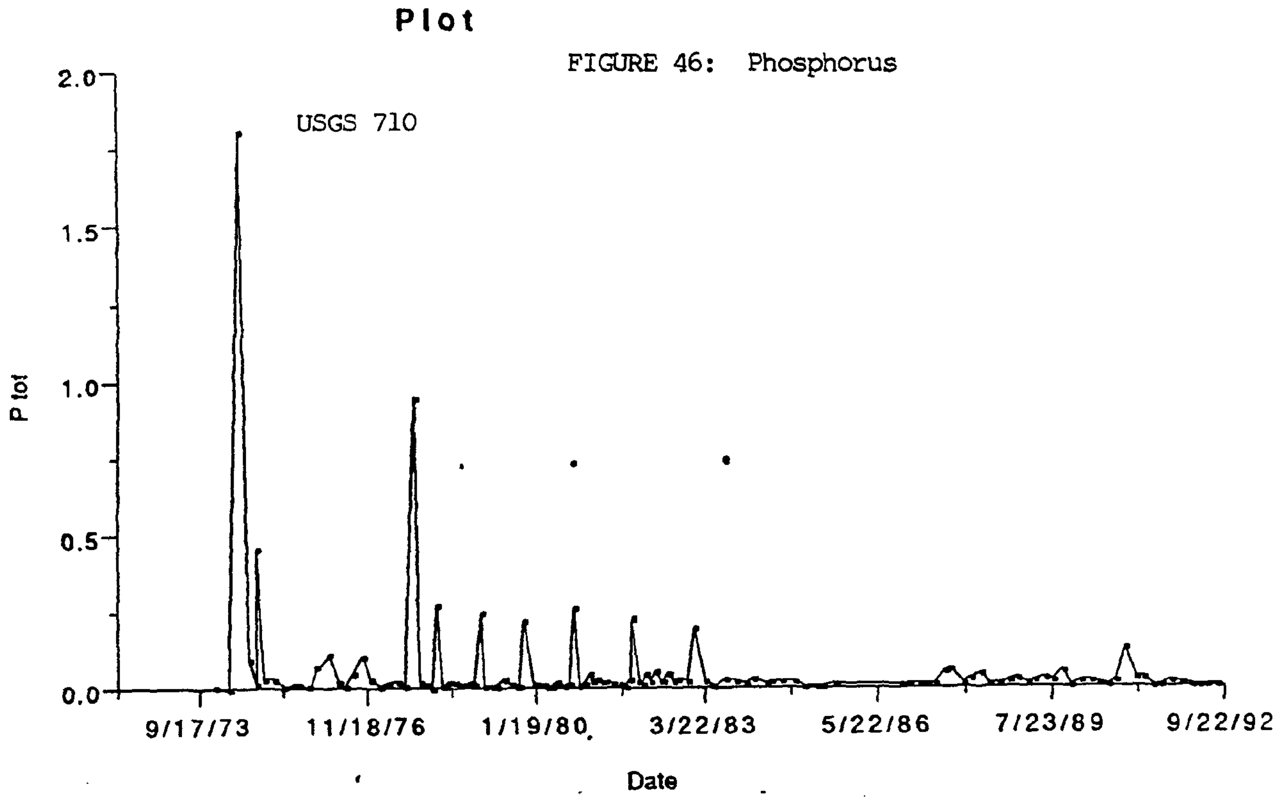
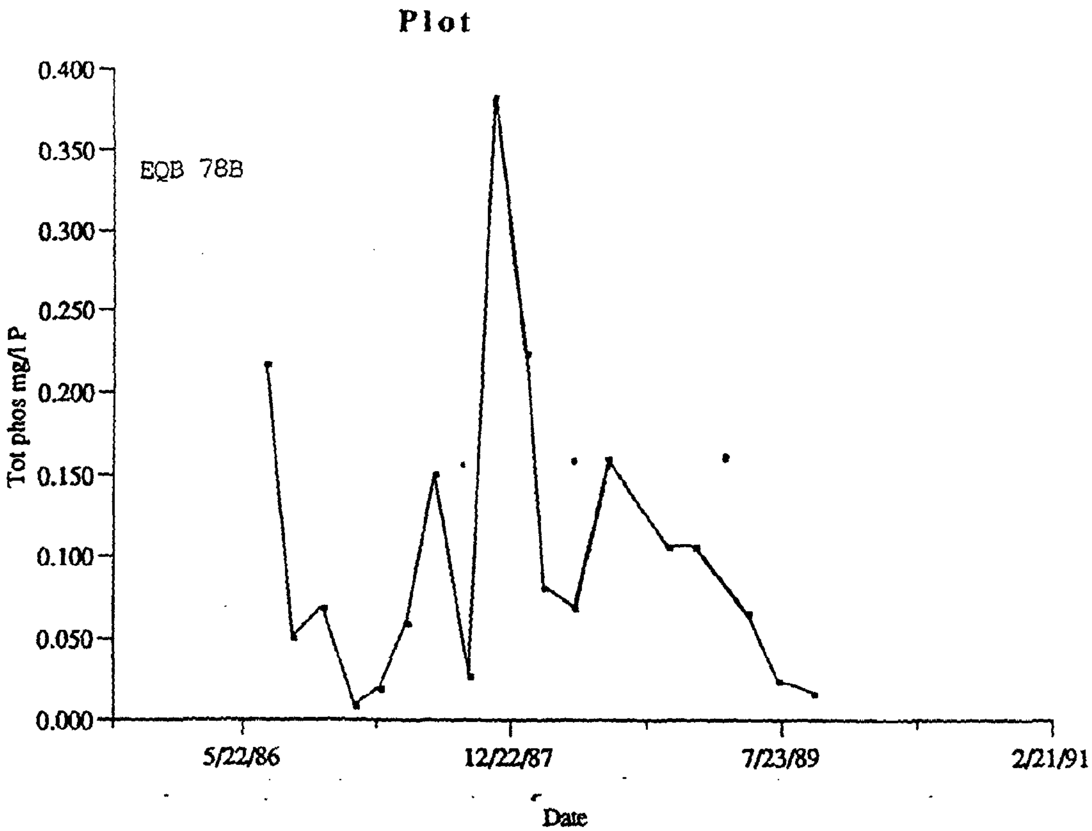


FIGURE 46: Phosphorus


Plot
0.400
0.350
0.300
0.250
0.200
0.150
0.100
0.050
0.000
EQB 78B
Tot phos mg/l P
5/22/86
12/22/87
7/23/89
2/21/91
Date

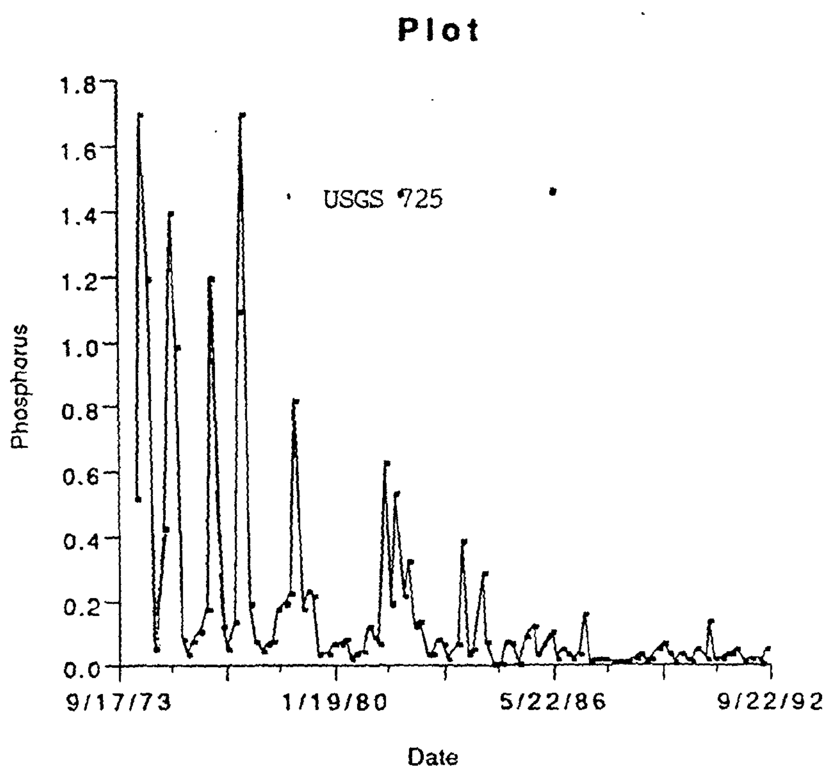
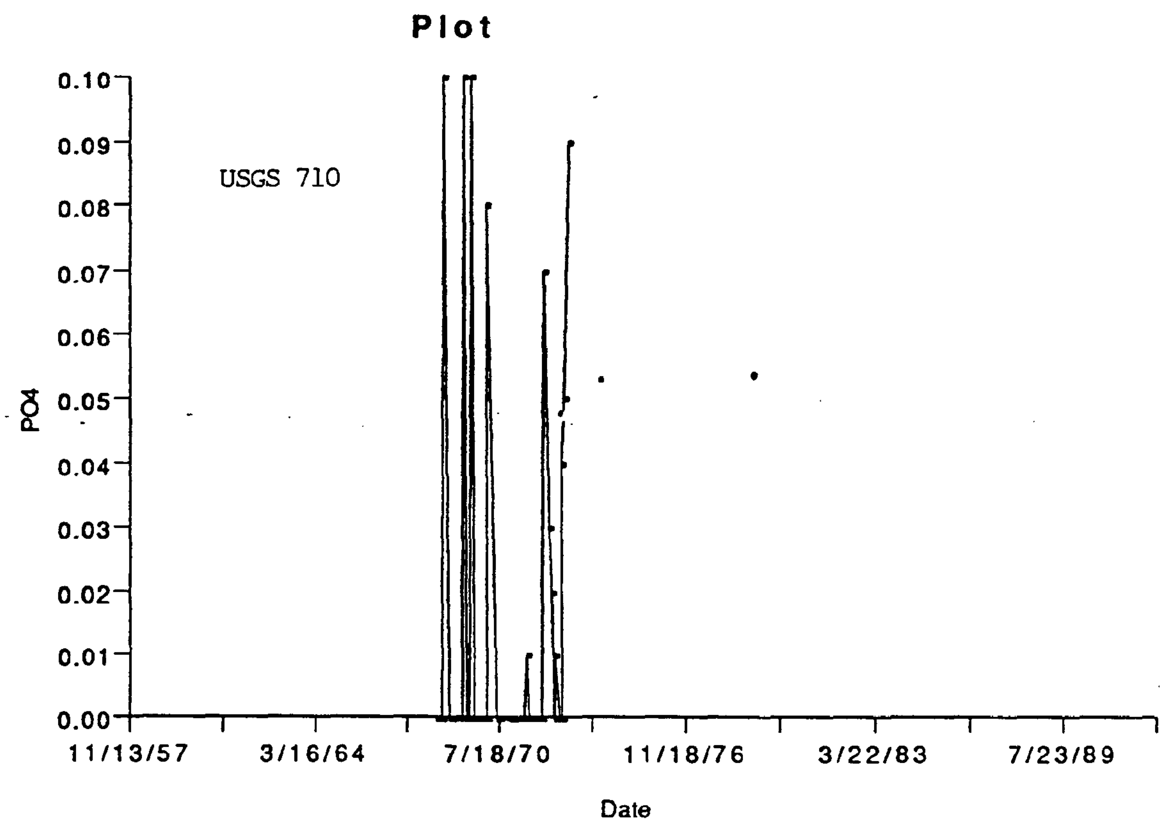

Plot
1.8
1.6
1.4
1.2
1.0
0.8
0.6
0.4
0.2
0.0
USGS 725
Phosphorus
9/17/73
1/19/80
5/22/86
9/22/92
Date

FIGURE 47: Phosphates



Phenolic substances

Phenols are by-products of organic matter in decomposition. Thus, phenolic levels are used mostly as an indication of sewage and wastewater pollution. In the Fajardo River, phenolics peaked in 1986 at USGS 710, perhaps reflecting wastewater influx from a nearby landfill (Table 9: parameter #60; Figure 48).

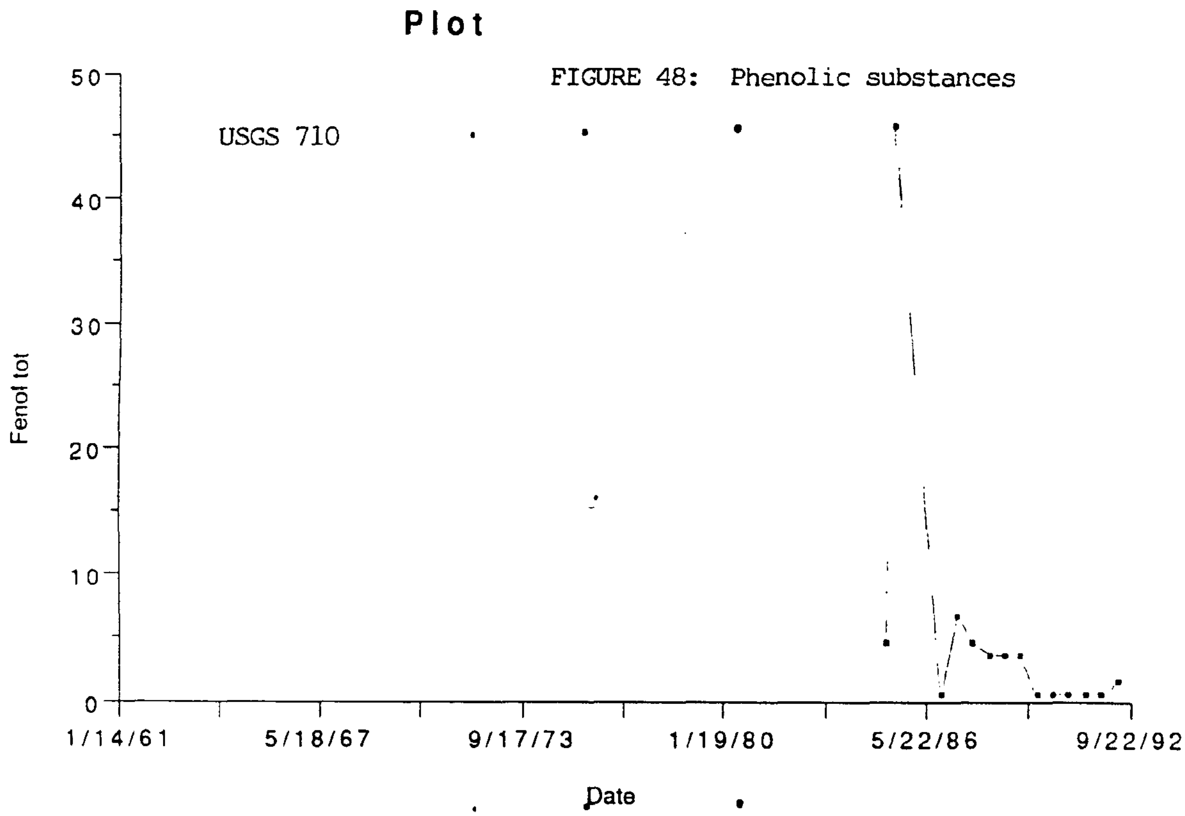
The carbon system and pH

Carbon dioxide (CO_2) is the most important material in a body of water, besides water itself. It is picked up from the atmosphere, from the soil, from decomposition of organic matter, and from the respiration of aquatic organisms. In water, CO_2 produces carbonic acid (H_2CO_3), bicarbonate (HCO_3^-), carbonate (CO_3^{-2}), and hydrogen ions (H^+) turning the water slightly acidic, and increasing the water's ability to carry alkaline compounds. Waters that flow through soils that contain no alkaline materials will remain acidic and will be slightly corrosive. Such waters are low in mineral content and are called "soft". Aquatic plant life depends upon CO_2 and HCO_3 to survive, using it (in the presence of sunlight) in photosynthesis (Renn, 1968). They excrete oxygen. In the absence of sufficient sunlight, the process reverses, and plants consume oxygen to produce CO_2. Aquatic animals always consume oxygen to produce CO_2.

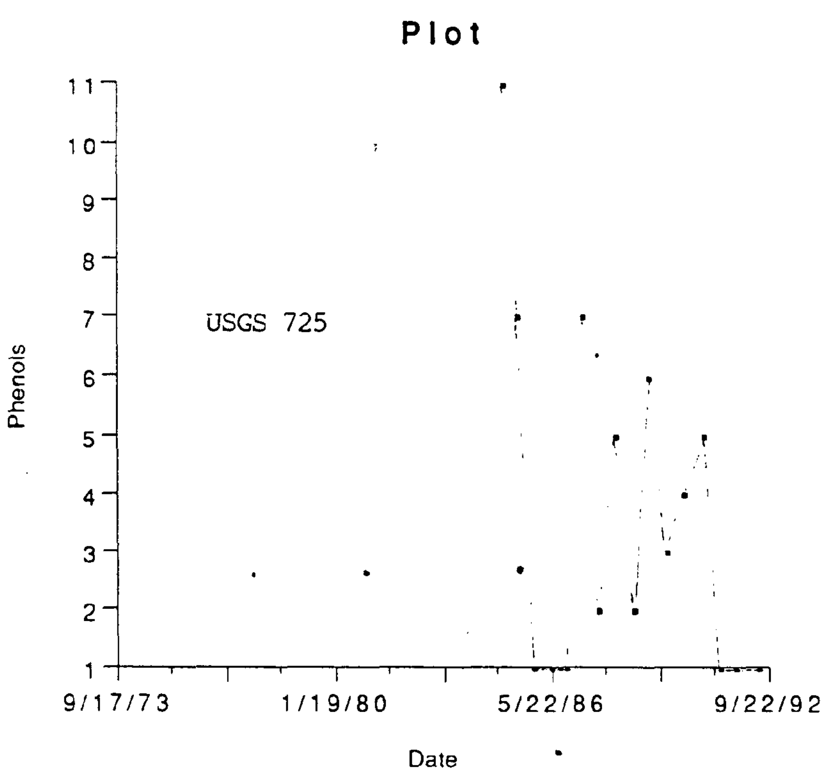
The pH measurement estimates the relative concentrations of hydrogen (H+) and hydroxyl (OH-) ions in water; the proportions of acids and bases. To a large extent, pH in water bodies is determined by those chemical processes of the carbon system. As plants remove CO_2 from the water, the oxygen content, pH, and alkalinity increases. Plants will also take from the water dissolved salts, minerals, and metals.

Data from the Fajardo River shows a decreasing tendency of bicarbonate at USGS 725 and of organic carbon at both USGS 725 &710. However, it shows an increasing tendency for bicarbonate at USGS 720 (Table 9: parameters #28, 29, 30, 31; Figures 49, 50, 51 & 52). This may be due to localized discharges of organic matter at stations USGS 710 and 725 that do not reach station USGS 720.

FIGURE 48: Phenolic substances

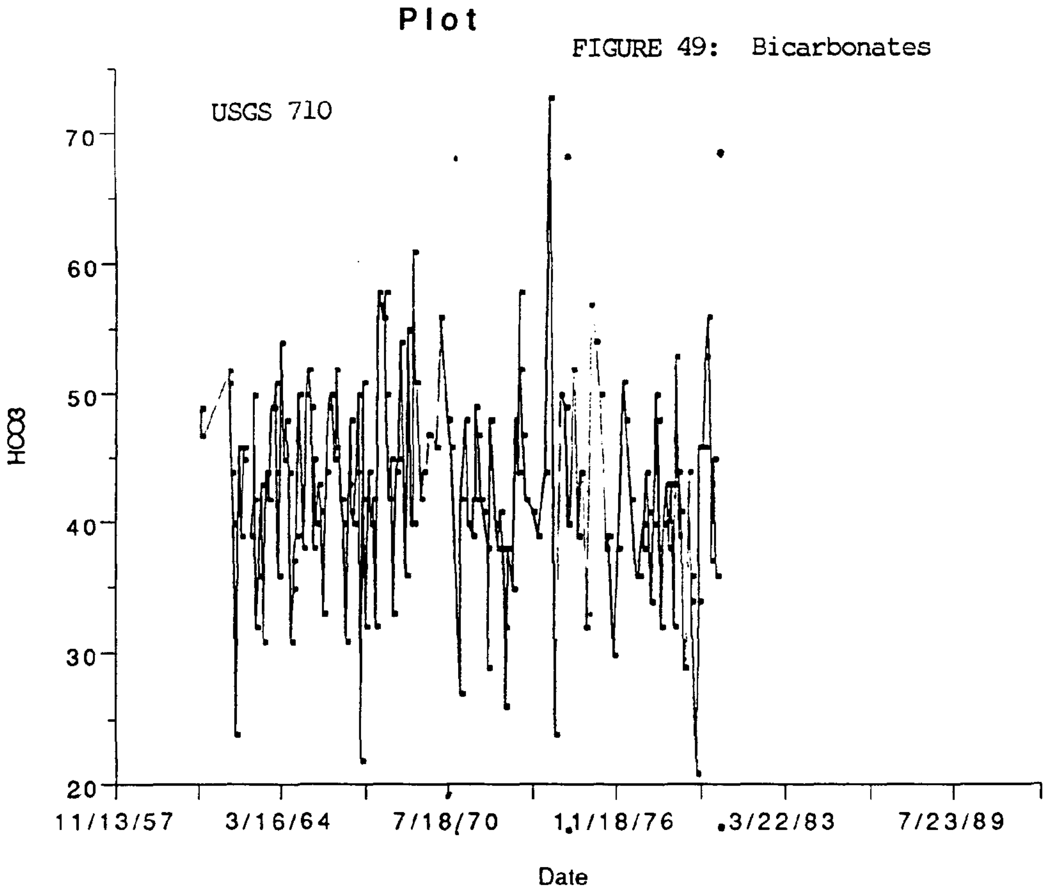


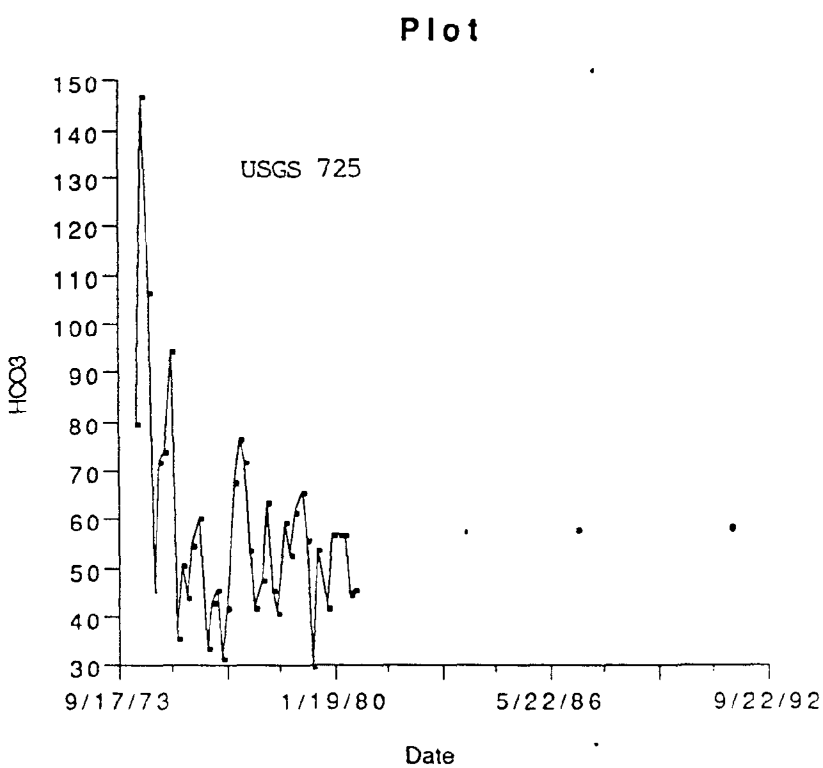
Fenol tot

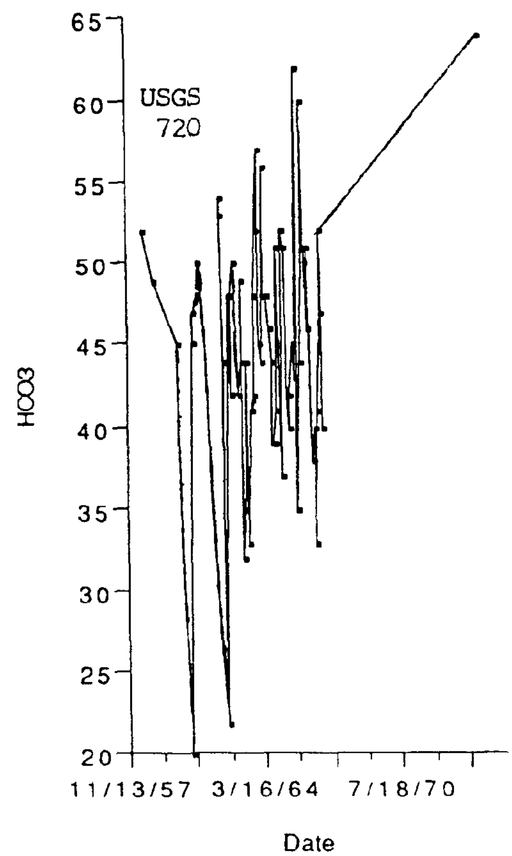


Phenols

FIGURE 49: Bicarbonates







HCO3

FIGURE 50: Carbonates

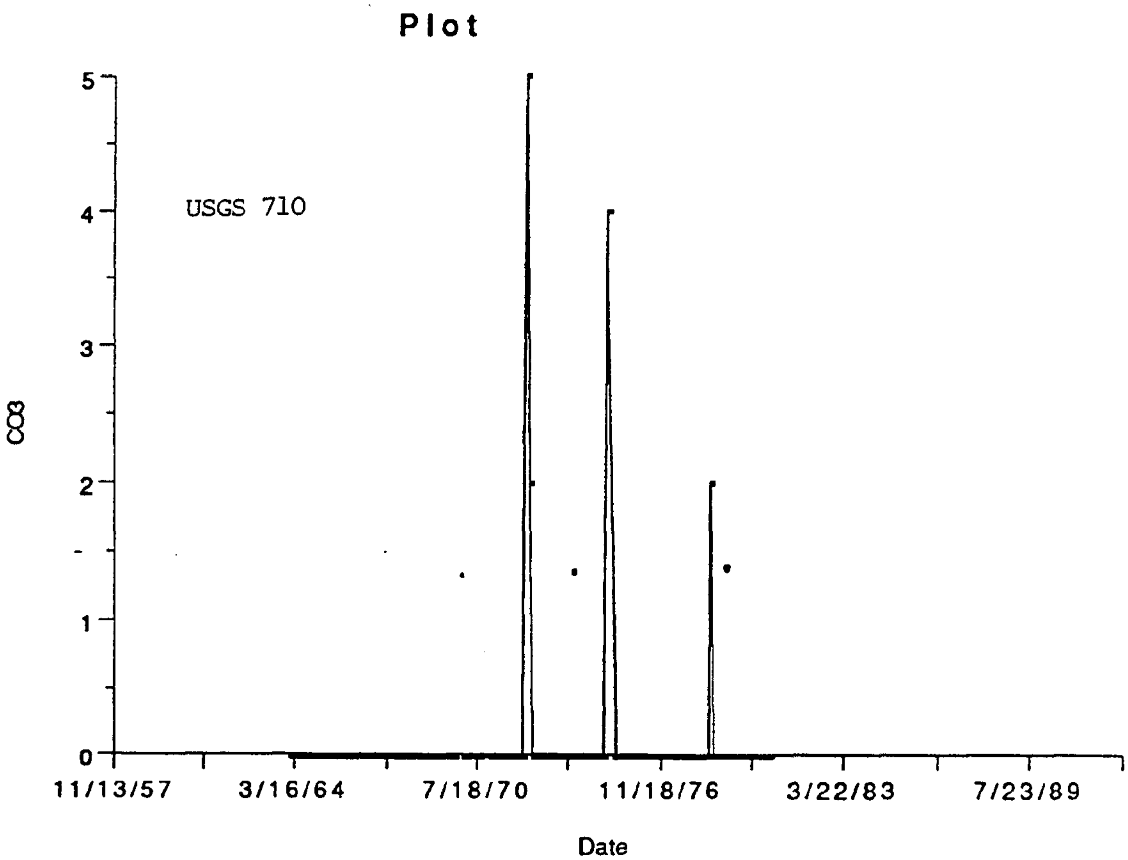
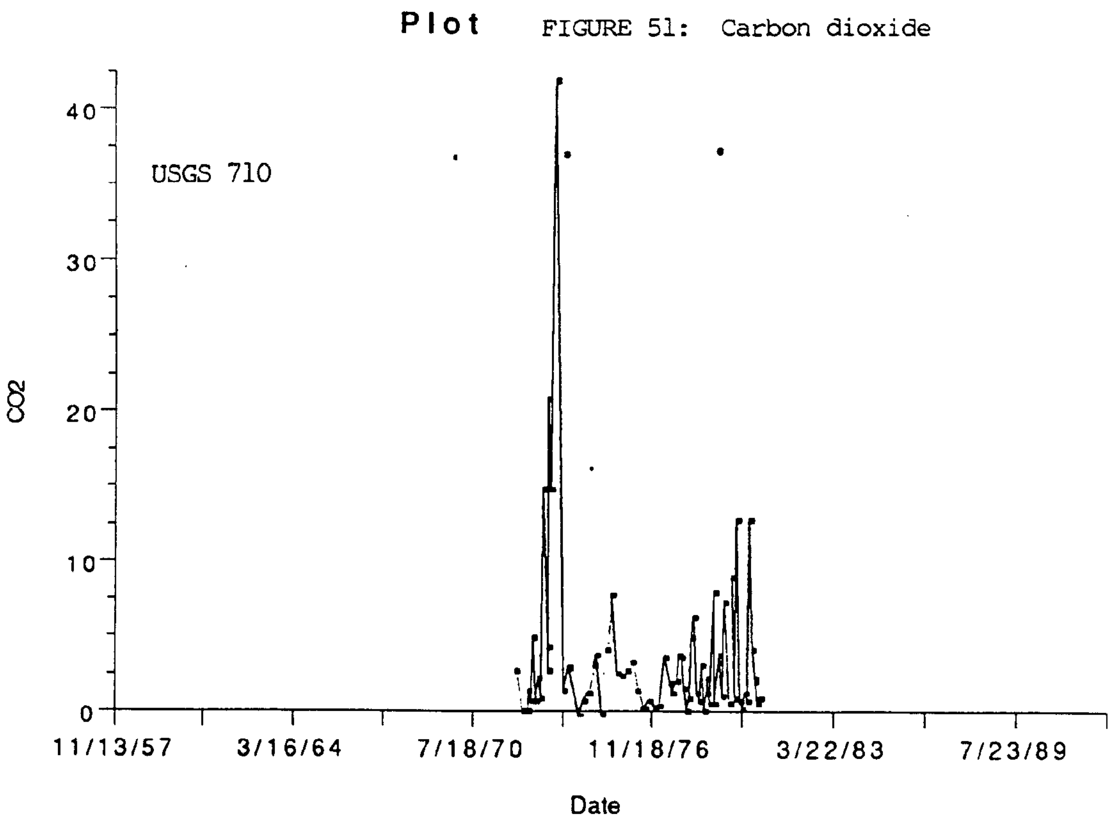
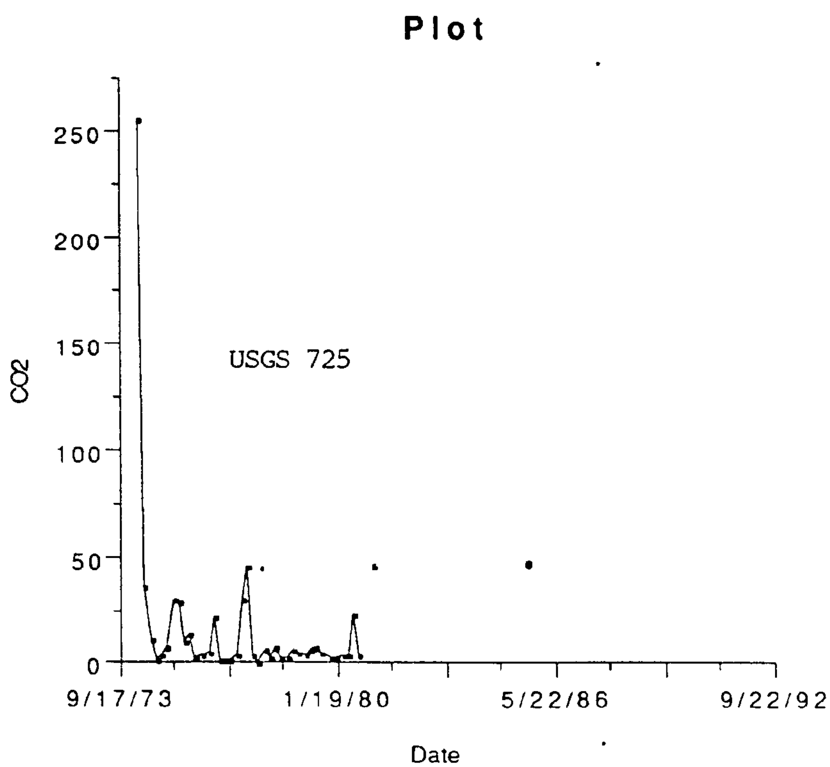


FIGURE 51: Carbon dioxide

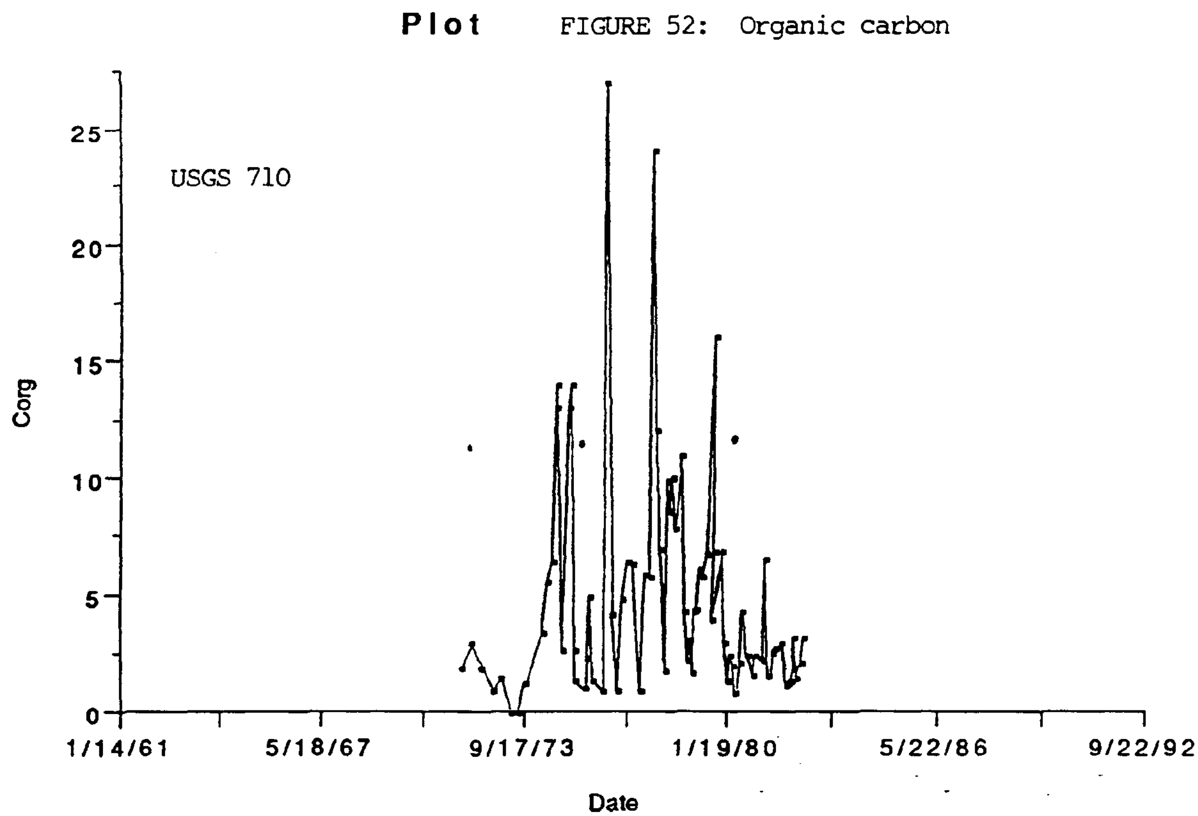


CO2



CO2

FIGURE 52: Organic carbon



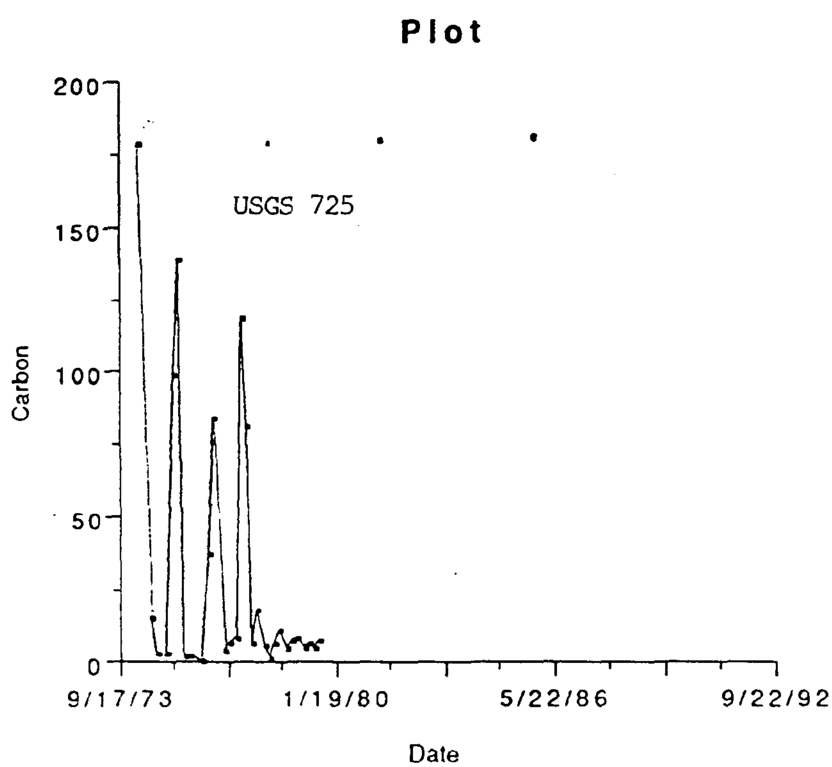
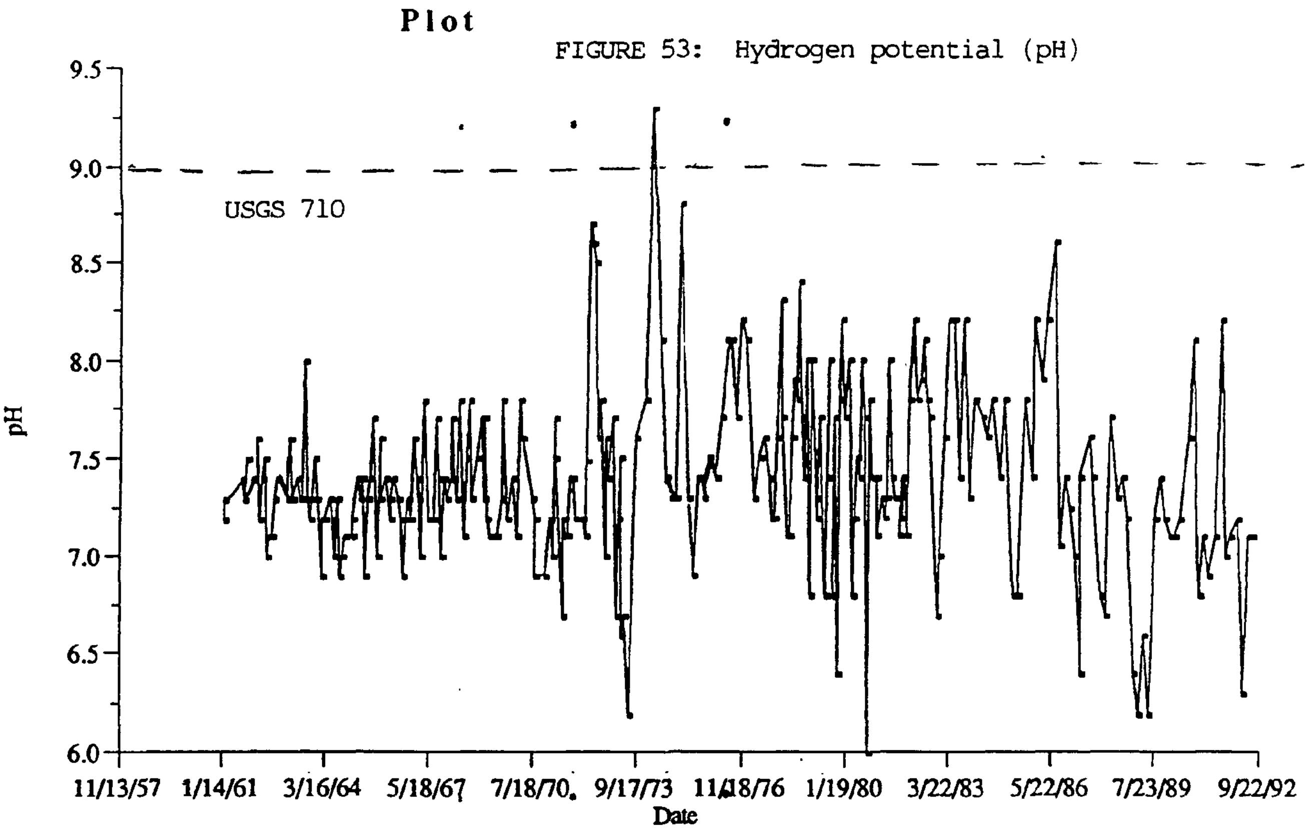
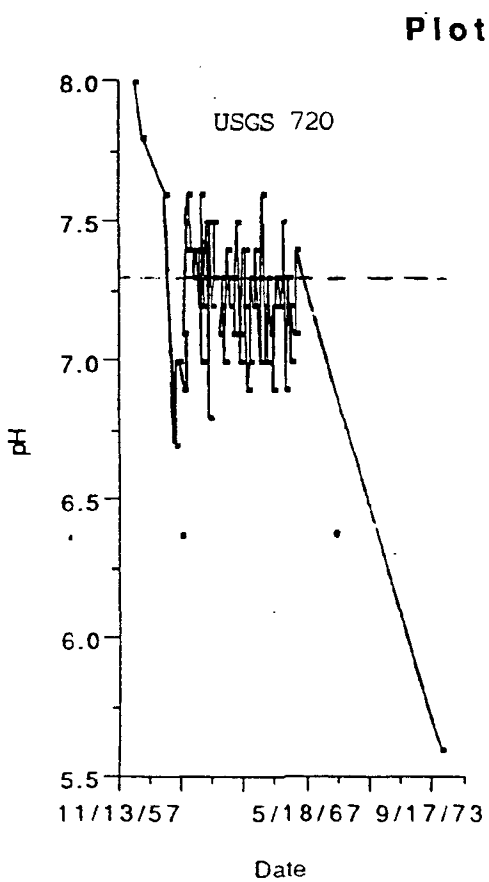
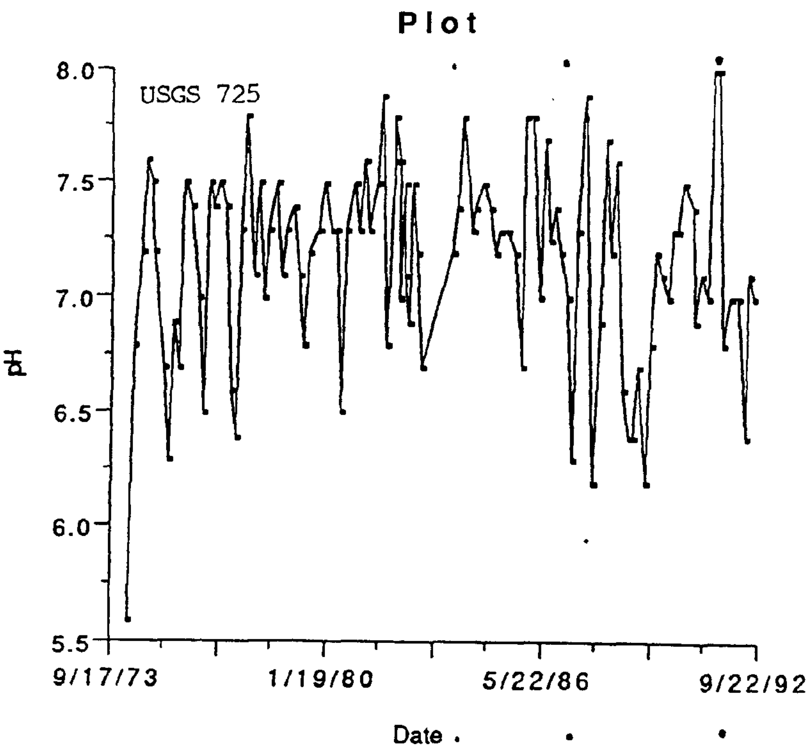


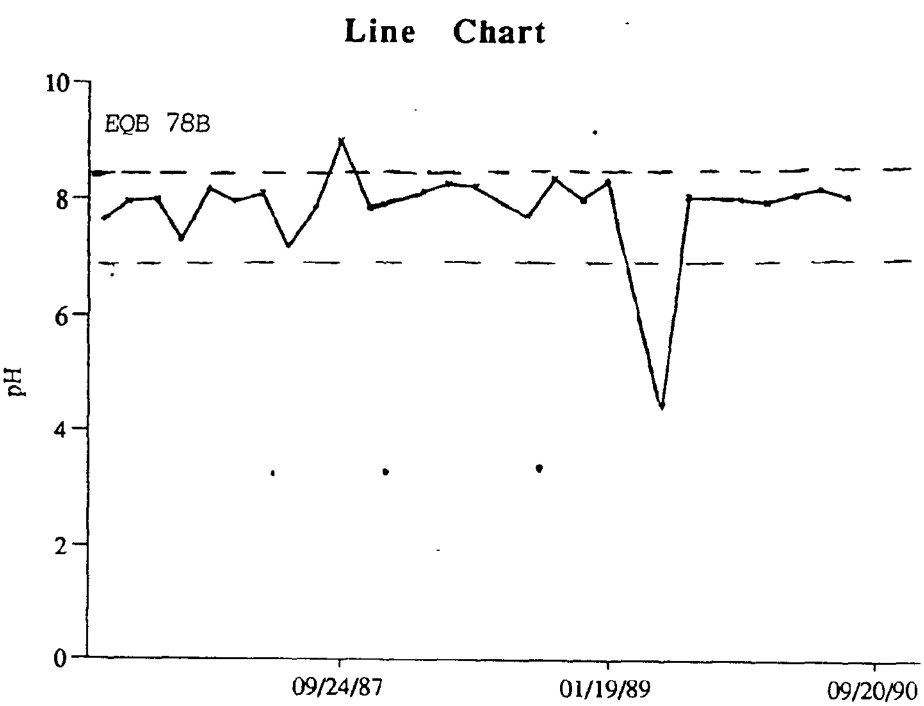
FIGURE 53: Hydrogen potential (pH)



pH




Plot
USGS 725
8.0
7.5
7.0
6.5
6.0
5.5
pH
9/17/73
1/19/80
5/22/86
9/22/92
Date


Line Chart
EQB 78B
10
8
6
4
2
0
pH
09/24/87
01/19/89
09/20/90

pH peaked in 1973 at USGS 710, while showing valleys for the same period at USGS 720 & 725 (Table 9: parameter #6; Figure 53). It may be due to influx of organic matter at st. 720 which reached st. 725. Station EQB 78B shows more recent high fluctuations.

Metals, silica and toxic substances

Metals, silica (which are micronutrients) and toxic substances like cyanide, can come from soils, metallic pipes in contact or near the river, wastewater, landfills or solid wastes thrown directly onto the river. Silica, another micronutrient, comes mostly from the soil. Data from the Fajardo River shows an increase tendency in silica, decreasing tendencies of copper, chromium and cobalt and stable fluctuations for the other components (Table 9: parameters #13, 44, 45, 46, 47, 48 , 49, 50 , 51, 52 53, 54, 55, 56, 57, 58 & 59; Figures 54, 55, 56, 57, 58, 59, 60, 61, 62, 63, 64, 65, 66, 67, 68, 69 & 70). Amounts of toxic substances have been low.

Pesticides

Samples for pesticides are taken once a year from station USGS 710. It has never found significant traces of pesticides. However, since EQB has established that pesticides is one of the most important types of NPSP at the Fajardo River, it is possible that USGS sampling methods are inadequate for this group of parameters.

TABLE 9: Summarized analysis of historical water quality data gathered at monitoring stations USGS 710, USGS 720, USGS 725, and EQB 78B (1958-1992).

Parameter	Station	H	L	Comments
1. Instantaneous Discharge (ft^3/s)	USGS 710			Fluctuations: 10-200. Peaks: 1961, 1975, 1979, 1980,1982, 1990.
	USGS 720			Fluctuations: 10-100. Peaks: 1961, 1962, 1963.
	USGS 725			Fluctuations: 10-180. Peaks: 1973, 1975, 1990.
2. Total Volume (ft^3)	USGS 710			Fluctuations: 10,000-35,000. Peaks: 1968, 1969, 1986.
	USGS 720			Fluctuations: 15,000-30,000. Peak: 1962.

Parameter	Station	H	L	Comments
3. Temperature (°C)	USGS 710	32.2		
	USGS 720	32.2		
	USGS 725	32.2		Fluctuations: 24-33. Peaks: 1974, 1975, 1977, 1981.
	EQB 78B	32.2		Fluctuations: 25-33. Peak; 1988.
4. Conductance (µs/cm)	USGS 710			Fluctuations: 75-150. Valleys: 1962, 1972, 1980, 1981, 1985. Peaks: 1973, 1980, 1984.
	USGS 720			Fluctuations around 100. Very high peak in 1973.
	USGS 725			Fluctuations: 100-500. Very high peaks in 1973-1974.
5. Salinity (ppt)	EQB 78B			Fluctuations: 25-40. Very low valley in 1988.
6. pH (standard units)	USGS 710	9.0	6.0	Fluctuations: 7.0-8.0 from 1961-1971 and afterwards from 6.0-9.0. Peak: 1973.
	USGS 720	9.0	6.0	Fluctuations: 6.0-8.0. Valley: 1973.
	USGS 725	9.0	6.0	Fluctuations: 6.0-8.0. Valley: 1973.
	EQB 78B	8.5	7.3	Fluctuations: 7.3-8.5. Peak: 1987. Valley: 1989.
7. Color (standard units)	USGS 710			Fluctuations: 2-7. Peaks in 1967; valley in 1966.
	USGS 725			Fluctuations: 3-15. Peaks: 1962, 1966, Valleys: 1965, 1966.
	EQB 78B			Fluctuations: 0-5. Peaks: 1987, 1989, 1990.
8. Turbidity (NTU)	USGS 710	50		Fluctuations: 0-20. Peaks: 1977, 1978, 1980, 1981, 1989, 1990.
	USGS 725	50		Fluctuations: 0-10. Peaks: 1979, 1981, 1985 (very high), 1986, 1990.
	EQB 78B	10		Fluctuations: 0-20. Peaks: 1986, 1987, 1988-1989.
9. Suspended Sediments (mg/l)	USGS 710			Fluctuations: 0-600. Peaks: 1962, 1974, 1977, 1980.
	USGS 725			Fluctuations: 0-600. Peaks: 1974, 1975.
10. Dissolved Solids (tons/day)	USGS 710			Fluctuations: 0-25. Peaks: 1977, 1978, 1979. Decrease tendency.
	USGS 725			Fluctuations: 0-25. Peaks: 1979, 1986. Decrease tendency.
11. Total Sum Diss. Solids (mg/l)	USGS 710	500		Fluctuations: 40-100. Peaks in 1964 and 1979 were within acceptable levels.
	USGS 720	500		Fluctuations: 40-100. Peaks in 1962 and 1963 were within acceptable levels.
	USGS 725	500		Fluctuations: 60-130. Peak in 1983 was within acceptable levels.

Parameter	Station	H	L	Comments
12. Residue of Susp. Solids (mg/l)	USGS 710			Fluctuations between 1963 and 1979 were 50-120. From 1980 on, fluctuations are 0-50. Peaks: 1977, 1979, 1981, 1989. Increase tendency.
	USGS 720			Fluctuations: 60-95. Peak in 1966. Increase tendency.
	USGS 725			Fluctuations: 0-50. Peaks: 1980, 1982, 1986.
	EQB 78B			Fluctuations: 10-80. Peaks: 1987, 1988.
13. Silica, diss (mg/l)	USGS 710			Fluctuations: 10-30.
	USGS 720			Fluctuations: 16-27. Peak in 1962.
	USGS 725			Fluctuations: 12-26. Increase tendency.
14. Oil/grease (mg/l)	EQB 78B			Fluctuations 0-3. Peaks: 1988, 1989-1990.
15. Dissolved Oxygen (mg/l)	USGS 710		5.0	Fluctuations: 7.0-11.0. Very low valley in 1974.
	USGS 725		5.0	Fluctuations: 6.0-11.0. Valleys: 1973-1974, 1976.
	EQB 78B		4.0	Fluctuations: 5.0-7.0.
16. % Saturation Diss. Oxygen	USGS 710			Fluctuations: 90-120. Decrease tendency.
	USGS 725			Fluctuations: 80-120. Decrease tendency.
	EQB 78B			Fluctuations: 50-100.
17. BOD (mg/l)	USGS 710			Fluctuations: 0-3. Peaks: 1968, 1971, 1973, 1979. Increase tendency.
	USGS 725			Fluctuations: 0-200. Peaks: 1973-1974, 1977.
18. COD (mg/l)	USGS 710			Fluctuations: 0-30, increasing since 1983. Peaks: 1983, 1987, 1988, 1990, 1992.
	USGS 725			Fluctuations: 0-40. Peaks: 1983, 1986, 1988, 1989.
19. Hardness, Total (mg/l)	USGS 710			Fluctuations: 0-5. Peaks: 1962, 1966, 1967, 1980. Decrease tendency.
	USGS 720			Fluctuations: 0-4. Peaks in 1966.
	USGS 725			Fluctuations: 0-7. Peaks: 1981, 1984, 1985. Decrease tendency.
20. Hardness, Noncarbonate (mg/l)	USGS 710			Fluctuations: 15-45. Peaks: 1962, 1966, 1972, 1980.
	USGS 720			Fluctuations: 15-45. Peak in 1966. Increase tendency
	USGS 725			Fluctuations: 35-60. Peak in 1984. Valleys: 1978, 1979.
21. Alkalinity (mg/l)	USGS 710			Fluctuations: 10-50. Peaks: 1973, 1991.
	USGS 725			Fluctuations: 10-70. Peaks: 1973, 1974. Decrease tendency.
22. Sodium, diss (mg/l)	USGS 710			Fluctuations: 5-15. Peaks: 1974, 1980.
	USGS 720			Fluctuations: 5-14.
	USGS 725			Fluctuations; 0-50. Very high peaks in 1974.

Parameter	Station	H	L	Comments
23. Calcium, diss (mg/l)	USGS 710			Fluctuations: 4-10. Peaks: 1968, 1970.
	USGS 725			Fluctuation: 5-9. Peak in 1966. Increase tendency.
	USGS 720			Fluctuations: 5-15. Peak in 1984.
24. Potassium, diss (mg/l)	USGS 710			Fluctuations: 0.5-2.0. Peaks: 1974, 1980, 1989-1990, 1991. Increase tendency.
	USGS 725			Fluctuations: 0-5.0. High peaks: 1973-1975, 1978.
25. Magnessium, diss (mg/l)	USGS 710			Fluctuations: 1.5-5.5. Peaks: 1962, 1967, 1980.
	USGS 720			Fluctuations: 1.5-6.0. Peaks: 1963, 1967.
	USGS 725			Fluctuations: 3.0-5.0. Peaks: 1984, 1985, 1990.
26. Chloride, diss (mg/l)	USGS 710	250		Fluctuations: 5-15. Peaks within acceptable levels: 1962, 1974, 1976, 1978, 1979.
	USGS 720	250		Fluctuations: 5-15. Peak in 1962 within acceptable levels. Increase tendency.
	USGS 725	250		Fluctuations: 0-100. Very high peaks in 1973-1974.
27. Fluoride, diss (mg/l)	USGS 710	0.7		Fluctuations: 0-0.3. Peak in 1973 within acceptable levels.
	USGS 720	0.7		Fluctuations: 0-0.4. Peak in 1962.
	USGS 725	0.7		Fluctuations: 0-0.3. Peak in 1973 within acceptable levels.
28. Bicarbonate, diss (mg/l)	USGS 710			Fluctuations: 20-60. Peak in 1973.
	USGS 720			Fluctuations: 20-60. Peaks: 1966, 1973. Increase tendency.
	USGS 725			Fluctuations: 30-80. Peaks; 1973, 1974. Decrease tendency.
29. Carbonate, diss (mg/l)	USGS 710			Around 0, except in 1971, 1974, 1978.
30. Carbon dioxide, diss (mg/l)	USGS 710			Fluctuations: 0-10. Peaks: 1973, 1980, 1981.
	USGS 725			Fluctuations: 0-40. Peaks: 1973, 1977.
31. Carbon, organic total (mg/l)	USGS 710			Fluctuations: 0-15. Peaks: 1975, 1977. Decrease tendency.
	USGS 725			Fluctuations: 0-25. Peaks: 1973, 1975, 1976, 1977. Decrease tendency.
32. Sulfate, diss (mg/l)	USGS 710	250		Fluctuations: 0-10. Peaks (1973, 1974) are within acceptable levels. Increase tendency.
	USGS 720	250		Fluctuations: 0-10.
	USGS 725	250		Fluctuations: 0-10. Peaks: 1973-1974.

Parameter	Station	H	L	Comments
33. Nitrate, total (mg/l)	USGS 710			Fluctuations of 0-1.0 between 1962 and 1967, of 0-1.5 in 1968-1973, and of 0-0.5 in 1974 on.
	USGS 720			Fluctuations: 0-1.5. Peaks: 1960, 1961.
	USGS 725			Fluctuations: 0-0.5. Peaks: 1981, 1990.
	EQB 78B			A single peak in 1990 (0.1-0).
34. Nitrite, total (mg/l)	USGS 710			Fluctuations: 0-0.3. Peaks: 1976, 1980.
	USGS 725			Fluctuations: 0-0.8. Peak in 1980.
35. NO_3 + NO_2, total (mg/l)	USGS 710	relative*		Fluctuations: 0-0.4. Peaks: 1981, 1985.
	USGS 725	relative*		Fluctuations: 0-0.5. Peak in 1981.
	EQB 78B			Fluctuations: 0-0.2. Peaks: 1988, 1989.
36. Ammonia, total (mg/l)	USGS 710	1.0**		Fluctuations: 0-0.3. Peak in 1974.
	USGS 725	1.0**		Fluctuations: 0-1.0. Peaks: 1973, 1978, 1982.
37. Nitrogen, organic, total (mg/l)	USGS 710			Fluctuations: 1.0-2.0.
	USGS 725			Fluctuations: 1.0-2.0. Peaks 1973, 1974, 1975, 1976.
38. Nitrogen (NO_3), total (mg/l)	USGS 710			Fluctuations: 0-2. Peaks in 1973.
	USGS 725			Fluctuations: 0-2. Peaks: 1973, 1974, 1975, 1976.
39. Amonnia + Norg + N (mg/l)	USGS 710			Fluctuations: 0-2. Peak in 1973.
	USGS 725			Fluctuations: 0-2. Peaks: 1973, 1974, 1975, 1976.
	EQB 78B			Fluctuations: 0-1.
40. Phosphorus, total (mg/l)	USGS 710	1		Fluctuations: 0-1. Significant peak in 1973.
	USGS 725	1		Fluctuations over 1.0 in 1973, 1974, 1975 & 1976. Descending tendency since.
	EQB 78B			Fluctuations: 0-0.4. Peak in 1987.
41. Phosphate, total (mg/l)	USGS 710			Fluctuations: 0-0.1.
42. Fecal Coliforms (colonies/100 ml)	USGS 710	2,000***		Fluctuations: 0-10,000. Very high peaks: 1973, 1974, 1978, 1980, 1981, 1989, 1991. Decrease tendency.
	USGS 725	2,000***		From an extremely high count of near 20,000,000 in 1973, situation has normalized since 1983.
	EQB 78B	2,000***		From a very high count in 1973, situation normalized.
43. Fecal Streptococci (colonies/100 ml)	USGS 710			Fluctuation: 0-10,000. High peaks in 1973, 1978, 1980, 1981, 1982, 1988, 1989.
	USGS 725			Fluctuations: 0-10,000. Peaks: 1973, 1974, 1975, 1976, 1978.

Parameter	Station	H	L	Comments
44. Iron, total (µg/l)	USGS 710			Fluctuations: 0-250. Peaks: 1978, 1980, 1990.
	USGS 725			Fluctuations: 0-2,000. Peaks: 1979, 1986.
	EQB 78B			Fluctuations: 0-500. Peaks: 1987, 1988.
45. Iron, diss (mg/l)	USGS 720			Values at 0, except peak in 1970.
46. Copper, total (µg/l)	USGS 710	relative*		Fluctuations: 0-10. Peaks: 1977, 1981, 1987, 1990.
	USGS 725	relative*		Fluctuations: 0-25 after 1980. Peaks: 1975, 1976, 1977. Decrease tendency.
	EQB 78B	50		Fluctuations: 0-10. Peak in 1987 within acceptable levels.
47. Arsenic, total (µg/l)	USGS 710	50		Peaks in 1974, 1983 within acceptable levels.
	USGS 725	50		Peaks in 1974, 1983 within acceptable levels.
48. Barium, total (µg/l)	USGS 710	1,000		Fluctuations between 0-100.
49. Boron, total (µg/l)	USGS 710	1,000		Fluctuations between 10-30.
	USGS 725	1,000		Fluctuations between 10-50.
	EQB 78B	4,800		Fluctuations between 2,000-4,500. Peak in 1987.
50. Cadmiun, total (µg/l)	USGS 710	relative*		Fluctuations between 0-5. Peaks in 1978, 1980.
	USGS 725	relative*		Fluctuations between 0-3. Peaks in 1973, 1982.
	EQB 78B	5		Fluctuations: 0-5. Decrease tendency.
51. Chromium, total, (µg/l)	USGS 710	50		Fluctuations: 0-20. Peak in 1980 within acceptable levels. Decrease tendency.
	USGS 725	50		Fluctuations: 0-20. Peak in 1975 within acceptable levels. Decrease tendency.
	EQB 78B	300		Values at 0, except peak in 1987 within acceptable levels.
52. Lead, total (µg/l)	USGS 710	relative*		Fluctuations: 0-20. Peaks: 1978, 1981, 1989.
	USGS 725	relative*		Fluctuations: 0-10. Peaks: 1974, 1975, 1976, 1977.
	EQB 78B	15		Values at 0 except peak in 1986.
53. Manganese, total (µg/l)	USGS 710	50		Fluctuations: 0-50. Peaks: 1974, 1975, 1977, 1979, 1981, 1987, 1989.
	USGS 725	50		Fluctuations over acceptable levels: 0-250. High peaks in 1975, 1976, 1977.
	EQB 78B	100		Fluctuations: 0-100. Peaks: 1986, 1987.
54. Cyanide, total (mg/l)	USGS 710	0.02		Values at 0, except high peak in 1978.
55. Cobalt, total (µg/l)	USGS 710			Fluctuations: 0-2. Peaks: 1978, 1980.

Parameter	Station	H	L	Comments
56. Mercury, total (µg/l)	USGS 725	1		Fluctuations: 0-0.5. Peaks: 1979, 1986.
57. Nickel, total (µg/l)	USGS 710	relative*		Fluctuations: 0-4. Peaks: 1974, 1980.
	USGS 725	relative*		Fluctuations: 0-25.
58. Selenium, total (µg/l)	USGS 725	10		Fluctuations: 0-1. Peak in 1976 within acceptable levels.
59. Zinc, total (µg/l)	USGS 710	50		Fluctuations: 0-50. Peaks: 1980, 1988.
	USGS 725	50		Fluctuations after 1980: 0-50. Peaks: 1973-1974, 1975, 1976, 1977, 1978, 1979. Decrease tendency.
	EQB 78B	50		Fluctuations over acceptable levels: 0-100. High peaks 1986, 1987.
60. Phenols, total (µg/l)	USGS 710			Fluctuations: 0-10, except peak in 1986.
61. Methylene Blue Active Substance, total (µg/l)	USGS 710	0.1		Fluctuations: 0-0.05 except peak in 1989 within acceptable levels.
	USGS 725	0.1		Fluctuations: 0-0.4 except peak in 1986 within acceptable levels.

H and L refer to the highest and lowest limits allowed by EQB.

* Limit values depends on values for hardness obtained from the same sample.

** Ammonia levels are restricted in specific water bodies which do not include the Fajardo River.

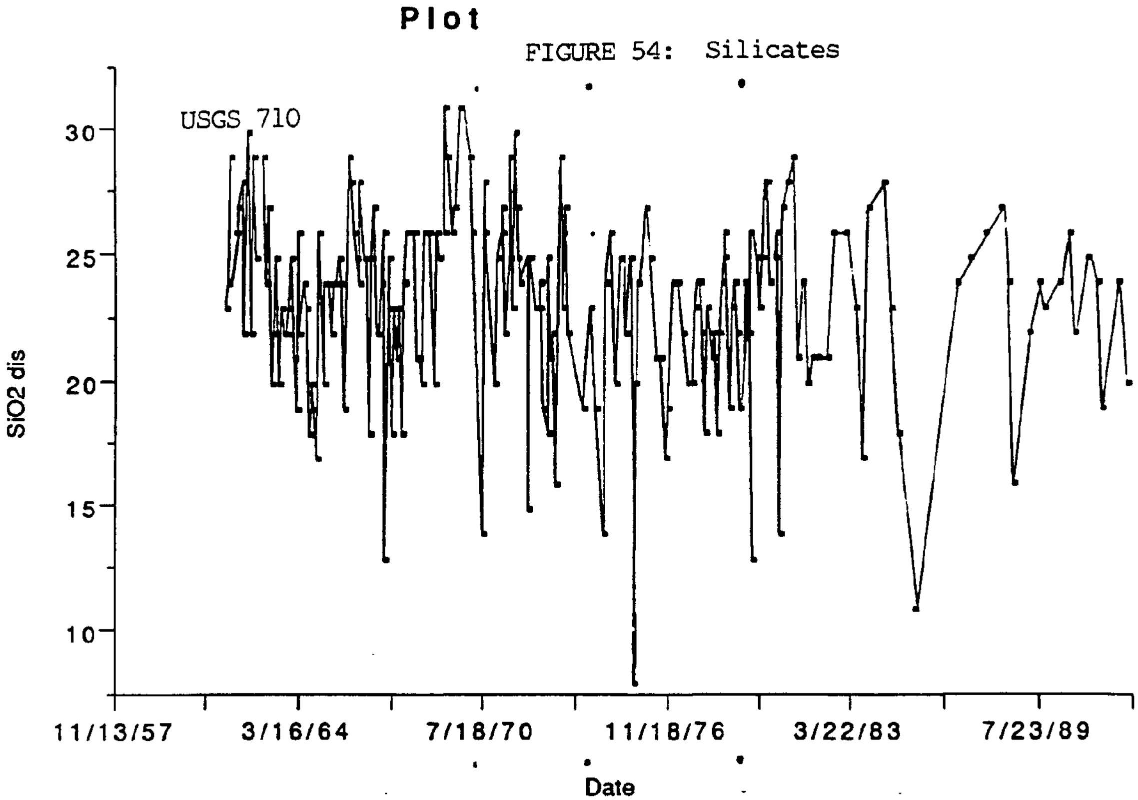
*** Fecal bacteria levels are calculated as the geometric mean in a series of samples taken sequentially.

Field sampling at the Fajardo River

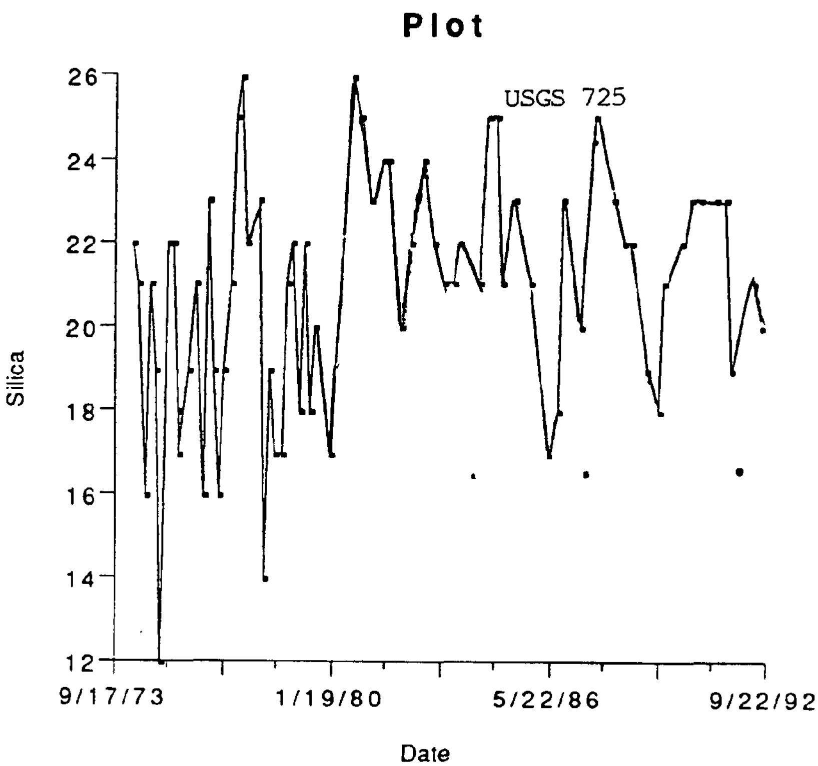
For the purpose of confirming historical data, this projects personnel, established two water sampling stations at the river and two additional stations at the coast, just outside the river mouth (See Table 10; Figures 71 & 72). Samples were taken three times in 1992-1993. Results are summarized in Table 11.

Laboratory analyses results of our field water samples were consistent with recent water quality data from USGS monitoring stations. They show that, during sampling periods, levels of pollutants were relatively low.

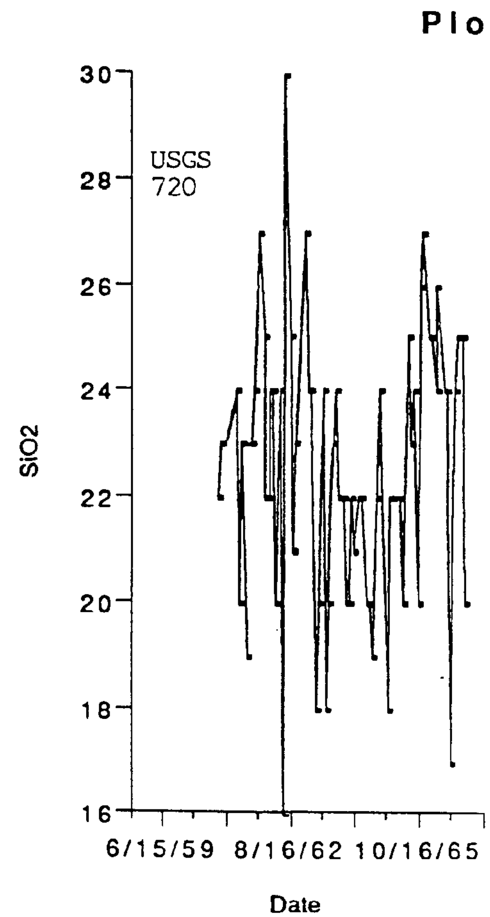
FIGURE 54: Silicates



SiO2 dis

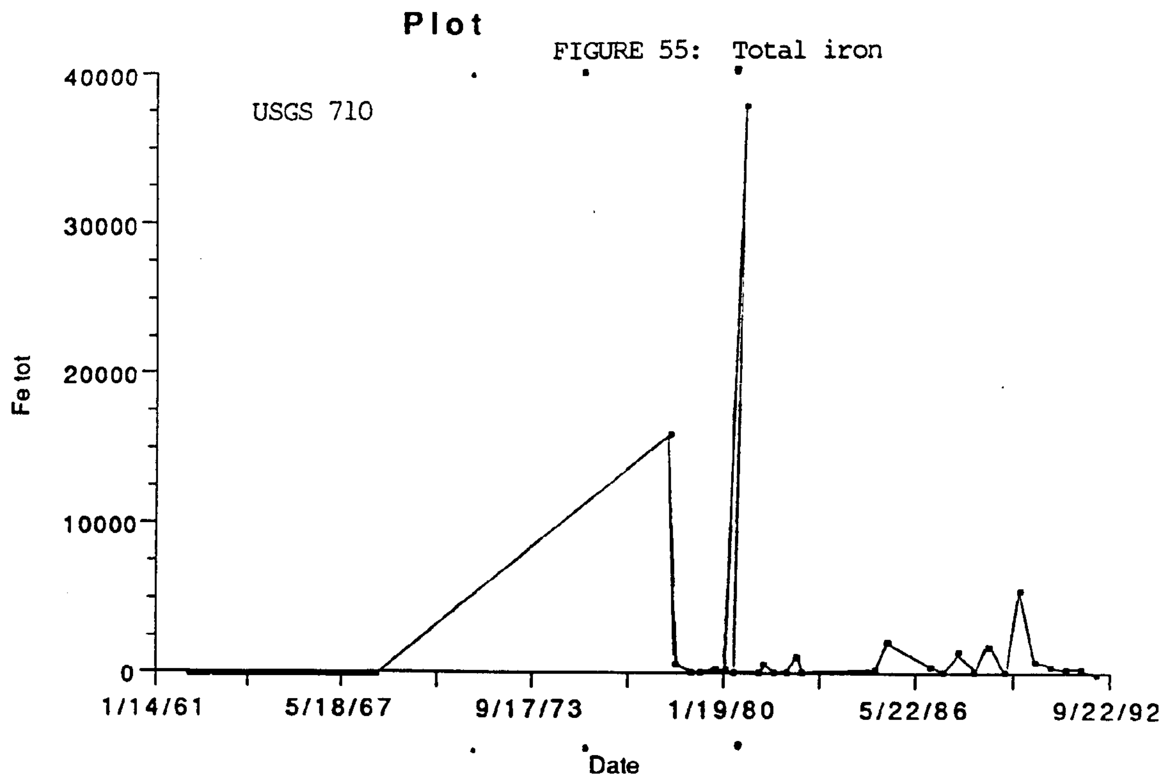


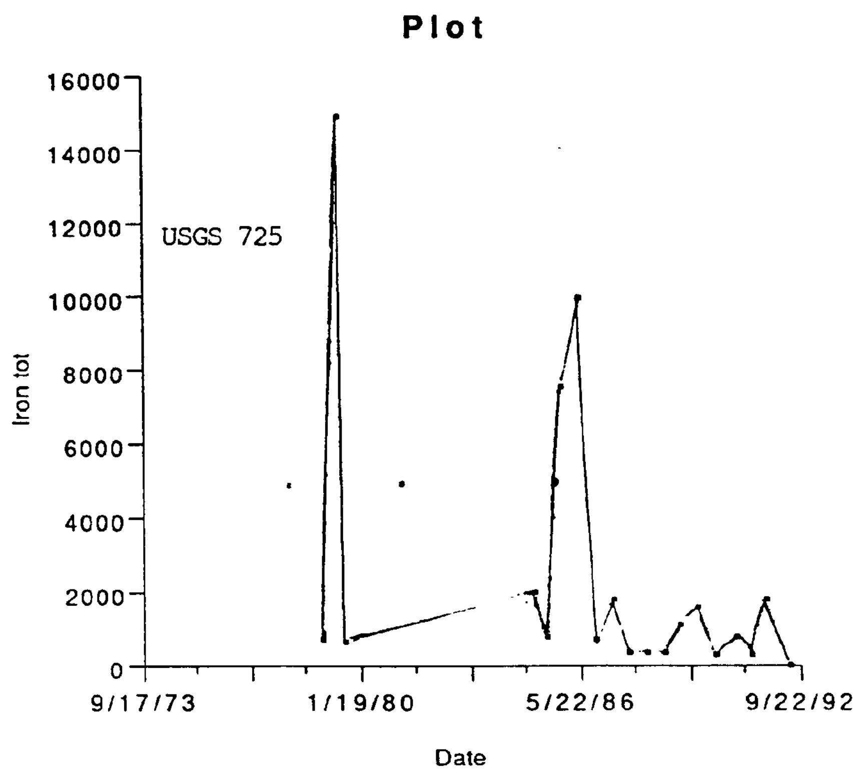
Silica



SiO2

FIGURE 55: Total iron





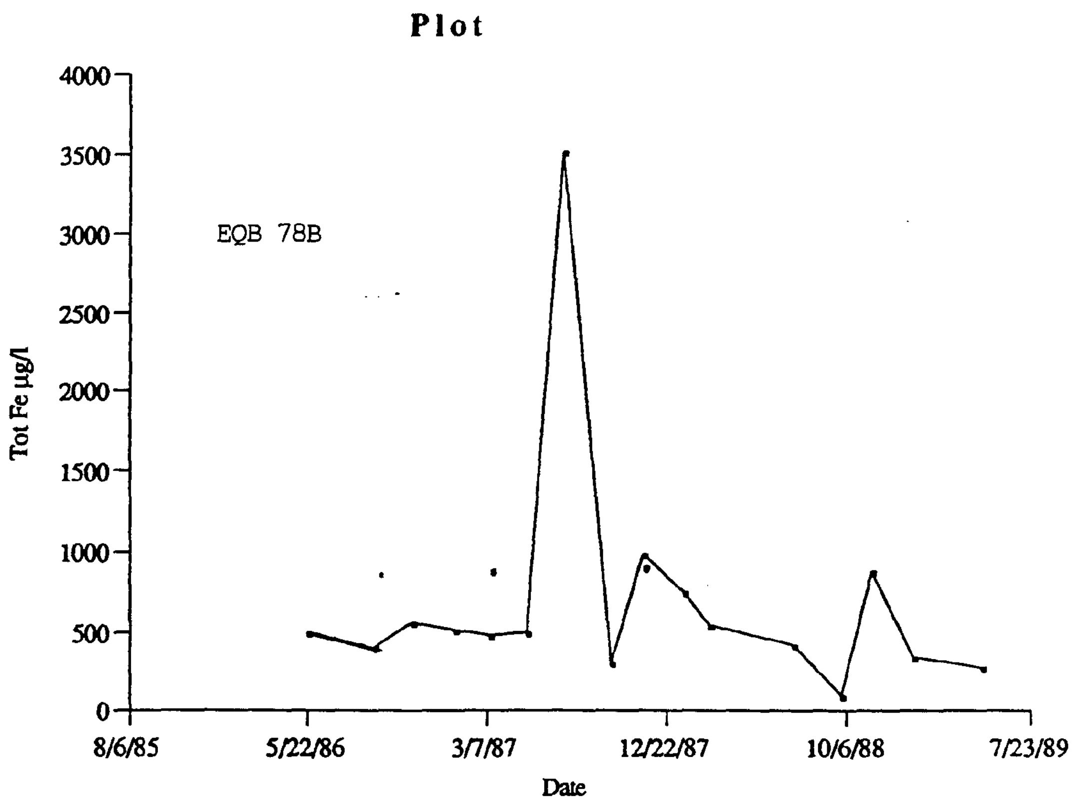
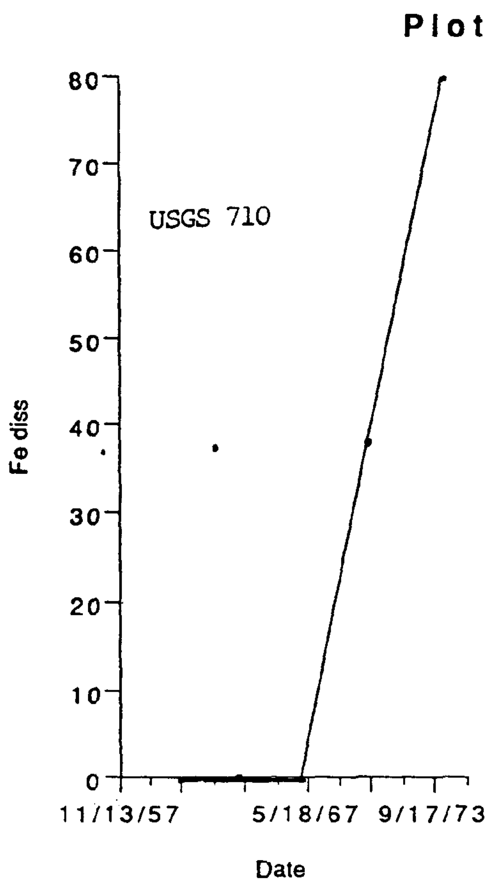
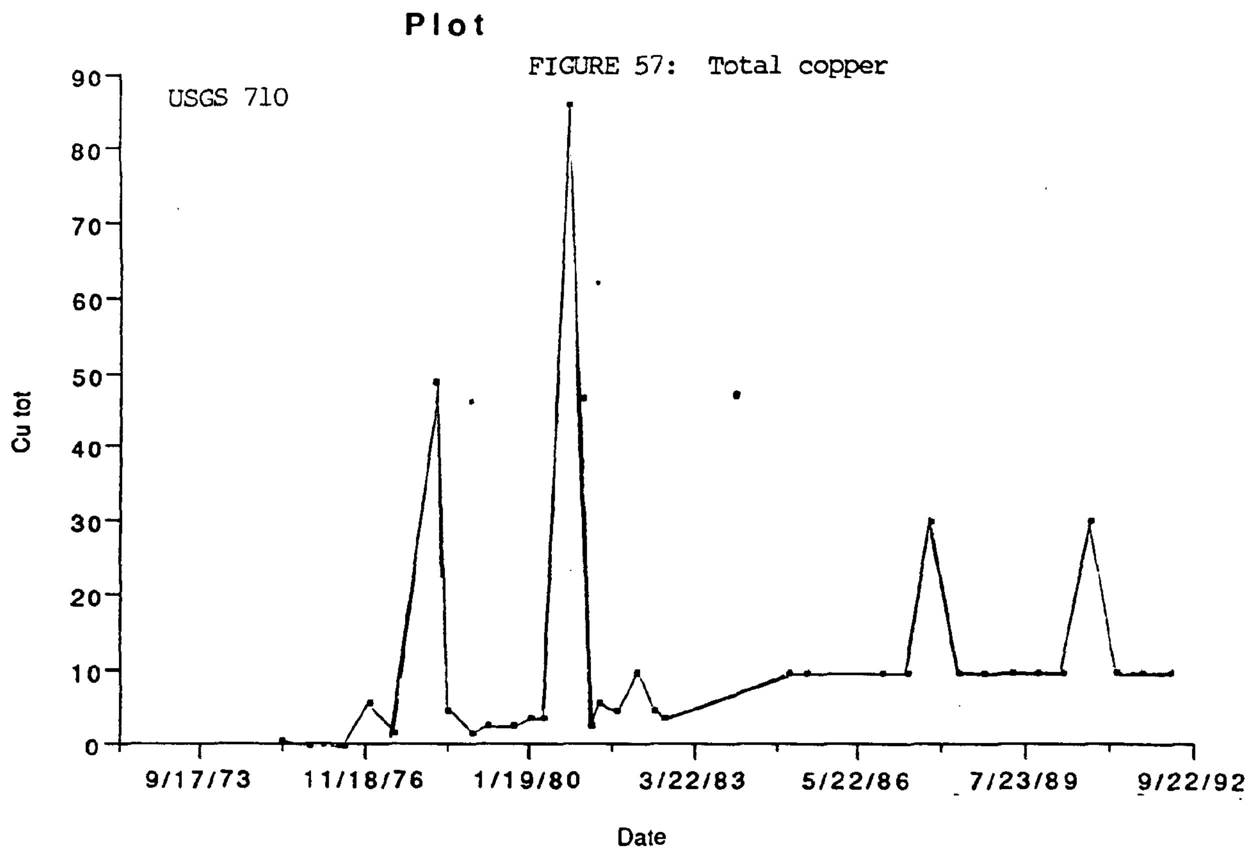
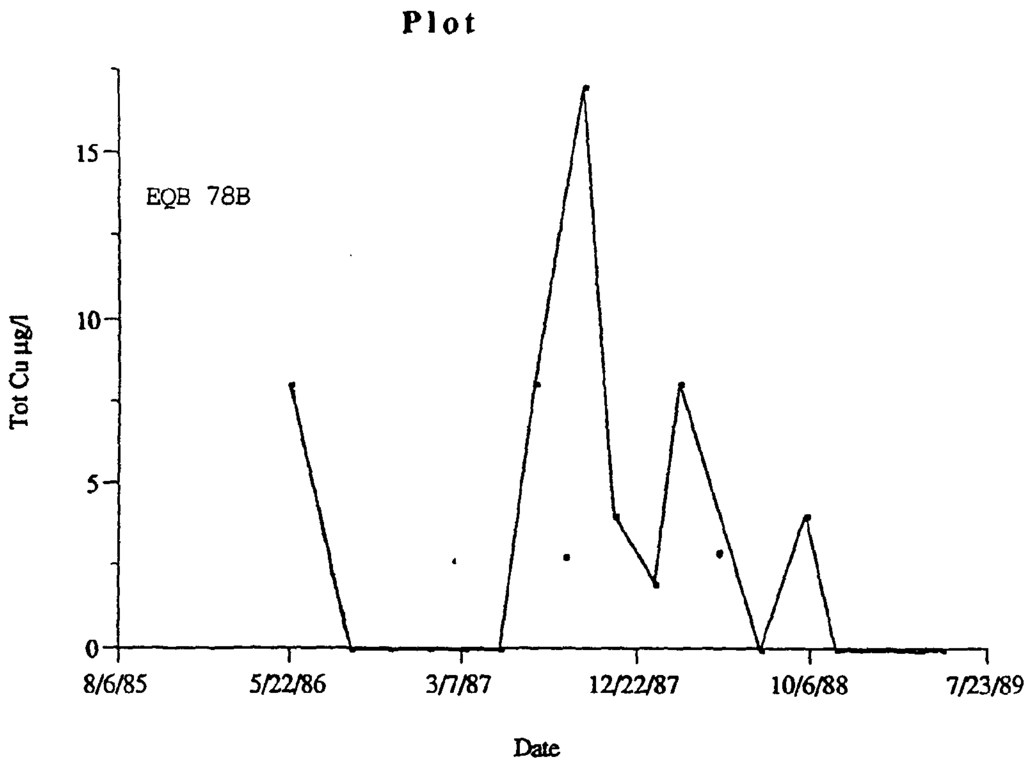

Plot
4000
3500
3000
2500
2000
1500
1000
500
0
Tot Fe µg/l
EQB 78B
8/6/85
5/22/86
3/7/87
12/22/87
10/6/88
7/23/89
Date

FIGURE 56: Dissolved iron





Plot
FIGURE 57: Total copper
USGS 710
90
80
70
60
50
40
30
20
10
0
Cu tot
9/17/73
11/18/76
1/19/80
3/22/83
5/22/86
7/23/89
9/22/92
Date


Plot
EQB 78B
Tot Cu µg/l
15
10
5
0
8/6/85
5/22/86
3/7/87
12/22/87
10/6/88
7/23/89
Date

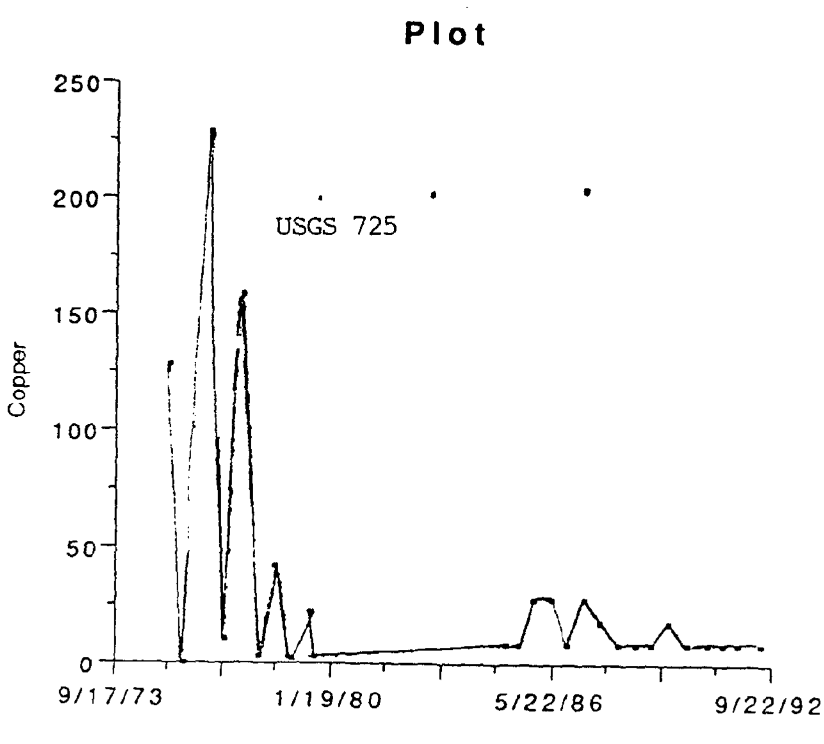
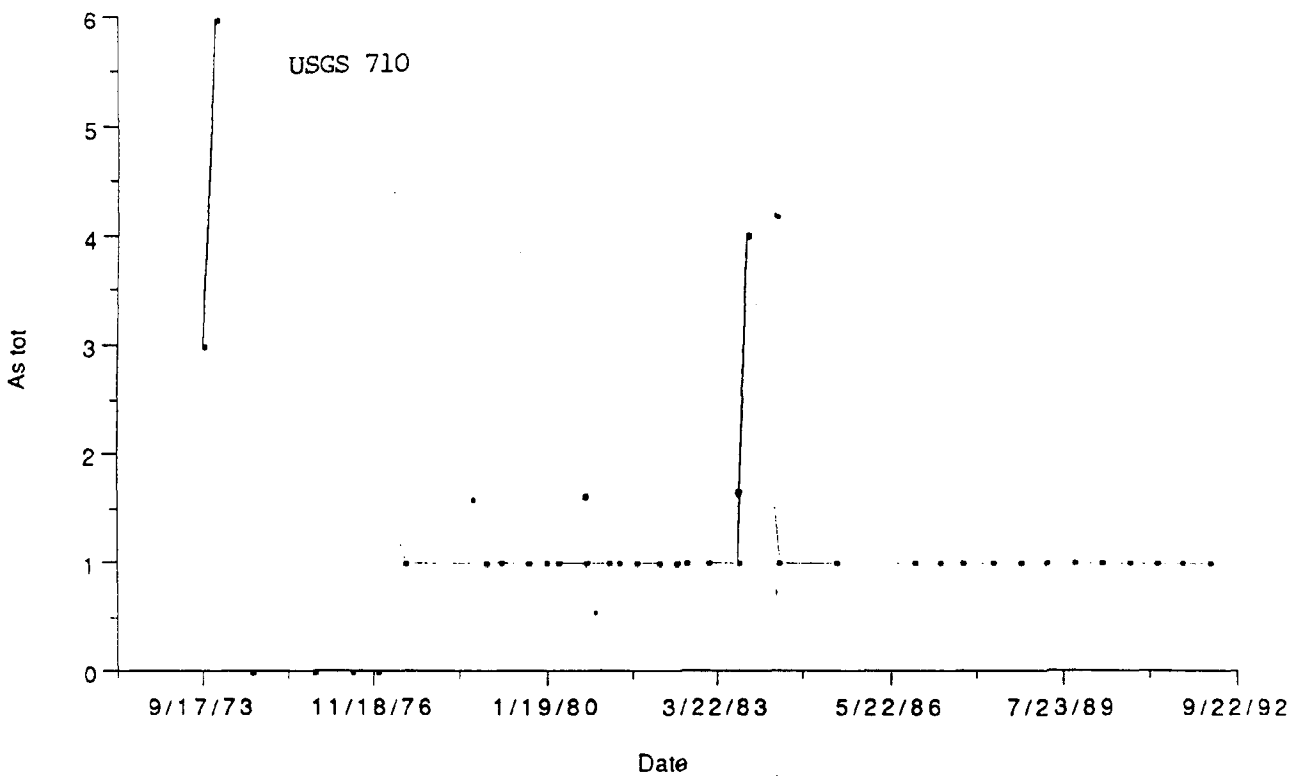
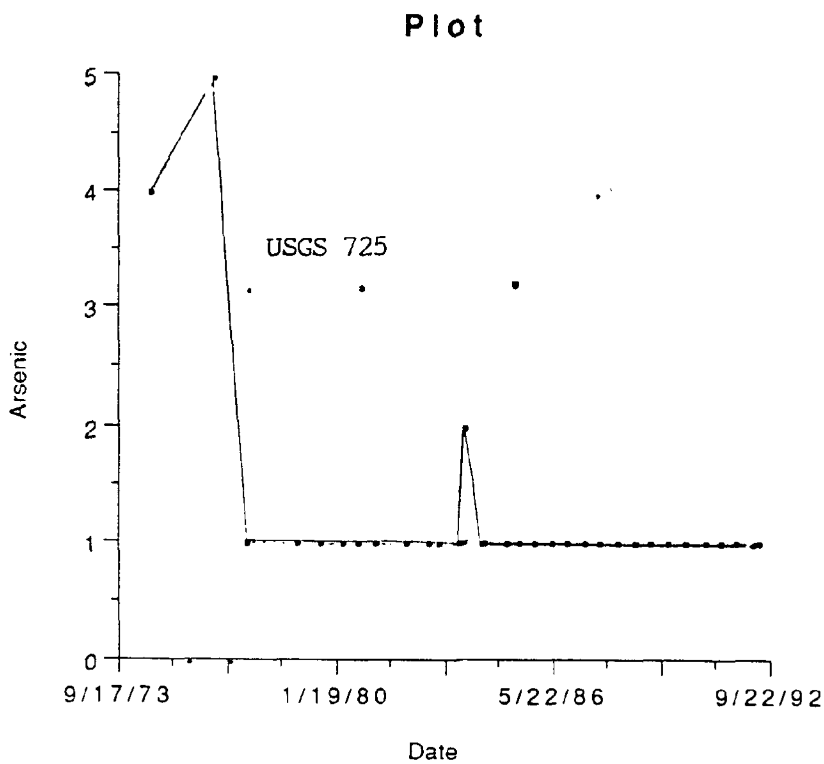

Plot
USGS 725
Copper
250
200
150
100
50
0
9/17/73
1/19/80
5/22/86
9/22/92

FIGURE 58: Total arssenic



As tot



Arsenic

FIGURE 59: Total barium

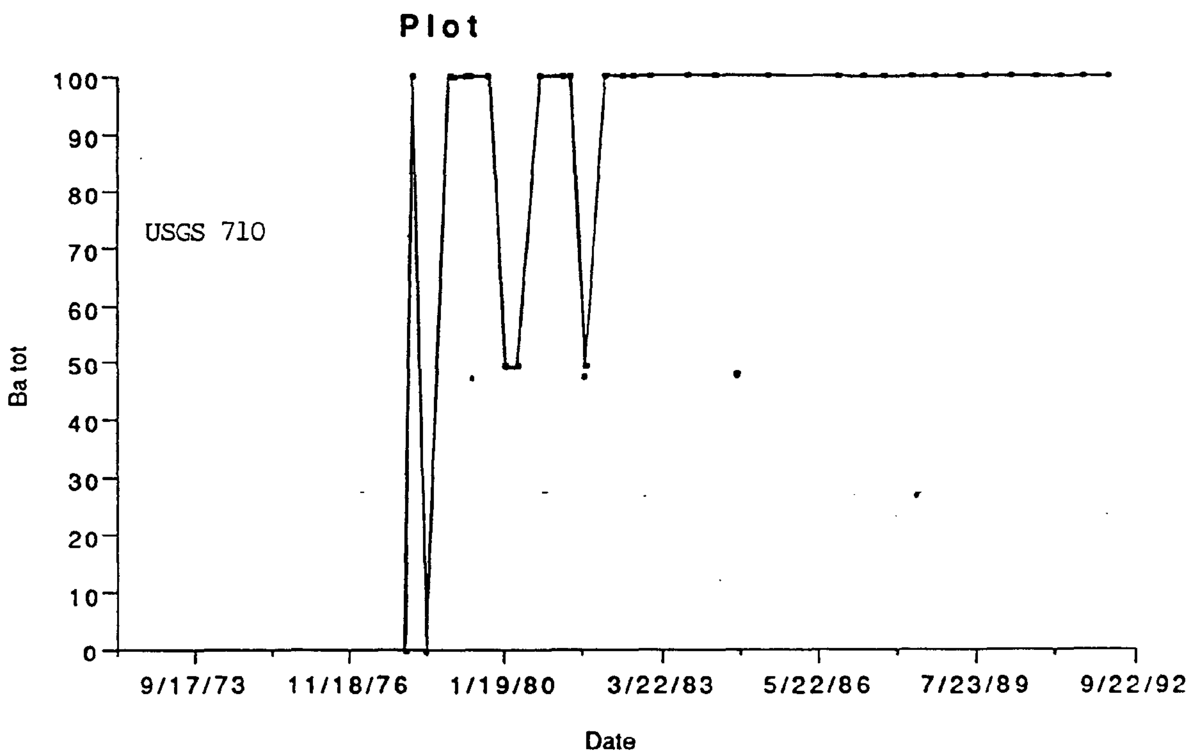
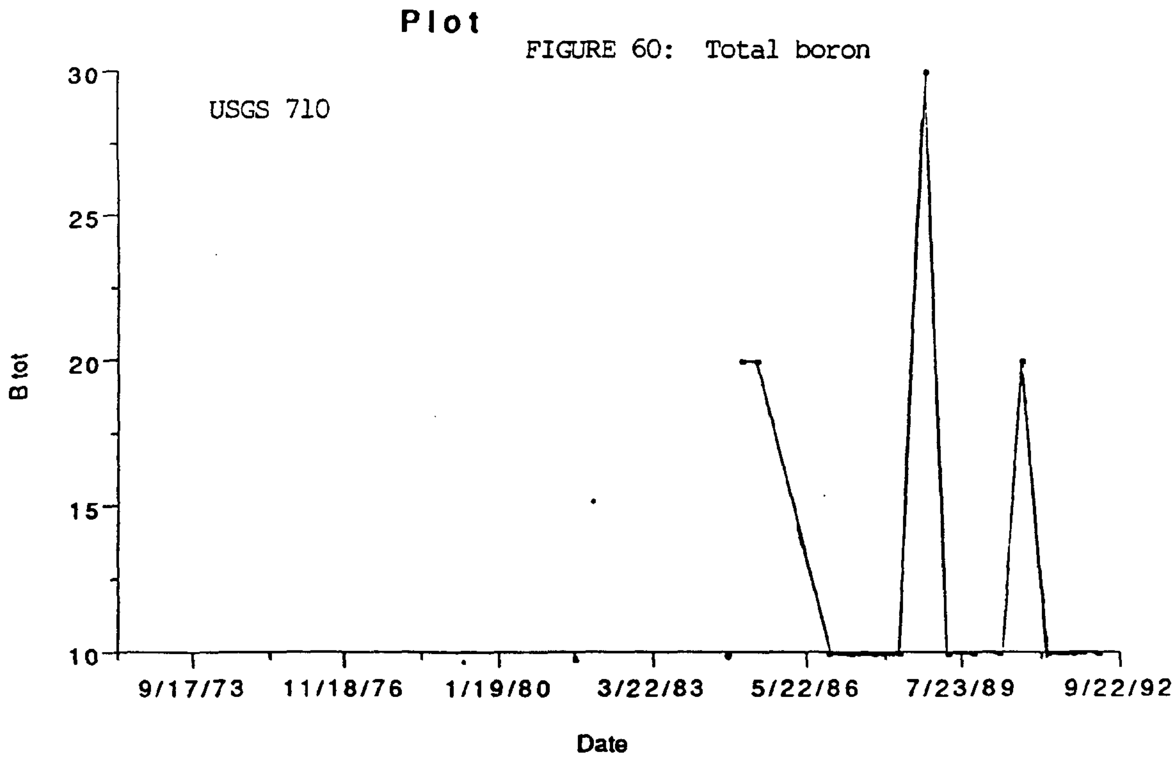
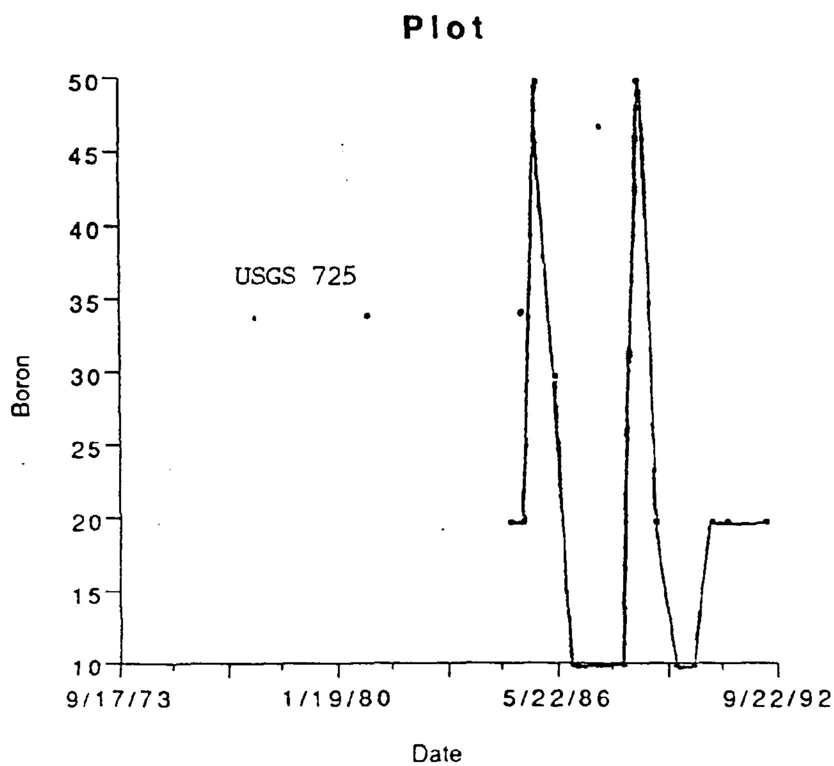


FIGURE 60: Total boron





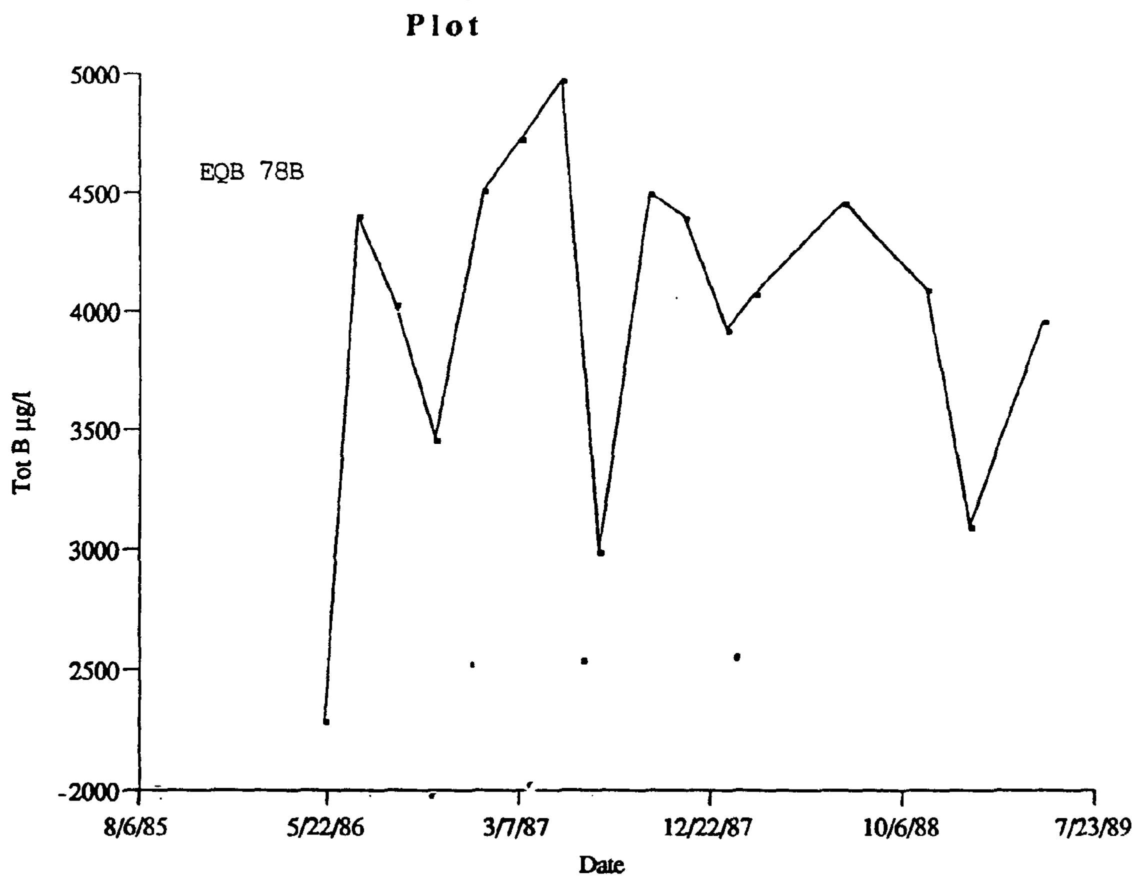
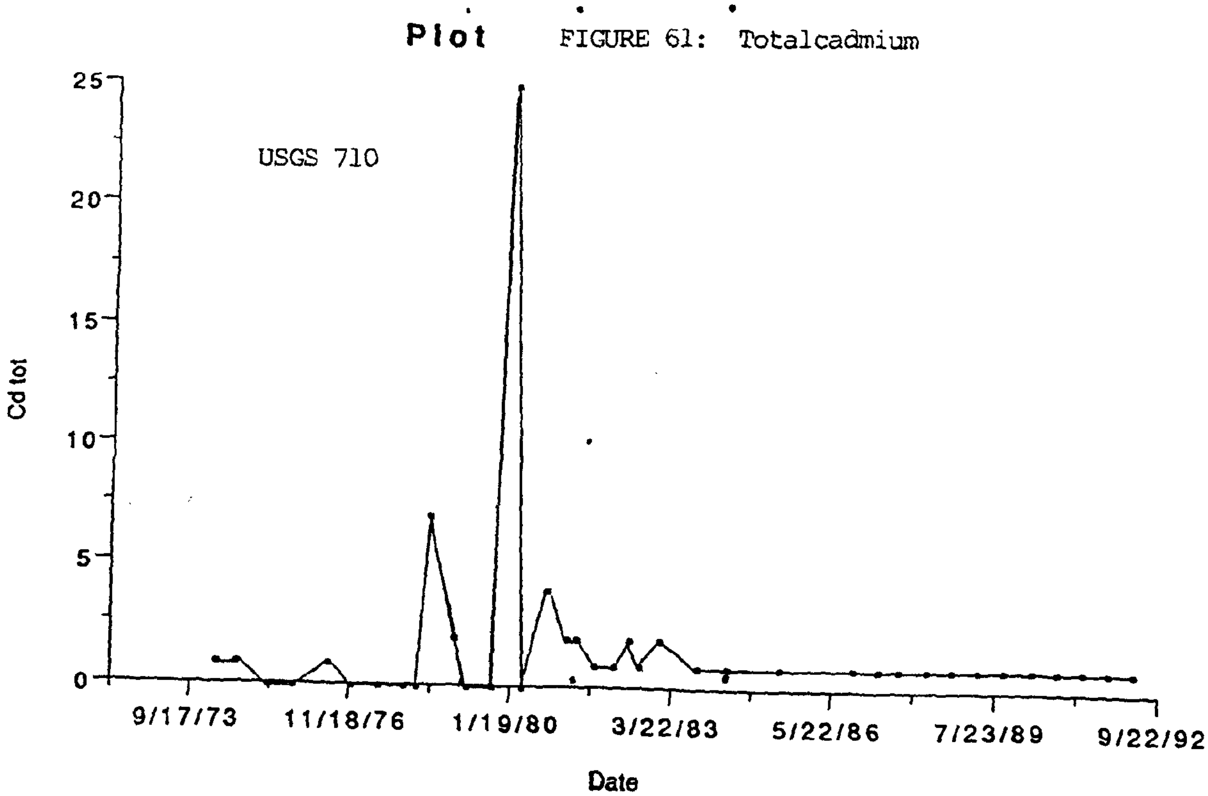
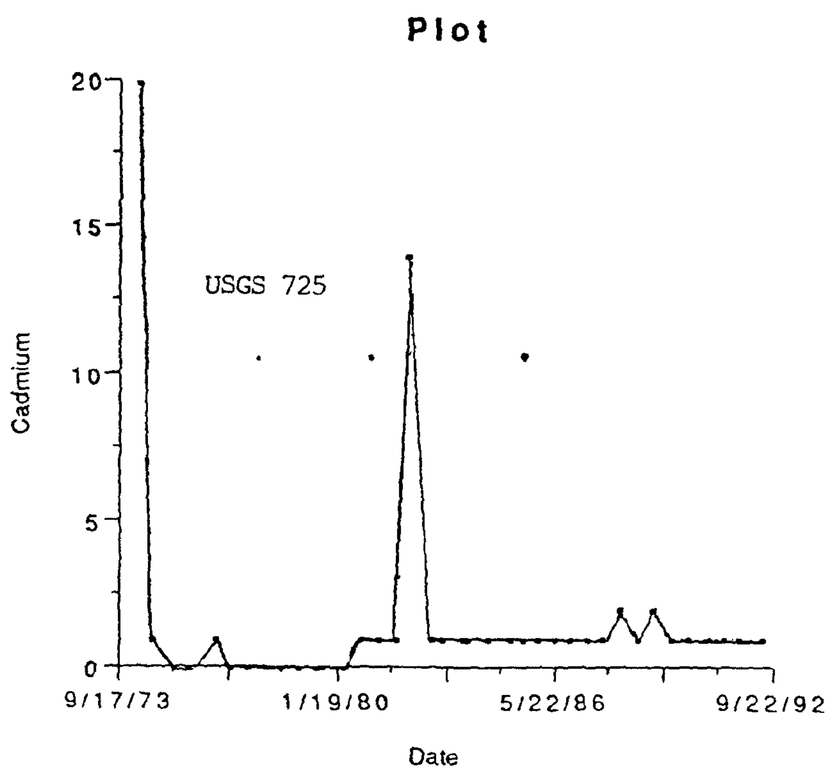

Plot
EQB 78B
Tot B µg/l
5000
4500
4000
3500
3000
2500
-2000
8/6/85
5/22/86
3/7/87
12/22/87
10/6/88
7/23/89
Date

FIGURE 61: Totalcadmium





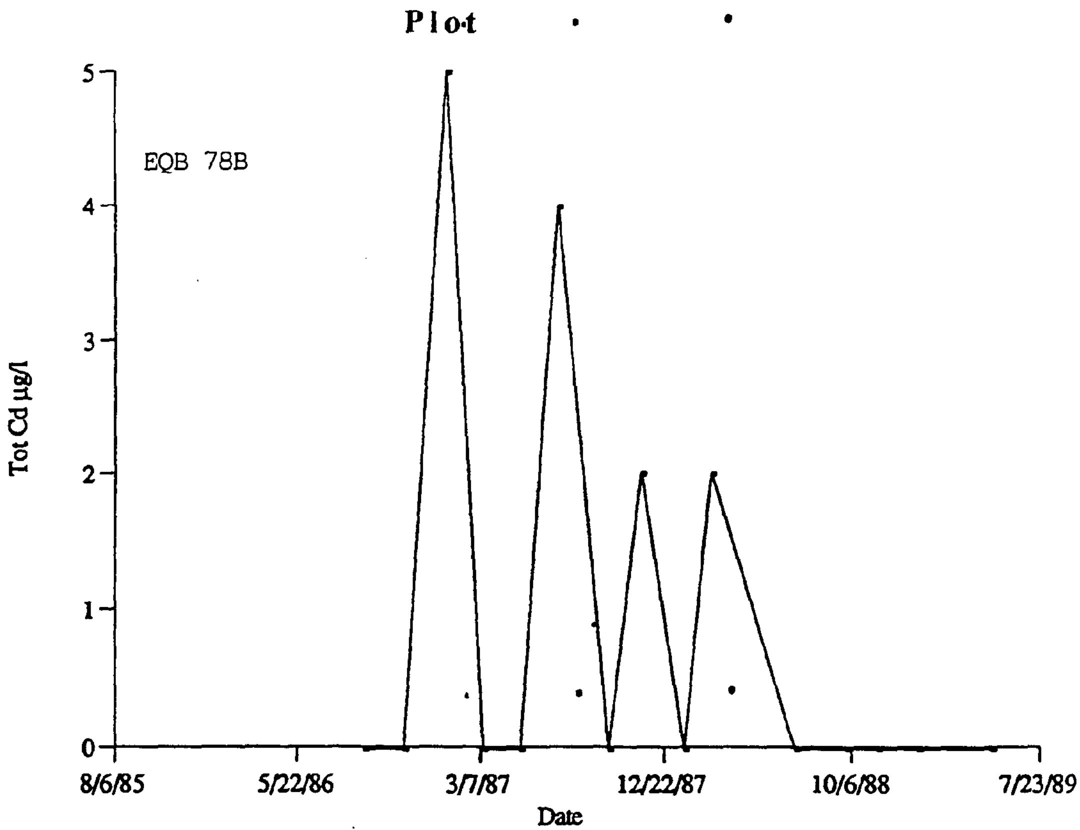
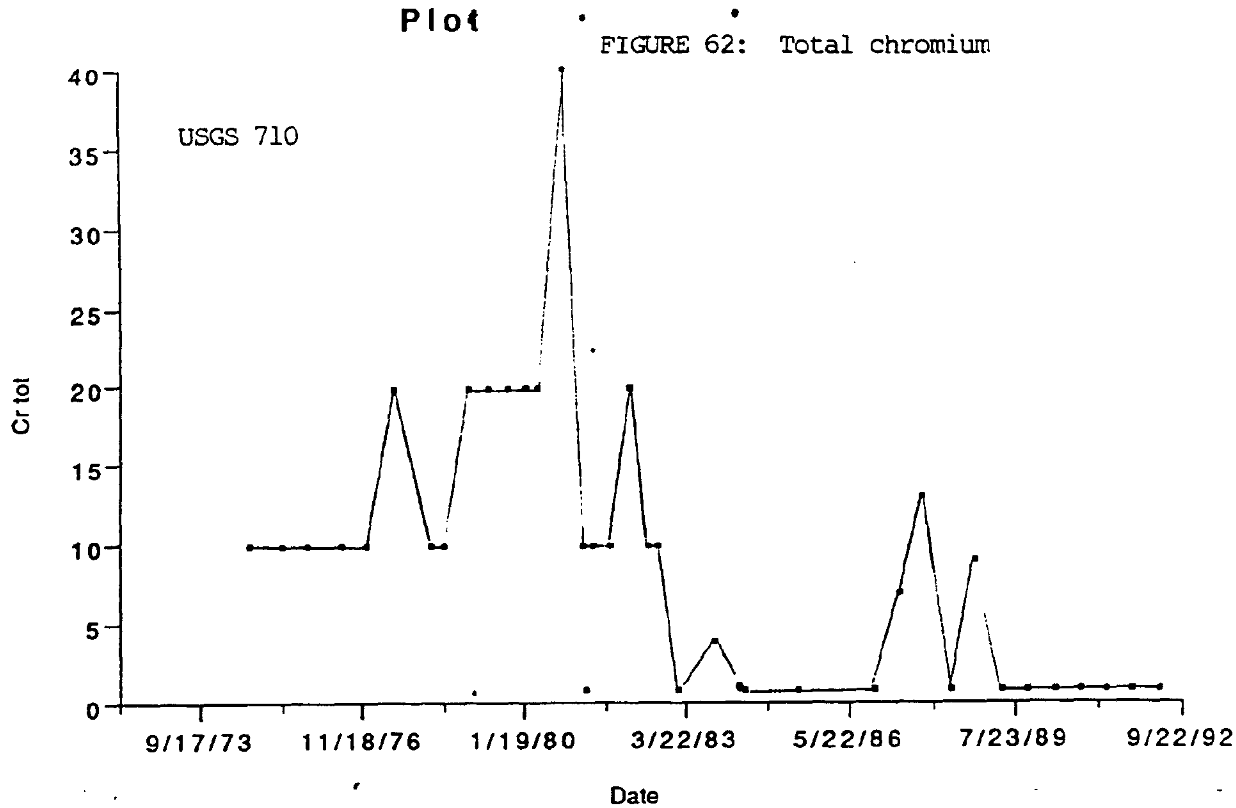
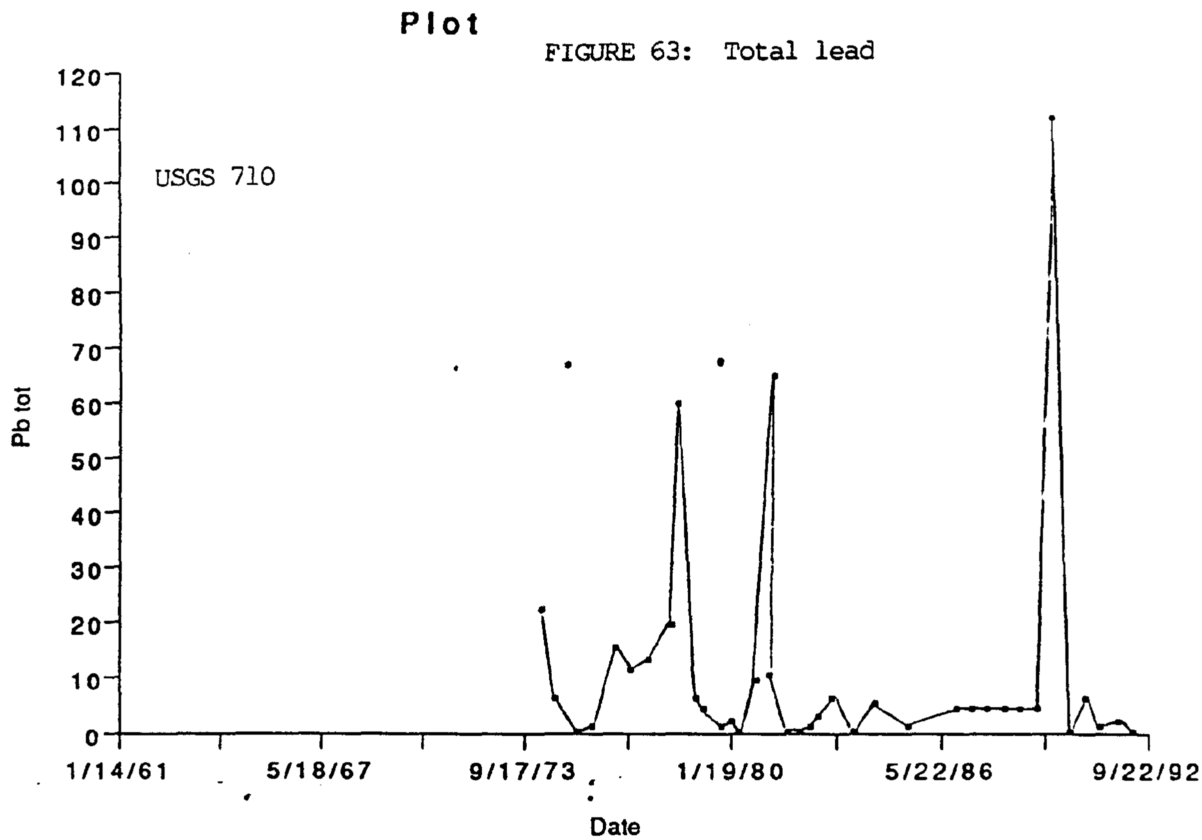
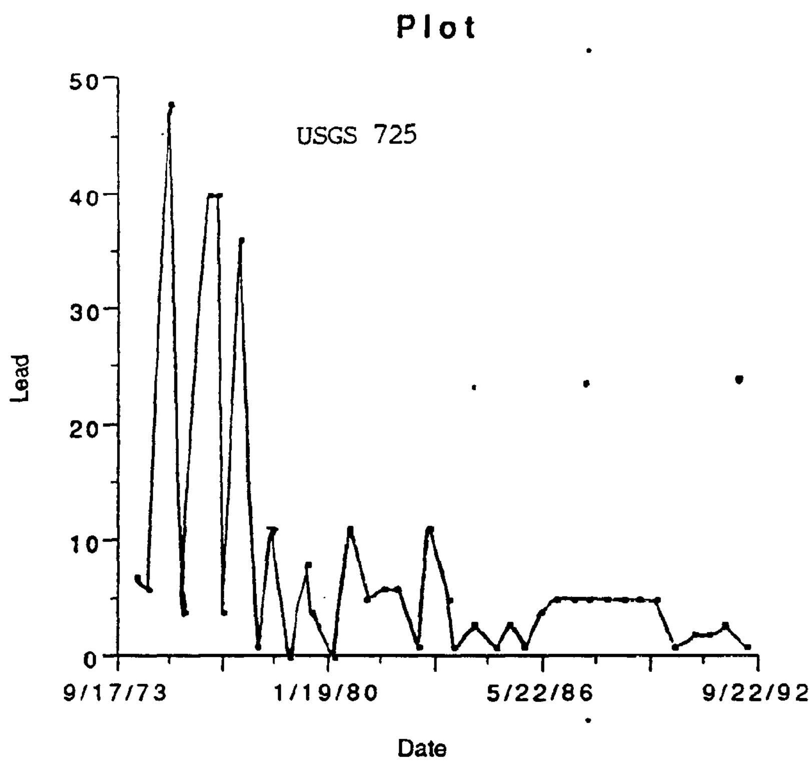
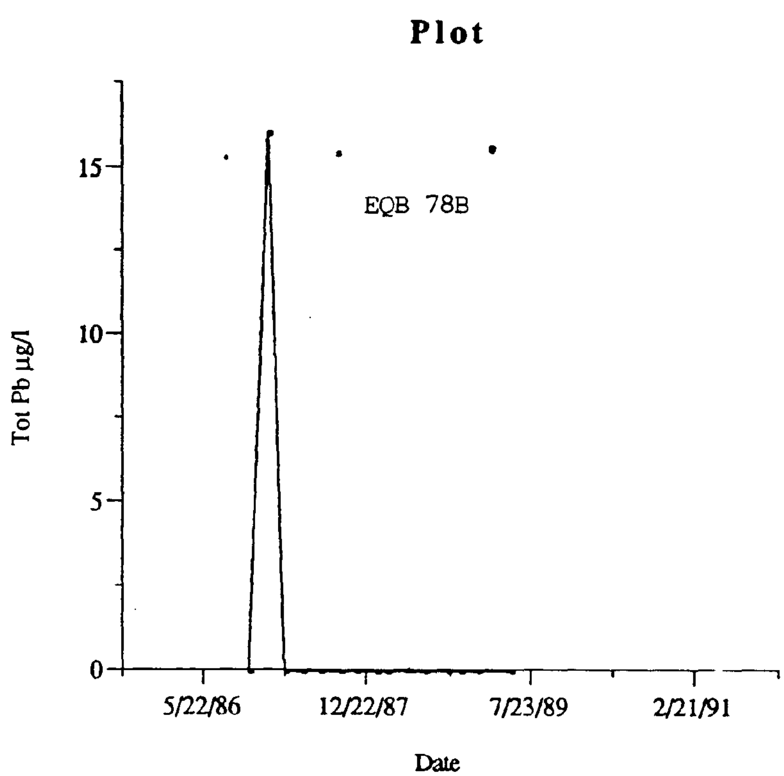

Plot
EQB 78B
Tot Cd µg/l
0
1
2
3
4
5
8/6/85
5/22/86
3/7/87
12/22/87
10/6/88
7/23/89
Date

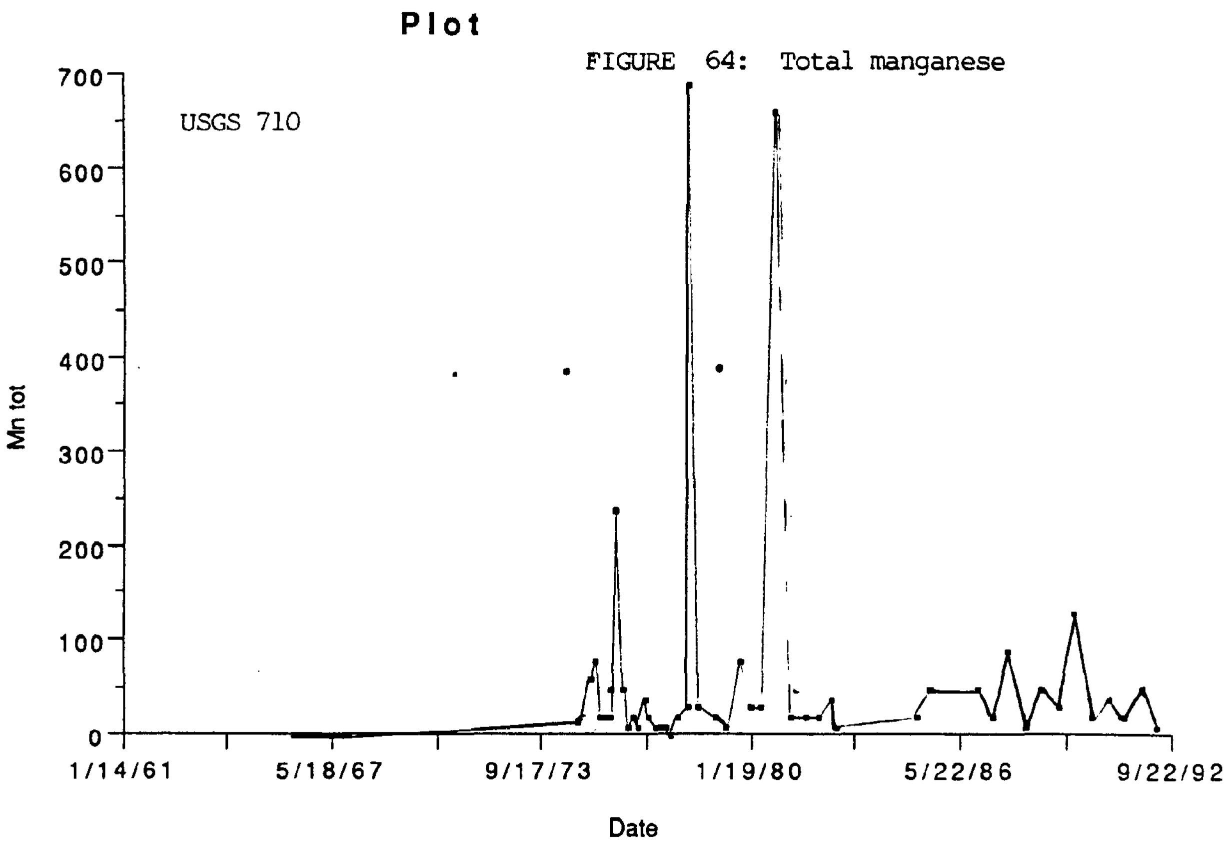
FIGURE 62: Total chromium



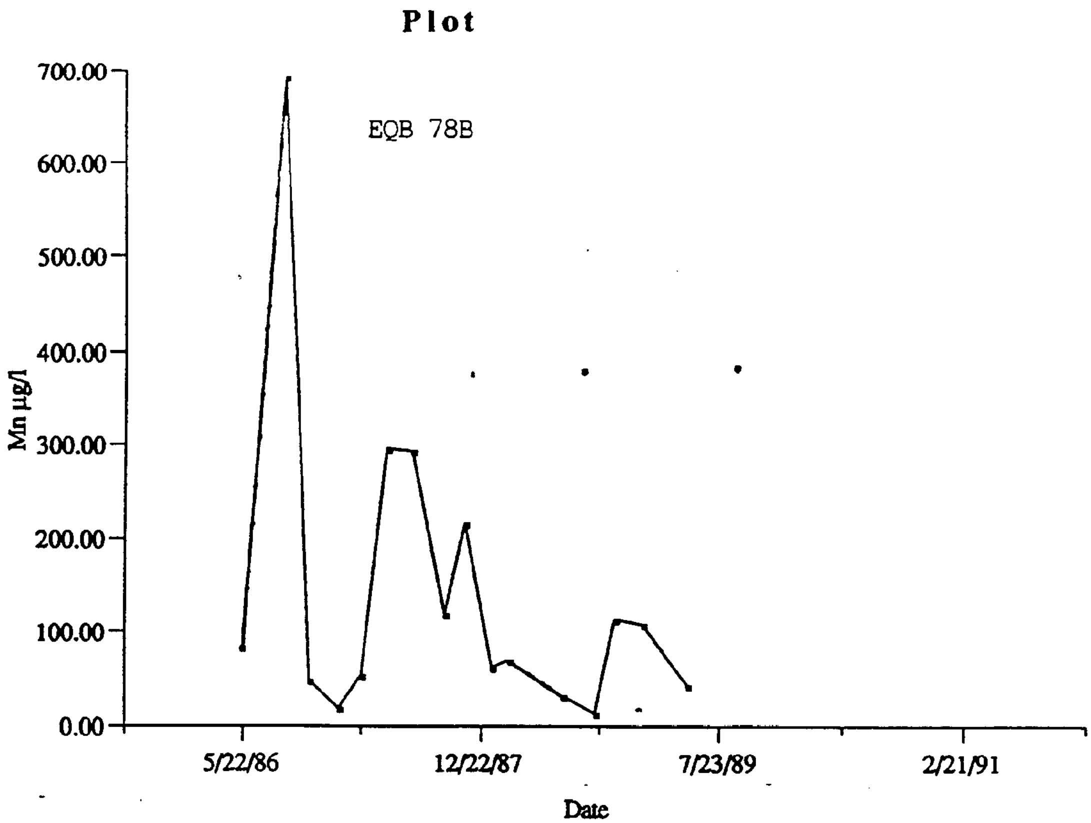

Plot
FIGURE 63: Total lead
USGS 710
Pb tot
120
110
100
90
80
70
60
50
40
30
20
10
0
1/14/61
5/18/67
9/17/73
1/19/80
5/22/86
9/22/92
Date


Plot
USGS 725
Lead
50
40
30
20
10
0
9/17/73
1/19/80
5/22/86
9/22/92
Date


Plot
EQB 78B
Tot Pb µg/l
15
10
5
0
5/22/86
12/22/87
7/23/89
2/21/91
Date


Plot
FIGURE 64: Total manganese
USGS 710
Mn tot
700
600
500
400
300
200
100
0
1/14/61
5/18/67
9/17/73
1/19/80
5/22/86
9/22/92
Date

Mn tot


Plot
EQB 78B
700.00
600.00
500.00
400.00
300.00
200.00
100.00
0.00
Mn µg/l
5/22/86
12/22/87
7/23/89
2/21/91
Date

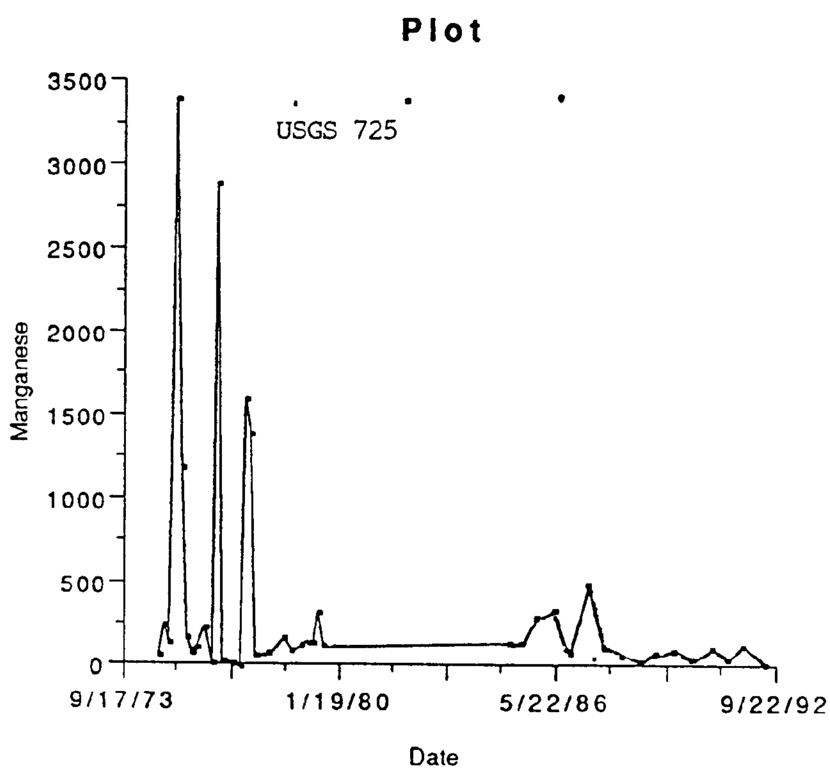

Plot
USGS 725
3500
3000
2500
2000
1500
1000
500
0
Manganese
9/17/73
1/19/80
5/22/86
9/22/92
Date

FIGURE 65: Total cianide

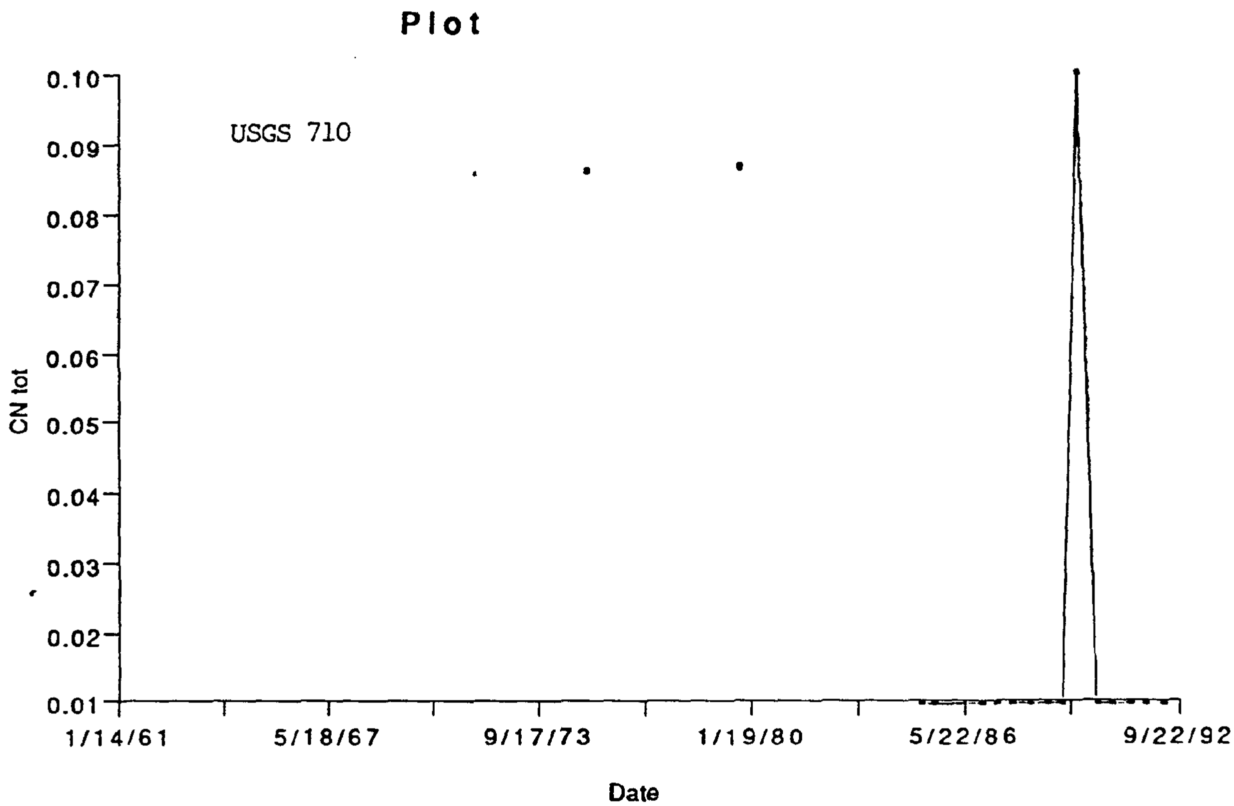


FIGURE 66: Total cobalt

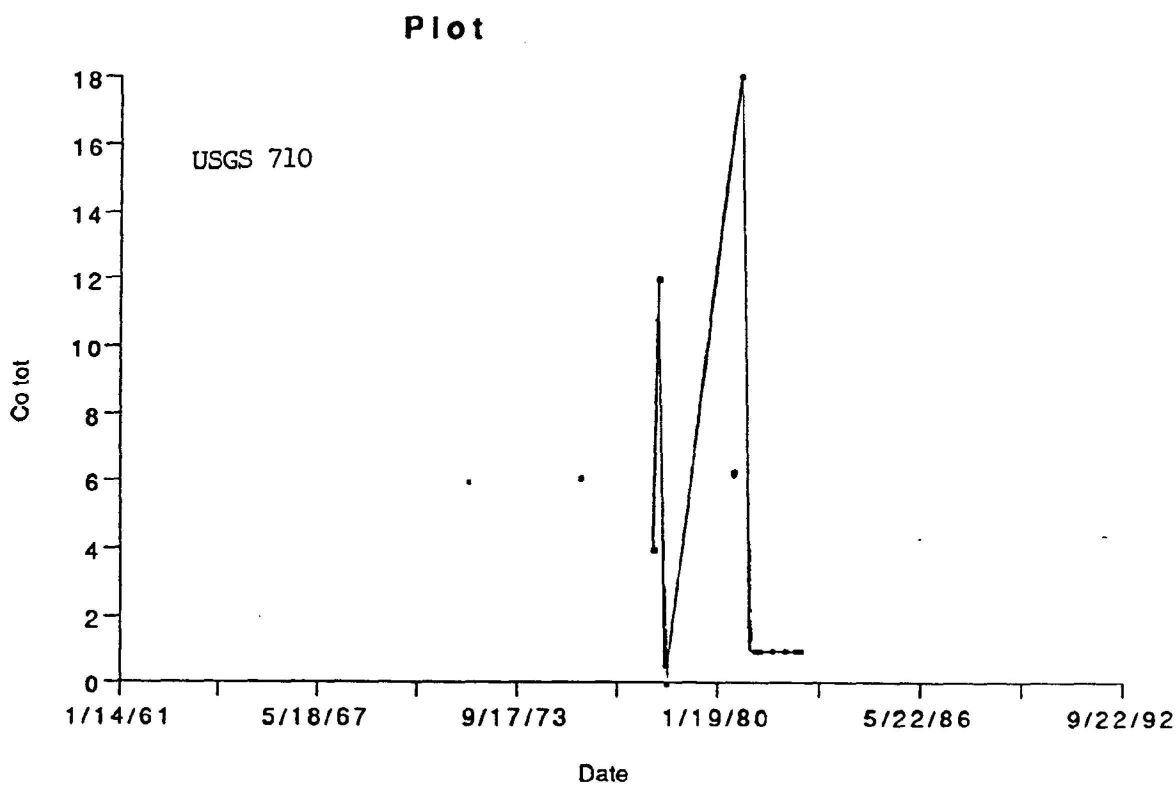
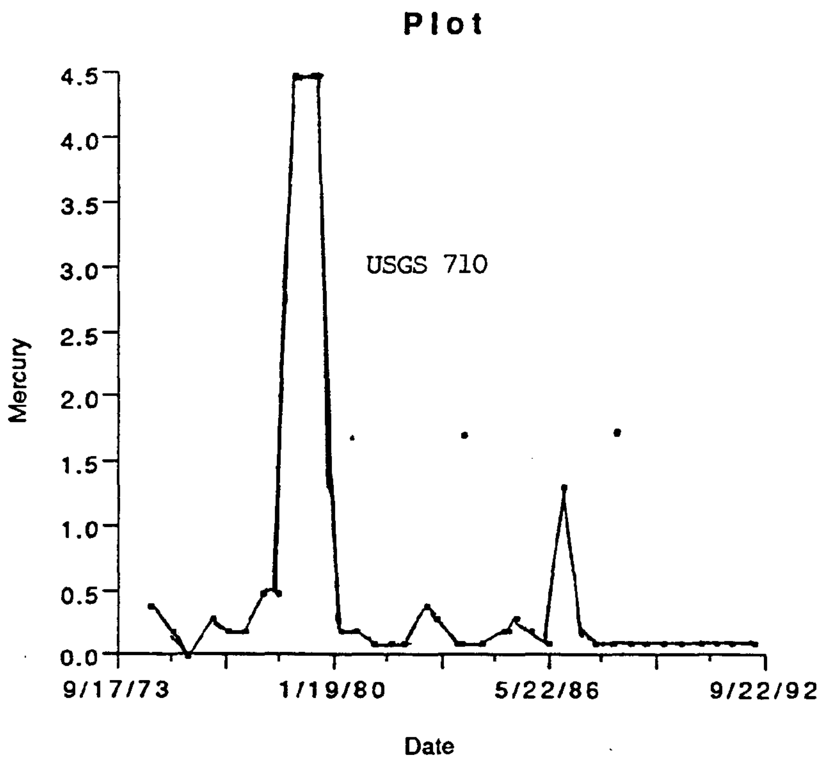
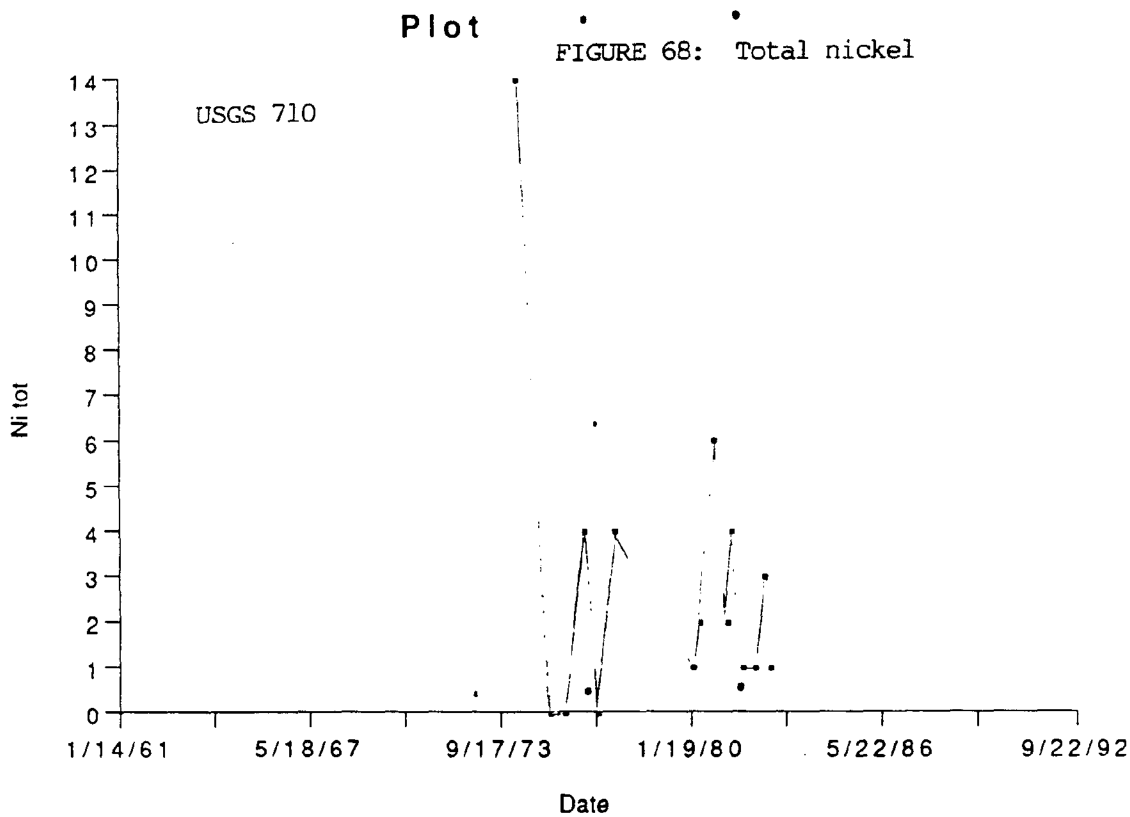


FIGURE 67: Total mercury

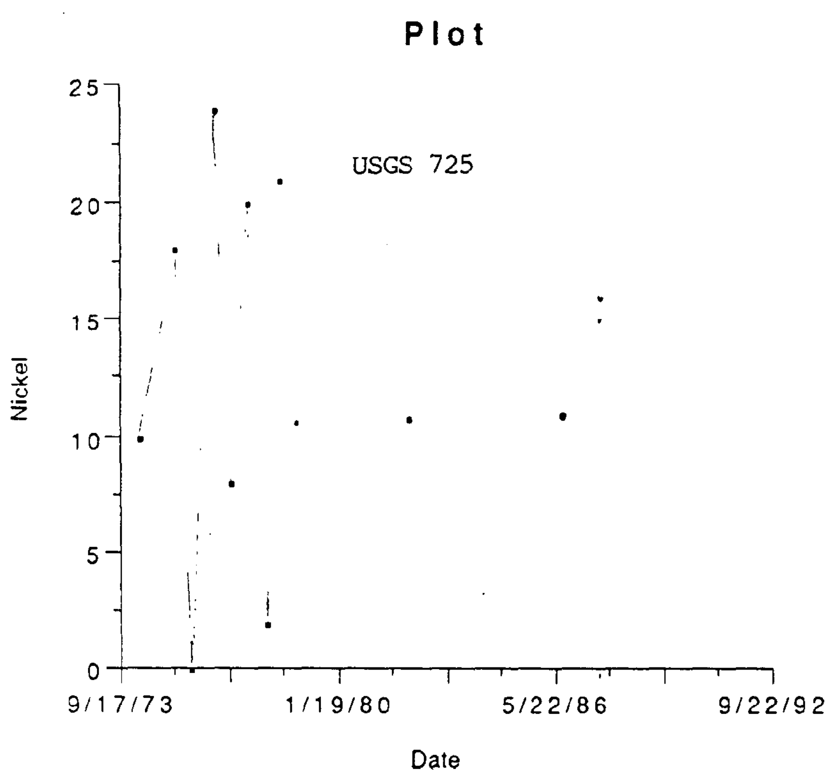


Mercury

FIGURE 68: Total nickel



Ni tot



Nickel

FIGURE 69: Selenium

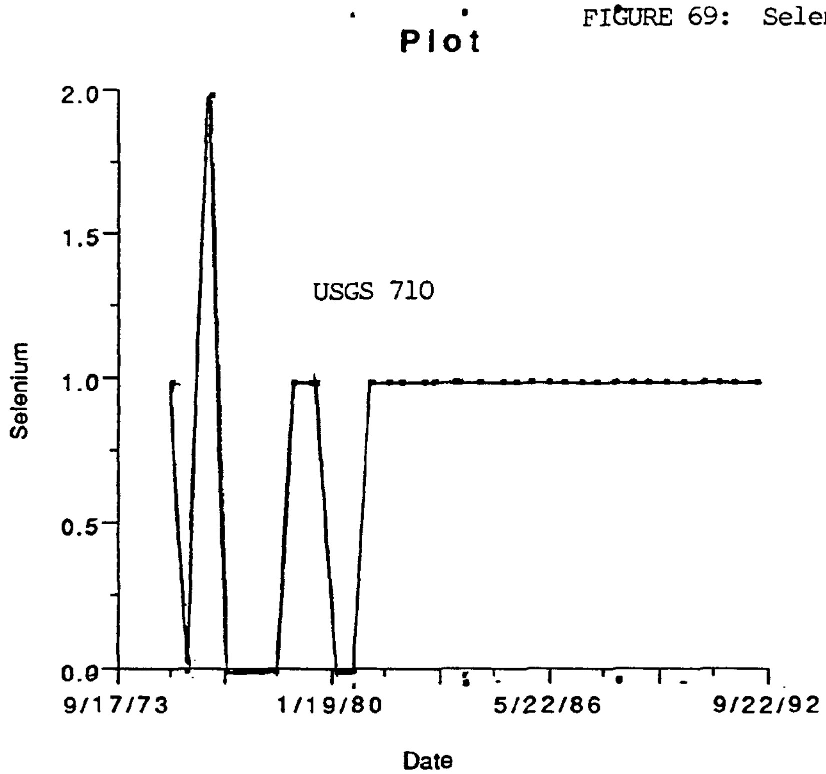
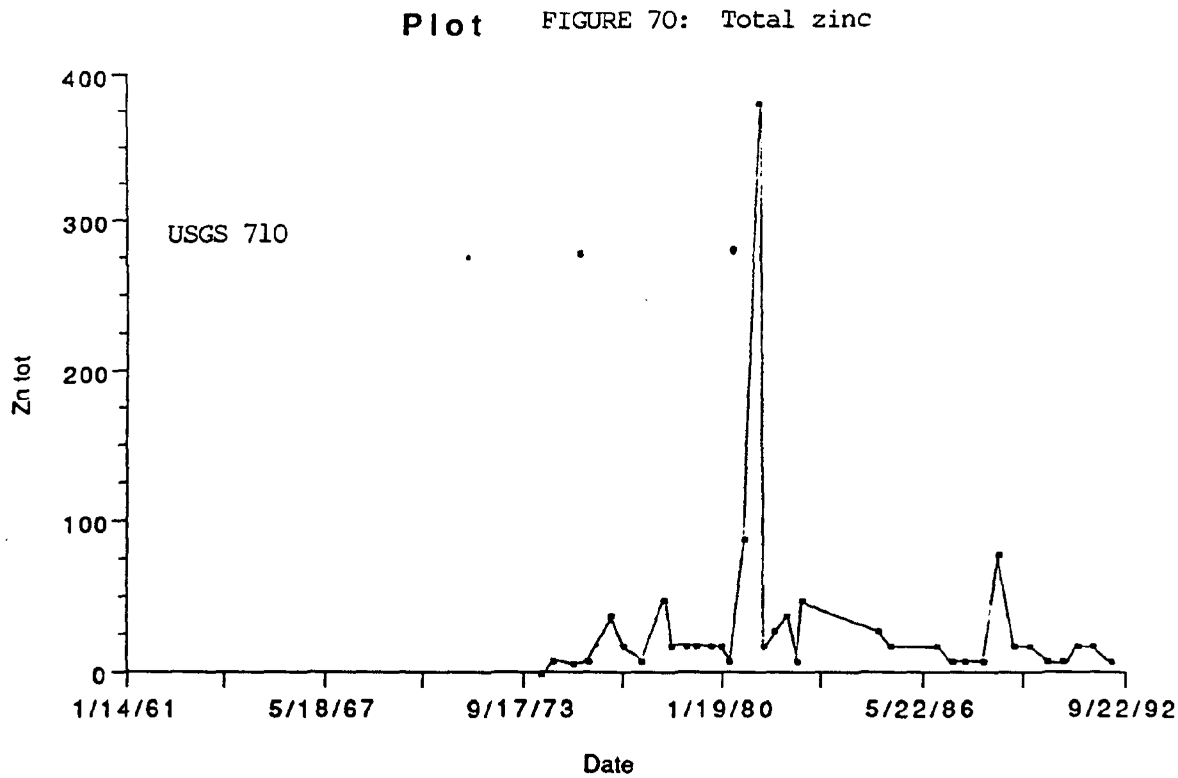
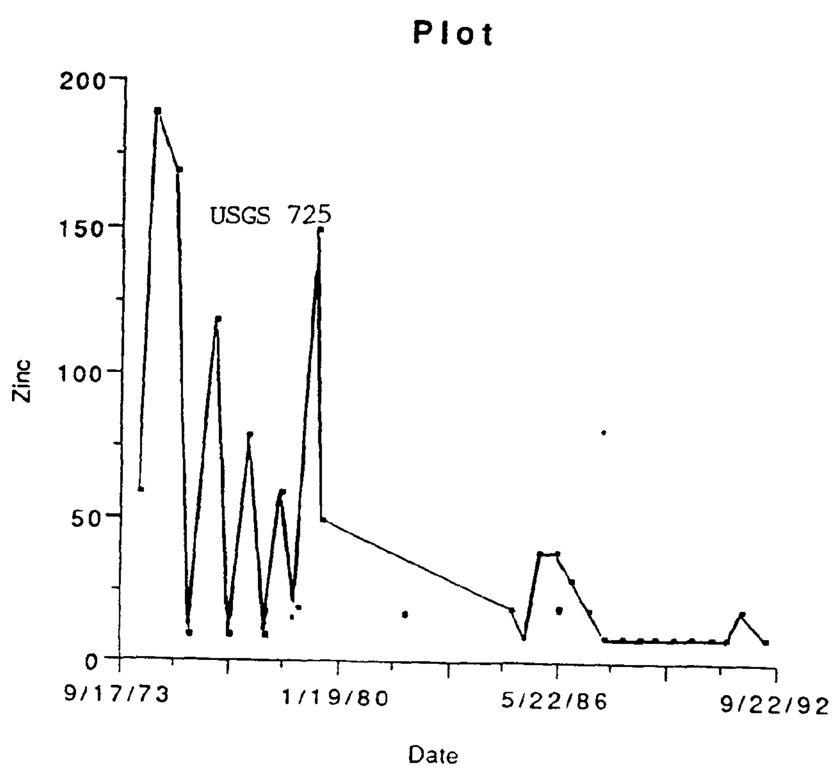


FIGURE 70: Total zinc





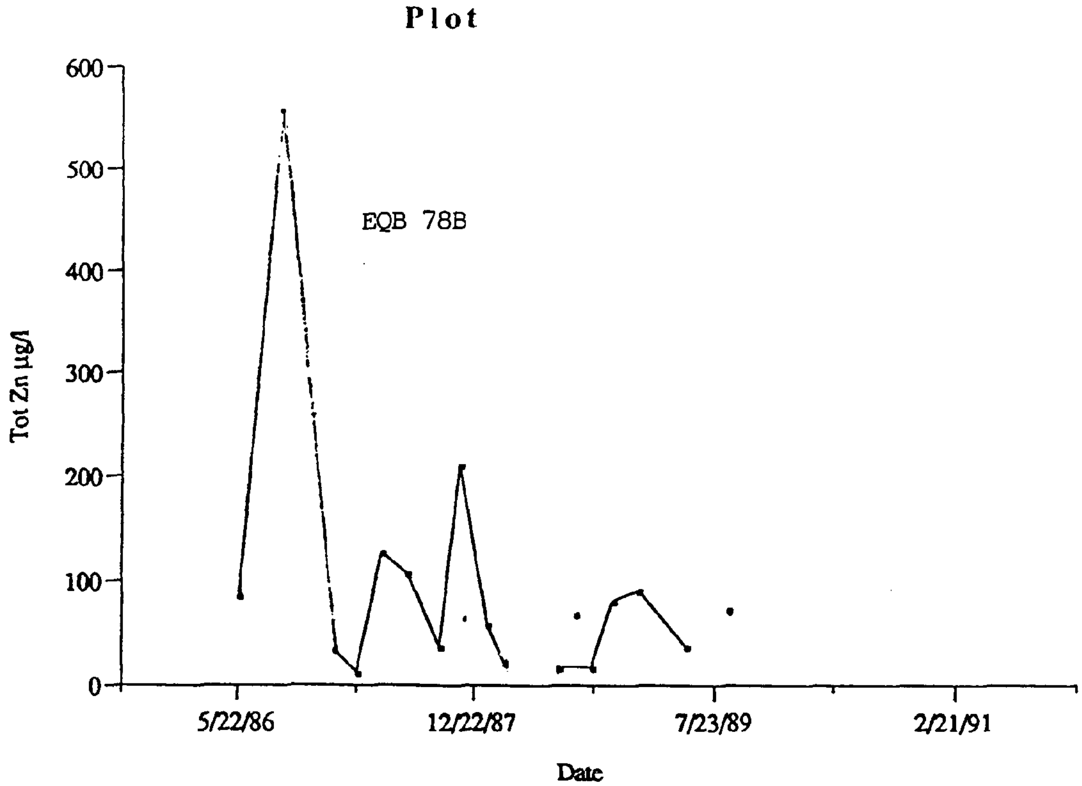
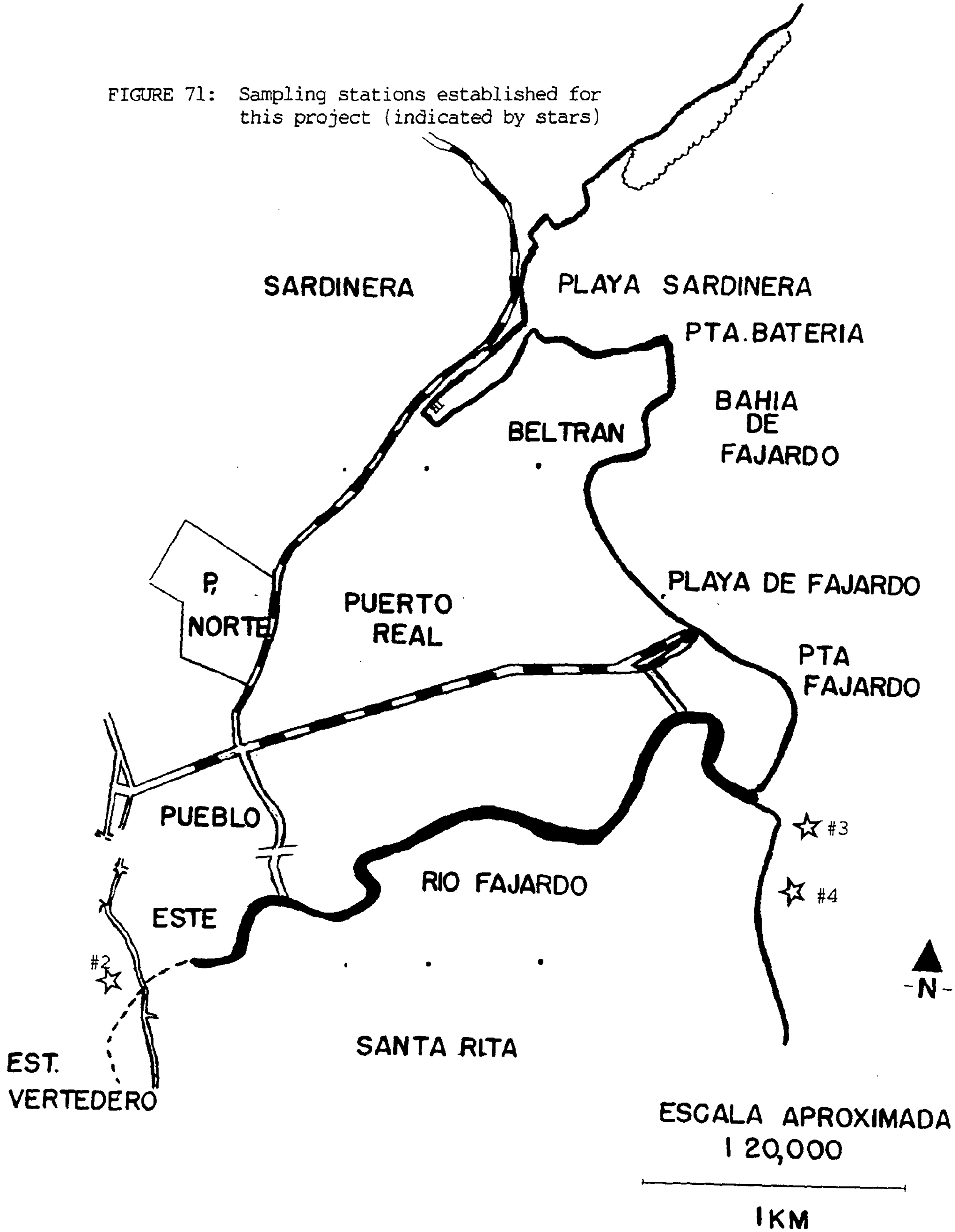
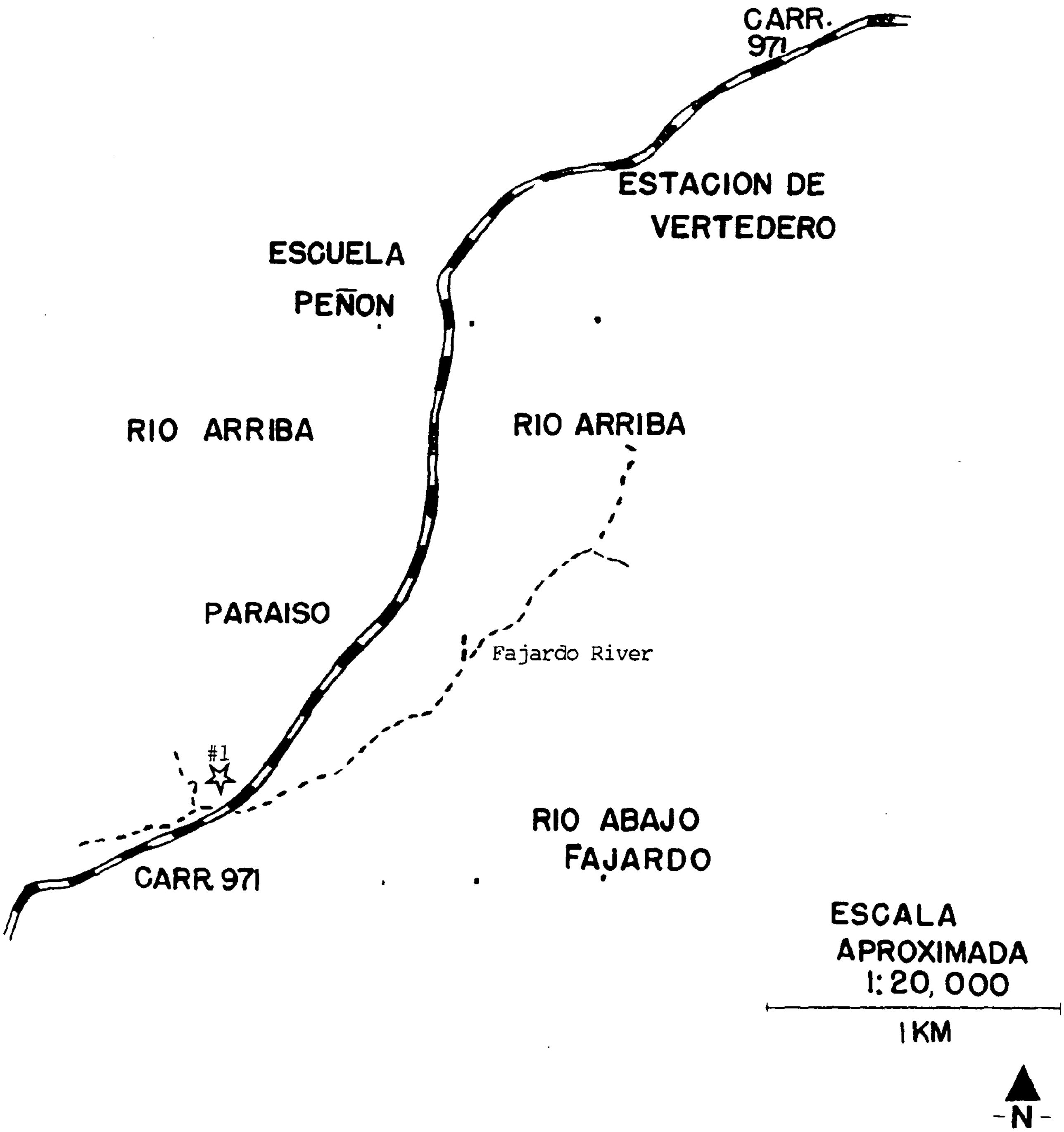

Plot
600
500
400
300
200
100
0
Tot Zn µg/l
EQB 78B
5/22/86
12/22/87
7/23/89
2/21/91
Date

FIGURE 71: Sampling stations established for this project (indicated by stars)



MAPA ESTACIONES DE MUESTREO DRN

FIGURE 72: Upstream station established for this project (as indicated by a star).



MAPA ESTACIONES DE MUESTREO DRN

TABLE 10: Water quality field stations established by this project at the Fajardo River system.

Station #	Location	Type of site
1.	HWY 971, 3km upriver from USGS 710.	freshwater, river
2.	Bridge at HWY 194, 0.5 km downriver from USGS 725.	estuarine, river
3.	Coast, 200m off rivermouth.	coastal estuarine
4.	Coast, 200 m south of Station #3.	coastal estuarine

TABLE 11: Water quality data from this project's field samples*.

Station 1:

Parameter	Dec. 17, 1992	Mar. 24, 1993	Jul. 14, 1993
NH_3 mg/l	NA	0.06	0.03
NO_2 mg/l	0.001	0.001	0.002
NO_3 mg/l	0.43	0.19	0.262
P total mg/l	0.02	0.02	0.02
PO_4 mg/l	0.01	0.01	0.01
Susp. Solids mg/l	1.6	7.1	9.3
Hardness mg/l	20	29	30
Fecal coliforms (colonies/100 ml)	NA	210	
Fecal streptococci (colonies/100 ml)	NA	220	
Lead µg/l	5		
Copper µg/l	1		
Zinc µg/l	12.5		
Cadmium µg/l	0.5		
Manganese µg/l	1		
Iron µg/l	1		
Cobalt µg/l	1		
Nickel µg/l	1.5		
Chromium µg/l	1		

Station 2:

Parameter	Dec. 17, 1992	Mar. 24, 1993	Jul. 14, 1993
NH_3 mg/l	NA	0.03	0.03
NO_2 mg/l	0.001	0.001	0.006
NO_3 mg/l	0.188	0.592	0.241
P total mg/l	0.01	0.02	0.01
PO_4 mg/l	0.01	0.01	0.01
Susp. Solids mg/l	2.3	0	
Hardness mg/l	45	42	38
Fecal coliforms (colonies/100 ml)	NA	200	
Fecal streptococci (colonies/100 ml)	NA	110	
Lead µg/l	5		
Copper µg/l	1		
Zinc µg/l	12.5		
Cadmium µg/l	0.5		
Manganese µg/l	35		
Iron µg/l	1		
Cobalt µg/l	1		
Nickel µg/l	1.5		
Chromium µg/l	1		

Station 3:

Parameter	Dec. 10, 1992	Mar. 23, 1993	Jul. 2, 1993
NH_3 mg/l	NA	0.06	
NO_2 mg/l	0.001	0.001	0.006
NO_3 mg/l	NA	0.02	0.226
P total mg/l	0.03	0.03	0.029
PO_4 mg/l	0.01	0.01	0.01
Susp. Solids mg/l	58	85.8	
Hardness mg/l		6098	5920
Calcium mg/l		375	
Magnesium mg/l		1300	
Fecal coliforms (colonies/100 ml)	NA	20	
Fecal streptococci (colonies/100 ml)	NA	1300	
Lead µg/l	5		
Copper µg/	1		
Zinc µg/l	22.5		
Cadmium µg/l	0.5		
Manganese µg/l	90		
Iron µg/l	1015		
Cobalt µg/l	1		
Nickel µg/l	3		
Chromium µg/l	1		

Station 4:

Parameter	Dec. 10, 1992	Mar. 23, 1993	Jul. 2, 1993
NH_3 mg/l	NA	0.18	
NO_2 mg/l	0.001	0.001	0.001
NO_3 mg/l	NA	0.30	0.033
P total mg/l		0.02	0.29
PO_4 mg/l	0.06	0.01	0.01
Susp. Solids mg/l	43.8	96.8	
Hardness mg/l		7207	6370
Calcium mg/l		399	
Magnesium mg/l		1300	
Fecal coliforms (colonies/100 ml)	NA	10	
Fecal streptococci (colonies/100 ml)	NA	2	
Lead µg/l	5		
Copper µg/l	1		
Zinc µg/l	62.5		
Cadmium µg/l	1		
Manganese µg/l	85		
Iron µg/l	525		
Cobalt µg/l	1		
Nickel µg/l	2.2		
Chromium µg/l	1		

* Ammonia, nitrate, and fecal bacterial tests could not be done for the first sample. Laboratory analyses are yet to be completed for some samples. They will be added to this Table as soon as we have them.

Summarized review of historical water quality data

When historical water quality data from the Fajardo River is reviewed together, a pattern can be discerned: there is some gradual increase in the level of pollutants in the river during the late sixties; then, during 1973-1975 there is an outburst of growth in most parameters. This explosion ends around 1975-1976, and then parameters' levels has very gradually been decreasing since. Maybe pollution levels were reduced as a result of a growth in forested lands and, consequently, in the water retention capability of the soil; most probably, however, graphs reflect the effect on the basin of the implementation of point-source pollution controls beginning in the mid-seventies. However, occasional peaks continue to appear in almost all graphs, and some parameters involving oxygen requirements (% of dissolved oxygen and COD) do show a slight worsening.

V. FIELD INTERVIEWS

To check in the field what impact, if any, government actions have had over local activities suspected of producing non-point source pollution (NPSP), a series of interviews were done along the basin. Questionnaires were produced based on EPA's *Guidance Specifying Management Measures For Sources Of Nonpoint Pollution In Coastal Waters* (1993) (see Appendix 1).

Agricultural activities

Four cattle farms and a pig farm were visited. Cattle farms ranged from 20 to 300 acres each. All their owners were aware in one way or another of nonpoint source pollution caused by soil erosion, wastewater, runoff, pesticides and fertilizers. Only the largest one had a holding pond for wastewater (cleaned once every five to six years), runoff ditches, vegetated filter strips, and critical area planting. All had their lands tested for pH, but again, only the larger farm had tested for nutrient and runoff potential and planned fertilizer application using such information. None had water troughs. Their animals were taken to the river or some tributary creek to drink. All had identified surface water bodies within their farms but none took this into account when planning any of the farms' activities. Pesticides and fertilizers and corresponding equipment were supplied to them by the Department of Agriculture (PRDA) along with instructions on their use. Equipment maintenance was the minimum necessary to maintain them operational. Two of the farms also planted plantains on a commercial scale. Pesticides and fertilizers were used on those crops according to PRDA instructions.

The pig farm had some 20 acres and about 200 pigs in a confined facility built according to Environmental Quality Board (EQB) and PRDA guidance. Animal wastes were washed daily into a functional oxidation pond. The farm included a plantain plantation to which pesticides and fertilizer were applied according to PRDA instructions. The owner was aware of low pH and erodibility potential of her land.

We tried, unsuccessfully to interview other farmers, including the owner of a crop farm planting cassava, limes, and papaya. We noticed that plantain was a favorite crop because of generous subsidies and services offered by PRDA. There was some oranges and grapefruits planted. We also noticed that stripping the land of vegetation and topsoil with machines is a common practices before planting crops or to let grasses grow for cattle. That was being done even in very steep terrains. Sugar cane still dominates agriculture in the lowlands. No commercial silviculture activity is currently under way within the Fajardo River Basin.

Marinas

Though the coasts of the municipalities of Fajardo and Ceiba are home to seven marinas, only one of them (*Villa Marina*), is within the Fajardo River Basin *per se*. The marina includes a fueling station and has a capacity for harboring as many as 870 boats (including 70 on land). Facilities were designed and built without taking into account water quality or any kind of waste or spill management. In fact, there is no water quality assessment program run by *Villa Marina* management (although government monitoring station EQB 78B was functioning here from 1986 to 1990). The marina has a revegetation program, but it is a beautification program, not a sediment-control one. Allegedly, the marina have implemented effective runoff control strategies, boat cleaning programs, and installed dumpstation, and restroom facilities to reduce release of sewage to surface waters. There are no sewage pumpout facilities. Solid wastes from boats are collected on docking and disposed by the municipal government. Absorbing pads are used to collect oils, greases, and fuel from surface waters. There are no restrictions, management or orientation regarding fish waste. There is no educational strategy regarding pollution and wastes in the marina, although occasional recordatories are offered via the marina's own monthly periodical and office memos. Management established a speed limit within the marina to reduce probabilities of boating accidents and turbidity in the water.

Hydromodifications

The Fajardo River is one of the very few rivers in Puerto Rico that, so far, has not been channelized or dammed. However, there is a current proposal in the hands of the U. S. Army Corps of Engineers for a flood control program in the river which includes the construction of a dike to divert water from the river directly into the mangrove forest that lies at the southern shore of the river mouth. It is hoped that the mangrove will be able to absorb this increased influx of freshwater and will act as a filtering system for pollutants as well. The project is in the stage of gathering permits and endorsements and its still collecting preliminary information for a future preparation of an Environmental Impact Statement. The river has also been mentioned by the Aqueducts and Sewers Authority as a probable site for a new dam and reservoir.

Wetlands

The Department of Natural Resources (DNR), administrator of Ceiba State Forest, and the Federal Forest Service (USFS), in charge of the Caribbean National Forest, administer almost all wetlands in the basin classified as ecologically sensitive or important. USFS has adopted a program for the protection of its lands, which include asking of all projects within the Forest to submit Best Management Practices Plans. Ceiba Forest is still lacking a similar DNR program.

Protection of mangroves, and other wetlands, is pursued in Puerto Rico mostly through EQB's Regulation of Environmental Impact Statements, the Environmental Public Policy Act, Planning Board's Resolution Num. 74-21, and Section 401 of the Federal Clean Water Act. In addition, through the Coastal Zone Management Program, certain construction and waste disposal activities are restricted in wetlands of special concern within the Maritime-Terrestrial Zone.

Wate disposal systems

The municipal landfills of both Fajardo and Ceiba are located within the Fajardo River Basin. Until very recently, there were no government controls on the production of non-point source pollutants from these sites. As a result, neither of them had any mechanisms or plans to deal with this problem. Farmers living near the landfills reported that it was usual to see a dense, blackish muck going down nearby creeks instead of water.

However, since the beginning of 1993, the Commonwealth and the Municipal governments were instructed by the Federal Environmental Protection Agency that they had to comply with the new regulations under the Clean Water Act. There are plans to close one of the landfills and turn the other into a regional system, and recyclable materials are being identified to try to reduce the load coming in.

Construction and soil extraction activities

Control of pollutants originating from construction and soil extraction activities is pursued mostly by requiring Control of Erosion and Sedimentation (CES) Plans at EQB and Soil Extraction Permits at DNR. CES Plans submitted to EQB during 1992 were reviewed for this project. Most of the measures they contain involves maintaining soil wet and compacted to inhibit clouds of particulates, establishing hay barriers and sedimentation ponds to capture runoff, dispositions on equipment washing and solid waste disposal, and mandating revegetation or pavimentation of open spaces remaining after completion of project.

VI. CONCLUSION AND RECOMMENDATIONS

All the information collected for this report presents a river system and its basin which has been significantly impacted by non-point source pollution (NPSP), at least since the early sixties. There are, for sure, natural causes responsible for some pollutants, some of the time: sudden, heavy rains common in the area, erodibility and acidity of the soils, valleys with steep gradients, small natural deposits of metal-containing minerals, etc. However, it is obvious that human activities are responsible for most NPS pollutants. Data confirm that the Environmental Quality Board correctly assessed the possible causes of NPSP at the river: agricultural activities, runoff, landfills, construction activities, waste disposal, and soil extraction operations. The existing marina is an NPSP source on the coastal region of the basin. Although the situation appears to have significantly improved since an upsurge in the early seventies, this improvement seems to reflect the imposition of point-source pollution control, more than anything else. There are some government controls on NPSP, but it is obvious that they are insufficient at the present moment. Since development pressure is growing along the basin, we can expect a future increase of pollutant production in the area, and if this is not addressed now, maybe water quality data in the late nineties will show a repetition of the crisis of the seventies.

The following are our short and mid-term recommendations in respect to NPSP in the Fajardo River Basin:

1. DNR should adopt a Management Plan or Program for the Ceiba State Forest with strict guidelines and requirements for all types of development proposals.

2. There such be a concerted effort between the Federal, Commonwealth and Municipal governments to avoid further destruction of wetlands and explore the possibility of creating new ones.
3. There such be a concerted effort between the Federal, Commonwealth and Municipal governments to maintain current levels of forested lands as one way to sustain soils' water retention capability.
4. The Environmental Quality Board should reopen monitoring station EQB 78B and establish at least one additional station on the river *per se.*
5. Pesticides should be monitored at least four times a year, instead of just once.
6. EQB's Best Management Practices Plans should be required to all commercial (animal or crops) farms. This plans should require an increase used of anti-erosion practices.
7. All direct wastewater discharges to the river should be closed.
8. Cattle should not be given direct access to surface waters. Drinking troughs should be mandatory for all animal farms.
9. All construction permits should include dispositions for revegetation and mitigation of natural areas.
10. All soil extraction permits should include dispositions to revegetate abandoned extraction areas.
11. There should be concerted efforts by the Federal, Commonwealth and Municipal governments to increase public education on NPSP and public participation in NSPS programs, as well as development projects' permits evaluation process.
12. Government's assessment of waste disposal in marinas should be done in a systematic, frequent way. Fish waste disposal should be better managed as well as current dispositions on boat fuels, oils, greases, paints and human wastes.
13. Being one of the few rivers left in Puerto Rico without hydromodifications, any such project should be considered with extreme care in respect to its impact on the river's (and estuary) hydrology, chemistry and biota, and effects on local community, particularly in terms of hidden costs of pollution, erosion, loss of farm and forest lands, etc.

VII. REFERENCES

Ahmad, R., F. N. Scatena & A. Gupta. 1993. Morphology and sedimentation in Caribbean montane streams: Examples from Jamaica and Puerto Rico. Sediment. Geol. 85:157-169.

Anonymous. 1973a. Water Resources Data For Puerto Rico, 1968. Part 1. Surface Water Records. USGS. San Juan, P. R. p. 53.

---------------. 1973b. Water Resources Data For Puerto Rico, 1968-1972. Part 2a. Water Quality Records. USGS. San Juan, P. R. p. 253-259.

---------------. 1973c. Water Resources Data For Puerto Rico, 1969. Part 1. Surface Water Records. USGS. San Juan, P. R. p. 46.

---------------. 1973d. Water Resources Data For Puerto Rico, 1970. Part 1. Surface Water Records. USGS. San Juan, P. R. p. 48.

---------------. 1973e. Water Resources Data For Puerto Rico, 1971. Part 1. Surface Water Records. USGS. San Juan, P. R. p. 37.

---------------. 1973f. Water Resources Data For Puerto Rico, 1972. Part 1. Surface Water Records. USGS. San Juan, P. R. p. 35.

---------------. 1975a. Water Resources Data For Puerto Rico, 1973. Part 1. Surface Water Records. USGS. San Juan, P. R. p. 37.

---------------. 1975b. Water Resources Data For Puerto Rico, 1973. Part 2. Water Quality Records. USGS. San Juan, P. R. p. 74-75.

---------------. 1976a. Water Resources Data For Puerto Rico, 1974. Part 1. Surface Water Records. USGS. San Juan, P. R. p. 34.

---------------. 1976b. Water Resources Data For Puerto Rico, 1974. Part 2. Water Quality Records. USGS. San Juan, P. R. p. 100-103.

---------------. 1977. Soil Survey of Humacao Area of Eastern Puerto Rico. USDA. San Juan, P. R. pp. 105.

---------------. 1978. Water Resources Data For Puerto Rico. Water Years 1973-76. USGS. San Juan, P. R. p. 206-214.

---------------. 1979. Geologic Map of the Fajardo and Cayo Icacos Quadrangles, Puerto Rico. USGS. San Juan, P. R.

---------------. 1980. Geologic Map of the Naguabo and Part of Punta Puerca Quadrangles, Puerto Rico. USGS. San Juan, P. R.

---------------. 1982. Inventario de los cuerpos de agua superficiales de Puerto Rico. EQB. San Juan, P. R.

---------------. 1990. Reglamento de estándares de calidad de agua de Puerto Rico. EQB. San Juan, P. R. 105 pp.

---------------. 1992. Goals and Progress Of Statewide Water Quality Management Planning: Puerto Rico 1990-1991. Rev. Ed. EQB. San Juan, P. R. 194 pp.

---------------. 1993. Guidance Specifying Management Measures For Sources Of Nonpoint Pollution In Coastal Waters. EPA. Washington, D. C. 909 pp.

Colón-Dieppa, E., P. L. Díaz & R. García. 1986. Water Resources Data for Puerto Rico. Water Year 1985. USGS. San Juan, P. R. p. 195-202.

Curtis, R. E., Jr., Z. Aquino, P. L. Díaz & R. García. 1987. Water Resources Data: Puerto Rico and the U. S. Virgin Islands: Water Year 1986. USGS. San Juan, P. R. p. 201-210.

Curtis, R. E., Jr., Z. Aquino, P. L. Díaz & R. J. Vachier. 1988. Water Resources Data: Puerto Rico and the U. S. Virgin Islands: Water Year 1987. USGS. San Juan, P. R. p. 195-199.

---------------. 1989. Water Resources Data: Puerto Rico and the U. S. Virgin Islands: Water Year 1988. USGS. San Juan, P. R. p. 293-297.

---------------. 1990. Water Resources Data: Puerto Rico and the U. S. Virgin Islands: Water Year 1989. USGS. San Juan, P. R. p. 223-227.

---------------. 1991. Water Resources Data: Puerto Rico and the U. S. Virgin Islands: Water Year 1990. USGS. San Juan, P. R. p. 301-304.

---------------. 1992. Water Resources Data: Puerto Rico and the U. S. Virgin Islands: Water Year 1991. USGS. San Juan, P. R. p. 303-307.

Curtis, R. E., Jr., S. Guzmán-Ríos & P. L. Díaz. 1980a. Water Resources Data: Puerto Rico and the U. S. Virgin Islands: Water Year 1977. USGS. San Juan, P. R. p. 101-104.

---------------. 1980b. Water Resources Data: Puerto Rico and the Virgin Islands: Water Year 1978. USGS. San Juan, P. R. p. 124-131.

---------------. 1981. Water Resources Data: Puerto Rico and the U. S. Virgin Islands: Water Years 1979-80. USGS. San Juan, P. R. p. 198-211.

---------------. 1982. Water Resources Data: Puerto Rico and the U. S. Virgin Islands: Water Years 1981-82. USGS. San Juan, P. R. p. 182-203.

---------------. 1984. Water Resources Data: Puerto Rico and the U. S. Virgin Islands: Water Year 1983. USGS. San Juan, P. R. p. 124-131.

---------------. 1985. Water Resources Data: Puerto Rico and the U. S. Virgin Islands: Water Year 1984. USGS. San Juan, P. R. p. 172-179.

Cintrón, B. 1993. Interagency field visit observations, Río Fajardo, Puerto Rico. Section 205 Study. Unpublished Memorandum. US Army CoE. Jacksonville, Fla. pp. 3.

Díaz, P. L. , Z. Aquino, C. Figueroa-Álamo, R. J. Vachier & A. V. Sánchez. 1993. Water Resources Data: Puerto Rico and the U. S. Virgin Islands: Water Year 1992. USGS. San Juan, P. R. p. 357-361.

Goenaga, C., & G. Cintrón. 1979. Inventory of the Puerto Rican coral reefs. DNR. San Juan, P. R. pp. 190.

Goenaga, C., V. Mestey, V. Vicente, J. Berríos, J. Caballero, O. Dávila, D. Delgado, I. Díaz, M. Rivera & V. Quevedo. 1990. Suplemento técnico para el Plan de Manejo de la Reserva Natural La Cordillera, Fajardo, Puerto Rico. P. M. González, M. T. García & R. F. Martínez (Eds.). DNR. San Juan, P. R. pp. 156.

Kipple, F. P. 1968. Water Records of Puerto Rico, 1958-63. USGS. San Juan, P. R. p. 165-176.

Lugo, A. E. 1993. Río Mameyes and the water intake project of PRASA. Unpublished document. USDA Forest Serv. San Juan, P. R. 17 pp.

Margalef, R. 1978. Diversity. *In:* Phytoplankton Manual. A. Sournia (Ed.). UNESCO. Paris, France. p. 251-260.

Renn, C. E. 1968. A Study Of Water Quality. La Motte Chem. Prod. Co. Chestertown, Mar. pp. 46.

---------------. 1969. Our Envitonment Battles Water Pollution. La Motte Chem. Prod. Co. Chestertown, Mar. pp. 32.

Rickher, J. G. 1970. Water Records of Puerto Rico, 1964-67. Vol. 1: North and Northeast Slopes. USGS. San Juan, P. R. p. 248-261.

Riley, J. P., & R. Chester. 1971. Introduction to Marine Chemistry. Academic Press. New York, N. Y. p. 105-218.

Zayas, E. 1993. Gold rush! Business booms in Puerto Rico's eastern region. Caribbean Business 21(4):1-2; 32-33.

APPENDIX 1: Field interviews' questionnaires.

AGRICULTURAL LANDS

1. Farm size: ______ acres (total). Estimate of acreage in active use: ____ acres.

2. Farm use: a. Crops ____. What crops? Plantains/bananas ____ Sugar cane _____
Others (explain): ______________________
b. Animals ____: Cattle ____ Horses ____ Pigs ____
Others (explain): ______________________

3. Farm location: ______________________. Is it adjacent to surface waterbodies?
Yes ____ No ____

4. Type(s) of soil in farm, if known: ______________________
Has the soil been classified as highly erodible? Yes ____ No ____ Do not know: __

5. Erosion management:

a. Does activities in this farm include the following: Conservation tillage ____
Contour strip-cropping ___ Sediment retention pond ___
Water control basin ___ Terraces ___
Sediment control basin ___ Critical area planting ___
Filter strip ___ Field borders ____
Grade stabilization structure ____ Reforestation ____ None ___
b. Other erosion control activities (explain): ______________________
____

6. Confined animal facility wastewater and runoff management:

a. Is wastewater/runoff routed through holding pond, treatment lagoon or other settling structure/ debris basin? Yes ____ No ____.
b. If Yes, How frequently are these structures cleaned/maintained? ______________
c. For small facilities:
Do you maintain vegetated filter strips or any other mitigation area vegetation?
Yes _____ No _____.

7. Nutrient and Pesticide management:

a. Do you use nutrients? Natural _____ Artificial _____ None ___.
b. Do you use pesticides? Natural _____ Artificial _____ None ___.
c. Have you evaluated soil for: pH ____ phosphorus ____ nitrogen ____
potassium ___ leaching/runoff potential? _____
d. Do you calibrate and maintain application equipment? Yes ____ No ____
e. Do you determine yield expectations through yield history or soil series information?
Yes ____ No _____.
f. Do you apply nutrients and pesticides after determination of real economic benefit?
Yes ____ No _____.
g. Do you plan type of pesticide/nutrient application and timing, amount and frequency taking into account: weather ____ stage of crop development _____
type of crop ____ soil type ____
pest problem ____ toxicity ____
previous pest control methods used ____ persistence _____
h. Have you identified environmental concerns (sinkholes, surface water, shallow aquifer,) highly erodible soil) in or near your farm? Yes ____ No ____ There are none _____.
i. If yes, Do you plan nutrient/pesticide application taking this into account? Yes__No__.

8. Grazing Management:

a. To protect sensitive areas (streambanks, wetlands, surface waters, riparian zones), do you:
Exclude livestock from these areas ____
Alternate grazing areas within farm ____
Provide alternate drinking location ___
Provide stream crossings or hardened access for drinking ____
Locate salt and shade away from sensitive areas ____

b. Grazing is not carried out in this farm ____.

9. Irrigation water management:

a. Do you use irrigation water? Yes ____ No ____.
b. If yes, Do you irrigate uniformly? Yes ___ No ____
c. Have you prepared an irrigation schedule? Yes ____ No ____
d. If yes, have you taken into account the following:
rainfall and temperature ____ soil properties ____
type of crop and its resistance to stress ____
stage of crop development ____
availability of water supply ____

URBAN RUNOFF

1. New development management:

   a. Type of development: ____________________________
   b. Area covered: Total: _____________
      Within the Fajardo River Basin: ___________.
   c. Have you designed or constructed development to be able to reduce average annual Total Suspended Solids (TSS) loadings by, at least, 80% after project completion?
      Yes _____ No ____
   d. Have you designed or constructed development to be able to reduce postdevelopment TSS loadings so that average annual loadings are no greater than predevelopment loadings? Yes ____ No ____

2. Watershed protection management:

   Have you developed a Watershed Protection Program:
   a. To protect areas particularly susceptible to erosion? _____
   b. To protect areas that provide important water quality benefits? ____
   c. To protect areas necessary to maintain riparian/aquatic biota? ____
   d. To site development to protect natural integrity of waterbodies and natural drainage systems? _____
   e. Have not prepared Program ____
   f. Program not necessary ____.

3. Site development management:

   Do you plan, design or develop sites to be able to:
   a. Protect areas that provide important water quality benefits or are susceptible to erosion ______
   b. Limit increases of impervious areas ____
   c. Limit land disturbance activities to reduce erosion ____
   d. Limit disturbances on natural drainages and vegetation _____

URBAN CONSTRUCTION ACTIVITIES

1. Site size:_____________.
2. Site location: ____

3. Construction site erosion and sediment control management:

   a. Have you prepared a plan to control erosion? Yes ____ No ____
   b. If yes, have you taken into account: soil type(s) ____
      site grading and present or future contours ____
      topsoil preservation ____ design for structural controls ___
      stabilization measures ____ revegetation ____
      description of sequence of construction ____
      mitigation areas near waterbodies or drainage systems ___
      others (explain) ____
      ____

4. Construction site chemical control management:

   a. How and where do you store chemicals? ____________________
   ____
   b. Do you have a plan for their application? Yes ____ No _____
   c. If yes, explain: ______________________________
   ____
   ____
   d. How do you dispose of chemicals? ______________________
   ____
   ____
   e. Have you established fuel and vehicle/equipment maintenance and washing areas away from all drainage courses? Yes ____ No ____
   f. Do you cover and isolate construction materials and chemicals to prevent runoff? Yes ____ No _____
   g. Have you prepare a spill prevention and control plan? Yes ___ No ____
   h. Do you provide proper sanitary facilities for construction workers? Yes ____ No ____

EXISTING DEVELOPMENT MANAGEMENT

a. Do you have a watershed management program to reduce runoff pollutants? Yes _____ No _____
b. If yes, does it include:
   Identification of priority local/regional watershed pollutant reduction opportunities _____
   A schedule for implementation of appropriate controls _____
   Limits for destruction of natural conveyance systems ____
   Preservation, enhancement or establishment of buffers along surface waterbodies ____
c. Location of development: ________________________________
d. Site size: ____________________.

POLLUTION PREVENTION MANAGEMENT

a. Agency: ____

b. Is there a pollution prevention and education program to reduce nonpoint source pollutants generated from the following activities:

_____ Improper storage, use, and disposal of household hazardous chemicals, including automobile fluids, pesticides, paints, solvents, etc.
_____ Application and disposal of garden care products, and improper disposal of leaves and yard trimmings.
_____ Turf management of golf courses, parks and recreational areas.
_____ Discharge of pollutants into storm drains, including floatables, oil and litter.
_____ Commercial activities including parking lots, gas stations, and other entities not under NPDES purview.
_____ Improper disposal of pet excrement.
_____ Others (explain) ____
____

ONSITE DISPOSAL SYSTEMS MANAGEMENT

1. New onsite disposal systems (OSDS) management:
   a. Do your agency has policies, regulations or plans to ensure that new OSDS are located, designed, installed, operated, inspected and maintained to prevent the discharge of pollutants to the ground, to ground waters and to surface waters?
   Yes ___ No ___
   b. If yes, do you: Discourage the installation of garbage disposal to reduce hydraulic and nutrient loadings? ____
   Reduced total hydraulic loadings to the OSDS by 25% in new developments or redevelopments where low-volume plumbing fixtures have not been installed? _______
   Direct placement of OSDS away from unsuitable areas including poorly or excessively drained soils, areas with shallow water tables or with high seasonal water tables, areas over fractured bedrock, floodplains, and areas where nutrient or pathogen concentrations in the effluent can not be reduced? ______
   Establish protective setbacks from surface waters, wetlands, and floodplains?___
   Establish protective separation distances between OSDS and groundwaters?__
   Require installation of OSDS that reduce total nitrogen loadings by 50% to groundwaters, where conditions indicate that surface waters may be adversely affected by excess nitrogen loadings from groundwaters? ____
   c. System location: ____
   d. System capacity: ____
2. Agency: ____

3. Operating onsite disposal systems (OSDS) management:
   a. Do your agency has policies, regulations or plans to ensure that existing OSDS are operated and maintained to prevent discharge of pollutants to the ground, groundwaters or surface waters? Yes _____ No ______
   b. If yes, do you: Discourage the reduced use of garbage disposals? _____
   Encourage the use of low-volume plumbing fixtures? _____
   Reduce total phosphorus loadings by 15%? _____
   Require an OSDS to be repaired, replaced, or modified when it fails or threaten or impairs surface waters? ______
   Inspect OSDS at a frequency adequate to ascertain whether OSDS are failing?__
   Consider replacing or upgrading OSDS to treat influent so that total nitrogen loadings in the effluent are reduced by 50%, if surface waters may be adversely affected by groundwater nitrogen loading from OSDS? _____
   c. System location: ____
   d. System capacity: ____

ROADS, HIGHWAYS AND BRIDGES

1. Agency: ____

2. Planning, siting, and developing roads and highways management:
   Do your agency plan, site and develop roads/highways taking into account:
   Protection of areas that provide important water quality benefits or are susceptible to erosion? ______
   Limits to land disturbance (clearing and grading, cut and fill, etc.) to reduce erosion? _____
   Limits to disturbance of natural drainage features and vegetation? ____

3. Bridges management:
   Do your agency site, design, and maintain bridges so that sensitive and valuable aquatic ecosystems and areas providing important water quality benefits are protected from adverse effects? Yes _____ No _____

4. Construction projects (roads, highways, bridges) management:
   Do you: Reduce erosion in construction projects? _____
   Retain sediment onsite during and after construction? ______
   Prior to land disturbance, prepare and implement an approved erosion control plan? ____

5. Construction site chemical control management:
   Do you Limit application, generation, and migration of toxic substances? _____
   Ensure proper storage and disposal of toxic materials? _____
   Apply nutrients at rates necessary to establish and maintain vegetation without causing significant nutrient runoff? ______

6. Operation and maintenance management:
   Do you incorporate pollution prevention procedures into the operation and maintenance of roads, highways and bridges to reduce pollutant loadings to surface waters? ______

7. Runoff systems management:
   a. Have you developed runoff management systems for existing roads, highways and bridges to reduce runoff pollutant concentration and volumes entering surface waters? Yes ______ No ______
   b. If yes, have you: Identified priority and watershed pollutant reduction opportunities?__
   Established schedules for implementing appropriate controls? _____

MARINAS AND RECREATIONAL BOATING

1. Marinas flushing management:
    a. Have you designed and site this marina such that tides or currents will aid in flushing of site or renew water regularly? Yes ____ No ____

2. Water quality assessment management:
    a. Do you assessed water quality as part of marina siting and design? Yes _____ No ___
    b. If yes, do you tested for: Dissolved oxygen? ____ Pathogens? _____
    c. Do you currently run a regular water quality assessment program? Yes ____ No ___
    d. If yes, what do you test for? ____

3. Shoreline stabilization management:
    a. Do you reforest/revegetate as a regular shoreline stabilization procedure? _____
    b. If you use other procedures, did you take into account their cost effectiveness against revegetation, prior to construction or implementation? Yes ____ No _____
    c. What are/were those other procedures? ________________________________

4. Storm water runoff management:
    a. Do you implement effective runoff control strategies? Yes ____ No ____
    b. If yes, do they include the following: Use of pollution prevention activities? ____
        Proper design of hull maintenance areas to reduce annual loadings of total suspended solids by 80%? _____

5. Fueling station design management:
    Have you designed fueling stations to allow for ease in spills cleanups? Yes __ No ___

6. Sewage facility management:
    Have you installed pumpout, dump station and restroom facilities to reduce release of sewage to surface waters? Yes _____ No ____

7. Solid waste management:
    a. Do you properly dispose of solid wastes from boats to limit their entry to surface waters?
        Yes ____ No ___
    b. If yes, how (explain): ____
    ____

8. Fish waste management:
    a. Do you apply any kind of fish cleaning restrictions? Yes ____ No ___
    b. Do you implement some kind of public education regarding fish waste disposal?
        Yes ______ No _____
    c. Do you implement proper disposal procedures for fish waste? Yes ____ No ___
    d. If yes, explain which ones: ____
    ____

9. Petroleum control management:
    a. Have you implemented measures to reduce amount of fuel and oil entering surface waters? Yes ____ No ____
    b. If yes, explain: ____
    ____

10. Boat cleaning management:
    a. Do you perform boat cleaning operations such that the release to surface waters of cleaners, solvents, and paints is minimized? Yes ____ No ____
    b. If yes, explain how: ____
    ____

11. Public education management:
    a. Do you implement any public education, outreach or training program dealing with proper disposal of polluting material? Yes ___ No ___
    b. If yes, describe: ____
    ____

12. Maintenance of sewage facilities management:
    a. Do you have sewage pumpout facilities? Yes _____ No ____
    b. If yes,: Do you encourage their use? Yes _____ No ____
    Do you ensure that they are maintained in operational conditions?
    Yes _____ No ____

13. Marina: ______________________________

14. Marina location: ____

15. Marina size and capacity: ____

BOAT OPERATION MANAGEMENT

1. Do you restrict boating activities where necessary to decrease turbidity and physical destruction of shallow-water habitat? Yes ____ No _____

2. If facility is not a marina, identify source of information: ______________________________
____

3. Source size/capacity and location, if apply: ______________________________
____

CHANNELIZATION AND CHANNEL MODIFICATION

1. Physical and chemical characteristics of surface waters management:
   a. Has there been an evaluation of chemical and physical characteristics of surface waters previous to construction? Yes _____ No _____
   b. Have you evaluated the potential effects of proposed channel modification on the chemical and physical characteristics of surface waters? Yes _____ No _____
   c. Have you planned and designed channel modification to reduce negative impact? Yes _____ No _____
   d. Do you have an operation/maintenance program for existing modified channels? Yes _____ No _____
   e. If yes, does it includes measures to improve chemical and physical characteristics of surface waters? Yes ____ No _____

2. Instream and riparian habitat restoration management:
   a. Has there been an.evaluation of instream and riparian habitats previous to construction? Yes ____ No _____
   b. Have you evaluated the potential effects of proposed channel modification to instream and riparian habitats? Yes _____ No ______
   c. Have you planned and designed channel modification to reduce negative impact? Yes _____ No _____
   d. If you do have an operation/maintenance program for existing modified channels, does it includes measures to restore instream and riparian habitats in those channels? Yes _____ No _____

ERODING STREAMBANKS AND SHORELINES MANAGEMENT

1. Have you identified areas of streambank and shorline erosion which represents a nonpoint pollution problem? Yes _____ No _____
2. If yes, are you taking measures to protect these areas? Yes ____ No ____
   a. What measures are you implementing?___________________________________
   ____
   ____

WETLANDS AND RIPARIAN AREAS

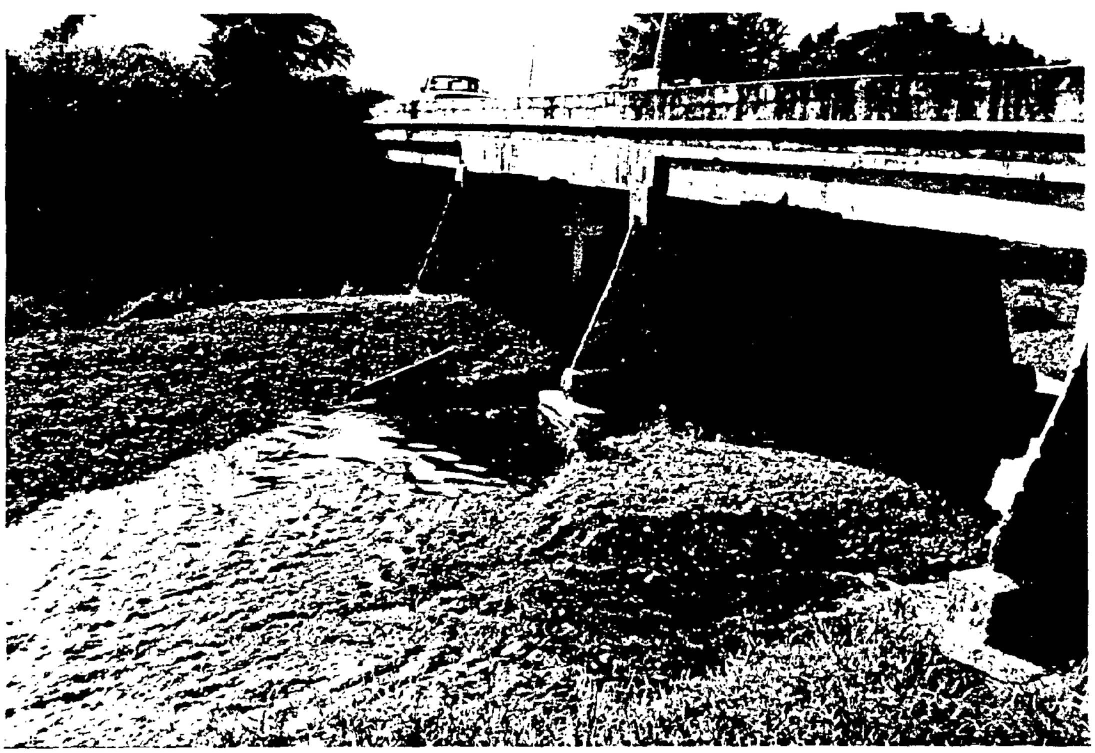
1. Wetlands and riparian areas protection management:
   a. Have you identified wetlands and riparian areas which serve a significant nonpoint source pollution abatement? Yes ____ No ____
   b. Do you have a program for the protection of these areas?
   c. If yes, does it include maintenance of the following:
      non point source pollution abatement ___ species composition ____
      vegetative cover ____ hydrology of surface water ____
      hydrology of ground water ____ substrate geochemistry _____

2. Wetlands and riparian areas restoration management:
   Do you promote the restoration of preexisting functions in damaged and destroyed wetlands and riparian systems? Yes ___ No ____

3. Vegetated treatment systems management:
   Do you promote the use of engineered vegetated treatment systems, such as:
      constructed wetlands ____ vegetated filter strips _____

APPENDIX 2: Field photographs.

Author F. A. Grana-Raffucci overlooking the Fajardo River at bridge over Field Station #1.



Field Station #2.

Plantain plantation adjacent to Field Station #1.

Author F. A. Grana-Raffucci taking water samples at Field Station #1.