1.0 INTRODUCTION

1.1 PURPOSE

This report embodies the findings of a preliminary study of the Rio Cobre (RC) and its contribution to the pollution load in the Kingston Harbour. The study determines surface water quality and the pollution load on the basis of BOD. It also categorises the pollution load by sector i.e. agricultural, industrial and domestic.

1.2 TERMS OF REFERENCE (TORs)

In a letter dated February 11, 1993, Sentar Consultants Limited requested that Environmental Solutions Limited (ESL) submit a proposal to conduct a preliminary evaluation of the BOD loading from the Cobre. In a subsequent meeting with the Project Engineer, Kenneth Hamman, to define the scope of the study, it was agreed that given the financial constraints sampling would be limited to strategic points along the river course. Against this background the TORs for the study were as follows:-

1) Identification of industries between Kingston and Ewarton discharging process waste into the Rio Cobre, establishing rough estimates of BOD loading by sampling with reference to product volumes and using EPA guidelines.

2) A preliminary survey of the domestic sanitary facilities to assess the potential BOD loading from these sources.

3) Determination of the agricultural load.

2. BACKGROUND

2.1 DESCRIPTION OF THE STUDY AREA

The Rio Cobre is Jamaica's third longest river and its watershed embraces most of the parish of St Catherine. The river originates in Linstead as the Black River (Figure 2.1) and flows in a south easterly direction to Hunts Bay.

Along the 27 miles of its course, the river is subject to discharges from various sources which adversely affects the water quality. This begins with inflows from the Pleasant Farm and Jordan Spring gullies which take effluent from the Ewarton Alumina Works and continues into the Bog Walk area where the

operation of the condensary, citrus, coffee and meat plants all impact on the river. There is also significant agricultural activity mainly sugar cane, banana and citrus in the upper parts of St. Catherine.

Fertilisers, herbicides and pesticides residues enter the Cobre through the washdown of soil which finds its way directly, or via gullies and/or tributaries, into the RC.

Spanish Town and its satellite communities impact on the river both in terms of industrial activity centered in Twickenham Park and Central Village and domestic sanitary facilities which discharge effluent into the river.

After exiting Spanish Town the RC winds its way through cane fields and as it nears the sea the vegetation gives way to salt tolerant types and mangroves. The river discharges into Hunts Bay.

2.2 LOCATION OF THE SAMPLING STATIONS

The study area (Figure 2.1) includes the entire length of the river, originating with its' first major tributary, the Black River. Sampling point 1 is located at Jericho along the (Plate 1) prior to joining with the Pleasant Farm and Jordan Spring gullies. These gullies are characterised by low flow and contain discharges from the Ewarton Alumina Works (EAW).

Sampling point 2 is the discharge from the Sewage Treatment Plant (STP) for the Charlemont Housing Scheme (Plate 2). This facility discharges into a gully which empties into the RC.

Healthfield Bridge, spans the river on the outskirts of the town of Linstead and is sampling point 3 (Plate 3). A reading here provides information on EAW's contribution of to the river's BOD loading. It also provides water quality data prior to the town of Linstead.

Sampling point 4 is downstream of Linstead but upstream of the main industrial activity in Bog Walk and is located in United Estates (Plate 5). It provides data on the water quality leaving Linstead as well as baseline data for the Bog Walk area.

The RC merges with three tributaries, the Rio Doro, Pedro and Thomas rivers. This occurs on the outskirts of Bog Walk as the river exits the town. This is sampling point 5 (Plate 7).

The Rio Pedro is the most significant of the three tributaries, in terms of flow and the agricultural activity which takes place upstream the river. Sampling point 6 was taken before the Pedro merges with the RC (Plate 8).

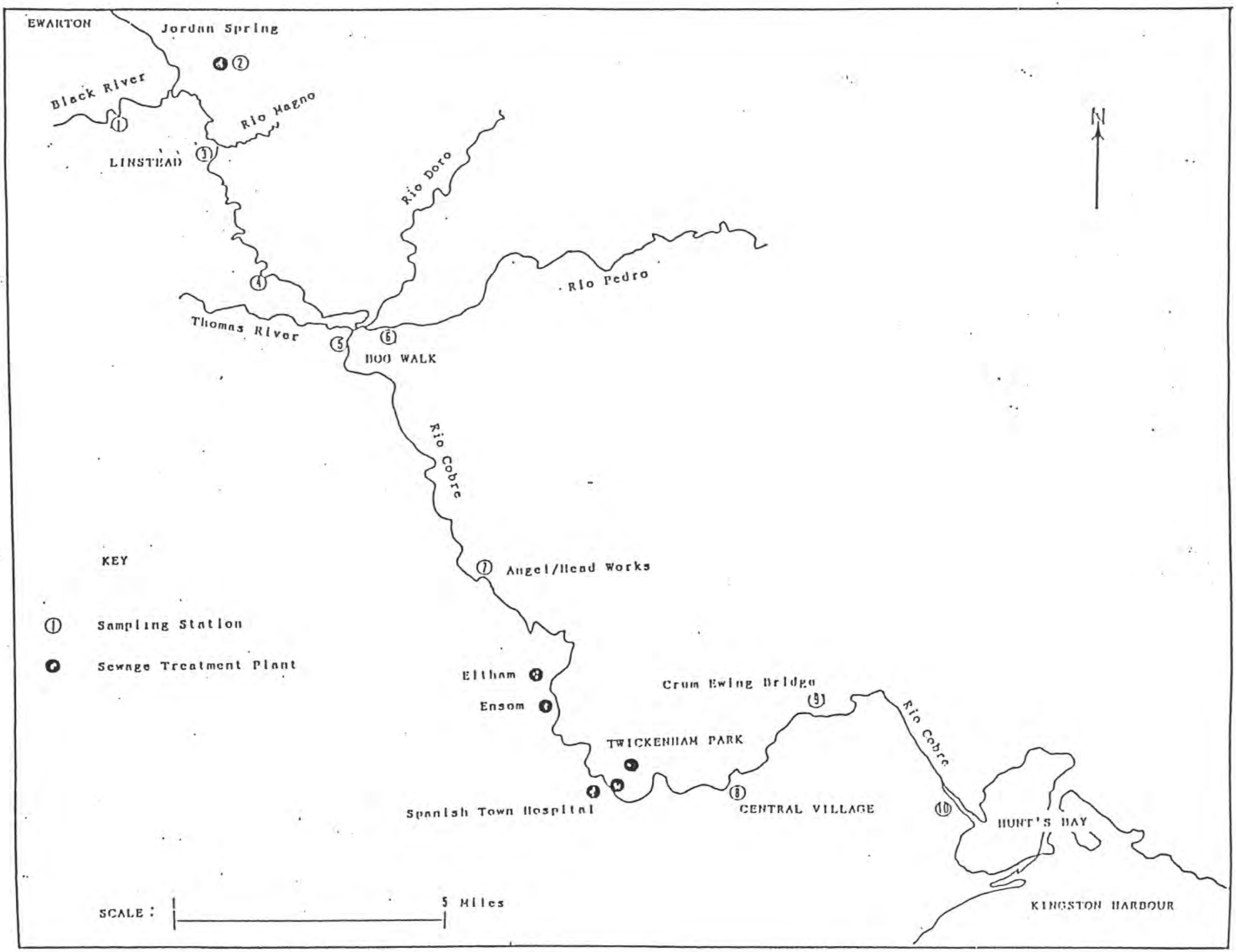


Figure 2.1 Sampling points in the study area along the Rio Cobre

At Headworks the RC is dammed (Plate 11). Water is drawn into the RC Irrigation System (Plate 12). The other branch of the river proceeds past Headworks, Sampling point 7 (Plate 13) into Spanish Town. The sample at this point provides baseline information on the water quality prior to the town and its satellite communities of Gordon Pen, Eltham, etc. and the industrial centers at Twickenham Park and White Marl.

Sampling point 8 is in Central Village as the RC leaves behind the major sources of discharges, both domestic and industrial, in the Spanish Town region. Half way between Spanish Town and the Hunts Bay is situated the Crum Ewing Bridge at where Sample point 9 is located (Plate 14). The final, Sample point 10 is sited at the mouth of the RC as it enters Hunts Bay.

3. METHODOLOGY

A total of 10 samples were collected on April 1, 1993 along the river course. Water samples were collected on one occasion between the hours 8:00 am and 2:30 pm for the analyses of BOD, nitrate, phosphate, and faecal coliform.

Samples were collected in three aliquots that were combined to make a homogenous sample. In some cases the aliquots were taken linearly across the stream to form a composite sample. Where this was not practical samples were collected to the side of the stream again in three aliquots collected over a period of time. Bacterial samples were collected directly in the bottle.

After collection, the samples were stored on ice for transportation to the laboratory. The samples were not preserved except for refrigeration as analyses were conducted within 24 hours of collection.

Standard methods were used for the determination of all parameters as described in Standard Methods for the Examination of Water and Wastewater (APHA) and outlined briefly below.

3.1 BOD

The samples were diluted with specially prepared dilution water and incubated at 20^0C for 5 days. Dissolved oxygen values were measured using an oxygen meter and a membrane filter probe. The BOD rates were calculated as mg/l.

3.2 Nitrate

Nitrate was determined using the cadmium reduction technique, where nitrate is reduced to nitrite which complexes with sulfanilamide and N-(1-naphthyl)-ethylenediamine to produce a dye which is then measured spectrophotometrically.

3.3 Phosphate

Phosphate values were determined using the ascorbic acid - molybdenum blue method.

3.4 Faecal Coliform

Multiple tube fermentation technique was used for bacterial enumeration. Preliminary assessments were done using lactose broth medium and samples were incubated for 48 hours. Confirmatory tests were conducted using Brilliant Green Bile medium with incubation again for 48 hours.

Five replicates of three dilutions (1 ml, 0.1 ml, 10 ml) were carried out in all cases and the most probable number (MPN) of bacteria per 100 ml was read from international tables. The samples and sampling stations are detailed in Table 3.1.

Table 3.1 Description of samples and sampling stations along the Rio Cobre

Sample	Sampling Station	Description
RC1	Jericho/Black River U W A Station	Surface Water from Rio Cobre
RC2	Charlemont STP Charlemont Housing Scheme	Treated Sewage Effluent
RC3	Healthfield Bridge	Surface Water Rio Cobre
RC4	United Estates	Surface Water Rio Cobre
RC5	Bog Walk Bridge (Merger of Rio Doro, Thomas and Pedro) UWA station	Surface Water Rio Cobre
RC6	Rio Pedro upstream Rio Cobre	Surface Water Rio Cobre
RC7	Rio Cobre Headworks - U W A - Station	Surface Water Rio Cobre
RC8	Central Village	Surface Water Rio Cobre
RC9	Crum Ewing Bridge	Surface Water Rio Cobre
RC10	Rio Cobre mouth	Surface Water Rio Cobre

4. RIVER CHARACTERISATION

The river was characterised both in terms of river discharge and the effect of rainfall on the flow at various times of the year. The discharge data on the day of and the period before sampling on April 1, 1993 is also provided.

4.1 RIVER DISCHARGE DATA

River discharge data is critical in determining the BOD loading at various points along the river and ultimately the pollution load contribution to the Kingston Harbour. The Underground Water Authority (UWA) is responsible for compiling this information and the data presented in the report was provided by the Authority. Table 4.1 summaries the stations and method of measurement. The detail readings are found in Appendices I - VII.

Table 4.1 List of UWA Recording Stations in the Rio Cobre Basin

River	Station	Type of Flow Measurement/Recording
Black River	Jericho	Continuous
Pleasant Farm/ Jordan Spring Gullies	Wedderly Spring	Intermittent
Indian River/ Rio Magno	Indian River	Continuous
Rio Doro	Williamsfield	Continuous
Rio Pedro	Harkers Hall	Continuous
Rio Cobre	Bog Walk Bridge	Continuous
Rio Cobre	Irrigation Canal at Headworks	Continuous
Rio Cobre	Over the Dam NR Spanish Town (Angels)	Continuous
Rio Cobre	Crum Ewing	Intermittent

It would have been desirable to use 30 year river discharge means in the calculations. However, this information was not available for all the tributaries. This was particularly critical in the case of the Crum Ewing Bridge which is located half way between Spanish Town and the Bay. River flow at Crum Ewing is considered to be most characteristic of the Cobre flow before discharging into the Harbour. While some data is available on this station the readings are intermittent.

4.2 COMPARISON OF RIVER FLOW WITH RAINFALL DATA

The 30-year average rainfall for selected regions in St. Catherine was plotted against RC discharge to determine the relationship between discharge and rainfall. In this case the regions used for the comparison were Headworks and Central Caymanas as these are the closest to Hunts Bay. Table 4.2 details annual readings of rainfall data from 1951-1980 for Headworks and compares these with RC discharge.

The plot of discharge and rainfall as seen in Graph 4.1 shows that rainfall increases as river discharge increases and visa versa.

RC flow at Crum Ewing is considered to be the typical discharge into Hunts Bay. A comparison was done of RC discharge at Crum Ewing and rainfall in the Central Caymanas areas in Table 4.3 and Graph 4.2. Unfortunately only one year (1992) was available for the river as against 30 year mean for rainfall. However the data was sufficient to help establish a trend, as was the case at Headworks.

4.3 CRUM EWING VS HEADWORKS

In order to verify the most appropriate station (Crum Ewing or Headworks) to extract river flows for load calculations (for the Kingston Harbour) and given the availability of more accurate data at Headworks. The rainfall figures for Headworks were plotted against those for Crum Ewing (Central Caymanas), in Graph 4.3.

The relationship between river discharges and rainfall is well known and has been established in Section 4.2. Graph 4.3 shows that the rainfall in Central Caymanas is lower than at Headworks. This suggests that river discharge at Crum Ewing will be consistently lower than Headworks.

The differences in flow between Headworks (5.50 m^3/s) and Crum Ewing (2.41 m^3/s) is therefore understandable. RC discharge at Crum Ewing will be used in calculating the pollution load contribution to the Bay. For the purpose of this study, the readings taken in 1992 were averaged and the results used as the characteristic discharge of RC at Crum Ewing.

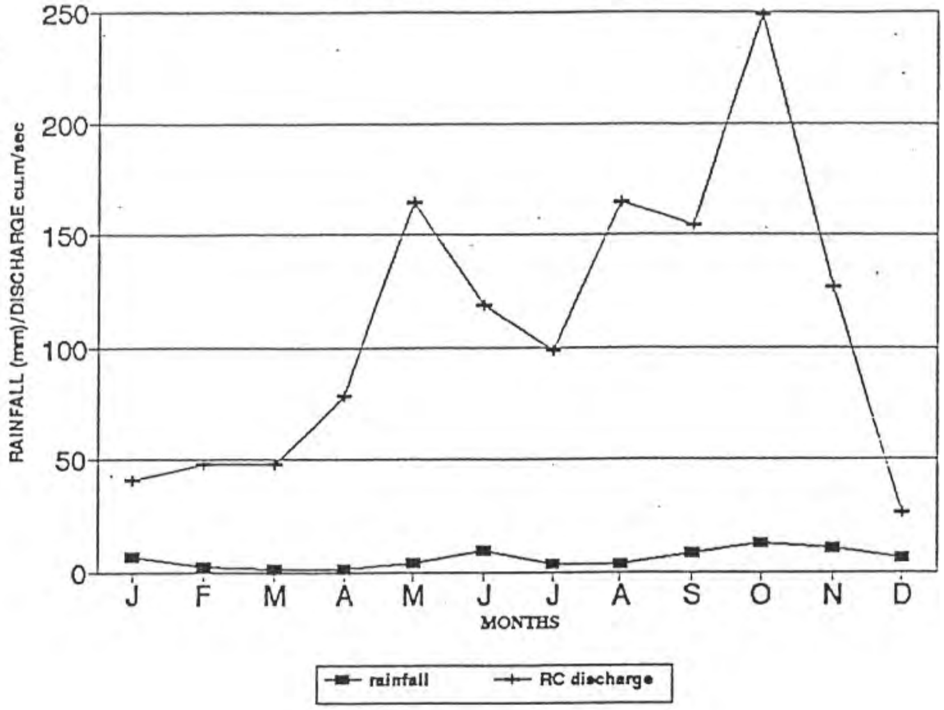
TABLE 4.2 A COMPARISON OF RAINFALL DATA (1951-1980) AND RIO COBRE DISCHARGE(1954-1991) AT HEADWORKS

MONTH	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV	DEC.	YRLY MEAN
DISCHARGE cu.m/sec.	7.15	2.14	1.25	1.30	4.09	9.56	3.68	3.54	8.53	12.56	10.32	5.75	5.82
RAINFALL mm	41	48	48	79	165	119	99	165	155	249	127	26	110.08

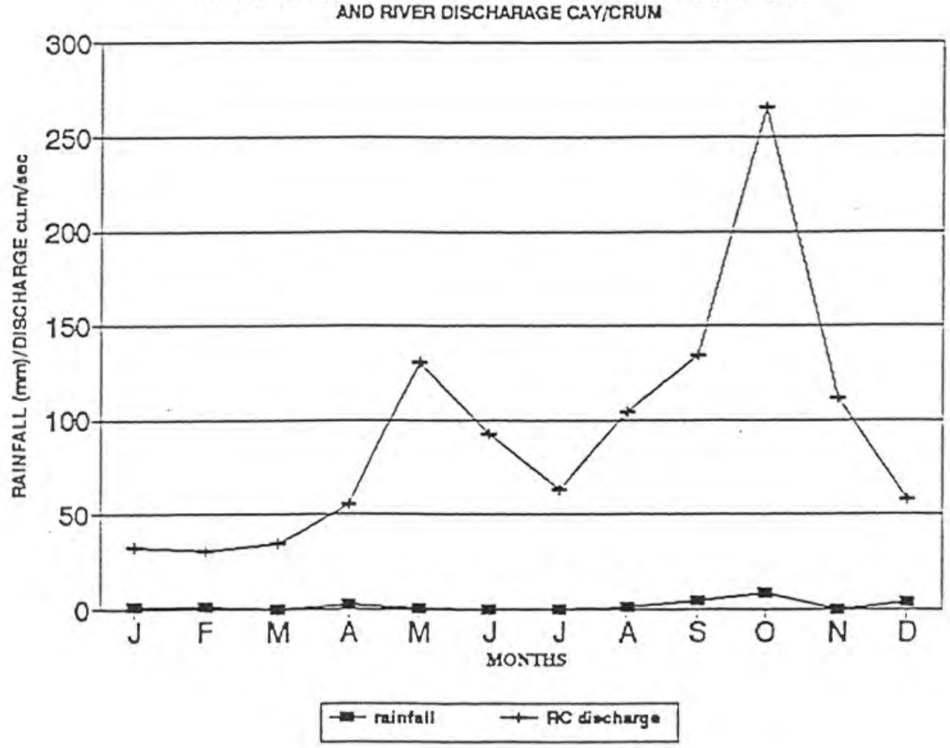
TABLE 4.3 A COMPARISON OF RAINFALL DATA (1957-1980) FOR THE CENTRAL CAYMANAS AREA AND THE RIO COBRE AT CRUM EWING (1992).

MONTH	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV	DEC.	YRLY MEAN
DISCHARGE cu.m/sec.	0.73	0.94		1.75	0.19			0.65	4.27	7.58		3.19	1.61
RAINFALL mm	32	30	34	55	130	92	63	104	134	265	111	58	92.33

GRAPH 4.I COMPARISON BETWEEN RAINFALL
AND RIVER DISCHARGE HEADWORKS



GRAPH 4.2 COMPARISION BETWEEN RAINFALL
AND RIVER DISCHARAGE CAY/CRUM



4.4 RIVER FLOWS AT THE TIME OF THE STUDY

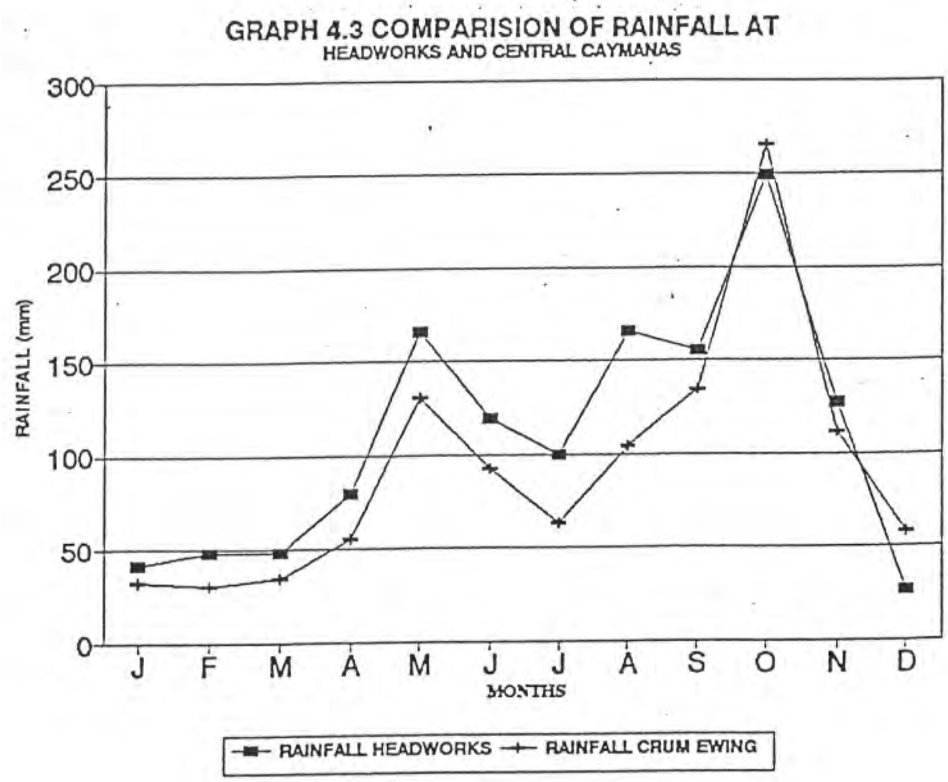
At the time of the study the island had been experiencing unusually heavy rains. The river discharges which were obtained during the period and on the day were not typical of previous April monthly averages.

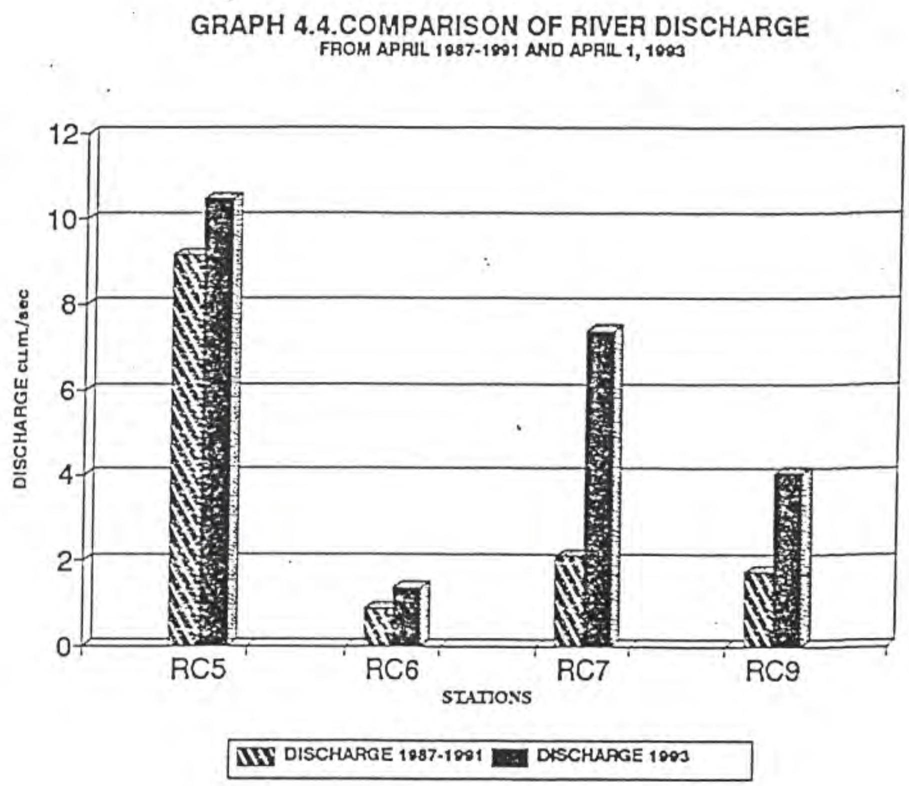
Table 4.4 A comparison of river discharge at selected UWA stations in the month of April 1993 against the previous average April discharges 1987-1991.

Station	Previous Monthly Av. M^3/s (1987-1991)	Reading on April 1, 1993 M^3/s
RC1 Black River	0.47	0.90
RC5 Bog Walk	9.17	10.47
RC6 Rio Pedro	0.88	1.36
RC7 Headworks	2.12	7.39 +
RC9 Crum Ewing	1.75 *	4.02

* 1992 reading + calculated

A comparison of RC discharge in April for 1987 - 1991 with readings obtained on April 1, 1993 highlights the increased flows (Table 4.4 and Graph 4.4). The calculations for BOD loading along RC's course were done using the April 1, 1993 data instead of historical averages because of the usually heavy flows during the period . Appendix VIII - XIII contain data on 1993


GRAPH 4.3 COMPARISION OF RAINFALL AT
HEADWORKS AND CENTRAL CAYMANAS
RAINFALL (mm)
0
50
100
150
200
250
300
J F M A M J J A S O N D
MONTHS
RAINFALL HEADWORKS
RAINFALL CRUM EWING


GRAPH 4.4.COMPARISON OF RIVER DISCHARGE
FROM APRIL 1987-1991 AND APRIL 1, 1993
DISCHARGE cu.m./sec
0
2
4
6
8
10
12
RC5
RC6
RC7
RC9
STATIONS
DISCHARGE 1987-1991
DISCHARGE 1993

4.5 SUMMARY

In conclusion, river characterisation studies showed:

1) River discharges are related to rainfall.

2) River discharges at the time of the study were higher than previous 5 years' average.

3) RC discharge at Crum Ewing is the most appropriate for calculating BOD loading to the Bay.

5.0 RESULTS

5.1 STUDY DATA

The results of the analyses for the 10 sampling stations are found in Table 5.1.

Table 5.1 Results of sampling of the study Area

Sampling Station(s)	BOD mg/l	Nitrate mg/l	Phosphate mg/l	PH	Fecal Coliform MPN/100ml
RC1	2.03	2.20	0.17	8.44	170.
RC2	10.69	1.98	6.00	8.01	2,400.
RC3	3.68	5.28	0.10	8.10	2,400.
RC4	1.28	3.52	0.15	8.32	2,400
RC5	1.35	1.76	0.28	8.51	2,400.
RC6	1.20	1.32	0.25	8.86	540.
RC7	1.80	1.32	0.15	8.57	2,400.
RC8	N/A	-	-	-	-
RC9	1.65	1.10	0.35	8.85	2,400
RC10	13.60	1.32	0.13	8.65	350.

In addition to the results from the one day study, were was not considered adequate. Data was obtained from work done by the Environmental Control Division (ECD), Centre for Nuclear Science (CNS) and Wade *et al* (1979). The results for the relevant stations are found in Table 5.2 - 5.4.

Table 5.2 ECD Results of Sampling of the Rio Cobre 1992

Station	BOD mg/l	NO_3 mg/l	PO_4 mg/l
RC1 Black River	8.30	2.30	0.83
Citrus Growers etc Bog Walk	4.08	4.38	5.22
RC5 Bog Walk	5.30	3.05	4.64
RC7 Headworks	2.46	3.40	2.84

Note The values were averaged.

Table 5.3 CNS Results of Sampling of the Rio Cobre 1992

Station	BOD mg/l	NO_3 mg/l	PO_4 mg/l	Sample Size
RC1 Black River	2.50	3.70	0.32	52
Jordan Spring Gully	6.60	4.50	1.68	54
Citrus Growers, Nestle etc Bog Walk	5.30	4.60	0.33	52
RC5 Bog Walk	12.70	3.00	7.25	49
RC7 Headworks	2.30	2.40	3.00	23
RC9 Crum Ewing Bridge	1.90	2.70	0.86 *	15

* Note Analysis was done only once.

Table 5.4 Wade *et al* Results of Sampling of the Rio Cobre 1979

Station	BOD mg/l	NO_3 mg/l	PO4 mg/l	MPN/100ml Total Coliform	MPN/100ml Fecal Coliform
RC9 Crum Ewing	3.5	3.70	0.42	79,000	0
RC10 Mouth	2.1	2.83	0.41	27,000	0

There appears to be reasonable correlation between the study data and that of ECD, CNS and Wade *et al*.

5.2 BOD AND OTHER NUTRIENT LOADING INTO HUNTS BAY

The BOD, nitrate and phosphate loading for various points along the river were calculated using results obtained from the day of sampling. In estimating a yearly nutrient load, it was assumed that water quality was about the same for each day as too were flows. These assumptions were made because of the limitation of the study data. Table 5.5 details the results.

In addition, it was decided to use the information from ECD, CNS and Wade *et al* sources to calculate the pollution loads into Hunts Bay for the corresponding periods. The average river flows for those years were used in the calculation.

The average discharge for 1992 (obtained from continuous measurement) was used for station RC1, RC5 and RC7. For Rio Cobre at Crum Ewing the average intermittent readings were used. The results are shown in Table 5.6. The results of those calculations were compared with the results from the study.

Table 5.5 Calculation of BOD, NO_3 and PO_4 Loadings (Tonne/yr) for Rio Cobre (April 1, 1993) and a yearly estimate

Sampling Station	River Disch m_3/s	Tonne /day BOD	Tonne /day NO_3	Tonne /day PO_4	Tonne /year BOD	Tonne /year NO_3	Tonne /year PO_4
RC1	0.91	0.16	0.17	0.013	58.4	52.70	4.84
RC5	10.48	1.22	1.59	0.25	445.3	529.95	92.27
RC6	1.36	0.14	0.15	0.029	51.1	51.43	10.69
RC7	7.39	1.15	0.34	0.10	418.40	306.83	34.87
RC9	4.02	0.57	0.38	0.12	208.67	139.11	43.80

Table 5.6 Annual BOD and Nutrient Loading (Tonne/yr) for the Rio Cobre using ECD and CNS Data for 1992

Sta	ECD Tonne/ yr BOD	ECD Tonne/ yr NO_3	ECD Tonne/ yr PO_4	CNS Tonne/ yr BOD	CNS Tonne/ yr NO_3	CNS Tonne/ yr PO_4	Av. Dis. 1992 m_3/s
RC1	593.01	165.71	59.30	130.12	265.58	23.06	2.29
RC5	1165.36	671.21	1021.11	2794.85	650.20	1595.49	7.00
RC7	482.40	277.61	422.32	203.34	213.45	273.06	2.89
RC9	N/A	N/A	N/A	144.23	205.60	65.23	2.41

Graphing the BOD,phosphate and nitrate values (Graphs 5.1 -5.3) shows that the loadings peak in the Bog Walk area and then decreases as the river moves closer to the Harbour. One possible reason for the increased load is due to the merging of the major tributaries in the Bog Walk area. The decrease obverse at Headworks is due to the diversion of the river for irrigation purposes. The diversion ultimately reduces the BOD and nutrient loading which finds its way into the Harbour via the Cobre.

5.3 OTHER POLLUTION SOURCES TO THE BAY

While sampling the RC at the mouth it was observed that another canal the Waterford Gully also carried material into the Bay (Figure 5.1). Data generated from sampling this gully is found in Appendix XIV.

5.4 SUMMARY

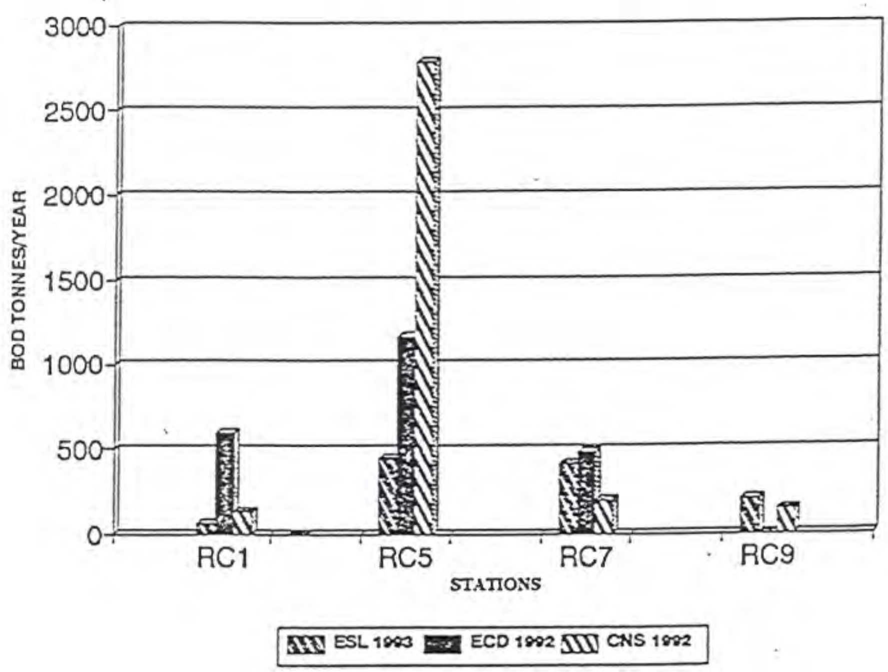
The BOD, nitrate and phosphate annual contribution to the Bay via the Rio Cobre can be said to be within the following range:-

BOD 144.33 - 208.67 tonnes/year

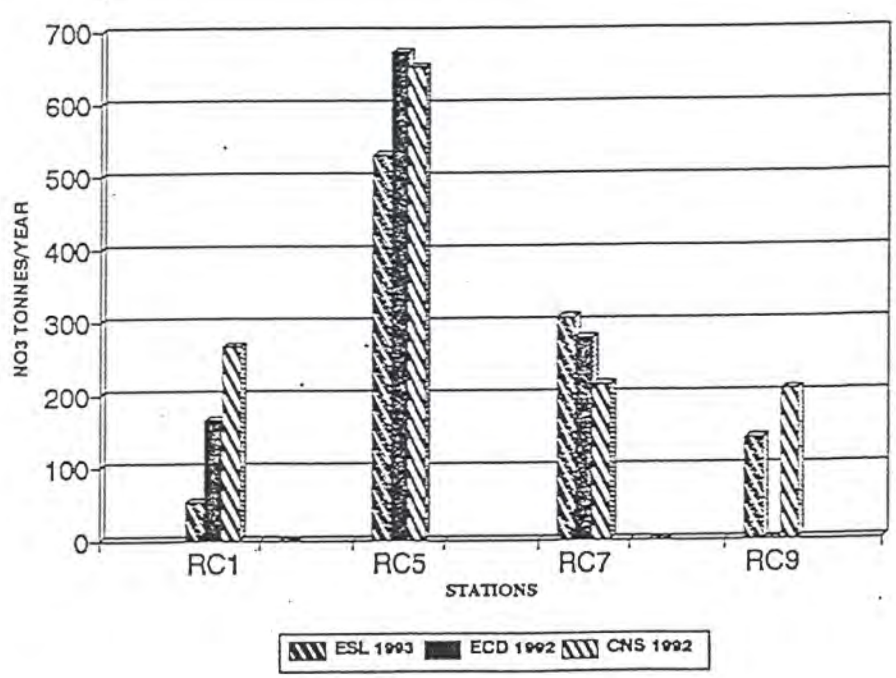
NO_3 139.11 - 205.60 tonnes/year

PO_4 43.80 - 65.23 tonnes/year

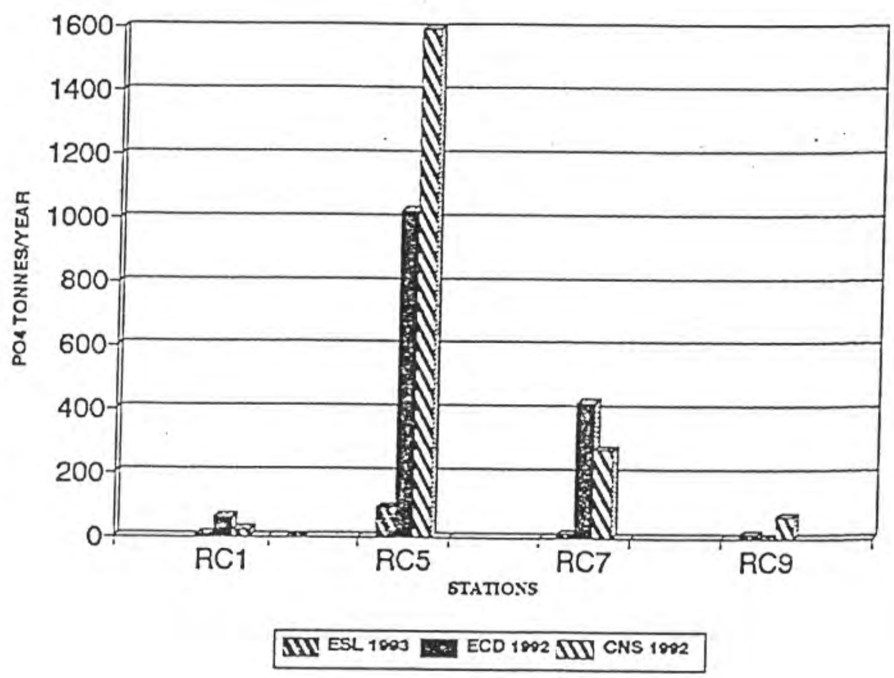
GRAPH 5.1 BOD LOADINGS AT STATIONS ON
THE CORBE GOING TOWARDS HUNTS BAY



GRAPH 5.2 NO3 LOADINGS AT STATIONS ON
THE CORBE GOING TOWARDS HUNTS BAY



GRAPH 5.3 PO4 LOADINGS AT STATIONS ON
THE CORBE GOING TOWARDS HUNTS BAY



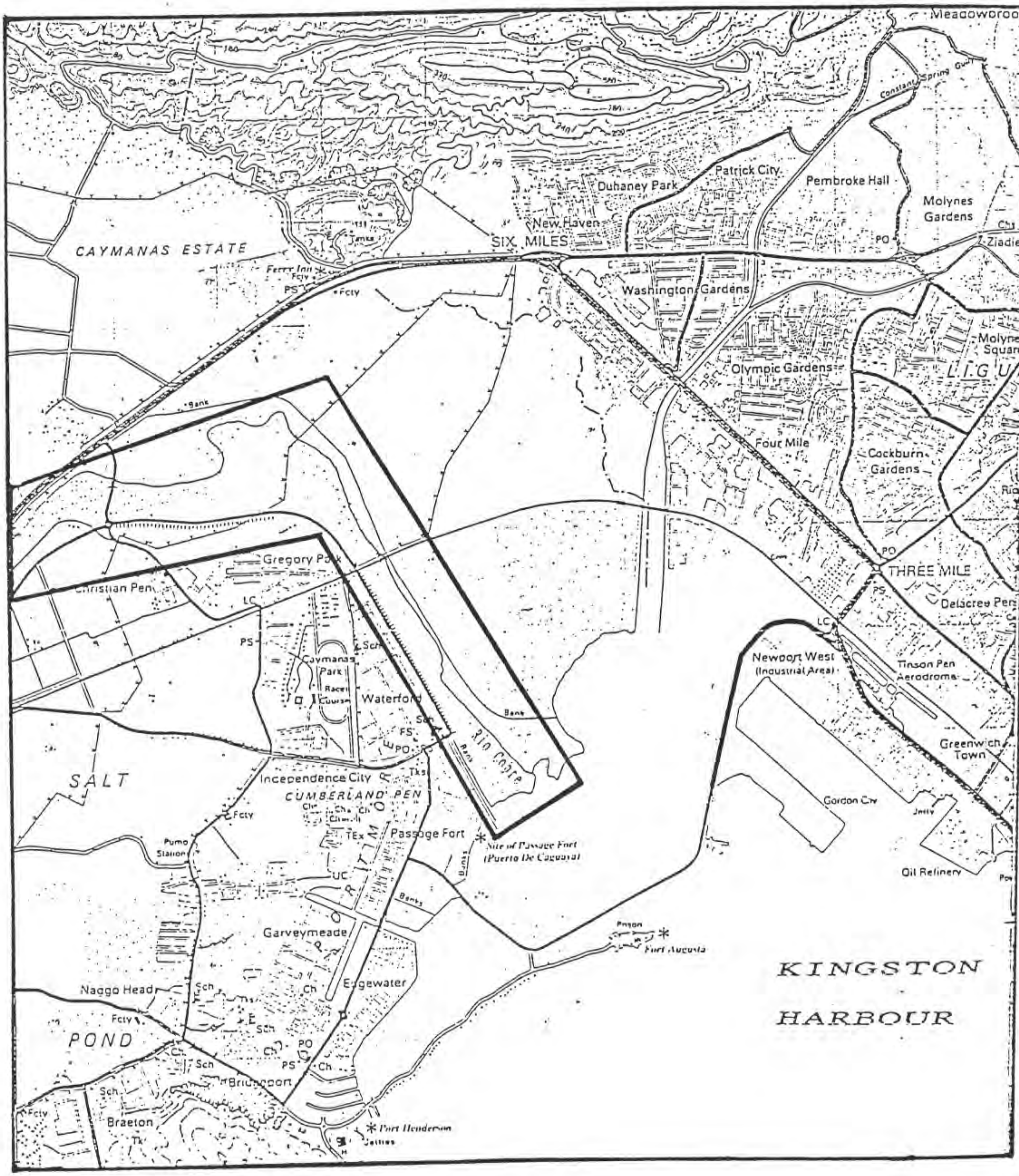


Figure 5.1. Figure showing Waterford Gully.

6. SECTORIAL BOD LOADING

6.1 INDUSTRY

Industries which discharge industrial waste into the Rio Cobre River have for the most part been identified and are listed in Appendix XV.

A review of the study data (Table 5.5) shows that the RC water quality as it enters Linstead (RC3) is in the order of 0.16 BOD tonnes. By the time the river exits Bog Walk (RC5) the figure is 1.22 tonnes BOD. Of the 1.22 tonnes the agricultural contribution can be regarded as 0.14 tonnes BOD from the Rio Pedro (RC6). If one assumes that the domestic loading must be at least equal to that of the Rio Pedro. Industrial loading appears to be the major contributor to BOD in the Bog Walk area can be calculated as follows:-

$$1.22 - 0.16 - (0.14 \times 2) = 0.78 \text{ tonnes BOD/day}$$

or approximately 64% of total value.

However, the calculation is academic as there is no correlation with factory operations. In the case of Spanish Town the other major industrial centre situated on the banks of the RC, while it was possible to identify the industries it was not possible to estimate the BOD contribution because of the lack of information on the volume of industrial waste which enters the RC.

In summary no meaningful estimation of BOD loading by sector was possible for the following reasons:-

a) Volumes of industrial effluent leaving factories unknown.

b) More detailed information required on surface water quality downstream the industries.

c) The study must be correlated to factory operations.

6.2 DOMESTIC

6.2.1 Population Data

The 1992 population data for settlements within a 3 mile radius of the Cobre was supplied by Statistical Institute of Jamaica (STATIN). The communities identified are those where the sewage disposal system most likely emptied into the RC are listed in Table 6.1.

Table 6.1 Population Data (1992) for selected communities in the Rio Cobre Basin

Area	No. of Dwelling	Population	Average person/dwelling
Linstead	3367	14081	4.18
Bog Walk	2399	11401	4.20
Knollis/Tulloch	495	2196	4.43
Dovehall/ Vauxhall	149	617	4.14
Spanish Town	N/A	N/A	N/A
Gordon Pen	1030	4409	4.20
Eltham	1939	6559	3.30
Ensom	2347	5268	2.24
Twickenham Park	1371	5888	4.30
Central Village	1708	7704	4.51

6.2.2 Sewage Treatment Plants (STP)

In the Rio Cobre basin there are a total of eight STP's of different designs and operating efficiencies. Of the eight plants six are under the control of the National Water Commission (NWC), one under the Ministry of Construction and the other, located at the Spanish Town Hospital, is under the control of the Ministry of Health. Table 6.2 summaries the plants design capacities and operating status.

Table 6.2 List of sewage treatment facilities in Rio Cobre Basin Emptying into the river

Location	Type of Plant	Capacity US Gallon/day	Operating Status	Controlled By
Charlemont Housing Scheme	Oxidation Secondary Treatment	162,000	Functional	NWC
New Works	Tile Fields	2,000	Functional	NWC
Knollis	Sand filter Secondary Treatment	30,000	N/A	NWC
Ensom City	Oxidation Secondary Treatment	N/A	N/A	NWC
Eltham	Oxidation Secondary Treatment	N/A	N/A	NWC
Twickenham Park	Oxidation Secondary Treatment	N/A	N/A	NWC
De La Vega	Stabilisation Ponds	N/A	Functional	Ministry of Const.
Spanish Town Hospital	Oxidation Secondary Treatment	N/A	Not working	Ministry of Health

Note Refer to Plates 15 - 22.

6.2.3 Calculation of BOD Loading

It was not possible to obtain from any of the agencies responsible for the 8 plants the following information:-

a) the number of persons/households served by each plant.

b) the capacity of the plants.

c) the quality of effluent being discharged by the plants.

In the absence of sufficient information no attempt was made to calculate loadings.

6.3 AGRICULTURE

The determination of the agricultural contribution was totally dependent on the estimation and/or calculation of the total BOD loading, as well as the industrial and domestic contribution. As stated in Sections 6.1 and 6.2 respectively, it was not possible to determine those values. The agricultural contribution could not be determined.

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PLATES

Plate 1 Sampling point 1 - the Black River at Jericho.

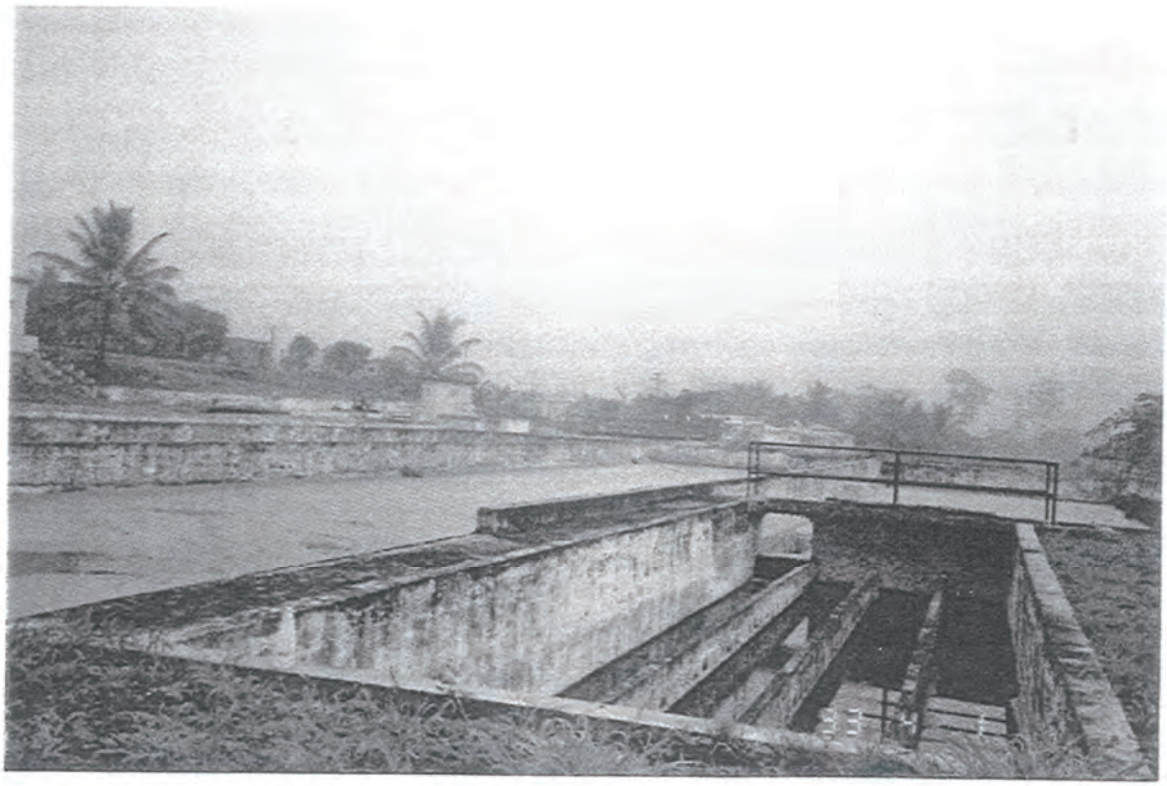


Plate 2 Sampling point 2 - Sewage Treatment Plant at Charlemont Housing Scheme

Plate 3 Healthfield Bridge - Sampling point 3 the mouth of the Rio Cobre outside of Linstead.

Plate 4 Small Farming activity on the banks of the Rio Cobre outside Linstead.

Plate 5 Sampling point 4 - Rio Cobre exiting Linstead, upstream Bog Walk on the United Estates.

Plate 6 Cane and Citrus cultivation on the Banks of the Rio Cobre - United Estates.

Plate 7 Sampling point 5 - the Rio Cobre merger with Thomas and Pedro Rivers outside Bog Walk.

Plate 8 Rio Pedro upstream the Cobre - sampling point 6

Plate 9   Banana cultivation on the bank of the Rio Pedro.

Plate 10   Sand dredging activities on the banks of the Rio Pedro.

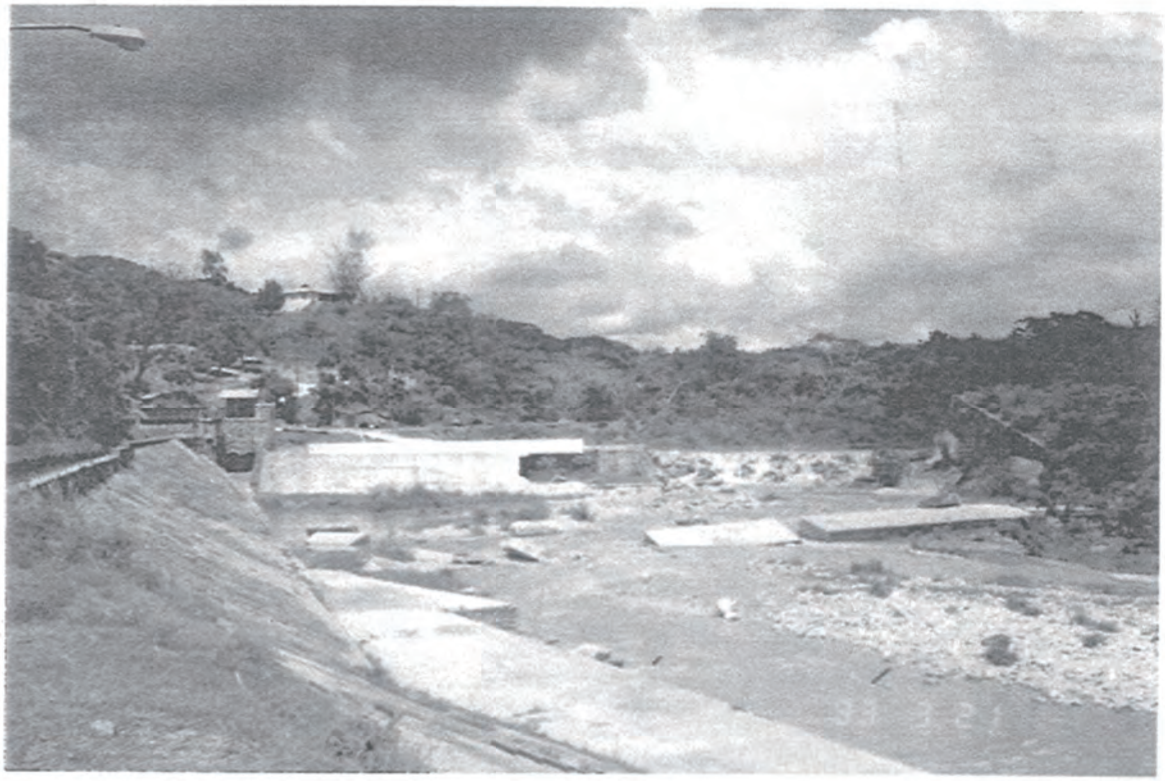


Plate 11   Rio Cobre at Headworks.

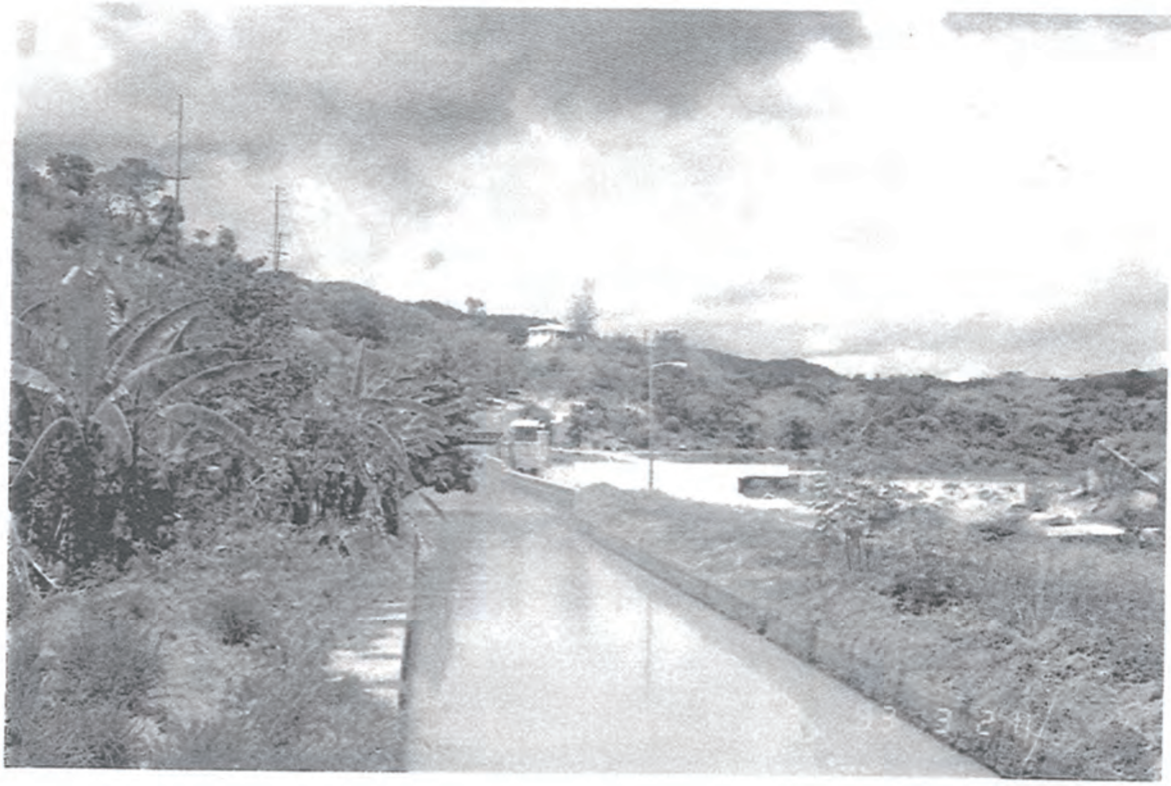


Plate 12   Irrigation Canal, Rio Cobre at Headworks

Plate 13 Sampling point 7 - Rio Cobre at Angels outside Spanish Town

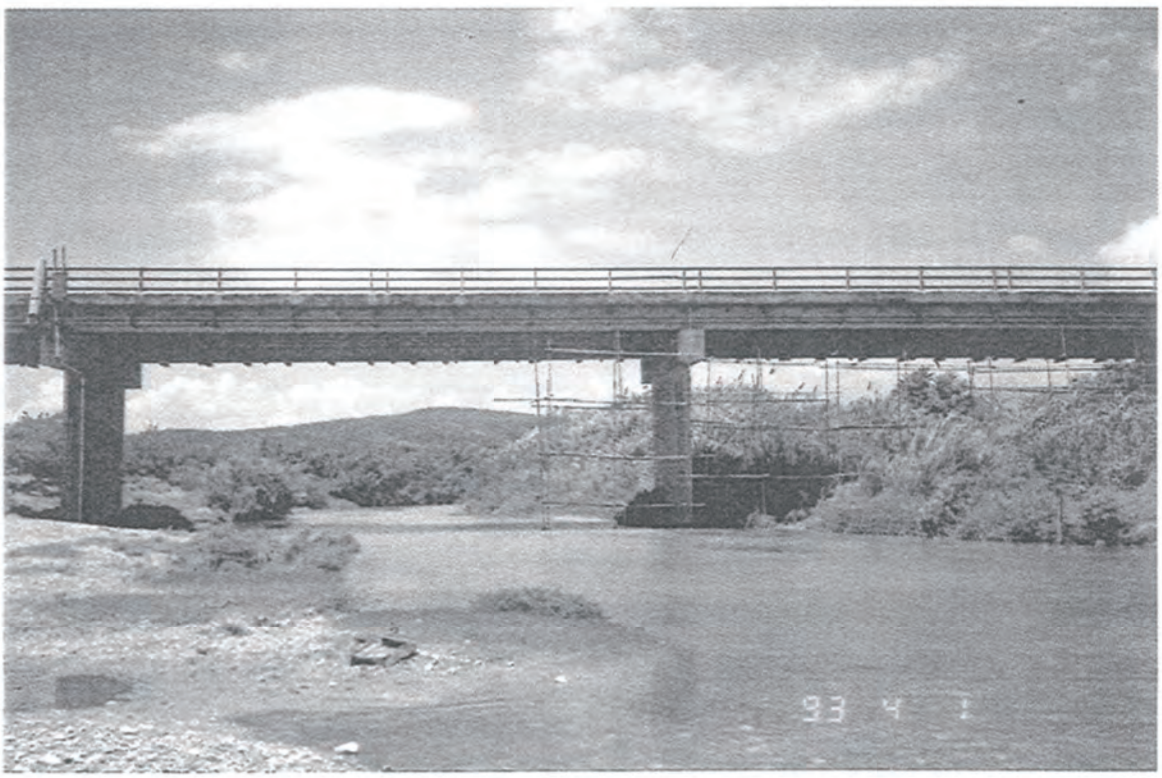


Plate 14 Sampling point 9 - Crum Ewing Bridge.

Plate 15 Charlemont Housing Scheme Sewage Treatment Plant.

Plate 16 Tile fields at New Works.

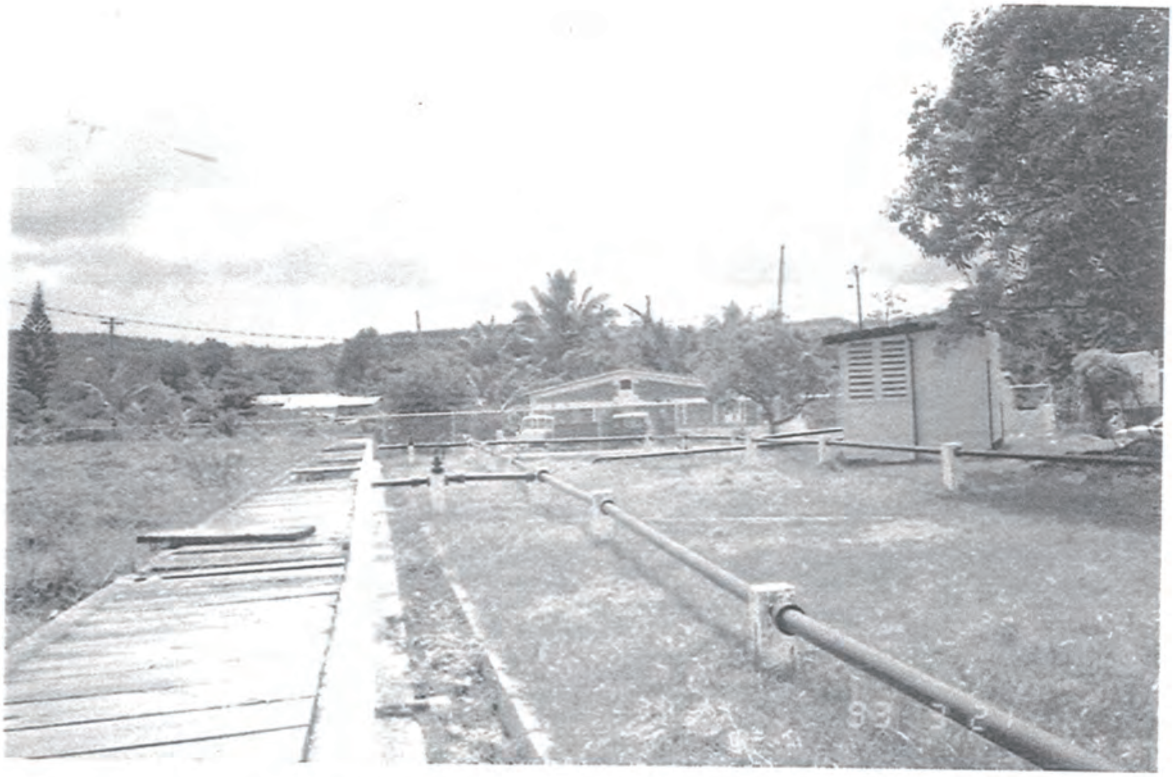


Plate 17 Knollis Sewage Treatment Plant in Bog Walk.

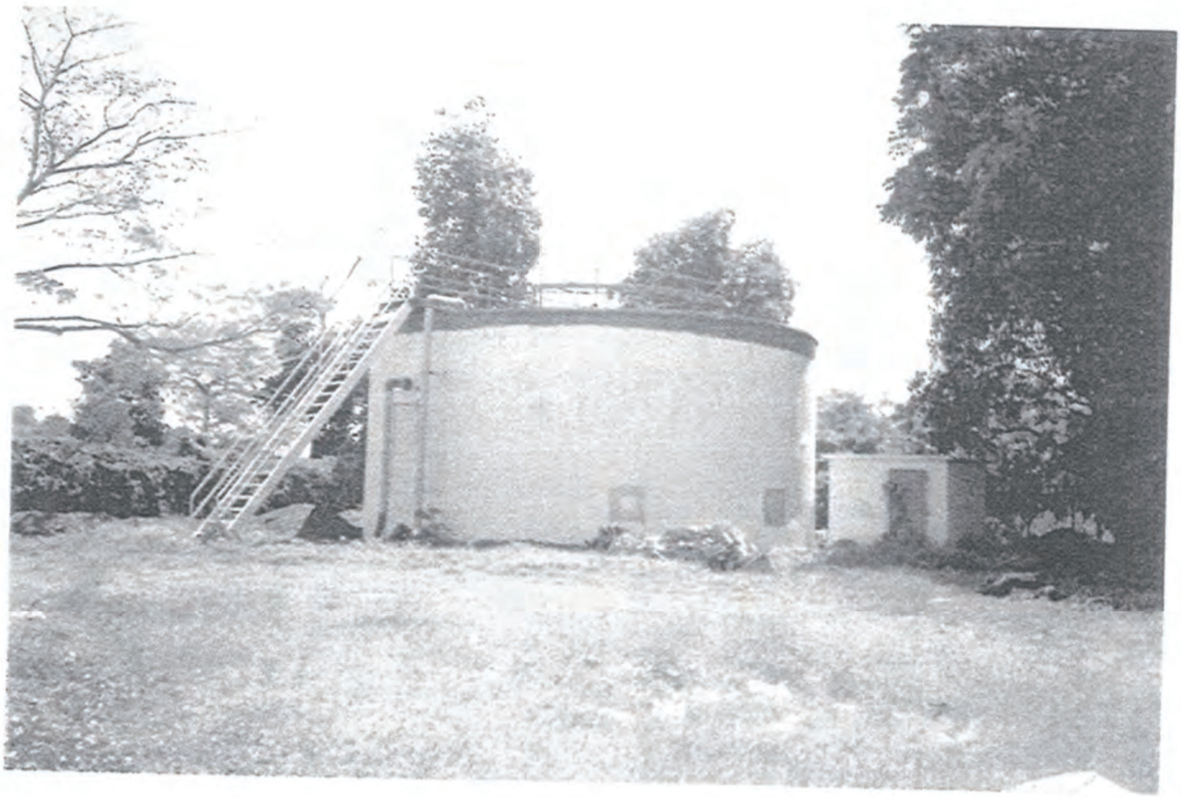


Plate 18 The Spanish Town Hospital Sewage Treatment Plant.

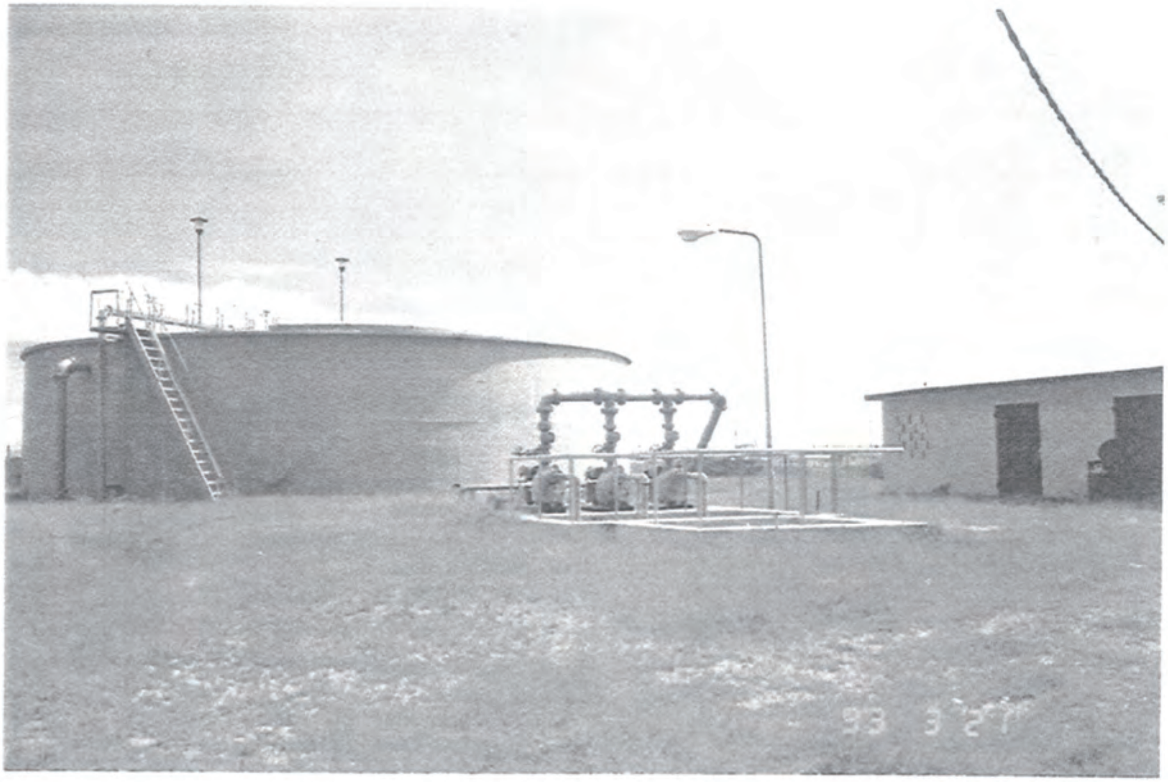


Plate 19   Eltham Sewage Treatment Plant.

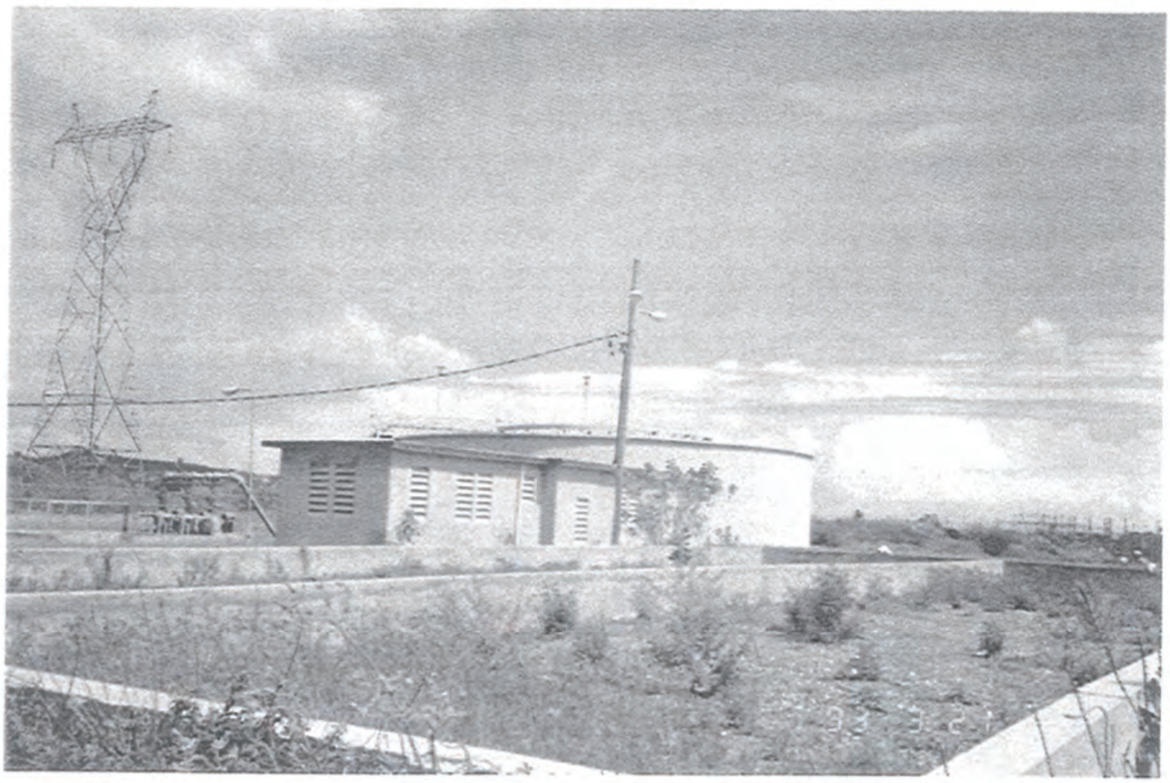


Plate 20   Eltham Sewage Treatment Plant.

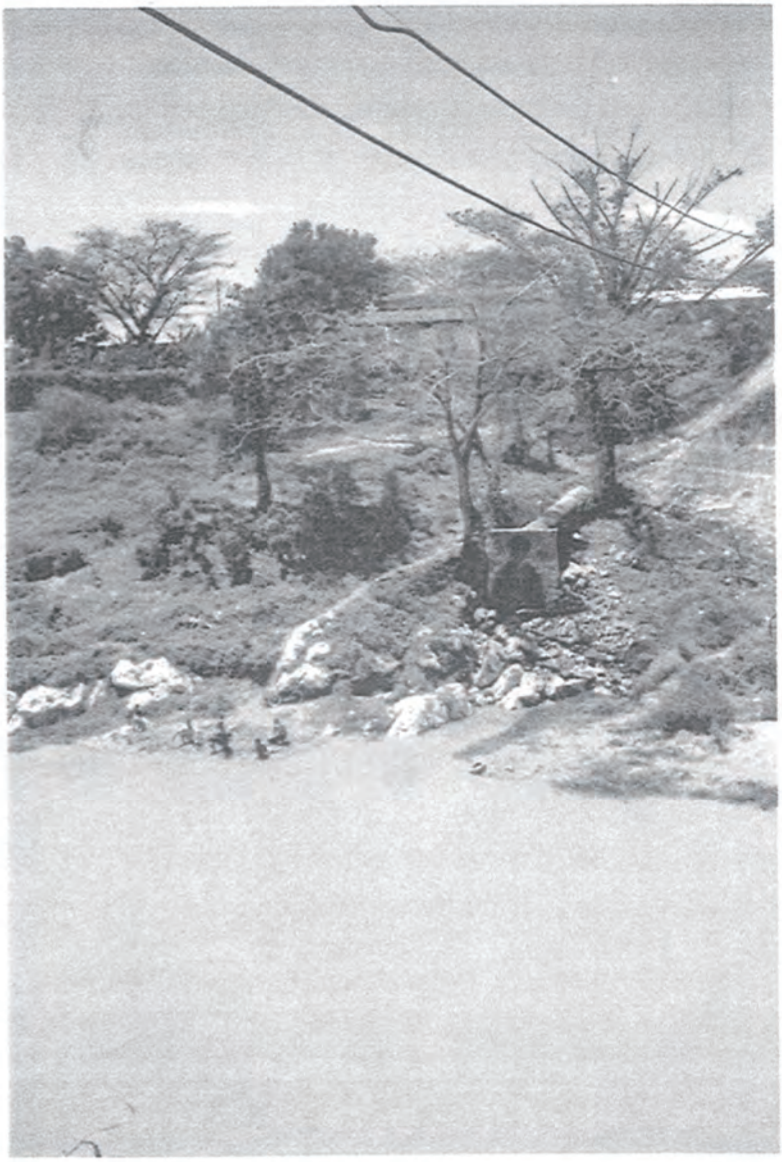


Plate 21 - Culvert taking wastewater into Rio Cobre in Spanish Town.

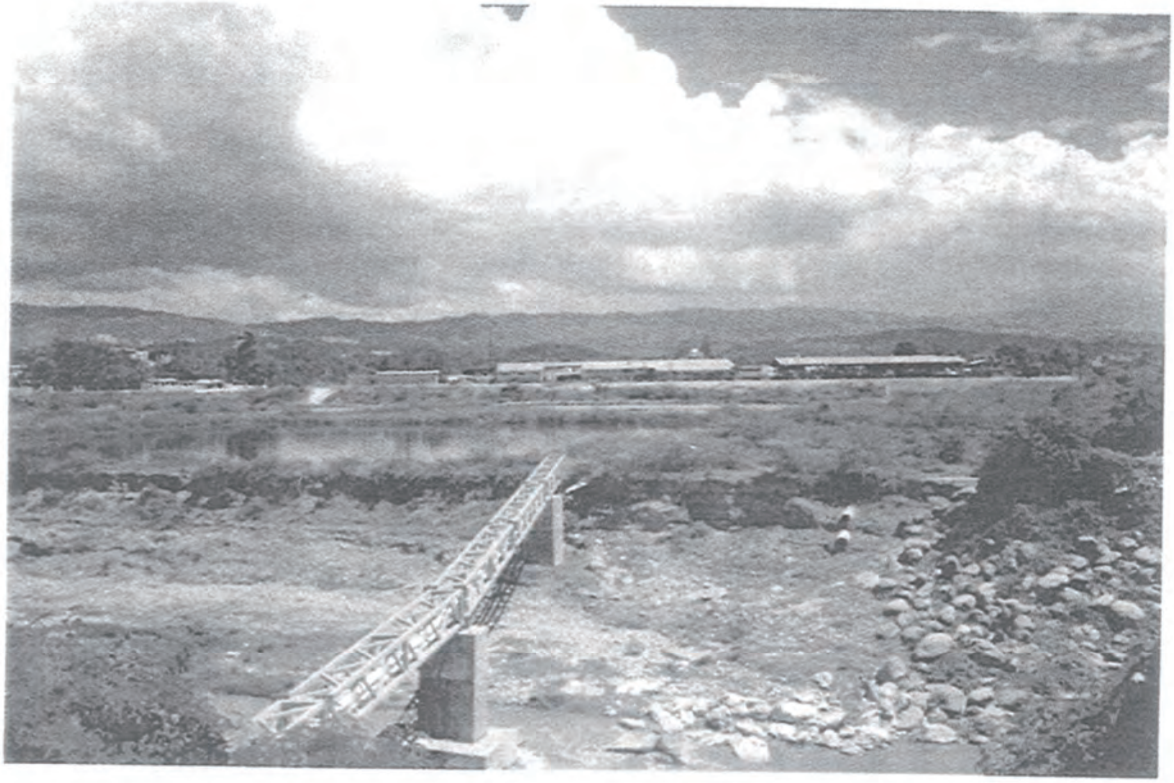


Plate 22 - De La Vega City oxidation Ponds.

APPENDICES

Appendix I Black River - Station Jericho.

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average Yearly Mean (cu. ft/sec.)
1987	0.3	0	0	72.2	160	52	18.9	7.7	10.5	178	462	50.2	84.27
1988	84.8*	100*	14.4	6.6	16.8	12.8	30.6	7.3	314.3+	131.7	55.2	14.1	65.2
1989	12.9	8.05	3.11	1.44	27.38	6.05	0.69	14.19	9.36	10.27	12.42	2.7	9.08
1990	0.29	0.02	0	3.34	37.58	12	12.7	8.8	n/a	n/a	93.5	32	16.7
1991	8.9	2.1	0.53	0.02	721@	135	23.8	5	1.6	5.4	37.4	1.2	79.52
1992	0	0	0	0	96.5	10.7	10.7	23	7.9	169	0	0	80.9

Note: 1988 *Flash Flood
1988 +Hurricane Gilbert
1989 Superceded
1991 @Gorge Flood

Appendix II Indian River - Rio Magno.

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average Yearly Mean (cu. ft/sec.)
1987	6.4	4.9	1.9	4.5	4.4	4.7	1.4	0.7	5.2	16.4	27.9	19.3	8.1
1988	12.5	27.8	9.45	7.36	13.4	26.3	7.85	17.5	77.8	23.2	6.33	16.37	20.89
1989	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	
1990	n/a	n/a	28.8	14.6	4.4	2.2	3.2	1.9	1.5	11.8	27.4	30	12.6
1991	9.4	4	2.2	4.2	105.6	21.2	3.9	4.7	5.3	14.6	15.7	12.7	79.52

Note: 1988 19 days in Dec. available
1988 gorge washed away
1989 not available
1990 gorge washed away

Appendix III Rio Doro - Station Williamsfield.

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average Yearly Mean (cu. ft/sec.)
1987	8.22	7	3.1	3.2	11.1	5	3.1	4.2	14.8	85	12.5	21.5	14.6
1988	49.6*	26.4	99.5	6.7	7.4	246.4	13.2	11.3	38.1	20.4	12.3	24.5	46.32
1989	11.1	7.9	5.9	4.5	6.5	3.6	2.9	2.7	3.9	4.1	11.1	3.2	5.62
1990	5.48	9.24	4.49	10.48	3.59	2.56	8.58	5.28	3.2	43.91	60.3	40.04	16.46
1991	6.7	4.9	4	4.1	17.2	21.4	8.1	5.7	4.8	3.9	13.8	7.7	8.5
1992	3.5	2.5	2.2	4	3.4	6.1	2.3	7	93.7	16.4	0	0	0

Note: 1988 affected by flash flood

Appendix IV Rio Pedro - Station Harker Hall/ Paradise Bridge.

Year	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sep.	Oct.	Nov.	Dec.	Average Yearly Mean (cu. ft/sec.)
1989	53.5	53	39.3	41.3	53	52.3	24	52.4	86	126.2	120	69.5	
1990	n/a	38	36	46	42	22	51	n/a	101	n/a	126	82	
1991	29.2	18.4	14.3	17.9	222.7	51.9	25.7	11.1	14	10.1	41.1	17.7	39.5
1992	0.4	0	0.6	32	18	45	3						

Note: 1989 20 days in Dec.

APPENDIX IV

?? WATER AUTHORITY
?AICA

RIO PEDRO NR HAKKERS HALL (0330001)

MONTHLY MEAN DISCHARGE IN CUBIC FEET PER SECOND

1980 - 1988

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEARLY MEAN
1980	35.7	18.3	8.61	21.53	33.8	38.9	13.29	47.44	81.8	83.8	54.7	143.5	43.4
81	51.1	56.1	28.5	13.84	92.9	59.6	68.5	103.4	117.1	200.7	164.2	57.8	33.7
82	34.9	25.4	18.5	17.43	18.88	25.68	7.18	9.88	28.75	27.46	23.2	8.31	20.32
83	4.56	20.80	3.95	5.39	11.58	14.99	2.81	4.93	8.89	39.41	33.07	6.51	13.88
84	6.92	84.49	16.73	8.45	12.95	41.24	21.82	16.03	92.52	114.2	44.8	18.6	39.9
85	8.17	5.01	3.24	10.37	4.88	1.29	1.93	12.96	32.23	14.99	110.5	10.35	17.99
86	21.74	40.18	9.12	4.99	81.41	267.8	30.8	14.95	20.80	157.5	71.8	27.2	62.2
87	13.65	5.26	8.31	35.45	49.5	39.2	13.06	18.17	87.2	92.8	106.5	36.9	41.4
88	54.4	44.3	19.58	15.25	18.38	38.88	29.66	57.8	383.3	256	88.1	72.5	39.1
	25.68	33.37	12.85	14.66	35.93	58.52	19.94	31.55	94.56	109.53	76.55	42.44	45.2
	54.42	84.49	28.45	35.45	92.87	267.88	68.48	103.39	383.38	255.58	164.23	143.55	89.1
	4.56	5.01	8.31	4.99	4.88	1.29	1.93	4.93	8.89	14.99	23.17	6.51	13.8
	18.82	24.38	8.75	8.99	30.21	75.67	17.46	30.39	105.13	77.13	42.16	41.75	26.1

APPENDIX V

.ROUND WATER AUTHORITY
'ON, JAMAICA

15/12/9.

RIO COBRE AT BOG WALK (03BA012)

MONTHLY MEAN DISCHARGE IN CUBIC FEET PER SECOND

	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEARLY MEAN
71' – 73	368	388	218	193	262	184	195	211	386	464	781	358	313
	313	265	176	178	356	346	245	246	319	678	321	465	326
	255	231	227	211	168	242	215						228
86	—	—	—	193.8	789.6	3255	489	338	384	543	361	235	722
87	284	163	139	624	554	428	314	327	384	683	1288	438	454
88	547	528	318	238	272	326	271	332	* 2,245	893	685	652	442
89	325	254	252	381	392	388	289	236	339	451	423	227	318
90	287	223	245	332	383	289	344	248	332	435	689	532	346
91	229	158	147	132	— N/A	—	—	—	—	—	—	227	138
	~~278~~	267	214	266.8	386.1	661	285	275	~~344~~	593	614	396	369
	~~368~~	528	318	624.1	789.5	3255	439	332	~~386~~	893	1288	652	722
	~~284~~	158	139	131.6	168.3	184	195	211	~~384~~	435	321	227	138
	~~58~~	185	56	138.9	186.5	983	91	49	~~31~~	156	273	155	158
92	164	188	155	349	255	283	88	245	332	452	N/A	N/A	[illegible]

* HURRICANE GILBERT

UNDERGROUND WATER AUTHORITY

APPENDIX VI

RIO COBRE NR SPANISH TWN (03BA003)

MONTHLY MEAN DISCHARGE IN CUBIC FEET PER SECOND

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	YEARLY MEAN
1954											316	100.5	238.2
1955	24.01	129.0	3.03	4.53	19.37	132.1	191.6	92.6	141.29	313	91.9	37.6	102.5
1956	9.75	3.04	4.55	16.83	65.25	208.44	125.77	192.1	175.3	569.1	284.2	108.1	146.9
1957	47.61	3.75	16.72	12.76	65.43	42.63	32.10	15.72	164.64	253.8	55.75	20.90	60.99
1958	152.98	6.20	4.97	2.47	277.02	422	173	209.3	266	2103	335	248	350
1959	125.5	43.5	5.73	34.82	106.21	56.84	9.50	14.67	13.21	82.55	24.15	588	92
1960	170.0	45.71	14.52	190.92	118.2	1018.6	247	148.1	139.4	334.2	565	313	275
1961	101.0	63.8	9.74	37.36	26.94	32.26	59.81	8.84	147.72	614.8	357	509	164
1962	221.0	75.6	15.88	108.31	142.01	232.8	103.5	115.8	175.3	284.4	390	225.2	174.2
1963	58.5	26.86	46.13	66.51	292.11	624	145.2	171.6			1155	619	320
1964	301	151	78.2	100.0	86.7	190.0	166.3	281.5	279	492	198.7	94.5	201.6
1965	16.15	0.90	2.54	5.54	82.7	72.24						106.6	41.0
1966	83.87	5.79	11.20	23.50	97.25	1360.10	805	205.7	254.3	565	785	203.5	366.7
1967	68.4	35.6	16.38	46.09	3.58	4.48	10.19	4.18	31.15	48.33	20.46	2.58	24.2
1968	2.30	1.97	1.97	2.02	8.25	11.93	23.76	19.30	16.77	191.56	215.0	22.85	43.14
1969	3.17	1.43	3.02	6.40	237.17	1776	479.0	183.94	641	558	934	196	418
1970	393.1	58.0	33.32	34.20	430.52	202.0	128.8	205.0	411	557	1815	315	382
1971	158.3	111.8	34.5	32.83	134.29	23.93	27.16	65.74	250.90	343.1	496	111.5	149.2
1972	141.9	23.59	2.81	35.87	147.39	142.73	27.45	72.45	138.23	588	108.5	260.1	134.1
1973	79.0	44.47	54.59	40.88	2.05	54.87	55.08	117.90	316.8	2024	461	520	314
1974	172	155.6	298.8	87.7	71.5	66.6	19.86	79.33	655	539	593	296	257
1975	93.0	49.1	30.2	7.05	38.14	28.26	32.92	64.58	350.8	204	478	175.6	129.3
1976	109.1	23.28	30.13	42.78	13.37	11.71	6.34	17.25	26.06	71.62	34.66	13.62	33.33
1977	3.31	2.29	4.60	10.88	119.34	85.66	20.25	40.04	113.50	175.5	47.94	65.79	57.4
1978	56.05	54.01	23.8	43.69	149.9	258.5	68.13	74.64	98.6	807	288	103.3	168.8
1979	40.9	157.9	99.6	438.7	706	933	411	337	1727	769	571	280	539
1980	176	127.5	79.9	111.2	108.6	154.1	35.2	280.0	224.8	228	135.7	519.6	181.7
1981	155.3	89.3	40.6	23.8	249.5	183.2	154.2	465.1	329	613	734	262	275
1982	121.7	104.1	48.0	40.6	82.6	79.9	39.9	71.9	81.6	95.5	46.5	24.2	69.7
1983	24.5	81.9	43.50	2.91	19.88	68.5	17.33	20.14	41.60	81.1	71.59	31.0	42.0
1984	29.10	112.39	83.60	11.63	39.80	152.0	79.7	80.8	171.0	259	275.1	37.0	111.0
1985	40.7	80.1	77.15	64.2	65.8	46.0	33.8	85.7	77.8	90.95	685	81.6	119.1
1986	194.0	251.4	75.3	129.6	436.8	2910	386	251	206	326	228	126.3	459.9
1987	84.7	40.2	48.4	315.7	404	263	165	166	1802				185
1988	400	357	76.46	109.5	78.8	173.2	97.21	126.5	2281.0	552	287	364	409
1989	110.8	140.9	79.1	56.6	161.3	112.1	49.3	65.5	120.9	159.9	191.9	83.6	111.0
1990	70.6	85.50	88.5	178.0	117.3	28.6	126.77	41.7	114.1	232.7	396	334	151
1991	70.1	53.1	55.5	14.37				236	188	112.9	212.1	123.1	118.4
1992	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]
MEAN	111.07	75.62	44.41	67.31	144.59	339.21	130.05	128.57	301.41	447.34	385.53	203.37	194.4
MAX	399.58	357.17	298.82	438.71	706.19	2909.50	805.06	465.13	2280.97	2103.13	1814.50	619.48	539.4
MIN	2.30	0.90	1.97	2.02	2.05	4.48	6.34	4.18	13.21	48.33	20.46	2.58	24.3
STDV	95.93	73.59	51.92	88.90	148.99	585.28	162.86	104.77	448.77	455.94	361.15	171.34	131.7

APPENDIX VII Summary of monthly data - Flow

Station number : 3021402 Name : RIO COBRE MAIN CANAL

Basin no. : 0 Latitude : 0: 0: 0 N Longitude : 0: 0: 0 E Altitude : 0.0
Area : 1.0

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Mean
1961	203.	207.	208.	189.	183.	177.	184.	176.	172.	136.	162.	200.	183.
1962	199.	186.	188.	193.	176.	195.	204.	211.	218.	211.	181.	189.	196.
1963	193.	194.	191.	170.	172.	119.	197.	205.	208.	107.	97.6	115.	164.
1964	168.	179.	191.	197.	188.	171.	204.	184.	179.	150.	175.	206.	183.
1965	203.	194.	197.	208.	194.	170.	190.	208.	197.	207.	195.	163.	194.
1966	192.	175.	156.	160.	160.	164.	166.	209.	219.	119.	139.	200.	172.
1967	211.	212.	212.	171.	169.	172.	162.	183.	194.	197.	178.	138.	183.
1968	148.	124.	97.0	88.1	102.	111.	111.	108.	121.	145.	175.	182.	126.
1969	143.	138.	107.	104.	111.	151.	189.	209.	198.	191.	192.	195.	161.
1970	190.	188.	192.	155.	122.	190.	165.	147.	177.	173.	127.	166.	166.
1971	187.	172.	169.	160.	140.	162.	168.	149.	196.	170.	128.	144.	162.
1972	156.	171.	168.	145.	172.	133.	164.	161.	176.	140.	180.	156.	160.
1973	163.	179.	178.	162.	144.	151.	153.	167.	153.	132.	170.	129.	157.
1974	149.	158.	136.	155.	145.	154.	134.	183.	122.	130.	143.	147.	146.
1975	161.	166.	144.	138.	128.	146.	137.	142.	123.	117.	96.5	105.	133.
1976	102.	109.	110.	105.	103.	110.	85.5	113.	111.	126.	131.	94.9	108.
1977	119.	127.	126.	143.	140.	124.	130.	139.	166.	103.	141.	147.	134.
1978	148.	146.	189.	214.	220.	169.	167.	178.	166.	118.	131.	128.	165.
1979	119.	77.4	84.7	84.3	94.2	104.	140.	151.	88.6	107.	120.	149.	110.
1980	139.	86.3e	113.	106.	101.	118.	134.	95.4	138.	121.	152.e	133.	120.
1981	135.	-	129.	103.	103.	-	149.	135.	114.	152.	-	-	-
1982	132.	126.	120.	117.	119.	98.0	77.5	72.1	88.7	94.7	108.	97.2	104.
1983	94.5	120.	139.	90.2	129.	146.	92.8	87.4	124.	114.	124.	187.	121.
1984	122.	102.	132.	130.	146.	122.	119.	155.	159.	133.	169.	149.	136.
1985	73.1	72.9	64.0	62.7	55.3	63.4	57.8	60.9	56.1	47.5	32.5	51.4	58.1
1986	45.6	43.7	53.7	54.7	36.4	46.0	73.5	43.7	65.4	142.	101.	101.	67.3
1987	87.9	106.	80.3	80.2	40.8	73.2	82.7	111.	115.	82.3	86.0e	90.8	86.2
1988	97.4e	91.2e	142.	105.	148.	145.	172.	199.e	133.	190.	220.	199.	154.
1989	190.	158.	173.	165.	146.	158.	146.	138.	124.	162.	147.	143.	154.
1990	95.7	127.	142.	176.	129.	144.	143.	165.	165.	146.	119.	95.0	137.
1991	122.	132.	140.	121.	82.8	0.0	5.71	54.5e	57.4	110.e	66.4e	99.5	82.5
1992	88.1	91.6	86.5	122	65.1	112	93.2	x	-	-	64		

Summary of monthly data - Flow

Station number : 3021402 Name : RIO COBRE MAIN CANAL

Basin no. : 0 Latitude : 0: 0: 0 N Longitude : 0: 0: 0 E Altitude : 0.0
Area : 1.0

	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual Mean
Mean	145.	142.	144.	137.	132.	133.	139.	146.	146.	138.	140.	143.	140.
St.d	43.1	43.7	42.6	43.3	43.6	44.0	47.0	48.7	46.4	37.3	41.3	40.4	
CV	0.298	0.307	0.295	0.315	0.330	0.331	0.339	0.333	0.318	0.271	0.296	0.282	

Mean monthly flow in cubic ~~metres~~ ft per second

Data flags

Missing - flag "-" Original - no flag Estimate - flag "e"

Limit to missing daily data permissible [5]

Printed on 3/ 3/1993

APPENDIX VIII

9-192-a. July 1937

Daily Gage Height, in Feet, and Discharge, in Second-Feet, of Rio Cañe (Black r.) River / Creek

At / Near Linstead (Jemilo.) for the year Ending December 31, 1993

Drainage Area.............Square Miles. Water-Stage Recorder............ Ratio............

Max. Disch..........Sec. ...ft. on........(G. H..........ft.). Max. G. H..........ft. on..........

Min. Disch..........Sec.-ft. on........(G. H..........ft.). Min. G. H..........ft. on..........

Calendar Year 1993

Day	January Gage height	January Discharge (cfs)	February Gage height	February Discharge	March Gage height	March Discharge	April Gage height	April Discharge	May Gage height	May Discharge	June Gage height	June Discharge
1		.40		7.3		0.4		32				
2		.10		5.1		0.3		30				
3		.64		4.0		0.2		24				
4		.52		2.9		0.4		20				
5		4.92		2.5		8.7		16				
6		3.4		2.3		5.4		15				
7		1.78		105.		2.5		13				
8		2.5		130		1.0		39				
9		.88		70		0.8		34				
10		1.36		49		0.4		19				
11		1.6		30		0.4						
12		.88		20		0.4						
13		.20		14		11						
14		.12		10		28						
15		0		8.7		6.2						
16		0		7.3		3.0						
17		0		5.6		2.0						
18		.5		5.6		32						
19		0		4.8		132						
20		0		4.0		89						
21		0		3.7		147						
22		0		3.4		153						
23		0		4.2		99						
24		.05		6.2		82						
25		0		5.9		67						
26		45		11		58						
27		228		12		51						
28		73		2.0		45						
29		45				38						
30		24				48						
31		11				39						
Total		448.8		536.5		1151						
Mean		14.5		19.2		37.1						
Second-feet per square mile												
Run-off in inches												
feet												
Maximum		228		130		153						

APPENDIX IX

Daily Gage Height, in Feet, and Discharge, in Second-Feet, of KIO FEERD River ~~Creek~~

At Near HARKERS HALL for the year Ending December 31, 1993

Drainage Area........ Square Miles. Water-Stage Recorder........ Ratio........

Max. G. H. .... ft. at .... on ...., Min. G. H. .... ft. on .... (G. H. .... ft.). Max. Disch. .... sec.-ft. at .... on .... (G. H. ....). Min. Disch. .... sec.-ft. on ....

CALENDAR YEAR 1993

Day	January Gage height	January Discharge	February Gage height	February Discharge	March Gage height	March Discharge	April Gage height	April Discharge	May Gage height	May Discharge	June Gage height	June Discharge
1		54		44		13		48				
2		58		39		11		67				
3		17		36		10		49				
4		10		34		12		35				
5		12		32		17		30				
6		8.5		31		22		44				
7		9.8		125		12		50				
8		0		71		95		103				
9				47		8		53				
10				32		8.5		34				
11				33		12						
12				30		6.8						
13				28		5.9						
14				26		13						
15				22		7.0						
16				22		6.8						
17				21		5.9						
18		0		20		6.1						
19		9.8		19		6.1						
20		0		18		29						
21				18		132						
22				20		55						
23				15		26						
24				14		22						
25		0		27		28						
26		326		30		21						
27		559		20		24						
28		98		15		30						
29		68				83						
30		56				130						
31		53				22						
Total		1399.1		897		8336						
Mean		45.1		32.0		26.9						
Second-feet per square mile												
Run-off in inches												
feet												
Maximum		559		125		132						
Minimum		0		14		5.9						

Daily Gage Height, in Feet, and Discharge, in Second-Feet, of RIO COBRE River ~~Creek~~

At ~~Near~~ BOG WALK for the year Ending December 31, 1993

Drainage Area 205.00 Square Miles. Water-Stage Recorder .... Ratio ....

Max. G. H. .... ft. on .... Min. G. H. .... ft. on .... (G. H. .... ft.) Max. Disch. .... Sec.-ft. on .... (G. H. .... ft.) Min. Disch. .... Sec.-ft. on ....

Day	January Gage height	January Discharge (cfs.)	February Gage height	February Discharge	March Gage height	March Discharge	April Gage height	April Discharge	May Gage height	May Discharge	June Gage height	June Discharge
1		318		228		207		370				
2		291		225		210		335				
3		282		216		213		335				
4		300		210		213		335				
5		279		207		213		335				
6		255		204		216		410				
7		246		750		216		335				
8		243		402		219		760				
9		240		363		222		1271				
10		243		304		240		1275				
11		237		216		216						
12		234		231		219						
13		231		210		675						
14		231		201		482						
15		228		204		279						
16		300		207		240						
17		291		201		240						
18		291		201		249						
19		285		201		258						
20		285		204		261						
21		282		219		1208						
22		270		222		1080						
23		267		216		990						
24		267		219		930						
25		267		219		870						
26		2895		216		430						
27		1620		213		410						
28		579		210		410						
29		538				370						
30		530				430						
31		530				370						

Calendar Year 1993	January	February	March	April	May	June
Total	13355	6919	12786			
Mean	431	247	412			
Second-feet per square mile						
Run-off in inches						
feet						
Maximum	2895	750	1208			
Minimum	228	201	207			

TENTATIVE APPENDIX XI

9-192-a. July 1937

Daily Gage Height, in Feet, and Discharge, in Second-Feet, of RIO COBRE River ~~Creek~~

At/Near OVER DAM (NR. SPANISH TOWN) for the year Ending December 31, 19 93

Drainage Area .... Square Miles. Water-Stage Recorder .... Ratio ....

Max. G. H. .... ft. on .... Min. G. H. .... ft. on .... (G. H. .... ft.). (G. H. .... ft.). Max. Disch. .... Sec.-ft. on .... Min. Disch. .... Sec.-ft. on ....

CALENDAR YEAR 1993

DAY	JANUARY c/s Gage height	JANUARY Discharge	FEBRUARY Gage height	FEBRUARY Discharge	MARCH Gage height	MARCH Discharge	APRIL Gage height	APRIL Discharge	MAY Gage height	MAY Discharge	JUNE Gage height	JUNE Disch.
1		38		194		102						
2		209		202		88						
3		222		191		94						
4		153		177		85						
5		180		181		77						
6		154		178		101						
7		148		256		107						
8		142		351		81						
9		132		174		67						
10		132		225		62						
11		132		203		68						
12		124		193		54						
13		130		184		22						
14		140		184		22						
15		132		169		65						
16		131		158		66						
17		129		142		91						
18		134		139		66						
19		154		136		95						
20		150		140		118						
21		150		130		266						
22		150		132		307						
23		158		131								
24		152		124								
25		154		120								
26		129		120								
27		909		112								
28		355		104								
29		212										
30		215										
31		196										
TOTAL		5646		4750								
Mean		182.13		169.64								
Second-feet per square mile												
Run-off in inches												
feet												

Daily Gage Height, in Feet, and Discharge, in Second-Feet, of Rio Cobre Migui Canal River / Creek

~~At~~ Near Spanish Town for the year Ending December 31, 1993

~~Drainage Area~~ .... Square Miles. Water-Stage Recorder .... Ratio ....

Day	January Gage height	January Discharge	February Gage height	February Discharge	March Gage height	March Discharge	April Gage height	April Discharge	May Gage height	May Discharge	June Gage height	June Discharge
1		47		60		113		109				
2		50		50		122		108				
3		66		53		80		117				
4		73		69		128		118				
5		79		58		117		121				
6		80		63		35		117				
7		75		59		40		120				
8		84		52		73		121				
9		79		55		81		126				
10		75		57		81		129				
11		76		55		83						
12		73		59		82						
13		79		55		79						
14		72		66		77						
15		7[illegible]		54		85						
16		76		72		87						
17		73		99		88						
18		63		102		80						
19		59		93		63						
20		58		81		72						
21		47		99		80						
22		53		89		71						
23		47		81		72						
24		58		78		91						
25		51		121		97						
26		41		117		96						
27		39		118		88						
28		39		111		97						
29		44				97						
30		55				102						
31		63				104						
Total		1954		2126		2661						
Mean		63		76		86						
Second-feet per square mile												
Run-off in inches												
feet												
Maximum		84		121		128						
Minimum		39		50		35						

Max. G. H. ...... ft. on ...... , Min. G. H. ...... ft. on ......

Max. Disch. ...... Sec.-ft. on ...... Min. Disch. ...... Sec.-ft. on ......

Calendar Year 1993

9-192-a. July 1937

APPENDIX XIII

Daily Gage Height, in Feet, and Discharge, in Second-Feet, of Rio Cobre River

At / Near Camp Ewing for the year Ending December 31, 1992

Drainage Area .... Square Miles. Water-Stage Recorder .... Ratio ....

DAY	JANUARY Gage height	JANUARY Discharge	FEBRUARY Gage height	FEBRUARY Discharge	MARCH Gage height	MARCH Discharge	APRIL Gage height	APRIL Discharge	MAY Gage height	MAY Discharge	JUNE Gage height	JUNE Discharge
1		87		233		87		142				
2		104		235		82		127				
3		91		212		77		122				
4		85		192		67		122				
5		85		171		61		117				
6		78		163		60		113				
7		72		569		60		113				
8		66		473		58		117				
9		64		405		56		113				
10		64		330		43		113				
11		62		302		47						
12		61		156		54						
13		59		144		60						
14		60		142		92						
15		63		142		84						
16		74		130		100						
17		85		109		134						
18		111		104		178						
19		93		93		235						
20		84		105		214						
21		78		111		595						
22		75		129		490						
23		72		134		411						
24		74		134		277						
25		70		134		183						
26		70		130		227						
27		1020		129		199						
28		398		96		235						
29		420				302						
30		308				252						
31		[illegible]				199						
Total		4403		5286		5234						
Mean		142.03		182.8		168.84						
Second-feet per square mile												
Run-off in inches												
feet												
Maximum		1020		569		595						

Max. G. H. .... ft. on ....

Min. G. H. .... ft. on ....

(G. H. .... ft.). Max. Disch. .... Sec.-ft. on ....

(G. H. .... ft.). Min. Disch. .... Sec.-ft. on ....

CALENDAR YEAR 1992

Appendix XlV

TEST RESULTS WATERFORD GULLY

SAMPLE NOS.	B.O.D. (mg/l)	NITRATE (mg/l)	PHOSPHATE (mg/l)	pH	SS (mg/l)	SALINITY 0.00
JW 1	15.00	0.44	4.50	8.07	89.90	8.50
JW 2	89.07	1.32	0.08	8.25	184.00	12.50
JW 3	26.25	0.66	15.60	8.41	56.50	0.30

SUMMARY OF INDUSTRIES IMPACTING ON RIO COBRE

Area/Name of Factory	Ques.	Data Water Consum.	Volume Wastewater	Method of Disposal
1) Linstead/Bog Walk				
Coffee Industry	X			
Nestle Ja Ltd	X			
JCG Ltd	+	+	+	RC
United Estates	X			
Content Beef	X			
2) Twickenham Park/ Spanish Town				
Scotts Perserve	+	+	X	RC
Rickett & Coleman	+	+	X	Absorp. Pit
Cigarette Co of Ja	+	+	X	X
Thermo Plastics	+(2)	+	X	Gutter/ Pit
Ja. Carpet Mills	X			
West Indies Synthetics	+	+	X	Soak Away
Berec	+	+	X	X
Carib Pipe Co	X			
Matrix Chemicals	X			
Matrix Ice	+	+	X	Soak Away
Acco	+	+	X	Soak Away
Plas Pak.	+	+	X	X

Area/Name of Factory	Ques.	Data Water Consum.	Volume Wastewater	Method of Disposal
Alcan Sproston	+	+	X	RC
Caribbean Foods	+	+	X	RC
West Indies Yeast	+	+	+	RC
ICI	X			
Betapac	+	+	X	Soak Away
Grace Food Processors	+	+	X	Gully
Caribbean Steel	+	+	+	RC
Specialist Manufacturing	+	+	X	X
3) White Marl/ <u>Spanish Town</u>				
Jamaica Broilers	+	+	X	Soak Away
Sherwin Williams	+	X	X	X
Gator Ja Ltd	+	+	X	RC
Guiness Ja Ltd	X			
BRC	+	+	X	X

<u>KEY</u>

+ some information available

X no information supplied

APPENDIX II

Profile of Duhaney River above Six Mile Bridge - Pollution Loading

II. PROFILE ON DUHANEY RIVER ABOVE SIX-MILE BRIDGE POLLUTION LOADING

II.1 INTRODUCTION

Earlier project assessment of Harbour pollution loading from the Duhaney River, based on water samples taken below the Six-Mile Bridge, revealed the presence of high levels of pollutants. In order to determine possible sources of this pollution above the main highway, an investigation of the Upper Duhaney River was undertaken.

This investigation seeks to identify, through an area survey and river sampling program, the nature of the pollutants that enter the Upper Duhaney River and the point sources of this pollution; thus, their contribution to the pollution characteristics of the river discharge to the Kingston Harbour may be assessed.

From its source at the foothills of the Ferry Pen Mountain, the Duhaney River flows east and then south through a series of wetlands to the "Six Miles" area. The total length is approximately 11 kilometres. As the river flows south, it passes through a low income residential community, a section of New Haven called Riverside Gardens. Domestic waste from this community is expected to be a major contributor of pollution to the Duhaney River (see Figure 1).

Two gullies discharge into the Upper Duhaney River, the Northern and Southern gullies. The Northern gully flows from east to west along the foothills of Mount Patience and receives storm drainage from the communities of New Haven, Duhaney Park and Meadowbrook Estate. The Southern gully is along Washington Boulevard and is fed by runoff from the Duhaney Park and Cooreville Gardens areas. Unlike the Northern gully which only discharges when it rains, the Southern gully provides a constant waste stream to the Duhaney River.

II.2 METHOD OF ASSESSMENT

Five site visits were made to the Upper Duhaney River drainage area. On the first visit, the sampling points were established and a tour was made of the river channel and the gully courses. On subsequent visits, a random survey of the types of sewage disposal facilities and grey water disposal methods was carried out. Pictures were taken of items of interest to this study. Five sample sites were chosen. Three of these sites are located on the main course of the Duhaney River and the other two on each of the gullies (see Map 1).

Samples were collected and analyzed for the following parameters:

- BOD
- Nitrates
- Phosphates
- Total and Fecal Coliform

Repeat samples were taken for BOD and nitrates and analysis done at the laboratories of the Natural Resources Conservation Authority (NRCA) and the Petroleum Corporation of Jamaica (PCJ). Analysis for total and fecal coliform was done at the Environmental Control Division (ECD) of the Ministry of Health.

II.3 DISCUSSION

At the times of our visits, the mouth of the Northern gully was blocked with garbage and growing plants (see Plates 1 and 2) and according to residents, this has been the case for the past two years. When it rains, as it had been over the period leading up to this survey, the water in the gully backs up and flows over into sections of the community and then through the wetlands and eventually into the Duhaney River.

Sewage from the malfunctioning Duhaney Park sewer system flows into storm drains which discharge to this gully at approximately 1.5 kilometres from the blocked entrance to the Duhaney River (see Plates 3, 4, 5 and 6).

The Northern gully also serves as an illegal disposal area for garbage. Presently liquid waste in the gully is partially stagnant and discharge is to the wetlands at the confluence of the gully and the Duhaney River.

It appears from visual observation and from the water sample results that this wetland is serving to reduce the volume and level of pollutants that enters this northern section of the Duhaney River during low rainfall periods. At sample point #2, the Duhaney

River is relatively clean and a number of fishermen fish in this location. Moving south, however, the river becomes increasingly polluted.

Most residential activity adjacent to the Duhaney River takes place between sample point #2 and the Six-Mile Bridge. Approximately 90% of the dwellings in this vicinity have pit latrines, while the other 10% use soakaway pits. In some cases, these facilities are located as close as four metres away from the river.

A broken sewer just south of the New Haven pumping station results in a constant stream of raw sewage to storm drains, which drain to the Duhaney River (see Plates 7, 8, 9 and 10).

A pig farm with approximately 30 pigs is located on the eastern bank of the Duhaney River below sample point #2. All the waste is discharged to the river.

The Southern gully is also a major point source of pollution to the Duhaney River. It receives wastewater from the surrounding residential communities as well as from light manufacturers located in the area. It is alleged that sewage from cooreville Gardens also enters this gully; however, this was not verified.

II.4 TEST RESULTS

Three sets of water sample analyses are presented in Tables 1, 2 and 3. Table 1 represents samples taken during the evaluation of the Upper Duhaney River at the locations shown on Figure 1. These results indicate the degree of pollution above the Six-Mile Bridge.

Tables 2 and 3 represent earlier sampling carried out at different times, immediately south of the Six-Mile Bridge and adjacent to the Cremo Milk Factory, respectively. These test results offer a comparison of pollution levels above and below the Six-Mile Bridge.

It should be noted that the coliform counts reported in Table #1 had an upper count of 2,400 while those reported in Table #2 indicated 24,000 as the upper count. It is therefore possible that the results in Table #1 could actually be over 24,000.

II.5 CONCLUSIONS

Tests carries out, although limited, indicate that a significant portion of the Harbour pollution loading from the Duhaney River is contributed by sources in the upper reaches of the river above the Six-Mile Bridge. observations and test results also indicate that the major source of pollution is from human waste, with some contribution from agriculture and small home industries.

It should be noted that the general area is sewered except for some fringe slum development between sample point #2 and the Six-Mile Bridge. Observations and local information, however, indicate that due to regular malfunction of the sewage lift stations, raw sewage is regularly discharged to storm drains which drain to the Duhaney River.

Proper operation of the sewerage facilities in the area will contribute to the reduction of pollution. However, the areas of slum development which are on marginal land unsuitable for planned development, will continue to be a source of pollution unless the occupants are relocated. Facilities such as the pig farm could be managed in a way which would eliminate direct discharge to the river. The dumping of solid waste can be eliminated through monitoring.

TABLE II.1

DUHANEY RIVER
SAMPLE ANALYSIS
(Above Six-Mile Bridge)

	DATE	SAMPLE POINT	BOD (mg/L)	N-N03 (mg/L)	P-PO4 (mg/L)	T.COLI. (MPN)	F.COLI. (MPN)
N	16/06/93	1	34.80	1.29			
N		2	1.00	0.76			
N		3	2.50	1.13			
N		4	3.20	1.20			
N		5	0.80	0.59			
P	30/06/93	1	3.15	1.32	0.102		
P		2	0.80	0.81	0.086		
P		3	2.30	1.32	0.089		
P		4	3.75	1.32	0.086		
P		5	3.35	0.40	0.096		
E	09/07/93	1				>2,400	>2,400
E		2				>2,400	>2,400
E		3				>2,400	>2,400
E		4				>2,400	>2,400
E		5				>2,400	>2,400

LEGEND

N NRCA Lab
P PCJ Lab
E ECD Lab

TABLE II.2

EARLIER DUHANEY RIVER SAMPLE ANALYSIS

(Southern Side of the Six-Mile Bridge)

DATE	SAMPLE POINT	BOD (mg/L)	N-N03 (mg/L)	P-PO4 (mg/L)	T.COLI. (MPN)	F.COLI. (MPN)
03/03/93	South Side Of Six-Mile Bridge	17.3	0.04	-	>24,000	1,100
10/03/93	South Side Of Six-Mile Bridge	27.7	0.07	-	>24,000	9,200

Extract from U.W.A. water sampling for Riverton Leachate Study
Testing by University Of West Indies Botony Lab

TABLE II.3

EARLIER DUHANEY RIVER SAMPLE ANALYSIS
(Below Six-Mile Bridge, adjacent to Cremo Milk Factory)

DATE	SAMPLE POINT	BOD (mg/L)	N-N03 (mg/L)	P-PO4 (mg/L)	T.COLI. (MPN)	F.COLI. (MPN)
29/07/92 (Low Flow)		14.5	0.5	0.007	-	-
19/08/92 (Low Flow)		155.8	2.18	0.17	-	-
10/92 (High Flow)		105.8	4.81	0.21	-	-
29/11/92 (Low Flow)		90.83	3.86	0.02	-	-
Low Flow Average		87.04	2.18	0.014	-	-

Extract from Appendix 1 (Station 3 results)
Phase 1 Report, Volume 2

Plate 1

Plate 2 - Plates 1 and 2; The Northern Gully blocked with garbage and vegetation.

Plate 3 - Duhaney Park lift station.

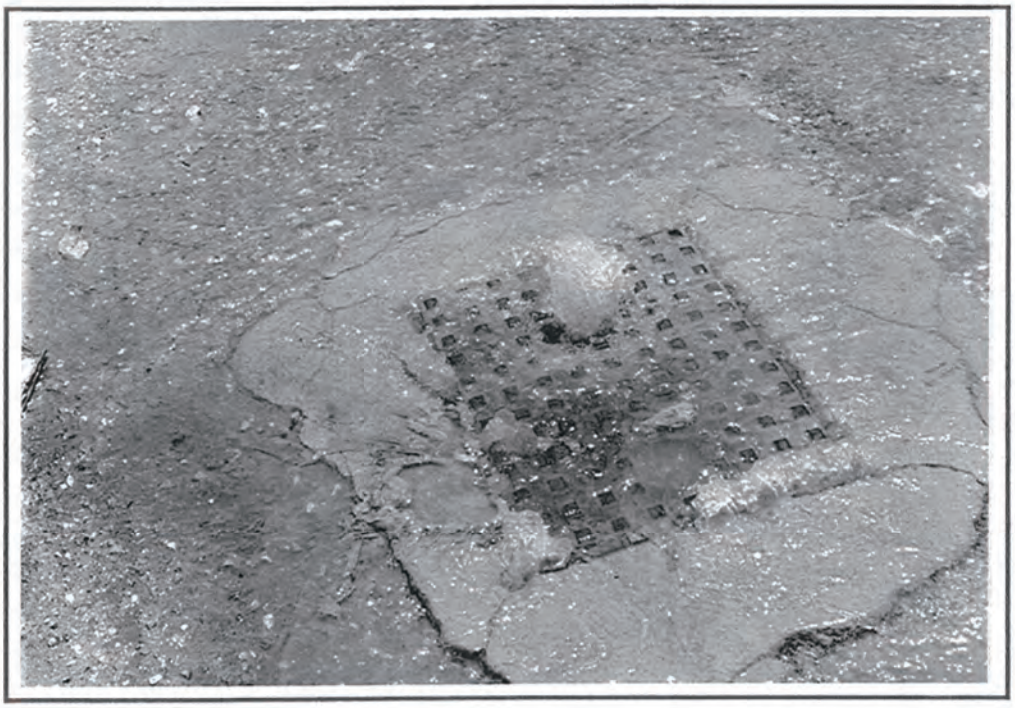


Plate 4

Plate 5

Plate 6 - Plates 4, 5, 6; Sewage emanating from surcharged sewer and entering storm drains. Note the retired Duhaney Treatment Plant in the background.

SENTAR

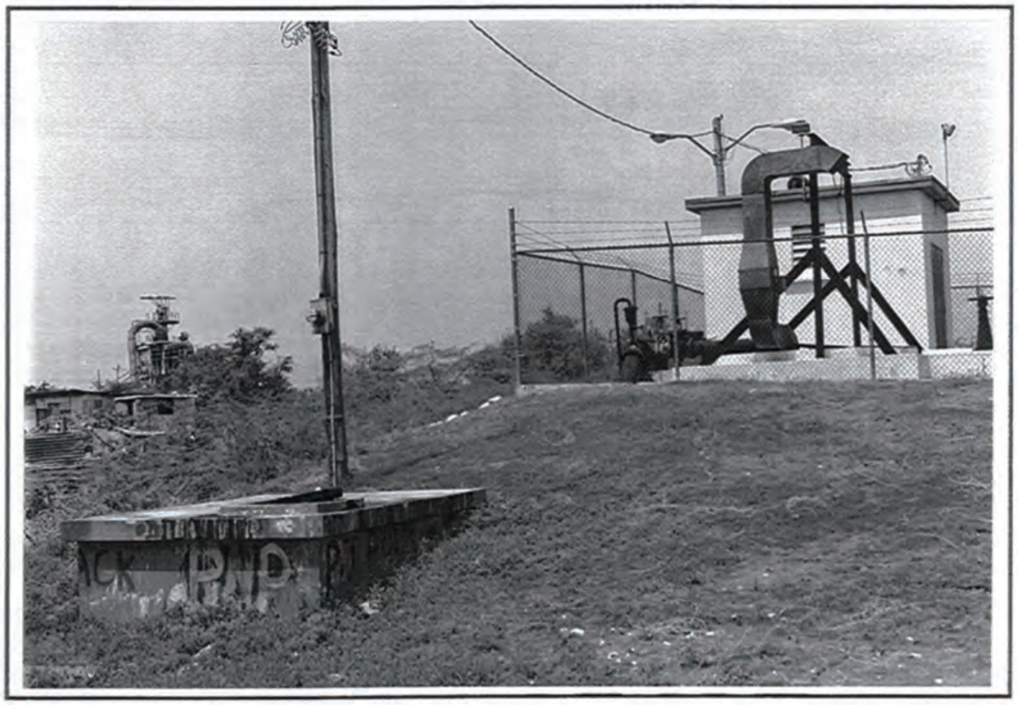


Plate 7 - New Haven pumping station.

Plate 8

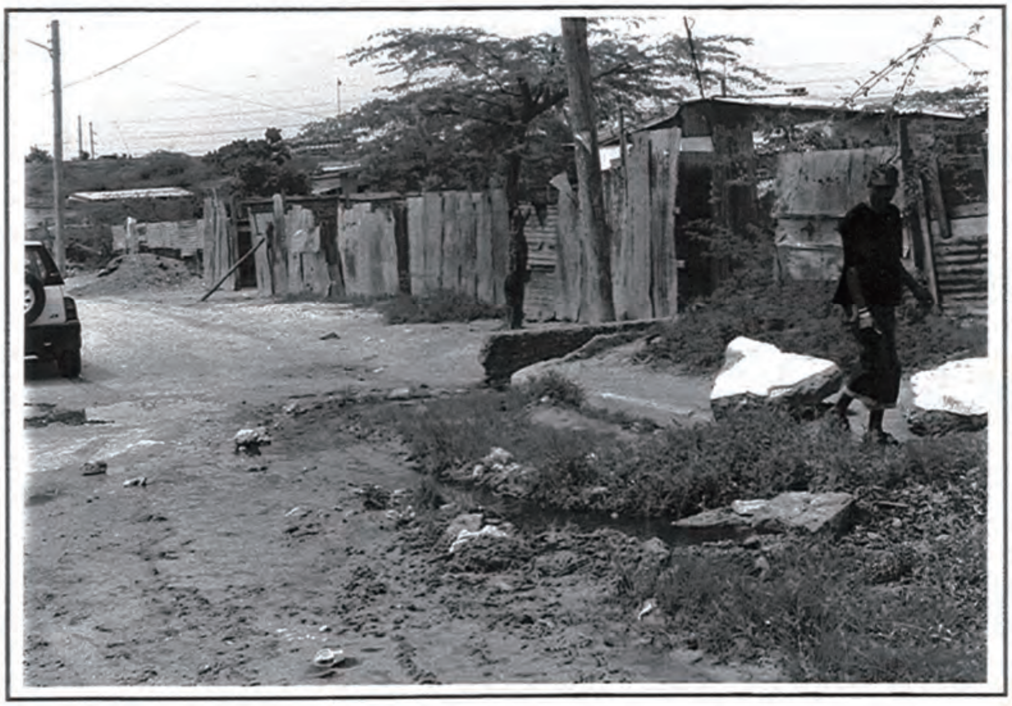


Plate 9

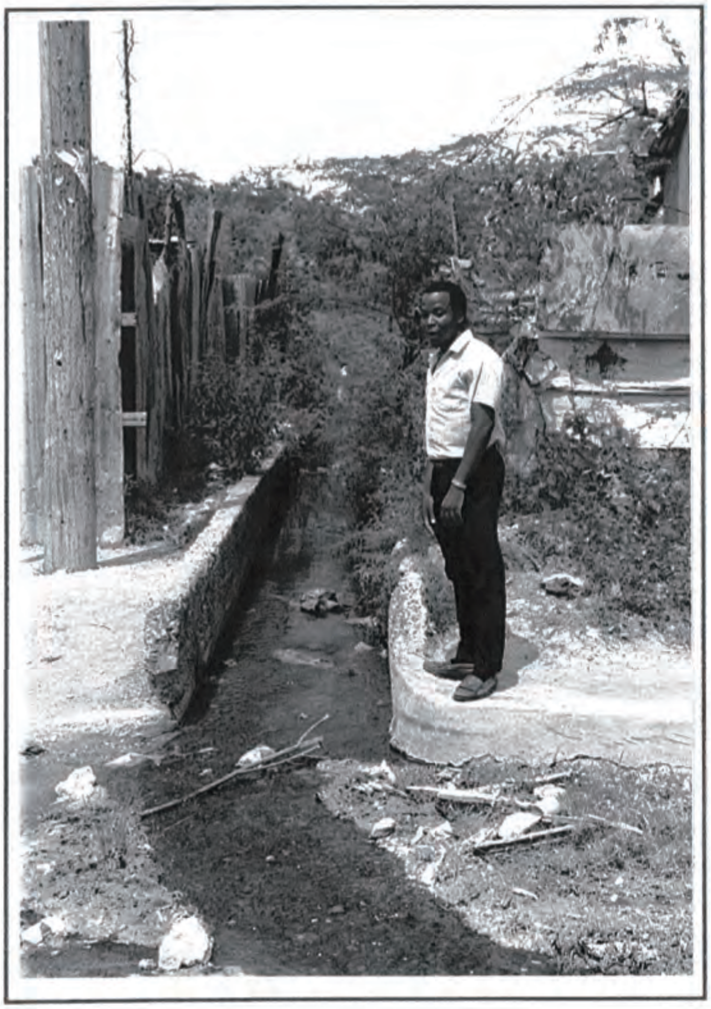
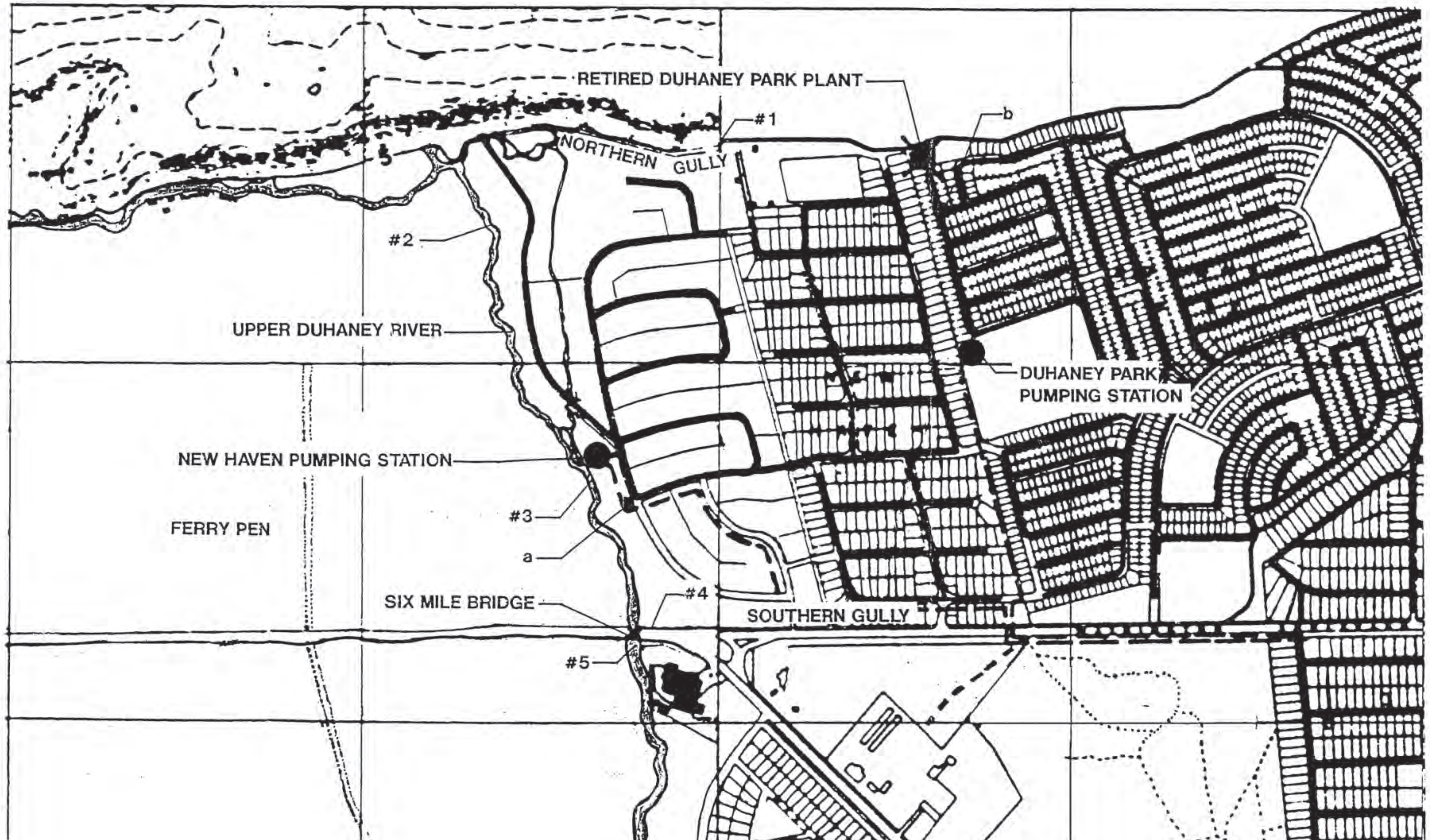


Plate 10 - Plates 8, 9, 10; Sewage from sewer flows to the Duhaney, south of the New Haven pumping station.

Plate 11 - The wetlands overflows onto the road in Riverside Gardens.

Plate 12 - View of the Duhaney River from the Six Mile bridge looking north.

SENTAR



NORTH

KEY

#1	SAMPLE POINT
a	PLATES 8, 9 & 10
b	PLATES 4, 5 & 6

FIGURE II.1
KINGSTON HARBOUR ENVIRONMENTAL PROJECT
Map of Upper Duhaney River
(Not to scale)

APPENDIX III

UWA Communication Regards Fate of Pollutant Loading on Groundwater and Surface Water Due to Soakaways in St. Andrew Hills

III. UWA COMMUNICATION REGARDS FATE OF POLLUTANT LOADING ON GROUNDWATER AND SURFACE WATER DUE TO SOAKAWAYS IN ST. ANDREW HILLS

SENTAR requested advice from UWA on the probable fate of pollutant loading, especially nitrates, arising from soakaway disposal of sewage in the St. Andrew Hills. The purpose of the request was to determine whether this results in loading to the Duhaney River; to the Liguanea Aquifer; to the underlying limestone aquifer; and/or to Kingston Harbour. UWA's communication of their assessment follows.

> As urban development continues within KMR, housing development has moved into the St. Andrew Hills. These hills are primarily composed of limestone rocks, which have a high development of secondary permeability, with conduit flow being the main flow component. The limestone Hills act as recharge areas for the limestone reservoir areas down gradient where groundwater development has been concentrated. The development of secondary permeability in the limestone enhances the soakaway capability and the use of soakaway pits to dispose of sewage is the preferred method.
>
> The limestone aquifer dips steeply toward the sea. This aquifer is overlain by alluvium deposited by the Hope River and the Rio Cobre. The alluvial deposits are also classified as an aquifer and wells have been constructed tapping this aquifer. The limestone aquifer, has been tapped in the northern section around Havendale and Meadowbrook, where the aquifer outcrops at the surface. It is not tapped further south because of the great depth at which it lies below the alluvium. This depth is in excess of 200 metres, the depth of the deepest well on the plain.
>
> Already there are signs of increasing nitrate concentration in the limestone wells such as:
>
> 1) Havendale 1
> 2) Havendale 2
> 3) Forest Hills
> 4) Chancery Hall

Water quality assessments indicate that in May 1974 all four wells had nitrate concentration of < 10 mg/l. Since the 1980's up to 1993 the following nitrate concentrations were noted.

Well Name	No_3 (mg/l) - Date	No_3 (mg/l) - Date
Chancery Hall	20 - 02/80	20.4 - 93
Havendale 2	20 - 05/84	21.7 - 92
Havendale 1	20 - 05/84	No data
Forest Hills	23 - 08/85	19.1 - 92

These values represent a 100% increase in No_3 concentration over a 10 year period (from 1974) although the No_3 concentrations do not differ significantly between the 1980 and 1990's.

Between the underlying limestone and the overlying alluvium is a thick layer of clay. This clay layer prevents mixture of water between both aquifers so that the alluvium with high No_3 concentration cannot contaminate the waters with low No_3 concentration in the limestone aquifer.

There is no doubt that the limestone aquifer drains out to sea. However, whether it goes directly to the coastal waters or drains indirectly into these waters is still not accurately determined. However, since the Havendale, Meadowbrook, Chancery Heights areas form a part of the Rio Cobre Basin lower limestone, and based on groundwater contours/flow net analysis, the preferred flow path is towards the Duhaney River and into Kingston Harbour. The springs at Six Miles that support flow in the Duhaney River, are partially fed with recharge from the St. Andrew Hills.

The nitrate concentration of the springs that support river flow as well as the Duhaney River could be coming from the limestone hills of St. Andrew.

Soakaway systems installed in the Long Mountain area, also an aquifer, would join ground water flowing south-east to the Rockfort area culminating in springs along the limestone aquifer/limestone aquiclude boundary in that area.

APPENDIX IV

Kingston Abattoir Waste Discharge Review

IV. KINGSTON ABATTOIR WASTE DISCHARGE REVIEW

During the Phase 1 survey of industrial discharges undertaken for SENTAR by Conrad Douglas and Associates, observed conditions at the Kingston Abattoir were thought not to be typical. Notably, although the facility is served by a sanitary sewer connection, on-site pretreatment systems were found to be disfunctional, with a discharge of bypassed waste to a storm drain. Although the discharge was obviously extremely heavily laden with solids and distasteful materials, because the discharge was reported to be atypical, the resultant Harbour loading was <u>not</u> included in the cumulative estimate of Harbour loading.

During subsequent discussions of the Phase 1 Report results it was concluded that the conditions were <u>not</u> atypical, and that a further effort was needed to better assess this facility.

Accordingly, Mr. Anthony McKenzie, seconded to the Project by NRCA, undertook a further assessment of the Abattoir. His report follows.

> Untreated water, offal and uncollected garbage have left the Municipal Abattoir in an unsanitary condition. Apart from the irregular collection of offals, there is a large pool of water contaminated with animal waste at the entrance to the abattoir on Darling Street.
>
> Between November and December 1992, 2,588 animals were slaughtered and in January 1993, 1,196 animals were killed.
>
> It is estimated that 30,000 gallons per day of water is consumed in the slaughter and washing of these animals. The effluent goes untreated by way of storm water drains to the Kingston Harbour in the vicinity of the Wysinco Fishing Complex. Effluent from the abattoir formerly entered the NWC's Darling Street pumping station, but presently the septic tanks at the abattoir are in need of maintenance so the effluent is diverted to the Harbour. This has been the case on and off for a number of years.

Water is supplied to the abattoir by way of a well on the property supplemented by the NWC.

The attached map shows the approximate location of the abattoir and point of effluent discharge to the Kingston Harbour.

SENTAR

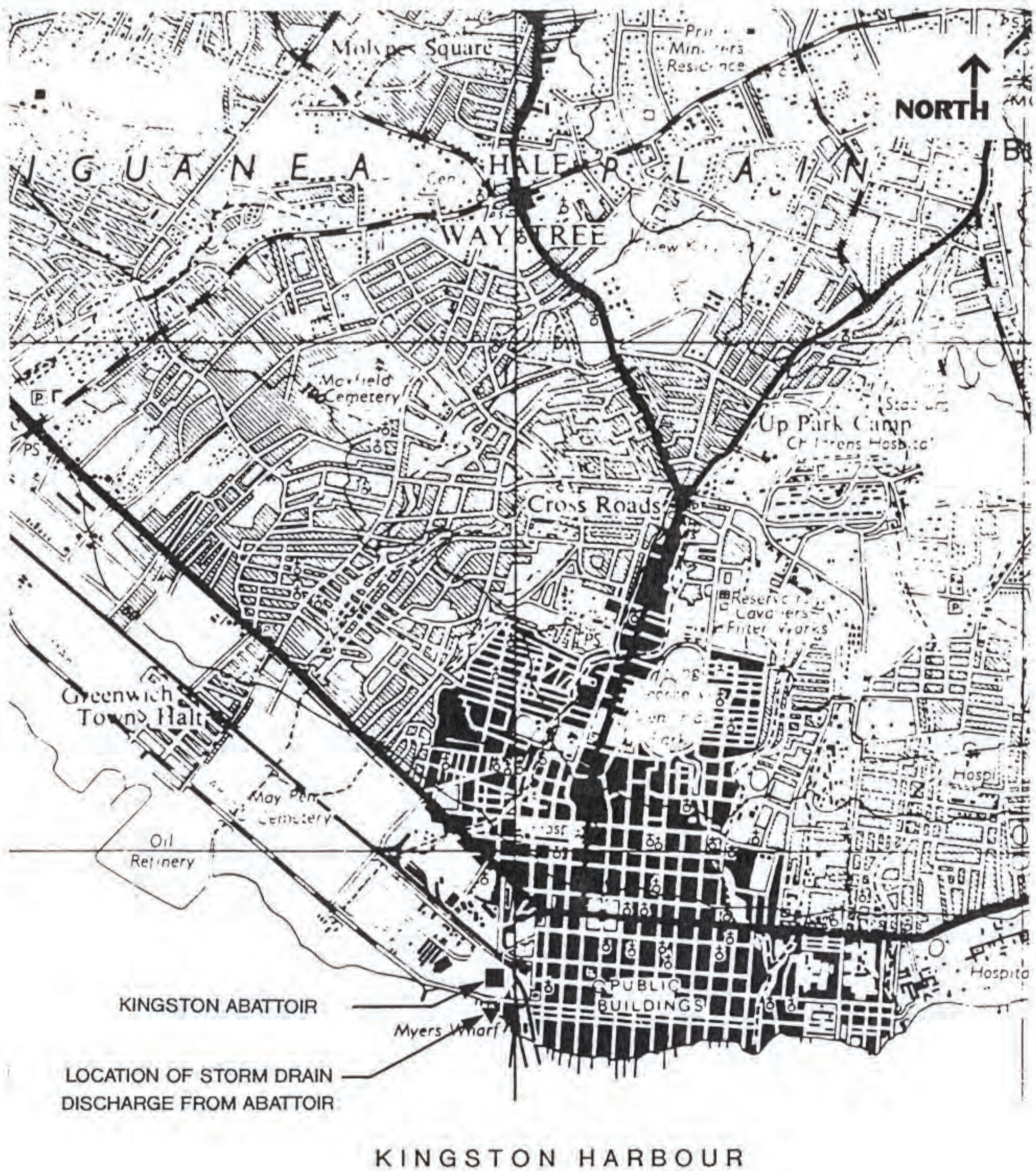


FIGURE IV.I
KINGSTON HARBOUR ENVIRONMENTAL PROJECT