MINISTRY OF ENVIRONMENT
PROVINCE OF BRITISH COLUMBIA

CAMPBELL RIVER AREA

OYSTER RIVER BASIN

WATER QUALITY ASSESSMENT AND OBJECTIVES

TECHNICAL APPENDIX

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TABLE OF CONTENTS

	Page
LIST OF FIGURES	iv
LIST OF TABLES	v
1. INTRODUCTION	1
2. HYDROLOGY	2
3. WATER USES	5
3.1 Fisheries and Aquatic Life	5
3.2 Licensed Water Uses	5
3.3 Recreational Water Uses	6
4. WASTE DISCHARGES	8
4.1 Mt. Washington Ski Resort Discharge	8
4.2 Mineral and Coal Resources	8
4.3 Forestry	9
4.4 Agriculture	9
5. WATER QUALITY ASSESSMENT AND OBJECTIVES	11
5.1 Introduction	11
5.2 Particulate Matter	12
5.3 Nitrogen	20
5.3.1 Ammonia	20
5.3.2 Nitrite	24
5.3.3 Nitrate	24

TABLE OF CONTENTS (Continued)

	Page
5.4 Microbiological Characteristics	27
5.4.1 Sources of Fecal Contamination	27
5.4.2 Piggott Creek	29
5.4.3 Woodhus Creek and Little Oyster River	30
5.4.4 Mainstem Oyster River	33
5.5 Aluminum	34
5.6 Arsenic	37
5.7 Cadmium	39
5.8 Chromium	39
5.9 Cobalt	41
5.10 Copper	44
5.11 Iron	49
5.12 Lead	53
5.13 Manganese	55
5.14 Mercury	57
5.15 Nickel	61
5.16 Zinc	63
5.17 pH	65
6. MONITORING RECOMMENDATIONS	68
7. REFERENCES	69
8. APPENDIX 1: Detailed water quality data for sites in the Oyster River basin.	71
9. APPENDIX 2: Graphical correlation between non-filterable residue and various metals as well as turbidity.	86

LIST OF FIGURES

Figure		Page
1.	Oyster River waterhsed showing locations of water quality sampling and effluent permit sites.	3
2.	Oyster River monthly mean discharges based on Hydrometric Station 08HD011 and streamflow records from 1974 to 1985.	4
3.	Current and future forest harvesting areas, and agricultural areas (approximate locations) in the Oyster River watershed.	10
4.	Non-filterable residue and turbidity for site 0125580 on the mainstem Oyster River.	15
5.	Non-filterable residue and turbidity as a function of time for site 0125582 on the mainstem Oyster River.	18
6.	Total versus dissolved copper in the Oyster River watershed.	45
7.	Total versus dissolved copper in the Oyster River watershed (Lower end of Figure 6).	46
8.	Dissolved versus total iron in the Oyster River watershed.	52
9.	Iron and manganese relationships for Little Oyster River (Site E207430).	58

LIST OF TABLES

Table		Page
1.	Existing water licences on Oyster River and tributaries.	7
2.	Turbidity in the Oyster River watershed.	14
3.	Non-filterable residue concentrations in the Oyster River watershed.	17
4.	Dissolved ammonia concentrations in the Oyster River watershed.	21
5.	Average 30-day concentration of total ammonia-N for protection of aquatic life.	22
6.	Maximum concentration of total ammonia-N for protection of aquatic life.	23
7.	Dissolved nitrite nitrogen concentrations in the Oyster River watershed.	25
8.	Dissolved nitrate plus nitrite nitrogen concentrations in the Oyster River watershed.	26
9A.	Fecal coliform (FC) and enterococci (EC) concentrations in the Oyster River watershed.	28
9B.	Fecal coliform concentrations in the Oyster River watershed.	31
9C.	Fecal coliform/E. Coli concentrations in the Oyster River watershed.	32
10.	Dissolved aluminum concentrations in the Oyster River watershed.	35
11.	Water quality data for site E206514 on Mt. Washington.	36
12.	Total arsenic concentrations in the Oyster River watershed.	38
13.	Total cadmium concentrations in the Oyster River watershed.	40
14.	Total chromium concentrations in the Oyster River watershed.	42
15.	Total cobalt concentrations in the Oyster River watershed.	43
16.	Total copper concentrations in the Oyster River watershed.	47
17.	Total (and dissolved) iron concentrations in the Oyster River watershed.	51
18.	Total lead concentrations in the Oyster River watershed.	54
19.	Total (and dissolved) manganese concentrations in the Oyster River watershed.	56
20.	Total mercury concentrations in the Oyster River watershed.	60

LIST OF TABLES (Continued)

Table		Page
21.	Total nickel concentrations in the Oyster River watershed.	62
22.	Total zinc concentrations in the Oyster River watershed.	64
23	pH in the Oyster River watershed.	67

1. INTRODUCTION

1.1 BACKGROUND

The Ministry of Environment has undertaken the task of assessing and preparing water quality objectives for various basins and sub-basins within the province, selected on a priority basis. Recently, the Vancouver Island Region and the Planning and Assessment Branch of the Ministry of Environment prepared a Water Management Plan for the Oyster River watershed (Oyster River Water Management Plan, 1988). In the report, several concerns were identified with regard to the water quality of the Oyster River. They are:

-Chemical water quality which does not meet public health standards for drinking water during peak runoff periods,

-Poor physical water quality due to colour, turbidity, and non-filterable residues,

-Bacterial water quality (based on coliform count) which is poor all year round in the lower portion of the mainstem river, and

-Total metal (e.g., aluminum, copper,and iron) concentrations in water occasionally exceeding the recommended criteria for the most sensitive water use.

These water quality problems were expected to become worse in view of future activities related to forestry and mining. Although forestry is the dominant activity in the watershed, coal-bearing and mineral-bearing formations have also been found in the watershed. Currently, there is no active coal or mineral mining within the watershed. However, several licences have been issued and new projects have been proposed to extract coal and mineral resources from the area. Therefore, it was recommended that water quality objectives should be established for the Oyster River watershed.

This report examines water quality within the Oyster River watershed, in keeping with the recommendation in the Oyster River Water Management Plan (1988). All up-to-date information available from SEAM and EQUIS data sources was examined in this report. The sections on `Hydrology', `Water Uses', and `Waste Discharges' in this report, were based on information presented in the Oyster River Water Management Plan (1988).

2. HYDROLOGY

The Oyster River originates in the mountains of the Forbidden Plateau on Vancouver Island, and drains an area of about 376 km^2 at the mouth before entering the Strait of Georgia. Little Oyster River (42 km^2), Woodhus Creek (37.1 km^2), Piggott Creek (90.6 km^2), and Adrian Creek (39.4 km^2) are the major tributaries to the Oyster river (Figure 1).

Water Survey of Canada (Environment Canada) has maintained a stream gauging station (08HD011) on the Oyster River below Woodhus Creek since 1974. The watershed area above the gauging station is about 298 km^2, and does not include the Little Oyster River watershed. There was another gauging station (08HD002 Oyster River near Campbell River, drainage area = 363 km^2) in operation between 1914 and 1917. The maximum, minimum, and the mean monthly flows, recorded between 1974 and 1985 at the 08HD011 stream gauging station, are shown in Figure 2.

In general, the streamflow is characterized by a high flow in November due to fall rains, and another high flow in May and June due to snowmelt from high elevations. Minimum flows generally occurred between August and October (Figure 2).

FIGURE 1 : OYSTER RIVER WATERSHED SHOWING LOCATIONS OF WATER QUALITY SAMPLING SITES, HATCHERY, HYDROMETRIC STATION , EFFLUENT DISPOSAL, AND WATER LICENCES.

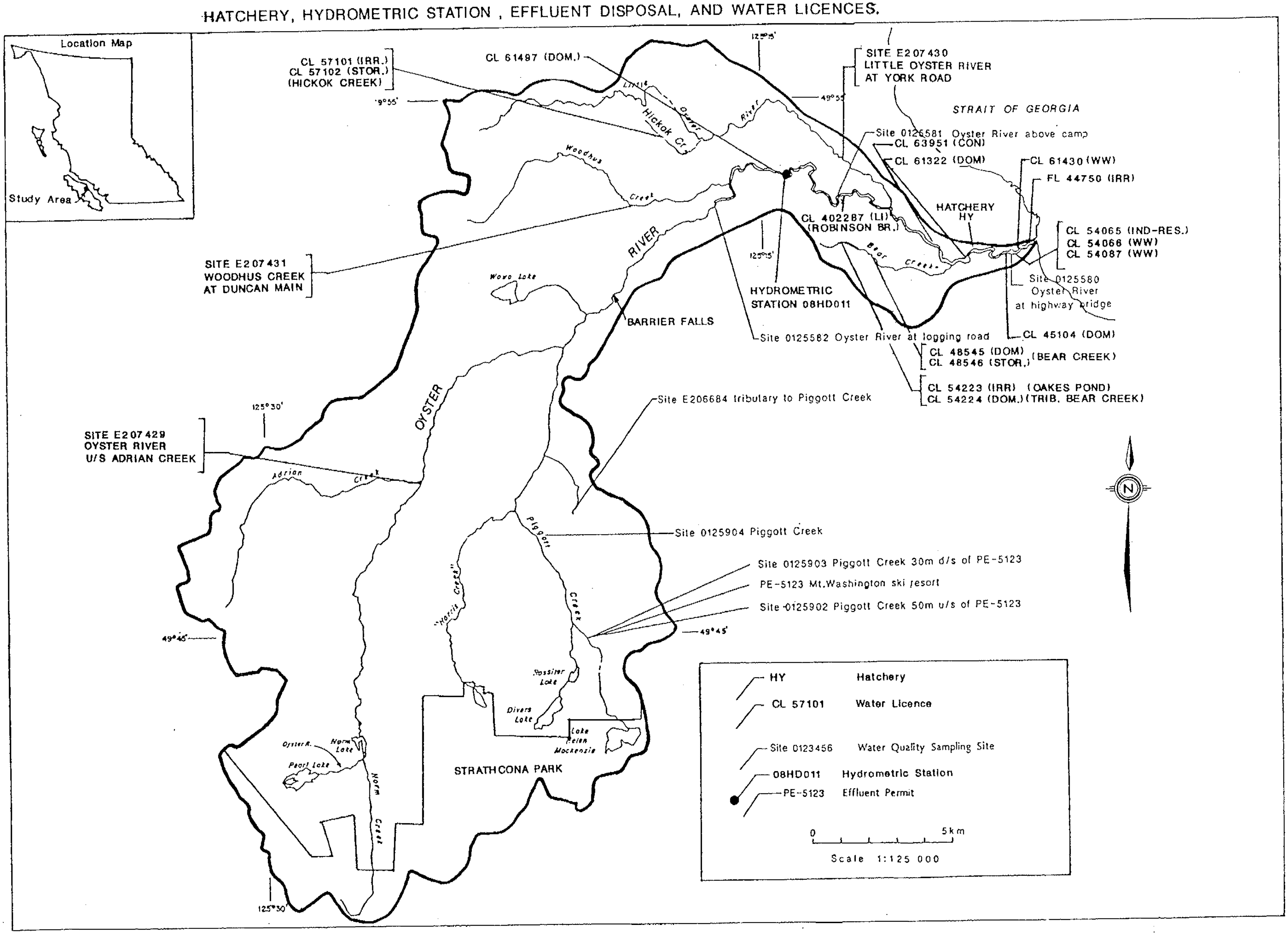
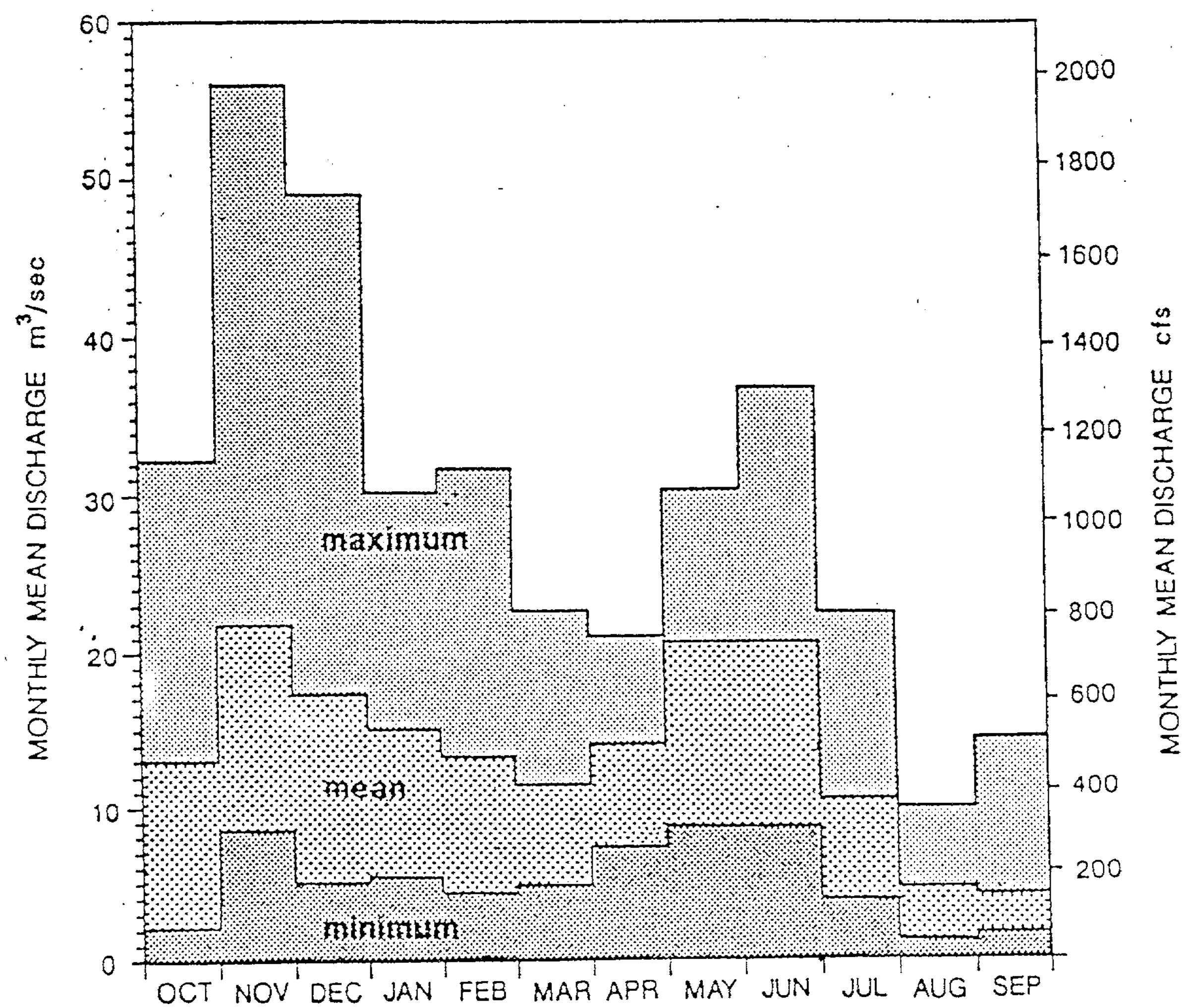


FIGURE 2 : OYSTER RIVER MONTHLY MEAN DISCHARGES BASED UPON HYDROMETRIC STATION 08HD011 AND STREAMFLOW RECORDS FROM 1974 TO 1985.



3. WATER USES

3.1 FISHERIES AND AQUATIC LIFE

Several commercially and recreationally important species of fish breed in the Oyster River watershed. The Oyster River watershed ranks twelfth in steelhead catch on Vancouver Island. The production capability of the watershed for steelhead was estimated at 1 300 adult fish, with the Oyster River mainstem (to 24 km upstream from the mouth) accounting for 90% of that production. Enhancement of steelhead stock (with smolt and fry stocking) on the river was carried out between 1981 and 1984 and is predicted to continue in future.

Cutthroat trout, the most important sport fish in the Oyster River watershed, migrate to the mainstem between August and October, but move to the Little Oyster River and Bear Creek to spawn. The estimated wild smolt production for these streams is 8 000 and 2 000, respectively. A hatchery near the mouth (Figure 1) has also been introducing cutthroat yearling smolts to the river since 1980. Currently, the escapement stock is estimated to run at 800 adults, with 50% hatchery and 50% wild origin. There is also a resident cutthroat trout population on the Oyster mainstem above and below the barrier falls between Woodhus Creek and Piggott Creek (Figure 1).

The Oyster River also supports chinook, chum, coho, and pink salmon. In 1986, the escapement of chinook, chum, and coho salmon was estimated at 100, 500, and 2 000 fish, respectively. The maximum recorded pink salmon escapement ranges from 100 000 (even year) to 15 000 (odd year). The hatchery located adjacent to the mainstem Oyster River below the Little Oyster River (Figure 1) has the potential capacity to produce 100 000 coho smolts and 650 000 chinook fry annually. A sidechannel enhancement project near the hatchery transplanted 2 000 000 pink eggs from the Quinsam River watershed in 1980. Future sidechannel developments are planned to improve chum and coho stocks.

3.2 LICENSED WATER USES

Table 1 lists the existing water licences on the Oyster River and its tributaries. All of the licences are within a stretch of about 20 km from the mouth of the river (Figure 1).

There are three irrigation licences (0.054 m^3/s) recorded which account for about 53% of the total water (0.096 m^3/s) extracted from the Oyster River Watershed. The U.B.C. Research Farms use 88% of the irrigation water and draw it directly from the Oyster River. Dalcor Holdings Ltd., the second major user of irrigation water, holds its licence on Hickok Creek (a tributary to Little Oyster River). This licnece is totally supported by storage. The Oyster River watershed has 3 480 hectares of ALR (Agricultural Land Reserve) land (Buble, 1979) which may require 1.13 m^3/s (255 mm/year) of irrigation water; however, realization of this requirement is considered to be unlikely at this point (Oyster River Water Management Plan, 1988).

Waterworks and Industrial (resort) uses (primarily for drinking or domestic water supply), and domestic water licences combined account for about 47% the total water consumption from the Oyster River watershed. In addition, the Oyster River may be considered: (a) as a significant water supply for any future residential development between the two major centers of Campbell River and Courtenay-Comox, (b) as an auxiliary supply to the Greater Campbell River Water District, and (c) as a possible third source of supply between the Campbell River and the Puntledge River (Associated Engineering Services Ltd., 1975 and 1976, as reported in Oyster River Water Management Plan, 1988).

A spawning channel on the U.B.C. Farm lands near the confluence of Bear Creek is licensed to divert up to 0.23 m^3/s from the Oyster River for conservation purposes. This flow is, however, returned to the river a short distance downstream without a significant loss. Similarly, the land improvement licences held for the construction and maintenance of a dugout pond for recreational purposes on Robinson Brook do not contribute to any significant water use.

3.3 RECREATIONAL WATER USES

Water-based recreational activities in the Oyster River watershed include fishing, boating, and swimming. These are mainly centered on the Oyster River below Woodhus Creek.

Fishing is most common in the lower reaches and at the mouth of the river; some fishing also takes place upstream almost to the confluence of Piggott Creek. Boating activity is restricted to non-motorized shallow-draft craft and includes canoeing, kayaking, rafting, and tubing. Swimming is also popular and is centered in pools from Woodhus Creek to the ocean.

TABLE 1

EXISTING WATER LICENCES ON OYSTER RIVER AND TRIBUTARIES
(From Oyster River Management Plan, 1988)

Priority Date	Stream	Licence No.	Licensee	Purpose	Quantity	Equivalent Flow (m^3/s)
03/07/1968	Oyster River	FL44750	UBC Res. Farm #2	Irrigation	300 ac.ft.	0.04760
11/10/1974	Oyster River	CL45105	Ferguson	Domestic	1 000 gpd	0.00006
23/01/1975	Oyster River	CL54065	Pacific Playground	Industrial (resort)	45 000 gpd	0.00238
23/01/1975	Oyster River	CL54066	Watutco Ent. Ltd.	Waterworks	54 500 gpd	0.00286
09/11/1982	Oyster River	CL59087	Watutco Ent. Ltd.	Waterworks	10 000 gpd	0.00054
19/04/1983	Oyster River	CL61322	Grutzmacher	Domestic	500 gpd	0.00003
15/08/1984	Oyster River	CL61497	Gunn	Domestic	500 gpd	0.00003
24/05/1985	Oyster River	CL61430	Regional District Comox-Strathcona	Waterworks	800 000 gpd	0.04208
06/08/1953	Oyster River	CL63951	UBC Res. Farm #2	Conservation	8 cfs	0.00
05/07/1974	Bear Creek	CL48545	Pederson	Domestic	1 000 gpd	0.00006
05/07/1974	(Trib. to Oyster River)	CL48546	Pederson	Storage	1 ac.ft.	
26/02/1979	Oakes Pond	CL54223	Edward	Irrigation	1 ac.ft.	0.00017
26/07/1979	(Trib. to Bear Creek)	CL54224	Edward	Domestic	500 gpd	0.00003
01/03/1972	Robinson Brook (Trib. to Oyster River)	CL40287	Robinson Lake Rec. Assn.	Land Improvement	150 ac.ft.	0.00
03/03/1983	Hickok Creek (Trib. to Little	CL57101	Delcor Holdings Ltd.	Irrigation Ind. (Frost Prev.)	40 ac.ft. 100 ac.ft.	0.00634 0.00
03/03/1980	Oyster River)	CL57102	Delcor Hold. Ltd.	Storage	40 ac.ft.	-

4. WASTE DISCHARGES

4.1 Mt. WASHINGTON SKI RESORT DISCHARGE

The only Waste Management Permit (PE-5123) in the Oyster River watershed was issued to Mt. Washington Ski Resort on November 7, 1978. The permit was amended on April 22, 1986 authorizing discharge of a maximum of 480 m^3/d of domestic sewage effluent from a recreational ski development into Piggott Creek. The effluent is subjected to secondary treatment, chlorination, and dechlorination prior to discharge to the creek.

The discharge of domestic-type effluent could cause enrichment of nutrients (e.g., nitrogen and phosphorus), pathogenic microorganisms, and biological oxygen demand in receiving waters. So far no algal problem has been documented in Piggott Creek (Oyster River Water Management Plan, 1988). The influence of this discharge on water quality is discussed in chapter 5.

4.2 MINERAL AND COAL RESOURCES

Much of the Oyster River watershed contains coal-bearing and mineral-bearing formations. Several companies hold licences for exploration in the watershed. Nuspar Resources is proposing to develop its Chute Creek coal project in an area which includes the headwaters of Woodhus Creek. Several placer leases and petroleum and natural gas permits have been issued in the Oyster River watershed. These permits or projects, although inactive presently, could become active in the foreseeable future.

Mining can result in increased levels of suspended solids and turbidity due to land disturbances, and higher levels of nitrogen (e.g., nitrate, nitrite, and ammonia) due to explosives residuals. For a mine site where waste rock and tailings are of an acid-generating nature, effluent produced may be contaminated with a wide variety of metals. Some acid mine drainage from an old, inactive copper mine on Mount Washington (predominantly in the Tsolum River watershed) has been recognized to enter tributaries to upper Piggott Creek in the Oyster River watershed (Kangasniemi and Erickson, 1986). In the same general area of Mount Washington, Better Resources conducted a drilling program, in 1986 and 1987, to test the ore for minerals.

4.3 FORESTRY

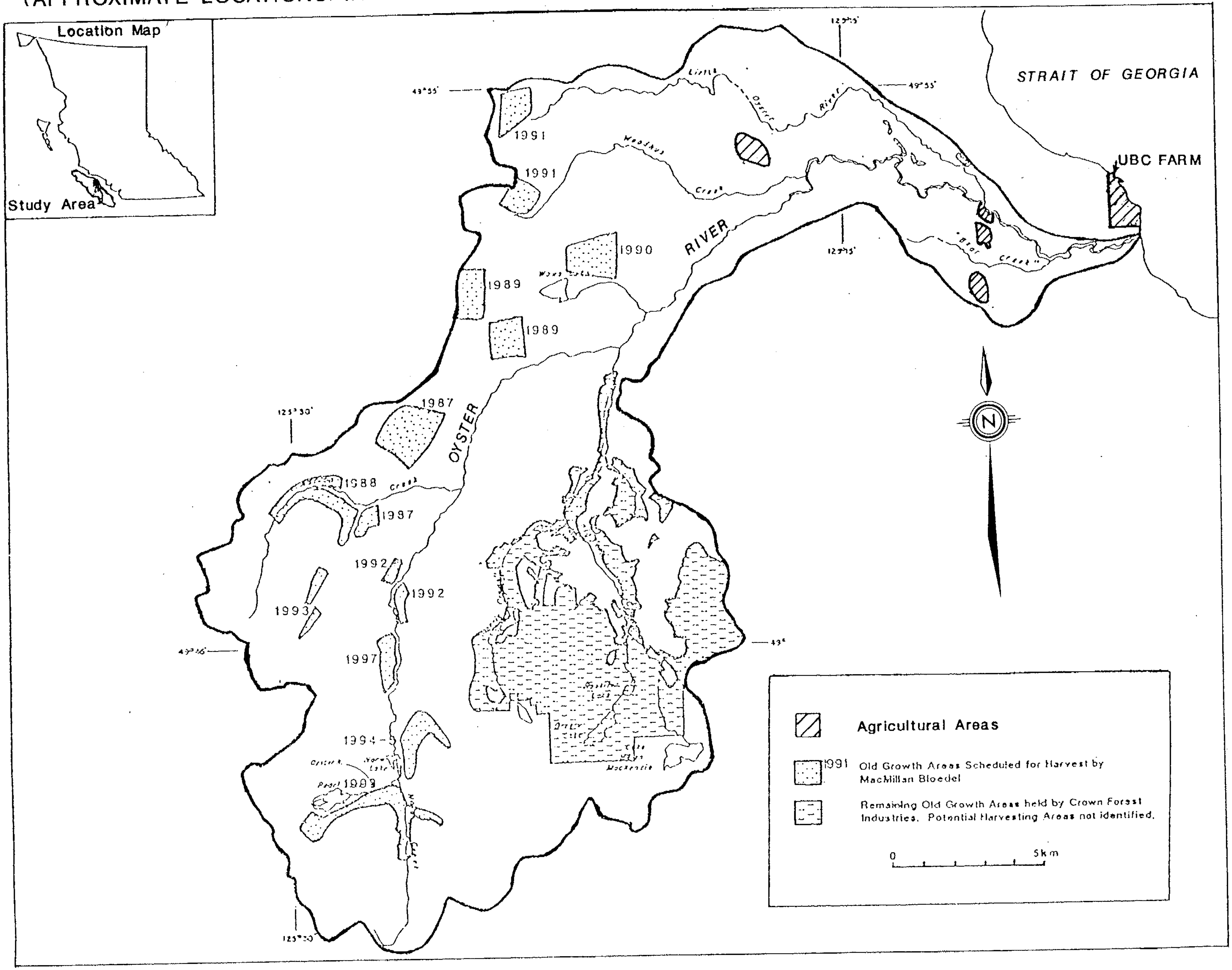
Forestry is by far the dominant activity in the Oyster River watershed. Forest harvesting is of concern as it may affect both water quantity and quality (e.g., increased levels of nutrients and suspended matter, sedimentation of spawning gravels, rise in water temperature, etc.). Timber is currently being harvested in the watershed; also, future harvest areas have been identified by several private companies, who own most of the forest land in the watershed. Figure 3 shows the current and future logging activities in the Oyster River watershed.

4.4 AGRICULTURE

Agriculture can cause deterioration of surface water quality by introducing additional loadings of nutrients, suspended solids, oxygen demand and a variety of organic and inorganic ions and compounds. The lower portion of the Oyster River watershed contains extensive areas (34.8 km^2) of Agricultural Land Reserve (ALR). However, much of the ALR land is tree-covered.

The major agricultural operations in the watershed include: (i) a cranberry farm (51 acres), which is located in the watershed of Little Oyster River in the vicinity of Hickok Creek; (ii) a horse facility with a riding ring (~ 50 acres), in the Bear Creek watershed area which houses about 20 horses. The number of horses at the site increases when the riding ring is in use; and (iii) the University of British Columbia Research Farm. The U.B.C. farm operates on two parcels of land. The main farm (150 acres), supporting the majority of agricultural activity, is located north of the junction of the Oyster River and the Strait of Georgia (This parcel of the farms lies outside the Oyster River watershed). The other location is on the south side of the Oyster River about 5 km upstream, near the confluence of Bear Creek. The majority of the farm's forestry program takes place on these 600 acres. In addition, the Oyster River Enhancement Society operates a salmonid rearing and spawning channel at this location. The dairy herd is the major revenue generating activity on the farms. The herd consists of about 150 milking cows in a total herd of 340 animals. Grasses and legumes are grown for pasture, hay or silage (field corn is also grown for silage). Soil fertility is maintained through the recycling of manure and the addition of purchased manure and limestone. Figure 3 shows the agricultural land use in the watershed.

FIGURE 3 : CURRENT AND FUTURE FOREST HARVESTING AREAS, AND AGRICULTURAL AREAS (APPROXIMATE LOCATIONS) IN THE OYSTER RIVER WATERSHED.



5. WATER QUALITY ASSESSMENT AND OBJECTIVES

5.1 INTRODUCTION

The variables selected for the purpose of setting objectives include suspended solids, turbidity, nitrogen, fecal coliforms, aluminum, arsenic, cadmium, chromium, cobalt, copper, iron, lead, manganese, mercury, nickel, zinc, and pH. Their selection was primarily based on the fact that the present and future land use activities in the watershed were deemed to influence it. It was assumed that the potential for acid mine drainage exists in the Oyster River watershed, due to coal mining activities planned for the area in future. This assumption was based on the fact that acid mine drainage was prevalent in the adjacent Tsolum River and Quinsam River watersheds (Kangasniemi and Erickson, 1986; Kangasniemi, 1989). No objectives were set for those variables which might be affected by future land use activities, but for which (a) data were unavailable, and (b) concentrations were undetectable despite low detection limits being used for the measurement.

The selection of the above variables for the purpose of setting water quality objectives in the Oyster River should not be interpreted to imply that a conflict with a designated water use is likely, but merely that the potential exists. The purpose of the objectives is to provide references against which water quality may be compared, and to protect water uses against contamination that may be produced by man's activities. It should be recognized that objectives may exceed the B.C. Ministry of Environment criteria, especially for those variables where the natural background levels exceed the criteria for the most sensitive water use.

The water quality objectives are designed to protect the most sensitive water use. The water uses considered include aquatic life and wildlife, recreation and aesthetics, livestock water supply, irrigation, and drinking water supply. In most cases aquatic life was the most sensitive water use. Most of the metal objectives are expressed in terms of total rather than dissolved or extractable concentrations. The reason for this choice was several-fold; (i) the data for dissolved metals are scarce, (ii) metals criteria are mostly given in terms of the total metal concentration, and (iii) the concentration of total metals was poorly correlated with the suspended solids concentration in the watershed (Appendix 2). Since the dissolved metal is generally the most toxic fraction of the total metal in a water column, the objectives based on the total metal concentration will provide an added safety factor against metal toxicity. The objectives for iron and manganese [for which concentrations showed strong dependence on suspended solids (Appendix 2)], and aluminum were expressed in terms of the dissolved fractions.

Water quality objectives have no legal standing and would not be directly enforced. They, however, provide policy direction for resource managers in protecting water uses in the specific water bodies. Also, by providing a reference, the objectives will guide (i) the evaluation of water quality which, in turn, may help decide whether to initiate a basin-wide water quality study, (ii) the issuing of permits, licences, and orders, and (iii) the management of the fisheries and of the Province's land base. The objectives do not apply within the initial dilution zones of waste discharges permitted under the Waste Management Act. These zones, established on a site-specific basis, normally do not extend more than 100 m downstream from a waste discharge or occupy more than 50% of the width of the waterbody (from surface to bottom).

The water quality data obtained from the SEAM and EQUIS data bases of the B.C. Ministry of Environment (Appendix 1) formed the basis for the proposed objectives. The locations of the water quality monitoring stations are shown in Figure 1. During the assessment of the data, it was found that measurements for a given variable varied widely. Such variability in the water quality data from a watershed is not unusual. However, occasionally extremely high values were measured for some variables which were considered isolated and anomalous. In some cases, these extreme values were the result of a rare event (e.g., non-filterable residue content of 307 mg/L on October 1, 1981 for Site 0125580, due to an abnormally high precipitation; Table A1-1 in Appendix-1). In other cases, no obvious reasons were found to justify them (e.g., total Cu level of 140 µg/L on June 4, 1987 for Site 0125580; non-filterable residue and turbidity on this day were very low; Table A1-1 in Appendix-1); in such instances a measurement was considered to be anomalous if it exceeded the limits given by the relation $\mu \pm 3$ s, where the quantities μ and s represent the mean and the standard deviation, respectively, obtained from the data set.

5.2 PARTICULATE MATTER

Particulate matter refers to the presence of particles such as clay, silt, organic matter, plankton, microscopic organisms, etc. It is generally measured in terms of turbidity and the total suspended solids (or non-filterable residue) content of water. Turbidity, an optical property, is an indirect measure of the suspended matter concentration in a water column. It is, however, a preferred measurement from both health and aesthetics view points. Non-filterable residue, on the other hand, refers to the portion of suspended matter which is retained on 0.45 or 1.0 μm filters. Both turbidity and non-filterable residue were considered in setting water quality criteria for the protection of aquatic life (Singleton, 1985).

Health and Welfare Canada (1987) recommends a maximum acceptable turbidity of 1 NTU in finished drinking water. A maximum of 5 NTU may be permitted if it is shown that disinfection is not compromised by the use of this less stringent guideline; an aesthetic objective of 5 NTU is recommended for finished water. According to the B.C. Ministry of Environment, (i) in a raw drinking water supply of exceptional clarity which does not require treatment for removal of particulate matter, turbidity should not exceed 1 NTU above background, while the maximum turbidity at any time should be ≤ 5 NTU; (ii) where raw drinking water must be treated for particulate matter, the induced turbidity should not exceed 5 NTU when background level is ≤ 50 NTU (Singleton, 1985).

Turbidity in the mainstem Oyster River at a site just upstream from Woodhus Creek (Site 0125582, Figure 1) ranged between 0.2 and 3.4 NTU (Table 2). The average turbidity at two sites further downstream (Sites 0125581 and 0125580) was also low (~ 2.0 NTU). However, one of 6 measurements for site 0125581 and 4 of 36 measurements for site 0125580, exceeded the recommended guideline of 5 NTU (the maximum turbidity in the mainstem Oyster River was 18 NTU at site 0125580 near the mouth of the river). In all 5 instances, high turbidity appeared to be associated with high flow (or precipitation) conditions. Some fluctuations in turbidity and suspended solids concentrations with time are expected especially in actively logged watersheds. Figure 4 shows that these water quality parameters were more adversely affected during the late eighties. An exception was the October 1, 1981 measurement for suspended solids which was considered to be an anomaly in the data set; turbidity, although not measured, is also expected to have been abnormally high on that day since it was significantly correlated with the suspended solid fraction (Figure A2-1, Appendix-2).

Obviously, a treatment for turbidity or suspended solids removal (e.g., filtration) will be required, especially during the periods of high flow, if water from the Oyster River downstream from Woodhus Creek is to be used for drinking purposes. Currently water for domestic uses (Table 1) is drawn from wells dug (or drilled) along the banks of the Oyster river. Apparently, the natural filtration provided by gravel during subsurface water movement

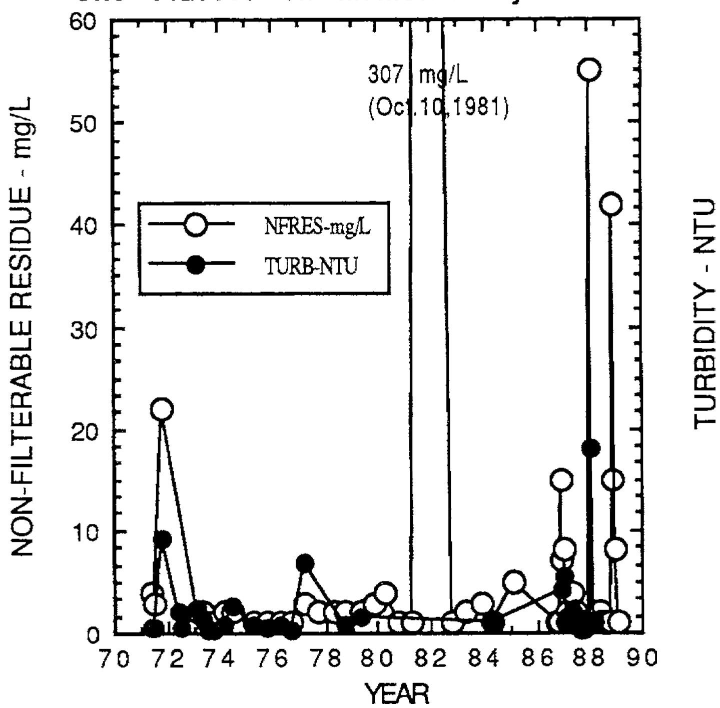
TABLE 2

TURBIDITY IN THE OYSTER RIVER WATERSHED

Site number and Description	Data Characteristics*						
	n	max	min	measurements > 5	measurements > 50	90th percentile	Time period
		- NTU -		- NTU -			
E207429: Oyster River d/s Adrian Creek				no data			
E207474: Trib. to Piggott Cr. at Rossiter Road				no data			
0125902: Piggott Cr. 50 m u/s PE-5123	1	1.2	1.2	0	0	-	1979
0125903: Piggott Cr. 30 m d/s PE-5123	1	1.4	1.4	0	0	-	1979
0125904: Piggott Cr. u/s branch 161 bridge	1	1.5	1.5	0	0	-	1979
E206684: Tributary Piggott Creek				no data			
0125582: Oyster River at Logging Rd. bridge	14	3.4	0.2	0	0	3.1	1986-88
E207431: Woodhus Cr. at Duncan main				no data			
0125581: Oyster River above camp	6	8.9	0.2	1	0		1975-76
E207430: Little Oyster River at York Rd.				no data			
0125580: Oyster River at highway bridge	36	18	0.2	4	0	5.9	1971-88

* n = total number of measurements

FIGURE 4
Non-filterable residue and turbidity for Site 0125580 on mainstem Oyster River.



from the river to the wells is adequate, as water quality problems due to turbidity or suspended solids in the drinking water supplies have not been reported in the area.

Turbidity was not measured in the Piggott Creek, Woodhus Creek and Little Oyster River waters.

To protect aquatic life, the B.C. Ministry of Environment recommends that the non-filterable residue in water should not exceed 10 mg/L over the background level (when background is $\leq$ 100 mg/L) or the turbidity should not exceed 5 NTU over background (when background is $\leq$ 50) (Singleton, 1985). The maximum concentration of non-filterable residue in the the Oyster River upstream from site 0125580 was 12 mg/L (Table 3). It was exceeded only once; e. g., 18 mg/L on Nov. 2, 1988 at site E207430 on the Little Oyster River; however, 11 of the total of 12 non-filterable residue measurements for the site were $\leq$ 9 mg/L.

At a site near the mouth of the Oyster river (Site 0125580), the non-filterable residue and turbidity ranged from < 1 to 307 mg/L and 0.2 to 18 NTU, respectively. In about 94% of the measurements the non-filterable residue (61 of 65) and turbidity (34 of 36) were less than or equal to 15 mg/L and 5.6 NTU, respectively (Table A1-1, Appendix 1). Also, over 35% of the measurements for site 0125580 were below the detection limit of 1.0 mg/L (Table 3). One (e.g., 307 mg/L on Oct.1,1981) of the 65 measurements of the suspended solids fraction was exceptionally higher than 15 mg/L. This, in part, was attributed to extremely wet conditions of the day; for instance, the average daily flow (60.1 m^3/s) on Oct.1,1981 at the hydrometric station 08HD011 was much higher than both long-term monthly mean (19.8 m^3/s) and monthly maximum (32.4 m^3/s) discharges shown in Figure 2.

The true background levels for turbidity and non-filterable residue in the Oyster River were difficult to establish because of continuing logging activity in the watershed and lack of data upstream from actively logged areas. To estimate background levels for turbidity and non-filterable residue, the results from a site just upstream from Woodhus Creek (Site 0125582) were analyzed. The plots of turbidity and non-filterable residue versus time for site 0125582 suggested that these parameters were fairly constant during the monitoring period despite the ongoing logging activities in the watershed (Figure 5). Occasionally high values were measured during wet (rain or snowmelt) periods of fall and spring months It was assumed that these high values were the result of logging activities in the area. Considering that the effect of logging on water quality was minimum during low flow periods, the background levels for turbidity and

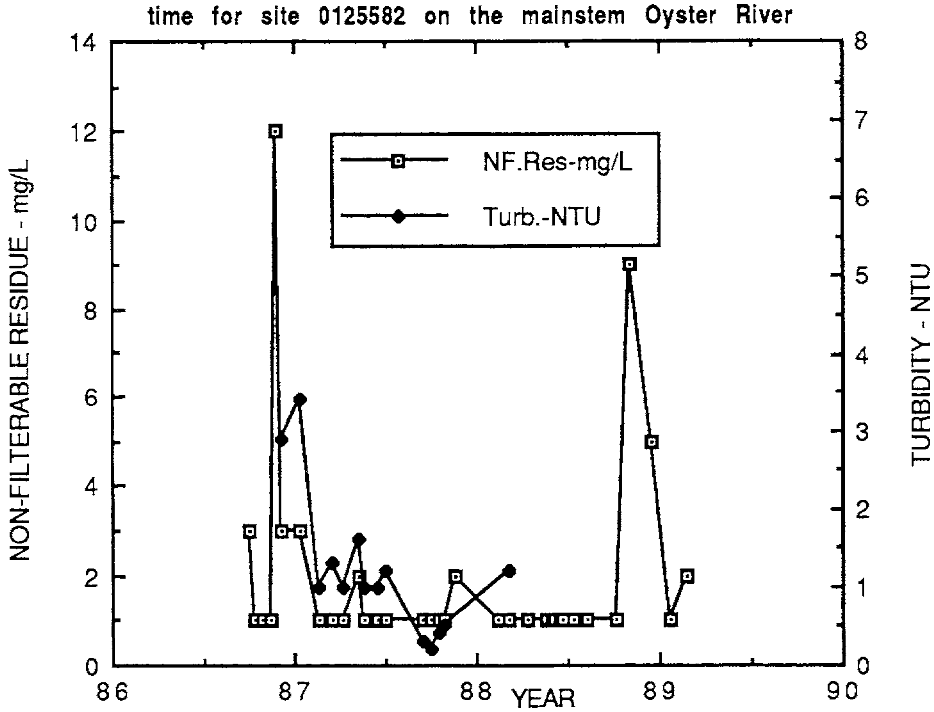
TABLE 3

NON-FILTERABLE RESIDUE CONCENTRATIONS IN THE OYSTER RIVER WATERSHED

Site number and Description	Data Characteristics*					
	n	max	min	Values < D.L.	90th percentile	Time period
		- mg/L-		%		
E207429: Oyster River d/s Adrian Creek	4	1	< 1	50.0	-	1988
E207474: Trib. to Piggott Cr. at Rossiter Rd.	8	1	< 1	87.5	-	1988
0125902: Piggott Creek 50 m u/s PE-5123	10	3	< 1	30.0	-	1979-88
0125903: Piggott Creek 30 m d/s PE-5123	13	5	< 1	30.8	-	1979-88
0125904: Piggott Creek u/s branch 161 bridge	6	2	< 1	33.3	-	1979-85
E206684: Tributary to Piggott Creek	12	< 1	< 1	100.	-	1987-88
0125582: Oyster River at Logging Rd. bridge	34	12	< 1	52.9	4.0	1986-89
E207431: Woodhus Creek at Duncan main	13	7	< 1	53.8	-	1988-89
0125581: Oyster River at Logging Rd. bridge	4	2	< 1	25.0	-	1975-76
E207430: Little Oyster River at York Road	12	18	1	00.0	-	1988-89
0125580: Oyster River at highway bridge	65	307	< 1	35.4	10.8	1971-89

* n = total number of values; D.L. = detection limit

Figure 5
Non-filterable residue and turbidity as a function of time for site 0125582 on the mainstem Oyster River



non-filterable residue in the Oyster River were estimated to be ≤ 2 NTU and ≤ 2 mg/L, respectively.

OBJECTIVE: To protect drinking water use of the Oyster River watershed upstream from Woodhus Creek (including Piggott Creek) without treatment, it is recommended that the turbidity should not exceed 5 NTU at any time. To protect aquatic life in the watershed upstream from Woodhus Creek, the non-filterable residue should not exceed 12 mg/L at any time.

In the Oyster River downstream from Woodhus Creek (especially near the mouth of the river but excluding Little Oyster River) where water must be treated for high turbidity and suspended solids on occasion, the following objectives are recommended.

OBJECTIVE: To protect aquatic life and drinking water uses of the Oyster River watershed downstream from and including Woodhus Creek, the 90th percentile for non-filterable residue should not exceed 15 mg/L and the 90th percentile for turbidity should not exceed 7 NTU.

The objectives for the protection of raw untreated drinking water and aquatic life upstream from Woodhus Creek, are based on the background for turbidity (estimated using the data for site 0125582) and induced levels of non-filterable residue recommended by the B.C. Ministry of Environment (Singleton, 1985). The objectives near the mouth of the river (downstream from site 0125582) are based on the available data and do not apply during exceptionally high precipitation and/or streamflow (i.e., average daily flow exceeding the long-term monthly maximum discharge) events. It is recommended that at least five but preferably ten samples in a period of 30 days be collected at equal intervals to determine the 90th percentiles for non-filterable residue and turbidity.

5.3 NITROGEN

5.3.1 Ammonia

Among several factors that modify ammonia toxicity to aquatic life, the effects of pH and temperature are well studied. The toxicity of ammonia increases with both pH and temperature of water. The un-ionized ammonia (NH_3) is the principal toxic form of ammonia; however, the criteria to protect aquatic life (the most sensitive water use) are expressed in terms of total ammonia (NH_4-N + NH_3-N) concentration as a function of pH and temperature of water (Tables 5 and 6, Nordin and Pommen, 1986).

The concentration of dissolved ammonia in the mainstem Oyster River was generally low, varying between < 0.005 and 0.015 mg/L NH_3-N (Table 4). The maximum concentration in the watershed was 0.238 mg/L dissolved ammonia for site 0125903 on Piggott Creek, about 30 m downstream from the point where Mt. Washington Ski Resort (PE-5123) is permitted to discharge its effluent. While the pH (average value = 7.2) of the water samples collected from the site was measured, temperature was not. Considering a worst case situation, it was assumed that the maximum water temperature for site 0125903 was 14.5 °C which was also the maximum temperature for site 0125580. From tables 4, 5, and 6, it was obvious that the maximum concentration of dissolved ammonia for site 0125903 (Table 4) did not exceed the 30-day average or the maximum criteria (Tables 5 and 6) proposed by the B.C. Ministry of Environment. Note that the water temperature for site 0125903, located at a higher elevation, is expected to be lower than that for site 0125580, and the toxicity of ammonia decreases with a decrease in temperature (Tables 5 and 6). Also, site 0125903 lies inside the initial dilution zone (100 m from point of discharge) and the objectives do not apply within the zone.

OBJECTIVE: To protect aquatic life anywhere in the Oyster River watershed, the 30-day average total ammonia nitrogen concentration should not exceed the values given in Table 5, and the maximum concentration should not exceed the values given in Table 6, outside the initial dilution zones of waste discharges mentioned in section 5.1. The average concentration is based on a minimum of 5 weekly samples collected over a period of 30 days.

TABLE 4

DISSOLVED AMMONIA CONCENTRATIONS IN THE OYSTER RIVER WATERSHED

Site number and Description	Data Characteristics*						
	n	max	min	values < D.L.	Temp range (av.)	pH range (av.)	Time period
		- mg/L -		%	°C		
0125902: Piggott CR. 50 m u/s PE-5123	14	0.014	<0.005	71.4	-	6.8-7.8 (7.1)	1979-88
0125903 Piggott CR. 30 m d/s PE-5123	14	0.238	<0.005	28.6	-	6.8-7.8 (7.2)	1979-88
0125904: Piggott CR. u/s Branch 161 bridge	5	0.01	<0.005	40.0	-	7.0-7.4 (7.1)	1979-85
0125582: Oyster R. at Logging Rd. bridge	20	0.01	<0.005	75.0	-	6.8-7.5 (7.1)	1986-88
0125580: Oyster R. at highway bridge	35	0.015	<0.005	74.3	1-14.5 (8.2)	6.4-8.2 (7.1)	1977-88

* n = number of measurements; D.L. = detection limit; av. = average

TABLE 5#

AVERAGE 30-DAY CONCENTRATION OF TOTAL AMMONIA-N FOR THE PROTECTION OF AQUATIC LIFE

Temp. °C	0.0	2.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0.
pH	- mg/L Ammonia-Nitrogen -										
6.5	2.08	2.02	1.97	1.92	1.88	1.84	1.81	1.78	1.64	1.41	1.22
6.6	2.08	2.02	1.97	1.92	1.88	1.84	1.81	1.78	1.64	1.41	1.22
6.7	2.08	2.02	1.97	1.92	1.88	1.84	1.81	1.78	1.64	1.41	1.22
6.8	2.08	2.02	1.97	1.92	1.88	1.84	1.81	1.78	1.64	1.42	1.22
6.9	2.08	2.02	1.97	1.92	1.88	1.84	1.81	1.78	1.64	1.42	1.22
7.0	2.08	2.02	1.97	1.92	1.88	1.84	1.81	1.79	1.64	1.42	1.22
7.1	2.08	2.02	1.97	1.92	1.88	1.84	1.81	1.79	1.65	1.42	1.23
7.2	2.08	2.02	1.97	1.92	1.88	1.85	1.81	1.79	1.65	1.42	1.23
7.3	2.08	2.02	1.97	1.92	1.88	1.85	1.82	1.79	1.65	1.42	1.23
7.4	2.08	2.02	1.97	1.92	1.88	1.85	1.82	1.79	1.65	1.42	1.23
7.5	2.08	2.02	1.97	1.93	1.88	1.85	1.82	1.80	1.66	1.43	1.23
7.6	2.09	2.03	1.97	1.93	1.89	1.85	1.82	1.80	1.66	1.43	1.24
7.7	2.09	2.03	1.98	1.93	1.89	1.86	1.83	1.80	1.66	1.44	1.24
7.8	1.78	1.73	1.69	1.65	1.62	1.59	1.56	1.54	1.42	1.23	1.07
7.9	1.50	1.46	1.43	1.39	1.36	1.34	1.32	1.31	1.21	1.04	0.904
8.0	1.26	1.23	1.20	1.17	1.15	1.13	1.11	1.10	1.02	0.878	0.762
8.1	1.00	0.976	0.952	0.932	0.914	0.899	0.887	0.878	0.812	0.704	0.611
8.2	0.799	0.777	0.759	0.743	0.730	0.718	0.709	0.703	0.651	0.565	0.491
8.3	0.636	0.620	0.606	0.594	0.583	0.575	0.568	0.564	0.523	0.455	0.396
8.4	0.508	0.495	0.484	0.475	0.467	0.461	0.456	0.453	0.421	0.367	0.321
8.5	0.405	0.396	0.387	0.380	0.375	0.370	0.367	0.366	0.341	0.298	0.261
8.6	0.324	0.317	0.310	0.305	0.301	0.298	0.297	0.296	0.277	0.242	0.213
8.7	0.260	0.254	0.249	0.246	0.243	0.241	0.240	0.241	0.226	0.198	0.175
8.8	0.208	0.204	0.201	0.198	0.197	0.196	0.196	0.197	0.185	0.164	0.145
8.9	0.168	0.165	0.162	0.161	0.160	0.160	0.161	0.162	0.153	0.136	0.121
9.0	0.135	0.133	0.132	0.131	0.131	0.131	0.132	0.134	0.128	0.114	0.102

the average of the measured values must be less than the average of the corresponding individual value in this Table. Each measured value is compared to the corresponding individual values in this Table; no more than one in five of the measured values can be greater than one-and-a-half times the corresponding values in the Table. Linear interpolation may be used to determine average concentrations at water temperatures between the limits shown in the Table.

TABLE 6#

MAXIMUM CONCENTRATION OF TOTAL AMMONIA-N FOR PROTECTION OF AQUATIC LIFE

Temp. °C	0.0	2.0	4.0	6.0	8.0	10.0	12.0	14.0	16.0	18.0	20.0.
pH					- mg/L Ammonia-Nitrogen -						
6.5	27.7	27.9	27.2	26.5	26.0	25.5	25.0	24.6	24.3	24.0	23.8
6.6	27.9	27.2	26.4	25.8	25.2	24.7	24.3	23.9	23.6	23.3	23.2
6.7	26.9	26.2	25.5	24.9	24.4	23.9	23.5	23.1	22.8	22.6	22.4
6.8	25.8	25.1	24.5	23.9	23.4	22.9	22.5	22.2	21.9	21.7	21.5
6.9	24.6	23.9	23.3	22.7	22.2	21.8	21.4	21.1	20.8	20.0	20.4
7.0	23.2	22.5	21.9	21.4	20.9	20.5	20.2	19.9	19.6	19.4	19.2
7.1	21.6	20.9	20.4	19.9	19.5	19.1	18.8	18.5	18.3	18.1	17.9
7.2	19.9	19.3	18.8	18.3	17.9	17.6	17.3	17.1	16.8	16.7	16.5
7.3	18.1	17.5	17.1	16.7	16.3	16.0	15.7	15.5	15.3	15.2	15.1
7.4	16.2	15.7	15.3	15.0	14.7	14.4	14.1	13.9	13.8	13.6	13.5
7.5	14.4	14.0	13.6	13.3	13.0	12.7	12.5	12.4	12.2	12.1	12.0
7.6	12.6	12.2	11.9	11.6	11.4	11.2	11.0	10.8	10.7	10.6	10.5
7.7	10.8	10.5	10.3	10.0	9.83	9.65	9.50	9.37	9.26	9.81	9.12
7.8	9.26	8.98	8.77	8.57	8.40	8.25	8.12	8.02	7.93	7.87	7.82
7.9	7.82	7.60	7.42	7.25	7.10	6.98	6.88	6.79	6.72	6.67	6.64
8.0	6.55	6.37	6.22	6.08	5.96	5.86	5.78	5.71	5.66	5.62	5.60
8.1	5.21	5.07	4.95	4.84	4.75	4.67	4.61	4.56	4.53	4.50	4.49
8.2	4.15	4.04	3.95	3.86	3.80	3.74	3.69	3.65	3.63	3.61	3.61
8.3	3.31	3.22	3.15	3.09	3.03	2.99	2.96	2.93	2.92	2.91	2.91
8.4	2.64	2.57	2.52	2.47	2.43	2.40	2.37	2.36	2.35	2.35	2.36
8.5	2.11	2.06	2.01	1.98	1.95	1.93	1.91	1.90	1.90	1.90	1.92
8.6	1.69	1.65	1.61	1.59	1.57	1.55	1.54	1.54	1.54	1.55	1.57
8.7	1.35	1.32	1.30	1.28	1.26	1.25	1.25	1.25	1.26	1.27	1.29
8.8	1.08	1.06	1.04	1.03	1.02	1.02	1.02	1.02	1.03	1.05	1.07
8.9	0.871	0.856	0.844	0.836	0.832	0.831	0.834	0.842	0.853	0.870	0.891
9.0	0.703	0.692	0.685	0.681	0.680	0.682	0.688	0.698	0.711	0.729	0.752

Linear interpolation may be used to determine average concentrations at water temperatures between the limits shown in the Table.

5.3.2 Nitrite

Nitrite is the most toxic form of inorganic nitrogen irrespective of water use classification. Among various water uses considered in this document, aquatic life is the most sensitive water use for nitrite. The toxicity of NO_2-N decreases as the chloride (Cl^-) concentration in water increases. To protect aquatic life, the B.C. Ministry of Environment recommends that the 30-day average NO_2-N concentration should not exceed 0.02 mg/L in water containing $\leq$ 2 mg/L Cl^-. The maximum NO_2-N concentration, on the other hand, is recommended not to exceed 0.06 mg/L (Nordin and Pommen, 1986).

All 43 measurements of nitrite nitrogen in the Oyster River watershed, were below the detection limit of 0.005 mg/L (Table 7). The average Cl^- concentration in the watershed varied between < 0.5 and 1.1 mg/L.

OBJECTIVE: To protect aquatic life in the Oyster River watershed, the 30-day average nitrite nitrogen concentration should not exceed 0.02 mg/L, and the maximum concentration should not exceed 0.06 mg/L at any time. The average concentration should be based on a minimum of 5 weekly samples taken in a period of 30 days.

5.3.3 Nitrate

Drinking water is the most sensitive water use with respect to nitrate nitrogen (NO_3-N). A high nitrate concentration in drinking water is known to cause methaemoglobinaemia which results from reduction of nitrate to nitrite in the stomach as well as in the saliva; children are especially sensitive to this condition. The maximum concentration of (NO_3+NO_2)-N in raw drinking water is recommended not to exceed 10 mg/L by the B.C. Ministry of Environment (Nordin and Pommen, 1986).

The (NO_3+NO_2)-N concentration in the Oyster River watershed varied between < 0.02 and 0.82 mg/L (Table 8). A maximum concentration of 0.69 mg/L NO_3-N was noted for site 0125903 on Piggott Creek, 30 m downstream from the permit (PE-5123) site for the discharge of effluent from the Mt. Washington Ski Resort. However, the discharge from the ski resort appears to have a minimum effect downstream from this site.

TABLE 7

DISSOLVED NITRITE NITROGEN CONCENTRATIONS IN THE OYSTER RIVER WATERSHED

Site number an Description	Data Characteristics*				
	n	max	min	Dissolved Cl^- range (average)	Time period
		-µg/L-		-mg/L-	
0125902: Piggott Cr. 50 m u/s PE-5123	7	< 5	< 5	< 0.5	1980-88
0125903: Piggott Cr. 30 m d/s PE-5123	7	< 5	< 5	0.5-0.6 (0.55)	1980-88
0125904: Piggott Cr. u/s Branch161 bridge	2	< 5	< 5	-	1980-85
0125580: Oyster R. at highway bridge	27	< 5	< 5	0.7-1.5 (1.1)	1971-84

* n = total number of measurements

TABLE 8

DISSOLVED NITRATE PLUS NITRITE NITROGEN CONCENTRATIONS IN THE OYSTER RIVER WATERSHED

Site number an Description	Data Characteristics*				
	n	max	min	Values < D.L.	Time period
		- mg/L-		%	
0125902: Piggott Cr. 50 m u/s PE-5123	16	0.12	< 0.02	43.7	1979-88
0125903: Piggott Cr. 30 m d/s PE-5123	20	0.69	< 0.02	55.0	1979-88
0125904: Piggott Cr. u/s Branch 161 bridge	6	0.05	< 0.02	50.0	1979-85
0125582: Oyster R. at Logging Rd. bridge	35	0.16	< 0.02	34.3	1986-89
0125580: Oyster R. at highway bridge	43	0.82	< 0.02	20.9	1972-88

* n = total number of measurements; D.L. = detection limit

OBJECTIVE: To protect drinking water use, the concentration of nitrate plus nitrite nitrogen in the Oyster River watershed should not exceed 10 mg/L at any time.

5.4 MICROBIOLOGICAL CHARACTERISTICS

The British Columbia Ministry of Environment criteria for microbiological water quality are given in terms of such indicators as *E. Coli*, Enterococci, *Pseudomonas aeruginosa*, and fecal coliforms (Warrington, 1988). However, most of the available microbiological data from the Oyster River watershed are in terms of fecal and total coliforms. The objectives proposed here are in terms of fecal coliforms, which are considered to be better indicators of fecal contamination and the risk of pathogens being present, than total coliform. More recently, the *E. Coli* concentration was also measured in the watershed (Table 9A). The results suggest that fecal coliform and *E. Coli* concentrations in the watershed were positively correlated; also, fecal coliforms constituted the major proportion of *E. Coli*, indicating that human activities and/or wildlife are the major sources of fecal contamination in the watershed.

Drinking water is the most sensitive water use with respect to microbiological water quality. The criteria recommended by the B.C. Ministry of Environment are a function of the water treatment. The number of fecal coliforms in a raw drinking water supply receiving a treatment of disinfection only should not exceed 10 CFU/cL (colony-forming units per centilitre) in more than 10% of the samples taken in a period of 30 days. Where raw water must receive partial treatment consisting of filtration (or sedimentation) and disinfection before distribution, the fecal coliform count should not exceed 100 CFU/cL in more than 10% of the samples. The criteria for primary-contact recreation, general irrigation (crops which may be eaten raw are not grown in the Oyster River watershed), and general livestock water use state that the fecal concentration should not exceed 200 CFU/cL (geometric mean), 1 000 CFU/cL (geometric mean), and 200 CFU/cL (maximum), respectively. (Warrington, 1988).

5.4.1 Sources of Fecal Contamination

The ratio of fecal coliform/fecal streptococcus (FC/FS) has been used to characterize the origin of fecal contamination. Geldreich and Kenner (1969) suggested that the FC/FS ratio

TABLE 9A

FECAL COLIFORM (FC) AND ENTEROCOCCI (EC) CONCENTRATIONS IN THE OYSTER RIVER WATERSHED

Site Number and Description	Date	Fecal coliform	Enterococci	FC/EC
		CFU/cL	CFU/cL	
0125582: Oyster R. Logging Rd. bridge	23-10-89	119	330	0.4
	30-10-89	2	9	0.2
	06-11-89	2	16	0.1
	13-11-89	2	6	0.3
E207431: Woodhus Cr. at Duncan Main	23-10-89	80	139	0.6
	30-10-89	9	2	4.5
	06-11-89	7	5	1.4
	13-11-89	8	4	2.0
E207430: Little Oyster R. at York Rd.	23-10-89	44	77	0.6
	30-10-89	5	2	2.5
	06-11-89	12	10	1.2
	13-11-89	9	4	2.2
0125580: Oyster R. at highway bridge	23-10-89	200	403	0.5
	30-10-89	9	5	1.8
	06-11-89	8	9	0.9

CFU/cL = colony-forming units per centilitre (based on median values) is greater than 4 for human waste and less than 0.7 for other animals Recently, however, the enterococcus (EC) concentration was measured in the mainstem Oyster River, Woodhus Creek and the Little Oyster River. The enterococci bacteria are a subgroup of the fecal streptococci restricted to the strains of Streptococcus faecalis and S. faecium (Olivieri, 1982). Obviously, the ratio FC/EC for human waste and other warm blooded animals will be greater than or equal to 4 and 0.7, respectively, depending upon the proportion of enterococci in fecal streptococci. The results in Table 9A suggest that fecal contamination in the mainstem Oyster River upstream (Site 0125582) from Woodhus Creek was solely due to wildlife (agricultural activities are non-existent in the Oyster River watershed upstream from Woodhus Creek). Assuming, on the average, enterococci concentration to be one-half of the fecal streptococci, FC/EC ratio for animal wastes will be 1.4. The data in Table 9A indicate that 50% of the FC/EC ratios for Woodhus Creek (Site E207431) and Little Oyster River (Site E207430) were ≤1.4. Except for the cranberry farm in the Little Oyster River watershed, there is little human or agricultural activity upstream from sites E207430 and E207431. Also, water for irrigation of the cranberry crop is drawn from a tributary (Hickok Creek) to the Little Oyster River (Table 1). It appears, therefore, that wildlife in the area was responsible for the observed fecal coliform levels in these streams also. However, more data are required to confirm this hypothesis, especially in the Little Oyster River.

Due to several additional sources (e.g., septic fields) and insufficient data no attempt is made to identify sources of fecal contamination in the Oyster River downstream from Woodhus Creek.

5.4.2 Piggott Creek

The maximum concentration of fecal coliforms (>2400 MPN/cL) in the Oyster River watershed, was measured for site 0125903 on January 5, 1982 (Table 9B). The site is located on Piggott Creek 30 m downstream from the point where the Mt. Washington Ski Resort (PE-5123) discharged its effluent. Two methods (multiple tube or MPN procedure and membrane filter technique) were used to determine the fecal coliform concentration in Piggott Creek. However, water samples for the two sets of analyses were collected at different times. Assuming the results obtained from the two techniques were comparable, it was determined that in about 90% (23 of 27 measurements) of the samples the fecal count was ≤ 33 CFU/cL and the geometric mean was <15 CFU/cL (Tables 9B and 9C). On three occasions, however, the fecal concentration exceeded the recommended water quality guidelines for drinking water requiring partial treatment, primary-contact recreation, and general livestock use.

The fecal contamination of Piggott Creek (Site 0125902) upstream from site 0125903 was relatively minor. The maximum and the geometric mean concentrations of fecal coliform were <18 and <3 MPN/cL, respectively.

The above results suggest that complete treatment may be needed if the Piggott Creek water downstream from the permitted discharge (PE-5123) is to be used for drinking purposes. Note, however, that primary-contact recreation, irrigation, livestock, and drinking water uses have not been identified for Piggott Creek to-date. The Piggott creek system is, however, considered to have a moderate to high potential for coho salmon fisheries (Oyster River Water Management Plan, 1988), but the fecal coliform guideline for aquatic life pertains only to shellfish harvesting (Warrington, 1988).

5.4.3 Woodhus Creek and Little Oyster River

The fecal coliform concentrations in Woodhus Creek (Site E207431) and Little Oyster River (Site E207430) ranged from 34 to 200 CFU/cL and 25 to 350 CFU/cL, respectively (Table 9C). Obviously complete treatment would be required if water from these streams is to be used for drinking purposes. Although the geometric means (based on all data) of 23 and 16 CFU/cL for the Woodhus Creek and Little Oyster River, respectively, meet the primary-contact recreation and general irrigation criteria recommended by the B.C. Ministry of Environment, the maximum concentrations (i.e., 200 and 340 CFU/cL, respectively) for the sites equalled or exceeded the maximum criterion for general livestock water use.

The agricultural (except for Hickok Creek in the Little Oyster River watershed), contact recreational, and drinking water uses have not been identified for Woodhus Creek and Little Oyster River. These streams are important fish rearing channels; however, guidelines to protect fish from fecal contamination have not been proposed.

TABLE 9B

FECAL COLIFORM CONCENTRATIONS IN THE OYSTER RIVER WATERSHED

Site number and Description	Data Characteristics*								
	n	geom. mean	max	min	values <D.L	values >10/cL	values >100/cL	90th perc.	Time period
		-MPN- (CFU/cL)				- % - (%)		MPN (CFU/cL)	
0125902: Piggott Cr. 50 m u/s PE-5123	13 (11)	3 (1)	<18 (8)	<2 (0)	54 46	0 (0)	0 (0)	14 (8)	1980-88
0125903: Piggott Cr. 30 m d/s PE-5123	14 (11)	14 (2)	>2400 (10)	<2 (<1)	50 (45)	36 (0)	21 (0)	2400 (10)	1980-88
0125904: Piggott Cr. u/s Branch 161 bridge	3	2	2	<2	67	0	0		1980-81
0125582: Oyster R. Logging Rd. bridge	5	4	33	<2	80	20	0		1987-89
E207431: Woodhus Cr. at Duncan Main	1		21	21					1989
0125581: Oyster R. above camp	2	2	<2	<2	100				1976
0125580: Oyster R. at highway bridge	29	7	240	<2	24	31	7	79	1971-89

* n = number of measurements; D.L. = detection limit; values in parentheses are in units of CFU/cL; means are calculated assuming 'less than' values numerically equal to the detection limit

TABLE 9C

FECAL COLIFORM/E. COLI CONCENTRATIONS IN THE OYSTER RIVER WATERSHED

Site number and Description	Data Characteristics*								
	n	geom. mean	max	min	values <D.L	values >10/cL	values >100/cL	90th perc.	Time period
		CFU/cL			%			CFU/cL	
0125902: Piggott Cr. 50 m u/s PE-5123	2	2	2	<2	50	0	0		1989-90
0125903: Piggott Cr. 30 m d/s PE-5123	2	2.4	3	2	0	0	0		1989-90
0125582: Oyster R. Logging Rd. bridge	10 (9)	3 (3)	119 (139)	<2 (<2)	40 (33)	10 (11)	10 (11)	107	1989 (1989)
E207431: Woodhus Cr. at Duncan Main	10 (9)	23 (27)	200 (245)	6 (6)	0 (0)	50 (67)	20 (11)	190	1989 (1989)
E207430: Little Oyster R. at York Rd.	10 (9)	16 (23)	340 (350)	<2 (5)	10 (0)	60 (67)	10 (11)	311	1989 (1989)
0125580: Oyster R. at highway bridge	9 (8)	7 (6)	200 (259)	<2 (2)	11 (0)	22 (33)	11 (17)		1989 (1989)

* n = number of measurements; D.L. = detection limit; values in parentheses are for E. Coli.
means are calculated assuming 'less than' values numerically equal to the detection limit

5.4.4 Mainstem Oyster River

As in Woodhus Creek and Little Oyster River, the contamination of the mainstem Oyster River (Site 0125582) upstream from Woodhus Creek with fecal coliforms was associated with wildlife (Section 5.4.1). The data show that 13 of the 15 measurements were either below the detection limit (2 CFU/cL) or 10 CFU/cL. However, on two occasions values as high as 33 MPN (Feb. 23, 1989) and 119 CFU/cL (Oct. 23, 1989) were found (Tables 9B and 9C). The geometric mean and the maximum concentrations suggest that the Oyster River water upstream from Woodhus Creek is safe for contact recreation, general irrigation, and general livestock use (Tables 9B and 9C). Drinking water use on the mainstem upstream from Woodhus Creek is non-existent.

Site 0125580 is located near the mouth of the Oyster River in an area of high population density and recreational and agricultural use, and is relatively more contaminated with fecal coliforms than the upstream site 0125582 (Tables 9B and 9C). Of the total of 38 fecal measurements at this site, 3 (or 7.8.%) exceeded 100 CFU/cL. Also, one (240 CFU/cL on Jan. 10, 1981) of the measurements exceeded the 200 CFU/cL maximum guideline for general livestock use. The 90th percentile and geometric mean concentrations (based on all data) suggest that water in the Oyster River at the mouth is suitable for drinking (requiring partial treatment), primary-contact recreation, and general irrigation use (Table 9B and 9C).

As noted in section 5.2, the Oyster River water goes through a natural (in situ) filtration process before entering the drinking water supply wells located along the river banks. The Regional District of Comox-Strathcona chlorinates its water before distribution to the community at large.

OBJECTIVE: To protect drinking water use in the Oyster River watershed, where partial treatments consisting of filtration (or sedimentation) and disinfection are considered necessary at times, the fecal coliform count should not exceed 100 CFU/cL in more than 10% of the samples. This objective will also protect primary-contact recreation, irrigation, and livestock watering. The available data are too sparse to be conclusive, but this objective may imply a reduction in the current coliform levels in the Oyster River. A

minimum of 5 but preferably 10 samples collected at equal intervals in 30 days is required for the 90th percentile determination.

Objectives for Woodhus Creek, Little Oyster River, and Piggott Creek are not proposed at this time because of limited data. Also, water uses such as drinking water and contact recreation including rafting and boating have not been identified for these streams. Although these streams are important from a fisheries point of view, no microbiological guidelines (except for shellfish harvesting) have been proposed by the Ministry of Environment to protect fish.

5.5 ALUMINUM

Aquatic life is the most sensitive water use with respect to aluminum (Al). The toxicity of Al is pH dependent and increases with a decrease in pH. The criteria approved by the British Columbia Ministry of Environment are expressed in terms of maximum and 30-day average concentrations of dissolved Al (Butcher, 1988). It was recommended that the maximum and the 30-day average concentration in water of pH ≥ 6.5 should not exceed 0.1 and 0.05 mg/L dissolved Al, respectively. For waters having pH < 6.5, the maximum and the 30-day average criteria were dictated by two pH-dependent relationships.

The dissolved Al concentrations in the Oyster River and its tributaries varied from < 0.02 to 0.15 mg/L; the corresponding values for pH ranged between 6.6 and 7.2 (Table 10). The maximum concentration of 0.15 mg/L dissolved Al was found in the mainstem river at a site (0125581) located a few kilometers downstream from Woodhus Creek. The significance of this measurement is difficult to assess since there was only one data point for the site. This was the only value out of 20 to exceed the maximum criterion of 0.1 mg/L (pH ≥ 6.5).

The average concentration of dissolved Al for the other two sites on the mainstem Oyster River (0125580 and 0125582) was ≤ 0.05 mg/L, and did not exceed the 30-day average criterion (0.05 mg/L for pH ≥ 6.5) recommended by the B. C. Ministry of Environment. However, the average concentration for site E206684 on a tributary to Piggott Creek was slightly higher than the criterion at 0.06 mg/L dissolved Al. This slight increase in the average concentration for site E206684 may have resulted from contamination by seepage originating from an abandoned mine site on Mt. Washington (E206514), which contains much higher levels

TABLE 10

DISSOLVED ALUMINUM CONCENTRATIONS IN THE OYSTER RIVER WATERSHED

Site number and Description	Data Characteristics*						
	n	mean@	max	min	Values < D.L.	pH range (av.)	Time period
		- mg/L -			%		
E206684: Tributary to Piggott Creek	10	0.06	0.08	< 0.02	10	6.6-7.6 (7.1)	1986-87
0125582: Oyster R. at Logging Rd. bridge	4	0.04	0.05	0.03	0	7.0-7.2 (7.1)	1988
0125581: Oyster R. at Duncan Main	1	0.15	0.15	0.15	0	7.0	1975
0125580: Oyster R. at highway bridge	5	0.05	0.08	0.03	0	7.2	1987-88

* n = total number of measurements; D.L. = detection limit;
@ `less than' values considered equal to the detection limit.

TABLE 11

WATER QUALITY DATA FOR SITE E206514# ON Mt. WASHINGTON

Date	pH	Al-D	Al-T	As-T	Cr-D	Cr-T	Cu-D	Cu-T	Fe-T	Mn-T	Pb-D	Pb-T	Zn-D	Zn-T
		mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	mg/L	mg/L	µg/L	µg/L	mg/L	mg/L
85/10/23	5.5	0.29	0.34	<0.25	<10	<10	120	130	0.13	0.13	<100	<100	<0.01	0.02
85/10/31	n.d.	n.d.	0.26	<0.25	n.d.	<10	n.d.	100	0.13	0.13	n.d.	<100	n.d.	<0.01
85/11/06	5.6	n.d.	0.34	<0.25	n.d.	<10	n.d.	140	0.08	0.14	n.d.	<100	n.d.	0.02
85/11/12	6.0	0.12	0.28	<0.25	<10	<10	110	110	0.17	0.14	<100	<100	<0.01	<0.01
86/04/16	6.2	n.d.	0.13	<0.25	n.d.	<10	n.d.	100	0.09	0.07	n.d.	<100	n.d.	0.01
86/04/23	n.d.	0.27	0.27	<0.25	<10	<10	140	140	<0.01	0.07	<100	<100	0.03	<0.01
86/04/30	n.d.	0.14	0.42	<0.25	<10	<10	110	140	0.11	0.08	<100	<100	0.03	<0.01
86/05/13	n.d.	0.25	0.37	<0.25	<10	<10	130	130	0.10	0.29	<100	<100	<0.01	0.01
86/05/21	n.d.	0.29	0.40	<0.25	<10	<10	100	110	0.11	0.06	<100	<100	0.01	0.01
86/05/27	n.d.	0.46	0.58	<0.25	<10	<10	220	220	0.16	0.06	<100	<100	<0.01	0.02
86/06/03	n.d.	0.45	0.51	<0.25	<10	<10	290	300	0.10	0.07	<100	<100	0.02	0.03
86/06/09	n.d.	0.46	0.61	<0.25	<10	<10	390	400	0.18	0.10	<100	<100	0.02	0.02
86/06/24	n.d.	n.d.	0.51	<0.25	n.d.	<10	n.d.	280	0.12	0.09	n.d.	<100	n.d.	0.02

predominantly in the Tsolum River watershed; n.d.= no data

of both total and dissolved Al (Table 11) (Site E206514 mainly drains into the Tsolum River watershed; some drainage, however,spills over into Piggot Creek in the Oyster River watershed- Kangasniemi and Erickson, 1986) . The influence of the higher Al levels noted for site E206684 on the Oyster River water quality was minor, if any.

OBJECTIVE: To protect aquatic life in the Oyster River watershed, it is recommended that the 30-day average concentration of dissolved aluminum should not exceed 0.05 mg/L. The maximum concentration of dissolved aluminum should not exceed 0.1 mg/L. The average concentration should be based on at least 5 weekly samples taken in a period of 30 days.

5.6 ARSENIC

Both drinking water and aquatic life are equally sensitive uses with respect to arsenic (As) levels in freshwater. To protect human health and aquatic life, the maximum concentration of total As in water should not exceed 0.05 mg/L (Health and Welfare Canada, 1979: CCREM, 1987). The same guidelines have been adopted by the B.C. Ministries of Health and Environment (BCMH, 1982; Pommen, 1989).

The total arsenic concentrations in the Oyster River watershed were less than the detection limits (Table 12). The two detection limits used were 0.001 and 0.3 mg/L. Unfortunately, in most cases (83%), the detection limit employed for the analyses exceeded the guideline of 0.05 mg/L total As; for the other 17% (9 of 52) of the samples, the only value (0.003 mg/L) which exceeded the detection limit was lower than the guideline. From the limited data, it appears unlikely that arsenic levels will pose a serious problem in the Oyster River.

OBJECTIVE: To protect aquatic life and drinking water uses in the Oyster River watershed, it is recommended that total arsenic should not exceed 0.05 mg/L at any time.

TABLE 12

TOTAL ARSENIC CONCENTRATIONS IN THE OYSTER RIVER WATERSHED

Site number and Description	Data Characteristics*				
	n	max	min	Values < D.L.	Time period
		- mg/L -		%	
E207429: Oyster R. d/s Adrian Creek	2	<0.001	<0.001	100	1988
0125903: Piggott Cr. 30 m d/s PE-5123	1	<0.3	<0.3	100	1987
0125904: Piggott Cr. u/s Branch 161 bridge	1	<0.001	<0.001	100	1985
E206684: Tributary to Piggott Creek	13	<0.3	0.003	92.3	1986-87
0125582: Oyster R. at Duncan Main	13	<0.3	<0.25	100	1986-87
0125580: Oyster R. at highway bridge	23	<0.3	<0.005	100	1979-87

* n = total number of measurements; D.L. = detection limit

5.7 CADMIUM

Aquatic life is the most sensitive use with respect to cadmium (Cd) in water. The toxicity of cadmium to aquatic life is a function of hardness of water; cadmium is more toxic in soft water than hard water. The Canadian Council of Resource and Environment Ministers (1987) suggests a guideline of 0.2 µg/L total Cd for the protection of aquatic life in soft waters (hardness = 0-60 mg/L $CaCO_3$). It was also recognized that some species of zooplankton may not be protected if continuously exposed to this concentration. The CCREM guidelines are currently used as working criteria for British Columbia waters (Pommen, 1989).

Both the total and dissolved (not shown) Cd levels in Oyster River and its tributaries are below the detection limits (Table 13). However, the detection limits employed for the analyses (viz., 0.5 and 10 µg/L) were much higher than the guidelines proposed by CCREM (1987) for the protection of aquatic life. To assess the true status of water quality in the Oyster River watershed, Cd analyses must be carried out using detection limits equivalent to or below the guideline.

Oyster River and its tributaries represent a system of soft water, as is the case with the surrounding watersheds (e.g., Quinsam River). The maximum hardness in Oyster River for site 0125580 near the mouth, was measured at < 15 mg/L $CaCO_3$ (Only two hardness measurements have been made; however, based on data from similar streams, such as the Quinsam River, it is unlikely that it ever exceeds 60 mg/L $CaCO_3$).

OBJECTIVE: To protect aquatic life, it is recommended that the total cadmium concentration in the Oyster River watershed should not exceed 0.2 µg/L at any time.

5.8 CHROMIUM

Aquatic life is the most sensitive water use with respect to chromium (Cr). To protect fish from Cr toxicity, the Canadian Council of Resource and Environment Ministers (1987) recommended that the concentration of total chromium should not exceed 20 µg/L in water. Phytoplankton are, however, more sensitive to Cr than fish (Strik et al., 1975). In order to

TABLE 13

TOTAL CADMIUM CONCENTRATIONS IN THE OYSTER RIVER WATERSHED

Site number and Description	Data Characteristics*				
	n	max	min	Values < D.L.	Time period
		- µg/L -		%	
E207429: Oyster R. d/s Adrian Creek	4	<10	<10	100	1988
E207474: Trib. Piggott Cr. at Rossiter Rd.	8	<10	<10	100	1988
0125902: Piggott Cr. 50 m u/s PE-5123	3	<10	<10	100	1987-88
0125903: Piggott Cr. 30 m d/s PE-5123	6	<10	<10	100	1987-88
0125904: Piggott Cr. u/s Branch 161 bridge	1	<0.5	<0.5	100	1985
E206684: Tributary to Piggott Creek	25	<10	<10	100	1986-88
0125582: Oyster R. at Duncan Main	36	<10	<0.5	100	1986-89
E207431: Woodhus Cr. at Duncan Main	13	<10	<10	100	1988-89
E207430: Little Oyster River at York Road	12	<10	<10	100	1988-89
0125580: Oyster R. at highway bridge	52	<10	<0.5	100	1979-89

* n = total number of measurements; D.L. = detection limit

protect the aquatic community including zooplankton and phytoplankton, CCREM recommends adopted as working criteria by the B.C. Ministry of Environment (Pommen, 1989).

The detection limits (5 and 10 µg/L) employed for the total chromium analyses in the Oyster River watershed were substantially above the CCREM guideline of 2 µg/L for the protection of the aquatic community. Nonetheless, concentrations as high as 70 µg/L (for site E206684 on a tributary to Piggott Creek) and 20 µg/L (for site 0125580 on the Oyster River at the mouth) were measured in the watershed (Table 14). However, more than 90% of all measurements were below the detection limits. Also, most of the measurements were made using the higher detection limit. As a result, true chromium levels in the Oyster River watershed are difficult to assess with the available data.

OBJECTIVE: To protect aquatic life, it is recommended that the total chromium in the Oyster River should not exceed 2 µg/L.

5.9 COBALT

Irrigation and aquatic life are the most sensitive water uses with respect to cobalt (Co) levels. CCREM (1987) recommends that the maximum concentration of total Co in irrigation water for continuous use on all soils should not exceed 50 µg/L. The same guideline has been adopted as a working criterion by the B.C. Ministry of Environment for irrigation and aquatic life (Pommen, 1989).

As in the case of cadmium, the total Co concentration in the Oyster River watershed was below the detection limit (Table 15). Although two detection limits (1 and 100 µg/L) were employed, only 1 of 155 analyses was performed using the lower detection limit. As a result, the true cobalt levels in the Oyster River watershed can not be assessed at the present time.

OBJECTIVE: To protect aquatic life and irrigation water use, it is recommended that the total cobalt concentration in the Oyster River watershed should not exceed 50 µg/L at any time.

TABLE 14

TOTAL CHROMIUM CONCENTRATIONS IN THE OYSTER RIVER WATERSHED

Site number and Description	Data Characteristics*					
	n	mean@	max	min	Values < D.L.	Time period
		- µg/L -			%	
E207429: Oyster R. d/s Adrian Creek	4	-	<10	<10	100	1988
E207474: Trib. Piggott Cr. at Rossiter Rd.	8	-	<10	<10	100	1988
0125902: Piggott Cr. 50 m u/s PE-5123	3	-	<10	<10	100	1987-88
0125903: Piggott Cr. 30 m d/s PE-5123	6	10	10	<10	83.3	1987-88
0125904: Piggott Cr. u/s Branch 161 bridge	1	-	<5	<5	100	1985
E206684: Tributary to Piggott Creek	25	12	70	<10	92	1986-88
0125582: Oyster R. at Duncan Main	36	10	10	<10	97.2	1986-89
E207431: Woodhus Cr. at Duncan Main	13	-	<10	<10	100	1988-89
0125581: Oyster River above camp	1	-	<10	<10	100	1986
E207430: Little Oyster River at York Road	12	-	<10	<10	100	1988-89
0125580: Oyster R. at highway bridge	52	10	20	<5	90.4	1979-89

* n = total number of measurements; D.L. = detection limit
@ `less than' values were considered equal to the detection limit

TABLE 15

TOTAL COBALT CONCENTRATIONS IN THE OYSTER RIVER WATERSHED

Site number and Description	Data Characteristics*				
	n	max	min	Values < D.L.	Time period
		- µg/L -		%	
E207429: Oyster R. d/s Adrian Creek	4	<100	<100	100	1988
E207474: Trib. Piggott Cr. at Rossiter Rd.	8	<100	<100	100	1988
0125902: Piggott Cr. 50 m u/s PE-5123	3	<100	<100	100	1987-88
0125903: Piggott Cr. 30 m d/s PE-5123	6	<100	<100	100	1987-88
0125904: Piggott Cr. u/s Branch 161 bridge	1	<1	<1	100	1985
E206684: Tributary to Piggott Creek	25	<100	<100	100	1986-88
0125582: Oyster R. at Duncan Main	36	<100	<100	100	1986-89
E207431: Woodhus Cr. at Duncan Main	13	<100	<100	100	1988-89
E207430: Little Oyster River at York Road	12	<100	<100	100	1988-89
0125580: Oyster R. at highway bridge	47	<100	<100	100	1979-89

* n = total number of measurements; D.L. = detection limit

5.10 COPPER

Aquatic life is the most sensitive water use with respect to copper (Cu). The toxicity of copper to fresh water aquatic life is a function of the hardness of water. The 30-d average criterion, approved by the B.C. Ministry of Environment, to protect fish from long-term effects of Cu in soft waters (hardness ≤ 50 mg/L $CaCO_3$) is 2 µg/L total Cu (Singleton, 1987). The maximum criterion is also a function of hardness and varies from 2 µg/L total Cu at zero hardness to 3.4 µg/L total Cu at hardness 15 mg/L as $CaCO_3$, the maximum hardness recorded in the Oyster River.

Figure 6 shows dissolved Cu as a function of total Cu. This plot was obtained using all the data in the Oyster River watershed, excluding values which were less than the detection limit. The plot shows that copper levels in the Oyster River watershed are expected to be about the same whether measured as total or as dissolved fraction. However, at the lower end of the scale when the Cu concentration in water was ≤ 10 µg/L, a wide variability in the data was noted (Figure 7). This variability was not associated with the suspended solids fraction of the water, since total Cu was poorly correlated with the non-filterable residue or turbidity in the Oyster River watershed (Appendix 2). Because (i) on occasion, the dissolved Cu could be as high as the total Cu even at the lower end of the scale (Figure 7), and (ii) objectives based on total levels may provide added protection to the system when dissolved Cu levels are lower than the total, the objectives for Cu in the Oyster River watershed were set in terms of total concentration.

The concentration of total Cu in the Oyster River watershed varied widely, ranging between < 1 and 140 µg/L (Table 16) (excluding site E206684 which was influenced by acid mine drainage from an abandoned copper mine on Mt. Washington). Based on all data, the 90th percentile concentration at the highway bridge (Site 0125580) was determined to be 10 µg/L total Cu, which is well above the maximum concentration (3.4 µg/L total Cu) recommended by the Ministry of Environment to protect aquatic life. Several conditions were recognized in the data set which may have biased the statistical results noted above. For instance, (i) two values in the data set were extraordinarily high and may be considered to be anomalous (viz., 140 and 31 µg/L total Cu observed on June 4, 1987 and October 1, 1981, respectively); (ii) on three occasions more than one sample was collected during the same day (viz., Jan. 14, Feb. 10, and Mar. 7, 1988), which may skew the statistical results depending upon the magnitude of the measurements; (iii) on several occasions analyses were performed using a detection limit (10 µg/L) which was higher than the recommended criterion. To eliminate these discrepancies,

Figure 6
Total Versus Dissolved Copper in the Oyster River Watershed

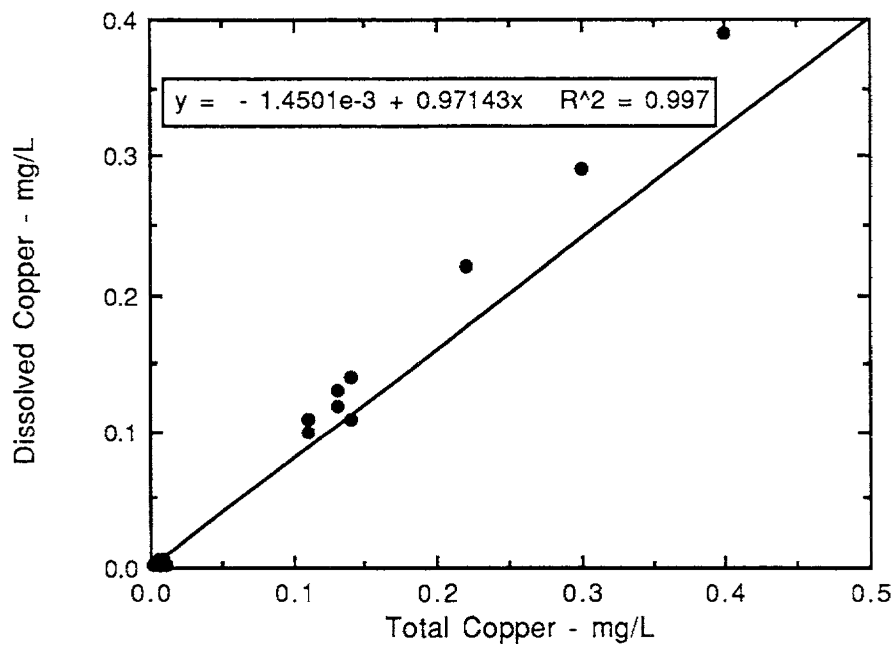


FIGURE 7
Total Versus Dissolved Copper in the Oyster River Watershed (Lower end of Figure 6)

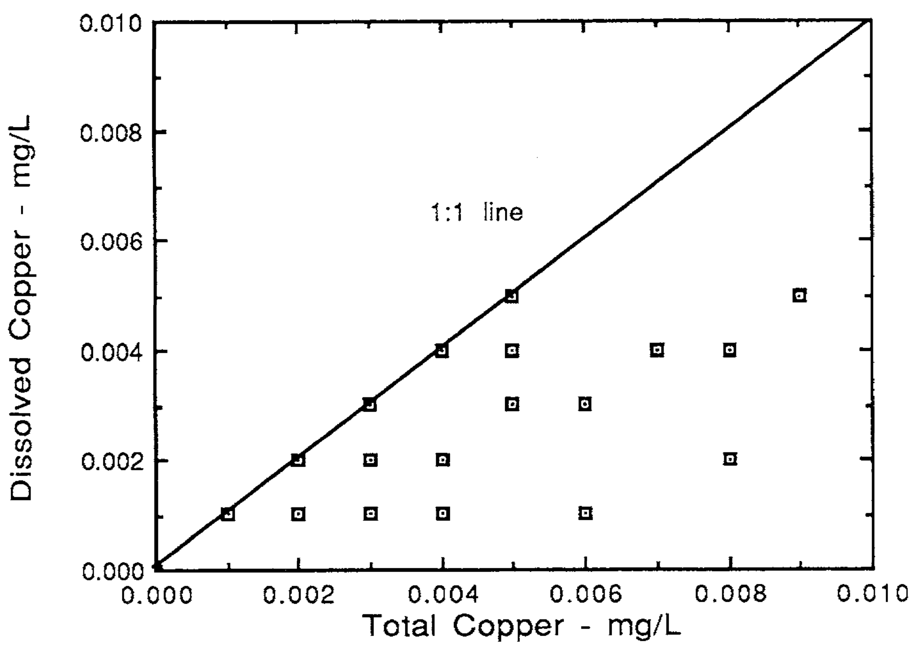


TABLE 16

TOTAL COPPER CONCENTRATIONS IN THE OYSTER RIVER WATERSHED

Site number and Description	Data Characteristics*								
	n	mean@	max	min	values less than D.L.	values less than 4µg/L	values less than 5µg/L	90th perc.	Time period
		- µg/L -			%			µg/L	
E207429: Oyster R. d/s Adrian Creek	4	1.7	2	1	0				1988
E207474: Trib. Piggott ** Cr. at Rossiter Rd.	8	4.0	9	1	0		7		1988
0125902: Piggott Cr. 50 m u/s PE-5123	3	2.0	4	<1	33.3				1987 -88
0125903: Piggott Cr. 30 m d/s PE-5123	6	2.2	4	<1	0				1987 -88
0125904: Piggott Cr. u/s Branch 161 bridge	1	-	<1	<1	100				1985
E206684: Tributary** to Piggott Creek	25	14	220	<1	0			12	1986 -88
0125582: Oyster R. at Duncan Main	36	4.5 (2.8)	30	<1	22.2	28		10 (≤4)	1986 -89
E207431: Woodhus Cr. at Duncan Main	13	2.5	9	<1	15.4	11		8	1988 -89
0125581: Oyster River above camp	7	2.9 (1.7)	4	<1	71.4				1975 -86
E207430: Little Oyster River at York Road	12	3.2	11	<1	8.3		11	9	1988 -89
0125580: Oyster R. at highway bridge	69	6.2 (3.0)	140	<1	40.6		48	10 (5)	1979 -89

* n = total number of measurements; D.L. = detection limit; values in the parentheses are adjusted means or 90th percentile (see text for the definition of `adjusted')
@ `less than' values were considered equal to the detection limit
** affected by drainage from abandoned copper mine site on Mt. Washington

adjusted percentiles (and means) were calculated by excluding the values which were anomalous or recorded as < 10 µg/L (the upper detection limit) from the data set, and by considering only a single (average) value where more than one measurement was made. The adjusted 90th percentile concentration of about 5 µg/L total Cu was estimated for site 0125580, which is much closer to the maximum criterion recommended by the Ministry of Environment. The adjusted 90th percentile for site 0125582 on the mainstem Oyster River was determined to be ≤ 4 µg/L total Cu.

For most other sites in the watershed (viz., those on Woodhus Creek, Little Oyster River, and Piggott Creek tributaries) 87 to 100% of the measurements were below 5 µg/L total Cu (Table 16). The only exception to this was site E206684, which received some seepage from an abandoned copper mine on Mt. Washington (Erickson and Deniseger, 1987; Table 11); both the mean and the 90th percentile concentrations for this site were higher than elsewhere in the watershed (Table 16). The influence of this contamination was, however, not apparent at sites downstream from E206684; e.g., at site E207474 at the mouth of this tributary, the copper levels were only slightly elevated above background (Table 16).

Besides the abandoned copper mine site on Mt. Washington, no other source of metals contamination was noted in the watershed. As noted above, the effect of seepage from the mine site on the mainstem Oyster River water quality is minor, if any.

The adjusted mean concentration of total Cu in the Oyster River watershed (except site E206684 and E207474 on tributaries to the Piggott Creek) varied narrowly between 2 to 3 µg/L (Table 16). Also, an average of 30% of the total Cu measurements in the mainstem Oyster River, were below the lower detection limit of 1.0 µg/L (in estimating means and adjusted means values less than the lower detection limit were considered to be equal to the detection limit).

The maximum and the average concentrations at a background site (E207429) on the mainstem Oyster River were measured at ≤ 2 µg/L. Site E207429 is located well upstream on the mainstem, and was not contaminated with seepage originating from the abandoned Cu mine on Mt. Washington.

OBJECTIVE: To protect aquatic life in the Oyster River watershed, it is recommended that the 30-day average concentration of total Cu

should not exceed 3 μg/L (The average should be based on a minimum of 5 weekly samples taken over a period of 30 days). The total Cu concentration in the watershed (excluding Woodhus Creek and Little Oyster River) should not exceed 5 μg/L in 90% of the measurements (i.e., 90th percentile is ≤ 5 μg/L). The 90th percentile should be based on a minimum of 5 but preferably 10 samples taken at equal intervals in a period of 30 days.

In Woodhus Creek and Little Oyster River, the 90th percentile concentration of total Cu should not exceed 10 μg/L, using a minimum of 5 but preferably 10 samples taken at equal intervals in a period of 30 days.

5.11 IRON

Iron (Fe) is an essential element in human nutrition. The maximum acceptable concentration in drinking water has been set at 0.3 mg/L total Fe by Canada and British Columbia, on the basis of aesthetic considerations (Health and Welfare Canada, 1987; B.C. Ministry of Health, 1982).

The guideline of 0.3 mg/L total Fe has been recommended by CCREM (1987) to protect aquatic life. It was apparently based on the work of Warnick and Bell (1969). These investigators noted that total iron concentrations ranging from 0.32 to 16.0 mg/L were acutely toxic to aquatic insects; however, iron may not be toxic to fish until levels are far greater than the 1.0 mg/L total Fe. The U.S. EPA (1976) and the Province of Manitoba (Williamson, 1983) adopted a guideline of 1.0 mg/L total Fe for the protection of aquatic life.

Background (Site E207429) concentrations of total iron in the Oyster River varied between 0.07 and 0.10 mg/L (Table 17). In the mainstem of the river, the concentration increased towards the mouth of the river (Site 0125580). This increase was primarily due to naturally occurring high levels of Fe in the Little Oyster River drainage system, although both Woodhus Creek and Little Oyster River contributed to it. The total Fe concentration in Little Oyster River (Site E207430) was among the highest and ranged between 0.23 and 2.24 mg/L; only one of 12 measurements was below the 0.3 mg/L total Fe drinking water and aquatic life guidelines (Table 17). Similarly, 46% of the measurements exceeded the drinking water and aquatic life guidelines in Woodhus Creek (Site E207431). Currently, water licences for domestic purposes are non-existent on Little Oyster River and Woodhus Creek.

In the mainstem Oyster River, the concentration of total Fe was the highest for site 0125580 near the mouth of the river. The data suggest that 2 of 72 measurements for the site were anomalously high (e.g., 15 mg/L on October 1, 1981 and 4.93 mg/L on June 4, 1987). Also on three occasions two to three measurements were made in a day, which may skew the statistics depending upon the magnitude of the values. Upon exclusion of the anomalous values and averaging the replicate measurements, it was noted that about 17% of the measurements exceeded the drinking water and aquatic life guidelines of 0.3 mg/L total Fe; the 90th percentile concentration for the site was estimated to be 0.56 mg/L total Fe.

The results in Appendix 2 (Figure A2-4) suggest that total Fe and non-filterable residue (or turbidity) in the mainstem Oyster River were significantly correlated ($r^2 = 0.9$). In general, the total Fe concentration at the mouth of the river (Site 0125580) exceeded the guideline of 0.3 mg/L only during high flow periods when non-filterable residue (or turbidity) was also high (Table A1-1, Appendix 1). Obviously a treatment for turbidity/suspended solids will be needed at times to meet the drinking water guideline for Fe near the mouth of the river. It was noted that water drawn from drinking water supply wells along the Oyster River undergoes a process of natural filtration (section 5.2). From a fisheries point of view, the dissolved form of iron is likely to be more hazardous than the total. Figure 8 was obtained using all significant data (i.e., values ≥ detection limit) in the watershed. These results suggest that at a total Fe concentration of 0.56 mg/L in the Oyster River, the dissolved Fe concentration will be about 0.3 mg/L. The maximum value for the 90th percentile of dissolved iron in the Oyster River watershed (excluding Woodhus Creek and Little Oyster River) was < 0.3 mg/L (Table 17).

OBJECTIVE: To protect drinking water use and aquatic life it is recommended that the 90th percentile concentration should not exceed 0.3 mg/L dissolved Fe in the Oyster River watershed, excluding Woodhus Creek and Little Oyster which have naturally occurring Fe levels in excess of this objective. The 90th percentile should be calculated from a minimum of 5 but preferably 10 samples taken at equal intervals in a period of 30 days.

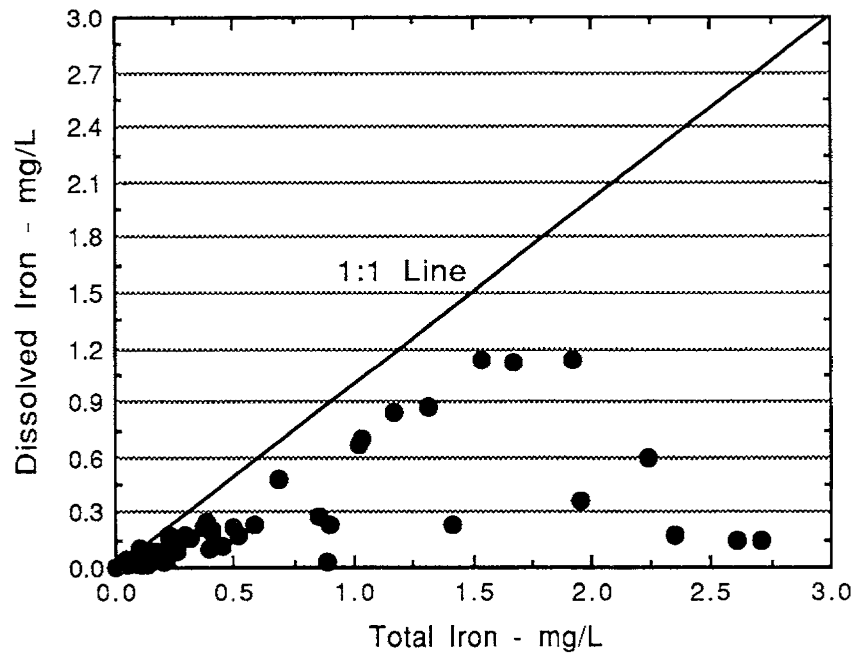
TABLE 17

TOTAL (and DISSOLVED) IRON CONCENTRATIONS IN THE OYSTER RIVER WATERSHED

Site number and Description	Data Characteristics*								
	n	mean@	max	min	measurements <D.L.	>0.3mg/L	>1mg/L	90th perc.	Time period
		- mg/L -			%				
E207429: Oyster R. d/s Adrian Creek	4 (4)	0.09 (0.03)	0.10 (0.05)	0.07 (0.03)	0	0			1988
E207474: Trib. Piggott Cr. at Rossiter Rd.	8 (8)	0.09 (0.04)	0.12 (0.08)	0.05 (<0.01)	0	0			1988
0125902: Piggott Cr. 50 m u/s PE-5123	3	0.08	0.09	0.07	0	0			1987 -88
0125903: Piggott Cr. 30 m d/s PE-5123	6 (4)	0.13 (0.05)	0.39 (0.1)	<0.1 (<0.01)	16.7	16.7	0		1987 -88
0125904: Piggott Cr. u/s Branch 161 bridge	1	0.12	0.12	0.12	0	0			1985
E206684: Tributary to Piggott Creek	25 (14)	0.15 (0.06)	0.89 (0.1)	0.04 (0.02)	0	8.0	0	 (0.1)	1986 -88
0125582: Oyster R. at Duncan Main	36 (16)	0.15 (0.06)	0.9 (0.23)	0.02 (<0.01)	2.7	11.8	0	 (0.2)	1986 -89
E207431: Woodhus Cr. at Duncan Main	13 (13)	0.34 (0.18)	0.69 (0.48)	0.09 (0.06)	0	46.1	0	 (0.39)	1988 -89
0125581: Oyster River above camp	4	0.12	0.19	<0.1	50	0			1975 -86
E207430: Little Oyster River at York Road	12 (12)	1.15 (0.66)	2.24 (1.14)	0.23 (0.17)	0	91.7	58.3	 (1.1)	1988 -89
0125580: Oyster R. at highway bridge	72 (23)	0.59 (0.09)	15.0 (0.37)	<0.01 0	9.7	17.9	7.4	 (0.24)	1979 -89

* n = total number of measurements; D.L. = detection limit
@ `less than' values were considered equal to the detection limit

FIGURE 8
Dissolved versus Total Iron in the Oyster River watershed



5.12 LEAD

Aquatic Life is the most sensitive water use with respect to lead (Pb) levels in surface water. The toxicity of Pb to fish is a function of the hardness of water; the acute and chronic toxic effects decrease with increasing hardness.

Only two measurements (at Site 0125580) for water hardness were made in the Oyster River watershed. These were 11.9 mg/L $CaCO_3$ on April 26, 1983 and 12.3 mg/L $CaCO_3$ on April 18, 1984 (Table A1-1, Appendix 1).

To protect aquatic life from acute and chronic effects of Pb and consumers of fish, the B.C. Ministry of Environment has recommended the following guidelines: (i) the 30-day average concentration (based on at least 5 weekly samples taken in a period of 30 days) of total Pb in waters with hardness >8 mg/L $CaCO_3$ should be $\leq 3.31 + e^{(1.273 \ln(\text{average hardness}) - 4.705)}$; at the same time 80% of the measurements should be ≤1.5 x the 30-day average; (ii) the maximum concentration in water at hardness ≤ 8 mg/L $CaCO_3$ should not exceed 3 µg/L total Pb ; at hardness ≥ 8 mg/L $CaCO_3$ the maximum concentration at any time.should not exceed $e^{(1.273 \ln(\text{hardness}) - 1.46)}$; (iii) a site specific investigation should be done if levels in the edible portion of fish exceed 0.8 µg/g (wet weight) (Nagpal, 1988).

The maximum concentration of total Pb at a background site (Site E207429) in the Oyster River was determined to be 2 µg/L (Table 18). Among all the measurements made in the watershed using the lower detection limit (1 µg/L), the maximum concentration was 8 µg/L total Pb for site 0125580 on Feb. 7, 1973.

Assuming that all measurements below the detection limits were numerically equal to the detection limit, the average concentration of total Pb in the Oyster River at the mouth (Site 0125580) was determined to be about 51 µg/L. However, a large number of measurements (35 of 70) were below the upper detection limit of 100 µg/L (Table 18). Using the same assumption for all sites where measurements were made using the lower detection limit (1 µg/L), the average concentration in the watershed was determined to be ≤ 1.5 µg/L total Pb. Also, note that the average concentration of total Pb for site 0125580 based on 5 consecutive measurements from more recent (1988 calender year) data, was about 2 µg/L.

There are no data on lead levels in fish in the Oyster River.

TABLE 18

TOTAL LEAD CONCENTRATIONS IN THE OYSTER RIVER WATERSHED

Site number and Description	Data Characteristics*							
	n	mean@	max	min	values less than D.L.	L.D.L.	U.D.L.	Time period
		- µg/L -			%			
E207429: Oyster R. d/s Adrian Creek	4		2	<1	50	2		1988
E207474: Trib. Piggott Cr. at Rossiter Rd.	8		2	<1	50	4		1988
0125902: Piggott Cr. 50 m u/s PE-5123	3		<100	<100	100		3	1987 -88
0125903: Piggott Cr. 30 m d/s PE-5123	6		3	<1	83.3	5		1987 -88
0125904: Piggott Cr. u/s Branch 161 bridge	1		<1	<1	100	1		1985
E206684: Tributary to Piggott Creek	25		<100	<100	100		25	1986 -88
0125582: Oyster R. at Duncan Main	36		<100	<1	91.7	9	24	1986 -89
E207431: Woodhus Cr. at Duncan Main	13		4	<1	46.2	6	-	1988 -89
0125581: Oyster River above camp	7		<100	<1	100	6	1	1975 -86
E207430: Little Oyster River at York Road	12		2	<1	41.7	5	-	1988 -89
0125580: Oyster R. at highway bridge	70		8	<1	81.4	21	35	1979 -89

* n = total number of measurements; D.L., L.D.L. & U.D.L. = Lower and upper detection limits
@ `less than' values were considered equal to the detection limit

<u>OBJECTIVE</u>: To protect aquatic life in the Oyster River watershed from chronic effects of lead, it is recommended that the 30-day average concentration of total Pb should not exceed 3.31 + $e^{\{1.273 \ln (\text{average hardness}) - 4.705\}}$ µg/L when hardness is ≥ 8 mg/L $CaCO_3$; also, no more than 20% of the measurements should exceed 1.5 times the 30-day average concentration. To protect aquatic life from acute toxic effects, the maximum concentration of total Pb should not exceed 3 µg/L at hardness ≤ 8 mg/L $CaCO_3$; when hardness exceeds 8 mg/L $CaCO_3$, the maximum should not exceed $e^{\{1.273 \ln (\text{hardness}) - 1.46\}}$. The total lead level in the edible portion of fish should not exceed 0.8 µg/g (wet weight). The 30-day average should be based on at least 5 weekly samples collected over a period of 30 days.

5.13 <u>MANGANESE</u>

Manganese (Mn), an essential element in animal and human nutrition, belongs to a category of chemical substances which are of no immediate health significance. However, if present in excessive amounts, it (i) is aesthetically objectionable, (ii) interferes with water-treatment processes and distribution, or (iii) stains fixtures and plumbing (Health and Welfare Canada, 1979). Drinking water is the most sensitive use with respect to Mn; to protect this use Health and Welfare Canada (1987) and B.C. Ministry of Health (1982) recommended that the total Mn concentration in water should not exceed 0.05 mg/L.

Background (Site E207429) concentrations of total Mn in the Oyster River were < 0.01 mg/L (Table 19). Concentrations above the level (0.05 mg/L total Mn) recommended by Health and Welfare Canada and the B.C. Ministry of Health were measured for three of the eleven sites in the watershed. However, only a small number of measurements exceeded the recommended criterion at a site; e.g., 2 of 25 values for site E206684 on a tributary to Piggott Creek, 4 of 12 values for site E207430 on the Little Oyster River, and 5 of 50 values for site 0125580 on the Oyster River at the mouth. Also, more than 76% of all values were below the detection limit of 0.01 mg/L total Mn. In terms of dissolved Mn, the maximum concentration in the Oyster River watershed was measured at 0.01 mg/L, and only exceeded the guideline in the Little Oyster River (0.11 mg/L) (Table 19).

TABLE 19

TOTAL (and DISSOLVED) MANGANESE CONCENTRATIONS IN THE OYSTER RIVER WATERSHED

Site number and Description	Data Characteristics*						
	n	mean@	max	min	measurements < D.L.	measurements > 0.05 mg/L	Time period
		- mg/L -			%	%	
E207429: Oyster R. d/s Adrian Creek	4 (4)	-	<0.01 (<0.01)	<0.01 (<0.01)	100		1988
E207474: Trib. Piggott Cr. at Rossiter Rd.	8 (8)	0.01	0.03 (<0.01)	<0.01 (<0.01)	87.5		1988
0125902: Piggott Cr. 50 m u/s PE-5123	3	-	<0.01	<0.01	100		1987 -88
0125903: Piggott Cr. 30 m d/s PE-5123	6 (4)	-	<0.01 (<0.01)	<0.01 (<0.01)	100		1987 -88
0125904: Piggott Cr. u/s Branch 161 bridge	1	-	<0.01	<0.01	100		1985
E206684: Tributary to Piggott Creek	25 (14)	0.02	0.07 (0.01)	<0.01 (<0.01)	72	10	1986 -88
0125582: Oyster R. at Duncan Main	36 (16)	0.01	0.02 (<0.01)	<0.01 (<0.01)	94.4		1986 -89
E207431: Woodhus Cr. at Duncan Main	13 (13)	0.01	0.02 (<0.01)	<0.01 (<0.01)	84.6		1988 -89
0125581: Oyster River above camp	1 (5)	-	<0.01 (<0.02)	<0.01 (<0.02)	100		1986
E207430: Little Oyster River at York Road	12 (12)	0.05	0.15 (0.11)	0.01 (<0.01)	0	33.3	1988 -89
0125580: Oyster R. at highway bridge	50 (21)	0.02	0.30 (0.01)	<0.01 (<0.01)	76	10	1979 -89

* n = total number of measurements; D.L. = detection limit

@ \`less than' values were considered equal to the detection limit

A plot of total Mn and suspended solids for site 0125580 suggests that these parameters are strongly correlated (r^2 = 0.829) (Figure A2-6, Appendix 2). Furthermore, all of the high values (greater than the recommended drinking water guideline of 0.05 mg/L total Mn) were either anomalous or measured during wet periods when the suspended matter content of the river was also high (Table A1-1, Appendix 1). Obviously, treatment (e.g., filtration) to remove turbidity and non-filterable residue will substantially reduce the Mn level in the Oyster River water used for domestic purposes. As noted in section 5.2, before entering the drinking water supply wells along the banks of the Oyster River, the water goes through a process of natural filtration.

The Little Oyster River (Site E207430) had the highest average concentration of total Mn (0.05 mg/L) in the watershed (Table 19) as it did for iron. Also, the number of instances in which the total (33.3%) and the dissolved (17%) Mn concentration exceeded the guideline of 0.05 mg/L was highest for the site. Figure 9 suggests a strong association (r^2 = 0.945) between iron and manganese in the Little Oyster River.

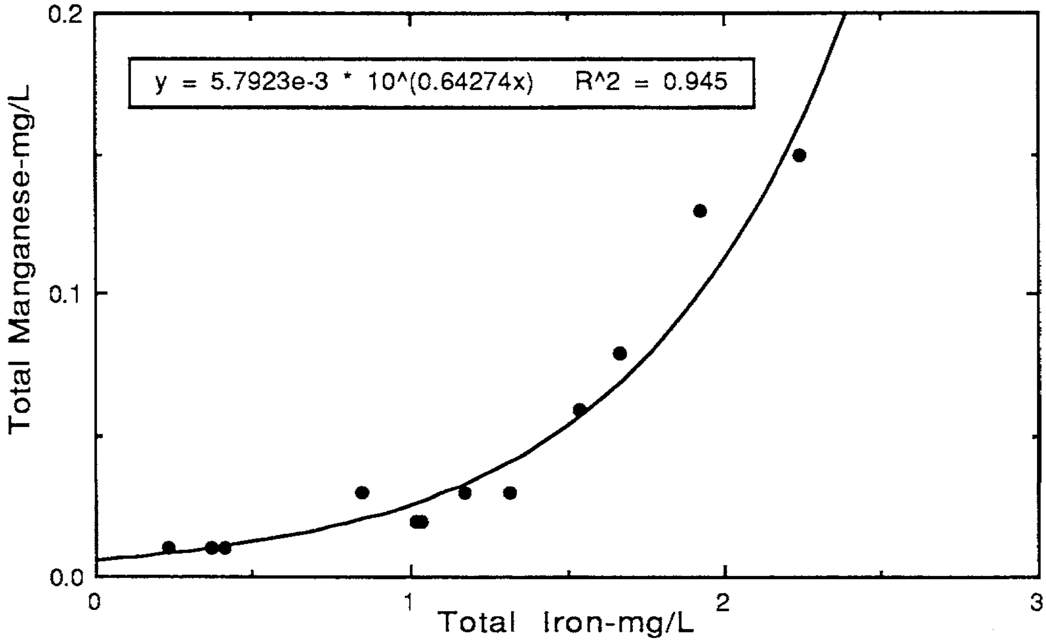
OBJECTIVE: To protect drinking water use, it is recommended that the maximum concentration in the Oyster River watershed should not exceed 0.05 mg/L dissolved Mn, excluding the Little Oyster River which has naturally occurring levels above this objective.

5.14 MERCURY

Aquatic life and its consumption by humans and wildlife are the most sensitive uses with respect to mercury (Hg) in water. The Ministry of Environment recommends that the 30-day average concentration of total Hg in water should not exceed 0.02 µg/L, to prevent undesirable accumulation of mercury in fish tissue (> 0.5 mg Hg/kg wet weight) and to protect aquatic life from chronic toxic effects. To protect fish from acute toxic effects, the concentration in water should not exceed 0.1 µg/L total Hg (Nagpal, 1989).

The mercury data for the Oyster River Watershed are limited both in quantity and quality (Table 20). Only two of the total of eleven sites in the watershed were monitored for Hg. Both these sites are located on the mainstem Oyster River; one (Site 0125581) a few

Figure 9
Iron and Manganese Relationship for Little Oyster River (SITE E207430)



kilometers upstream from the Little Oyster River, and the other (Site 0125580) at the mouth of the river. Site 0125581 has a total of six measurements to-date. From the data quality point of view, the detection limit of 0.05 µg/L total Hg used for the analyses is above the 30-day criterion recommended by the B.C. Ministry of Environment (Nagpal, 1989). Therefore, the objective proposed here should be considered tentative at present.

Assuming that all values below the detection limit were numerically equal to 0.05 µg/L (the detection limit), the average concentration of total Hg in Oyster River at the two sites ranged between 0.05 and 0.07 µg/L (Table 20). Fish reared in waters containing > 0.02 µg/L total Hg may accumulate an undesirable level of mercury in their flesh (> 0.5 mg/kg wet weight). This may be the case, especially with the resident species of steelhead and cutthroat found in Oyster River. However, no data on mercury in fish from the Oyster River were available to check this. Also, 66% (4 of 6 measurements; Site 0125581) to 76% (19 of 25 measurements; Site 0125580) of measurements were below the detection limit of 0.05 µg/L; obviously the average Hg levels in the Oyster River will be much lower than those shown in Table 20.

The data also indicate that only one (0.13 µg/L total Hg for site 0125581 on June 28, 1976) of the total of thirty one measurements from both sites (Table 20), exceeded the maximum criterion of 0.1 µg/L recommended by the B.C. Ministry of Environment (Nagpal, 1989). The significance of a single high value can not be assessed at this time for the lack of sufficient and recent data. Note that 6 of the 8 values greater than the detection limit for mercury were for samples collected before mid-1976 (Appendix 1), and that no field blanks are available to determine if the detectable values are due to contamination during the sampling and analytical process.

OBJECTIVE: To protect aquatic life and consumers of fish, it is recommended that the average concentration of total Hg in the Oyster River watershed should not exceed 0.02 µg/L. To prevent acute toxicity to aquatic life, the total Hg concentration in water should not exceed 0.1 µg/L. The total Hg in the edible portion of fish should not exceed 0.5 mg/kg wet weight. The objective should be considered tentative until additional data using low detection limits establish the mercury concentrations in the Oyster River watershed. The

TABLE 20

TOTAL MERCURY CONCENTRATIONS IN THE OYSTER RIVER WATERSHED

Site number and Description	Data Characteristics*					
	n	mean@	max	min	values < D.L.	Time period
		- µg/L -			%	
0125581: Oyster River above camp	6	0.07	0.13	<0.05	66.7	1975 -76
0125580: Oyster R. at highway bridge	25	0.05	0.09	<0.05	76.0	1971 -85

* n = total number of measurements; D.L. = detection limit
@ `less than' values were considered equal to the detection limit

average concentration should be based on at least 5 weekly samples collected in a period of 30 days.

All resident fish species consumed by man should be monitored for Hg levels. Hg analyses in water should be performed using a laboratory detection limit of at least 0.02 µg/L. Field blanks should be performed to determine the detection limit of the entire sampling and analytical process.

5.15 NICKEL

Aquatic life is the most sensitive water use with respect to nickel (Ni). The toxicity of Ni to aquatic life is a function of the hardness of water; the sensitivity to Ni decreases as hardness increases. Based on data from the literature, the U.S. Environmental Protection Agency (1986) has developed relationships between toxic (acute and chronic) levels of Ni and water hardness. These relationships formed the basis of its maximum (1-h average) and average (4-d average) criteria for the protection of aquatic life from Ni toxicity. The CCREM (1987) used the U.S. EPA models as the basis for its guidelines for Canadian waters. To protect aquatic life in soft water (0-60 mg/L $CaCO_3$), the CCREM recommends that the total concentration of Ni should not exceed 0.025 mg/L.

The total Ni concentration in the majority (> 98%) of samples taken in the Oyster River watershed was below the detection limits (0.01 and 0.05 mg/L) (Table 21). Only two of the 156 measurements exceeded the detection limits; one (0.09 mg/L total Ni) for site E207430 on the Little Oyster River and the other (0.01 mg/L total Ni) for site 0125580 on mainstem Oyster River at the mouth. However, only one of these two values exceeded the guideline for soft waters suggested by the CCREM (1987). The hardness in the mainstem Oyster River was < 15 mg/L $CaCO_3$ for the two measurements made to-date.

Since the majority (154 of 156) of the analyses were performed using a detection limit which was greater than the guideline, the true water quality conditions with respect to Ni could not be assessed for the Oyster River watershed at this time.

TABLE 21

TOTAL NICKEL CONCENTRATIONS IN THE OYSTER RIVER WATERSHED

Site number an Description	Data Characteristics*							
	n	mean@	max	min	values less than D.L.	L.D.L.	U.D.L.	Time period
			- mg/L -		%			
E207429: Oyster R. d/s Adrian Creek	4		<0.05	<0.05	100		4	1988
E207474: Trib. Piggott Cr. at Rossiter Rd.	8		<0.05	<0.05	100		8	1988
0125902: Piggott Cr. 50 m u/s PE-5123	3		<0.05	<0.05	100		3	1987 -88
0125903: Piggott Cr. 30 m d/s PE-5123	6		<0.05	<0.05	100		6	1987 -88
0125904: Piggott Cr. u/s Branch 161 bridge	1		<0.05	<0.05	100		1	1985
E206684: Tributary to Piggott Creek	25		<0.05	<0.05	100		25	1986 -88
0125582: Oyster R. at Duncan Main	36		<0.05	<0.05	100		36	1986 -89
E207431: Woodhus Cr. at Duncan Main	13		<0.05	<0.05	100		13	1988 -89
E207430: Little Oyster River at York Road	12		0.09	<0.05	91.7		11	1988 -89
0125580: Oyster R. at highway bridge	50		<0.05	<0.01	98.0	2	47	1979 -89

* n = total number of measurements; D.L., L.D.L. & U.D.L. = Lower and upper detection limits

@ `less than' values were considered equal to the detection limit

OBJECTIVE: To protect aquatic life in the Oyster River watershed, it is recommended that the total nickel concentration should not exceed 0.025 mg/L at any time.

5.16 ZINC

Aquatic life is the most sensitive water use with respect to zinc (Zn). The acute toxicity of Zn to aquatic life is modified by water hardness, but chronic toxicity is not (U.S. EPA, 1986). The Canadian Council of Resource and Environment Ministers (1987) recommends that the total Zn concentration in freshwater should not exceed 0.03 mg/L. This guideline coincides with the measured no-effect concentration for rainbow trout (0.036 mg/L) and fathead minnow (0.03 mg/L) (Goettl et al., 1976; Brungs, 1969). A more recent report by the International Joint Commission shows that phytoplankton are affected by zinc levels as low as 0.014 mg/L, and recommends a guideline of 0.01 mg/L total zinc for the Great Lakes (IJC, 1987). According to Affleck (1952) 0.01 mg/L zinc increased rainbow trout (Salmo gairdneri) alevin mortality in soft (hardness = 8 mg/L), poorly buffered (alkalinity = 8 mg/L) water (as quoted in IJC, 1987).

The majority (79.5%) of zinc data from the Oyster River watershed were below the detection limits (0.005 and 0.01 mg/L total Zn) (Table 22). Only 3 of 185 measurements in the Oyster River watershed exceeded the CCREM guideline of 0.03 mg/L total Zn. One of the seventy measurements for site 0125580 (e.g., 0.29 mg/L on June 4, 1987) was well above the CCREM guideline. This measurement was considered an anomaly, and corresponded to the anomalies noted for the copper, iron, and the manganese data sets (Appendix 1); in all cases the reason for the anomaly was not clear because suspended solids and turbidity were 1 mg/L and 1 NTU, respectively, in this sample. On two other occasions values greater than the CCREM guideline were measured; e.g., 0.18 mg/L total Zn on June 8, 1987 at site E206684 and 0.04 mg/L total Zn on September 29, 1986 at site 0125582. Only 7 of 185 measurements in the Oyster River watershed exceeded the IJC guideline of 0.01 mg/L total Zn, including 4 of 70 measurements for site 0125580 at the mouth. In general, less than 10% of the measurements exceeded the guideline of 0.01 mg/L total Zn at any site in the watershed.

Site E206684 is considered to be contaminated by seepage originating from an abandoned mine site on Mt. Washington. As noted above, only one of the values (e.g., 0.18 mg/L total Zn)

TABLE 22

TOTAL ZINC CONCENTRATIONS IN THE OYSTER RIVER WATERSHED

Site number and Description	Data Characteristics*						
	n	mean@ max	min	measurements <D.L.	>0.01mg/L	>.03mg/L	Time period
		- mg/L -		%			
E207429: Oyster R. d/s Adrian Creek	4	0.006	<0.005	50	0		1988
E207474: Trib. Piggott Cr. at Rossiter Rd.	8	<0.01	<0.005	100	0		1988
0125902: Piggott Cr. 50 m u/s PE-5123	3	<0.01	<0.005	100	0		1987 -88
0125903: Piggott Cr. 30 m d/s PE-5123	6	0.008	<0.005	50	0		1987 -88
0125904: Piggott Cr. u/s Branch 161 bridge	1	<0.005	<0.005	100	0		1985
E206684: Tributary to Piggott Creek	25	0.18	<0.005	84	1	1	1986 -88
0125582: Oyster R. at Duncan Main	36	0.04	<0.005	80.6	1	1	1986 -89
E207431: Woodhus Cr. at Duncan Main	13	0.007	<0.005	84.6	0		1988 -89
0125581: Oyster River above camp	7	<0.01	<0.005	100	0		1975 -86
E207430: Little Oyster River at York Road	12	0.02	<0.005	58.3	1	0	1988 -89
0125580: Oyster R. at highway bridge	70	0.29	<0.005	75.7	4	1	1971 -89

* n = total number of measurements; D.L. = detection limit
@ `less than' values were considered equal to the detection limit

was abnormally high. As for the likelihood of contamination of site E206684 with Zn from the abandoned mine site, it may be real, but the seepage from the mine site (E206514, Table 11) does not account for the high levels (e.g.,0.18 mg/L total Zn) observed for site E206684.

OBJECTIVE: To protect aquatic life, it is recommended that the 30-d average concentration of total zinc in the Oyster River watershed should not exceed 0.01 mg/L. The maximum concentration should not exceed 0.03 mg/L total zinc. The average concentration should be based on at least 5 weekly samples collected in a period of 30 days.

5.17 pH

A pH between 6.5 and 9.0 is considered to be safe for fish. Lower pHs (down to pH 5) can also be harmless to fish if the secondary effects due to other factors (e.g., sufficient release of free carbon dioxide from bicarbonate especially when oxygen availability is low, increased toxicity of several common pollutants at lower pH, etc.) are not present (CCREM, 1987). The acceptable range for drinking water supplies is given to be pH 6.5-8.5 (Health and Welfare Canada, 1987).

In the Oyster River watershed, pH varied widely between 6.4 and 8.2, but mostly remained within the limits recommended for drinking water and aquatic life.(Table 23). Of the total of 69 measurements for site 0125580 at the mouth of the mainstem Oyster River, two (at pH 6.4) were outside the recommended range of 6.5-8.5 for drinking water. For all other sites (143 measurements), pH was within these limits.

The mean alkalinity in the Oyster River watershed was measured between 9.7 mg/L (for site 0125904 on Piggott Creek) and about 16.2 mg/L (for sites 0125580 and 0125582 on the mainstem Oyster River). This suggests a moderate (10 to 20 mg/L) to low (<10 mg/L) buffering capacity for the streams in the Oyster River watershed (Swain, 1987). Furthermore, the fact that acid mine drainge can potentially occur in the watershed means that a development such as the proposed Chute Creek coal project in the headwaters of Woodhus Creek (see section 4.2) could be of concern, especially if proper measures are not taken to reduce the impact of acid generation. The following objectives are proposed for the Oyster River watershed.

<u>OBJECTIVE</u>: To protect aquatic life and drinking water uses in the Oyster River watershed (except in the mainstem Oyster River below Woodhus Creek), pH should not decline below 6.5. In the Oyster River downstream from Woodhus Creek, it is recommended that the 95th percentile pH should be greater than or equal to 6.5. The maximum pH in the Oyster River watershed should not exceed 8.5 at any time.

At least 5 but preferably10 samples should be taken in the period of 30 days (2 samples per sampling time) to determine the 95th percentile.

TABLE 23

pH IN THE OYSTER RIVER WATERSHED

Site number and Description	Data Characteristics*				
	n	mean	max	min	Time period
			- µg/L -		
E207429: Oyster R. d/s Adrian Creek	4	7.2	7.5	7.1	1988
E207474: Trib. Piggott Cr. at Rossiter Rd.	8	7.5	7.9	7.2	1988
0125902: Piggott Cr. 50 m u/s PE-5123	16	7.1	7.4	6.8	1979-88
0125903: Piggott Cr. 30 m d/s PE-5123	21	7.2	7.8	6.8	1979-88
0125904: Piggott Cr. u/s Branch 161 bridge	6	7.2	7.4	7.0	1979-88
E206684: Tributary to Piggott Creek	17	7.1	7.6	6.6	1987-88
0125582: Oyster R. at Duncan Main	35	7.1	7.5	6.8	1986-89
E207431: Woodhus Cr. at Duncan Main	13	7.3	7.7	6.8	1988-89
0125581: Oyster River above camp	11	7.3	7.5	7.0	1975-76, 1986
E207430: Little Oyster River at York Road	12	7.3	7.5	7.0	1988-89
0125580: Oyster R. at highway bridge	69	7.2	8.2	6.4	1971-89

* n = total number of measurements

6. MONITORING RECOMMENDATIONS

The purpose of the monitoring program outlined below is several-fold; (a) to check compliance with the water quality objectives proposed in section 5, (b) to provide biological and water quality data to assess the impact of future developments in the area, and (c) to manage more carefully water resources in the watershed in view of (b).

In general, water quality monitoring in the Oyster River watershed has been performed at too low a frequency (once in a period of three or more weeks). Weekly samples over at least 30 days will be required to ensure that water quality objectives are being met. Figure 1 shows sites currently being monitored. The same sites should be monitored in future to check the water quality status in the watershed.

Water quality characteristics that are considered in this report are pH, turbidity, non-filterable residue, ammonia, nitrate-N, nitrite-N, fecal coliforms, dissolved aluminum, total cadmium, total chromium, total cobalt, total copper, dissolved iron, total lead, dissolved manganese, total mercury, total nickel, and total zinc. In addition to coliforms, other microbiological indicators such as E. Coli, fecal streptococci, Pseudomonas aeruginosa, and enterococci should also be measured. Fecal streptococci along with the knowledge of land use may be useful in identifying sources of fecal contamination in the watershed.

Currently, several water quality characteristics such as arsenic, cadmium, cobalt, mercury, and nickel are being measured using detection limits which exceed the proposed objective levels. Detection limits less than or equal to the objectives should be used to analyze water for these characteristics. Lead and mercury levels in resident fish should also be monitored to check if the objectives for the edible (muscle) tissue are being met.

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Appendix-1

Detailed Water Quality Data for Sites in the Oyster River Basin

Table A1-1. Water quality data for site 0125580 on the mainstem Oyster River at the mouth (1 0f 3 pages).

DATE	PH	TEMP. °C	T.RES. mg/L	NF.RES. mg/L	TURB. NTU	HARD. mg/L	FE.COLI. MPN	FE.COLI. CFU/cL	T.COL1. MPN	Amm-D mg/L	NO2NO3-D mg/L	NO2-D µg/L	Al-D mg/L	As-T mg/L	Cd-T µg/L	Co-T µg/L	Cr-T µg/L	Cu-T µg/L	Fe-T mg/L	Hg-T µg/L	Mn-T mg/L	Ni-T mg/L	Pb-T µg/L	Zn-T mg/L
71/05/20	6.9	6	25	4	0.5	•	5		23	•	•	< 5	•				•	•	0.16	•	•		•	•
71/05/21	•	•	•	•	•	•	5		23	•	•		•				•	•	•	•	•		•	•
71/07/21	6.9	10	21	3	0.5	•	23		130	•	•	< 5	•				•	•	0	•	•		•	•
71/09/21	•	•	•	•	•	•	23		130	•	•		•				•	•	•	•	•		•	•
71/10/20	•	•	502	22	9.1	•	79		348	•	•	< 5	•				•	< 10	0.98	0.08	•		4	0.006
72/05/24	•	9	•	•	•	•	2		17	•	•		•				•	•	•	•	•		•	•
72/05/24	8.2	•	•	•	•	•	•		•	•	< 0.02	< 5	•				•	•	•	•	•		•	•
72/05/24	•	•	26	•	2.2	•	•		•	•	•		•				•	< 1	< 0.02	< 0.05	•		5	0.008
72/07/11	•	•	•	•	•	•	49		170	•	0.05	< 5	•				•	•	•	•	•		•	•
72/07/11	7.7	11	•	•	•	•	•		•	•	•		•				•	•	•	•	•		•	•
72/07/11	•	•	38	•	0.6	•	•		•	•	•		•				•	< 1	0.04	0.07	•		< 3	< 0.005
73/02/07	•	•	•	•	•	•	2		8	•	•	< 5	•				•	•	•	•	•		•	•
73/02/07	•	1	•	•	•	•	•		•	•	•		•				•	•	•	•	•		•	•
73/02/07	7.2	•	40	2	2.3	•	•		•	•	•		•				•	3	0.2	•	•		8	< 0.005
73/04/25	•	•	•	•	•	•	2		23	•	•	< 5	•				•	•	•	•	•		•	•
73/04/25	7.6	8	•	•	•	•	•		•	•	•		•				•	•	•	•	•		•	•
73/04/25	•	•	26	2.1	1.3	•	•		•	•	•		•				•	< 1	0.29	< 0.05	•		1	< 0.005
73/08/07	•	•	•	•	•	•	7		33	•	•	< 5	•				•	•	•	•	•		•	•
73/08/07	7.5	14.5	•	•	•	•	•		•	•	•		•				•	•	•	•	•		•	•
73/08/07	•	•	•	•	•	•	•		•	•	•		•				•	< 1	< 0.04	0.06	•		< 1	< 0.005
73/08/07	•	•	28	< 1	0.3	•	•		•	•	•		•				•	•	•	•	•		•	•
73/10/16	•	•	•	•	•	•	5		17	•	•	< 5	•				•	•	•	•	•		•	•
73/10/16	•	7	•	•	•	•	•		•	•	•		•				•	•	•	•	•		•	•
73/10/16	•	•	•	•	•	•	•		•	•	•		•				•	3	0.06	< 0.05	•		1	< 0.005
73/10/16	7.4	•	32	< 1	0.3	•	•		•	•	•		•				•	•	•	•	•		•	•
74/03/07	•	2	•	•	•	•	•		•	•	•	< 5	•				•	•	•	•	•		•	•
74/03/07	•	•	•	•	•	•	•		•	•	•		•				•	13	< 0.1	< 0.05	•		< 1	< 0.005
74/03/07	6.9	•	34	2	0.8	•	•		•	•	•		•				•	•	•	•	•		•	•
74/06/05	•	•	•	•	•	•	2		2	•	•	< 5	•				•	•	•	•	•		•	•
74/06/05	6.9	7	•	•	•	•	•		•	•	•		•				•	•	•	•	•		•	•
74/06/05	•	•	•	•	•	•	•		•	•	•		•				•	1	0.2	< 0.05	•		< 1	< 0.005
74/06/05	•	•	28	2	2.7	•	•		•	•	•		•				•	•	•	•	•		•	•
75/04/15	6.9	9	•	•	•	•	•		•	•	•	< 5	•				•	•	•	•	•		•	•
75/04/15	7.3	•	32	1	0.9	•	•		•	•	•		•				•	< 1	0.2	< 0.05	•		< 1	< 0.005
75/10/07	7.3	9	•	•	•	•	•		•	•	0.03	< 5	•				•	•	•	•	•		•	•
75/10/07	7.1	•	28	< 1	0.6	•	•		•	•	•		•				•	< 1	0.1	< 0.05	•		< 1	< 0.005
76/04/22	•	•	•	•	•	•	< 2		2	•	0.02	< 5	•				•	•	•	•	•		•	•
76/04/22	•	10	•	•	•	•	•		•	•	•		•				•	•	•	•	•		•	•
76/04/22	7.2	•	30	1	0.9	•	•		•	•	•		•				•	< 1	0.2	0.09	•		< 1	< 0.005
76/09/23	•	•	•	•	•	•	13		33	•	•	< 5	•				•	•	•	•	•		•	•
76/09/23	7.2	13	•	•	•	•	•		•	•	•		•				•	•	•	•	•		•	•
76/09/23	7.4	•	24	1	0.2	•	•		•	•	•		•				•	< 1	< 0.1	< 0.05	•		< 1	< 0.005
77/04/04	•	•	•	•	•	•	2		5	•	0.04	< 5	•				•	•	•	•	•		•	•
77/04/04	7.3	•	34	3	6.8	•	•		•	•	•		•				•	•	0.5	< 0.05	•		< 1	0.005
77/09/28	•	10	•	•	•	•	•		•	0.014	0.02	< 5	•				•	•	•	•	•		•	•
77/09/28	7.5	•	28	2	•	•	•		•	•	•		•				•	< 1	0.2	< 0.05	•		< 1	< 0.005
78/04/13	•	•	•	•	•	•	< 2		•	< 0.005	0.03	< 5	•				•	•	•	•	•		•	•
78/04/13	7	•	28	2	•	•	•		•	•	•		•				•	< 1	0.2	< 0.05	•		< 1	< 0.005
78/09/25	•	•	•	•	•	•	13		•	< 0.005	0.03	< 5	•				•	•	•	•	•		•	•
78/09/25	7.4	•	36	2	0.8	•	•		•	•	•		•				•	< 1	0.1	< 0.05	•		< 1	< 0.005
79/04/26	•	•	•	•	•	•	•		7	< 0.005	0.03	< 5	•				•	•	•	•	•		•	•
79/04/26	7.3	•	30	2	1.7	•	•		•	•	•		•				•	2	0.2	•	•		< 1	0.008
79/10/30	•	•	•	•	•	•	110		170	0.015	0.15	< 5	•	< 0.005	< 5		•	•	•	•	•		•	•
79/10/30	7.2	•	32	3	•	•	•		•	•	•		•				< 5	1	0.3	< 0.05	•		1	< 0.005

anomalous value

Table A1-1 (contd.). Water quality data for site 0125580 on the mainstem Oyster River at the mouth (2 of 3 pages).

DATE	PH	TEMP. °C	T.RES. mg/L	NF.RES. mg/L	TURB. NTU	HARD. mg/L	FE.COLI. MPN	FE.COLI. CFU/cL	T.COLI. MPN	Amm-D mg/L	NO2NO3-D mg/L	NO2-D µg/L	Al-D mg/L	As-T mg/L	Cd-T µg/L	Co-T µg/L	Cr-T µg/L	Cu-T µg/L	Fe-T mg/L	Hg-T µg/L	Mn-T mg/L	Ni-T mg/L	Pb-T µg/L	Zn-T mg/L
80/04/17	7.3	8	32	4	•	•	•		•	0.008	0.04	< 5	•	< 0.05	< 10		< 10	< 1	0.1	< 0.05	< 0.01	< 0.05	< 100	< 0.01
80/04/17	•	•	•	•	•	•	2		•	•	•		•				•	•	•	•	•		•	•
80/10/09	•	•	•	•	•	•	5		13	< 0.005	0.04	< 5	•	< 0.005	< 5		•	•	•	•	•		•	•
80/10/09	7.5	•	30	< 1	•	•	•		•	•	•		•				5	< 1	0.1	< 0.05	•		< 1	0.005
81/04/16	•	•	32	1	•	•	•		•	•	•		•	< 0.005	< 5		< 5	1	0.2	0.06	< 0.02	< 0.01	2	< 0.005
81/10/01	•	•	•	•	•	•	240		•	< 0.005	0.03	< 5	•	< 0.005	< 5		•	•	•	•	•	0.01	•	•
81/10/01	6.4	•	326	307.00#	•	•	•		•	•	•		•				18	31#	15#	< 0.05	0.30#		< 1	0.019
82/10/19	•	•	•	•	•	•	< 2		< 2	•	0.03		•	< 0.25	< 10	< 100	•	•	•	•	•	< 0.05	•	•
82/10/19	6.4	•	•	1	•	•	•		•	•	•		•				< 10	< 10	0.02	•	< 0.01		< 100	< 0.01
83/04/26	7.3	•	30	2	•	11.9	•		•	< 0.005	< 0.02	< 5	•	< 0.25	< 10	< 100	< 10	< 10	0.19	< 0.05	< 0.01	< 0.05	< 100	< 0.01
83/12/01	•	•	•	•	•	•	8		•	< 0.005	0.11	< 5	•	< 0.25	< 10	< 100	•	•	•	•	•	< 0.05	•	•
83/12/01	6.9	•	36	3	•	•	•		•	•	•		•				< 10	< 10	0.18	0.06	< 0.01		< 100	< 0.01
84/04/18	•	6	•	•	•	•	•		•	0.009	0.06	< 5	•	< 0.25	< 10	< 100	•	•	•	•	•	< 0.05	•	•
84/04/18	7	•	30	1	1	12.3	•		•	•	•		•				< 10	< 10	0.09	< 0.05	< 0.01		< 100	< 0.01
85/03/05	7.5	•	42	5	•	•	•		•	0.013	0.22		•	< 0.25	< 10	< 100	< 10	< 10	0.34	< 0.05	0.01	< 0.05	< 100	< 0.01
86/08/13	7.5	•	•	•	•	•	•		•	•	0.03		•	< 0.25	< 10	< 100	< 10	2	0.09	•	< 0.01	< 0.05	< 100	< 0.005
86/09/29	7.2	•	•	< 1	•	•	•		•	< 0.005	0.02		•	< 0.25	< 10	< 100	10	2	< 0.01	•	< 0.01	< 0.05	< 100	0.01
86/10/14	7.1	•	•	< 1	•	•	•		•	0.009	0.02		•	< 0.25	< 10	< 100	< 10	4	0.06	•	< 0.01	< 0.05	< 100	< 0.01
86/10/27	7	•	•	1	•	•	•		•	< 0.005	0.05		•	< 0.25	< 10	< 100	< 10	< 10	0.08	•	< 0.01	< 0.05	< 100	< 0.01
86/11/13	7.2	•	•	< 1	•	•	•		•	< 0.005	0.07		•	< 0.25	< 10	< 100	< 10	< 10	0.07	•	< 0.01	< 0.05	< 100	< 0.01
86/11/26	7.1	•	•	15	•	•	•		•	0.006	0.82		•	< 0.25	< 5	< 100	< 10	2	0.89	•	0.02	< 0.05	< 100	< 0.01
86/12/02	7	•	•	7	4.2	•	•		•	< 0.005	0.23		•	< 0.25	< 10	< 100	< 10	10	0.56	•	0.01	< 0.05	< 100	0.02
87/01/13	7	•	•	8	5.6	•	•		•	< 0.005	0.07		•	< 0.25	< 10	< 100	< 10	< 10	0.5	•	0.01	< 0.05	< 100	< 0.01
87/02/18	7.1	•	•	< 1	1	•	•		•	< 0.005	0.1		•	< 0.25	< 10	< 100	< 10	2	0.1	•	< 0.01	< 0.05	< 100	< 0.005
87/03/17	7	•	•	2	1.7	•	•		•	< 0.005	0.05		•	< 0.25	< 10	< 100	< 10	< 10	0.17	•	< 0.01	< 0.05	< 100	< 0.01
87/04/08	6.9	•	•	< 1	1.2	•	•		•	< 0.005	0.04		•	< 0.30	< 10	< 100	< 10	3	0.16	•	< 0.01	< 0.05	< 100	< 0.005
87/05/07	6.9	•	•	4	2.1	•	•		•	< 0.005	< 0.02		•	< 0.30	< 10	< 100	< 10	2	0.32	•	< 0.01	< 0.05	< 100	< 0.005
87/05/21	6.9	•	•	< 1	0.8	•	•		•	< 0.005	< 0.02		•	< 0.25	< 10	< 100	< 10	< 1	0.07	•	< 0.01	< 0.05	< 100	< 0.005
87/06/04	6.8	•	•	1	1	•	< 2		< 2	< 0.005	< 0.02		•		< 10	< 100	20	140#	4.93#	•	0.14#	< 0.05	< 100	0.29#
87/06/17	6.8	•	•	2	1	•	< 2		11	0.007	< 0.02		•		< 10	< 100	< 10	1	0.14	•	< 0.01	< 0.05	< 100	< 0.005
87/07/02	6.7	•	•	< 1	1.2	•	< 2		< 2	0.007	0.17		•		< 10	< 100	< 10	2	0.22	•	< 0.01	< 0.05	< 100	< 0.005
87/09/16	7	•	•	1	0.3	•	< 2		< 2	< 0.005	< 0.02		•		< 10	< 100	< 10	2	< 0.01	•	< 0.01	< 0.05	< 100	< 0.005
87/09/30	7.2	•	•	< 1	0.4	•	•		•	< 0.005	0.02		•		< 10	< 100	< 10	2	< 0.01	•	< 0.01	< 0.05	< 100	0.005
87/10/15	7	•	•	1	0.2	•	7		•	< 0.005	< 0.02		•		< 10	< 100	< 10	7	0.02	•	< 0.01	< 0.05	< 100	< 0.005
87/10/28	7.1	•	•	1	0.4	•	•		•	< 0.005	< 0.02		•		< 10	< 100	< 10	3	0.03	•	< 0.01	< 0.05	< 100	< 0.005
87/11/17	7	•	•	< 1	•	•	•		•	< 0.005	0.06		•		< 10	< 100	< 10	2	0.09	•	< 0.01	< 0.05	< 100	0.01
87/12/15	7.2	•	•	< 1	1	•	•		•	< 0.005	0.27		0.08		< 10	< 100	< 10	1	0.11	•	< 0.01	< 0.05	< 100	< 0.005
88/01/14	•	•	•	•	•	•	•		•	< 0.005	0.61		•		< 10	< 100	10	5	2.71	•	0.06	< 0.05	< 100	0.013
88/01/14	•	•	•	•	•	•	•		•	•	•		•		< 10	< 100	< 10	8	2.35	•	0.07	< 0.05	< 100	0.005
88/01/14	6.8	•	•	55	18	•	•		•	•	•		•		< 10	< 100	< 10	6	2.61	•	0.06	< 0.05	< 100	0.005
88/02/10	7.2	•	•	< 1	•	•	•		•	•	0.16		•		< 10	< 100	•	•	•	•	•	< 0.05	•	•
88/02/10	•	•	•	•	•	•	•		•	•	•		0.03		< 10	< 100	< 10	3	0.1	•	< 0.01	< 0.05	< 100	< 0.005
88/02/10	•	•	•	•	•	•	•		•	•	•		0.04		< 10	< 100	< 10	2	0.09	•	< 0.01	< 0.05	< 100	< 0.005
88/03/07	7.2	•	•	< 1	1.1	•	•		•	< 0.005	0.12		•		< 10	< 100	•	•	•	•	•		•	•
88/03/07	•	•	•	•	•	•	•		•	•	•		0.05		< 10	< 100	< 10	8	0.14	•	< 0.01	< 0.05	< 100	< 0.005
88/03/07	•	•	•	•	•	•	•		•	•	•		0.06		< 10	< 100	< 10	3	0.11	•	< 0.01	< 0.05	< 100	< 0.005
88/04/13	7.1	•	•	< 1	•	•	•		•	•	•		•		< 10	< 100	< 10	2	0.16	•	< 0.01	< 0.05	< 1	< 0.005
88/05/18	7.1	•	•	2	•	•	•		•	•	•		•		< 10	< 100	< 10	< 1	0.17	•	< 0.01	< 0.05	< 1	< 0.005
88/05/31	7.3	•	•	< 1	•	•	•		•	•	•		•		< 10	< 100	< 10	6	0.16	•	< 0.01	< 0.05	< 1	< 0.005
88/06/07	7.4	•	•	1	•	•	•		•	•	•		•		< 10	< 100	< 10	< 1	0.1	•	< 0.01	< 0.05	< 1	< 0.005
88/06/13	7.5	•	•	< 1	•	•	•		•	•	•		•		< 10	< 100	< 10	1	0.09	•	< 0.01	< 0.05	2	< 0.005
88/06/22	7.4	•	•	1	•	•	•		•	•	•		•		< 10	< 100	< 10	2	0.15	•	< 0.01	< 0.05	3	< 0.005
88/07/13	7.4	•	•	< 1	•	•	•		•	•	•		•		< 10	< 100	< 10	< 1	0.12	•	< 0.01	< 0.05	3	0.012
88/08/09	7.4	•	•	< 1	•	•	•		•	•	•		•		< 10	< 100	< 10	1	0.14	•	< 0.01	< 0.05	< 1	< 0.005

anomalous value

Table A1-1 (contd.). Water quality data for site 0125580 on the mainstem Oyster River at the mouth (3 0f 3 pages).

DATE	PH		T.RES. mg/L	NF.RES. mg/L	TURB. NTU	HARD. mg/L	FE.COLI. MPN	FE.COLI. CFU/cL	T.COL1. MPN	Amm-D mg/L	NO2NO3-D mg/L	NO2-D µg/L	Al-D mg/L		Cd-T µg/L	Co-T µg/L	Cr-T µg/L	Cu-T µg/L	Fe-T mg/L	Hg-T µg/L	Mn-T mg/L		Pb-T µg/L	Zn-T mg/L
88/10/05	7.8	•	•	< 1	•	•	•		•	•	•		•		< 10	< 100	< 10	1	0.05	•	< 0.01	< 0.05	< 1	< 0.005
88/11/02	7.1	•	•	15	•	•	•		•	•	•		•		< 10	< 100	< 10	4	1.42	•	0.03	< 0.05	< 1	< 0.005
88/11/22	7.6	•	•	42	•	•	•		•	•	•		•		< 10	< 100	< 10	3	1.96	•	0.05	< 0.05	5	0.005
88/12/13	7.6	•	•	8	•	•	•		•	•	•		•		< 10	< 100	< 10	3	0.58	•	0.01	< 0.05	1	0.007
89/01/23	7.2	•	•	< 1	•	•	•		•	•	•		•		< 10	< 100	< 10	< 1	0.09	•	< 0.01	< 0.05	1	< 0.005
89/02/03							27		49															
89/05/08								2																
89/05/15								3																
89/05/23								15																
89/05/29								6																
89/06/05								< 2																
89/10/16								4																
89/10/23								200																
89/10/30								9																
89/11/06								8																

anomalous value

Table A1-2. Water quality data for site 0125581 on the mainstem Oyster River upstream from Little Oyster River.

DATA	pH	T.RES.	F.RES.	NF.RES.	TURB.	F.COLI.	T.COLI.	Al-T	Cr-T	Cu-T	Fe-T	Hg-T	Mn-D	Mn-T	Pb-T	Zn-T
		mg/L	mg/L	mg/L	NTU	MPN	MPN	mg/L	mg/L	µg/L	mg/L	mg/L	mg/L	mg/L	µg/L	mg/L
75/06/24	7.2	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
75/06/24	7.4	28	*	1	0.7	*	*	*	*	< 1	0.1	<0.00005	*	*	< 1	< 0.005
75/08/05	7.5	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
75/08/05	7.5	28	26	*	0.2	*	*	*	*	< 1	*	<0.00005	< 0.02	*	< 1	< 0.005
75/10/07	7.3	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
75/10/07	7.3	30	28	*	0.6	*	*	*	*	< 1	*	<0.00005	< 0.02	*	< 1	< 0.005
75/12/03	7.3	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
75/12/03	7.2	42	22	*	8.9	*	*	*	*	4	*	<0.00005	< 0.02	*	< 1	< 0.005
76/04/22	*	*	*	*	*	< 2	2	*	*	*	*	*	*	*	*	*
76/04/22	7.1	28	*	< 1	0.7	*	*	*	*	< 1	< 0.1	0.00007	< 0.02	*	< 1	< 0.005
76/04/27	*	*	*	*	*	< 2	2	*	*	*	*	*	*	*	*	*
76/06/28	7.2	20	*	1	0.8	*	*	*	*	2	< 0.1	0.00013	< 0.02	*	< 1	< 0.005
86/03/10	7	*	22	2	*	*	*	0.15	< 0.01	< 10	0.19	*	*	< 0.01	< 100	< 0.01

Table A1-3. Water quality data for site 0125582 on the mainstem Oyster River upstream from Woodhus Creek (1 of 2 pages).

DATE	PH	F.RES.	NF.RES	TURB.	FE.COLI.	FE.COLI.	T.COLI.	Amm-D	NO3NO3-D	Al-D	As-T	Cd-T	Co-T	Cr-T	Cu-T	Fe-T	Mn-T	Ni-T	Pb-D	Pb-T	Zn-T
		mg/L	mg/L	NTU	MPN	CFU/cL	MPN	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	mg/L	mg/L	mg/L	µg/L	µg/L	mg/L
86/08/13	7.5	*	*	*	*		*	< 0.005	0.04	*	< 0.25	< 10	< 100	< 10	1	0.08	< 0.01	< 0.05	*	< 100	< 0.005
86/09/29	7.3	32	3	*	*		*	0.01	0.04	*	< 0.25	< 10	< 100	10	3	0.13	< 0.01	< 0.05	*	< 100	0.04
86/10/14	7.1	38	< 1	*	*		*	< 0.005	0.05	*	< 0.25	< 10	< 100	< 10	< 10	0.04	< 0.01	< 0.05	*	< 100	< 0.01
86/10/27	7	28	< 1	*	*		*	0.005	0.04	*	< 0.25	< 10	< 100	< 10	< 10	0.05	< 0.01	< 0.05	*	< 100	< 0.01
86/11/13	7.2	32	1	*	*		*	0.005	0.06	*	< 0.25	< 10	< 100	< 10	< 10	0.02	< 0.01	< 0.05	*	< 100	0.01
86/11/26	7.1	26	12	*	*		*	0.005	0.04	*	< 0.25	< 5	< 100	< 10	2	0.8	0.01	< 0.05	*	< 100	< 0.01
86/12/02	7.1	20	3	2.9	*		*	< 0.005	0.04	*	< 0.25	< 10	< 100	< 10	10	0.3	< 0.01	< 0.05	*	< 100	< 0.01
87/01/13	7	28	3	3.4	*		*	< 0.005	0.02	*	< 0.25	< 10	< 100	< 10	< 10	0.36	< 0.01	< 0.05	*	< 100	< 0.01
87/02/18	7.2	*	< 1	1	*		*	< 0.005	0.02	*	< 0.30	< 10	< 100	< 10	30	0.07	< 0.01	< 0.05	*	< 100	< 0.005
87/03/17	7	*	1	1.3	*		*	< 0.005	< 0.02	*	< 0.25	< 10	< 100	< 10	2	0.1	< 0.01	< 0.05	*	< 100	< 0.005
87/04/08	7	*	< 1	1	*		*	< 0.005	< 0.02	*	< 0.30	< 10	< 100	< 10	3	< 0.10	< 0.01	< 0.05	*	< 100	< 0.005
87/05/07	6.9	*	2	1.6	*		*	< 0.005	< 0.02	*	< 0.30	< 10	< 100	< 10	2	0.22	< 0.01	< 0.05	*	< 100	< 0.005
87/05/21	6.8	*	< 1	1	*		*	< 0.005	< 0.02	*	< 0.30	< 10	< 100	< 10	3	0.09	< 0.01	< 0.05	*	< 100	< 0.005
87/06/17	6.8	*	1	1	< 2		12	0.007	< 0.02	*		< 10	< 100	< 10	< 1	0.16	< 0.01	< 0.05	*	< 100	< 0.005
87/07/02	6.8	*	< 1	1.2	< 2		< 2	< 0.005	0.02	*		< 10	< 100	< 10	3	0.1	< 0.01	< 0.05	*	< 100	< 0.005
87/09/16	7	*	< 1	0.3	< 2		< 2	< 0.005	0.03	*		< 10	< 100	< 10	3	0.03	< 0.01	< 0.05	*	< 100	< 0.005
87/09/30	6.9	*	< 1	0.2	*		*	< 0.005	0.04	*		< 10	< 100	< 10	2	0.03	< 0.01	< 0.05	*	< 100	< 0.005
87/10/15	7.1	*	1	0.4	< 2		*	< 0.005	0.04	*		< 10	< 100	< 10	7	0.05	< 0.01	< 0.05	*	< 100	< 0.005
87/10/28	7	*	< 1	0.5	*		*	< 0.005	0.16	*		< 10	< 100	< 10	2	0.04	< 0.01	< 0.05	*	< 100	< 0.005
87/11/17	7	*	2	*	*		*	< 0.005	0.06	*		< 10	< 100	< 10	3	0.09	< 0.01	< 0.05	*	< 100	< 0.005
88/02/10	*	*	*	*	*		*	*	*	0.03		< 10	< 100	< 10	3	0.06	< 0.01	< 0.05	< 100	< 100	< 0.005
88/02/10	*	*	*	*	*		*	*	*	0.03		< 10	< 100	< 10	3	0.06	< 0.01	< 0.05	< 100	< 100	< 0.005
88/02/10	7	*	< 1	*	*		*	*	0.08	*		< 10	< 100	< 10	*	*	*	< 0.05	*	*	*
88/03/07	7.2	*	< 1	1.2	*		*	< 0.005	0.04	*		< 10	< 100	< 10	*	*	*	*	*	*	*
88/03/07	*	*	*	*	*		*	*	*	0.03		< 10	< 100	< 10	6	0.19	< 0.01	< 0.05	< 100	< 100	< 0.005
88/03/07	*	*	*	*	*		*	*	*	0.05		< 10	< 100	< 10	4	0.13	< 0.01	< 0.05	< 100	< 100	< 0.005
88/04/13	7.2	*	1	*	*		*	*	0.03	*		< 10	< 100	< 10	2	0.16	< 0.01	< 0.05	< 1	< 1	0.006
88/05/18	7.2	*	1	*	*		*	*	0.02	*		< 10	< 100	< 10	< 1	0.12	< 0.01	< 0.05	< 1	< 1	< 0.005
88/05/31	7.3	*	< 1	*	*		*	*	< 0.02	*		< 10	< 100	< 10	4	0.14	< 0.01	< 0.05	< 1	< 1	< 0.005
88/06/07	7.3	*	< 1	*	*		*	*	< 0.02	*		< 10	< 100	< 10	2	0.07	< 0.01	< 0.05	< 1	< 1	0.006
88/06/13	7.5	*	< 1	*	*		*	*	< 0.02	*		< 10	< 100	< 10	4	0.08	< 0.01	< 0.05	< 1	56	< 0.005
88/06/21	7.3	*	1	*	*		*	*	< 0.02	*		< 10	< 100	< 10	< 1	0.07	< 0.01	< 0.05	< 1	< 1	< 0.005
88/07/13	7.1	*	< 1	*	*		*	*	< 0.02	*		< 10	< 100	< 10	2	0.2	< 0.01	< 0.05	< 1	< 1	< 0.005
88/08/09	7.5	*	< 1	*	*		*	*	< 0.02	*		< 10	< 100	< 10	1	0.06	< 0.01	< 0.05	< 1	< 1	< 0.005
88/10/05	7.5	*	< 1	*	*		*	*	0.03	*		< 10	< 100	< 10	1	0.03	< 0.01	< 0.05	< 1	1	0.005
88/11/02	6.9	*	9	*	*		*	*	< 0.02	*		< 10	< 100	< 10	7	0.9	0.02	< 0.05	< 1	< 1	< 0.005
88/12/13	7	*	5	*	*		*	*	0.03	*		< 10	< 100	< 10	2	0.4	< 0.01	< 0.05	< 1	2	0.006
89/01/23	7.3	*	< 1	*	*		*	*	0.06	*		*	*	*	*	*	*	*	*	*	*
89/01/23	*	*	*	*	*		*	*	*	*		< 10	< 100	< 10	< 1	0.05	< 0.01	< 0.05	< 1	< 1	0.005
89/02/23	7.3	*	2	*	33		49		0.08	*				*	*	*	*	*	*	*	*
89/05/08						< 2															
89/05/15						< 2															
89/05/23						< 2															
89/05/29						2															
89/06/05						2															
89/10/16						< 2															
89/10/23						119															

Table A1-3 (contd.). Water quality data for site 0125582 on the mainstem Oyster River upstream from Woodhus Creek (2 of 2 pages).

DATE	PH	F.RES.	NF.RES	TURB.	FE.COLI.	FE.COLI.	T.COL1.	Amm-D	NO3NO3-D	Al-D	As-T	Cd-T	Co-T	Cr-T	Cu-T	Fe-T	Mn-T	Ni-T	Pb-D	Pb-T	Zn-T
		mg/L	mg/L	NTU	MPN	CFU/cL	MPN	mg/L	mg/L	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	mg/L	mg/L	mg/L	µg/L	µg/L	mg/L
89/10/30						2															
89/11/06						2															
89/11/13						2															

Table A1-4. Water quality data for site 0125902 on Piggott Creek ar Rossiter Main upstream from PE 5123.

DATE	PH	T.RES.	NF.RES	TURB.	FE.COLI.	FE.COLI	T.COL1.	Amm-D	NO2NO3-D	NO2-D	Cd-T	Co-T	Cr-T	Cu-T	Fe-T	Mn-T	Ni-T	Pb-T	Zn-T
		mg/L	mg/L	NTU	MPN	CFU/cL	MPN	mg/L	mg/L	µg/L	µg/L	µg/L	µg/L	µg/L	mg/L	mg/L	mg/L	µg/L	mg/L
79/10/09	7.1	18	< 1	•	•	•	•	•	0.03	•	•	•	•	•	•	•	•	•	•
79/10/31	7.2	26	2	1.2	•	•	•	< 0.005	< 0.02	•	•	•	•	•	•	•	•	•	•
80/01/29	6.8	•	•	•	•	•	•	0.007	0.02	•	•	•	•	•	•	•	•	•	•
80/01/29	•	•	•	•	< 2	•	< 2	•	•	•	•	•	•	•	•	•	•	•	•
80/03/02	•	•	•	•	•	< 1	•	•	•	•	•	•	•	•	•	•	•	•	•
80/04/01	•	•	•	•	•	< 1	•	•	•	•	•	•	•	•	•	•	•	•	•
80/04/02	•	•	•	•	< 2	•	2	•	•	•	•	•	•	•	•	•	•	•	•
80/04/21	•	•	•	•	•	1	•	•	•	•	•	•	•	•	•	•	•	•	•
80/06/02	•	•	•	•	•	< 2	•	•	•	•	•	•	•	•	•	•	•	•	•
80/07/07	•	•	•	•	•	< 1	•	•	•	•	•	•	•	•	•	•	•	•	•
80/07/10	7.4	24	1	•	•	•	•	0.014	0.03	< 5	•	•	•	•	•	•	•	•	•
80/07/30	•	•	•	•	•	8	•	•	•	•	•	•	•	•	•	•	•	•	•
80/08/06	7.3	•	< 1	•	•	•	•	< 0.005	0.05	< 5	•	•	•	•	•	•	•	•	•
80/08/06	•	•	•	•	9	•	14	•	•	•	•	•	•	•	•	•	•	•	•
80/09/02	•	•	•	•	•	2	•	•	•	•	•	•	•	•	•	•	•	•	•
80/10/02	•	•	•	•	2	•	14	•	•	•	•	•	•	•	•	•	•	•	•
80/10/02	7.1	•	1	•	•	•	•	< 0.005	0.03	•	•	•	•	•	•	•	•	•	•
80/10/08	•	•	•	•	•	< 1	•	•	•	•	•	•	•	•	•	•	•	•	•
80/11/27	•	•	•	•	•	1	•	•	•	•	•	•	•	•	•	•	•	•	•
81/05/25	6.9	16	1	•	•	•	•	0.007	< 0.02	•	•	•	•	•	•	•	•	•	•
81/05/25	•	•	•	•	2	•	•	•	•	•	•	•	•	•	•	•	•	•	•
82/01/05	•	•	•	•	< 2	•	•	•	•	•	•	•	•	•	•	•	•	•	•
83/03/15	•	•	•	•	< 2	•	13	•	< 0.02	•	•	•	•	•	•	•	•	•	•
83/03/15	7.3	•	1	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•	•
84/02/20	•	•	•	•	2	•	5	•	•	•	•	•	•	•	•	•	•	•	•
84/02/20	7.3	•	3	•	•	•	•	< 0.005	< 0.02	•	•	•	•	•	•	•	•	•	•
86/02/12	7.2	•	2	•	< 2	•	•	< 0.005	< 0.02	•	•	•	•	•	•	•	•	•	•
86/10/01	7.3	•	•	•	2	•	•	< 0.05	0.04	•	•	•	•	•	•	•	•	•	•
87/01/12	6.9	•	•	•	2	•	•	< 0.005	< 0.02	< 5	•	•	•	•	•	•	•	•	•
87/05/07	7.1	•	•	•	•	0	•	< 0.005	< 0.02	< 5	•	•	•	•	•	•	•	•	•
87/10/27	6.8	•	•	•	< 2	•	•	< 0.005	0.12	< 5	< 10	< 100	< 10	4	0.09	< 0.01	< 0.05	< 100	< 0.005
88/02/04	7	•	•	•	< 18	•	•	0.008	< 0.02	< 5	< 10	< 100	< 10	1	0.07	< 0.01	< 0.05	< 100	< 0.005
88/12/08	6.8	•	< 1	•	4	•	•	< 0.005	< 0.02	< 5	< 10	< 100	< 10	< 1	0.07	< 0.01	< 0.05	< 100	< 0.01
89/10/31						2													
90/01/10						< 2													

Table A1-5. Water quality data for site 0125903 on Piggott Creek upstream from Branch 161 bridge and downstream from PE 5123.

DATE	PH	T.RES	NF.RES	TURB.	FE.COLI.	FE.COLI.	T.COL1.	Amm-D	NO2NO3-D	NO2-D	As-T	Cd-T	Co-T	Cr-T	Cu-T	Fe-T	Mn-T	Ni-T	Pb-T	Zn-T
		mg/L	mg/L	NTU	MPN	CFU/cL	MPN	mg/L	mg/L	µg/L	mg/L	µg/L	µg/L	µg/L	µg/L	mg/L	mg/L	mg/L	µg/L	mg/L
79/10/09	7	18	<1	*	*	*	*	*	0.03	*	*			*	*	*	*	*	*	*
79/10/31	7.1	24	2	1.4	*	*	*	< 0.005	< 0.02	*	*			*	*	*	*	*	*	*
80/01/29	6.8	*	*	*	*	*	*	0.008	< 0.02	*	*			*	*	*	*	*	*	*
80/01/29	*	*	*	*	< 2	*	< 2				*			*	*	*	*	*	*	*
80/03/02	*	*	*	*	*	< 1	*				*			*	*	*	*	*	*	*
80/04/01	*	*	*	*	*	< 1	*				*			*	*	*	*	*	*	*
80/04/02	*	*	*	*	< 2	*	5				*			*	*	*	*	*	*	*
80/04/21	*	*	*	*	*	< 1	*				*			*	*	*	*	*	*	*
80/06/02	*	*	*	*	*	6	*				*			*	*	*	*	*	*	*
80/07/07	*	*	*	*	*	< 1	*				*			*	*	*	*	*	*	*
80/07/10	7.3	24	1	*	*	*	*	0.02	0.05	< 5	*			*	*	*	*	*	*	*
80/07/30	*	*	*	*	*	6	*				*			*	*	*	*	*	*	*
80/08/06	7.4	*	<1	*	*	*	*	< 0.005	0.05	< 5	*			*	*	*	*	*	*	*
80/08/06	*	*	*	*	5	*	8				*			*	*	*	*	*	*	*
80/09/02	*	*	*	*	*	2	*				*			*	*	*	*	*	*	*
80/10/02	*	*	*	*	2	*	23				*			*	*	*	*	*	*	*
80/10/02	7.1	*	2	*	*	*	*	0.007	0.07	*	*			*	*	*	*	*	*	*
80/10/08	*	*	*	*	*	< 1	*				*			*	*	*	*	*	*	*
80/11/27	*	*	*	*	*	2	*				*			*	*	*	*	*	*	*
81/05/25	6.9	17	1	*	*	*	*	0.013	< 0.02	*	*			*	*	*	*	*	*	*
81/05/25	*	*	*	*	< 2	*	*				*			*	*	*	*	*	*	*
82/01/05	*	*	*	*	> 2400	*	*				*			*	*	*	*	*	*	*
82/01/05	*	*	*	*	> 2400	*	*				*			*	*	*	*	*	*	*
83/03/15	*	*	*	*	4	*	7				*			*	*	*	*	*	*	*
83/03/15	7.2	*	1	*	*	*	*	*	< 0.02	*	*			*	*	*	*	*	*	*
84/02/20	*	*	*	*	8	*	170				*			*	*	*	*	*	*	*
84/02/20	7.8	*	2	*	*	*	*	0.07	< 0.02	*	*			*	*	*	*	*	*	*
86/02/12	7.1	*	2	*	33	*	*	0.134	0.03	*	*			*	*	*	*	*	*	*
86/10/01	7.5	*	*	*	2	*	*	< 0.005	0.09	*	*			*	*	*	*	*	*	*
87/01/12	6.9	*	*	*	< 2	*	*	0.05	< 0.02	< 5	*			*	*	*	*	*	*	*
87/05/07	6.9	*	*	*	*	5	*	< 0.005	< 0.02	< 5	< 0.30	< 10	< 100	< 10	1	0.06	< 0.01	< 0.05	< 100	< 0.005
87/09/30	6.9	*	*	*	*	*	*				*	< 10	< 100	< 10	2	< 0.01	< 0.01	< 0.05	< 100	< 0.005
87/10/27	7.4	*	*	*	240	*	*	0.211	0.69	< 5	*	*	*	*	*	*	*	*	*	*
88/02/04	7.2	*	*	*	< 18	*	*	0.238	0.05	< 5	*	*	*	*	*	*	*	*	*	*
88/06/21	7.3	*	1	*	*	*	*	*	< 0.02	*	*	< 10	< 100	< 10	2	0.1	< 0.01	< 0.05	< 1	< 0.005
88/07/13	6.9	*	<1	*	*	*	*	*	< 0.02	*	*	< 10	< 100	< 10	2	0.04	< 0.01	< 0.05	< 1	0.008
88/08/09	7.5	*	5	*	*	*	*	*	< 0.02	*	*	< 10	< 100	10	4	0.39	< 0.01	< 0.05	3	0.008
88/10/05	7.5	*	<1	*	*	*	*	*	0.02	*	*	< 10	< 100	< 10	2	0.05	< 0.01	< 0.05	< 1	0.005
88/12/08	6.8	*	*	*	*	10	*	0.027	< 0.02	< 5	*	*	*	*	*	*	*	*	*	*
89/10/31						2														
90/01/10						3														

Table A1-6. Water quality data for site o125904 on Piggott Creek upstream of Branch 161 bridge.

DATE	PH	T.RES.	F.RES.	NF.RES	TURB.	COLOR	FE.COLI.	T.COL1.	Amm-D	NO2NO3-D	NO2-D	As-T	Cd-T	Co-T	Cr-T	Cu-T	Fe-T	Mn-T	Ni-T	Pb-T	Zn-T
		mg/L	mg/L	mg/L	NTU	TAC	MPN	MPN	mg/L	mg/L	μg/L	mg/L	μg/L	μg/L	μg/L	μg/L	mg/L	mg/L	mg/L	μg/L	mg/L
79/10/09	7.1	18	•	< 1	•	•	•	•	•	0.02	•	•	•	•	•	•	•	•	•	•	•
79/10/31	7.0	22	•	2	1.5	•	•	•	< 0.005	< 0.02	•	•	•	•	•	•	•	•	•	•	•
80/08/06	7.4	•	•	< 1	•	•	•	•	0.005	0.03	< 5	•	•	•	•	•	•	•	•	•	•
80/08/06	•	•	•	•	•	•	< 2	< 2	•	•	•	•	•	•	•	•	•	•	•	•	•
80/10/02	•	•	•	•	•	•	2	23	•	•	•	•	•	•	•	•	•	•	•	•	•
80/10/02	7.3	•	•	2	•	•	•	•	0.005	0.05	•	•	•	•	•	•	•	•	•	•	•
81/05/23	•	•	•	•	•	•	< 2	•	•	•	•	•	•	•	•	•	•	•	•	•	•
81/05/25	7.1	18	•	1	•	•	•	•	0.01	< 0.02	•	•	•	•	•	•	•	•	•	•	•
85/05/01	7.1	•	34	2	•	9	•	•	< 0.005	< 0.02	< 5	< 0.001	< 0.5	< 1	< 5	< 1	0.12	< 0.01	< 0.05	< 1	< 0.005

Table A1-7. Water quality data for site E206684 on tributary to Piggott Creek at Piggott Main.

DATE	PH	NF.RES	Al-D	As-T	Cd-T	Co-T	Cr-T	Cu-T	Fe-T	Mn-T	Ni-T	Pb-D	Pb-T	Zn-T
		mg/L	mg/L	mg/L	µg/L	µg/L	mg/L	µg/L	mg/L	mg/L	mg/L	µg/L	µg/L	mg/L
86/05/27	*	*	0.08	*	*	*	*	*	*	*	*	< 100	*	*
86/07/07	*	*	*	< 0.25	< 10	< 100	< 0.01	4	0.05	< 0.01	< 0.05	*	< 100	0.01
86/08/13	*	*	*	< 0.25	< 10	< 100	< 0.01	4	0.08	< 0.01	< 0.05	*	< 100	< 0.01
86/09/15	*	*	*	< 0.25	< 10	< 100	< 0.01	1	0.15	0.02	< 0.05	*	< 100	< 0.01
86/09/26	*	*	*	< 0.25	< 10	< 100	< 0.01	4	0.05	< 0.01	< 0.05	*	< 100	< 0.01
86/10/14	*	*	*	< 0.25	< 10	< 100	< 0.01	1	0.52	0.07	< 0.05	*	< 100	< 0.01
86/10/27	*	*	*	< 0.25	< 10	< 100	< 0.01	4	0.1	< 0.01	< 0.05	*	< 100	< 0.01
86/11/13	*	*	*	< 0.25	< 10	< 100	< 0.01	5	0.05	< 0.01	< 0.05	*	< 100	0.01
87/04/28	7	*	*	< 0.30	< 10	< 100	< 0.01	10	0.12	< 0.01	< 0.05	*	< 100	< 0.005
87/05/07	6.9	*	*	< 0.30	< 10	< 100	< 0.01	10	0.07	< 0.01	< 0.05	*	< 100	< 0.005
87/05/13	6.6	*	*	< 0.30	< 10	< 100	< 0.01	9	0.06	< 0.01	< 0.05	*	< 100	< 0.005
87/05/21	7.4	*	*	< 0.30	< 10	< 100	< 0.01	10	0.05	< 0.01	< 0.05	*	< 100	< 0.005
87/05/27	6.8	*	*	< 0.30	< 10	< 100	< 0.01	10	0.04	< 0.01	< 0.05	*	< 100	< 0.005
87/06/04	6.6	< 1	0.03	*	< 10	< 100	< 0.01	15	0.08	< 0.01	< 0.05	< 100	< 100	< 0.005
87/06/08	6.8	< 1	0.08	*	< 10	< 100	0.07	220	0.89	0.06	< 0.05	< 100	< 100	0.18
87/06/17	6.9	< 1	0.04	*	< 10	< 100	< 0.01	6	0.08	< 0.01	< 0.05	< 100	< 100	< 0.005
87/06/24	7.1	< 1	< 0.02	*	< 10	< 100	< 0.01	7	0.11	< 0.01	< 0.05	< 100	< 100	< 0.005
87/07/02	*	*	0.05	*	< 10	< 100	< 0.01	8	0.09	< 0.01	< 0.05	< 100	< 100	< 0.005
87/09/16	7.4	< 1	0.08	*	< 10	< 100	0.02	3	0.25	0.02	< 0.05	< 100	< 100	< 0.005
87/10/15	7.6	< 1	0.03	*	< 10	< 100	< 0.01	3	0.08	< 0.01	< 0.05	< 100	< 100	< 0.005
87/10/28	7.5	< 1	0.08	*	< 10	< 100	< 0.01	3	0.09	0.01	< 0.05	< 100	< 100	< 0.005
87/11/17	7.1	< 1	0.06	0.003	< 10	< 100	< 0.01	4	0.13	0.01	< 0.05	< 100	< 100	< 0.005
88/05/18	7.1	< 1	*	*	< 10	< 100	< 0.01	8	0.1	< 0.01	< 0.05	< 100	< 100	< 0.01
88/05/25	7	< 1	*	*	< 10	< 100	< 0.01	7	0.26	0.01	< 0.05	< 100	< 100	0.006
88/05/31	7.2	< 1	*	*	< 10	< 100	< 0.01	9	0.09	< 0.01	< 0.05	< 100	< 100	< 0.005
88/06/07	6.9	< 1	*	*	< 10	< 100	< 0.01	5	0.08	< 0.01	< 0.05	< 100	< 100	< 0.005

Table A1-8. Water quality data for site E207429 on the mainstem Oyster River upstream from Adrian Creel.

DATE	PH	NF.RES	Cd-T	Co-T	Cr-T	Cu-T	Fe-T	Mn-T	Ni-T	Pb-D	Pb-T	Zn-T
		mg/L	µg/L	µg/L	mg/L	µg/L	mg/L	mg/L	mg/L	µg/L	µg/l	mg/L
88/06/15	7.2	1	< 10	< 100	< 0.01	1	0.1	< 0.01	< 0.05	< 1	2	< 0.005
88/06/22	7.5	1	< 10	< 100	< 0.01	2	0.08	< 0.01	< 0.05	< 1	1	< 0.005
88/07/13	7.2	< 1	< 10	< 100	< 0.01	2	0.1	< 0.01	< 0.05	< 1	< 1	0.006
88/08/09	7.1	< 1	< 10	< 100	< 0.01	2	0.07	< 0.01	< 0.05	< 1	< 1	0.005

Table A1-9. Water quality data for site E207430 on Little Oyster River at York Road.

DATE	PH	NF.RES	E.COLI	FE.COLI.	Cd-T	Co-T	Cr-T	Cu-T	Fe-T	Mn-T	Ni-T	Pb-D	Pb-T	Zn-T
		mg/L	CFU/cL	CFU/cL	µg/L	µg/L	µg/L	µg/L	mg/L	mg/L	mg/L	µg/L	µg/L	mg/L
88/04/13	7	1			< 10	< 100	< 10	2	0.41	0.01	< 0.05	< 1	< 1	0.005
88/05/18	7.4	2			< 10	< 100	< 10	3	1.02	0.02	< 0.05	< 1	< 1	< 0.005
88/05/31	7.3	4			< 10	< 100	< 10	11	1.32	0.03	< 0.05	< 1	2	< 0.005
88/06/07	7.2	1			< 10	< 100	< 10	5	1.03	0.02	0.09	< 1	< 1	< 0.005
88/06/13	7.4	3			< 10	< 100	< 10	2	1.17	0.03	< 0.05	< 1	2	< 0.005
88/06/21	7.5	1			< 10	< 100	< 10	2	1.54	0.06	< 0.05	< 1	< 1	< 0.005
88/07/13	7.2	5			< 10	< 100	< 10	3	1.67	0.08	< 0.05	< 1	1	0.005
88/10/05	7.1	2			< 10	< 100	< 10	3	1.92	0.13	< 0.05	1	1	< 0.005
88/11/02	7.1	18			< 10	< 100	< 10	5	2.24	0.15	< 0.05	< 1	1	0.009
88/11/22	7.3	9			< 10	< 100	< 10	1	0.85	0.03	< 0.05	< 1	< 1	< 0.005
88/12/13	7.5	2			< 10	< 100	< 10	3	0.37	0.01	< 0.05	< 100	1	0.02
89/01/23	7.2	1			< 10	< 100	< 10	< 1	0.23	0.01	< 0.05	< 1	1	0.005
89/05/08			5	2										
89/05/15			25	32										
89/05/23			350	340										
89/05/29			44	53										
89/06/05			27	18										
89/10/16			*	< 2										
89/10/23			33	44										
89/10/30			8	5										
89/11/06			17	12										
89/11/13			8	9										
								2.730	0.629	0.048			0.4880	0.006

Table A1-10. Water quality data for site E207431 on Woodhus Creek at Duncan Main.

DATE	PH	NF.RES.	E.COLI	FE.COLI.	FE.COLI.	T.COLI.	Cd-T	Co-T	Cr-T	Cu-T	Fe-T	Mn-T	Ni-T	Pb-D	Pb-T	Zn-T
		mg/L	CFU/cL	CFU/cL	MPN	MPN	µg/L	µg/L	µg/L	µg/L	mg/L	mg/L	mg/L	µg/L	µg/L	mg/L
88/04/13	6.8	< 1					< 10	< 100	< 10	1	0.24	< 0.01	< 0.05	< 1	< 1	< 0.005
88/05/18	7.3	1					< 10	< 100	< 10	< 1	0.27	< 0.01	< 0.05	< 1	1	< 0.005
88/05/31	7.4	< 1					< 10	< 100	< 10	9	0.52	< 0.01	< 0.05	< 1	< 1	< 0.005
88/06/07	7.4	< 1					< 10	< 100	< 10	< 1	0.23	< 0.01	< 0.05	1	4	< 0.005
88/06/13	7.5	1					< 10	< 100	< 10	2	0.29	< 0.01	< 0.05	< 1	2	< 0.005
88/06/21	7.7	< 1					< 10	< 100	< 10	1	0.38	< 0.01	< 0.05	< 1	2	< 0.005
88/07/13	7.2	< 1					< 10	< 100	< 10	1	0.69	< 0.01	< 0.05	< 1	< 1	< 0.005
88/08/09	7.6	3					< 10	< 100	< 10	1	0.31	< 0.01	< 0.05	< 1	< 1	< 0.005
88/10/05	7.4	< 1					< 10	< 100	< 10	1	0.25	< 0.01	< 0.05	< 1	1	0.007
88/11/02	7.3	3					< 10	< 100	< 10	7	0.5	0.02	< 0.05	< 1	< 1	< 0.005
88/11/22	7.1	7					< 10	< 100	< 10	4	0.45	0.01	< 0.05	< 1	< 1	< 0.005
88/12/13	7	1					< 10	< 100	< 10	2	0.17	< 0.01	< 0.05	< 1	1	0.005
89/01/23	7.2	< 1					< 10	< 100	< 10	1	0.09	< 0.01	< 0.05	< 1	1	< 0.005
89/02/23					21	21										
89/05/08			6	6												
89/05/15			80	102												
89/05/23			35	35												
89/05/29			34	37												
89/06/05			245	200												
89/10/16			*	6												
89/10/23			84	80												
89/10/30			6	9												
89/11/06			15	7												
89/11/13			8	8												

Table A1-11. Water quality data for site E207474 on tributary to Piggott Creek at Rossiter Main.

DATE	PH	NF.RES.	As-T	Cd-T	Co-T	Cr-T	Cu-T	Fe-T	Mn-T	Ni-T	Pb-D	Pb-T	Zn-T
		mg/L	mg/L	µg/L	µg/L	mg/L	µg/L	mg/L	mg/L	mg/L	µg/L	µg/L	mg/L
88/05/18	7.2	1	< 0.001	< 10	< 100	< 0.01	5	0.07	< 0.01	< 0.05	< 1	< 1	< 0.01
88/05/31	7.2	< 1	< 0.001	< 10	< 100	< 0.01	9	0.12	< 0.01	< 0.05	< 1	< 1	< 0.01
88/06/07	7.3	< 1	*	< 10	< 100	< 0.01	4	0.09	< 0.01	< 0.05	< 1	2	< 0.005
88/06/15	7.3	< 1	*	< 10	< 100	< 0.01	2	0.05	< 0.01	< 0.05	< 1	1	< 0.005
88/06/21	7.4	< 1	*	< 10	< 100	< 0.01	3	0.1	< 0.01	< 0.05	< 1	< 1	< 0.005
88/07/13	7.6	< 1	*	< 10	< 100	< 0.01	5	0.09	0.03	< 0.05	< 1	1	< 0.005
88/08/09	7.9	< 1	*	< 10	< 100	< 0.01	3	0.08	< 0.01	< 0.05	< 1	< 1	< 0.005
88/10/05	7.8	< 1	*	< 10	< 100	< 0.01	1	0.09	< 0.01	< 0.05	< 1	1	< 0.005

Appendix-2

Graphical Correlation between Non-filterable Residue and Various Metals as well as Turbidity

Figure A2-1
Turbidity versus Non-filterable residue for Site 0125580 on Oyster River.

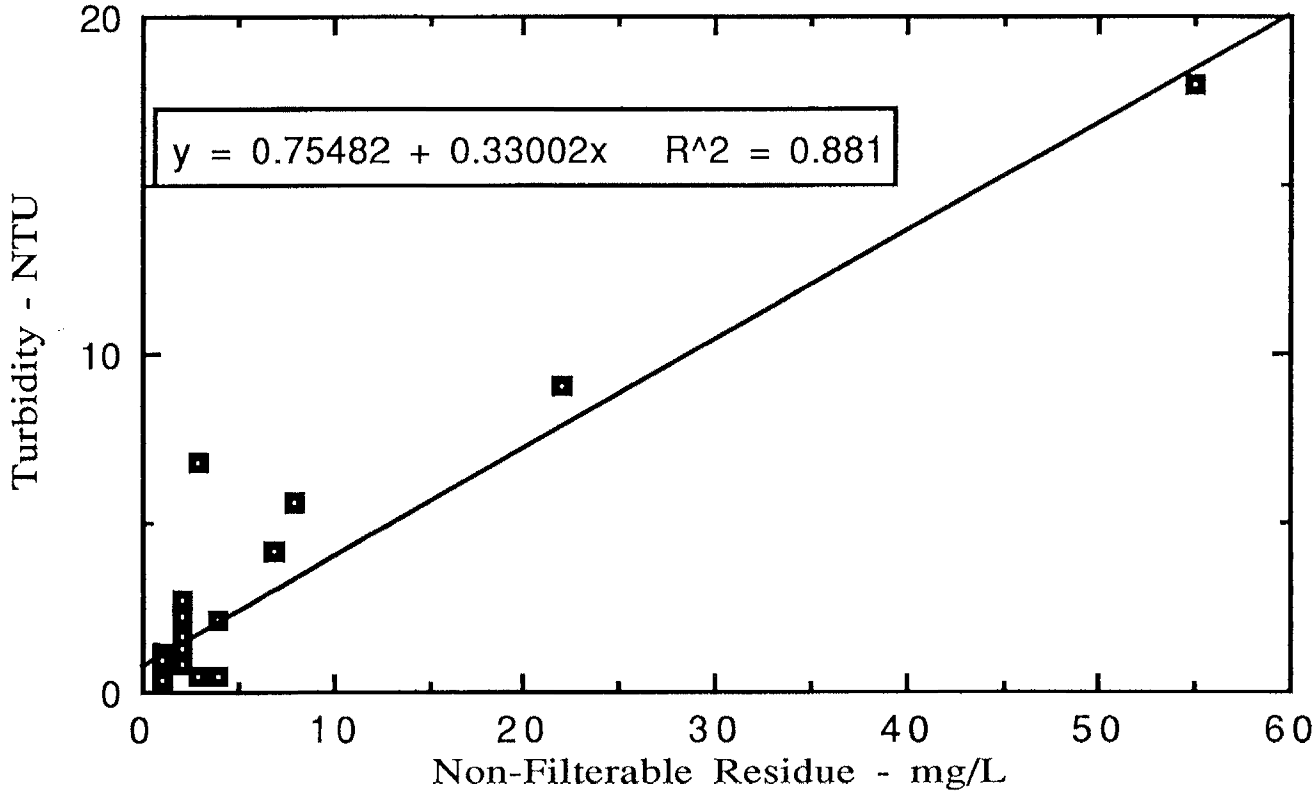

Figure A2-2

Total Chromium versus Non-filterable residue for site 0125580 on Oyster River.

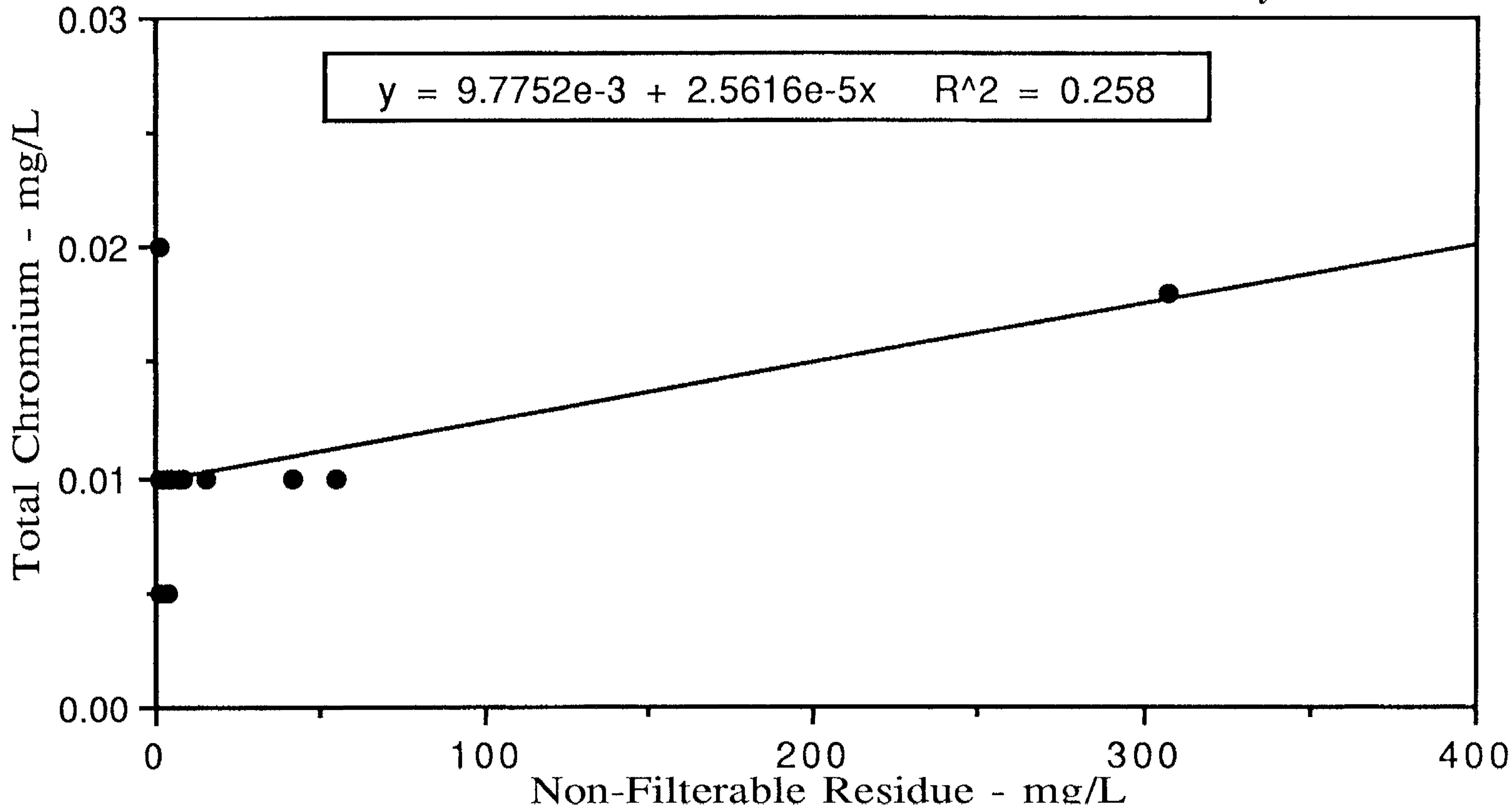

Figure A2-3
Total Copper versus Non-filterable residue for Site 0125580 on Oyster River

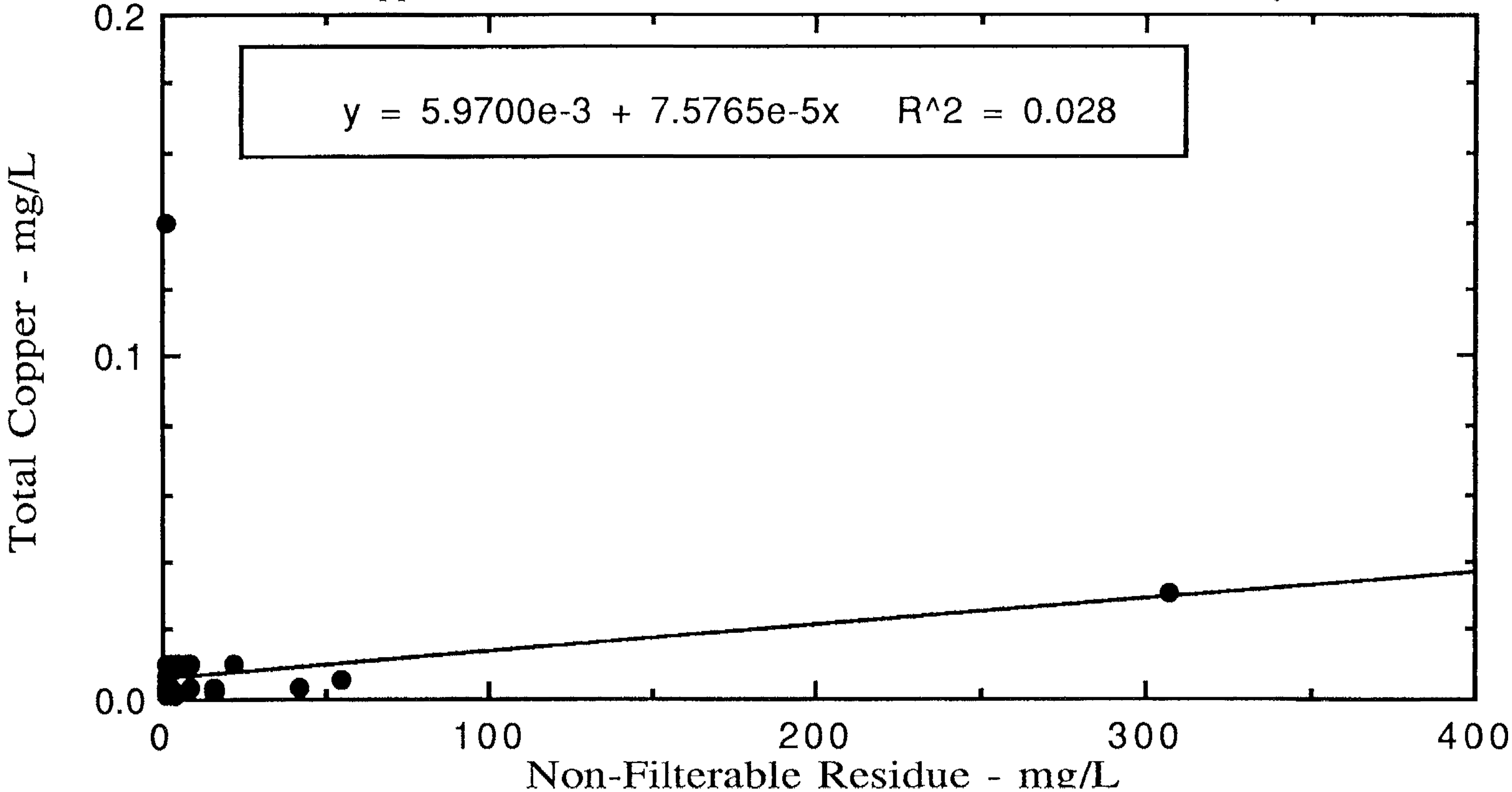

Figure A2-4

Total Iron versus Non-filterable residue for site 0125580 on Oyster River

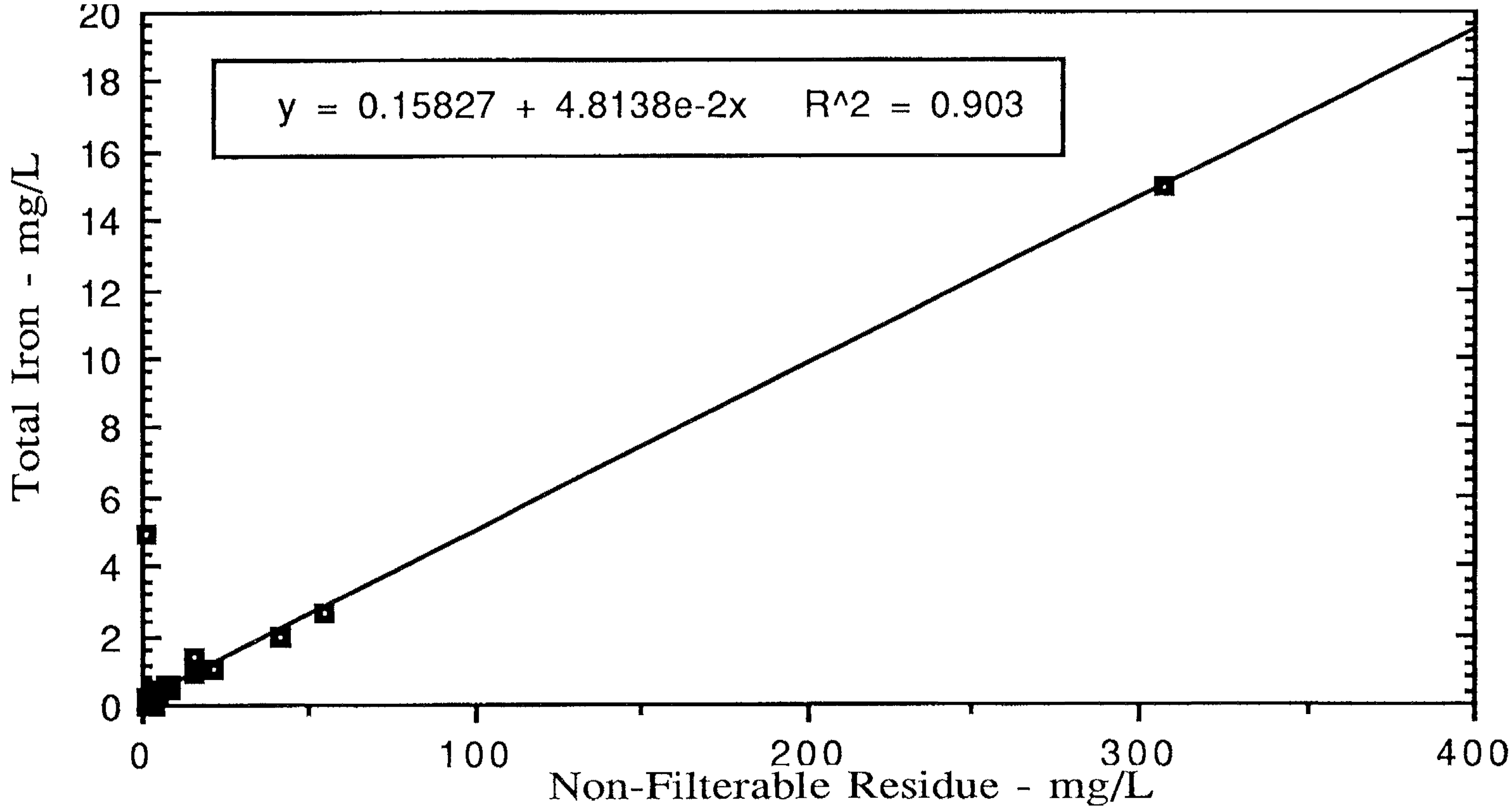

Figure A2-5
Total Lead versus Non-filterable residue for site 0125580 on Oyster River.

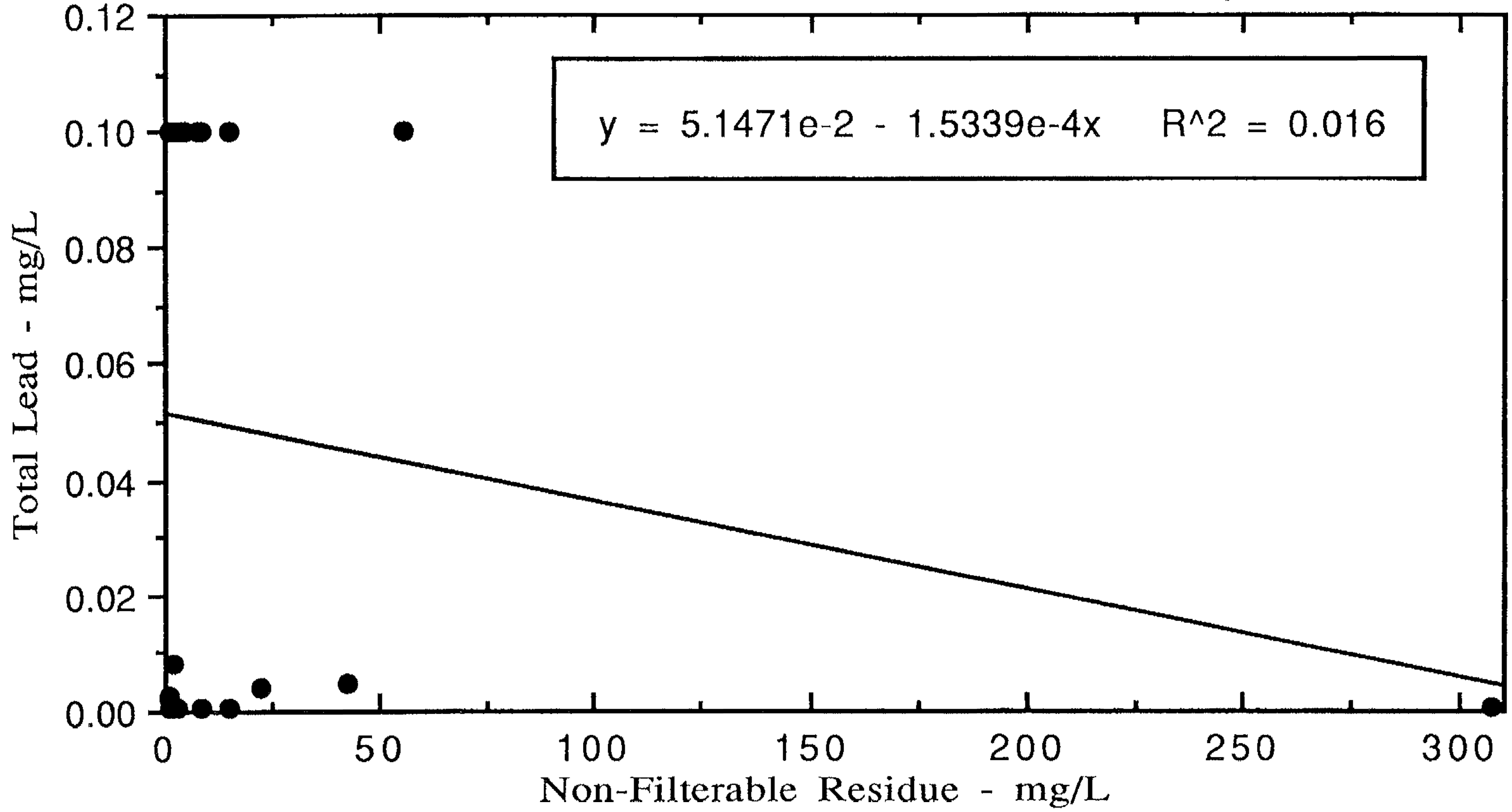

Figure A2-6

Total Manganese versus Non-filterable residue for Site 0125580 on Oyster River.

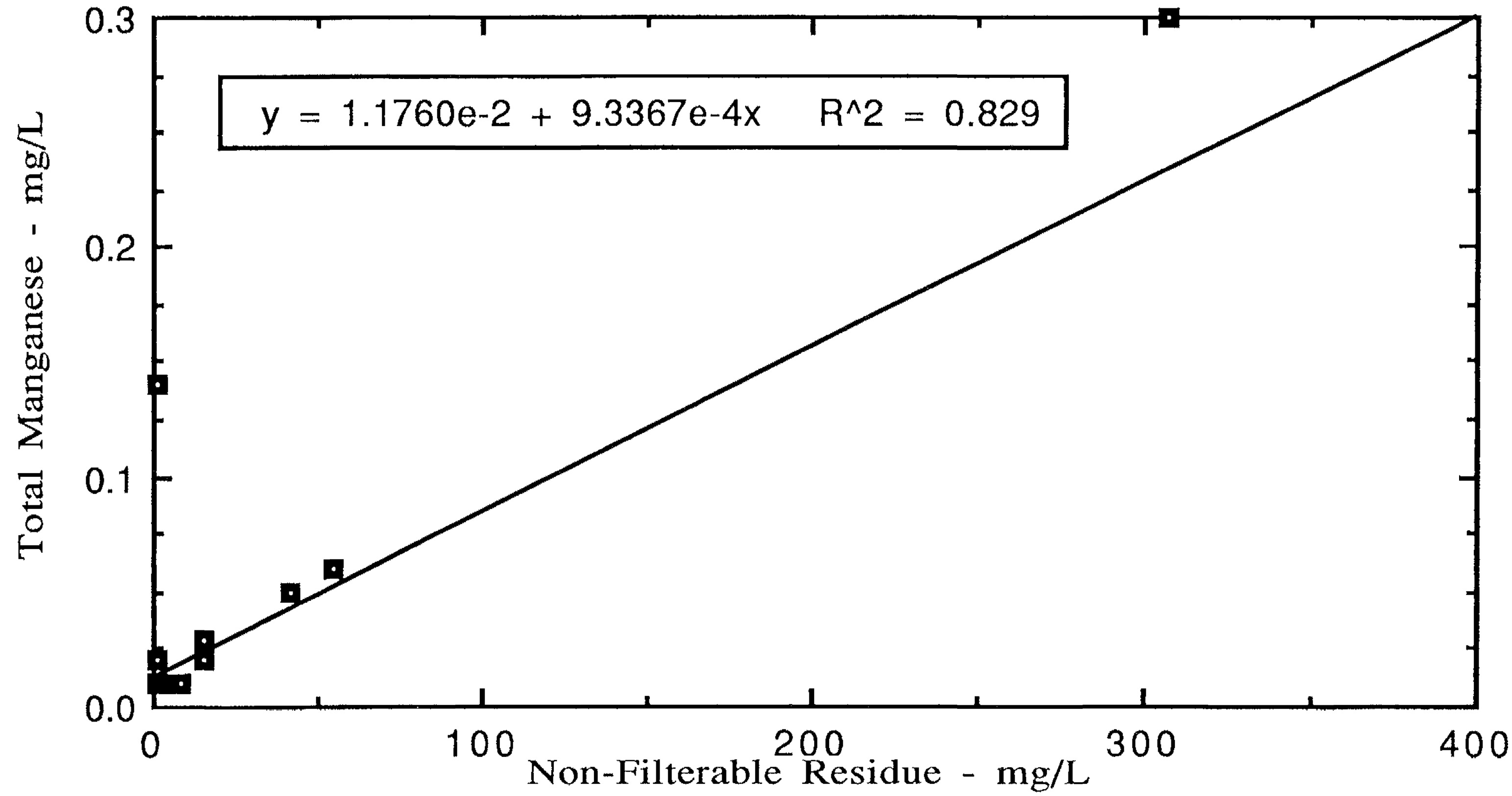

Figure A2-7
Total Mercury versus Non-filterable residue for SITE 0125580 on Oyster River.

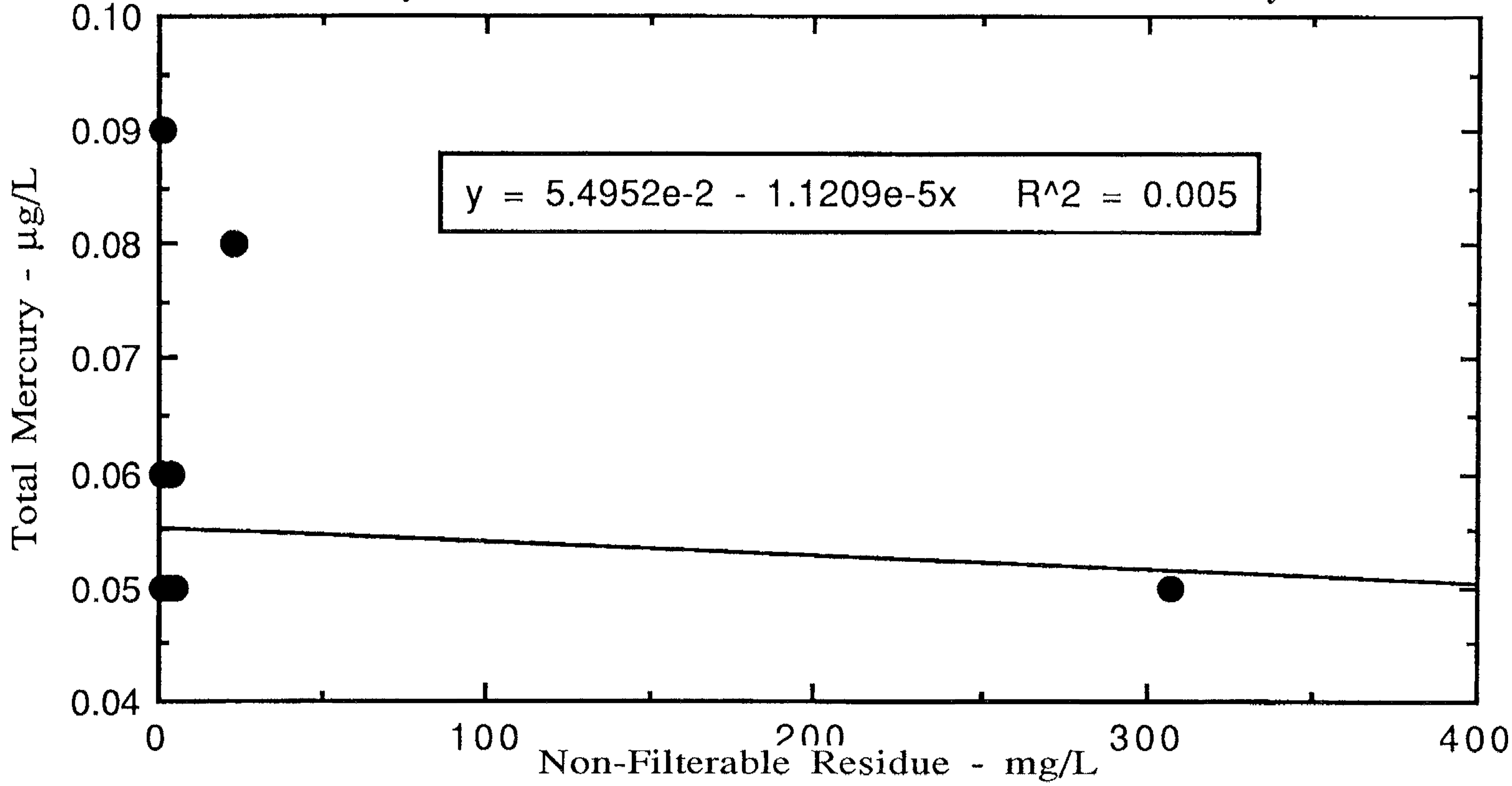

Figure A2-8
Total Zinc versus Non-filterable residue for Site 0125580 on the Oyster River.

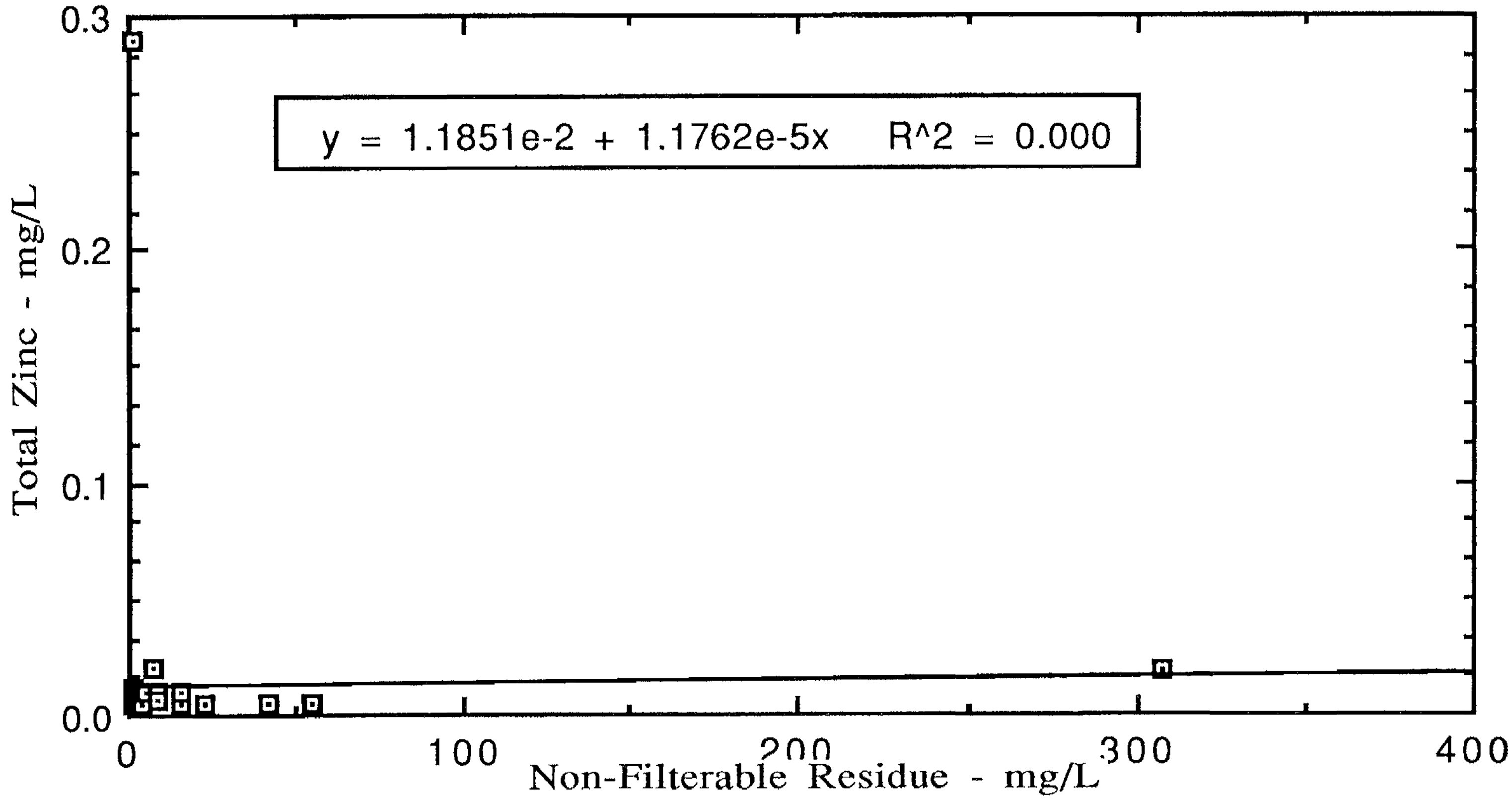

Figure A2-9

Turbidity versus Non-filterable residue for Site 0125582 on Oyster River.

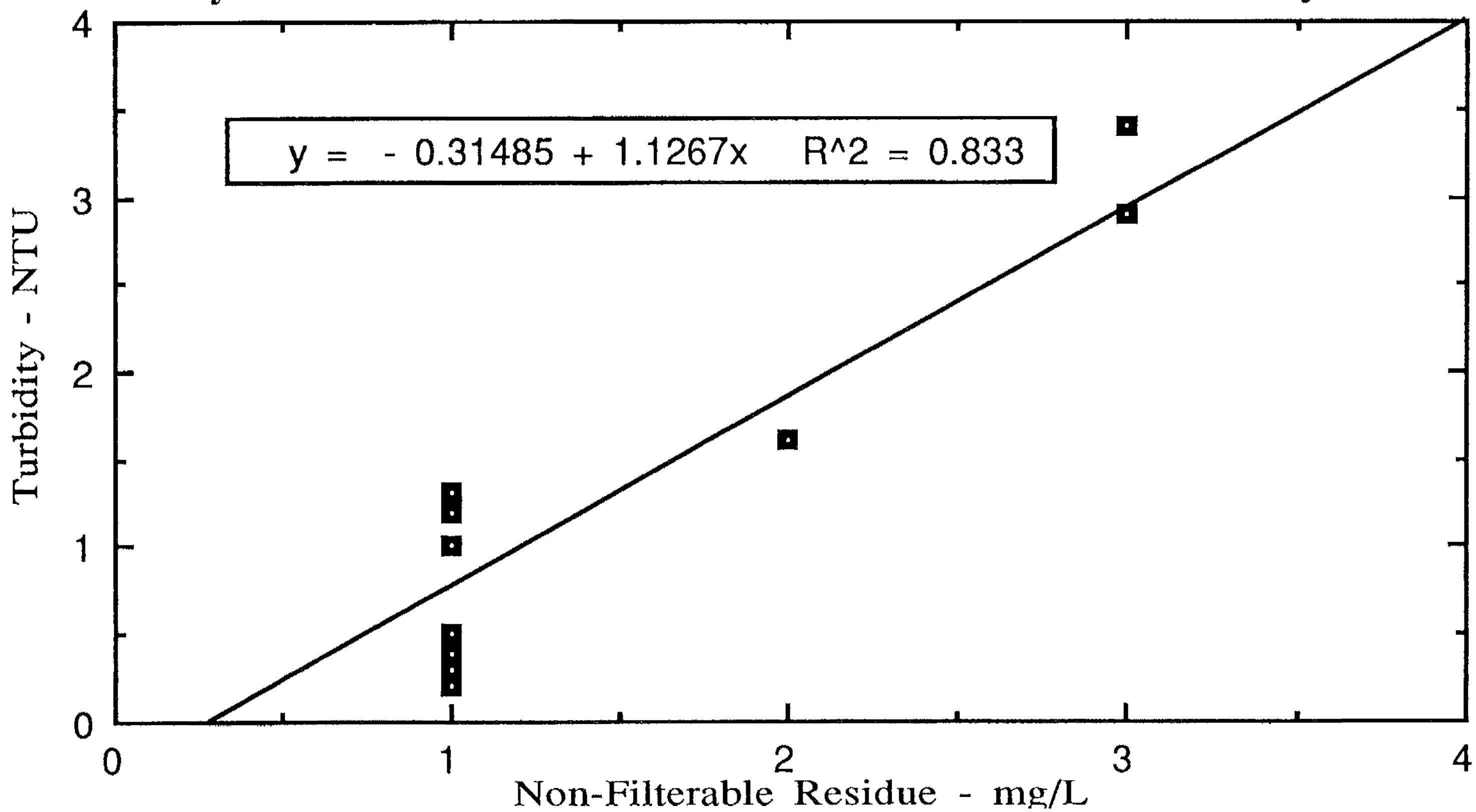

Figure A2-10
Total Copper versus Turbidity for Site 0125582 on Oyster River.

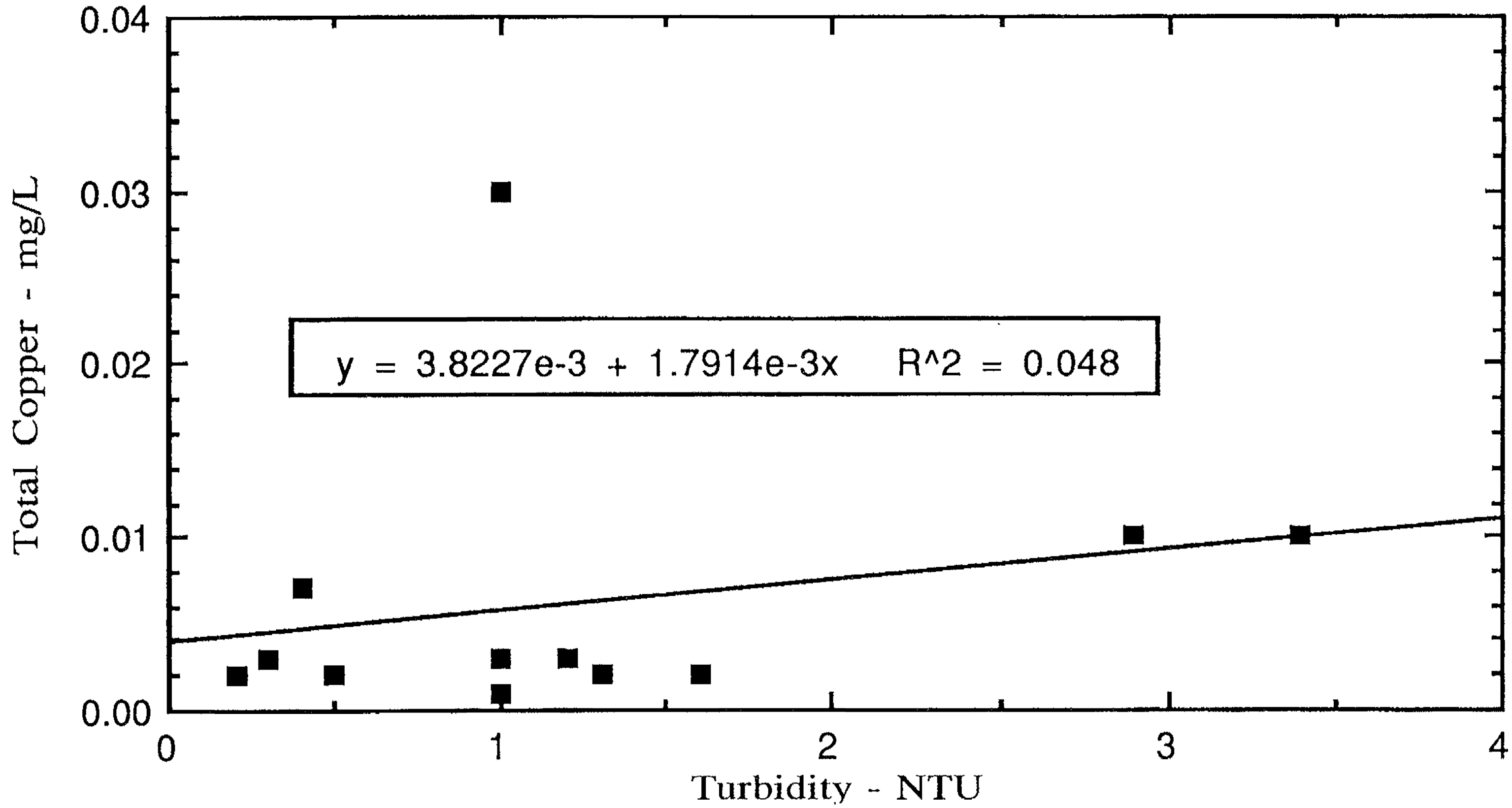

Figure A2-11
Total Copper versus Non-filterable residue for Site 0125582 on Oyster River.

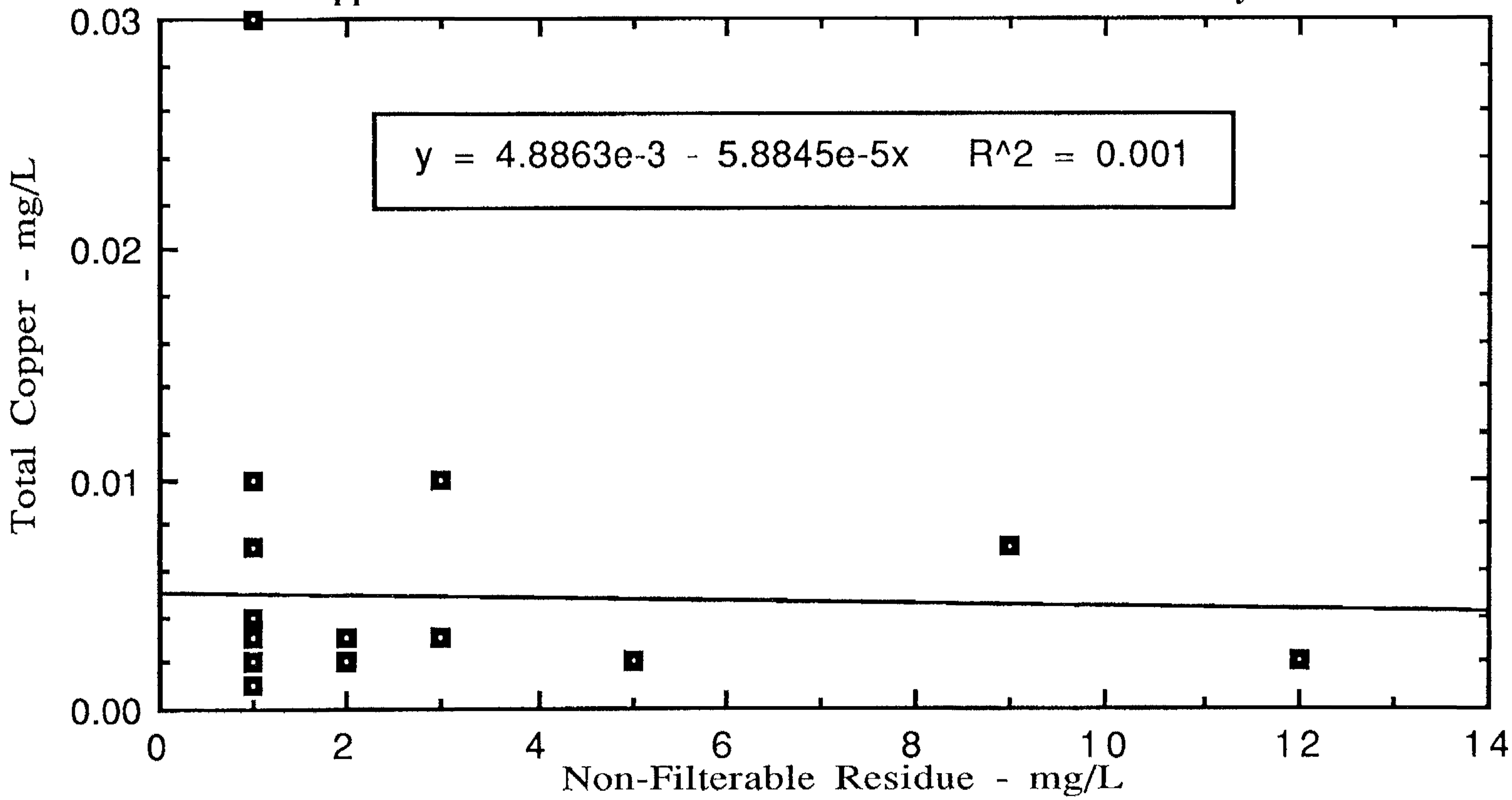

Figure A2-12

Total Iron versus Non-filterable residue for Site 0125582 on Oyster River.

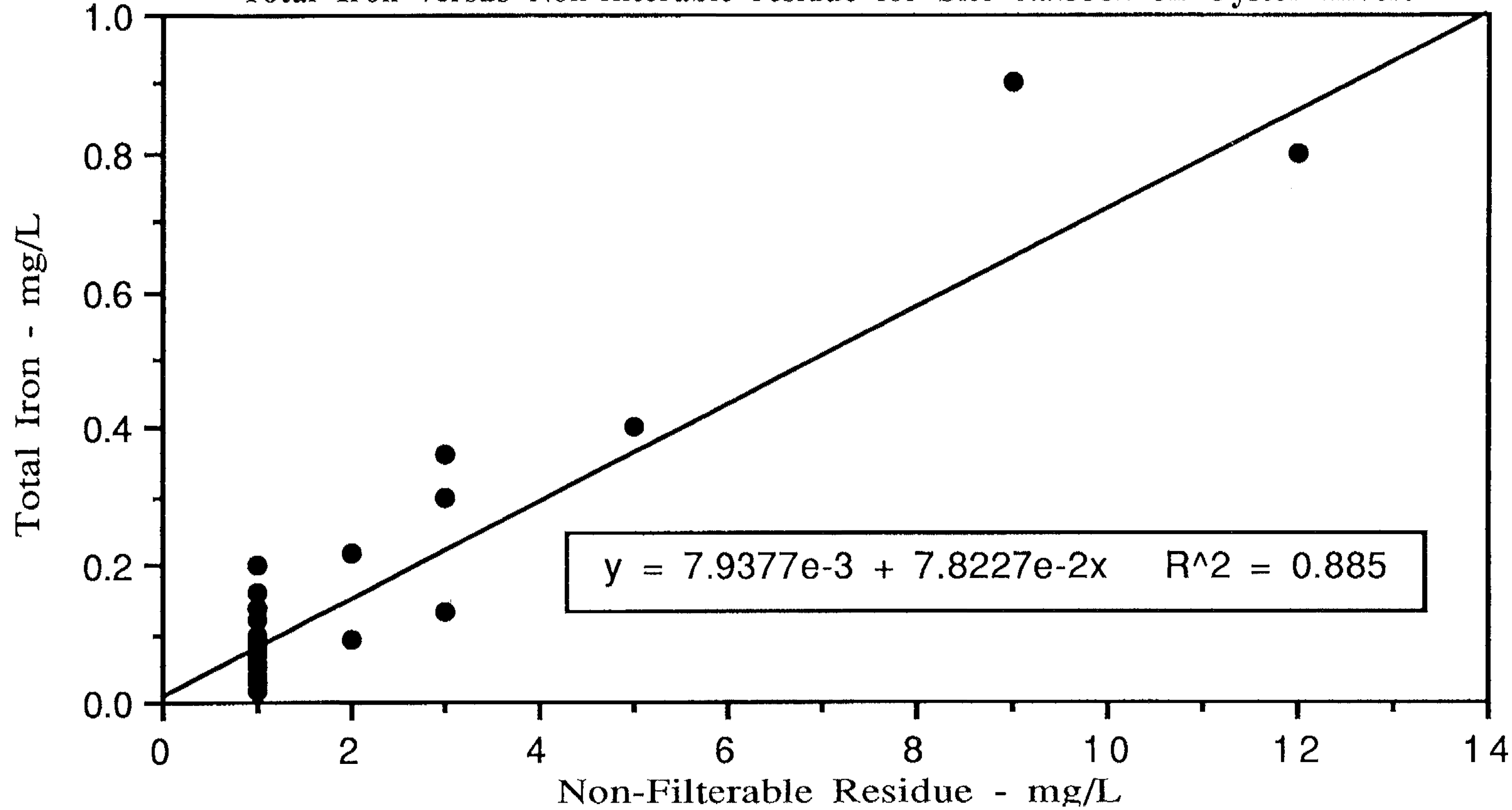

Figure A2-13

Total Iron versus Turbidity for Site 0125582 on Oyster River.

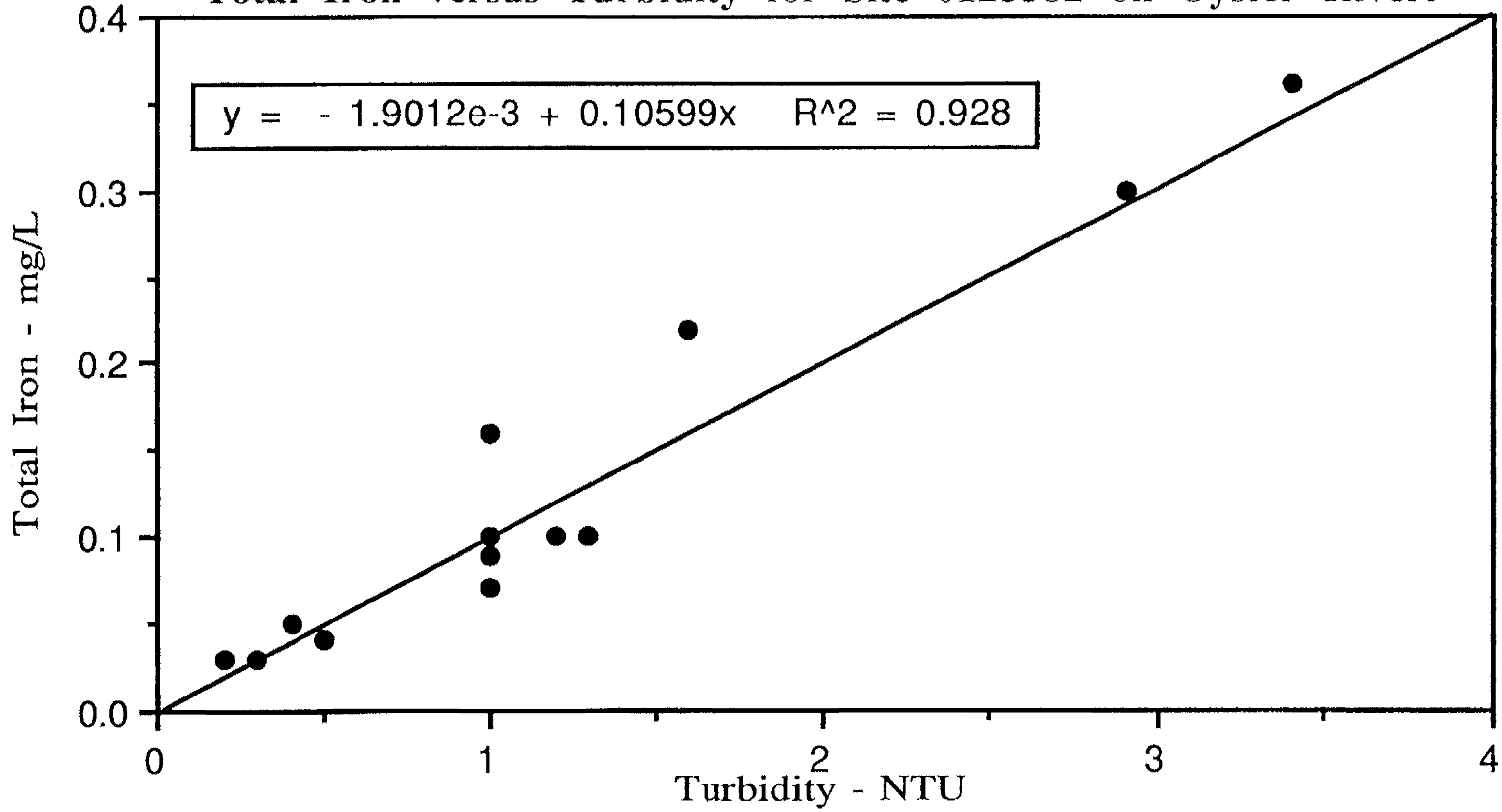

Figure A2-14
Total Manganese versus Non-filterable residue for Site 0125582 on Oyster River.

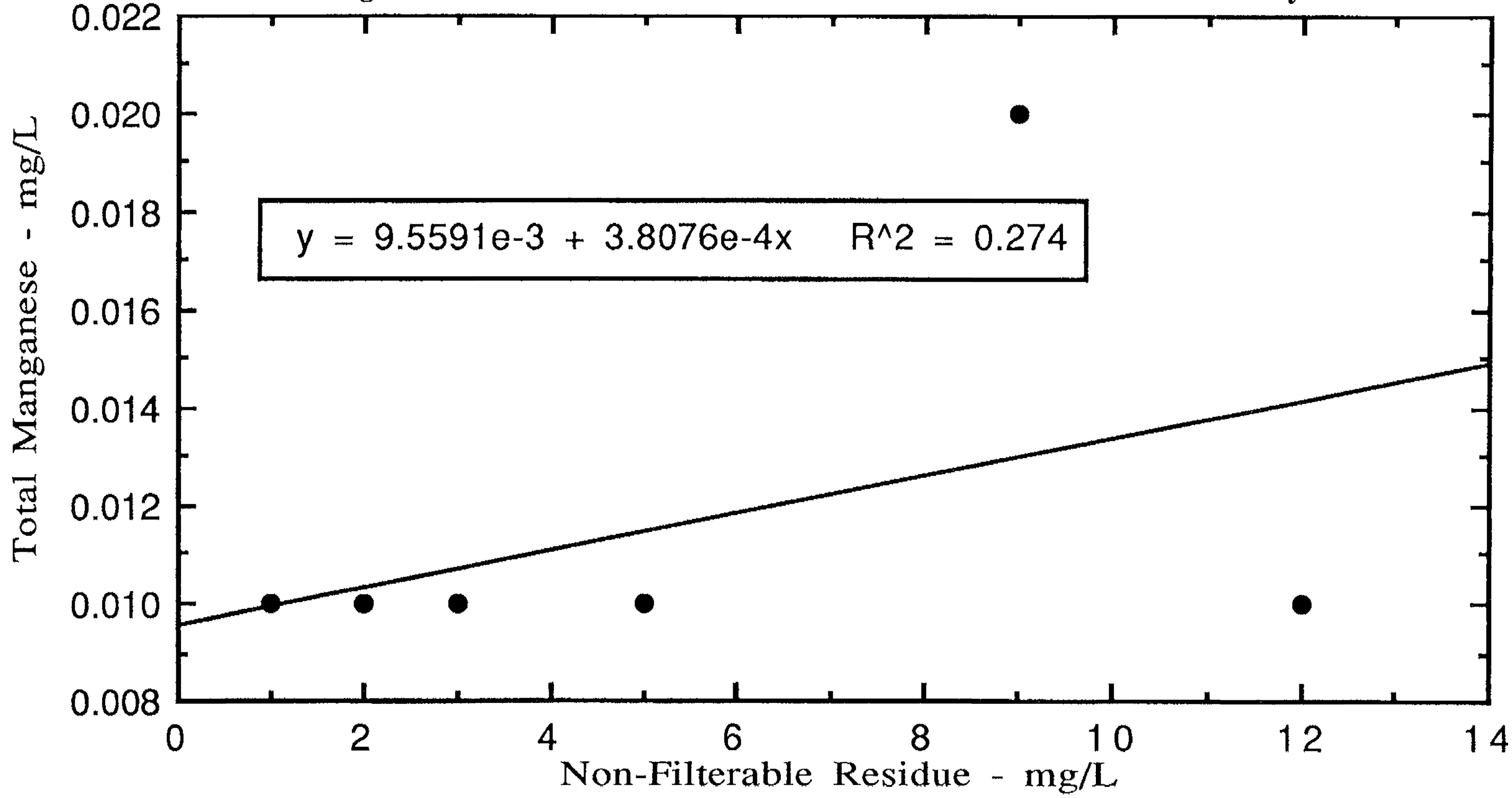

Figure A2-15

Total Zinc versus Non-filterable residue for Site 0125582 on Oyster River.

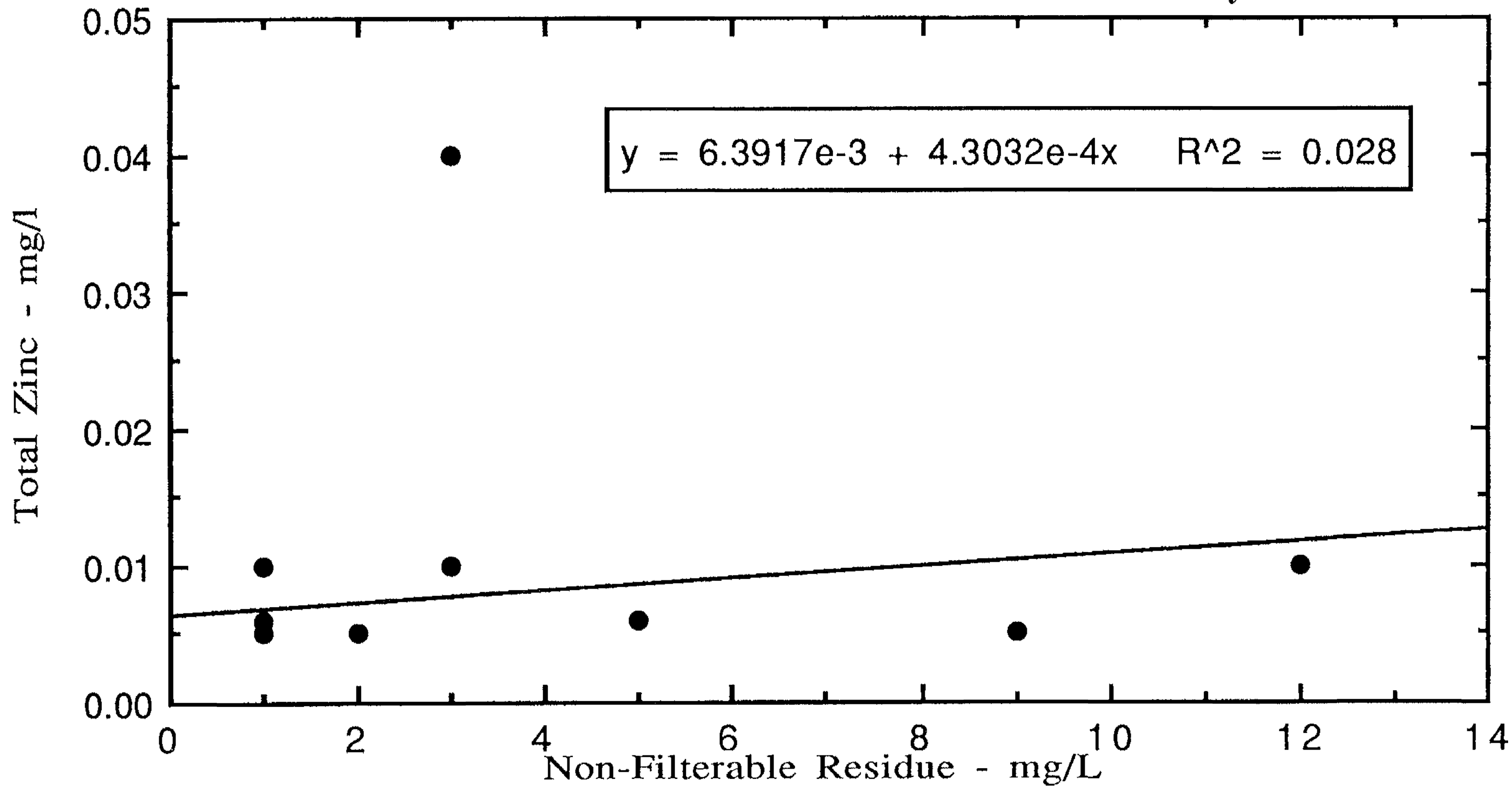

Figure A2-16
Total Copper versus Non-filterable residue for Site E207430 on Little Oyster River.

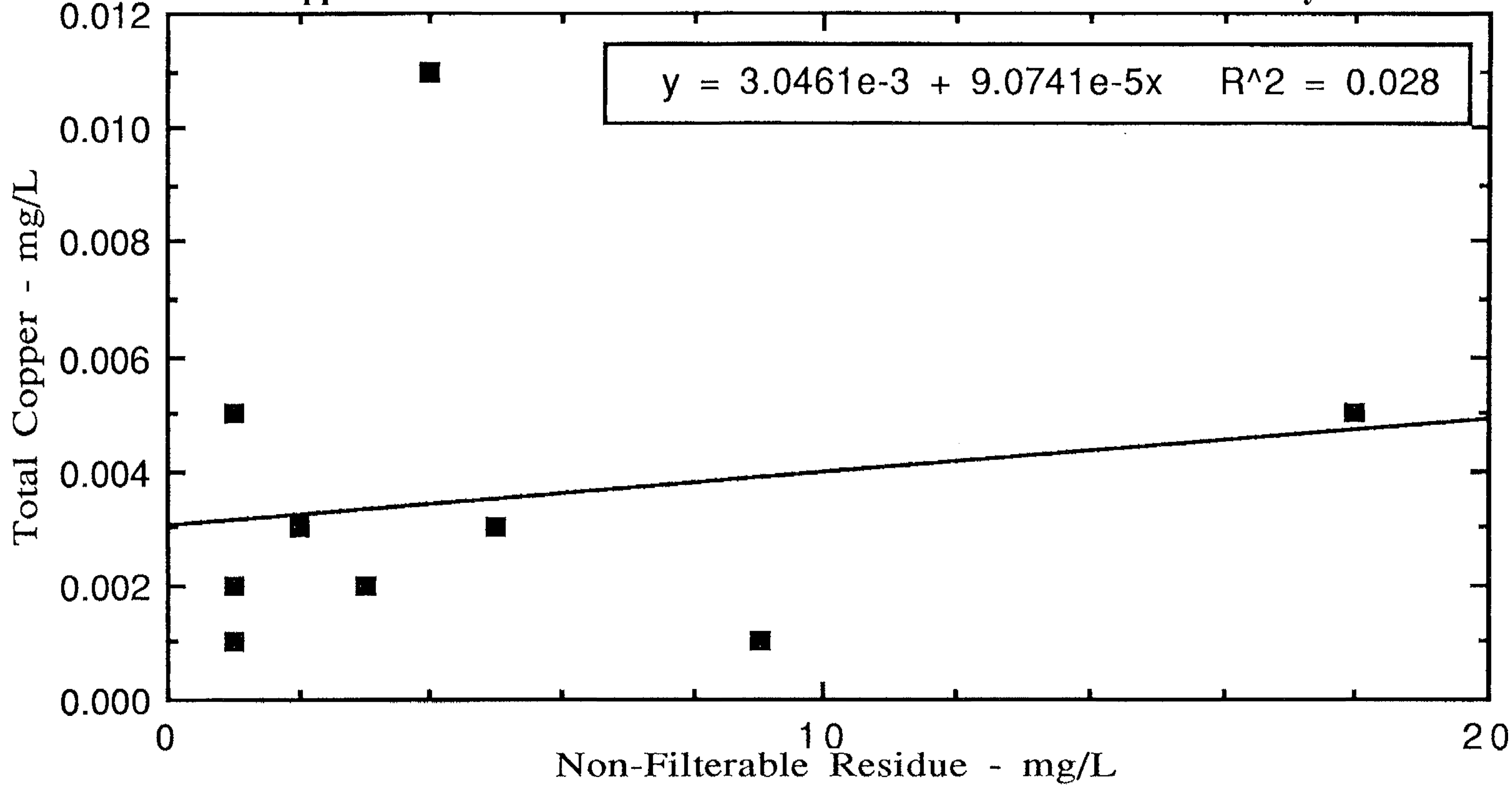

Figure A2-17
Total Iron versus Non-filterable residue for Site E207430 on Little Oyster River.

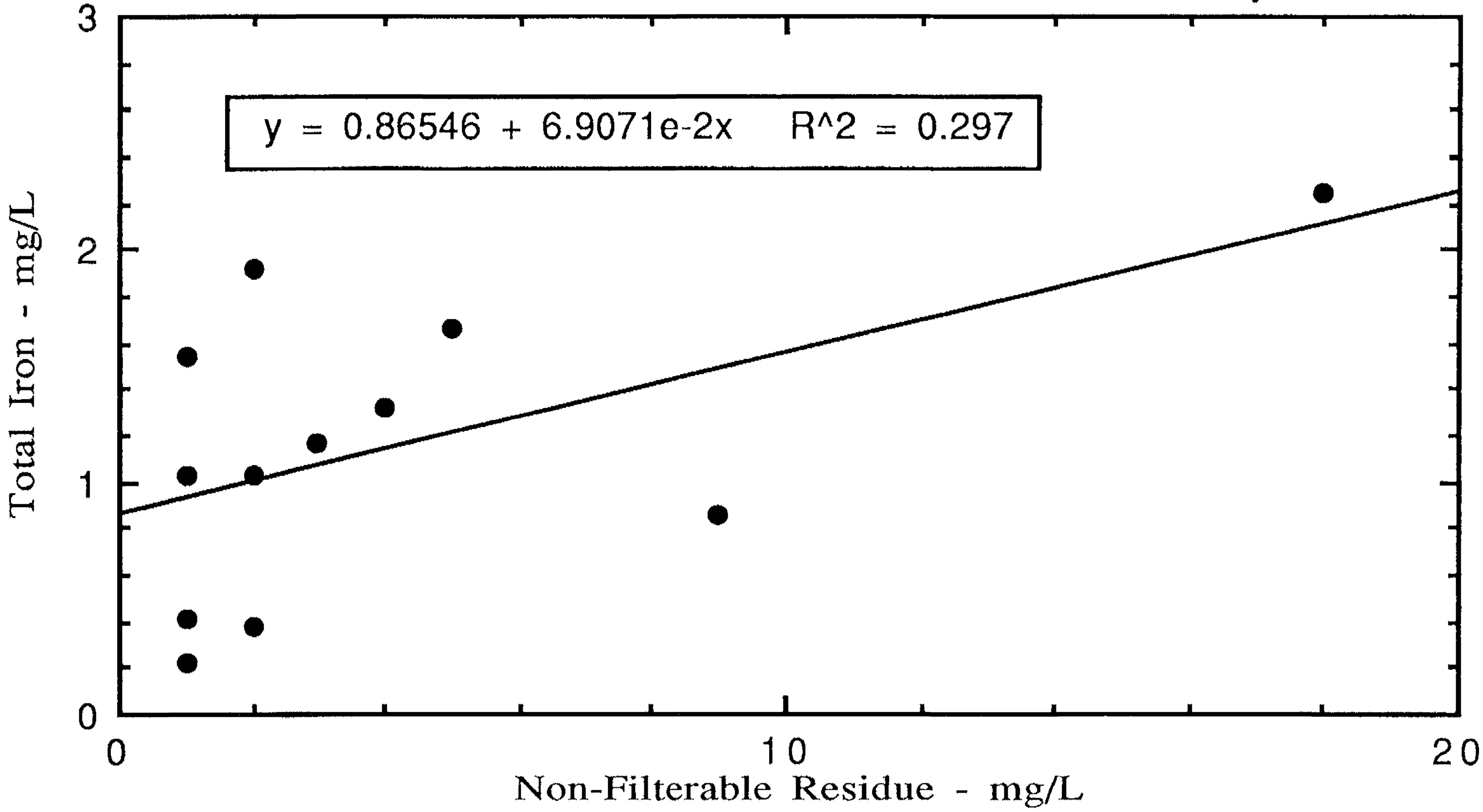

Figure A2-18

Total Manganese versus Non-filterable residue for Site E207430 on Little Oyster River.

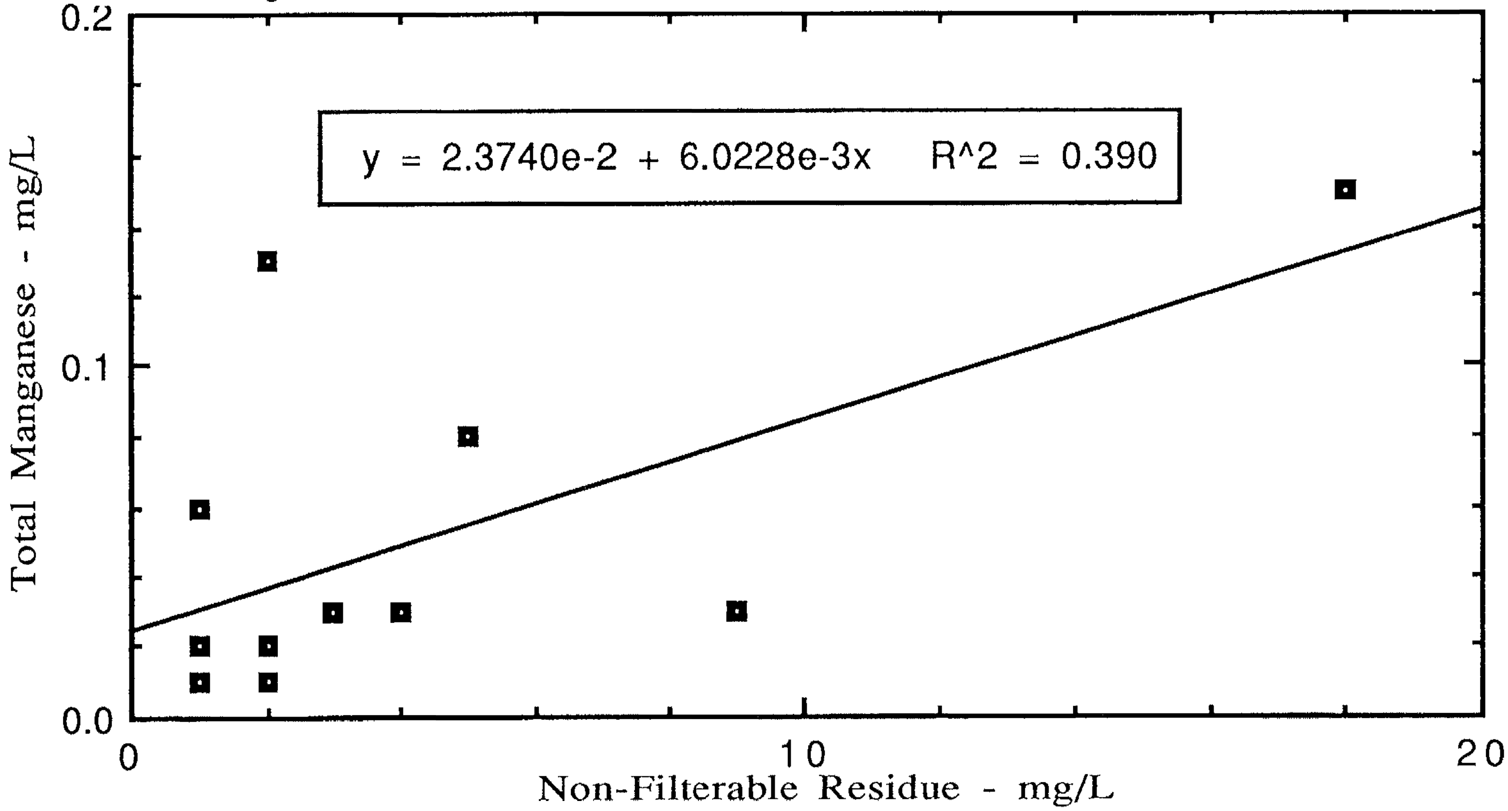

Figure A2-19

Total Zinc versus Non-filterable residue for Site E207430 on Little Oyster River.

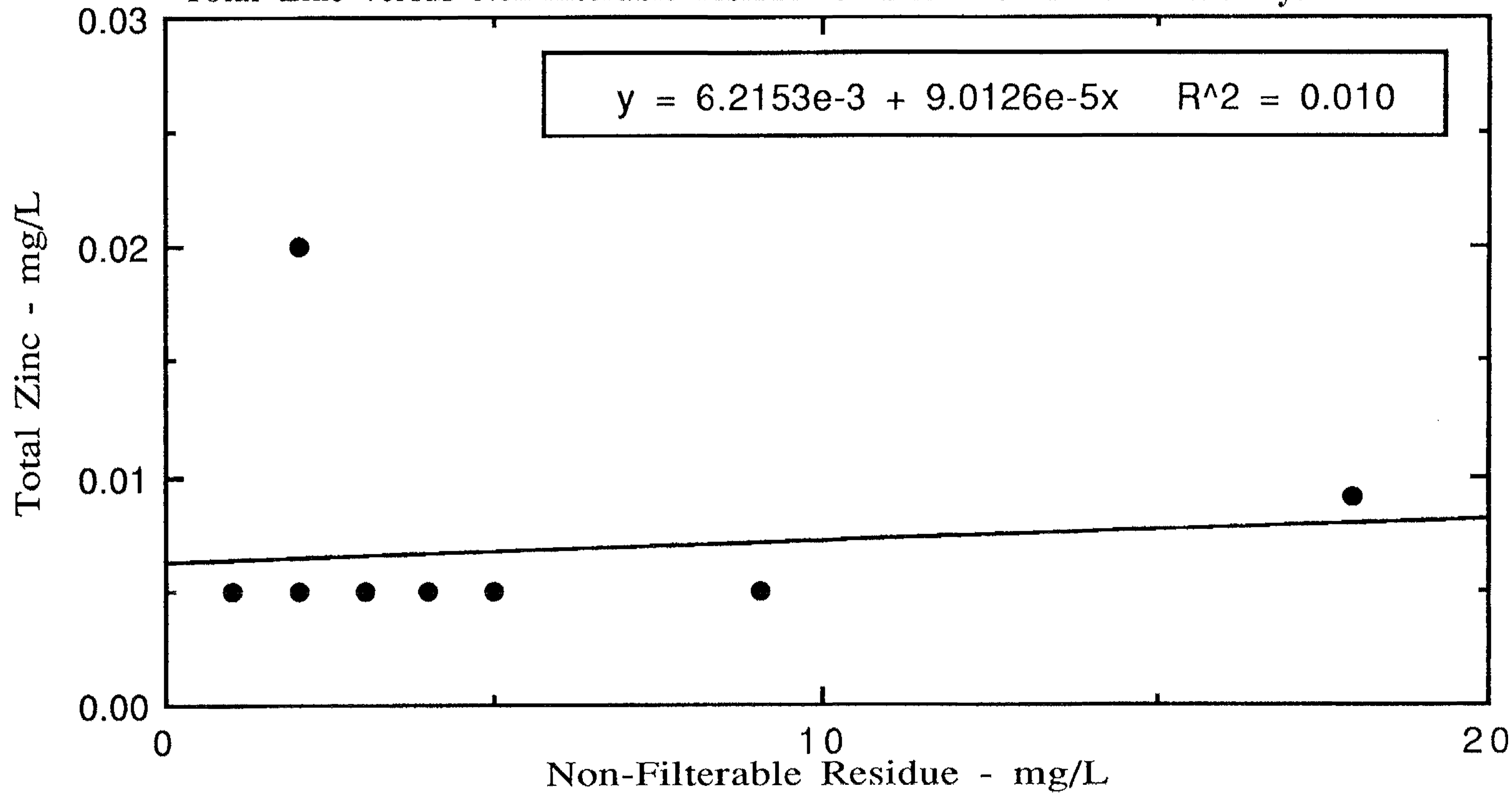

Figure A2-20

Total Copper versus Non-filterable residue for Site E207431 on Woodhus Creek.

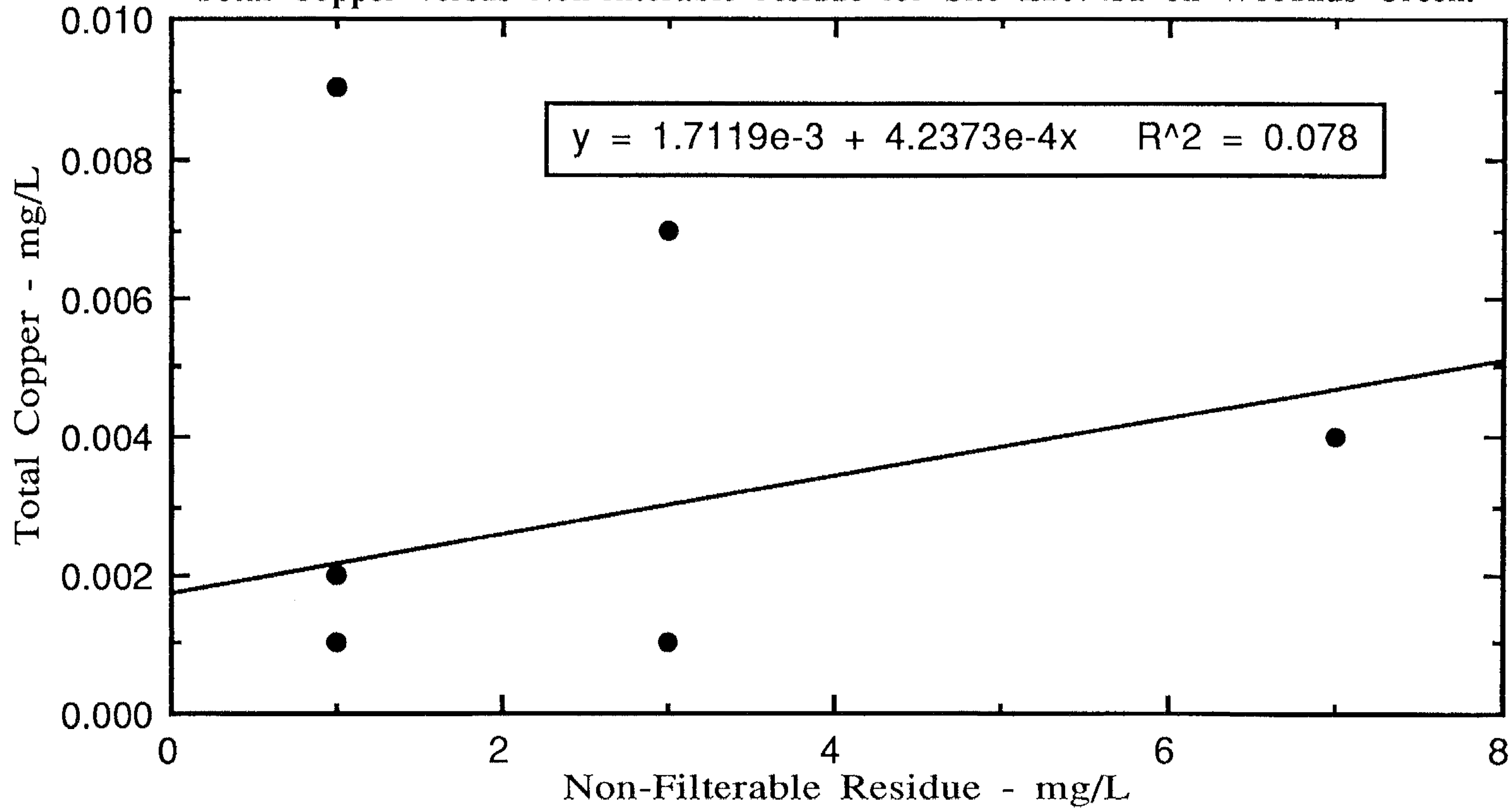

Figure A2-21
Total Iron versus Non-filterable residue for Site E207431 on Woodhus Creek.