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Gill Creek Sediment Study
Niagara Falls, New York
April 7, 1989

Prepared for:

E. I. du Pont de Nemours and Company
Niagara Falls, New York

Olin Corporation
Charleston, Tennessee

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April 7, 1989
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Attention: Mr. Dave Wright

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Attention: Mr. Blaine Butaud

Gentlemen:

Woodward-Clyde Consultants (WCC) is pleased to present the following report for the Gill Creek Sediment Study. The Report summarizes results of previous investigations, analytical data from the current study, and findings of the environmental assessment and preliminary feasibility study.

We appreciate the opportunity to work with Du Pont and Olin on this project. If you should have any questions please do not hesitate to contact us.

Very truly yours,

WOODWARD-CLYDE CONSULTANTS

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GILL CREEK SEDIMENT STUDY

Prepared for:

E. I. DU PONT DE NEMOURS AND COMPANY
AND
OLIN CORPORATION

Prepared by:

WOODWARD-CLYDE CONSULTANTS
Plymouth Meeting, Pennsylvania

EXECUTIVE SUMMARY

Previous remediation activities (1981) were undertaken by E.I. du Pont de Nemours and Company (Du Pont) and Olin Corporation (Olin) on a portion of Gill Creek which passes through their respective Niagara Falls Plant sites. The 1981 remediation removed contaminated sediments and then lined the creek bed with compacted clay (Du Pont) and crushed stone (Olin). The mouth area of Gill Creek, south of the Robert Moses Parkway Bridge, was not included in the previous remediation.

Investigations within the mouth of Gill Creek since the 1981 remediation indicated the presence of PCB-1248, chlorobenzene compounds, hexachlorobutadiene, and mercury in creek sediment. Biomonitoring studies revealed PCB-1248, mercury, alpha-BHC, and hexachlorobenzene to be bioavailable to benthic organisms. Woodward-Clyde Consultants (WCC) was retained by Du Pont and Olin to further investigate the sediments in and around the mouth of Gill Creek and to evaluate the need for remediation. An environmental assessment and qualitative risk assessment was performed to evaluate the potential effects of the contaminants that exist in the mouth of Gill Creek. Remedial alternatives to address the potential environmental problem were then evaluated in a preliminary feasibility study.

Analytical results from the current investigation were similar to previous studies. Creek sediments were characterized by elevated levels of PCB-1248, chlorobenzenes, hexachlorobutadiene, alpha- and beta-BHC, mercury, and volatile organic chemicals. Contaminant concentrations were highest in the previously unremediated portion of the creek. Significantly lower levels of contaminants were detected in the remediated section of the creek and in the Niagara River. The remediated area was found to still meet the cleanup criteria established in 1981.

Based on results of the environmental assessment, contaminated sediments within the previously unremediated section of Gill Creek will require remediation. Creek remediation is not recommended to extend into the river beyond sample location 5-1G, the observed extent of historic sediment disposition. Remediation is not recommended for the nearshore area of the Niagara River downstream of Gill Creek due to the lower levels of contamination and overall lack of significant sediment accumulation within the river. The recommended upstream limit of remediation within Gill Creek is Staub Road.

The preliminary feasibility study was conducted to evaluate various alternatives for remediation of sediment contamination in the mouth area of Gill Creek. The remediation objective is to minimize or prevent the transport of contaminants from the source (sediments) to receptors. Response actions were evaluated which would prevent, eliminate, or minimize migration of organic and inorganic contaminants from creek sediment to surface water and groundwater.

Remedial alternatives which incorporate source removal and sediment treatment or disposal were determined to more effectively address the remedial action objective than source containment strategies. However, source removal alternatives have significant disadvantages in implementation. The containment alternatives address the primary contaminant migration pathway (sediment to surface water), however, these remedial actions may not totally mitigate impact to groundwater. Long-term groundwater monitoring would be necessary to quantitatively evaluate the potential impact and need for any additional remedial measures.

A significant limiting factor with a majority of the source removal alternatives is the ultimate treatment and/or disposal of the sediment. There is a potential lack of capacity for handling wastes such as the Gill Creek sediment in landfilling, incineration, and innovative treatment technologies. Land disposal regulations may prevent disposal of untreated waste in a commercial landfill. It is not known whether off-site incineration can handle the mixtue of organic and inorganic compounds and, in addition, extensive permitting and test burns would be required for the on-site option. Innovative treatment options are available, but are not proven technologies and would therefore require significant testing and evaluation prior to implementation.

In summary, the physical containment of creek sediments in place and the excavation/treatment/disposal of creek sediments are both feasible remedial alternatives. Both options adequately address the remedial action objectives: to prevent or mitigate the transport of contaminants from the source (sediments) to receptors. The containment alternative can be implemented over a relatively short time schedule, which is a distinct advantage for this alternative. It is possible that some of the excavation/treatment/disposal alternatives could be implemented within a similar schedule, assuming regulatory approval and acceptance of the wastes by commercial disposal or incineration facilities can be obtained on a timely basis. However, should land disposal restrictions make landfilling non-feasible or off-site incineration prove non-feasible, the time schedule for a sediment treatment/disposal approach would be lengthened significantly. As a result, some form of interim storage might be necessary while a capacity for final sediment treatment/disposal is developed. However, interim storage would only be viable as a short-time schedule alternative if a RCRA permit is not required for the storage facility. If RCRA permiting were required, the increased time requirements would essentially eliminate any advantage of the interim storage alternative.

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1.0 INTRODUCTION

1.1 BACKGROUND

In 1981, E.I. du Pont de Nemours and Company (Du Pont) and Olin Corporation (Olin) undertook voluntary programs to remediate contaminated sediments from portions of Gill Creek which pass through their plant sites. Contaminated sediments were excavated from the creek bed and some adjacent areas and disposed of in a secure landfill. Areas of past remediation efforts of both companies are illustrated in Figure 1-1.

The Ontario Ministry of the Environment (MOE) conducted a biomonitoring study in the Niagara River basin in 1982 which included monitoring sites at the mouth of Gill Creek. Results from the study revealed that PCB's and mercury were bioavailable to filamentous algae Cladaphora growing in the creek mouth. Additional biomonitoring studies also revealed alpha-BHC and hexachlorobenzene as bioavailable to benthic organisms. In June 1986, the New York State Department of Environmental Conservation (NYSDEC) collected sediment samples from Gill Creek and other areas along the Niagara River as part of the Niagara River Implementation Sediment Studies. PCB-1248, chlorobenzene compounds, hexachlorobutadiene, and mercury were measured in the sediments.

These data suggested a potential environmental concern resulting from contaminated sediment in the mouth of Gill Creek. The current study was conducted to supplement the existing Gill Creek database and collect sufficient information to evaluate the extent of contamination and evaluate the need for remediation.

1.2 INVESTIGATION OBJECTIVES

Woodward-Clyde Consultants (WCC) was retained by Du Pont and Olin to investigate sediments in and around the mouth of Gill Creek and to evaluate the need for remediation. The primary area of investigation for the study encompassed the reach of Gill Creek from just north of the Robert Moses Parkway (RMP) to its confluence with the Niagara River (Figure 1-2). Sediments were also investigated upstream in Gill Creek within the remediated section and out in the Niagara River.

Using data collected from the current study and incorporating existing data sources, WCC performed an environmental assessment and a qualitative endangerment assessment to evaluate the potential effects of contaminants in the mouth of Gill Creek. Based on conclusions from the environmental assessment, WCC conducted a preliminary feasibility study to evaluate potentially feasible remedial alternatives.

This report is divided into seven sections: Introduction (1.0), Previous Investigations (2.0), Sediment Sampling Program (3.0), Results (4.0), Environmental Assessment (5.0), Preliminary Feasibility Study (6.0), and Conclusions (7.0).

1.3 SITE DESCRIPTION

Gill Creek is a minor tributary to the Niagara River, flowing south from Hyde Park into the Niagara River just downstream of the Robert Moses Power project water intakes, as shown on Figure 1-3. The section of Gill Creek south of Du Pont Road crosses what was apparently a low marshy area bordering the Niagara River. This area was subsequently filled in, extending the creek and shoreline to the south.

Within the Gill Creek channel, the subsurface profile consists of a veneer of loose, fine-grained, recent sediment and river cobbles. The recent sediments, in turn, overlie either the natural silty clay stratum, compacted clay backfill emplaced during creek restoration, or bedrock, depending on location within the creek. Sediment thicknesses within the creek are ultimately constrained by the shallow depths to bedrock. The bedrock surface dips to the south decreasing in elevation towards the Niagara River. As such, sediment thicknesses increase toward the creek mouth.

2.0 PREVIOUS INVESTIGATIONS

A significant amount of environmental data has been collected at Gill Creek since the late 1970's. The database is comprised of sediment and water analytical data, EP toxicity data, biomonitoring studies, and benthic sampling and analysis.

1) September 1978 - Gill Creek sediment and water analysis (Du Pont)
2) November 1978 - Gill Creek sediment analysis for Du Pont (Recra Research)
3) June 1979 - Gill Creek sediment analysis for Du Pont (Recra Research)
4) 1981 - Sediment and water analyses during Du Pont creek remediation (Recra Research)
5) 1981 - Sediment analysis during Olin creek remediation
6) 1983 - Ministry of the Environment (MOE) biomonitoring data
7) October 1984 - Report of the Niagara River Toxics Committee, containing 1982 MOE biomonitoring data
8) November 1984 - Gill Creek bulk sediment and EP Toxicity analysis (City of Niagara Falls, ETC)
9) December 1984 - Gill Creek benthic sampling and analysis for Niachlor (Great Lakes Laboratories)
10) December 1987 - "Niagara River Area Sediments," sediment analysis and biomonitoring studies from NYSDEC sampling programs conducted in June and November 1986 and February 1987
11) March 1988 - Gill Creek bulk sediment and EP Toxicity analysis (City of Niagara Falls, Ecology and Environment)

The historic data are summarized below and are grouped in the following categories: analytical data both prior to and subsequent to 1981 remediation, and biomonitoring studies.

2.1 ANALYTICAL DATA PRIOR TO 1981 REMEDIATION ACTIVITIES

A total of five sediment and water sampling programs were conducted in Gill Creek from 1978 up until the 1981 remediation.

During the September 1978 sampling event performed by Du Pont, three water samples and three sediment samples were collected within Gill Creek. The depth of the sediment samples is unknown. The samples were analyzed by Du Pont for volatiles, semi-volatiles, PCB's and other chlorinated organics. The first pair of samples (water sample #1 and sediment sample #2) were collected 25 and 100 feet upstream of the RMP Bridge in the area to be remediated in 1981. Water sample #7 and sediment sample #8 were taken from the north side of the Adams Avenue Bridge. Water sample #9 and sediment sample #10 were collected just north of the Buffalo Avenue Bridge. Results from just north of the RMP Bridge indicated the presence of PCB's (1,200,000 ppb), hexachlorocyclohexanes (BHC) (700,000 ppb), hexachlorobutadiene (125,000 ppb), and hexachlorobenzene (144,000 ppb) in the sediment. Surface water results indicated the presence of eleven volatile organics with a high concentration of 520 ppb (trichloroethylene). Gill Creek sediment in the vicinity of Adams Avenue contained PCB's (3,820,000 ppb), BHC (741,000 ppb), dichlorobenzenes (175,000 ppb), and trichlorobenzenes (650,000 ppb). Surface water near Adams Avenue contained four volatile organics ranging from 14 ppb (methylene chloride) to 940 ppb (benzene). Sediments from above Buffalo Avenue contained BHC (90,000 ppb) and p-dichlorobenzene (326,000 ppb). PCB's were not detected above Buffalo Avenue. No compounds were detected in the Gill Creek surface water above Buffalo Avenue.

On November 1 and 2, 1978, six sediment cores were collected by Recra Research in the portion of Gill Creek within the Du Pont Plant boundaries. One-inch sections of the sediment cores were analyzed for PCB's. Aroclor 1248, the dominant PCB, was detected in all sections analyzed ranging in concentration from 13,300 ppb to 379,000,000 ppb.

An additional November study (November 8, 1978) was conducted by Du Pont within Gill Creek from Porter Avenue to the Niagara River (Figure 1-3). Sample depths and collection techniques were not documented. A total of 21 sediment and 4 water samples were collected and analyzed for PCB's by Recra Research. PCB's were not detected in significant concentrations above Buffalo Avenue. Aroclor 1248 was the dominant PCB mixture detected during the study. From Buffalo Avenue to the Niagara River, sediment concentrations ranged from less than 1,500 to 11,100 ppb. No PCB's were detected in the surface water samples.

Gill Creek sediments south of the RMP Bridge were investigated by Du Pont in March 1979. Four sediment cores were collected in the creek mouth by Recra Research. The sediment cores were sectioned into 2-inch intervals and analyzed for PCB's and chlorinated benzene compounds. Sediment core recoveries ranged from 18 to 28-inches. Aroclor 1248 was detected in all sections analyzed ranging in concentration from 21,700 ppb to 16,900,000 ppb. Elevated levels of chlorobenzene compounds (mono- through hexa-) were detected at concentrations up to 20,000,000 ppb (monochlorobenzene).

During the 1981 Du Pont remediation of Gill Creek, numerous sediment samples were collected between July and October by Recra Research. All sediment samples were analyzed for PCB's as Aroclor. PCB concentrations of up to 19,000,000 ppb were detected in soil samples removed during the remediation effort.

Similar remediations efforts were performed by Olin during 1981. Sediment samples were taken under the Adams Avenue Bridge and analyzed for pesticides. Alpha-BHC (1,600,000 to 5,400,000 ppb) and gamma-BHC (340,000 to 3,200,000 ppb) were detected.

2.2 ANALYTICAL DATA SUBSEQUENT TO 1981 REMEDIATION ACTIVITIES

In November 1984 the City of Niagara Falls conducted a sediment sampling program where five sediment cores were collected from near Pine Avenue to Buffalo Avenue (Figure 1-3). The samples were analyzed for priority pollutant volatiles, base/neutrals, acid extractables, and PCB's. The samples were also extracted according to the EP Toxicity procedure and the extract analyzed for pesticides, metals, and PCB's. Analyses were performed by both the City of Niagara Falls and ETC Laboratories. The sediment sample collected at the Buffalo Avenue Bridge was considered the closest and most applicable to the current investigation. There were some discrepancies in data reporting between laboratories; however, the following conclusions can be stated. From the EP Toxicity analyses, only alpha-BHC was detected (3.6 ppb). In the bulk analyses, the four BHC isomers (2,000 to 17,000 ppb) and mercury (3,900 ppb) were detected.

In June and November 1986, as part of the NYSDEC Niagara River Implementation Sediment Studies, sediment samples were taken from the mouth of Gill Creek as well as nine other locations along the Niagara River. During the two stage sampling program, four sediment core samples were taken in the mouth area and two grab samples taken upstream. The cores were sectioned into one-inch intervals for analysis. The main analytical program consisted of total volatile solids, priority pollutant metals, pesticide/PCB's (EPA Method 8080), and chlorinated hydrocarbons (EPA Method 8125). Selected samples were also analyzed for Polychlorinated dibenzofurans and dibenzo-p-dioxins (EPA Method 8280).

Aroclor 1248 was the sole PCB, detected in all samples analyses ranging from 210,000 ppb to 100,000,000 ppb. Several chlorobenzene compounds were detected in most samples. Hexachlorobutadiene was detected in many samples with concentrations up to 13,000,000 ppb.

Pesticide compounds were not detected in any of the samples, however, detection limits were high (20,000 to 8,000,000 ppb). Elevated levels of mercury (550 ppm), silver (14 ppm), copper (990 ppm), zinc (2300 ppm), and chromium (110 ppm) were detected in the core samples at various depths. Distributions of contaminants with depth were different between cores.

The dioxin and furan analyses were performed on the two grab samples taken upstream of Buffalo Avenue and a bridge on Du Pont property, and a section from one of the core samples taken in the mouth area. Polychlorinated dibenzofurans (PCDF) were detected in the ppb range for tetra through octa isomers in samples from the mouth of Gill Creek and from the Du Pont bridge. Tetrachlorodibenzofurans (TCDF) and Octachlorodibenzofurans (OCDF) were detected in the Gill Creek upstream sample. Furans appear to increase in a downstream direction. The data also suggest the possibility of an additional upstream Gill Creek source. The dioxin results are similar to the furan data, except the tetra dioxin isomer was not detected. Again, dioxins were detected in the upstream sample suggesting an additional upstream source.

The City of Niagara Falls followed up the 1984 sampling program with a second Gill Creek investigation in March 1988. Two sediment samples (one composite grab sample and one sediment core) were collected just north of the Buffalo Avenue Bridge. The grab sample and the 18- to 36-inch interval of the core were analyzed for EP Toxicity and volatile and semi-volatile organics and Pesticide/PCB's. The samples were analyzed by both the City of Niagara Falls and Ecology and Environment Laboratories. EP Toxicity results from the 18- to 36-inch depth detected gamma-BHC (0.85 mg/L). In the bulk analyses, the surface grab sample was characterized by low to non-detectable concentrations of a few compounds. In contrast, the 18- to 36-inch sample contained chlorobenzene (2,700 ppb), 1,4-Dichlorobenzene (800 ppb), and all four BHC isomers (17,000 to 72,000 ppb).

2.3 BIOMONITORING STUDIES

Intensive biological monitoring studies have been carried out in the Niagara River by the Ontario Ministry of the Environment (MOE). Data up to 1982 is included in the October 1984 report of the Niagara River Toxics Committee (NRTC). During the 1982 field year, one biomonitoring station was established at the mouth of Gill Creek. As part of the program, filamentous algae (Cladaphora) were collected and clean clams (Elliptio complanata) were exposed at the site for a three week period. The biota were analyzed for heavy metals, PCB's, pesticides, chlorinated phenols, chlorinated aromatic hydrocarbons, and dioxin. Results from the Cladaphora analyses revealed elevated levels of PCB's (16,333 ppb) and mercury (0.75 ppb) at the mouth of Gill Creek. Analyses of the clam tissue detected PCB's (722 ppb), alpha-BHC (9 ppb), and hexachlorobenzene (19 ppb).

In 1983, the MOE conducted additional biomonitoring studies at two stations in Gill Creek, at the mouth and upstream. The 1983 study was more detailed than earlier work. In addition to collection of Cladaphora, young-of-the-year spottail shiners were also collected. The clam monitoring was conducted over five consecutive 3-week exposure periods to determine contaminant availability and temporal variation in contaminant impacts. Clams were also exposed for the full 15-week period.

Results of the 1983 study detected PCB's at 0.15 ppb in surface water, but significantly higher in Cladaphora (4000 ppb) and clams (2000 ppb). Alpha-BHC was measured at 0.09 ppb in surface water and 6 ppb in clams.

As part of the 1986 NYSDEC Niagara River Implementation Sediment Studies, sediment from Gill Creek was utilized in two biomonitoring studies. The sediments were evaluated in a 48-hour acute toxicity bioassay with two invertebrate species, Daphina magna and Hyalella azteca utilizing the Nebecker two-organism procedure. NYSDEC reported high acute toxicity to both species. A 28-day biouptake study using fathead minnows (Pimphales piomelas) was also attempted in 1986. However, due to cross-contamination problems this test had to be aborted.

Results of the various biomonitoring studies suggest that contaminants present in the sediment of Gill Creek are bioavailable to benthic organisms.

3.0 SEDIMENT SAMPLING PROGRAM

The following discussion presents a description of field activities performed to delineate vertical and horizontal extent of contamination within the mouth area of Gill Creek. The sampling program is based on procedures documented in a draft Work Plan prepared by WCC entitled "Gill Creek Sediment Study, Niagara Falls, New York" dated March 15, 1988. Some modifications were made to the original work plan based on NYSDEC comments dated April 20 and June 9, 1988. The first set of NYSDEC comments dated April 20, 1988, were addressed in a WCC response dated May 16, 1988. This section represents a synthesis of the various work plan revisions, and serves to document all procedures utilized during the field investigation. This section has been divided into four subsections: Sampling Locations (3.1), Methodology (3.2), Analytical Program (3.3), and Quality Assurance/Quality Control (3.4). Results and data interpretation from these activities are presented in subsequent sections.

3.1 SAMPLING LOCATIONS

A total of 38 locations within Gill Creek and the Niagara River were sampled for sediments and five locations for surface water samples during the June 1988 sampling program (Figure 3-1). Prior to sampling, the study area was divided into five distinct areas based on anticipated sediment type, past remediation activities, and physical constraints. The areas were numbered 1 through 5 from Gill Creek at Buffalo Avenue to the Niagara River.

Area 1 comprises part of the remediated section of Gill Creek (Du Pont and Olin, 1981) from Buffalo Avenue to Staub Road within the Du Pont and Olin Plants. Area 1 sample locations were selected to help assess the effect of reverse flows and re-sedimentation in lower Gill Creek and the Niagara River. Area 1 samples were also collected to evaluate possible upstream contaminant sources. Area 2 is located between Staub Road and the RMP Bridge. Area 2 is located in the transition area between the remediated and un-remediated portions of the creek. Samples were taken in this area to determine the southern extent of the 1981 remediation and if sediments have accumulated since creek remediation. Area 3 comprises the portion of Gill Creek which passes under the RMP Bridge culverts. Area 4 comprises the mouth area of the creek from the RMP Bridge to the Niagara River. This area of the creek was believed to have the most significant sediment accumulations based on previous investigations. Area 5 encompasses the Niagara River in the vicinity of the Gill Creek confluence. Sample locations were situated at positions both upstream and downstream of Gill Creek.

Eleven transects were established perpendicular to the creek (Figure 3-1). The transects were numbered T1 through T11 from above Buffalo Avenue to the Gill Creek mouth area. Three individual sample locations were established along each transect. Each sample location represents an individual analytical sample with the exception of Area 1 samples. In Area 1, due to the lack of significant sediment accumulation, a composite sample of these samples was obtained from each sampling transect. Area 5 samples were taken just south of Transect T11 out in the river upstream and downstream of Gill Creek.

The four-part sample numbering system devised for the sampling program identifies the sample location within the sample number. The first part of the sample number refers to the Area (number 1 through 5). The second part refers to the sample transect (T1 through T11) or river. The third part of the sample number refers to sample position along the transect (1, 2, and 3 from west to east). The final part of the number refers to sample type ((C) composite, (E) elutriate, (G) grab, (S) shallow, (M) medium, (D) deep).

3.2 METHODOLOGY

3.2.1 SAMPLING EQUIPMENT

The sediments sampled within the study area were highly variable in character. As such, four sampling methods were utilized, vibracoring, Ponar dredging, piston-coring, and hand grab sampling. The location of samples obtained and sample methodology employed is illustrated in Figure 3-2.

Vibracoring was the preferred sampling method as a continuous and relatively undisturbed sample of the sediment column is obtained. Vibracoring was utilized in areas where significant thicknesses of fine-grained sediment had accumulated (e.g., the mouth area, under the RMP Bridge). The presence of gravel or cobbles prohibits the use of the vibracorer. The vibracore sampler utilized in this investigation was a compressed-air powered, 3-inch diameter vibratory coring rig. The corer consisted of a 5-foot long core barrel, dedicated interior Lexan core liner, threaded cutting shoe, sediment trap, and interior piston (Figure 3-3). As the vibrating head forces the core barrel through the sediment column, the piston is drawn through the interior Lexan liner. The combination of vibracore and piston-core technologies allows for enhanced sample recovery over traditional vibracore units. Once the vibracore sample was obtained, the core-barrel was removed from the vibratory head, sealed in 6-mm plastic sheeting and delivered to the sample handling area for processing.

The vibracore unit was initially deployed suspended from a land-based hydraulic crane. This technique was employed at transects T9, T10, and T11. Where confined overhead clearance would not permit crane-supported vibracoring at Transects T7 and T8 (under the RMP Bridge), the coring unit was operated from a specially designed sampling barge.

A Ponar dredge sampler suspended from a land-based hydraulic crane was utilized to obtain all sediment samples from the Niagara River (Area 5). Vibracoring in the Niagara River was not feasible because of a lack of significant sediment accumulation and presence of large-grained material (gravel and cobbles). The Ponar sampler resembles a small "clamshell" bucket. The jaws of the sampler automatically close as they hit the sediment surface obtaining a surface "grab" type sample. During the river sampling portion of the investigation, numerous attempts with the Ponar dredge were necessary to identify a location with enough material for an analytical sample. Sediment collected with the Ponar dredge was transferred to a stainless steel bowl, covered in aluminum foil and transferred to the sample handling area.

A hand-pushed piston-corer was utilized in the upper reaches of Gill Creek (T2, T3). Vibracoring was deemed inappropriate due to the limited presence of sediment (less than 6-inches). The piston-corer consists of a 5-foot long, 1.5-inch diameter stainless steel tube. A Teflon piston, attached to a stainless steel rod is inserted into the tube. When using this piece of equipment, a member of the sampling team using waders, walked out into the creek and pushed the corer into the sediment until refusal. The core tube was then removed from the sediment column with a sample intact. The sample was then extruded into a stainless steel bowl, covered in aluminum foil and transported to the sample handling area.

One location in the upper reach of Gill Creek (Transect T1) could not be sampled with any of the aforementioned sampling techniques because of stoney creek bottom conditions and shallow water depths (6 to 12 inches). As an alternative, a grab sample was obtained utilizing a stainless steel hand shovel. Special care was taken to move the sample up through the water column as slow as possible to minimize loss of fine-grained material. The sediment obtained from the grab sample was transferred to a stainless steel bowl, covered with aluminum foil, and transported to the sample handling area.

3.2.2 SAMPLE HANDLING

Sediment samples collected were received in a centralized sample handling area located on the bank of Gill Creek near Staub Road. In the sample handling area, each sample received was sampled for volatiles, described geologically, homogenized, split into multiple analytical samples (if necessary), and placed in appropriate sample jars and stored at 4°C until delivered to the laboratory. Three types of samples were processed in the sample handing area: "grab" type samples from the Ponar dredge, hand piston-corer samples, and continuous vibracore samples. The "grab" type samples required limited sample handling. Each grab sample corresponded to one analytical sample. Following obtaining a sample for volatile analysis, the same was described, homogenized, and transferred into appropriate laboratory containers. The following homogenization procedure was utilized for all sediment samples after sediment for volatile analysis had been obtained:

- Transfer soil sediment mass into a hexane cleaned, stainless steel pan.
- Remove large items that are not characteristic of the soil sediment mass; i.e., large gravel, twigs sticks, etc....
- Quarter (split) the sediment with a stainless steel spatula. The quadrants are identified as 1, 2, 3, and 4 taken in a clockwise direction.
- Remove and composite quadrants 1 and 3. Mix thoroughly until the sample displays a uniform color and texture.
- Remove and composite quadrants 2 and 4. Mix thoroughly until the sample displays a uniform color and texture.
- Combine the composited quadrants 1 and 3 with composited quadrants 2 and 4. Mix thoroughly until the soil sediment mass displays a uniform color and texture.
- Repeat as necessary, until homogenization has been achieved by the criteria of uniform color and texture from a visual appearance.

A more detailed procedure was involved in preparation of vibracore sediment samples. The vibracore samples were received in the sample handling area still loaded within the core barrel. Upon receipt, the Lexan liner with sample intact was removed from the core barrel and capped. The Lexan liner was then placed into an extruder which extruded the sediment core sample onto a clean sheet of aluminum foil and measured. A pre-cleaned Lexan liner was dedicated to each vibracore sample and disposed of following sample extrusion. Following extrusion, the core was split longitudinally and sectioned into a 6-inch interval at the top of the core and 12-inch intervals thereafter.

Immediately following sectioning, a representative sediment sub-sample was scraped from appropriate core intervals for volatile analysis. Then the core was described geologically. Following core description a sediment sample was scooped along the centerline of the split core on select core intervals for analysis of non-volatile components. In some instances the core was too soft and saturated to collect sediment only from along the center line. The sediment sample collected from the core was then transferred to a stainless steel bowl and homogenized using the procedure described above. The sample was then placed in laboratory-supplied bottles and held at 4°C until delivery to the laboratory.

Selected samples from core intervals were retained for compositing of three locations across a sampling transect (see Section 3.3 Analytical Program). The sediment sub-sample to be composited was stored in a stainless steel bowl, covered with aluminum foil, and stored in a sample cooler until all three sections were obtained. Then the composite sample was mixed and homogenized and transferred to the laboratory-prepared sample bottles.

3.3 ANALYTICAL PROGRAM

The analytical scope of work for the Gill Creek Sediment Study consisted of four components as listed in Table 3-1. All analytical procedures, where applicable, followed U.S. EPA SW-846 third edition methodologies. One procedure, the elutriate test, was performed according to U.S. Army Corps of Engineers Protocol. All data reporting adhered to NYSDEC Contract Lab Program requirements. Most analytical work was performed by General Testing Corporation, Rochester, New York. The dioxin and furan analyses were performed by Midwest Research Institute, Kansas City, Missouri.

One component of the analytical program consisted of full Hazardous Substance List (HSL) analysis (Table 3-2). The HSL analytical samples were composites taken from the three sample locations along each transect T1, T4, T6, T8, T10, and river grab samples (non-composites) 5-4G and 5-6G. At transects T6, T8, and T10, a shallow and medium depth composite was taken. All other HSL samples were from shallow (0 to 6 inch) sediment depths. Table 3-3 lists the HSL composite samples collected and sample depth interval. The HSL analyses were performed on a limited number of samples to determine if any contaminants not detected in previous investigations were also present.

The majority of analytical samples collected were analyzed for the Site-Specific Compound List (Table 3-4). The Site-Specific Compound List (SSCL) consists of pesticide/PCB's (Method 8080), chlorinated hydrocarbons (Method 8120), mercury (Method 7471), monochlorobenzene (Method 8020), percent moisture content, and total volatile solids and was developed based on a review of previous site analytical data. The SSCL data provided the primary information in determining the horizontal and vertical extent of contamination. SSCL samples were collected from each sample location illustrated in Figure 3-1. Along sample transects T1, T2, T3, and T4 one composite sample was taken from each transect. Six river sample locations (Area 5) had one sample analyzed per location. Sediment sample locations within Areas 2, 3, or 4, taken with the vibracore, had up to three samples taken at varying depths within each core. Table 3-5 lists the sediment core depth intervals retained for SSCL analysis. The total core recovery dictated the number of analytical samples taken. If the core recovery was less than 48-inches, then the top 6-inches and bottom 12-inches were retained for analysis. If the core was greater than or equal to 48-inches, then, in addition to the shallow and deep samples, a medium depth 12-inch sample was also collected.

Analyses of polychlorinated dibenzo-p-dioxins (PCDD) and polychlorinated dibenzofurans (PCDF) were performed on a limited number of samples within the area. The PCDD/PCDF analysis conformed to EPA SW-846 Method 8280 and identified total tetra- through octa-isomers with quantification on specific 2, 3, 7, 8 congeners. The PCDD/PCDF analyses were performed on split samples of selected HSL composite samples (1-T4-C, 2-T6-SC, 2-T6-MC, 3-T8-SC, 3-T8-MC, 3-T8-MCDUP, 4-T10-SC, 4-T10-MC).

Five sediment and raw water samples were collected for elutriate testing. The elutriate test is typically utilized to evaluate the possible release of contaminants from sediments during dredging activities. The sediment/surface water pairs were collected within each of the five defined areas at sample locations 1-T4-2, 2-T6-2, 3-T8-2, 4-T10-2, and 5-1G. The corresponding elutriate sample numbers were 1-2E, 2-2E, 3-2E, 4-2E, and 5-1E, respectively.

3.4 QUALITY ASSURANCE/QUALITY CONTROL

As part of the Gill Creek sediment sampling plan, an analytical and field Quality Control (QC) program was developed. The field QC program consisted of collecting trip blanks, rinsate blanks, and field duplicates during sampling. Seven trip blanks (one for each day of sampling) accompanied the sample sets sent to the laboratory and were analyzed for volatiles (Method 8240). One rinsate blank (equipment blank) was collected each day of sampling and analyzed for SSCL parameters from decontaminated sampling equipment to check decontamination procedures. Field duplicates were analyzed for at least 10 percent of the samples collected. One field duplicate was analyzed for HSL compounds (10 samples collected). Eight field duplicates were analyzed for SSCL compounds (54 samples collected) and one field duplicate was analyzed for PCDD's and PCDF's (7 samples collected).

The analytical QC program was in accordance with the NYSDEC-CLP protocol using SW-846 third edition holding times. All analytical results were reviewed by WCC audit personnel using the QA/QC frequencies and limits stated in the NYSDEC-CLP. The data was reviewed for holding times, surrogate spike recoveries, matrix spike and matrix spike duplicate recoveries, instrument tuning and calibration, blank contamination and completed chain-of-custody forms.

A detailed QA/QC review of the Gill Creek data indicates several analytical violations (WCC, 1989). However, given the highly contaminated nature of the samples these violations are not considered to be serious ones. The samples do contain high percentages of the chemicals analyzed at fairly high concentrations. A QA/QC violation resulting in even an order-of-magnitude concentration difference would not change that conclusion. Consequently WCC recommends that this set of analytical data be accepted with the appropriate data qualifiers and that QA/QC criteria be adhered to more strictly during the remediation phase of the programs as contaminant concentrations are lowered.

4.0 RESULTS

4.1 CONTAMINANT DISTRIBUTION

This section of the report presents the 1988 analytical results from the Gill Creek Sediment Study. Section 4.1 has been divided into four subsections: Hazardous Substance List Analytical Results (4.1.1), Polychlorinated Dibenzofuran and Dibenzo-P-Dioxin Analytical Results (4.1.2), Site-Specific Compound List Analytical Results (4.1.3) and Elutriate Test Results (4.1.4). All analytical data discussed below are presented in Appendix A.

4.1.1 HAZARDOUS SUBSTANCE LIST ANALYTICAL RESULTS

As discussed in Section 3.3, the Hazardous Substance List (HSL) results represent composites of three sediment sample locations taken along sampling transects T1, T4, T6, T8, and T10. At transects T6 through T10 shallow (0 to 6-inch) and medium depth composite samples were obtained. Two grab samples from the Niagara River were also analyzed for HSL parameters. Table 4-1 summarizes HSL compounds detected, the number of detections and the maximum concentration detected.

A total of 15 volatile organics were detected in the Gill Creek sediments. Volatile compounds, tetrachloroethene, trichloroethene, and trans-1,2-dichloroethene were detected at maximum concentrations ranging from 0.23 to 1.16 percent. Figure 4-1 illustrates the distribution of total volatile organics (TVO) within the study area. TVO concentrations were elevated in the region of Gill Creek not remediated. There did not appear to be a relationship between concentration and depth.

Twelve base/neutral extractable compounds were detected in the composite samples. Of the 12 compounds, two compounds, polynuclear aromatic hydrocarbons (PAH), were only detected at the upstream sample above Buffalo Avenue. Chlorinated hydrocarbon compounds were the most abundant compounds detected, hexachlorobutadiene (7 detections) and hexachlorobenzene (6 detections). Figure 4-2 depicts the distribution of total base/neutral extractables (TBN). Similar to TVO results, TBN concentrations were elevated in the reach of Gill Creek not previously remediated. TBN's were not detected in the remediated section of the creek above Staub Road. TBN concentrations above Buffalo Avenue (14,230 ppb) are comprised entirely of PAH compounds which were not found within the rest of the study area. Of the base/neutrals detected in the river sediments, all but hexachlorobutadiene (5940 ppb) in 5-4G were comprised of phthalate compounds which are widespread in the environment.

BHCs were the only compounds detected in the pesticide fraction. The alpha and beta isomers were detected in maximum concentrations of 440,000 ppb and 10,200 ppb, respectively. The distribution of Total BHC's is illustrated in Figure 4-3. HSL BHC's were not detected upstream of transect T4, or in the Niagara River. This data conflicts with BHC data from the site-specific analyses presented in Section 4.2.3.

PCB-1248 was detected in each HSL sample analyzed ranging from 880 ppb at 1-T1-C above Buffalo Avenue to 10,700,000 ppb at 2-T6-MC within the unremediated portion of the creek. Figure 4-4 illustrates the distribution of HSL PCB's in the study area. Note that PCB's were detected in the Niagara River both upstream (4040 ppb) and downstream (36,000 ppb) of Gill Creek. As in all other cases, PCB concentrations are highest in the unremediated portion of Gill Creek.

Table 4-2 presents the Hazardous Substance List Metals results. The data are expressed as concentration ranges and logarithmic concentration averages. For comparison and evaluation purposes, the Gill Creek data is compared to background sediment quality data from the Great Lakes Harbor Region compiled by USEPA Region V. The EPA data was divided into three levels of sediment contamination, "non-polluted," "moderately polluted," and "heavily polluted." The classifications were based on subjectively defined breakpoints in the concentration distribution and are used here for comparison purposes only. Based on EPA Region V classifications and logarithmic concentration averages of Gill Creek sediment, chromium fit into the "moderately polluted" category while barium, copper, lead, mercury, and zinc concentrations were placed in the "heavily polluted" category, all other metals fell into the "non-polluted" classification.

Contaminant distributions for zinc, barium, copper, and mercury are included in Figure 4-5. These four metals were found in the highest concentrations within the unremediated area of Gill Creek, although elevated levels of barium and mercury were detected upstream above Staub Road and Buffalo Avenue. The elevated levels of barium and mercury above Buffalo Avenue suggest the possibility of additional upstream sources. Metals concentrations were significantly lower within the Niagara River sediments. However, relative to the EPA sediment classifications, mercury concentrations were elevated at both upstream and downstream river locations, while zinc was elevated at the downstream river location only.

4.1.2 POLYCHLORINATED DIBENZOFURAN AND DIBENZO-P-DIOXIN ANALYTICAL RESULTS

Polychlorinated Dibenzofurans and Dibenzo-p-Dioxins (PCDF and PCDD) were analyzed in split samples of eight of the eleven HSL composites (transects T4, T6, T8, T10). No dioxin/furan analyses were performed in the Niagara River or in Gill Creek above Buffalo Avenue. Results of total tetra through octa isomers with quantification of 2,3,7,8 congeners are presented in Table 4-3. The most toxic dioxin isomer, 2,3,7,8-TCDD, was not detected in any of the samples. The concentrations of the various other isomers were expressed as a toxic equivalent relative to 2,3,7,8-Tetrachlorodibenzo-p-dioxin (TCDD). This risk-based approach adopted by the USEPA Risk Assessment Forum allows for the calculation of one concentration with the toxic equivalency of 2,3,7,8-TCDD. A toxic equivalent of 1.0 ppb has been used as an alert level for dioxin/furan concentrations in residential soils. Concentration levels of concern for industrial areas are higher. In each of the eight sediment samples, the toxic equivalent concentration was below the 1 ppb level using the USEPA Method.

4.1.3 SITE-SPECIFIC COMPOUND ANALYTICAL RESULTS

A total of 62 sediment samples were analyzed for the Site-Specific Compound List (Table 3-4). Each parameter was detected at least twice within the study area. Table 4-4 summarizes the number of samples detected and the highest concentration measured for each of the site-specific parameters. The most commonly encountered contaminants (in decreasing number of detections) were mercury, a-BHC, PCB-1248, chlorobenzene, b-BHC, hexachlorobutadiene, and hexachlorobenzene. The compounds present in the highest concentration were PCB-1248, hexachlorobutadiene, hexachloroethane, hexachlorobenzene, 1,2,4-trichlorobenzene, a-BHC, and mercury.

Table 4-5 summarizes the analytical data as logarithmic concentration averages within distinct sections of the study area, namely within the previously remediated area (Area 1), the unremediated area (Areas 2, 3, and 4), and within the Niagara River (Area 5). Sample 5-1G, located in Area 5, was actually more representative of sediments within the mouth of Gill Creek (Area 4). This data generally illustrates that the majority of the site-specific compounds were significantly elevated within the unremediated section of the creek. Two exceptions to this trend were observed for mercury where high concentrations were also measured upstream of Buffalo Avenue in Gill Creek and within the Niagara River. This data suggests that additional sources of mercury may be present upstream in Gill Creek and the river. Figures 4-6 through 4-15 depict spacial distributions of contaminants in both shallow and deep sediment depth intervals for several of the more dominant chemical species present in Gill Creek sediment.

The distribution of PCB-1248 is depicted in Figures 4-6 and 4-7. The concentration of PCB's in the previously remediated area above Staub Road was below the initial cleanup criteria of 50 ppm. No PCB's were detected in transects T1 and T2. The presence of low levels of PCB's in the southernmost portion of the remediated zone suggest that a limited amount of upstream sediment re-deposition had occurred since 1981. Within the unremediated portion of the creek, PCB's were present in all samples ranging from 20,200 to 7,530,000 ppb. Under the RMP Bridge and in the mouth area PCB concentrations were typically higher in the shallow sediment samples than at depth. North of the RMP Bridge this depth trend was not as pronounced. Lower levels of PCB-1248 were detected in the Niagara

River downstream of Gill Creek at each of the three sample locations (31,300 to 143,000 ppb). The downstream river extent of PCB contamination was not delineated in the current study. However, it should be stressed that the lack of any significant sediment accumulation in the river needs to be factored into any evaluation of contaminant presence in the river.

The hexachlorobutadiene (HCBD) sediment distribution is illustrated in Figures 4-8 and 4-9. HCBD was not detected in the previously remediated area above Staub Road. In the Niagara River (HCBD was detected in only one sample immediately downstream of the creek in sample 5-4G) (10,900 ppb). The distribution of HCBD was variable within the shallow sediments (15,900 to 786,000 ppb) and deep sediments (less than 8000 to 1,119,000 ppb). No trend in concentration with depth was evident.

The distribution of alpha-BHC in shallow and deep sediments is depicted in Figures 4-10 and 4-11, respectively. Alpha-BHC was detected in all sediments in the remediated section of Gill Creek ranging in concentration from 210 ppb to 19,700 ppb. Alpha-BHC was detected at 1000 ppb in the shallow sediment above Buffalo Avenue. Variable alpha-BHC concentrations were observed in both shallow (1160 ppb to 313,000 ppb) and deep (14,400 ppb to 292,000 ppb) within the unremediated section. No consistent trend in concentration with depth was observed. Alpha-BHC was detected in the three Niagara River samples downstream of the creek mouth ranging in concentration from 3120 ppb (5-3G) to 13,600 ppb (5-2G). The presence of contaminants in the river should be examined with the sediment distribution data presented in Section 4.2. The lack of significant sediment accumulation in the river lessens the impact of the analytical results.

Mercury concentration distributions are presented in Figures 4-12 and 4-13. Unlike most other contaminants detected within the study area, mercury was detected in elevated levels outside the unremediated area. Upstream samples from transects T4 to T1 had mercury detected in each sample with the highest concentration detected at the furthest upstream Gill Creek location, 1-T1-C (113 ppm). High mercury concentrations in the study area were measured out in the river sediments both upstream (183 ppm) and downstream (217 ppm) of Gill Creek. The unusual distribution of mercury suggests the possibility of additional off-site sources. Mercury concentrations were variable within the unremediated area in shallow (1.7 ppm to 135 ppm) and deep (1.6 ppm to 118 ppm) sediments.

The distribution of hexachlorobenzene within Gill Creek sediments is depicted in Figures 4-14 and 4-15. Hexachlorobenzene was not detected in any sediment samples outside the unremediated portion of the creek. Within the unremediated area, sediment concentrations range form 7520 ppb to 580,000 ppb in shallow samples and 7180 ppb to 228,000 ppb in deep samples. Hexachlorobenzene concentrations were higher in the shallow sediments than at depth.

4.1.4 ELUTRIATE TEST RESULTS

As part of the elutriate test procedure, paired surface sediment grab samples and water samples were collected from five locations along Transects T4, T6, T8, T10 and in the Niagara River. The sediment and water samples were utilized in the elutriate procedure to simulate the leaching or desorption effect experienced during suspension of sediment in the water column. Both the raw surface water and elutriate test water were analyzed for the Site-Specific Compound List. Analytical results are presented in Table 4-6. PCB-1248, alpha-BHC, beta-BHC, and gamma-BHC were detected in the surface water samples analyzed.

Figure 4-16 illustrates the trend in PCB and total BHC concentrations in surface water from upstream above Staub Road (1-2E) to the Niagara River (5-1E). PCB and BHC concentrations in surface water samples from the unremediated area increased and then decreased approaching the Niagara River.

In the elutriate results, the BHC compounds were consistently released from the sediments. All four BHC isomers were detected in three of five samples. The alpha and beta BHC's were detected in all five samples at elevated concentrations (20 to 1500 ppb). The chlorobenzene compounds were also detected in the elutriate water. Chlorobenzene was detected in all five samples (38 - 950 ppb), while dichlorobenzene and trichlorobenzene were detected in two samples. Hexachlorobutadiene was detected within the unremediated area in three samples (22 - 64 ppb). In contrast, mercury and PCB-1248 were detected in one elutriate sample and did not appear to be readily released from the sediments.

4.2 SEDIMENT DISTRIBUTION

It is expected that the analytical results of sediment sampling conducted in the lower reaches of Gill Creek will, to some extent, reflect the dynamics of sediment transport in this area. While chemicals differ in their affinity for sediments, the adsorption potential for many is increased as a function of the surface area available for physical or chemical bonding. The available surface area depends first on the grain-size and type of sediment particles present (clay or organic versus silt or sand), and, second, on the mixing which brings chemical molecules and sediment particles into contact.

The concentrations of chemicals in sediments sampled may not reflect rates of introduction if sediment transport processes act to selectively remove or concentrate sediments with adsorped chemicals at particular locations or depths within the sediment column. Boring logs, grain-size analysis, and hydrodynamic observations are analyzed here to provide an assessment of these sediment transport processes in the lower Gill Creek area.

A conceptual profile of Gill Creek from Buffalo Avenue to its confluence with the Upper Niagara River is shown in Figure 4-17. Dry weather flow is primarily a result of discharge from the Niachlor cooling water outfall, which occurs in a section of the creek just downstream (south) of Adams Avenue (Figure 1-2). This outflow averages 49 cubic feet per second (cfs) and generates relatively high velocity flow conditions in the shallow (1 foot deep) section of the creek in the immediate vicinity of the outfall. An additional outfall, Du Pont 006 discharges cooling water at 1 cfs at Du Pont Road. The general bathymetry of Gill Creek at its confluence with the Upper Niagara River is illustrated in Figure 4-18. Creek depths in the reach shown in Figure 4-18 are significantly greater than upstream near the Niachlor outfall, ranging from 3 to 6 feet. Total cooling water discharge creates only a sluggish net flow toward the Niagara River in the unremediated area (typically less than 0.4 feet per second).

The majority of the sediment sampling program was directed at this area of deeper water (Figure 4-18) which is essentially an artificially created embayment on the north bank of the Upper Niagara River. It is artificial in two respects. First, the Creek bed shown in Figure 4-18 is not the natural course of the stream, but, instead, is an extension which was created as the bank of the river was extended south by filling activities. The most recent extension occurred in the early 1960's with construction of the RMP. Second, the entire section of the creek between Buffalo Avenue and the north wing-walls of the RMP Bridge was dredged down to bedrock or glacial till in a 1981 remediation action. A compacted clay (Du Pont) or crushed stone (Olin) layer was placed in the remediated section.

The Gill Creek embayment is strongly influenced by the Upper Niagara River. Despite the upstream input from the Niachlor outfall, flow in the area shown in Figure 4-17 was observed to periodically reverse depending upon wind and water level conditions in the river. Some of these reversals are caused by the 1.5 foot "tides" artificially induced in the river by the New York Power Authority (NYPA). The NYPA partially obstructs the Niagara River between Gill Creek and Niagara Falls by closing a gated structure each night and during the winter. This causes water levels to rise through the night and fall during the day, and to remain high during the winter.

Although flow in the Gill Creek embayment is typically less than 0.4 feet per second, velocities in the adjacent Niagara River are much higher, from 1.0 to 1.5 feet per second. Data from a 1984 survey indicates that the river bottom in this area is flat and that water depths are about 10 feet (Spotila, 1985). Gill Creek enters the broadest stretch of the river just before it begins to narrow toward the Falls. This funnelling effect results in an increase in river flow velocities in the direction of the Falls, roughly doubling every 1000 feet downstream.

The edge of the fill which forms the river bank adjacent to the south wing-walls of the RMP Bridge is eroding to the north under the influence of waves and ice. Wave fetches from the Gill Creek outlet to the southeast and southwest on both sides of Navy Island are the longest (2.2 miles) anywhere on the Niagara River. It is likely, however, that shoreline erosion is also due to the large ice floes rolling along the shoreline in the early spring after the opening of the Lake Erie ice boom. Some of these floes were observed in photographs to exceed 50 feet in diameter.

4.2.1 DATA COLLECTION

Patterns of sediment erosion, transport, and deposition are inferred from bathymetry, the depth of vibracore penetration, visual boring log descriptions, and surface grain-size analyses. All sediment data are included as Appendix B.

Water depths in Gill Creek, measured at 17:30 on the afternoon of May 15, 1988, at coring locations shown in Figure 4-18 ranged from 2.9 to 5.5 feet. Because of the time of day, these depths represent low water conditions. Gill Creek averages 4 feet deep between the Railroad Bridge and RMP Bridge, 3.3 feet under the RMP Bridge, and 4 feet deep between the south wing-walls of the RMP Bridge in the mouth area. The east culvert under the RMP Bridge is approximately one foot deeper than the other two culverts but has also accumulated cobbles along the eastern wall.

The bathymetry of the creek mouth has changed significantly since it was last surveyed in 1984. Figure 4-19 depicts the creek mouth bathymetry as surveyed by Great Lakes Laboratory November 14, 1984. More than 60 percent of the entrance to the river is now blocked by a partially submerged bar extending obliquely from the east shore. The bar is composed of "shot rock" which has eroded out of the fill shoreline adjacent to the creek entrance. The size of the cobbles making up this bar decrease with distance from the shoreline. Cobbles also have accumulated inside of both wing-walls of the RMP Bridge and throughout the eastern culvert.

Vibracore samples were obtained from 24 locations in the mouth area, underneath the RMP Bridge, and between the RMP Bridge and Railroad Bridge. Vibracoring was continued to refusal at each sampling location. Recent sediments were generally soft and rapidly penetrated. As a result, it is believed that the recent sediment column was generally sampled in its entirety. Cores obtained ranged in length from 0.3 feet in the section remediated in 1981 (T4) to 4.4 feet under the RMP Bridge. The total depth reached by these cores (measured from the water surface) was plotted and corresponds well to the estimated elevation of the top of the bedrock in this area. Vibracore logs are included in Appendix B. In most cases, sediments were unconsolidated, and, because of the high silt content, vibracoring resulted in disruption of some sedimentary features.

The most common sediment type observed was a black sandy silt, with variable amounts of clay and organics (roots). Living bivalves were observed near the surface in some cores from the creek mouth area. The silt unit appeared in all cores to coarsen upward and typically included gravel layers closer to the surface, although small crushed rock fragments are found scattered through all cores at all depths. Sections with an oily sheen were noted at intervals within several cores.

As mentioned previously, a medium brown firm clay was emplaced in the creek bed during the 1981 remediation. This clay was encountered in all cores from transects T2, T3, and T4. The brown clay was also encountered in two locations along transect T5 (2-T5-2 and 2-T5-3). However, at the T5 locations, a black to gray silt was encountered both above and below the emplaced clay layer. During the 1981 remediation the clay backfill was emplaced over existing creek silt which was below the 50 ppm PCB cleanup concentrations rather than directly over bedrock. The black to gray silt observed overlying the brown clay backfill at 2-T5-2 and 2-T5-3 indicates that some re-deposition of material has occurred since the 1981 remediation. However, the fact that T4 showed very little re-deposition of silt sized material indicates that only a limited portion of the remediated area has been effected by re-deposition since 1981.

A firm medium brown to gray clay was observed in most of the deeper cores underlying the black silt from the rest of the transects. This unit may pre-date construction of the RMP Bridge and probably represents the glacial lake deposits which often overlie bedrock in this area.

Five surface sediment samples were collected for grain-size analyses along transects T4, T6, T8, T10 and within the Niagara River. Each grain-size sample from within the creek was obtained from the center core location (position 2) of the transect of interest.

The grain-size sediment sample taken from the Niagara River (5-1E) was taken from a 10 foot deep hole just off the end of the "shot rock" bar which partially extends across the creek mouth. Sample 1-2E from transect T4 exhibited the highest gravel content of all samples, but also had a high silt/clay content. Samples obtained under and just north of the RMP Bridge were composed of a well sorted fine sand. Samples from the creek mouth and just off-shore within the Niagara River were poorly sorted and contained a significant gravel component.

4.2.2 SEDIMENT TRANSPORT

The entrainment and transport of contaminated sediment within Gill Creek is an environmental pathway which must be evaluated. To qualitatively identify the potential environmental risk associated with the sediment transport pathway, one must first define the depositional setting. The depositional history within Gill Creek has been severely influenced through man-made activities. Events such as the construction of the RMP Bridge and the 1981 creek remediation have had significant impacts on sediment accumulation and transport. The current rates of sediment deposition are relatively low within the Gill Creek study area and cannot readily account for the significant sediment thicknesses which have accumulated in the time period since construction of the RMP Bridge. The following discussion presents a depositional model based on existing sediment and contaminant distributions observed within the study area.

Disposition of sediment within the lower reaches of Gill Creek probably had its origins during the late 1950's to early 1960's. During this time period, the Niagara River shoreline was extended southward to accommodate the RMP and Gill Creek was channelized through the new emplaced fill. Upon construction of the RMP Bridge across Gill Creek, the area was excavated to bedrock to accommodate bridge box culvert construction. These activities created an artificial embayment within the mouth area and probably provided an area within the creek of deeper water and quiescent flow conditions, conducive to fine-grained sediment deposition. Fine-grained sediment was likely derived from upstream areas of the creek within the original creek channel. Coarser-grained sediment contributions from the Niagara River probably also occurred during this period. The depositional setting most likely remained the same through the early 1980's (prior to creek remediation). As the embayment filled with sediment, wave energies from the Niagara River likely became a more dominant influence in re-suspending or re-working sediments within the mouth area resulting in deposition of increasingly coarser-grained materials.

During 1981, remedial actions were undertaken whereby contaminated sediments were removed from Gill Creek over a length from Buffalo Avenue to the north wing-walls of the RMP Bridge. Although the remediation was performed in a dewatered creek bed and efforts were taken to minimize suspension of sediment, it is possible that the remediation efforts in the lower reaches of Gill Creek may have effected additional emplacement of sediment in the mouth area of the creek over a relatively short period of time.

In contrast to early depositional conditions in the creek prior to 1981, deposition of fine-grained sediment has declined significantly since the remedial effort. This decline is due in large part to the remedial activities upstream causing a depletion of available sediment. In 1987, the Niachlor cooling water outfall (007) began discharging to Gill Creek. The outfall discharge (49 cfs) greatly increases flow rates within the creek. Stream velocities increased dramatically in the immediate vicinity of the outfall. However, as the creek widens and deepens in a downstream direction, the actual flow velocity increases in the mouth related to Niachlor are low and should have little effect on the re-suspension of sediment. In addition, the Niachlor outfall discharges in an area of the creek previously remediated and backfilled with compacted clay. Thus, little sediment is present in this area.

Under current conditions, little sediment now appears to traverses the remediated section of Gill Creek south of Adams Avenue. Sediment accumulation in this area is also limited. The compacted clay layer emplaced as part of the remediation may constitute a minor source of fine-grained sediment for areas downstream. The primary current source of sediment in the mouth area is likely derived from the Niagara River through erosion of the adjacent fill shoreline. This material is of a larger grain-size than sediment originally deposited in the mouth area. Existing sediments in the mouth area are also subject to river energies (wave action) and subsequent mixing, re-working, and winnowing of the finer-grained fraction. Such wave action may have resulted in the limited re-deposition of sediment north of the RMP Bridge into the remediated area.

A thin veneer of sediments have been deposited in the southernmost portion of the previously remediated area just north of the RMP Bridge. These sediments which were deposited over the compacted clay layer emplaced during remediation, contain elevated levels of several site-specific chemicals. This limited zone of contaminated sediment re-deposition suggests that wave energies from the Niagara River have reworked contaminated sediment upstream into a small portion of the previously remediated zone.

Ice action appears to have had a major effect on the hydrography of the creek mouth in recent years. Ice grounding on the shoreline has pushed large pieces of "shot rock" from the adjacent shoreline, forming a submerged bar which obstructs a major portion of the creek mouth. The net effect of this feature is that river wave action is diminished. Thus, the amount of sediment re-working and re-suspension occurring in the mouth area has been reduced. In addition, in the absence of higher transport energies, the area should again be conducive to fine-grained sediment deposition.

Relevant sediment transport processes affecting the lower reaches of Gill Creek are summarized below:

- Little sediment now appears to traverse the remediated section of Gill Creek south of Adams Avenue. Sediment deposition in this area should also be minor. The compacted clay layer emplaced during remediation may be a source of some fine-grained sediment for areas downstream.

- The primary source of gravel, sand and silt-sized sediments in the creek mouth area is probably the Niagara River. More specifically, new sediment is being derived locally from the erosion of the adjacent fill shoreline. Now that the upstream (creek) source of clay-sized sediment is reduced, sediments currently being deposited tend to have a coarser composition than in the past.

- Existing sediments within the mouth area are also subjected to re-working and re-suspension through river wave action. Fine-grained sediment suspended in the mouth area likely exits the creek into the Niagara River. The degree of re-working decreases up the creek as distance from the Niagara River increases.

- Recently, deposition and transport of sediment within the mouth area resulting from adjacent Niagara River influences have decreased. Downstream ice movement within the Niagara River has eroded material from the river bank forming a submerged bar across much of the creek mouth. This feature has constricted the area and sheltered the mouth from Niagara River wave action.

- Very little sediment is present in the Niagara River near it's confluence with Gill Creek. Any nearshore deposits are typically coarse grained and isolated. Thus, the presence of contamination within this area is of less significance due to limited extent of sediment accumulation.

5.0 ENVIRONMENTAL ASSESSMENT

This section presents an assessment of the environmental impacts associated with the contaminated sediment in Gill Creek. Based on the assessment of environmental impacts, the need for remediation and/or additional investigation will be addressed. The environmental assessment for the Gill Creek Sediment Study was performed in accordance with USEPA guidelines for a semi-quantitative endangerment assessment (USEPA, 1985). This means that measured, or in some cases estimated, contaminant levels in the environment are compared to relevant environmental standards or criteria. These comparisons form the basis for WCC's conclusion regarding the need for remedial action for compliance with current environmental regulations. Individual doses to exposed organisms are not estimated. The environmental assessment is presented in five sections: Description of Environmental Setting (5.1); Selection of Indicator Chemicals (5.2); Toxicity Assessment (5.3); Transport/Exposure Pathway Analysis (5.4); Qualitative Risk Assessment (5.5); and Recommendations (5.6).

The environmental assessment is based primarily on data obtained from the extensive June 1988 sediment and surface water sampling program (see Section 4.0). Data from previous investigations (see Section 2.0) were considered and found to be consistent with the June 1988 results.

5.1 ENVIRONMENTAL SETTING

This section presents a brief description of the environmental conditions in the vicinity of the study area including hydrology, land use, water supply, and ecology.

5.1.1 HYDROLOGY

Gill Creek is a small tributary of the Niagara River. Gill Creek flows south from Hyde Park to its confluence with the Niagara River, located approximately 2000 feet downstream of the Robert Moses Power Project river water intakes and approximately 2 miles upstream of Niagara Falls. The sediments in Gill Creek between the RMP Bridge and Buffalo Avenue were excavated and replaced in 1981. Thus, the area of most concern in this investigation extends from the mouth of Gill Creek upstream to the north wing-wall of the RMP Bridge. As discussed in Section 4.2, this area is an "artificial" embayment on the north bank of the Niagara River. It was formed in the early 1960's as a result of filling activities to extend the river bank southward during construction of the RMP.

The natural flow rate of Gill Creek is estimated to average approximately 2 cfs (this flow rate includes flow augmentation received from the New York Power Authority (NYPA), upstream). This upstream flow is greatly augmented in the study area by non-contact cooling water discharge. At Niachlor outfall 007, located on the east bank of the creek, approximately 150 feet south of Adams Avenue, non-contact cooling water is discharged at a rate of approximately 49 cfs. An additional 1 cfs of non-contact cooling water is discharged at Du Pont outfall 006, located at the Du Pont Road crossing on the west bank of the creek.

The Gill Creek embayment is strongly influenced by the Upper Niagara River. Despite the upstream input from the Niachlor outfall, flow in the area shown in Figure 4-17 was observed to periodically reverse depending upon wind and water level conditions in the river. Some of these reversals are caused by the 1.5 foot "tides" artificially induced in the river by the NYPA. The NYPA opens and closes the gated intake structure causing river water levels to fluctuate.

Flow rates in the Niagara River vary dramatically in space and time because of the large power plant diversions from the NYPA intakes and from the Ontario Hydro intakes located across the river. The average flow above these withdrawal points is 204,000 cfs (USGS, 1984). The absolute minimum permissible flow over the falls is 50,000 cfs, and the minimum during daylight hours in the tourist season is 100,000 cfs. The remainder of the flow; usually between 100,000 and 150,000 cfs is divided between the NYPA project and the Canadian Ontario Hydropower project.

Data from monitoring of overburden wells in the vicinity of Gill Creek suggests that shallow (overburden) groundwater seeps into Gill Creek. The potential for seepage from Gill Creek to the groundwater also exists depending on the stage in Gill Creek and hydraulic head in the overburden and upper bedrock. The latter is influenced by the rate of withdrawal from the Olin Production wells.

Gill Creek is currently designated a Class D water by New York State. Class D waters are considered suitable for secondary contact recreation, but not for the propagation of fish. Water quality issues for the Niagara River identified in recent reports include toxic pollutant levels in the river resulting from industrial and municipal discharges and non-point sources in the Buffalo-Niagara Falls area. A wide variety of toxic substances, usually in relatively low concentrations, have been identified in Niagara River water and sediments. The Niagara River Toxics Committee (1984) has developed priorities for chemicals of concern identified in the river. These high priority chemicals include heavy metals, pesticides, PCBs, polynuclear aromatic hydrocarbons, and a variety of chlorinated hydrocarbons.

5.1.2 LAND USE

The study area is located in a heavily industrialized area of the City of Niagara Falls. The Buffalo Avenue area has historically been a prime location for chemical industries such as Carborundum, Du Pont, Olin and numerous manufacturing/processing facilities. To characterize the general vicinity of the study area, land use within a 1-mile radius was evaluated and mapped (Figure 5-1). Data sources included the Niagara County Department of Economic Development and Planning and the Niagara County Environmental Management Council. To simplify the figure, only the dominant land use form is shown where more than one use occurs in the same area.

As shown in Figure 5-1, the predominant land uses within a 1-mile radius are heavy industrial and residential. The primary land use within the immediate vicinity of the study area is heavy industrial. To the north and east of the study area is an area classified as inactive urban land. The land is occupied primarily by railroad lines to the north and utility right-of-ways to the east. To the west of the study area is a wastewater treatment plant. Farther north, land use is primarily residential, both medium and high density. This area is interspersed with several commercial properties. The RMP traverses the study area.

5.1.3 WATER SUPPLY

No water supply intakes drawing water from the Niagara River are located downstream of the Gill Creek (Niagara County Department of Health, 1986). There are currently four surface water supply systems in Niagara County and 10 in Erie County. Seven of these systems draw water from the Niagara River in the Town of Niagara from an intake located approximately 5000 feet upstream of Gill Creek. The intake is located 1500 to 2000 feet offshore near 53rd Street. The only other potable water intake in the vicinity is located in the west channel of the Niagara River between Navy Island and Grand Island, approximately 2 miles upstream of Gill Creek.

5.1.4 ECOLOGICAL RESOURCES

Ecological resources in the vicinity of the study area are discussed very briefly in this subsection. A more comprehensive treatment is presented in the Du Pont Niagara Plant Endangerment Assessment (WCC 1986). Due to the industrial/commercial nature of the area ecological resources in the immediate vicinity of the Niagara Plant are sparse. The two general types of ecological resources which are found in the overall area include the aquatic resources of Gill Creek and the Niagara River and small tracts of wetlands. Several "Significant Habitats," as defined by the NYSDEC, have also been identified along the Niagara Gorge.

Aquatic Resources: The aquatic communities of Gill Creek and the Niagara River are briefly described below. Hyde Park Lake, located on the upstream reach of Gill Creek, lies just over one mile north of the Niagara Plant. The lake is stocked by the NYSDEC each spring with warm-water species collected in Chautauqua Lake, New York. Species known to occur in the lake include carp, goldfish, brown bullhead, pumpkinseed, and black and white crappies (NYSDEC, 1982).

A total of eleven fish species were recovered from two sampling stations in Gill Creek during a fall-1984 sampling effort. Seven species were caught just below Hyde Park Lake, and nine species were caught downstream near Buffalo Avenue. Five species - carp, gizzard shad, golden shiner, pumpkinseed, and white crappie, were caught at both stations. The source of Gill Creek fish is mostly likely the Niagara River, although some individuals may come from Hyde Park Lake. No species found in Gill Creek are unique to the creek or to the Niagara River system.

Based on the dominant constituents, organismal densities, and community structure observed during a 1984 benthic sampling effort (Spotila, 1984), the benthic community in the mouth of Gill Creek is indicative of a moderately stressed aquatic environment. Oligochaetes dominated all four sampling stations by approximately 73 to 98 percent. In general, many oligochaete species are known to be tolerant of environmental stress. This, combined with an absence of intolerant forms, is a good indication of stress

(Carins and Dickson, 1971). Other tolerant forms recovered in Gill Creek include leeches and certain snails. Benthic organisms recovered from the study area which are known to be intermediate in tolerance include snails, sowbugs, and fingernail clams. The state of the aquatic habitat in Gill Creek is further characterized by the relatively low organismal densities observed. In a non-stressed ecosystem, densities may range as high as thousands of individuals per square meter. In Gill Creek, of the total of 32 samples collected, densities ranged from approximately 20 individuals per square meter to 1,248 individuals per square meter.

A total of 61 species of fish are reported to occur in the upper Niagara River, but only 43 have been collected recently. Thirty-two of these species are common to the Niagara River. Recreational fishing is common in the Niagara River.

Wetlands: Based on U.S Fish and Wildlife Service Wetland Inventory Maps (1978), no wetlands occur within a one mile radius of Gill Creek. However, several small unregulated wetland areas are located beyond the one mile radius in the Niagara Falls area. These are identified in the Du Pont Niagara Plant Endangerment Assessment (WCC, 1986). The closest NYSDEC regulated wetland is located approximately two miles northeast of the study area and is designated TW-3.

Significant Habitats: A program for the identification and protection of significant wildlife habitats in the State of New York was begun in 1975 by the NYSDEC. Under this program, habitats are designated significant if they provide some of the key factor(s) required for the survival, variety or abundance of wildlife, and/or for human recreation associated with such wildlife. Significant habitats include, but are not limited, to endangered species habitats, concentration migration routes, deer wintering areas, and areas supporting high wildlife concentrations.

There are no significant habitats in the immediate vicinity of the study area. However, a number of migratory waterfowl habitats and colonies have been identified along the Niagara River from Grand Island, near Niagara Falls, downstream to the Niagara

Escarpment. These are identified and discussed in the Du Pont Niagara Plant Endangerment Assessment (WCC, 1986).

5.2 SELECTION OF INDICATOR CHEMICALS

The first step in assessing the environmental impacts of contaminated sediments in Gill Creek was to identify the contaminants of concern. This was accomplished by rating each chemical detected in sediment using a formula incorporating concentration, toxicity and distribution factors. The formula used to rate chemicals was:

$$\text{Indicator Rating} = \frac{(\text{Cmax})\ (\text{No. Detects})}{(\text{Toxicity Factor})\ (\text{No. Samples})}$$

The concentration factor, Cmax, was the maximum measured concentration of the chemical in Gill Creek sediment during the June 1988 sampling program. The toxicity factor used was the NYSDEC surface water standard or guidance value. For chemicals lacking an NYSDEC standard, USEPA surface water criteria were used. Thus, WCC implicitly assumed that the NYSDEC (or USEPA) ambient requirement is proportional to the environmental toxicity of the chemical in sediment and surface water. The distribution factor was defined as the number of samples with results above detection limits divided by the total number of samples for which the chemical was analyzed.

Table 5-1 presents the indicator rating for all chemicals detected in any of the sediment samples. An indicator rating of 2×10^5 was chosen as the threshold for selection as an indicator chemical because: 1) the resulting list was short enough to allow detailed consideration; and 2) the list included chemicals representing a wide variety of physical and chemical characteristics. Eleven of the 53 chemicals detected exhibited indicator ratings of greater than 2×10^5. These eleven chemicals were:

Volatile Compounds	Indicator Rating
Tetrachloroethene	1.2×10^7
Trichloroethene	6.9×10^5
Vinyl Chloride	2.8×10^5
1,1,2,2-Tetrachloroethane	2.7×10^5

Base/Neutral Compounds	Indicator Rating
Hexachlorobenzene	2.3×10^7
Hexachlorobutadiene	2.9×10^6
Pentachlorobenzene	7.4×10^5

Pesticide/PCB Compounds	Indicator Rating
PCB-1248	1.0×10^{10}
a-BHC	3.9×10^7
b-BHC	1.0×10^7

Metals	Indicator Rating
Mercury	1.4×10^6

Based on the assumptions mentioned above, these chemicals represent the contaminants with the greatest potential for environmental impact.

Dioxin (PCDD) and furan (PCDF) compounds were treated separately because an accepted method is available for evaluation of the environmental significance of dioxins in sediments. This risk-based approach, adopted by the USEPA Risk Assessment Forum (USEPA 1987), involves expressing the concentration of individual dioxin and furan compounds in terms of toxicity relative to 2,3,7,8-TCDD. The units are termed "toxic equivalents." A value of 1.0 ppb total toxic equivalents has been recommended by USEPA as the trigger for remedial action in residential areas. Table 4-3 presents the toxic equivalent values for Gill Creek sediment samples. The highest value as calculated by the USEPA method was 0.44 ppb. Thus the dioxin and furan levels are not high enough to trigger a remedial effort by their presence alone. Therefore, these chemicals are not considered among the major contaminants of concern.

However, dioxin and furan compounds are extremely important with respect to feasibility of remedial alternatives. As discussed in Section 6.0, the presence of these chemicals, even at low levels may create problems with both landfilling and incineration/treatment remedial options.

5.3 TOXICITY ASSESSMENT

In this subsection, factors affecting the environmental toxicity of the contaminants of concern are summarized. More detailed toxicity profiles, presenting chemical, physical and toxicological properties of these chemicals, are included in Appendix C. References cited in this section are listed in Appendix C.

5.3.1 POLYCHLORINATED BIPHENYLS

Polychlorinated biphenyls (PCBs) are a class of organic compounds characterized by two linked phenyl rings that are chlorinated at from 2 to 10 sites. They were manufactured in the United States exclusively by Monsanto Corporation under the trade name Aroclor from 1929 until 1977 (Limburg, 1986).

Each Aroclor product is a mixture of chlorinated biphenyl congeners. In the name Aroclor 12XX, the 12 indicates 12 carbon atoms, and the XX denotes the percentage of chlorination (by weight) of the mixture. For example, Aroclor 1248 is a mixture of six PCB congeners with 48 percent chlorine, overall. An exception to the nomenclature is Aroclor 1016 which has 12 carbons and is 42 percent chlorine. The PCB congener mixture present in Gill Creek sediments is closest to Aroclor 1248, which is synonymous with PCB-1248 in this document.

The logarithm of the octanol/water partition coefficient (log K_{ow}) for PCB-1248 is approximately 6.0. This indicates a strong tendency to adsorb to organic carbon in sediments. The aqueous solubility of PCB-1248 is reported to be approximately 50 ug/L.

As a class of compounds, PCBs are extremely stable, slow to chemically or biochemically degrade. PCBs are now distributed worldwide, with measurable concentrations reported in polar bears of the Canadian Arctic, marine organisms in the Atlantic and Pacific oceans, birds and fish of the Great Lakes, and up to 90 percent of the adult human population of the United States. In animals, PCBs have been linked to reproductive failure, birth defects, tumors, and at elevated concentrations, death. Their toxicity is enhanced by their tendency to bioaccumulate and with some species, biomagnify due to extremely high liposolubility.

According to the USEPA, PCB compounds are classified as potentially carcinogenic to humans. Therefore, environmental exposure criteria established by the USEPA are quite low. Environmental exposure criteria have been established for PCB concentrations in water, and edible portions of fish and shellfish. The ambient water quality criteria as established by the USEPA (1980, 1986) for fresh water is 0.014 ug/L as a 24-hour average. Acute toxicity to aquatic organisms is expected at water concentrations of 2.0 ug/L or higher. For the maximum protection of human health from carcinogenic effects through ingestion of PCB-contaminated water and/or aquatic organisms, the ambient water concentration recommended by EPA is zero. Since zero concentrations are not attainable, a PCB criteria of 0.079 ng/L, corresponding to an incremental increase of cancer risk of 10^{-6} has been developed (USEPA, 1980; 1986). The Food and Drug Administration (FDA) has recently lowered the tolerance level (i.e., criteria) for PCBs in edible portions of fish and shellfish from 5 mg/kg to 2 mg/kg (21 CFR Part 109.30).

5.3.2 HEXACHLOROCYCLOHEXANE

Hexachlorocyclohexane (BHC) is a broad spectrum insecticide of the group of cyclic chlorinated hydrocarbons called organochlorine insecticides. It consists of a mixture of five configurational isomers and was introduced in 1942 as a contact insecticide under the trade names BHC, benzene hexachloride, and 666. Since its introduction, both the use and production volume of technical grade BHC have undergone dramatic changes as a result of the discovery that virtually all of the insecticidal activity of BHC resides with its gamma-isomer. All registrants of pesticide products containing BHC voluntarily cancelled their registrations or switched their former BHC products to lindane formulations. On the other hand, significant commercial use of the purified gamma-isomer of BHC continues (USEPA, 1980).

The log K_{OW} values for alpha-BHC, beta-BHC and gamma-BHC are reported to be 3.81, 3.80, and 3.72, respectively (Kawaharg et al, 1973). Reported solubilities in water at 28°C range from 1.2 to 2.0 mg/L for alpha-BHC, from 0.1 to 0.2 mg/L for beta-BHC, and from 5.8 to 7.4 mg/L for gamma-BHC. These values indicate that while the BHCs are relatively hydrophobic, they tend to desorb to the aqueous phase more readily than the PCB compounds.

BHC compounds are classified as potentially carcinogenic to humans by the USEPA. Therefore, as with the PCB compounds, the USEPA recommends a concentration of zero for BHCs in surface water. Since this is not attainable, environmental exposure criteria have been developed (USEPA, 1986) for protection of human health from potential carcinogenic effects of BHC compounds through ingestion of water and/or aquatic organisms. For alpha-BHC, the criterion corresponding to a 10^{-6} incremental cancer risk is 9.2×10^{-3} ug/L for ingestion of water and organisms. For consumption of aquatic organisms alone, the level for 10^{-6} incremental cancer risk is 3.1×10^{-2} ug/L. The 10^{-6} incremental cancer risk levels for beta-BHC are 1.63×10^{-2} ug/L (water and organisms) and 5.47×10^{-2} ug/L (organisms alone). Corresponding levels for gamma-BHC are 1.86×10^{-2} ug/L and 6.25×10^{-2} ug/L, respectively. Criteria for the protection of freshwater aquatic life from chronic toxicity of BHC are only available for the gamma isomer. This level is 8.0×10^{-2} ug/L.

5.3.3 CHLORINATED BENZENE COMPOUNDS

Chlorination of benzene yields 12 different compounds: monochlorobenzene, three dichlorobenzene, isomers (1,2-; 1,3-; 1,4-;), three trichlorobenzene, isomers (1,2,3-; 1,2,4-; 1,3,5-;), two tetrachlorobenzene, isomers (1,2,3,5-; 1,2,4,5-;), pentachlorobenzene, and hexachlorobenzene. The chlorinated benzenes are used as intermediates for herbicides, insecticides, dyestuffs, lubricants, and dielectric/heat transfer mediums. Two chlorinated benzene compounds, pentachlorobenzene and hexachlorobenzene were selected as indicator chemicals for the Gill Creek Sediment study.

Generally, as chlorination increases from mono- to hexa-, vapor pressure decreases, solubility decreases, and log K_{ow} increases. Consequently, HCB is the most environmentally-persistent compound and the one most apt to accumulate in ecosystems. The log K_{ow} values for pentachlorobenzene and hexachlorobenzene are 5.63 and 6.18, respectively. Aqueous solubilities are approximately 0.24 mg/L for pentachlorobenzene and 0.006 mg/L for hexachlorobenzene. These values indicate that these two indicator chemicals partition strongly to organic carbon in sediments.

Environmental exposure criteria are not available for pentachlorobenzene. Human health criteria are available for the more toxic hexachlorobenzene. Hexachlorobenzene is classified as a possible human carcinogen by the USEPA (1980) and a concentration of zero is recommended. Ambient surface water criteria corresponding to a 10^{-6} incremental cancer risk are 0.72 ng/L for ingestion of water and organisms and 0.74 ng/L for ingestion of organisms only. According to the USEPA, no data are available concerning the chronic toxicity of the the chlorinated benzenes to sensitive freshwater aquatic life.

5.3.4 HEXACHLOROBUTADIENE

Hexachlorobutadiene (HCBD) is produced as a by-product of the manufacture of chlorinated hydrocarbons such as tetrachloroethylene, trichloroethylene, and carbon tetrachloride. HCBD is used as a solvent for many organic substances; its relatively low vapor pressure gives it a distinct advantage over some other chlorohydrocarbons for this purpose.

The log K_{ow} for hexachlorobutadiene is 3.74 and its aqueous solubility is approximately 2 mg/L at 20°C.

According to the USEPA (1980), the available data for hexachlorobutadiene indicate that acute and chronic toxicity to freshwater aquatic life occur at concentrations as low as 90 and 9.3 ug/L, respectively, and would occur at lower concentrations among species that are more sensitive than those tested. The USEPA classifies hexachlorobutadiene as a possible human carcinogen and has established criteria corresponding to 10^{-6} incremental cancer risk of 0.45 ug/L (ingestion of water and organisms) and 50 ug/L (ingestion of organisms only).

5.3.5 VOLATILE ORGANIC COMPOUNDS

Four volatile organic compounds were selected as indicator chemicals: tetrachloroethene, trichloroethene, 1,1,2,2-tetrachloroethane, and vinyl chloride.

Log K_{ow} values and aqueous solubilities for these compounds are presented below:

Chemical	Log K_{ow}	Aqueous Solubility (mg/L)
Tetrachloroethene	2.88	150 mg/L at 25°C
Trichloroethene	2.42	1.1 mg/L at 20°C
1,1,2,2-Tetrachloroethane	2.56	2900 mg/L at 20°C
Vinyl chloride	1.36	2763 mg/L at 25°C

Each of these four chemicals is classified by the USEPA as a potential human carcinogen. USEPA criteria (1980) corresponding to an incremental cancer risk of 10^{-6} are presented below:

Chemical	Ingestion of Water and Organisms	Ingestion of Organisms Only
Tetrachloroethene	0.8 ug/L	8.85 ug/L
Trichloroethene	2.7 ug/L	80.7 ug/L
1,1,2,2-Tetrachloroethane	0.17 ug/L	10.7 ug/L
Vinyl chloride	2 ug/L	525 ug/L

The USEPA has not established water quality criteria for protection of aquatic life for any of these compounds. However, the lowest reported toxic concentrations are presented below:

Chemical	Concentration (ug/L) Chronic	Lowest Reported Toxic Acute
Tetrachloroethene	5,280	840
Trichloroethene	45,000	Not Available
1,1,2,2-Tetrachloroethane	9,320	2,400
Vinyl chloride	Not Available	Not Available

5.3.6 MERCURY

Mercury (Hg) has long been recognized as one of the most toxic of the heavy metals and is identified as a serious pollutant in the aquatic environment. Mercury levels in river, lake, and estuarine sediments have increased 2 to 5 times the precultural levels due to human activities. Some of the activities that contribute to the global input include: burning of fossil fuels; mining and processing of gold, copper and lead; and the operation of chloralkali plants (NRD, 1978). The major use of mercury in the United States has been as a cathode in the preparation of chlorine and caustic.

Within the aquatic environment, mercury can exist in three oxidation states: elemental mercury (Hg^o), mercurous ion (Hg_2^{2+}), and mercuric ion (Hg^{2+}). Elemental mercury has a melting point of -38.87°C and a density of 13.53. It is very volatile with a vapor pressure of 2×10^{-3} mm at 25°C. It's solubility in water is 0.056 mg/L; in benzene, solubility is 2.387 mg/L (Merck, 1983; Eisler, 1987).

For the protection of human health from the toxic properties of mercury ingestion through water and contaminated aquatic organisms, the ambient water criterion (USEPA, 1986) is determined to be 144 ug/L. For the protection of human health from the toxic properties of mercury through ingestion of contaminated aquatic organisms alone, the ambient water criterion is determined to be 146 ug/L. The FDA has established an Action Level (Guideline) of 1.0 mg/kg for methyl mercury in edible portions of fish and shellfish in their Compliance Policy Guides.

The USEPA (1985) reports that freshwater organisms will be protected from chronic effects if mercury levels do not exceed 0.012 ug/L (four-day average) and from acute effects if levels do not exceed 2.4 ug/L (one-hour average).

5.4 TRANSPORT/EXPOSURE PATHWAY EVALUATION

In this section of the environmental assessment the results presented in Section 4.0 are evaluated with respect to potential for contaminant release and transport to receptors. Exposure point concentrations are estimated from sediment and surface water analytical results.

5.4.1 IDENTIFICATION OF TRANSPORT/EXPOSURE PATHWAYS

Figure 5-2 presents a diagram illustrating environmental pathways through which contaminants associated with Gill Creek sediments could be transported to receptors. Each pathway begins at the source, defined herein as the contaminated sediment near the mouth of Gill Creek.

Potentially significant pathways leading to environmental or human exposure are summarized as follows. Aquatic organisms may contact and ingest contaminated sediment, detritus, and water within the source area. Direct contact with contaminated sediment which has been resuspended and transported from the source area could also occur. Exposures resulting from direct contact and ingestion would be highest within the study area and would dissipate with distance from the source area.

Aquatic organisms could also be exposed to chemicals which have desorbed from the sediments and been transported to the water column. Absorbtion of aqueous phase contaminants by aquatic organisms would also be highest within the study area and dissipate with distance from the source area. Aquatic organisms which have absorbed chemicals from direct contact with sediment, detritus, or aqueous phases are in turn consumed by carnivores. Volatile chemicals could be released to the atmosphere following desorption and transport to the air/water interface. It is also possible that contaminant migration from the sediments could occur through seepage into the groundwater.

In general, human exposure to sediment contaminants could occur through ingestion of water or aquatic organisms. As discussed in Section 5.1.3, no water supply intakes withdrawing water from the Niagara River are located downstream of the study area. The closest water supply withdrawal is located more than a mile upstream and could not be impacted by Gill Creek contaminants. Therefore human exposure via drinking water is not considered a potential exposure pathway.

Human exposure to Gill Creek contaminants could occur through ingestion of aquatic organisms. This exposure is somewhat lessened due to prohibition of fishing in the mouth of Gill Creek. However, fish caught in the river close to the confluence with Gill Creek, both upstream and downstream, could be contaminated. Some recreational fishing, but no commercial fishing, occurs in this area. Ingestion of aquatic organisms would not expose a large segment of the population.

5.4.2 ENVIRONMENTAL FATE AND TRANSPORT ANALYSIS

Sediment Transport: As described in Section 4.2, ice action appears to have had a major effect on the hydrography of the creek mouth in recent years. Ice grounding on the shoreline appears to have pushed large pieces of "shot rock" from the adjacent shoreline forming a submerged bar which obstructs a major portion of the creek mouth. The net effect of this feature is that river wave action is diminished. Thus recently, the amount of sediment re-working and re-suspension occurring in the mouth area has been reduced. In addition, in the absence of higher transport energies, the area should again be conducive to fine-grained sediment deposition under existing conditions. WCC concludes that although the flow in Gill Creek has increased greatly due to the Niachlor discharge, sediment transport from the embayment area is likely limited to increases in depositional energies during major storm events.

Prior to the development of the bar in the mouth of the creek, some sediment transport is likely to have occurred. This could account for the contaminant levels measured in river sediment samples. The degree of past deposition in the Niagara River is minimal as evidenced by the lack of sediment at the river sampling locations. At each of locations 5-2G, 5-3G, 5-4G, and 5-5G, very little sediment was present. Sufficient sample for analysis could only be obtained with repeated attempts using a Ponar dredge sampler.

Aqueous Transport: The rate of desorption should be limited by the rate of transport of desorbed chemicals away from the sediment water interface. If transport is slow, the concentration in the aqueous phase will build up and result in a lower concentration gradient between the sediments and interstitial water. If transport from the interface is rapid, the concentration gradient between the sediments and interstitial water will be high and desorption will be correspondingly rapid.

Partition coefficients derived from K_{OW} or K_{OC} (organic carbon) can be used to predict sorbed phase and aqueous phase concentrations under equilibrium conditions. It is probable, however, that the environmental system under consideration is not close to equilibrium. The kinetics of desorption from natural sediments is not well understood, although research on the subject is very active. Kinetic theory of desorption processes is not sufficiently developed for useful application to modeling or predicting aqueous concentrations resulting from contaminated sediment. We are therefore limited to interpretating the available aqueous phase data obtained from limited surface water sampling and elutriate analyses. Later in this section, aqueous phase analytical data are interpreted with respect to exposure point concentrations.

Volatilization: No volatile chemical data is available for Gill Creek surface water with the exception of monochlorobenzene. Based on the low levels of site-specific indicators detected in surface water, it is very unlikely that volatile contaminant levels could be present at levels sufficient for volatilization to pose a human health risk.

Seepage to Groundwater: Although Gill Creek appears to be influent (receiving groundwater discharge) in the vicinity of the study area, some seepage to groundwater may occur (see Section 5.1.1). Contaminants could be transported in groundwater and migrate either to the Niagara River or the Olin Production Wells. Data are not available to estimate the magnitude (if any) of this potential transport pathway.

5.4.3 IMPACT OF THE NIACHLOR DISCHARGE ON CONTAMINANT TRANSPORT

The Niachlor cooling water discharge (outfall 007) is located approximately 150 feet downstream of Adams Avenue in the previously remediated area. The impacts of the Niachlor discharge on contaminant transport from Gill Creek may be related to:

1) Elevation of stream water temperature
2) Increase in stream flow rate and velocity

The thermal impact is related to the effect of elevated temperature on desorption kinetics. Temperature monitoring and thermal plume modeling conducted by WCC indicate that the increase in temperature in the study area due to cooling water discharge is relatively small, on the order of a few degrees Celsius. Solubilities and partitioning behavior would not be expected to be appreciably affected by this small increase in temperature.

The impact of the added flow from cooling water discharge on contaminant transport is not clear. In a straight channel with flow only in the downstream direction, an increase in flow rate would increase both the quantity of water contacting sediments and the rate of physical transport from the sediment/water interface. The hydrodynamics of the study area are more complex than straight channel flow. Water enters the study area from both Gill Creek and the Niagara River. The rate of upstream inflow from Gill Creek is dependent on both the natural flow and cooling water discharge. This is also the net rate of discharge from Gill Creek to the Niagara River. The Niagara River contribution to circulation in the study area is dependent on river stage (which varies 1.5 feet depending on power plant withdrawal), windspeed, and direction. Because of the overwhelming volume of water in the Niagara River, flow conditions in lower Gill Creek are almost totally dependent on the Niagara River stage. Flow velocities in the mouth of Gill Creek are low during non-storm events and not likely to be sufficient for physical entrainment and transport of contaminated sediment. In addition, both the development of the "shot rock" bar across the mouth of Gill Creek has further diminished flow energies in this area. The effects of the Niachlor discharge on contaminant desorption are less clear than physical entrainment. The rate of contaminant desorption is not only dependent on the volume of water passing over the sediment, but also on the non-equilibrium partitioning behavior of the contaminants. Since the system is not likely to be near equilibrium with respect to partitioning, the desorption rate is not directly proportional to the flow rate. Thus, while the rate of desorption now occurring may be greater than prior to the Niachlor outfall, the magnitude of any desorption increase is probably much less than the magnitude of the flow increase.

5.4.4 ESTIMATED EXPOSURE POINT CONCENTRATIONS

As discussed above, human exposure to Gill Creek contaminants is expected to be minimal due to lack of public water supply withdrawals and commercial fishing. Based on the transport evaluation presented above, the most significant points of non-human exposure to Gill Creek sediments are:

1) Contact within the contaminated sediments
2) Ingestion of benthic organisms living in these sediments
3) Contact within the water column in the contaminated area.

Estimates of exposure levels are based on available analytical data for the media of concern. These estimates are presented below.

Contaminated Sediments: Exposure point concentrations for organisms living in the contaminated sediment were estimated by calculating the logarithmic average of sediment results for all shallow samples from areas 2, 3 and 4 (Table 4-5). Concentrations in these areas were generally highest. These concentrations are listed below for the indicator chemicals:

Indicator Chemical	Sediment Concentration (ug/kg)
Tetrachloroethene	6.1×10^6
Trichloroethene	1.6×10^6
Vinyl chloride	2.5×10^4
1,1,2,2-Tetrachloroethane	1.9×10^4
Hexachlorobenzene	7.8×10^4
Hexachlorobutadiene	2.0×10^5
Pentachlorobenzene	5.7×10^3
PCB-1248	1.5×10^6
a-BHC	4.5×10^4
b-BHC	1.9×10^4
Mercury, Total	3.6×10^4

Contaminated Surface Water: Table 4-6 presents the Gill Creek surface water results and elutriate water results for comparison. Note that only the site-specific chemicals were analyzed. The elutriate water results show that, of the site-specific chemicals, the BHC isomers, chlorinated benzene compounds, and hexachlorobutadiene show the greatest tendency to desorb under the elutriate testing conditions. However, PCB-1248 consistently was present along with the BHC isomers in the surface water samples. The lack of quantifiable levels of PCB-1248 in 4 out of 5 elutriate water samples is unexpected considering the sediment and surface water results. Note that elutriate water is centrifuged prior to analysis while no effort is made to remove particulates from surface water. Therefore, it is possible that the contaminant concentrations reported in surface water may actually be associated with a non-settling particulate phase. This is a particularly strong possibility for PCB-1248 and hexachlorobenzene which are the most hydrophobic of the contaminants of concern.

The maximum measured concentrations in surface water are presented below:

Indicator Chemical	Surface Water Concentration (ug/L)
Hexachlorobenzene	2.4 (estimated)
Hexachlorobutadiene	Not detected
Pentachlorobenzene	Not detected
PCB-1248	3.19
a-BHC	1.26
b-BHC	1.08
Mercury, Total	0.642

Measured concentrations are not available for the volatile indicator chemicals (tetrachloroethene, trichloroethene, vinyl chloride and 1,1,2,2-tetrachloroethane). These chemicals have a greater affinity for the aqueous phase than the site-specific parameters listed above. They are present in sediment at concentrations similar to the BHC's and PCB-1248. Therefore, it is likely that these volatile indicator chemicals are present at concentrations exceeding those for the BHC's and PCB-1248.

5.5 QUALITATIVE RISK ASSESSMENT

In this section, risks to the environment and human health are assessed by comparing the estimated exposure point concentrations (Section 5.4.4) with established toxicity criteria or risk-based environmental standards (Section 5.3). The purpose of this assessment is not to specifically address the risk to individual species in a quantitative manner, but rather to compare the measured environmental levels to regulatory criteria where available. The need for remedial action is then addressed based on this comparison.

Analytical data and/or environmental criteria are not available for all exposure media for all contaminants of concern. The approach taken in this semi-qualitative risk assessment was to compare the available measured concentrations with available relevant and appropriate criteria. Sufficient data have been collected such that these comparisons are adequate to form the basis for a conclusion regarding the need for remediation. Where analytical data are not available, such as for volatile chemicals in surface water, risks are assessed in a qualitative manner.

5.5.1 EXPOSURE TO CONTAMINATED SEDIMENT AND BIOTA

Sediment quality criteria applicable for environmental assessment are not available. Therefore, to assess the potential environmental impact through exposure to contaminated sediment and biota, actual results from tissue analysis are qualitatively considered.

As part of the 1982-1983 MOE biomonitoring studies, native filamentous algae (Cladaphora) were collected and clean clams (Elliptio complanata) were exposed to sediments in the mouth of Gill Creek. Results of tissue analyses revealed the presence of elevated levels of PCBs, mercury, alpha-BHC, and hexachlorobenzene in organisms collected or exposed in the mouth of Gill Creek. Results of the biomonitoring studies are presented in Section 2.3.

The biomonitoring studies indicate that contaminants in the creek sediments can accumulate in the tissues of bottom dwelling organisms. These organisms would then be a source of contamination to higher order consumers. The measured levels of the contaminants identified above are probably sufficient to cause toxicity in the organisms. However, due to the small aerial extent of contaminated sediments, relatively few individuals are expected to be impacted via this pathway.

5.5.2 EXPOSURE TO SURFACE WATER

Aquatic Organisms: Chemicals detected in surface water from the mouth of Gill Creek are compared to ambient water quality criteria for protection of aquatic life below:

Indicator Chemical	Maximum Concentration in Surface Water (ug/L)	Ambient Water Quality Criteria for Protection of Aquatic Life (ug/L)
Hexachlorobenzene	2.4 (estimate)	Not Available
PCB-1248	3.19	.014
a-BHC	1.26	.08 (gamma-BHC)
b-BHC	1.08	.08 (gamma-BHC)
Mercury	0.642	.025

As indicated, chronic toxicity data are not available for the BHC isomers, but the gamma-BHC criteria was used for comparison. Measured PCB levels exceed the criteria for protection of aquatic life from chronic toxicity by two orders of magnitude. Alpha-BHC, beta-BHC and mercury levels also exceed the criteria by one to two orders of magnitude.

Human Exposure: Human exposure to surface water contaminants could occur through ingestion of organisms from Gill Creek. Chemicals detected in surface water are compared below to ambient water quality criteria for protection of human health from ingestion of aquatic organisms:

Indicator Chemical	Measured Concentration in Surface Water (ug/L)	Ambient Water Quality Criteria for Protection of Human Health from Ingestion of Organisms (ug/L)
Hexachlorobenzene	2.4 (estimate)	7.4×10^{-4}
PCB-1248	3.19	7.9×10^{-5}
a-BHC	1.26	.031
b-BHC	1.08	.055
Mercury	0.642	0.146

Each of these chemicals exceed the recommended limit for protection of human health from ingestion of aquatic organisms.

Within the Niagara River, dilution of Gill Creek inflow is probably on the order of 1000 during low flow conditions. This dilution estimate assumes a complete mixing with a minimum Niagara River flow rate of 50,000 cfs. Given this dilution, PCB-1248 and hexachlorobenzene are likely to be present at concentrations (resulting from Gill Creek) exceeding the USEPA ambient water quality criteria for ingestion of organisms.

5.6 LIMITATIONS

The limitations of the assessment presented above should be considered before recommendations are made. Much of this assessment is based on the measured contaminant concentrations in surface water. Only five surface water samples were analyzed and these are certainly not sufficient to characterize the highly variable surface water conditions in the study area. For this reason, the maximum concentrations were used in the qualitative risk assessment to reduce the chances of underestimating, actual average surface water concentrations. A more comprehensive sampling program would be required to accurately estimate surface water concentrations. In addition, volatile compounds were not analyzed for in surface water and therefore could not be evaluated for this pathway.

Perhaps the most important assumption made in this assessment was that contaminant concentrations in surface water are a result of desorption from sediments. Given the similarity of the chemicals present (PCB-1248, BHC, mercury) to those found in the sediment, and the comparatively low concentrations of these chemicals in groundwater in the vicinity, this appears to be an appropriate assumption.

5.7 RECOMMENDATIONS

Although some of the data are limited in extent, the environmental concentrations resulting from the contaminated Gill Creek sediments are clearly sufficient to merit remedial action to conform with accepted regulatory guidelines. There are mitigating circumstances such as the small area of contamination and the small population of organisms potentially exposed.

Rather than perform a rigorous quantitative risk assessment, WCC has concluded from this preliminary environmental assessment that some remedial action is recommended. WCC does not recommend additional collection of data for site assessment unless it is found to be required for implementing the site remediation. The focus of the remainder of this document is to assess the feasibility of remedial alternatives based on environmental effectiveness, technical concerns, and cost.

6.0 PRELIMINARY FEASIBILITY STUDY

Various alternatives for remediating sediment contamination in lower Gill Creek are presented and evaluated in this Preliminary Feasibility Study. The methodology utilized to evaluate various remedial alternatives is in accordance with the United States Environmental Protection Agency (USEPA) document on remedial investigations/feasibility studies under CERCLA (draft USEPA, March 1988). The objective of the preliminary feasibility study is to identify the most viable remedial alternative(s) and provide insight into aspects of technical performance, implementability, and cost factors. The basic approach of the study in summarized as follows:

- Describe site problem.
- Define the remedial action objective.
- Identify and screen general response options.
- Present, discuss and screen potentially feasible technologies which could be used to remediate site problems.
- Formulate remedial alternatives.
- Summarize and evaluate remedial alternatives.

6.1 STATEMENT OF THE PROBLEM AND REMEDIAL ACTION OBJECTIVE

Data collected during previous investigations and the present study have defined an area of contaminated sediments within lower Gill Creek which, based on the environmental assessment, will require remediation. The following information was utilized in the Preliminary Feasibility Study to develop the remedial action objective, and to select and evaluate remedial alternatives.

Contaminants of Interest: Based on results of the environmental assessment and preliminary consideration of impacts on contaminant treatment/disposal feasibility, a list of seven compounds or compound groups containing contaminants expected to influence the selection of remediation alternatives was developed (Table 6-1). Most of these compounds were identified as contaminants of concern in Section 5.1 due to concentration, distribution, and toxicity. Some compounds were included because of impacts on the feasibility of certain disposal or treatment options. Specifically, although only low levels of dioxin and furan isomers were detected, the presence of even low levels of these compounds can potentially dictate certain landfilling and/or incineration options due to stringent permitting requirements. Other compounds were included on the list because of possible conflicts with current land disposal restrictions.

Sediments Requiring Remediation: Contaminated sediments within lower Gill Creek were identified as the contaminant source media in the environmental assessment. The vertical and horizontal extent of contaminated sediments were evaluated during the sediment sampling program. The area of Gill Creek requiring remediation is depicted in Figure 6-1.

The upstream limit of remediation was established as the area still complying with the 50 ppm PCB limit approved during the original 1981 creek cleanup. In addition, the previously remediated section has remained relatively sediment free although a thin layer of sediment has accumulated in places. Based on the environmental assessment, the downstream limit of remediation should include sediments within the mouth area. Sediments located out in the Niagara River beyond the deposition area of Gill Creek are not recommended for remediation due to the extremely limited extent of sediment volume and low degree of contamination.

The volume of contaminated sediment requiring remediation was estimated based on the area depicted in Figure 6-1 and the average vibracore penetration depths in this area. The entire sediment column was targeted for remediation because the analytical results do not delineate non-contaminated sediments at depth. Based on this approach, the estimated volume of sediment requiring remediation is 3200 cubic yards. An additional 400 cubic yards was estimated for removal of the shot rock bar at the mouth of Gill Creek.

Within the area to be remediated, the most common type of sediment observed was a soft, black sandy silt with varying amounts of clay and organic matter. Moisture content ranged from 16 to 70 percent with an average of 35.3 percent. Layers of gravel and crushed rock fragments were found throughout the finer-grained sediment. Large cobbles (6-inches) were observed scattered across the sediment surface.

Exposure Pathways: Potentially significant exposure or transport pathways are summarized in Figure 5-2. Primary pathways potentially leading to environmental or human exposure include:

- Direct contact of aquatic organisms with contaminated sediments at the site or with suspended sediments within the water column.
- Direct contact of aquatic organisms to contaminants in the water column desorbed from the contaminated sediments.
- Seepage of contaminants into groundwater.

- Volatilization of contaminants from surface water to the atmosphere.

Remedial Action Objective: The objective of remedial action proposed for Gill Creek will be to prevent or minimize the transport of contaminants from the source (sediments) to receptors. This would require implementation of actions which prevent, eliminate, or minimize migration of organic and inorganic contaminants (Table 6-1) from creek sediments to biota, surface water, and groundwater.

The Preliminary Feasibility Study included the development and evaluation of remedial alternatives as described herein. To develop potentially feasible remedial alternatives for evaluation, several screening steps are performed. Available response actions are considered first and those which cannot meet the remedial action objective are eliminated at this stage. Potentially feasible general response actions are then evaluated with respect to available technologies and process/treatment options which are further screened based on applicability to site conditions. Finally, the most feasible technologies are used to develop alternative remedial actions which are evaluated with respect to environmental effectiveness, technological considerations and cost.

6.2 GENERAL RESPONSE OPTIONS

Figure 6-2 illustrates the general response actions available. These are:

- No action
- Institutional action
- In-situ treatment
- Containment
- Source removal, treatment and disposal

Table 6-2 presents an initial evaluation of general response actions in terms of implementability, reduction of toxicity/mobility, and overall effectiveness.

No action and institutional action (access restrictions, monitoring) are easily implemented. However, the overall effectiveness of these response actions was rated limited because contaminant toxicity or mobility is not reduced. The in-situ treatment response action was rated questionable with respect to implementability due to several limiting factors, including overhead equipment space constraints (under the RMP Bridge) and unproven technology in this sort of environmental setting. The ability to reduce mobility in this specific environmental setting was also questionable and overall effectiveness was, therefore, questionable. The containment response action can be implemented and would effectively reduce contaminant mobility, however, it would not reduce toxicity. Due to the finite operational life of a containment device, the long-term effectiveness of the containment response is unknown and would require periodic monitoring and maintenance/replacement. Finally, the source removal/treatment response was rated positively in all three categories. At this stage, no action and institutional action are eliminated from further consideration because they are not applicable to attaining the objective of the remedial action.

6.3 SCREENING OF POTENTIALLY FEASIBLE TECHNOLOGIES

Remedial technologies with the potential to address the specific site problems are presented and evaluated in this section. The technologies are then subjected to another screening process to select the most feasible options for further consideration. It is the most feasible remedial technologies that are utilized in the formulation of complete remedial alternatives.

A generic list of remedial technologies was compiled based on review of the following documents: RI/FS Guidance document (USEPA, March 1988); USEPA Treatment Technology Briefs, Alternatives to Hazardous Waste Landfills (USEPA, July 1986); and Report on Decontamination of PCB-Bearing Sediments (USEPA, October 1987). Using experience and engineering judgement, a group of potentially feasible technologies were compiled (Table 6-3).

The potentially feasible technologies and process options within each technology category were then subjected to a technical screening process. The potentially feasible technologies and process options were evaluated for compatibility with sediment/waste characteristics and site conditions. Table 6-4 lists the general response actions developed along with the corresponding technologies, process options and applicable screening comments. The two in-situ treatment technologies, fixation and vitrification, are both severely limited by the environmental setting. Neither has been successfully used to remediate contaminated sediment with chemical concentrations similar to those within Gill Creek. Based on the information presented in Table 6-4, in-situ treatment was eliminated from further consideration.

Based on the technology screening process summarized in Table 6-4, the most feasible technologies and process options were determined and are summarized in Table 6-5. The most viable technologies applicable to Gill Creek are described in greater detail in the following sections.

6.3.1 CONTAINMENT

Based on evaluation of several containment options (see Table 6-4) a capping technology was identified as most applicable to on-site containment of the Gill Creek sediments. The objective of the cap is to isolate the contaminated sediments from surface water within Gill Creek. The cap does not directly address isolation of contaminants from groundwater. The capping technology selected is comprised of a 12-inch fabriform concrete cap and 60 ml Hypalon liner laid directly over the contaminated sediments. Using this technology, the Hypalon liner is laid over the contaminated sediments followed by the empty fabriform cap. Then, cement grout is pumped into the fabriform mold until it has reached the final 12-inch thickness. A major advantage of this cap design over other containment strategies is that it can be emplaced without dewatering the creek, thus minimizing exposure to contaminated sediments during remediation.

6.3.2 SEDIMENT REMOVAL

Removal of contaminated sediment from Gill Creek is feasible. However, a number of limitations and environmental concerns need to be addressed in selecting the appropriate removal technology. Primary concerns include:

- Release of contaminants (re-suspension) during removal.
- Contaminant volatilization during removal.
- Material handling problems.

Based on the technology screening process, two sediment removal techniques were identified as being feasible options; mechanical excavation and hydraulic dredging. Removal must be implemented in conjunction with other actions such as creek diversion and water treatment. Therefore, the two removal technologies are discussed in conjunction with other sediment removal dependent technologies.

Creek Diversion: Some level of creek diversion and/or dewatering activities will be necessary during any sediment removal efforts. The degree of creek dewatering required will be dictated by the method of sediment removal selected. The following actions may be implemented in creek diversion:

1. Installation of temporary, rock-fill dams with geomembrane liner within Gill Creek upstream of the area to be remediated and across the mouth of the creek.

2. Diversion of Gill Creek flow to either the Buffalo Avenue sanitary sewer or a temporary pipeline.

3. Temporary diversion of Du Pont outfall 006 and Niachlor outfall 007 directly to the Niagara River via an above ground pipeline.

4. Pumpage of standing creek water between the temporary dams, prior to dewatering to the Niagara River.

5. Pumpage of any subsequent groundwater inflow to an on-site settling basin and water treatment facility.

Water Treatment: During creek diversion and dewatering activities, water coming in contact with the contaminated sediments may require treatment. As part of the dewatering program, Niagara River water discharge limits of selected contaminants will need to be established and on-site water treatment utilized as necessary. It is possible that initial creek pumpdown water will not require treatment assuming sediment disturbance is kept to a minimum. However, once the water level falls below the sediment surface and groundwater inflow commences, the collected water will likely require treatment based on nearby groundwater quality data.

Initially, flocculation and sedimentation followed by carbon absorption appear to be the most appropriate water treatment process. A final water treatment design will require additional water/sediment analysis and evaluation. A temporary standard dual mobile treatment system with a capacity of 50 to 100 gpm should adequately serve treatment needs based on previous creek dewatering requirements; however, the actual rate could be higher and will not be known for certain until the excavation and dewatering are implemented. The sludge generated during water treatment will likely have to be handled as hazardous.

Mechanical Excavation: Sediment removal utilizing this technique would be performed within a completely dewatered creekbed using standard small-scale excavation equipment. The sediment would be allowed to gravity drain within the creekbed through pumping within sumps and channels in the sediment. The material would then be containerized for ultimate disposal. The excavated creekbed would then be restored with a compacted clay backfill.

Advantages of Mechanical Excavation are:

1) The ability to observe and sample the bottom of the excavation.
2) The sediment is excavated in a relatively dewatered state.
3) Excavation in the dry creekbed minimizes suspension and release of contaminated sediments in creek water.

Disadvantages of mechanical excavation are:

1) High groundwater inflow rates may require a sectioned dewatering approach.
2) Volatilization from exposed sediments could be a problem.
3) Potential for worker and community exposure during remediation.

Hydraulic Dredging: Utilizing hydraulic dredging allows sediment removal within a partially dewatered creekbed. This removal technique would only require a downstream temporary rock-fill dam to be emplaced. Water within the creek would then be pumped to maintain the water level in the creek lower than the Niagara River. The hydraulic dredge utilized would be a low turbidity floating dredge. Because of space constraints, the dredge operation would have to be modified for use under the bridge culverts. Sediment would be removed from the creek in slurry form and would require further dewatering.

Advantages of hydraulic dredging are:

1) Complete channel dewatering not required.
2) Minimizes air emissions and worker exposure during excavation by leaving a layer of water over the sediments.

Disadvantages of hydraulic dredging are:

1) Cannot handle large material (cobble-sized).
2) Cannot observe or test base of excavation.
3) May result in higher volumes of contaminated water.
4) Temporary dam likely to become contaminated from the high suspended solids content anticipated during dredging.
5) Sediment will require extensive dewatering activities following removal.

6.3.3 SEDIMENT TREATMENT

Given the variety of organic and inorganic contaminants present within the Gill Creek sediments, no single treatment technique will completely address the problem. However, it is likely that a combination of techniques will be required to effectively treat the material. Three treatment approaches described below were found to be most feasible during the technology screening process.

Solidification/Stabilization/Fixation: Each of these techniques involve mixing a substance with the waste to minimize contaminant mobility. However, each technique is slightly different. Solidification is the process of transforming a fluid mixture into solid form. Any loss in contaminant mobility will only result from decreasing the surface area. Thus solidification, through addition of fly ash or kiln dust, may be utilized to make saturated sediments suitable for commercial landfilling (paint filter test) or on-site interim storage. Stabilization is defined as a chemical reaction that occurs between the material added (reagent) and water within the sediments to immobilize contaminants. Fixation is similar except that a chemical reaction occurs between the material added and the contaminant to immobilize the contaminant.

Some proprietary lime-based stabilization techniques have recently been used to successfully immobilize organic contaminants, including PCB's, within sediments. However, given the high concentrations of total organics (percent levels) it is unlikely that a stabilization or fixation technology could be effectively applied to the sediment without some form of pre-treatment. The usefulness of stabilization/fixation technology for this project may be in immobilizing pre-treated sediment. Many of the treatment technologies reviewed will treat organics within the sediment. Elevated levels of mercury and some other metals may still classify organics-treated sediment as a RCRA hazardous waste. Therefore, stabilization/fixation may be a viable alternative to immobilize metals within the treated sediment.

Organic Extraction: As a potentially more cost-effective alternative to incineration and land disposal of PCB-contaminated sediments, a number of innovative treatment technologies have been evaluated. One category of treatment technologies, organic extraction, is presented below. The objective of this technique is to extract and concentrate organic contaminants from sediment resulting in a much smaller volume of liquid waste requiring further treatment. WCC has evaluated the extraction processes available based on compatibility with the waste stream and current development status. Two processes have been selected that warrant further attention: the Basic Extraction Sludge Treatment (BEST) by Resource Conservation Company and the Critical Fluids System Extraction (CFS) by Critical Fluids Systems Corporation.

The BEST treatment method has been successfully field tested on several projects. The process operation is as follows:

- Waste stream can be introduced as a slurry or as dewatered solids, thus compatible with both mechanical excavation and hydraulic dredging.
- Waste is pretreated to an alkaline composition and admixed with triethylamine (TEA).
- Heating separates batch into a solid-, water-, and amine-phase.
- Organic contaminants are contained within the amine-phase and are recovered as the amine-phase is recycled.

The CFS extraction method has been evaluated on pilot-scale tests. The CFS process operation is as follows:

- Waste is introduced in a slurry form, thus only compatible with hydraulically dredged sediments.
- Liquid propane or liquid carbon dioxide is introduced as a solvent to extract organic compounds from the sediment.
- Contaminants are recovered from the solvent in a separator which vaporizes the solvent for reuse.

Both extraction processes can be considered intermediate treatment techniques. The goal of organic extraction is to isolate contaminants from the sediment. The organic extract will still require treatment and the treated sediment may require stabilization and disposal because of metals content. One major limitation with both of these innovative extraction technologies is that they are not proven with a large scale operation. Each would require treatability tests to further evaluate compatibility of the process with the waste. In addition, it is likely this process would require permitting.

Chlorine Removal (Nucleophillic Substitution): An additional group of innovative technologies was evaluated to treat the organic liquid produced by utilizing organic extraction techniques on the contaminated sediment. There are two types of chlorine removal processes which are currently under evaluation; sodium-based and potassium polyethylene glycolate based. Of the various processes reviewed, KPEG Terraclean - Cl developed by Galson Research Corporation has been selected by USEPA as best suited for further testing and evaluation. The KPEG process operates through chlorine removal of organic compounds by nucleophillic substitution:

- The organic liquid extract is introduced into a reactor.
- The extract is mixed with equal volumes of potassium polyethylene glycolate and dimethyl sulfoxide at 150°C where dechlorination of PCB's and the other organics occur.

The developers of the chlorine removal processes claim that the processes are also effective on solid waste treatment. However, water content seriously slows down the process reaction; thus, the Gill Creek sediments with their anticipated high water contents would require extensive dewatering and may not be compatible. As with the innovative extraction techniques, chlorine removal is a relatively unproven technology and have only been advanced as far as pilot scale tests.

6.3.4 THERMAL DESTRUCTION

The variety and concentration of organic constituents within the Gill Creek sediments are suitable for application of thermal destruction technology. Thermal destruction by incineration is a preferred disposal method for PCB's under the Toxic Substance Control

Act. To date, the most favored incineration unit is the rotary kiln with a proven record at both fixed-base and on-site operations. The rotary kiln has the broadest flexibility in terms of waste types, variability in particle size, moisture content, and chemical composition. Incineration options are presented for both commercial off-site facilities and on-site mobile units.

Thermal destruction technologies subject the contaminated materials to high temperatures and appropriate residence times to volatilize and oxidize the organic constituents within the waste matrix. The effluent gas stream from the process is subjected to additional treatment of particulates and acidic gases. The solids residues from thermal treatment generally require additional treatment to chemically stabilize hazardous constituent metals in the treated waste.

Commercial Off-Site Incineration: There are currently four hazardous waste incinerators in the United States capable of handling PCB's: two Chemical Waste Management facilities in the Chicago area, Rollins Environmental's Deer Park, Texas facility, and ENSCO in El Dorado, Arkansas.

The limiting factor for utilizing a stationary, off-site commercial incinerator may be the low levels of PCDD and PCDF present in the Gill Creek sediment. The commercial PCB incinerators may require a variance to their current permit to accept wastes with low levels of dioxin or furan isomers. Of the four incineration facilities, only Rollins is currently pursuing such a variance.

On-Site Incineration: Mobile or transportable on-site incinerators have also been applied to the treatment of wastes containing a variety of hazardous constituents including PCB's, dioxins, and other organic compounds. The sediment volume to be treated is relatively low, thus mobile incineration is not very economical.

Should on-site incineration be pursued, the permitting process could be a lengthy one requiring test burns of representative waste materials and a full scale trial burn. Public participation in project development would also be a major factor in employing on-site incineration.

6.3.5 SEDIMENT DISPOSAL

For the case when sediment is removed, disposal will be necessary whether the material is untreated, stabilized, or incinerated (ash disposal). Disposal options to be considered include commercial off-site disposal and interim on-site storage. Advantages and limitations of each option are discussed below.

Off-Site Commercial Hazardous Waste Landfill: Within the state of New York one authorized hazardous waste landfill is permitted to receive PCB-contaminated wastes (Chemical Waste Management's SCA Model City landfill). However, the NYSDEC has placed a 2 percent hazardous organics limit for landfilling wastes within the state. Some of the recent analytical results exceed the total organics limit. Additionally, dioxin-wastes are not being landfilled in the state. Even though only trace levels of a few dioxin isomers were detected, the presence of dioxin may be enough to prohibit land disposal.

The wastes are also subject to the RCRA Land Disposal Prohibitions promulgated by the federal government. Following a detailed waste characterization of the Gill Creek sediment, it is possible that the material would be prohibited from landfilling. Although case-by-case extensions of landfill restrictions can be granted by the EPA, the applicant must demonstrate that an effort has been made to locate alternate treatment, recovery, or disposal facilities nationwide.

Interim On-Site Storage: Should a sediment treatment technology be selected which is still in the testing and evaluation stage or without sufficient existing capacity, it will be necessary to temporarily stage (store) the creek sediments on-site. Use of an interim storage facility allows for the contaminants to be removed and isolated from the environment while details on ultimate treatment and disposal are being developed. Unlike the commercial landfill, the liability remains on-site until a permanent solution is ultimately addressed.

It is anticipated that an interim storage facility could be situated on existing nearby industrial property. The contaminated sediment would be loaded into storage containers and staged within a one-story warehouse-type building. The storage containers would be above ground and easily monitored for integrity. Once a treatment technology has been selected, the treatment facility could be constructed at the storage area (if an on-site solution is selected) or the storage containers could be transported to a commercial off-site facility.

As defined by federal land disposal regulations (40 CFR 268.50), interim storage would likely require RCRA permitting. However, the NYSDEC has preliminarily indicated that a permit exemption is possible for the interim storage option. The primary objective of interim storage is a fast track removal of the contaminated sediments while ultimate disposal is determined. Should this option require a lengthy permitting process, the overall effectiveness and desirability would be diminished.

6.4 FORMULATION OF REMEDIAL ALTERNATIVES

The remedial technologies identified as most feasible in the technology screening process are assembled into complete site specific alternatives in this section. The remedial alternatives are classified into two groups of response actions:

- Source Containment
- Source Removal

Two alternatives are presented addressing source containment and six alternatives for source removal (Table 6-6). No action and related response actions were determined to be environmentally unacceptable during development of the remedial action objective and are therefore not given further consideration in this section. Although a larger number of potential alternative combinations are possible given the list of most feasible technologies (see Table 6-5), the eight alternatives presented below were judged to best address the remedial objective.

6.4.1 SOURCE CONTAINMENT ACTIONS

The two containment alternatives presented involve leaving the majority of the contaminated sediments in place and covering them with a combination fabriform concrete cap and 60 ml Hypalon liner. The schematic cross sections of cap placement design is illustrated in Figure 6-3. The cap would encompass the area requiring remediation illustrated in Figure 6-1. The limited sediment excavation proposed in the two containment alternatives involves removal of a shot rock bar which has accumulated at the mouth of Gill Creek. This coarse grained material has been apparently eroded from the rip rap fill along the Niagara River, pushed downstream and partially across the creek mouth during ice movement in the river. This material is not anticipated to be heavily contaminated and is therefore assumed suitable for disposed at a commercial landfill. The bar material needs to be removed so that the toe of the capping system can be properly anchored.

As the two containment alternatives leave a majority of the contaminated sediments in place, a significant operational component of these alternatives involves routine monitoring and maintenance. Annual monitoring and maintenance would be necessary to systematically evaluate the performance and condition of the containment device. An annual sampling program of surface water, groundwater, sediments, and biota in the vicinity of Gill Creek would be necessary to monitor containment performance. In addition, the cap would require annual inspection to assess integrity of the containment device and need for repair or replacement.

Alternative 1A - Fabriform Cap, Limited Sediment Removal (Hydraulic Dredging, No Temporary Dams), Monitoring: This alternative involves removal of the bar material using a low-turbidity dredging operation. Sediment removal would be accomplished without installation of any temporary dams. Following the limited excavation, the composite fabriform/Hypalon liner would be emplaced over the remaining contaminated sediments as described in Section 6.3.1.

Alternative 1B - Fabriform Cap, Limited Sediment Removal (Mechanical Excavation with Downstream Dam), Monitoring: This alternative is similar to Alternative 1A except for the proposed method of limited sediment removal. Alternative 1B requires the installation of a temporary dam across the mouth of Gill Creek and diversion of creek and outfall flow. A cross-section of the temporary dam design is illustrated in Figure 6-4. The shot rock bar will be excavated using a watertight clam shell bucket loader in a partially dewatered creekbed. Following Excavation, the cap system will be emplaced in the partially dewatered creekbed and the rock-fill dam removed.

6.4.2 SOURCE REMOVAL ACTIONS

Six remedial alternatives presented below involve removal of contaminated sediments from Gill Creek followed by treatment and/or disposal. Two alternatives involve sediment disposal (landfill/interim storage), two alternatives include incineration, and the final two alternatives combine several emerging and innovative sediment treatment technologies.

The area of sediment removal is the same for all six alternatives (Figure 6-1). Utilizing the average vibracore recovery depths obtained during the sampling program, a volume of 3200 cubic yards or 3600 tons is estimated. Adding a rough estimate of 500 tons for the shot rock bar a total estimate of 4100 tons is obtained.

Mechanical excavation in combination with upstream and downstream dam installation, creek and outfall diversion, and water treatment was determined to be the preferred approach for complete sediment removal. This sediment removal strategy is described in Section 6.3.2.

Mechanical excavation was selected over dredging techniques based on several deciding factors. First, working in a dewatered creek bed allows for better control in sediment removal and verification sampling . Also, any residual contamination left within the excavated area will be isolated from the environment with the compacted clay backfill. The compacted clay will extend up the bank (where exposed) to a point above the high-water line. Therefore, excavation of the stream bank will not be necessary. Emplacement of clay following dredging would not be possible due to the wet creek conditions. Finally, mechanical excavation was determined to be best suited to handle the variable particle sized material present (clay-to cobble-size). Dredging is not compatible with larger sized material.

Performance of all excavation work would require significant planning and implementation of Health and Safety procedures. It is likely that all personnel will require respiratory protection while working in the excavation. Strict air monitoring at the site perimeter would be required to ensure public safety. If elevated airborne contaminant concentrations are detected beyond the exclusion zone, containment measures may need to be implemented (i.e., construction of a temporary domed work area) or access restrictions to the RMP.

Alternative 2 - Excavation, Off-Site Commercial Landfill Disposal: This alternative involves the disposal of all excavated sediment at a commercial hazardous waste landfill. The waste would be loaded in bulk form into lined trucks for transport. The sediment would require an intermediate solidification step prior to transport to assure landfill acceptance.

Landfilling options at the one PCB landfill facility within New York State has been excluded from consideration because of NYSDEC landfill restrictions (2 percent organics limit, PCDD prohibition). Out-of-state landfill options can not be ruled out, however, it is likely that an exemption from RCRA land disposal prohibitions would be necessary.

Alternative 3 - Excavation, On-Site Interim Storage: This alternative provides for temporary storage of contaminated sediments while a commercial capacity for waste treatment is developed. With this option, the sediment would be excavated and transferred to bulk storage containers. The storage containers would then be stored in a warehouse to be constructed at a suitable location in the area.

Alternative 4 - Excavation, Off-Site Incineration: This alternative involves loading excavated sediment into reconditioned steel drums or combustible containers for shipment to a commercial hazardous waste incinerator facility. The alternative may require temporary staging of waste prior to delivery to the incinerator. Four incinerator facilities in the United States are permitted for PCB-waste incineration. Special permitting may be required to accept wastes with low levels of PCDD/PCDF. One facility (Rollins Environmental, Deer Park, Texas) is currently in the permitting process for treatment of dioxin wastes. The commercial facility handles the waste from incineration through ash stabilization and disposal.

Alternative 5 - Excavation, On-Site Incineration: This alternative involves staging a mobile rotary kiln incinerator on-site or at a nearby industrial facility owned by Du Pont/Olin. The on-site approach would require operational and air emission permitting by the NYSDEC consisting of test burns and public hearings. Emissions control, monitoring, ash stabilization, and ash and air cleaner residue disposal would be necessary.

Alternative 6 - Excavation, Organic Extraction, Incineration: The key element within this alternative is the application of an emerging sediment treatment technology, organic extraction. For the purposes of the preliminary feasibility study the Basic Extraction Sludge Treatment (BEST) process by Resource Conservation Corporation, was selected to represent this treatment category because it appears to be one of the more thoroughly field tested extraction processes. The primary benefit of organic extraction is that it greatly reduces the total waste volume requiring further organic treatment. This treatment technique would likely require RCRA permitting.

The waste treatment scheme for this alternative is illustrated in Figure 6-5. Following excavation, the sediment would be screened and all material gravel-sized and larger would be transported in reconditioned steel drums or combustible containers off-site to a commercial incinerator. The fine-grained fraction would feed into the on-site organic extraction process. Three waste streams would exit the organic extraction process; water, solids, and concentrated organics. The contaminated water would be processed in the on-site water treatment facility required to handle water from the creek dewatering. Solids would be stabilized or fixed as necessary to immobilize metals present and disposed of in a commercial landfill. The organic liquid concentrate (approximately 3 percent of the original sediment volume) would be drummed and transported to a commercial incinerator for final destruction. The same incineration limitations associated with Alternative 4 would also apply here.

Alternative 7 - Excavation, Organic Extraction, Dechlorination: This alternative is similar to alternative 6 except for final treatment of the organic liquid extracted from the contaminated sediment. In Alternative 7, the organic concentrate would be subjected to a chlorine removal process (sodium- or potassium polyethylene glycolate-based). All chlorinated organics would be dechlorinated to a form suitable for stabilization and disposal in a commercial landfill.

6.5 REMEDIAL ALTERNATIVES EVALUATION AND SUMMARY

6.5.1 TECHNICAL EVALUATION CRITERIA

The technical feasibility of each alternative was evaluated based on performance, reliability, and implementability. The technical performance of an alternative was evaluated in the degree to which the solution prevents or minimizes exposure to the public or environment and how long the solution will be effective. Reliability addresses the operation and maintenance requirements for the alternative as well as the performance record of the chosen technology. Finally, implementability evaluates the ease and time requirements with which the alternative can be initiated and summarizes potential problems that may be encountered. Table 6-7 summarizes the evaluation of the various technical criteria. A discussion of performance, reliability, and implementability for the various alternatives follows below.

Technical performance of the source removal alternatives (2 through 7) is generally more effective than the containment options (1A, 1B). Although the containment options address the most significant contaminant migration pathway (surface water), they may not adequately mitigate impact on groundwater. In addition, containment strategies will be effective for a finite length of time. The actual service life of the containment structure will be determined by the ability of the system to resist the extreme weather conditions anticipated. Conversely, sediment removal should permanently remove the contaminant source.

Alternatives utilizing any form of sediment disposal or storage (1A, 1B, 2, 3) do not mitigate the liability of the waste. Assuming off-site incineration could not be implemented in a rapid time schedule, of all the disposal options, interim on-site storage (3) yields the most favorable performance because the waste liability remains on-site until a permanent sediment treatment solution can be implemented. The sediment treatment alternatives (4, 5, 6, 7) are the most effective approaches from a performance standpoint because the objective of these solutions is to remove and destroy/treat the contaminants.

The reliability of the containment and source removal alternatives is similar. Capping and source removal are both proven technologies successfully applied in numerous other remediations. Implementation of either of the containment alternatives will require long-term monitoring of sediment, surface water, groundwater, and biota. Periodic inspection and maintenance will also be required to ensure cap integrity. The reliability of the alternatives incorporating incineration as the primary treatment technology (4, 5) are proven. However, on-site incineration will require a waste specific test burn to verify compatibility with the waste. The alternatives utilizing organic extraction or dechlorination (6, 7) are new technologies that are relatively unproven. These innovative technologies will require significant testing and evaluation to demonstrate reliability prior to implementation.

Factors affecting implementability are different for containment versus source removal alternatives. The source removal alternatives are significantly more complex than the containment alternatives simply because of the numerous additional aspects of the project that follow source removal: sediment handling, possible interim storage, ultimate treatment/disposal, and permitting. Additionally, the actual sediment excavation phase of the source removal alternatives has more potential obstacles to implementation than a containment approach. Implementation of containment in Gill Creek would be a relatively straightforward process. Because the cap would be emplaced over the contaminated sediments in a submerged creekbed, very little short term exposure or release of contaminants to the environment or community would be anticipated. Worker exposure during construction would also be expected to be relatively low. In contrast, source removal, which will proceed in a dewatered creekbed, will have a high potential for contaminant exposure/release during sediment excavation and handling given the elevated levels of volatile organics in the sediment. Also, actual creek dewatering may be complicated by excessive groundwater recharge (greater than the capacity of the on-site water treatment equipment), particularly in the very porous "shot rock" fill areas adjacent to the RMP. In order to properly implement the source removal action, a program will have to be designed to 1) effectively monitor the work area and vicinity and address possible contingency actions that may be necessary to contain or reduce short term contaminant releases, and 2) address contingencies to control physical aspects of sediment removal (excessive groundwater recharge, sediment water content).

Several examples of contingency items which may be required during sediment excavation are presented below. If during excavation the air monitoring program should determine that excessive volatilization of organic contaminants is occurring, measures would need to be implemented to reduce the potential exposure. One option would be to enclose the creekbed in a domed work area to contain volatile emissions and treat air discharged to the atmosphere. The enclosure would reduce exposure to the community, however, would likely increase the exposure within the work area. Another option would involve a compartmentalized approach to dewatering and excavation of the creekbed. Only small portions of the creekbed would be dewatered at one time, reducing the volume of contaminated sediments exposed to the atmosphere. The compartmentalized approached may also be necessary if excessive groundwater infiltration becomes a problem. A final contingency option would involve imposing access restrictions to the RMP during excavation. Each of these contingencies, if implemented, would add to the overall project cost and time schedule.

Sediment disposal alternatives may encounter implementability problems concerning conflicts with current state and federal land disposal restrictions. Due to the nature of the waste, there is a low probability that the sediment could be disposed of at a commercial landfill without a variance on land ban restrictions from the EPA. The interim storage alternative will also be implemented only after regulatory acceptance on a state and possibly federal level. Should RCRA permitting be required for interim storage, this alternative would become difficult to implement on a fast tracked time schedule.

Alternatives employing treatment of the sediment will have special requirements prior to implementation. Off-site commercial incineration (4) may require additional permits (for low levels of PCDD/PCDF) to handle the waste. On-site mobile incineration (5) will require extensive permitting and test burn evaluation. The innovative treatment alternatives (6, 7) will require treatability testing and evaluation to assure compatibility of the treatment process and waste stream and to obtain the necessary regulatory permits.

Implementation time requirements vary significantly between alternatives (Figure 6-6). Differences in implementation time are directly related to the degree of regulatory permitting, treatability evaluation, and public acceptance for each of the alternatives. The containment alternatives (1A, 1B) and off-site landfill disposal (2) could be implemented within a one to two year period. These "fast track" alternatives, assuming regulatory approval, should have minimum permit requirements (creek channel modification). Interim storage (3) could be implemented within the one to three year schedule, but only if RCRA permit is not required for the storage facility. Should the RCRA permit be required, interim storage could take an additional one to two years. The off-site incineration alternative (4) should require one to three years to implement. However, this alternative is totally dependent on commercial capacity to handle the waste. The remaining alternatives, on-site incineration (5) and organic extraction (6, 7) will require a greater level of testing and evaluation and permitting. The additional regulatory requirements reflect the increased implementation time (4 to 5 years).

6.5.2 ENVIRONMENTAL EVALUATION CRITERIA

Potential environmental impacts of each alternative both in long-term and short-term (construction) effects are summarized in Table 6-8. All of the alternatives should effectively mitigate the primary contaminant transport pathway present under no action conditions; sediment to surface water via resuspension and desorption. The source removal action alternatives (2 through 7) have the most positive environmental long-term impact because the source of contamination is removed. As a result, contaminant loading to surface water and groundwater are reduced or eliminated. The source containment alternatives address the primary migration pathway but may not be effective in completely mitigating impact on groundwater; also, long-term monitoring would be required to insure continued containment integrity.

Negative short-term environmental impact involving air quality during construction will be more significant for source removal versus containment alternatives. Air quality in the vicinity of the site may be adversely impacted during dewatering, excavation, and material handling activities in the source removal alternatives due to volatilization of contaminants from the exposed sediment. Potential worker exposure to contaminant volatilization can be effectively mitigated through use of proper respiratory protection. However, contaminant emissions could significantly impact air quality in the vicinity of the work area. Such potential short-term effects to the community will necessitate special contingencies to mitigate this impact.

The potential exists for some adverse short-term environmental impact associated with each proposed alternative during implementation. With both the source removal and source containment strategies, some release of resuspended sediment during remediation is anticipated. All alternatives involving mechanical excavation attempt to mitigate releases of suspended sediment through the water diversion and creek dewatering. The limited hydraulic dredging proposed in containment Alternative 1A probably represents the greatest risk for short-term release of contaminated sediment.

Each of the alternatives which require on-site treatment or storage (3, 5, 6, 7) will have additional short-term risks (beyond sediment excavation) associated with the greater waste handling and processing requirements. Similarly, alternatives associated with off-site disposal or treatment (2, 4) contain short-term risks to the community associated with the transport of waste materials to the TSD facility.

6.5.3 PRELIMINARY COST EVALUATION

Preliminary cost estimates for the two containment alternatives and six source removal alternatives are summarized in Table 6-9. The estimates were prepared using standard cost estimating techniques, quotations from subcontractors and vendors, and engineering experience. The estimates are preliminary in nature and are only intended to serve as a common reference for this economic evaluation. These costs can be used as a starting point for additional feasibility analyses or preliminary design. Major assumptions made in developing the cost estimate are summarized in Table 6-10.

As summarized in Table 6-9, containment alternatives 1A and 1B have the lowest capital costs, $1.8 and 2.3 million, respectively. Source removal/disposal Alternative 2 is estimated at $3.6 million (commercial landfill) and has the lowest capital costs of all the source removal alternatives. Alternative 3 (interim storage) is estimated at $3.1 million, however this cost does not take into account the final treatment/disposal costs of the waste. The excavation/incineration Alternatives 4 and 5 have the highest capital costs ($9.8 and 7.8 million, respectively). Excavation/innovative treatment Alternatives 6 and 7 are estimated to have a total capital cost of $5.9 million.

The estimated annual operation and maintenance costs vary significantly between containment and source removal alternatives. The source removal alternatives with the exception of Alternative 3 (interim storage), have limited O & M requirements. The only costs anticipated with source removal options are from a single sampling event of surface water and biota following remediation. Alternative 3 (interim storage) will require a more detailed program of inspection, monitoring, and maintenance during the storage facilities limited operational life. O & M requirements for the containment alternatives are more extensive than for source removal. Monitoring and maintenance will be required for the complete 30 year operational life of the containment device. As part of the monitoring program, shallow monitoring wells will be installed and groundwater, surface water, biota, and sediment when present will be sampled on an annual basis. In addition, integrity of the containment device will be evaluated during an annual inspection. It has been assumed that given the extreme environment in which the containment device will operate, some replacement and repair will be required periodically. For the purpose of this cost estimate it has been assumed that a portion of the cap will be replaced once every three years. O & M costs for the containment alternatives are estimated at $94,000 the first year and $78,000 for the next 29 years for a present worth value of $825,000.

Despite the significant O & M cost difference between containment ($825,000) and source removal ($50,000 to 300,000) alternatives, the high containment alternative O & M costs are not significant enough to alter the initial ranking of capital costs (Table 6-9).

6.5.4 SUMMARY

Eight remedial alternatives have been developed and evaluated based on their ability to satisfy the remedial action objective - to prevent, eliminate, or minimize migration of organic and inorganic contaminants from creek sediments to surface water and groundwater. The ability to satisfy this objective along with technical feasibility, environmental impact, and economic feasibility have been incorporated into the analysis. Table 6-11 presents costs, and major positive and negative features of each alternative or alternative group. Figure 6-7 summarizes the remedial alternatives and states implementation limitations for each.

Containment alternative (1B) displays obvious advantages in terms of ease of implementation, implementation schedule, minimal environmental impact during remediation activities and cost ($3.1 million). However, there are several negative performance factors associated with this alternative. First, although containment addresses the primary contaminant migration pathway (sediment to surface water), the impact of groundwater may not be totally mitigated. The quantitative impact on groundwater would have to be determined through long-term monitoring and the need for additional remedial measures determined. In addition, the containment remediation would have a finite effective duration and would require regular inspection and maintenance to ensure integrity.

The source removal alternative response actions (Alternatives 2 through 7) more thoroughly address the remedial objective for surface water and groundwater. However, significant adverse short-term environmental impacts would be experienced during a source removal remediation (sediment re-suspension, excessive contaminant volatilization). These short-term contaminant releases could potentially impact worker exposure as well as exposure to the community and environment. Potential exposure to the public is particularly significant considering the proximity of the area to be remediated to the RMP. Given the relatively small size of the area to be remediated, these adverse effects could be mitigated by taking various precautions and establishing contingencies to deal with exposure reduction (domed work area, compartmentalized excavation, continuous air monitoring, RMP access restrictions).

Ultimate treatment or disposal is the primary concern associated with the source removal alternatives. Commercial landfilling of the waste is one of the least expensive options. However, land disposal restrictions currently in effect and restrictions to be imposed in July 1989 make the implementation of this alternative difficult. A waste characterization of the Gill Creek sediments should be performed by potential waste acceptors and appropriate regulatory agencies to obtain a final determination on landfill acceptance. On-site incineration (Alternative 5) is an extremely costly option which also may have potential problems associated with permitting and public acceptance. There may be difficulty locating commercial off-site incineration capacity (Alternative 4) to handle the waste (due to low levels of PCDD/PCDF), although one incineration firm is currently pursuing a permit to handle dioxin and furan contaminated waste. The innovative treatment alternatives (6, 7), although less costly than incineration, are not ready for immediate implementation as they are relatively unproven treatment technologies. These techniques will require significant testing and evaluation prior to full scale use on Gill Creek sediments.

It is evident that there is presently a limited off-site commercial capacity to handle treatment and/or disposal of sediment from Gill Creek. Application of off-site incineration may be difficult due to the presence of low levels of PCDD/PCDF. Similarly, without an exemption from federal land disposal regulations, it is unlikely that commercial landfilling would be viable. All on-site treatment alternatives will require a lengthy time period for treatment testing and evaluation and permitting. If a selected source removal/treatment alternative was not able to be implemented in a reasonable time period, some form of interim storage may be required until capacity for the selected treatment/disposal approach can be developed. The one clear advantage of interim storage is that the contaminated sediment can be removed from the environment while still working on the development of the ultimate treatment technique. However, should RCRA permitting be required for implementing interim storage, the implementation schedule is significantly lengthened and the effectiveness of the alternative diminished.

A containment strategy (Alternative 1B) also allows for a rapid implementation schedule and would not likely be subject to the extensive permitting process which interim storage may require. Most regulatory agencies give preference to remedial alternatives which offer permanent remedies such as the source removal/treatment alternatives over traditional containment or control approaches. However, there are often situations in which a permanent solution is not practicable. Although source removal/treatment options effectively address the remedial action objective, the potential for adverse short-term environmental impacts during remediation and lack of present capacity for waste treatment/disposal suggest that containment is also a viable solution.

7.0 CONCLUSIONS

1. Based on the environmental assessment, contaminated sediments within the previously unremediated section of Gill Creek (Areas 2, 3, and 4) are recommended for remediation to comply with accepted regulatory guidelines.

2. Creek remediation is not recommended to extend into the river beyond sample location 5-1G, the apparent extent of historic sediment desposition. Remediation is not recommended for the nearshore area of the Niagara River downstream of Gill Creek due to the lower levels of contamination and overall paucity of significant sediment accumulation within the river. The recommended upstream limit of remediation within Gill Creek is Staub Road. This upstream limit of remediation includes a portion of the previously remediated area so that the limited amount of re-deposition that has occurred in this area since 1981 can be included in the current remediation effort.

3. Remedial alternatives which incorporate source removal and sediment treatment or disposal were determined to more effectively address the remedial action objective than source containment strategies. However, these source removal alternatives have serious disadvantages as summarized below. Although the containment alternatives address the primary contaminant migration pathway (sediment to surface water), these remedial actions may

not totally mitigate the impact to groundwater and require long term monitoring. The quantitative impact on groundwater would have to be determined through long-term monitoring.

A significant limiting factor with a majority of the source removal alternatives is the ultimate treatment and/or disposal of the sediment. There is a lack of capacity for handling wastes such as the Gill Creek sediment in landfilling, incineration, or innovative treatment technologies. Land disposal prohibitions may prevent disposal of untreated waste in a commercial landfill. It is not known whether off-site incineration can handle the mixture of organic and inorganic compounds and, in addition, extensive permitting and test burns would be required for the on-site option. Other innovative treatment options are available but are not proven technologies and would, therefore, require significant testing and evaluation prior to implementation. Additionally, there are potentially significant adverse short-term environmental impacts associated with a source removal that could put the community at risk during remediation. These risks are less significant with a containment approach.

In summary, the physical containment of creek sediments in place and the excavation/treatment/disposal of creek sediments are both feasible remedial alternatives. Both options adequately address the remedial action objectives: to prevent or mitigate the transport of contaminants from the source (sediments) to receptors. The containment alternative can be implemented over a relatively short time schedule, which is a distinct advantage for this alternative. It is possible that some of the excavation/treatment/disposal alternatives could be implemented within a similar schedule, assuming regulatory approval and acceptance of the wastes by commercial disposal or incineration facilities can be obtained on a timely basis. However, should land disposal restrictions make landfilling non-feasible or the waste require a permit variance for off-site incineration, the time schedule for a sediment treatment/disposal approach would be lengthened significantly. As a result, some form of interim storage might be necessary while a capacity for final sediment treatment/disposal is developed. However, interim storage would only be viable as a short-time schedule alternative if a RCRA permit is not required for the storage facility. If RCRA permiting were required, the increased time requirements would essentially eliminate any advantage of the interim storage alternative.

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TABLE 3-1

ANALYTICAL SCOPE OF WORK
GILL CREEK SEDIMENT STUDY

1. **Hazardous Substance List** - 11 sediment samples

   Method 8240 Volatiles
   Method 8270 Semi-volatiles
   Method 8080 Pesticides/PCB's
   Method 7000 Series (AA Inorganics)
   Percent Moisture Content
   Total Volatile Solids

2. **Site-Specific Compound List** - 62 sediment samples

   Method 8080 Pesticide/PCB's
   Method 8120 Chlorinated Hydrocarbons
   Method 7471 Mercury
   Method 8020 Monochlorobenzene
   Percent Moisture Content
   Total Volatile Solids

3. **Dioxins/Furans** - 8 sediment samples

   Method 8280 - Polychlorinated dibenzo-p-dioxins (PCDD) and Polychlorinated dibenzofurans (PCDF) with quantification of specific 2,3,7,8 congeners.

4. **Elutriate Procedure** - 5 sediment and 5 water samples

   A. Five surface water samples analysed for Site-Specific Compound List.

   B. Surface water and sediment mixed in Elutriate procedure and analysed for Site-Specific Compound List.

TABLE 3-2

HAZARDOUS SUBSTANCE LIST COMPOUNDS
GILL GREEK SEDIMENT STUDY

VOLATILES
(METHOD 8240)

Chloromethane
Bromomethane
Vinyl chloride
Chloroethane
Methylene chloride
Acetone
Carbon disulfide
1,1-Dichloroethene
1,1-Dichloroethane
trans-1-2-Dichloroethene
Chloroform
1,2-Dichloroethane
2-Butanone
1,1,1-Trichloroethane
Carbon tetrachloride
Vinyl acetate
Bromodichloromethane
1,1,2,2-Tetrachloroethane
1,2-Dichloropropane
trans-1,3-Dichloropropene
Trichloroethene
Dibromochloromethane
1,1,2-Trichloroethane
Benzene
cis-1,3-Dichloropropene
2-Chloroethyl vinyl ether
Bromoform
2-Hexanone
4-Methyl-2-pentanone
Tetrachloroethene
Toluene
Chlorobenzene
Ethyl benzene
Styrene
Total xylenes

ACID AND BASE/NEUTRAL EXTRACTABLES
(METHOD 8270)

N-Nitrosodimethylamine
Phenol
Aniline
bis(2-Chloroethyl)ether
2-Chlorophenol
1,3-Dichlorobenzene
1,4-Dichlorobenzene
Benzyl alcohol
1,2-Dichlorobenzene
2-Methylphenol
bis(2-Chloroisopropyl)ether
4-Methylphenol
N-Nitroso-dipropylamine
Hexachloroethane
Nitrobenzene
Isophorone
Acenaphthene
2,4-Dinitrophenol
4-Nitrophenol
Dibenzofuran
2,4-Dinitrotoluene
2,6-Dinitrotoluene
Diethyl phthalate
4-Chlorophenyl phenyl ether
Fluorene
4-Nitroaniline
4,6-Dinitro-2-methylphenol
N-nitrosodiphenylamine
4-Bromophenyl phenyl ether
Hexachlorobenzene
Pentachlorophenol
Phenanthrene

TABLE 3-2 (Continued)

ACID AND BASE/NEUTRAL EXTRACTABLES(continued)

- 2-Nitrophenol
- 2,4-Dimethylphenol
- Benzoic acid
- bis(2-Chloroethoxy)methane
- 2,4-Dichlorophenol
- 1,2,4-Trichlorobenzene
- Naphthalene
- 4-Chloroaniline
- Hexachlorobutadiene
- 4-Chloro-3-methylphenol
  (para-chloro-meta-cresol)
- 2-Methylnaphthalene
- Hexachlorocyclopentadiene
- 2,4,6-Trichlorophenol
- 2,4,5-Trichlorophenol
- 2-Chloronaphthalene
- 2-Nitroaniline
- Dimethyl phthalate
- Acenaphthylene
- 3-Nitroaniline
- Anthracene
- Di-n-butylphthalate
- Fluoranthene
- Benzidine
- Pyrene
- Butyl benzyl phthalate
- 3,3'-Dichlorobenzidine
- Benzo(a)anthracene
- bis(2-ethylhexyl)phthalate
- Chrysene
- Di-n-octyl phthalate
- Benzo(b)fluoranthene
- Benzo(k)fluoranthene
- Benzo(a)pyrene
- Indeno(1,2,3-cd)pyrene
- Dibenzo(a,h)anthracene
- Benzo(g,h,i)perylene

PESTICIDES/PCB'S
(METHOD 8080)

- alpha-BHC
- beta-BHC
- delta-BHC
- gamma-BHC (Lindane)
- Heptachlor
- Aldrin
- Heptachlor epoxide
- Endosulfan I
- Dieldrin
- 4,4'-DDE
- Endrin
- Endosulfan II
- 4,4'-DDD
- Endrin aldehyde
- Endosulfan sulfate
- 4,4'-DDT
- Methoxychlor
- Endrin ketone
- Chlordane
- Toxaphene
- PCB-1016
- PCB-1221
- PCB-1232
- PCB-1242
- PCB-1248
- PCB-1254
- PCB-1260

TABLE 3-2 (Continued)

METALS
(7000 SERIES)

- Aluminum
- Antimony
- Arsenic
- Barium
- Berylium
- Cadmium
- Calcium
- Chromium
- Cobalt
- Copper
- Iron
- Lead
- Magnesium
- Manganese
- Mercury
- Nickel
- Potassium
- Selenium
- Silver
- Sodium
- Thallium
- Tin
- Vanadium
- Zinc

TABLE 3-3

SAMPLE LOCATIONS
HAZARDOUS SUBSTANCE LIST
GILL CREEK SEDIMENT STUDY

Sample Number	Composites	Depth Interval (Inches)
1-T1-C	1-T1-1	0-6
	1-T1-2	0-6
	1-T1-3	0-6
1-T4-C	1-T4-1	0-6
	1-T4-2	0-6
	1-T4-3	0-6
2-T6-SC	2-T6-1S	0-6
	2-T6-2S	0-6
	2-T6-3S	0-6
2-T6-MC	2-T6-1M	18-30
	2-T6-2M	12-24
	2-T6-3M	6-13
3-T8-SC	3-T8-1S	0-6
	3-T8-2S	0-6
	3-T8-3S	0-6
3-T8-MC	3-T8-1M	22-34
	3-T8-2M	29-41
	3-T8-3M	22-34
4-T10-SC	4-T10-1S	0-6
	4-T10-2S	0-6
	4-T10-3S	0-6
4-T10-MC	4-T10-1M	18-30
	4-T10-2M	15-27
	4-T10-3M	18-30
5-4G	-	0-6
5-4G (Dup)	-	0-6
5-5G	-	0-6

TABLE 3-4

SITE-SPECIFIC COMPOUND LIST
GILL CREEK SEDIMENT STUDY

PESTICIDE/PCB'S (METHOD 8080)

alpha-BHC
beta-BHC
delta-BHC
gamma-BHC (Lindane)
Heptachlor
Aldrin
Heptachlor epoxide
Endosulfan I
Dieldrin
4,4'-DDE
Endrin
Endosulfan II
4,4'-DDD
Endrin aldehyde
Endosulfan sulfate
4,4'-DDT
Methoxychlor
Endrin ketone
Chlordane
Toxaphene
PCB-1016
PCB-1221
PCB-1232
PCB-1242
PCB-1248
PCB-1254
PCB-1260

CHLORINATED HYDROCARBONS (METHOD 8120)

Dichlorobenzenes
Trichlorobenzenes
Tetrachlorobenzenes
Pentachlorobenzene
Hexachlorobenzene
Hexachlorobutadiene

MERCURY (METHOD 7470)

MONOCHLOROBENZENE (METHOD 8010)

TABLE 3-5

SAMPLE LOCATIONS
DEPTH (INCHES)
SITE SPECIFIC COMPOUND LIST
GILL CREEK SEDIMENT STUDY

Sample Number	Shallow	Medium	Deep
1-T1-C	0-6	- -	- -
1-T2-C	0-6	- -	- -
1-T3-C	0-6	- -	- -
1-T4-C	0-6	- -	- -
2-T5-1	0-6	- -	16-28
2-T5-2	0-6	- -	18-30
2-T5-3	0-6	- -	6-17
2-T6-1	0-6	- -	30-42
2-T6-2	0-6	- -	12-24
2-T6-3	0-6	- -	6-13
3-T7-1	0-6	- -	30-42
3-T7-2	0-6	- -	19-31
3-T8-1	0-6	- -	22-34
3-T8-2	0-6	18-30	41-53
3-T8-3	0-6	- -	34-46
4-T9-1	0-6	18-30	38-50
4-T9-2	0-6	- -	30-42
4-T9-3	0-6	- -	8-20
4-T10-1	0-6	- -	18-30
4-T10-2	0-6	- -	27-39
4-T10-3	0-6	30-41	41-53
4-T11-1	0-6	18-30	36-48
4-T11-2	0-6	- -	24-36
4-T11-3	0-6	- -	30-42
5-1G	0-6	- -	- -
5-2G	0-6	- -	- -
5-3G	0-6	- -	- -
5-4G	0-6	- -	- -
5-5G	0-6	- -	- -
5-6G	0-6	- -	- -

TABLE 4-1

ANALYTICAL DATA SUMMARY
HAZARDOUS SUBSTANCE LIST
GILL CREEK SEDIMENT STUDY

Compound	Number of Samples Detected	Units	Highest Concentration	Sample Number
Cyanide	8	ug/g	7.98	(4-T10-MC)
Volatiles				
Acetone	4	ug/kg	81,000	(4-T10-SC)
Trans-1,2-Dichloroethene	8	ug/kg	2,300,000	(4-T10-MC)
MEK	7	ug/kg	330,000	(4-T10-MC)
Tetrachloroethene	7	ug/kg	11,600,000	(3-T8-MC)
Chlorobenzene	3	ug/kg	24,700	(4-T10-SC)
Vinyl Chloride	5	ug/kg	168,000	(4-T10-MC)
Methylene Chloride	4	ug/kg	8,980	(2-T6-MC)
Vinyl Acetate	1	ug/kg	10,500	(2-T6-SC)
Chloroform	3	ug/kg	6,400	(2-T6-SC)
1,1,1-Trichloroethane	3	ug/kg	21,000	(3-T8-MC)
Bromodichloroethane	1	ug/kg	12,000	(2-T6-SC)
Trichloroethene	6	ug/kg	3,460,000	(3-T8-SC)
1,1,1,2-Tetrachloroethane	3	ug/kg	181,000	(2-T6-SC)
1,1-Dichloroethene	1	ug/kg	11,800	(4-T10-MC)
O&P xylene	1	ug/kg	60.1	(5-4G)
Pesticide/PCB's				
a-BHC	5	ug/kg	440,000	(3-T8-SC)
b-BHC	1	ug/kg	10,200	(1-T4-SC)
PCB-1248	10	ug/kg	10,700,000	(2-T6-MC)
Base/Neutrals				
Bis(2-Ethylhexyl)phthalate	2	ug/kg	21,300	(3-T8-MC)
Phenanthrene	1	ug/kg	4,590	(1-T1-C)
Fluoranthene	1	ug/kg	4,660	(1-T1-C)
Hexachlorobutadiene	7	ug/kg	424,000	(3-T8-MC)
Hexachlorobenzene	6	ug/kg	84,600	(2-T6-MC)
Di-n-octyl-phthalate	2	ug/kg	5,220	(5-5G and 1-T1-C)
1,4-Dichlorobenzene	3	ug/kg	12,500	(4-T10-SC)
Hexachloroethane	3	ug/kg	449,000	(3-T8-MC)
1,2,4-Trichlorobenzene	4	ug/kg	21,700	(4-T10-SC)
1,2-Dichlorobenzene	1	ug/kg	7,260	(4-T10-SC)
Diethyl Phthalate	1	ug/kg	20,800	(5-4G)
Dimethyl Phthalate	2	ug/kg	10,000	(3-T8-MC)

TABLE 4-1
(continued)

Compound	Number of Samples Detected	Units	Highest Concentration	Sample Number
Metals				
Aluminum	10	ug/g	11,800	(1-T1-C)
Arsenic	10	ug/g	5.4	(4-T10-SC)
Barium	10	ug/g	572	(2-T6-SC)
Calcium	10	ug/g	206,000	(1-T1-C)
Chromium	10	ug/g	78	(4-T10-MC)
Copper	10	ug/g	493	(2-T6-MC)
Iron	10	ug/g	30,400	(4-T10-MC)
Lead	10	ug/g	267	(2-T6-MC)
Magnesium	10	ug/g	52,800	(1-T4-SC)
Manganese	10	ug/g	488	(5-4G)
Mercury	10	ug/g	60.1	(2-T6-MC)
Nickel	10	ug/g	62.7	(4-T10-MC)
Potassium	10	ug/g	1,540	(2-T6-MC)
Sodium	10	ug/g	381	(4-T10-SC)
Zinc	10	ug/g	1,690	(4-T10-SC)
Silver	10	ug/g	3.5	(3-T8-SC)
Cadmium	10	ug/g	1.6	(4-T10-SC)

TABLE 4-2

SEDIMENT CONCENTRATIONS
HAZARDOUS SUBSTANCE LIST METALS (PPM)
GILL CREEK SEDIMENT STUDY

Compound	Concentration Range	Concentration Mean	EPA Region V Classification
Aluminum	1900 - 11,800	4348	-
Antimony	-	< 2	-
Arsenic	1.5 - 7.6	2.9	< 3/3-8/> 8
Barium	26 - 572	178	< 20/20-60/> 60
Beryllium	-	< 0.5	-
Calcium	65,000 - 206,000	98,812	-
Cadmium	0.5 - 5.3	1.0	6
Chromium	7.2 - 78	35.6	< 25/25-75/> 75
Copper	9.1 - 493	88	< 25/25-50/> 50
Iron	7730 - 308,000	18,459	25,000
Lead	11 - 286	90	< 40/40-60/> 60
Magnesium	11,100 - 52,800	21,000	-
Manganese	171 - 488	320	500
Mercury	3.4 - 69	20	1
Nickel	11 - 63	28	50
Potassium	231 - 1730	758	-
Selenium	-	0.2	-
Silver	1 - 6.6	2.1	-
Sodium	74 - 381	195	-
Thallium	-	< 38	-
Tin	-	< 1	-
Vanadium	-	< 38	-
Zinc	56 - 2170	535	< 90/90-200/> 200

TABLE 4-3

ANALYTICAL DATA SUMMARY PCDD'S AND PCDF'S GILL CREEK SEDIMENT STUDY

Compound	1-T4-SC	2-T6-SC	2-T6-MC	3-T8-SC	3-T8-MC	3-T8-MC Dup	4-T10-SC	4-T10-MC
TCDF, Total	0.121	2.380	3.190	8.790	1.040	1.440	3.740	2.330
TCDD, Total	0.018	0.022	0.011	0.127	0.012	ND	0.186	0.018
PeCDF, Total	0.159	1.810	2.540	5.910	0.749	1.180	2.670	1.760
PeCDD, Total	0.020	0.031	ND	ND	0.050	ND	0.263	ND
HxCDF, Total	0.298	0.880	1.080	3.970	0.360	1.060	2.600	0.675
HxCDD, Total	0.230	0.322	0.289	1.990	0.287	0.367	2.330	0.493
HpCDF, Total	0.222	1.050	1.300	2.950	0.695	0.763	0.021	0.832
HpCDD, Total	0.708	0.790	1.250	3.500	0.942	0.798	ND	1.100
2378-TCDF	0.026	0.665	1.080	2.300	0.304	0.391	1.030	0.890
Other TCDF	0.095	1.715	2.110	6.490	0.736	1.049	2.710	1.440
2378-TCDD	ND	ND	ND	ND	ND	ND	ND	ND
Other TCDD	0.018	0.022	0.011	0.127	0.012	0.000	0.186	0.018
12378-PeCDF	0.008	0.012	0.166	0.541	0.008	0.013	0.073	0.012
23478-PeCDF	0.010	0.108	0.159	0.694	0.089	0.138	0.376	0.252
Other PeCDF	0.141	1.690	2.215	4.675	0.652	1.029	2.221	1.496
12378-PeCDD	ND	ND	ND	ND	ND	ND	ND	ND
Other PeCDD	0.020	0.031	0.000	0.000	0.050	0.000	0.263	ND
123478-HxCDF	0.170	0.310	0.493	1.660	0.239	0.373	0.908	0.266
123678-HxCDF	ND	0.057	ND	ND	ND	0.045	0.137	0.045
234678-HxCDF	0.003	ND	0.044	0.151	ND	0.040	0.065	0.037
123789-HxCDF	0.016	0.053	0.074	0.233	0.034	0.065	0.107	ND
Other HxCDF	0.125	0.514	0.543	2.159	0.121	0.602	1.491	0.328
123478-HxCDD	ND	ND	0.024	ND	ND	ND	ND	ND
123678-HxCDD	0.057	0.091	0.109	0.958	0.103	0.162	0.948	0.091
123789-HxCDD	0.038	0.039	0.048	0.229	0.046	0.073	0.241	0.047
Other HxCDD	0.135	0.192	0.108	0.803	0.138	0.132	1.141	0.355
1234678-HpCDF	0.153	0.492	0.629	1.520	0.337	0.336	0.567	0.427
1234789-HpCDF	0.044	0.091	0.135	0.345	0.081	0.094	0.105	0.076
Other HpCDF	0.025	0.467	0.536	1.085	0.277	0.333	ND	0.329
1234678-HpCDD	0.495	0.541	0.873	2.310	0.665	0.776	1.850	0.764
Other HpCDD	0.213	0.249	0.377	1.190	0.277	0.022	ND	0.336
2378-TCDD Toxic Equivalents*								
USEPA Method	0.012	0.094	0.160	0.442	0.052	0.073	0.223	0.130

* The toxic equivalent for a sample is the sum of the homolog or isomer concentration times the corresponding multiplication factor.

Concentrations in ng/g (ppb).

TABLE 4-3 (Continued)

TOTAL 2,3,7,8-TCDD
TOXIC EQUIVALENTS CALCULATION

Compound	Toxic Equivalent Factor USEPA Method
2378-TCDD	1
Other TCDDs	0.01
2378-PeCDDs	0.5
Other PeCDDs	0.005
2378-HxCDDs	0.04
Other HxCDDs	0.004
2378-HpCDDs	0.001
Other HpCDDs	0.00001
OCDD	-
2378-TCDF	0.1
Other TCDFs	0.001
2378-PeCDF	0.1
Other PeCDF	0.001
2378-HxCDF	0.01
Other HxCDF	0.0001
2378-HpCDF	0.001
Other HpCDF	0.00001
OCDF	-

TABLE 4-4

ANALYTICAL DATA SUMMARY
SITE SPECIFIC COMPOUND LIST
GILL CREEK SEDIMENT STUDY

Compound	Number of Samples Detected	Units	Highest Concentration	Sample Number
Mercury	62	ug/g	274	(4-T10-3M)
Chorobenzene	57	ug/kg	37,600	(4-T10-2D)
a-BHC	59	ug/kg	313,000	(4-T9-1S)
b-BHC	52	ug/kg	142,000	(4-T9-1D)
g-BHC	6	ug/kg	10,600	(4-T11-1M)
PCB-1248	58	ug/kg	8,340,000	(3-T7-2D DUP)
1,2-Dichlorobenzene	11	ug/kg	30,900	(4-T10-1S)
1,3-Dichlorobenzene	2	ug/kg	12,600	(3-T8-2D)
1,4-Dichlorobenzene	24	ug/kg	41,000	(4-T10-1S)
1,2,3-Trichlorobenzene	24	ug/kg	23,700	(4-T10-1S)
1,2,4-Trichlorobenzene	44	ug/kg	390,000	(3-T7-2D)
1,2,4,5-Tetrachlorobenzene	14	ug/kg	10,800	(4-T10-2S)
1,2,3,4-Tetrachlorobenzene	2	ug/kg	7,500	(4-T10-2S)
Pentachlorobenzene	27	ug/kg	33,900	(3-T7-1S)
Hexachlorobenzene	50	ug/kg	580,000	(3-T7-1S)
Hexachloroethane	17	ug/kg	1,260,000	(3-T7-2D)
Hexachlorobutadiene	52	ug/kg	1,740,000	(3-T7-2D DUP)

TABLE 4-5

SITE-SPECIFIC COMPOUND LIST
CONTAMINANT AVERAGES (PPB)
GILL CREEK SEDIMENT STUDY

Compound	(Area 1) Previous Remediated Area	(Areas 2, 3, 4) Unremediated Area			(Area 5) Niagara River
	Shallow	Shallow	Medium	Deep	Shallow
Mercury (ppm)	40	36	117	18	31
Chlorobenzene	148	5,389	6,163	6,494	31
a-BHC	1,104	44,616	57,899	57,066	3,512
b-BHC	581	18,682	14,482	21,855	1,829
g-BHC	356	12,619	17,064	13,802	1,326
PCB-1248	8,267	1,464,570	3,282,781	903,080	29,065
1,2-Dichlorobenzene	ND (8,000)	5,513	2,263	8,323	6,268
1,3-Dichlorobenzene	ND (8,000)	3,272	2,134	1,798	3,435
1,4-Dichlorobenzene	ND (8,000)	8,796	4,890	4,760	3,659
1,2,3-Trichlorobenzene	ND (8,000)	7,510	5,003	6,429	5,298
1,2,4-Trichlorobenzene	6,427	18,940	14,916	18,723	8,462
1,2,4,5-Tetrachlorobenzene	ND (8,000)	6,615	3,141	3,293	3,292
1,2,3,4-Tetrachlorobenzene	ND (8,000)	3,816	1,774	1,898	3,881
Pentachlorobenzene	ND (8,000)	5,690	7,809	7,474	ND (8,000)
Hexachlorobenzene	ND (8,000)	77,636	105,130	43,495	7,502
Hexachloroethane	ND (8,000)	12,747	39,486	14,893	ND (8,000)
Hexachlorobutadiene	4,600	204,912	278,159	179,356	7,813

ND (8000) - Not Detected (Detection Limit)

TABLE 4-6

ANALYTICAL DATA SUMMARY
ELUTRIATE TEST RESULTS
GILL CREEK SEDIMENT STUDY

GILL CREEK SURFACE WATER

Compound	Units	1-2E	2-2E	3-2E	4-2E	5-1E
Mercury	ug/l	0.642	0.495	ND (0.2)	ND (0.2)	0.544
Chlorobenzene	ug/l	ND (2)	ND (2)	ND (2)	ND (2)	ND (2)
a-BHC	ug/l	0.42	1.26	0.69	0.29	0.083
b-BHC	ug/l	0.091	0.056	ND (0.05)	0.071	1.08
g-BHC	ug/l	ND (0.05)	ND (0.05)	ND (0.05)	ND (0.05)	ND (0.05)
d-BHC	ug/l	ND (0.05)	ND (0.05)	0.05	0.05	ND (0.05)
PCB-1248	ug/l	2.10	2.50	3.19	0.05	1.64
1,2,4-Trichlorobenzene	ug/l	ND (8)	ND (8)	ND (8)	ND (8)	1.0
Hexachlorobenzene	ug/l	ND (8)	ND (8)	ND (8)	ND (8)	2.4

ELUTRIATE WATER

Compound	Units	1-2E	2-2E	3-2E	4-2E	5-1E
Mercury	ug/l	ND (0.2)	ND (0.2)	ND (0.2)	ND (0.2)	0.622
Chlorobenzene*	ug/l	62.7	42.5	950	54.7	38.6
a-BHC	ug/l	352	1500	1380	1280	168
b-BHC	ug/l	58.4	20.3	172	161	62.9
g-BHC	ug/l	0.58	0.98	25	2.28	0.7
d-BHC	ug/l	ND (0.5)	ND (0.5)	1.72	ND (0.50)	ND (0.50)
PCB-1248	ug/l	ND (5)	5	ND (10)	81.3	ND (5)
1,3-Dichlorobenzene	ug/l	1.3	0.5	31.4	3.5	ND (8)
1,4-Dichlorobenzene	ug/l	3.2	1.4	204	25	3.4
1,2-Dichlorobenzene	ug/l	2.4	0.7	276	24.3	2.8
1,2,4-Trichlorobenzene	ug/l	1.7	ND (8)	109	11	1.6
1,2,3-Trichlorobenzene	ug/l	1.3	ND (8)	57.2	5.1	1.8
Hexachlorobutadiene	ug/l	ND (8)	63.5	52	21.6	9.6
1,2,4,5-Tetrachlorobenzene		ND (8)	ND (8)	2.6	ND (8)	ND (8)
1,2,3,4-Tetrachlorobenzene		ND (8)	ND (8)	2.8	ND (8)	ND (8)
Hexachlorobenzene		ND (8)	ND (8)	ND (16)	2.3	ND (8)

* Chlorobenzene analysis performed on TCLP extract.
ND (0.2) - Not Detected (Detection Limit)

TABLE 5-1
CONTAMINANT RANKING
GILL CREEK SEDIMENT STUDY

CHEMICAL	NUMBER DETECTS	NUMBER SAMPLES	HIGHEST CONC. (ug/Kg)	NYSDEC * STANDARD (ug/L)	INDICATOR RATING
Cyanide	8	10	7980	100	6.38400E1
VOLATILES					
Tetrachloroethene	7	10	11600000	.70	1.16000E7
Trichloroethene	6	10	3460000	3.00	6.92000E5
Vinyl Chloride	5	10	168000	.30	2.80000E5
1,1,2,2-Tetrachloroethane	3	10	181000	.20	2.71500E5
MEK	7	10	330000	3**	7.70000E4
trans 1,2 Dichloroethene	8	10	2300000	50	3.68000E4
Acetone	4	10	81000	1**	3.24000E4
1,1-Dichloroethene	1	10	11800	.07	1.68571E4
Chloroform	3	10	6400	.20	9.60000E3
Vinyl Acetate	1	10	10500	1**	1.05000E3
Chlorobenzene	60	72	24700	20.00	1.02916E3
1,1,1-Trichloroethane	3	10	21000	50	1.26000E2
Methylene Chloride	4	10	8980	50.00	7.18400E1
Bromodichloroethane	1	10	12000	50**	2.40000E1
Ortho and Para Xylene	1	10	60.1	50.00	1.2020E-1
PESTICIDE/PCB					
PCB-1248	68	72	10700000	.001	1.0105E10
a-BHC	64	72	440000	.01	3.91111E7
b-BHC	53	72	142000	.01	1.04527E7
g-BHC	6	72	10600	.01	8.83333E4
BASE/NEUTRALS					
Hexachlorobenzene	56	72	580000	.02	2.25555E7
Hexachlorobutadiene	59	72	1740000	.50	2.85166E6
Pentachlorobenzene	27	62	33900	.02**	7.38145E5
Hexachloroethane	20	72	1260000	2***	1.75000E5
1,2,4-Trichlorobenzene	48	72	390000	5	5.20000E4
bis(2-ethylhexyl)phthalate	2	10	21300	4	1.06500E3
1,2,3-Trichlorobenzene	24	62	23700	5	1.83483E3
1,4-Dichlorobenzene	24	62	41000	30	5.29032E2
Di-n-octyl-phthalate	2	10	5220	4**	2.61000E2
1,2,4,5-Tetrachlorobenzene	14	62	10800	10	2.43870E2
1,2-Dichlorobenzene	12	72	30900	30	1.71666E2
Diethyl Phthalate	1	10	20800	50	4.16000E1
Dimethyl Phthalate	2	10	10000	50	4.00000E1
1,2,3,4-Tetrachlorobenzene	2	62	7500	10	2.41935E1
1,3-Dichlorobenzene	2	62	12600	20	2.03225E1
Fluoranthene	1	10	4660	50	9.32000E0
Phenanthrene	1	10	4590	50	9.18000E0

TABLE 5-1 (Continued)
CONTAMINANT RANKING
GILL CREEK SEDIMENT STUDY

CHEMICAL	NUMBER DETECTS	NUMBER SAMPLES	HIGHEST CONC. (ug/Kg)	NYSDEC * STANDARD (ug/L)	INDICATOR RATING
METALS					
Mercury	72	72	274000	.2	1.37000E6
Aluminum	10	10	1.18000E7	100	1.18000E5
Iron	10	10	3.08000E7	300	1.02666E5
Nickel	10	10	63000	7.1	8.87323E3
Zinc	10	10	2170000	300	7.23333E3
Lead	10	10	286000	50	5.72000E3
Copper	10	10	493000	200	2.46500E3
Manganese	10	10	488000	300	1.62666E3
Chromium	10	10	78000	50	1.56000E3
Magnesium	10	10	5.28000E7	35000	1.50857E3
Barium	10	10	572000	1000	5.72000E2
Cadmium	10	10	5300.0	10	5.30000E2
Arsenic	10	10	7600.0	50	1.52000E2
Silver	10	10	6600	50	1.32000E2
Sodium	10	10	270000	non toxic	
Potassium	10	10	1000000	non toxic	
Calcium	10	10	89000000	non toxic	

NOTES:

* New York State Ambient Water Quality Standards for Drinking Water Supply, July 1985.

** Standard not available, NYSDEC Standard for similar compound used.

*** USEPA Ambient Water Quality Criteria for Protection of Human Health (USEPA, 1986).

TABLE 6-1

CONTAMINANTS DRIVING REMEDIATION GILL CREEK SEDIMENT STUDY

PCBs (AROCLOR 1248) (0.88 - 10,700 mg/kg)

HEXACHLOROBUTADIENE (Less than 2 - 424 mg/kg)

CHLOROBENZENE COMPOUNDS (Less than 6.6 - 126 mg/kg)
(MONO- through HEXA-)

VOLATILE ORGANICS (Les than 0.5 - 30,431 mg/kg)
(PCE, TCE, Trans-1,2-Dichloroethylene, Vinyl chloride)

HEXACHLOROCYCLOHEXANES (BHCs) (Less than 0.05 - 450 mg/kg)

MERCURY (3.2 - 274 mg/kg)

POLYCHLORINATED DIBENZO-P-DIOXINS/
POLYCHLORINATED DIBENZOFURANS
(Less than 1 PPB toxic equivalents,
USEPA Methodology)

TABLE 6-2

INITIAL SCREENING
REMEDIAL RESPONSE ACTIONS
GILL CREEK SEDIMENT STUDY

General Response Action	Implementability	Reduction of Toxicity/Mobility	Overall Effectiveness
No Action	Yes	No	Limited
Institutional Action	Yes	No	Limited
Insitu Treatment	Questionable	Questionable	Questionable
Containment	Yes	Yes	Short-term - Positive Long-term - Unknown
Source Removal/ Treatment	Yes	Yes	Positive

TABLE 6-3

SUMMARY OF POTENTIALLY FEASIBLE TECHNOLOGIES
GILL CREEK SEDIMENT STUDY

Remedial Category	Technology/Process Option
In Situ Treatment	Stabilization, Fixation, Vitrification
	Biological
Containment	Capping
	Re-Channelization
Sediment Removal	Mechanical Excavation
	Mechanical Dredging
	Hydraulic Dredging
	Pneumatic Dredging
Sediment Dewatering	Centrifuges
	Gravity Thickening
	Sedimentation, Flocculation
	Belt Filter Press
	Vacuum - Assisted Drying Beds
Water Treatment	Sedimentation
	Flocculation
	Carbon Adsorbtion
	Preciptitation
	Filtration
	Stripping
	Reverse Osmosis
	Ion Exchange
Sediment Treatment	Stabilization
	Fixation
	Solidification
	Thermal Destruction
	Thermal Desorption
	Pyrolysis
	Radient Energy
	Wet Air Oxidation
	Supercritical Water Oxidation
	Chemical Oxidants
	Ozonation
	Dechlorination
	Reducing Agents
	Neucleophillic Substitution
	Chlorinalysis
	Heated Air Stripping
	Organic Extraction
	Vitrification
	Microorganisms
Sediment Disposal	Hazardous Waste Landfill (untreated)

TABLE 6-4

REMEDIAL TECHNOLOGY AND PROCESS OPTIONS SCREENING
GILL CREEK SEDIMENT STUDY

General Response Actions	Remedial Technology	Process Options	Screening Comments
Insitu Treatment	Physical/Chemical Treatment	Stabilization/Fixation Solidification	High organics are a problem, low perm material prevents fixing at depth. Physical (space) constraints severely restrict treatment option.
		Vitrification	High water content makes cost prohibitive. Emerging technology is not proven on large scale. Presence of low boiling point organics offers off-gassing problem.
Containment	Cap	Clay Asphalt Concrete Multimedia Cap	Closing in place may not be accepted by regulators because of potential future contaminant migration.
	Re-Channelization	Culvert Installation Creek Diversion (permanent) Outfall Diversion (permanent)	
Source Removal/ Treatment	Sediment Removal	Mechanical Excavation/Creek Divsersion Mechanical Dredging Hydraulic Dredging Pneumatic Dredging	Mechanical excavation and hydraulic dredging appear to merit further consideration based on project requirements (low turbidity, minimal exposure).
	Sediment Dewatering	Centrifuges Gravity Thickening Sedimentation, Flocculation Belt Filter Press, Filter Press Vacuum-Assisted Drying Beds Drying or Dewatering Beds Solidification	This step may or may not be necessary depending on ultimate disposal of treatment option. This is a two-step process requiring a large handling area to deal with contaminated liquids and solids. Worker exposure during this phase may also be a problem. At this time, the belt filter press or solidification appears to be the best option, because the technology is proven and can be mobilized for field operation.
	Water Treatment	Sedimentation, Flocculation Adsorption, Carbon Precipitation, Filtration Stripping, Reverse Osmosis Ion Exchange	Most likely candidate process is a combination of sedimentation/ flocculation and carbon adsorption. Effluent discharge criteria would need to be established.

TABLE 6-4
(Continued)

General Response Actions	Remedial Technology	Process Options	Screening Comments
Source/Removal/ Treatment	Sediment Treatment (Physical/Chemical Stabilization/Solidification/Fixation	Cement-based	Not suitable for organic wastes. High organic content, silt and clay will increase setting time.
		Lime-based	Reported to be suited for PCBs. Volatiles might be a problem and would require treatability study.
		Thermoplastic (Asphalt-based)	High water content and volatile organics present a problem.
		Organic Polymer	Not Compatible.
		Self-cementing Techniques	Not Compatible.
		Surface Encapsulation	Not Compatible.
		Glassification	Not Compatible.
		Solidification	Process only solidifies sediments, does not immobilize contaminants.
	Thermal Destruction (Incineration)	Rotary Kiln Fluidized Bed	High heavy metals could pose problem. Ash may require stabilization prior to landfilling. Increased costs with high H_2O. Commercially available, proven technology.
	Thermal Desorption	Low Temperature Thermal Desorption with Afterburner	Removes volatiles only, leaves high boiling point organics and would require additional treatment.
	Pyrolysis	Advanced Electric Reactor	Requires homogeneous waste input, metals may be leachable from residue, not commercially available.
	Radient Energy	U/V Photolysis	Too long treatment time, not commercially available.
		Syntec Photolytic	Data available for dioxins but not PCBs, too long treatment time.
		Thermal Corona Glow	Destroys PCBs in gas stream. Has not been demonstrated to work for sediments.
		Microwave Plasma	High costs.
		RF Insitu Heating	Not feasible for submerged sediments.
	Chemical		
	Wet Air Oxidation	Uncatalyzed, General	Unacceptable efficiencies.
		Zimpro Process	Unacceptable efficiencies.
		Dow Chemical (Catalypsco)	Unacceptable efficiencies.
		IT Environmental Science	Unacceptable efficiencies.
	Supercritical Water Oxidation	Modar	Waste stream must be introduced as a slurry. Sophisticated equipment not demonstrated to be reliable. Developmental Stage only.

TABLE 6-4
(Continued)

General Response Actions	Remedial Technology	Process Options	Screening Comments
Source Removal/ Treatment (Cont'd.)	Chemical (Continued)		
	Chemical Oxidants	(Variety)	Potassium permanganate/chromic acid/ nitric acid, chloroiodides, ruthenium tetroxide. Partial degradation products may be toxic.
	Ozonation	GE UV/Ozonation	Unacceptable efficiencies for PCBs.
	Chlorine Removal		
	Dehydrochlorination	(Variety)	Not commercially available.
	Reducing Agents	(Variety)	Partial degradation products may be toxic.
	Nucleophilic Subst.	Sodium-based	Water content interferes with process.
		Potassium poly(ethyleneglycolate) based	Greater than 7% moisture requires excess heat and reagent.
	Chlorinalysis	(Variety)	High costs.
	Physical		
	Heated Air Stripping	American Toxics Disposal	Still in concept stage for PCB-contaminated sediments.
	Extraction	Critical Fluid Systems	Pilot-scale tests have been performed for PCB-contaminated sediments.
		Furfural	Ineffective with PCBs.
		Acurex Solvent Wash	Removed from devel. by manufacturer.
		OHM Extraction	Removed from devel. by manufacturer.
		Soilex Process	Non-candidate.
		Basic Extraction Sludge Treatment (BEST)	Applied to PCB oily wastes, ready for testing and evaluation.
		CFS Propane Extraction	Has been applied in pilot-scale tests.
	Vitrification	Battelle Vitrification	High water content increases costs greatly. Process may not be compatible with volatile compounds.
	Biological		
	Microorganisms	Bio-Clean Sybron Bi-Chem Composting	Bench and pilot treatability testing would be required to establish whether these processes are applicable.
	Sediment Disposal	Secure Landfill (Untreated)	Landfills will only accept hazardous wastes which at a minimum meet the "paint filter" test. Land ban restrictions may apply.
		Interim On-Site Storage	

TABLE 6-5

SUMMARY OF MOST FEASIBLE TECHNOLOGIES AND PROCESS OPTIONS
GILL CREEK SEDIMENT STUDY

Containment

Fabriform Concrete Cap with Hypalon Liner

Sediment Removal

Mechanical Excavation
Hydraulic Dredging

Creek Diversion

Upstream and Downstream Coffer Dams
Outfall Diversions

Water Treatment

On-Site Treatment System
(Sedimentation/fluocculation/carbon absorption)

Sediment Treatment

Solidification/Stabilization/Fixation
Organic Extraction
Nucleophillic Substitution

Thermal Destruction

Off-Site Commercial Incinerator
On-Site Mobile Rotary Kiln Incinerator

Sediment Disposal

Off-Site Commerical Hazardous Waste Landfill
On-Site Interim Storage

TABLE 6-6

FORMULATED REMEDIAL ALTERNATIVES GILL CREEK SEDIMENT STUDY

CONTAINMENT ACTIONS

Alternative 1A - Fabriform Cap, Limited Sediment Removal (Hydraulic Dredging, no Temporary Coffer Dams), Monitoring

Alternative 1B - Fabriform Cap, Limited Sediment Removal (Mechanical Excavation with Downstream Coffer Dam), Monitoring

SOURCE REMOVAL ACTIONS

Alternative 2 - Mechanical Excavation/Creek Dewatering, Off-Site Commercial Landfill Disposal

Alternative 3 - Mechanical Excavation/Creek Dewatering, On-Site Interim Storage

Alternative 4 - Mechanical Excavation/Creek Dewatering, Off-Site Incineration

Alternative 5 - Mechanical Excavation/Creek Dewatering, On-Site Incineration

Alternative 6 - Mechanical Excavation/Creek Dewatering, Organic Extraction/ Incineration

Alternative 7 - Mechanical Excavation/Creek Dewatering, Organic Extraction/ Dechlorination

TABLE 6-7

SUMMARY OF TECHNICAL CRITERIA
GILL CREEK SEDIMENT STUDY

Alternative	Performance	Reliability	Implementability
1A: Fabriform Cap, Limited Sediment Excavation (Dredging), monitoring	- Isolates contaminants from contact with surface water - Does not mitigate impact on groundwater - Approximate 30 year operation - Extreme weather conditions may effect duration of effective operation	- Would require long term (30 years) surface water and biomonitoring - Cap system will require periodic maintenance to prevent failure in adverse environment	- Limited worker exposure during cap placement - Possible release of contaminants during limited dredging activities - 1 to 2 years to implement
1B: Fabriform Cap, Limited Sediment Removal (mechanical excavation with dam placement), monitoring	- Same as 1A	Same as 1A	- Limited worker exposure during cap placement - Construction of downstream dam limits contaminant release potential observed in 1A - Same as 1A
2: Excavate, Off-Site Commercial Landfill Disposal	- Removes contaminant sources from creek - Does not eliminate liability for waste	- Analytical testing of excavations during remediation will help verify complete cleanup	- Potential high worker exposure - Volitilization of contaminants may require setting up temporary dome over work area - Dewatering creek reduces the potential for contaminant release - May not be feasible if land disposal restriction apply - 1 to 2 years to implement
3: Excavate, On-Site Interim Storage	- Removes contaminant source from creek - Keeps waste liability on-site until effective treatment capacity is available	- Same as 2 - Visual monitoring of interim storage containers to ensure continued integrity	- Same as 2 - Interim storage will require siting a suitable parcel of land for storage - Will require regulatory acceptance - 1 to 3 years to implement
4: Excavate, Off-Site Incineration	- Removes contaminant source from creek - Results in destruction of organic contaminants	- Same as 2 - Proven treatment technology	- Same as 2 - Scheduling adequate incineration capacity may lengthen clean-up schedule - 2 to 3 years to implement
5: Excavate, On-Site Incineration	- Same as 4	- Same as 4	- Permitting incinerator will be a lengthy process - Will most likely require interm storage of waste - May be difficult finding sufficient space requirements for facility - Responsible for ash disposal - 4 to 5 years to implement
6: Excavation, Organic Extraction, Incineration	- Same as 4	- Analytical testing of excavations during remediation will help verify complete clean-up - Relatively unproven technology, will require treatability studies to verify process compatibility	- Same as 2 - Testing and Evaluation of innovative treatment technology will extend remediation schedule - 4 to 5 years to implement
7: Excavation, Organic Extraction, Dechlorination	- Same as 4	- Same as 6	- Same as 6 - 4 to 5 years to implement

TABLE 6-8

SUMMARY OF ENVIRONMENTAL CRITERIA
GILL CREEK SEDIMENT STUDY

Alternative	Environmental Impact	
	Long Term	Short-Term (Construction)
Source Containment Actions (1A, 1B)	- Isolates source of contaminants from surface water - Does not mitigate contaminant loadings to groundwater	- Dredging alternative (1A) may result in release of contaminants during remediation - Insignificant air emmissions anticipated during construction
Source Removal Actions (2, 3, 4, 5, 6, 7)	- Removes source of contamination - Reduces or eliminates contaminant loadings to surface water and groundwater	- Some release of contaminated sediments to Niagara River during sediment removal - Potential for excessive contaminant emissions during creek dewatering and excavation - Possible contamination of temporary coffer dam construction materials
Actions Involving On-Site Storage or Treatment (3,5,6,7)	- Removes source of contamination - Reduces or eliminates contaminant loadings to surface water and groundwater	- Potential for exposure to public during interim storage or on-site treatment of sediment
Actions Involving Off-Site Dispoal or Treatment (2,4)	- Removes source of contamination - Reduces or eliminates contaminant loadings to surface water and groundwater	- Potential for exposure during transportation of waste to TSD facility

TABLE 6-9

ESTIMATED COSTS OF REMEDIAL ALTERNATIVES
GILL CREEK SEDIMENT STUDY

Item	ALTERNATIVES							
	1A	1B	2	3	4	5	6	7
Excavation Mobilization/ Demobilization	$ 50,000	$ 150,000	$ 150,000	$ 150,000	$ 150,000	$ 150,000	$ 150,000	$ 150,000
Health and Safety	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000	$ 25,000
Air Monitoring	$ 35,000	$ 35,000	$ 70,000	$ 70,000	$ 70,000	$ 100,000	$ 100,000	$ 100,000
Dam Construction & Removal	-	$ 476,000	$ 655,600	$ 655,600	$ 655,600	$ 655,600	$ 655,600	$ 655,600
Gill Creek Diversion	$ 44,500	$ 44,500	$ 44,500	$ 44,500	$ 44,500	$ 44,500	$ 44,500	$ 44,500
Outfalls 006 and 007 Diversion	$1,000,000	$ 1,000,000	$1,000,000	$1,000,000	$1,000,000	$1,000,000	$ 1,000,000	$ 1,000,000
Creek Dewatering and Water Treatment	-	$ 20,000	$ 230,400	$ 230,400	$ 230,400	$ 230,400	$ 230,400	$ 230,400
Sediment Removal and Disposal	$ 467,500	$ 467,500	$1,366,900	$ 54,900	$ 54,900	$ 874,900	$ 310,900	$ 310,900
Backfill Creek Bottom	-	-	$ 42,600	$ 42,600	$ 42,600	$ 42,600	$ 42,600	$ 42,600
Transportation	-	-	-	$ 60,000	$ 386,000	-	-	-
Interim Storage Facility	-	-	-	$ 375,000	-	-	-	-
Cap Placement	$ 149,000	$ 149,000	-	-	-	-	-	-
Off-Site Incineration	-	-	-	-	$7,114,000*	-	$ 2,650,000	$ 2,500,000
On-Site Incineration	-	-	-	-	-	$4,100,000**	-	-
Process Water Treatment	-	-	-	-	-	$ 50,000	$ 20,000	$ 20,000
Solids Stabilization	-	-	-	$ 300,000	-	$ 328,000	$ 102,000	$ 102,000
Treatability Studies	-	-	-	-	-	-	$ 100,000	$ 200,000
Organic Extraction	-	-	-	-	-	-	$ 409,000	$ 409,000
Dechlorination	-	-	-	-	-	-	-	$ 21,000
Permitting	-	-	-	$ 100,000	-	$ 250,000	$ 100,000	$ 100,00
TOTAL CAPITAL COST	$1,771,000	$ 2,267,000	$3,615,000	$3,108,000	$9,773,000	$7,851,000	$ 5,940,000	$ 5,911,000
Operation and Maintenance (Present Worth)	$ 825,000	$ 825,000	$ 50,000	$ 300,000	$ 50,000	$ 50,000	$ 50,000	$ 50,000
TOTAL COST	$2,596,000	$ 3,092,000	$3,665,000	$3,408,000	$9,823,000	$7,901,000	$ 5,990,000	$ 5,961,000

* Off-site incineration cost includes packaging of waste through final disposition (ash stabilization and disposal).

** On-site incineration cost includes mobilization and demobilization of equipment, utilities, operation, materials, and labor, and a test burn. Item does not include costs for ash stabilization and disposal, permitting, contingency or engineering.

TABLE 6-10

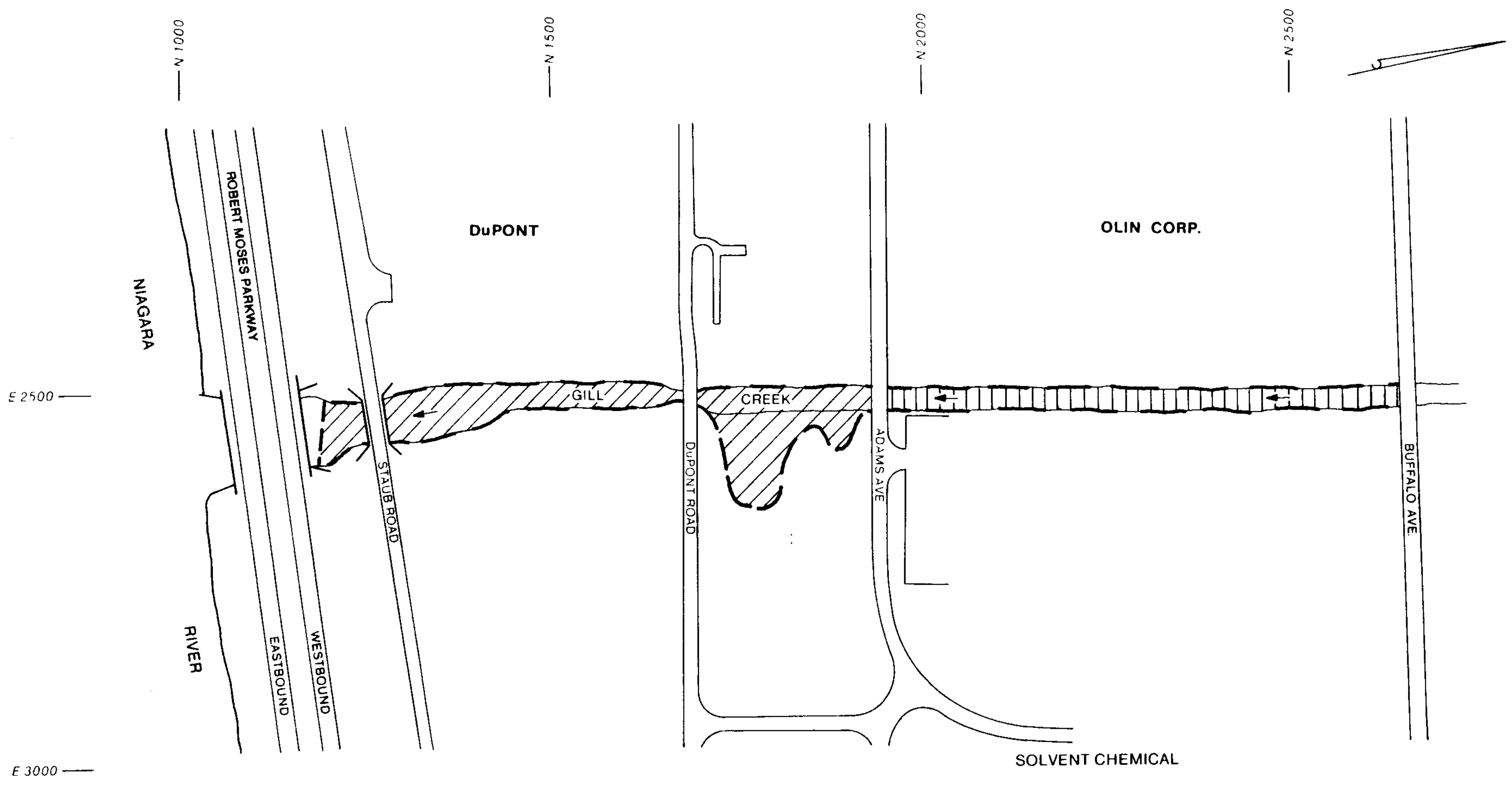
COST ESTIMATE ASSUMPTIONS
GILL CREEK SEDIMENT STUDY

- The area subject to containment was assessed to cover an area from 20 feet above Staub Road to 10 feet downstream of the Robert Moses Parkway wing walls, adjacent to the Niagara River (25,000 square feet).
- Mechanical excavation would be performed without any enclosure on the work area with susequent air treatment.
- The materials used to construct the coffer dams would not become contaminated and would not require disposal.
- Costs for the temporary diversion of the Niachlor outfall are based on an estimate provided by Du Pont.
- Assumes mechanical excavation could be peformed without extensive sectioning and continuous dewatering of the area. Following initial pumpdown, a constant dewatering rate of 100 gpm has been assumed for a period of three months.
- Sediment disposal costs based on October 1988 rate at Chemical Waste Managements Model City Facility.
- Off-site incineration costs obtained for Chemical Waste Managements SCA incinerator in Chicago.
- Mobile incinerator costs based on quotation from ENSCO operating a facility at Gill Creek or a nearby industrial property.
- Cost estimates for organic extraction and dechlorination treatment processes were obtained form Resource Conservation Corporation, and Galson Research, respectively. The actual treatment costs cannot be determined prior to testing and evaluation with Gill Creek sediment.

TABLE 6-11

REMEDIAL ALTERNATIVES SUMMARY
GILL CREEK SEDIMENT STUDY

Alternative	Estimated Total Cost	Positive Factors	Negative Factors
1A	$2.6 M	o Isolates contaminants from surface water o Minimizes exposure to workers during implementation	o Potential contaminant release during dredging o May not mitigate impact to groundwater o Limited effective life of option o May not be acceptable to regulatory agencies
1B	$3.1 M	o Same as 1A o Minimizes potential for contaminant release during limited sediment removal	o May not mitigate impact to groundwater o Limited operational life o May not be acceptable to regulatory agencies
2	$3.7 M	o Removes contaminant source	o Potential worker exposure during remediation o Landfilling does not eliminate liability and may not be possible due to land ban restrictions
3	$3.4 M	o Same as 2 o Keeps liability of waste on-site	o Potential worker exposure during remediation o Not a permanent solution
4	$9.8 M	o Removes contaminant source o Destroys organic contaminants o Proven technology	o Commercial facility will require additional permitting to handle the waste o Extensive transportation requirements
5	$7.8 M	Same as 4	o Permitting of on-site facility o May require interim storage of waste o Responsible for ash disposal o Low sediment volume makes option less economical
6	$6.0 M	o Removes contaminant source o Destroys organics contaminants	o Unproven technology o Responsible for pre-treated solids disposal
7	$6.0 M	Same as 6	o Based on two unproven technologies o Responsible for pre-treated solids disposal



LEGEND:

▨ DuPONT CREEK REMEDIATION AREA

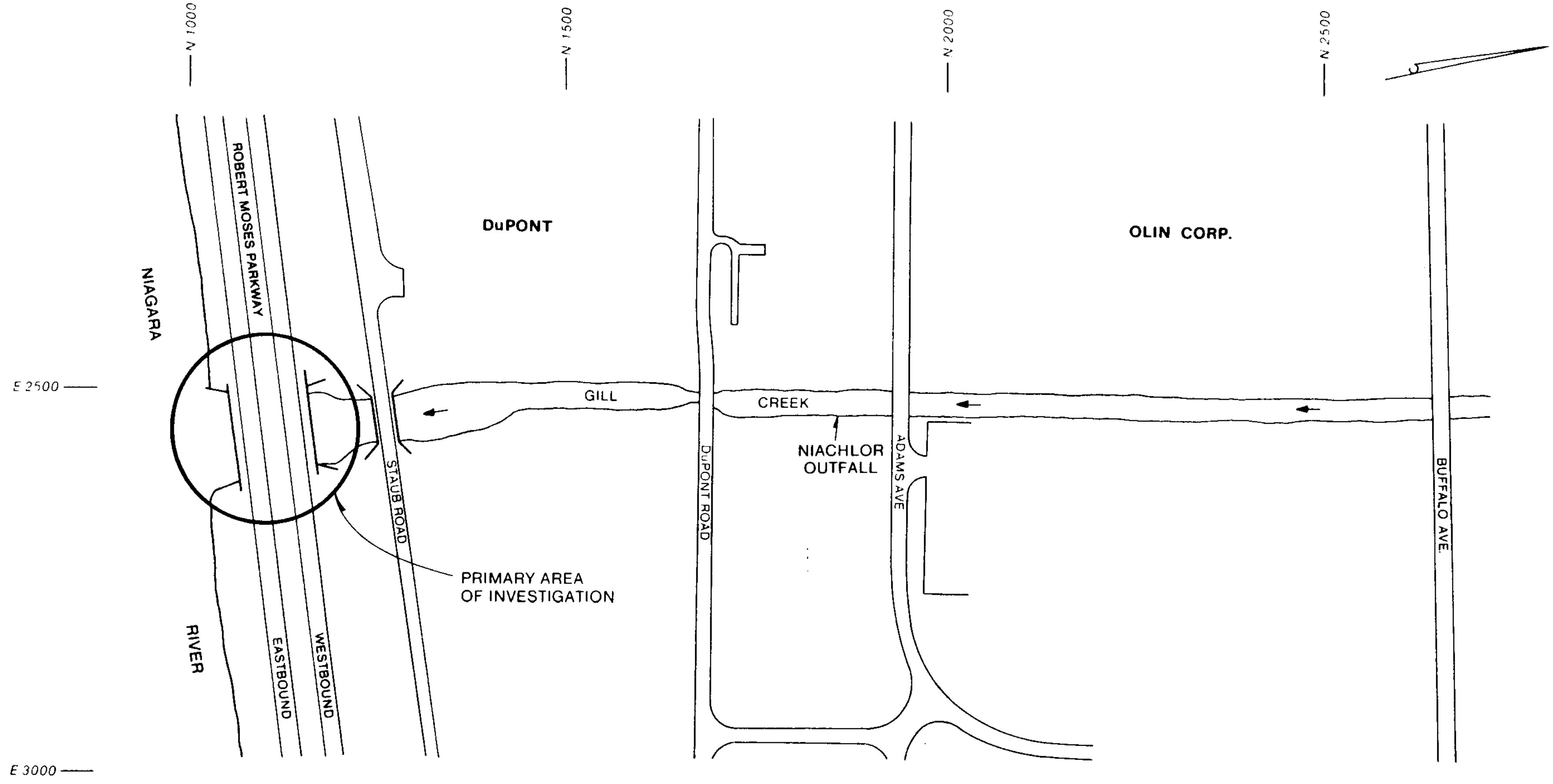
▥ OLIN CREEK REMEDIATION AREA

GILL CREEK REMEDIATION SUMMARY
NIAGARA FALLS, NEW YORK

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by J.C.	SCALE IN FEET 0 150	Date 1/5/89
Checked by R.G.		Job 88C2056-5

FIGURE 1-1

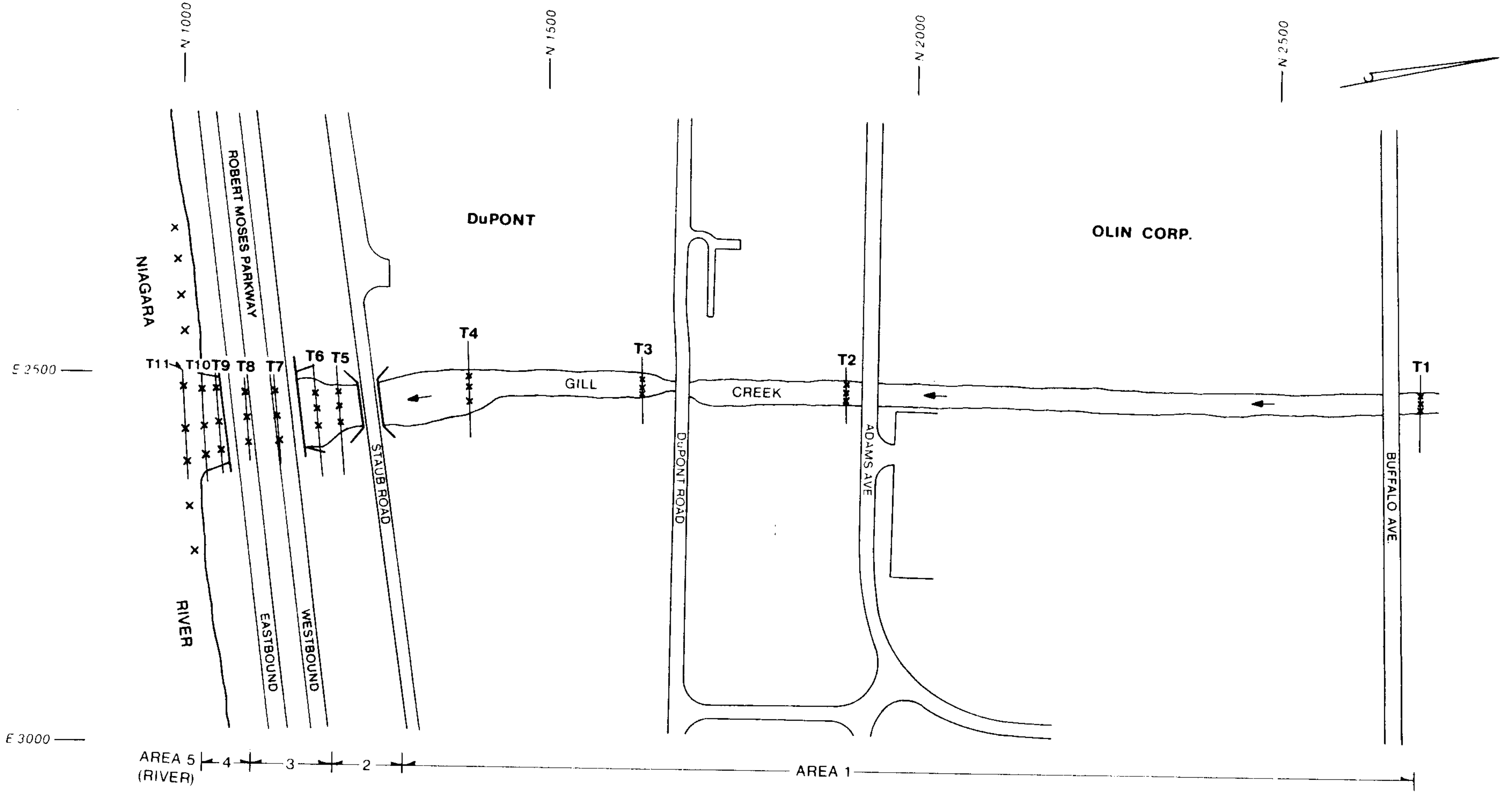


LOCATION PLAN
GILL CREEK SEDIMENT STUDY
NIAGARA FALLS, NEW YORK

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by J.C.	SCALE IN FEET 0 150	Date	1/5/89
Checked by R.G.		Job	88C2056-5

FIGURE 1-2



LEGEND

T1 — SAMPLING TRANSECT

× SEDIMENT SAMPLING LOCATION

SAMPLE LOCATION PLAN
GILL CREEK SEDIMENT STUDY
NIAGARA FALLS, NEW YORK

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Drawn by J.C.	SCALE IN FEET 0 150	Date	1/5/89
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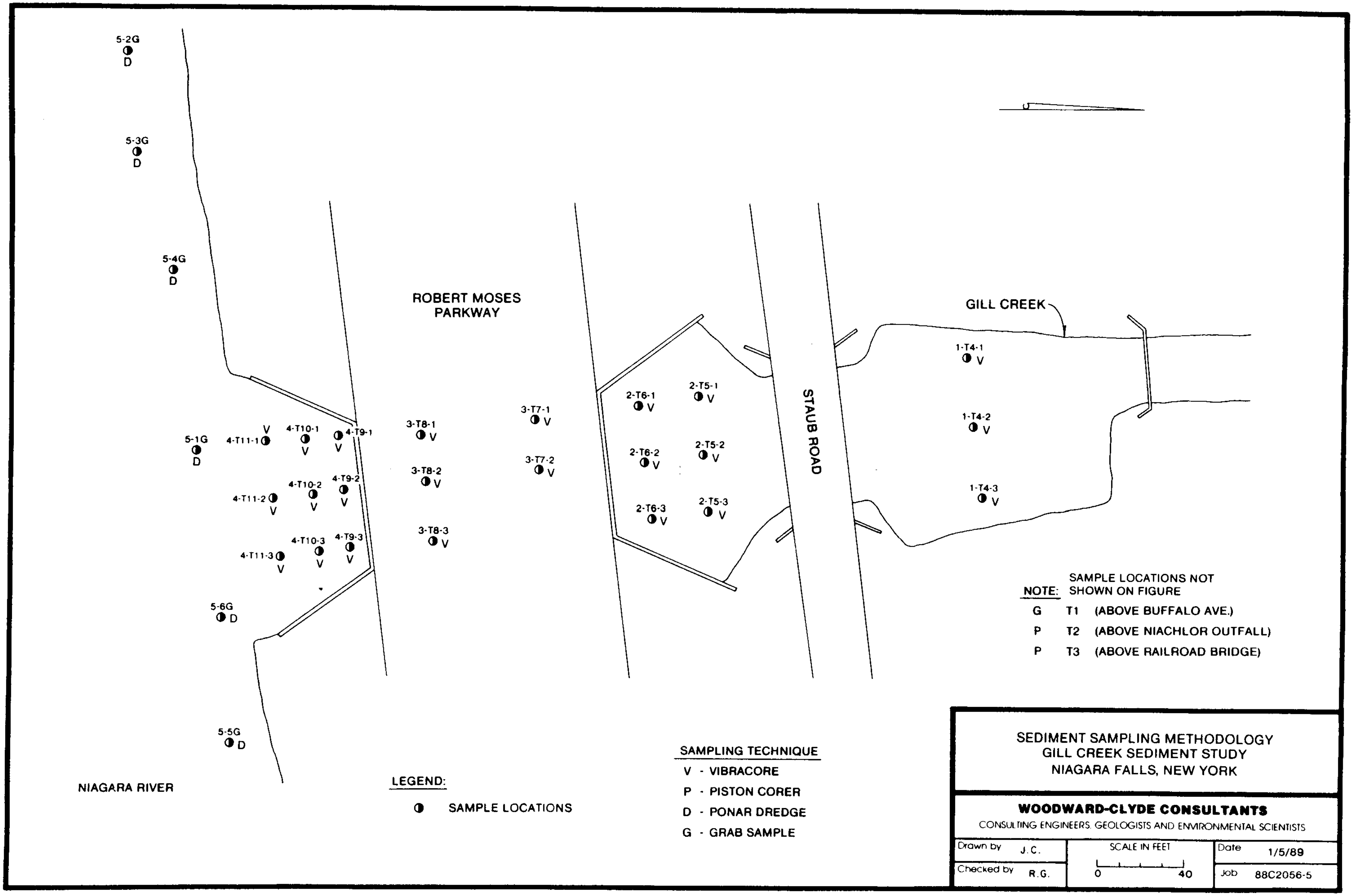
FIGURE 3-1



SEDIMENT SAMPLING METHODOLOGY
GILL CREEK SEDIMENT STUDY
NIAGARA FALLS, NEW YORK

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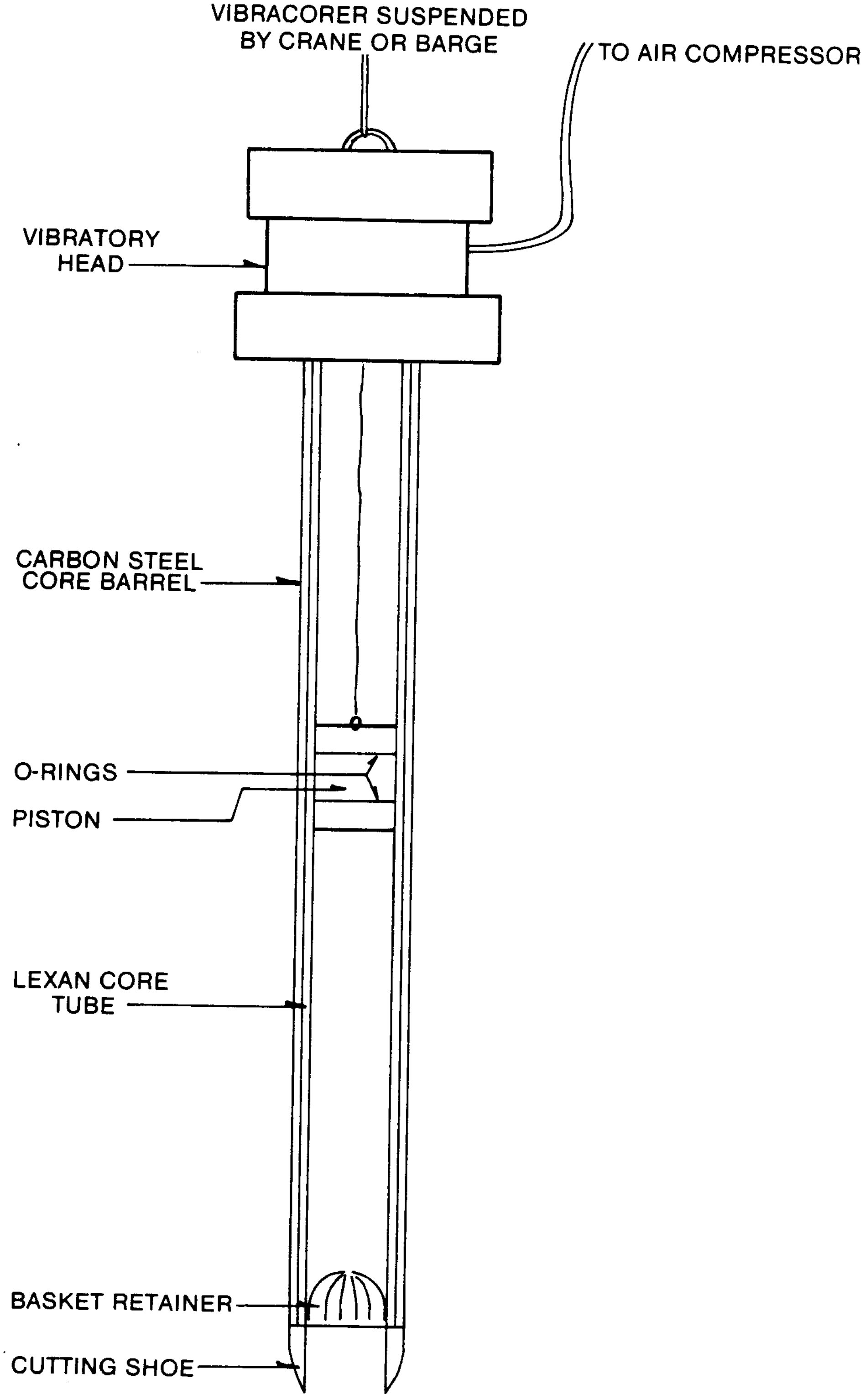
Drawn by	J.C.	Date	1/5/89
Checked by	R.G.	Job	88C2056-5

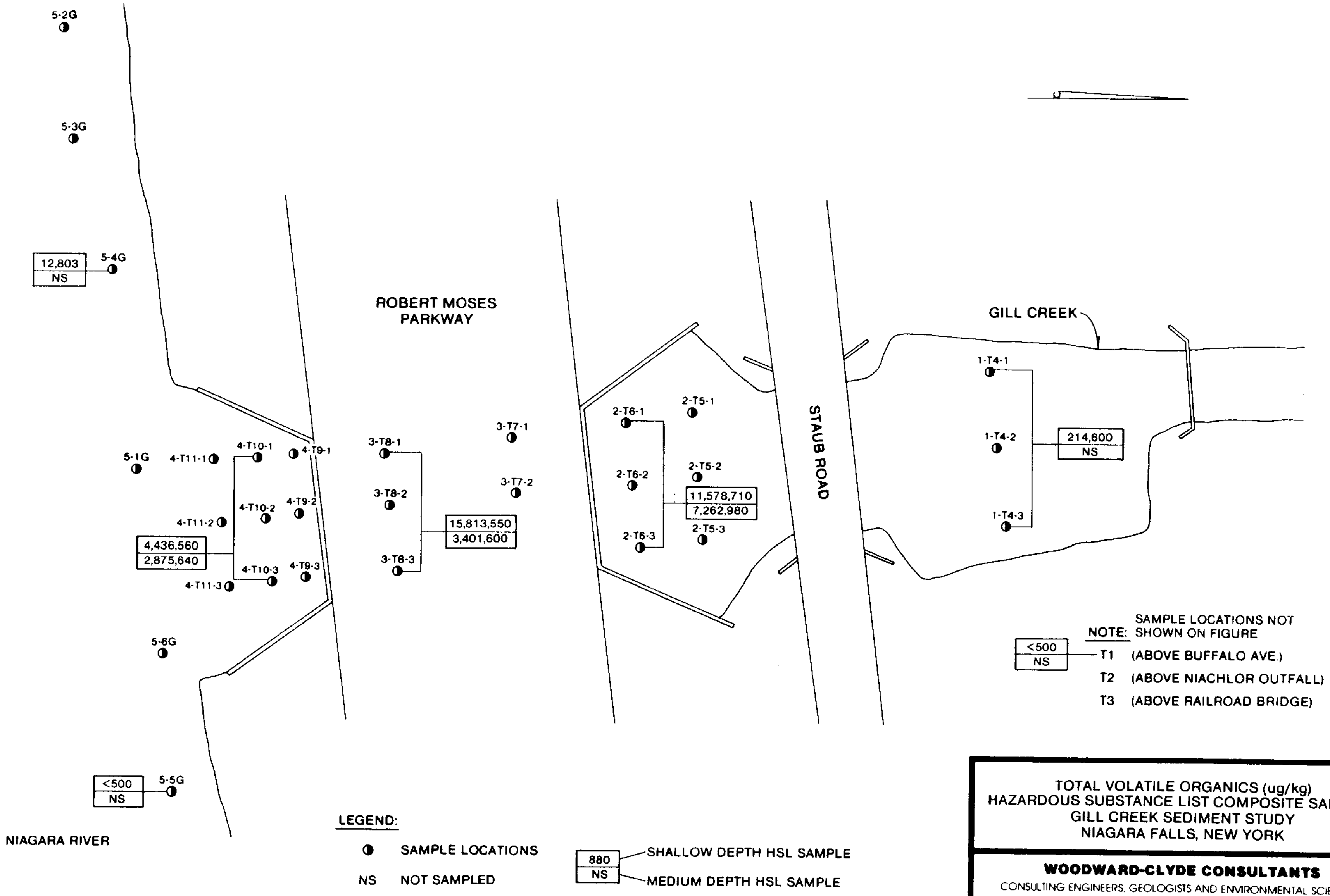
FIGURE 3-2



VIBRACORE DESCRIPTION
GILL CREEK SEDIMENT STUDY
NIAGARA FALLS, NEW YORK

Drawn by J.C.	SCALE IN FEET	Date. 1/5/89
Checked by R.G.	N.T.S.	Job 88C2056-5

FIGURE 3-3

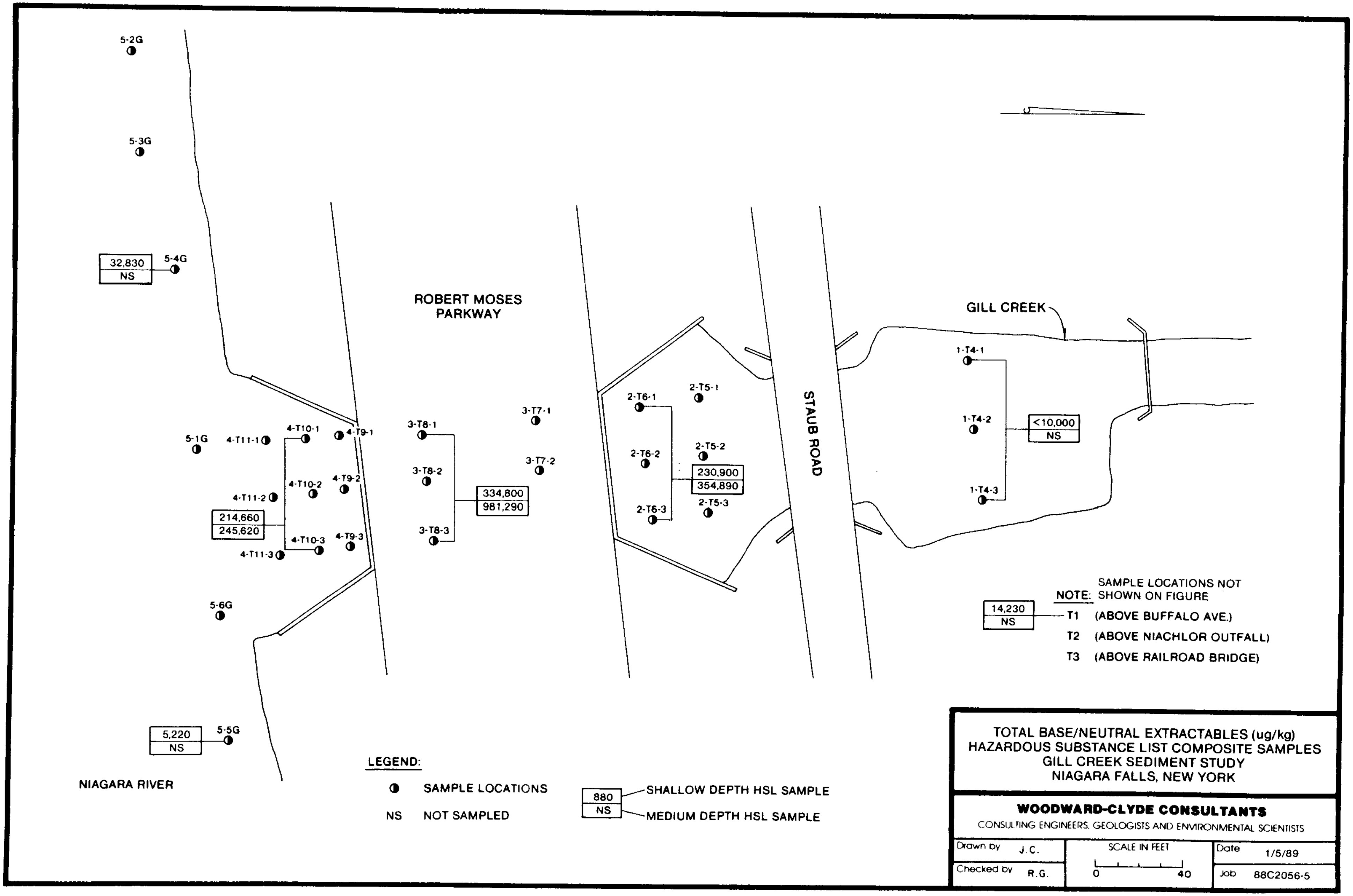


TOTAL VOLATILE ORGANICS (ug/kg)
HAZARDOUS SUBSTANCE LIST COMPOSITE SAMPLES
GILL CREEK SEDIMENT STUDY
NIAGARA FALLS, NEW YORK

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by J.C.	SCALE IN FEET 0 40	Date	1/5/89
Checked by R.G.		Job	88C2056-5

FIGURE 4-1

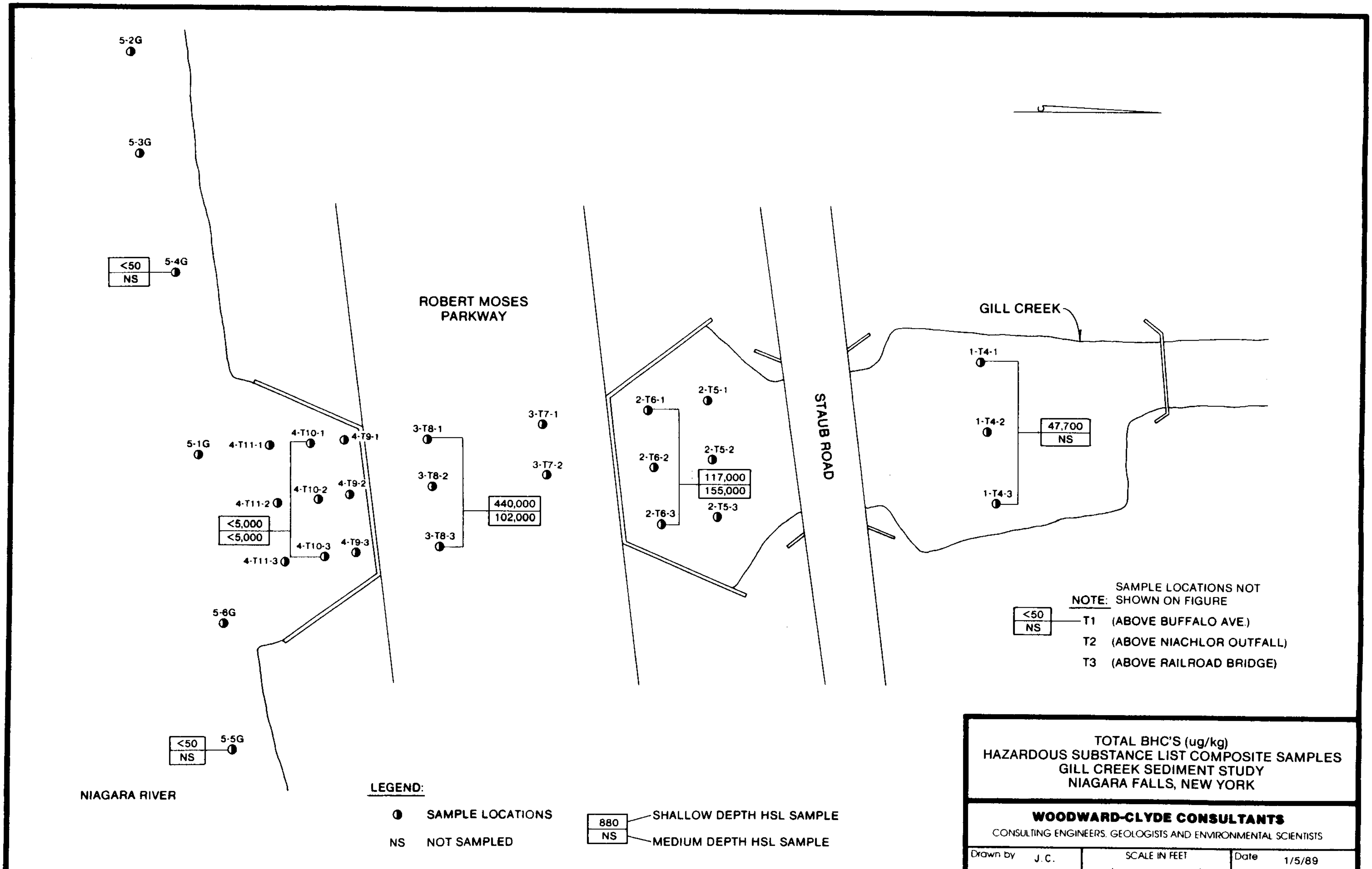


TOTAL BASE/NEUTRAL EXTRACTABLES (ug/kg)
HAZARDOUS SUBSTANCE LIST COMPOSITE SAMPLES
GILL CREEK SEDIMENT STUDY
NIAGARA FALLS, NEW YORK

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by J.C.	SCALE IN FEET	Date	1/5/89
Checked by R.G.	0 40	Job	88C2056-5

FIGURE 4-2

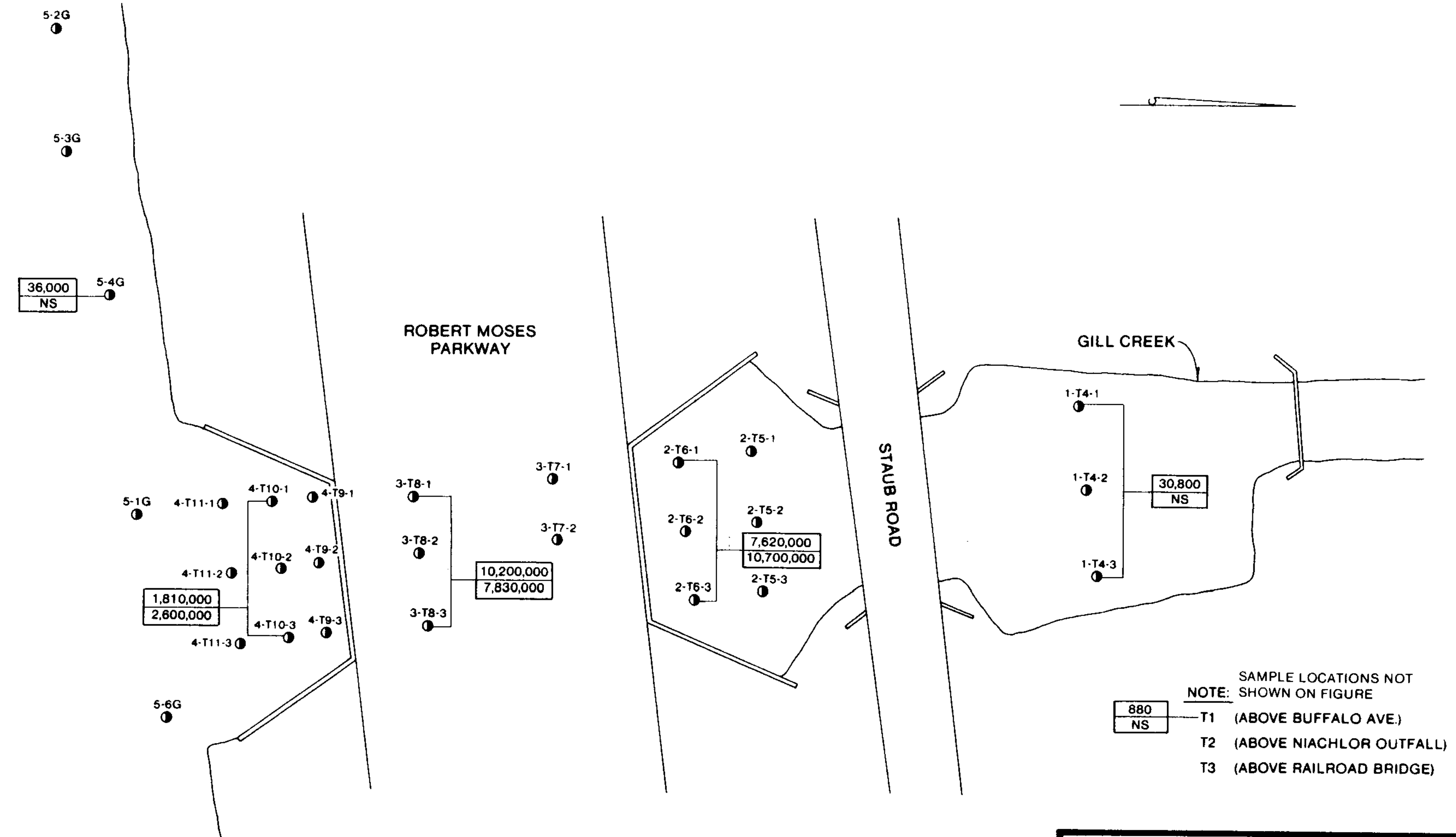


TOTAL BHC'S (ug/kg)
HAZARDOUS SUBSTANCE LIST COMPOSITE SAMPLES
GILL CREEK SEDIMENT STUDY
NIAGARA FALLS, NEW YORK

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by	J.C.	SCALE IN FEET 0 40	Date	1/5/89
Checked by	R.G.		Job	88C2056-5

FIGURE 4-3

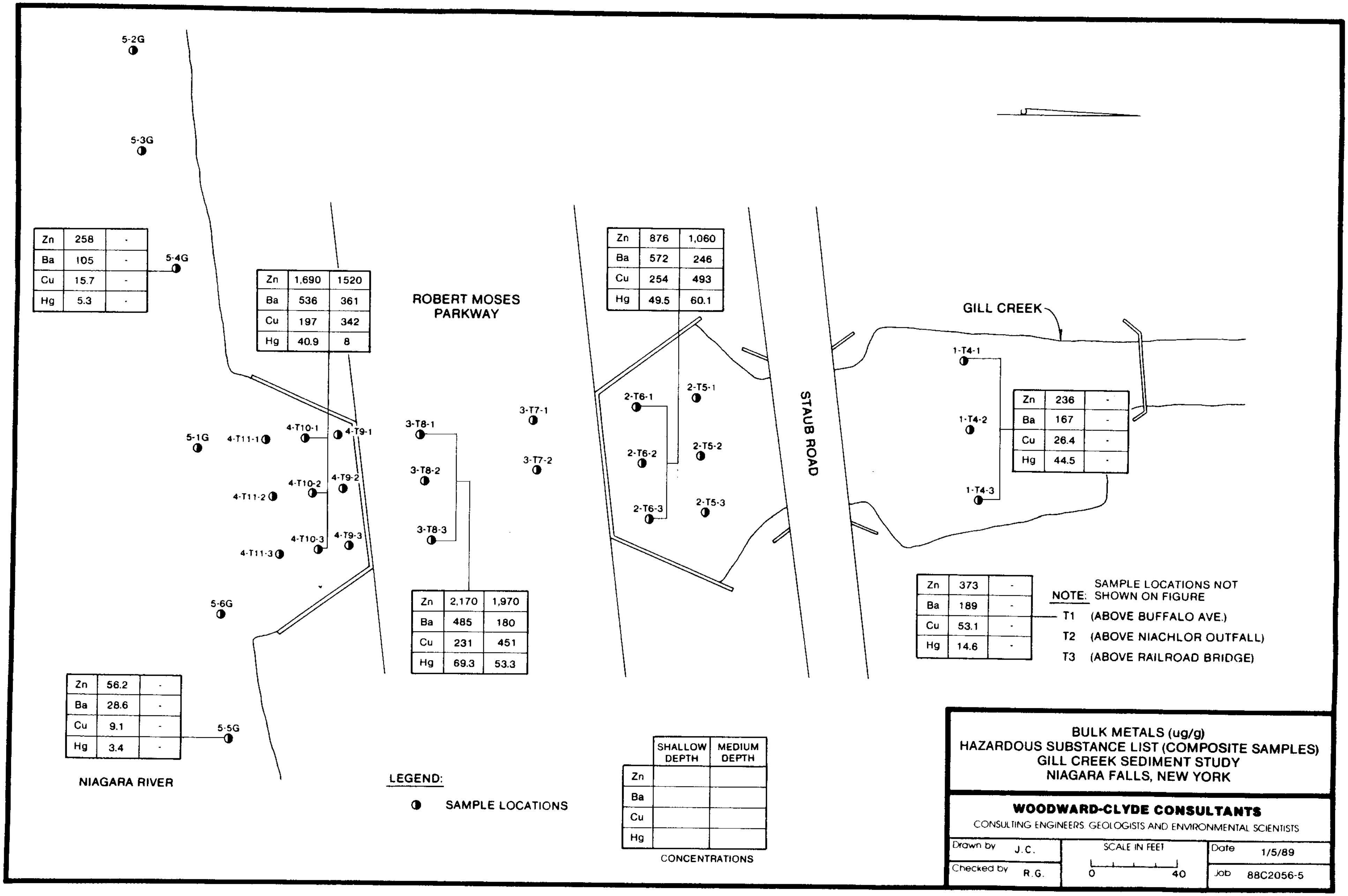


PCB - 1248 (ug/kg)
HAZARDOUS SUBSTANCE LIST COMPOSITE SAMPLES
GILL CREEK SEDIMENT STUDY
NIAGARA FALLS, NEW YORK

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by J.C.
Checked by R.G.
SCALE IN FEET 0 40
Date 10/11/88
Job 88C2056-5

FIGURE 4-4



Zn	258	-
Ba	105	-
Cu	15.7	-
Hg	5.3	-

Zn	56.2	-
Ba	28.6	-
Cu	9.1	-
Hg	3.4	-

Zn	1,690	1520
Ba	536	361
Cu	197	342
Hg	40.9	8

Zn	2,170	1,970
Ba	485	180
Cu	231	451
Hg	69.3	53.3

Zn	876	1,060
Ba	572	246
Cu	254	493
Hg	49.5	60.1

Zn	236	-
Ba	167	-
Cu	26.4	-
Hg	44.5	-

Zn	373	-
Ba	189	-
Cu	53.1	-
Hg	14.6	-

NOTE: SAMPLE LOCATIONS NOT SHOWN ON FIGURE

T1 (ABOVE BUFFALO AVE.)
T2 (ABOVE NIACHLOR OUTFALL)
T3 (ABOVE RAILROAD BRIDGE)

LEGEND:

◑ SAMPLE LOCATIONS

	SHALLOW DEPTH	MEDIUM DEPTH
Zn		
Ba		
Cu		
Hg		

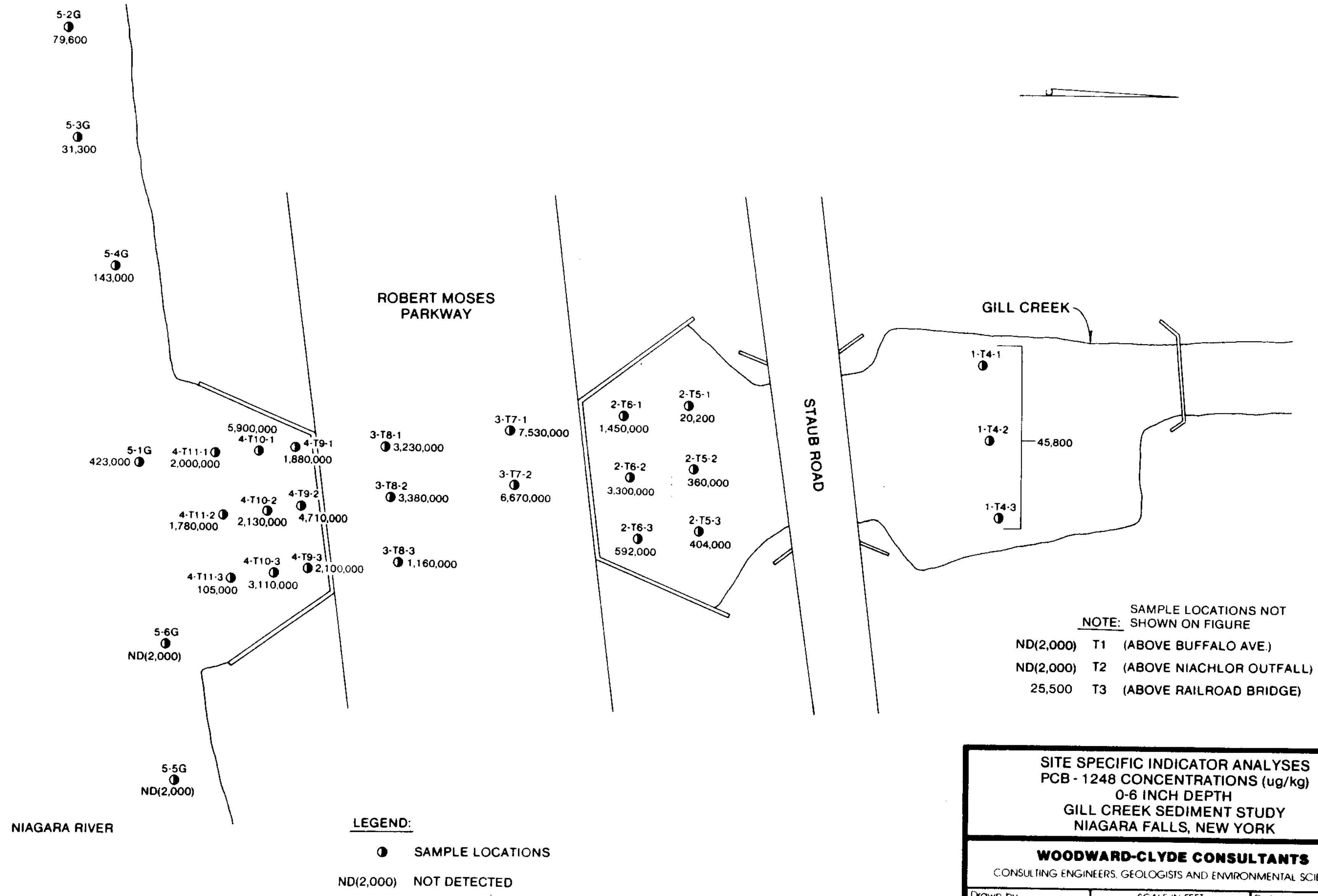
CONCENTRATIONS

BULK METALS (ug/g)
HAZARDOUS SUBSTANCE LIST (COMPOSITE SAMPLES)
GILL CREEK SEDIMENT STUDY
NIAGARA FALLS, NEW YORK

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by	J.C.	Date	1/5/89
Checked by	R.G.	Job	88C2056-5

FIGURE 4-5

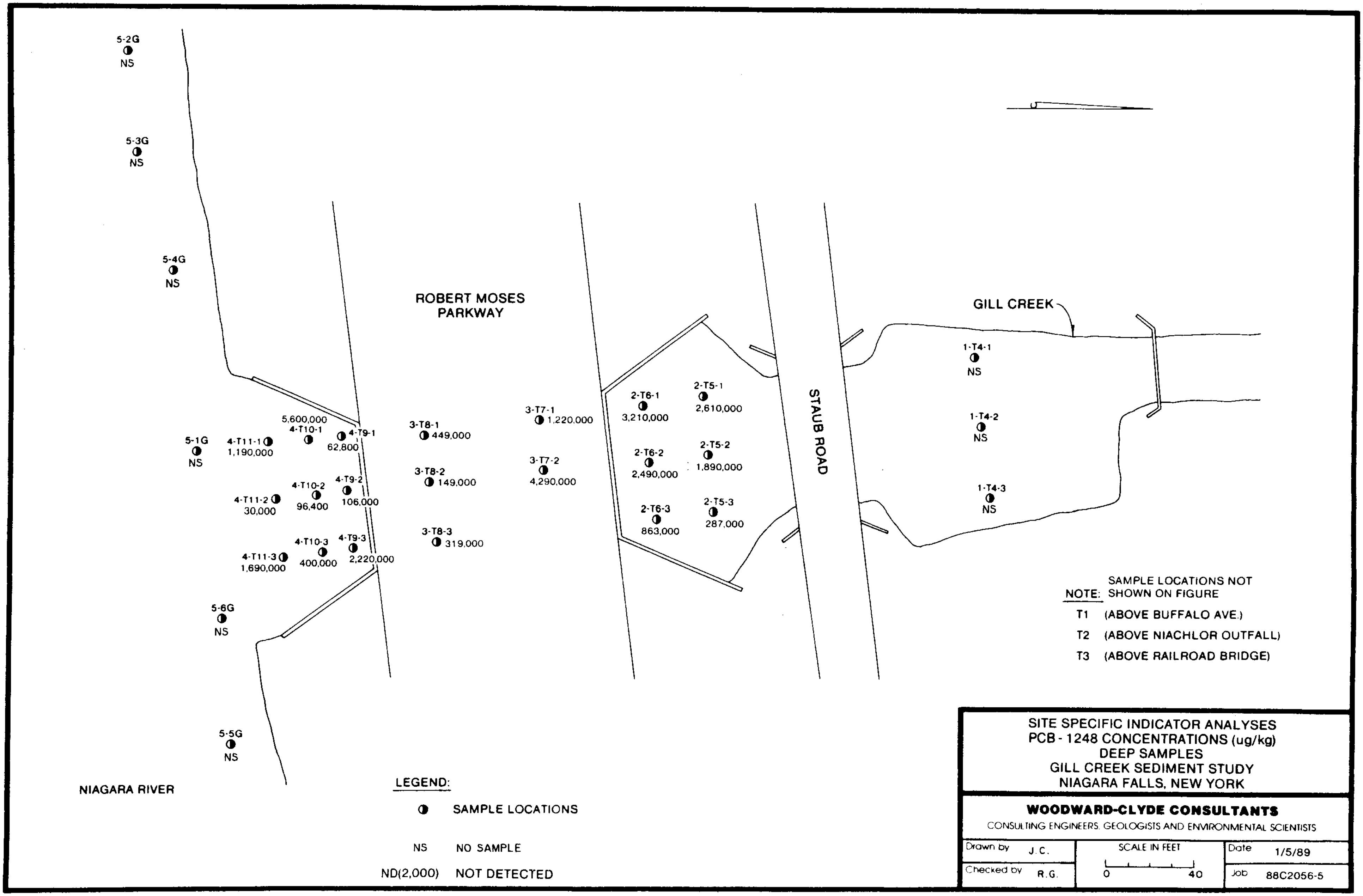


SITE SPECIFIC INDICATOR ANALYSES
PCB - 1248 CONCENTRATIONS (ug/kg)
0-6 INCH DEPTH
GILL CREEK SEDIMENT STUDY
NIAGARA FALLS, NEW YORK

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by J.C.	SCALE IN FEET 0 40	Date	1/5/89
Checked by R.G.		Job	88C2056-5

FIGURE 4-6



NOTE: SAMPLE LOCATIONS NOT SHOWN ON FIGURE

T1 (ABOVE BUFFALO AVE.)
T2 (ABOVE NIACHLOR OUTFALL)
T3 (ABOVE RAILROAD BRIDGE)

LEGEND:

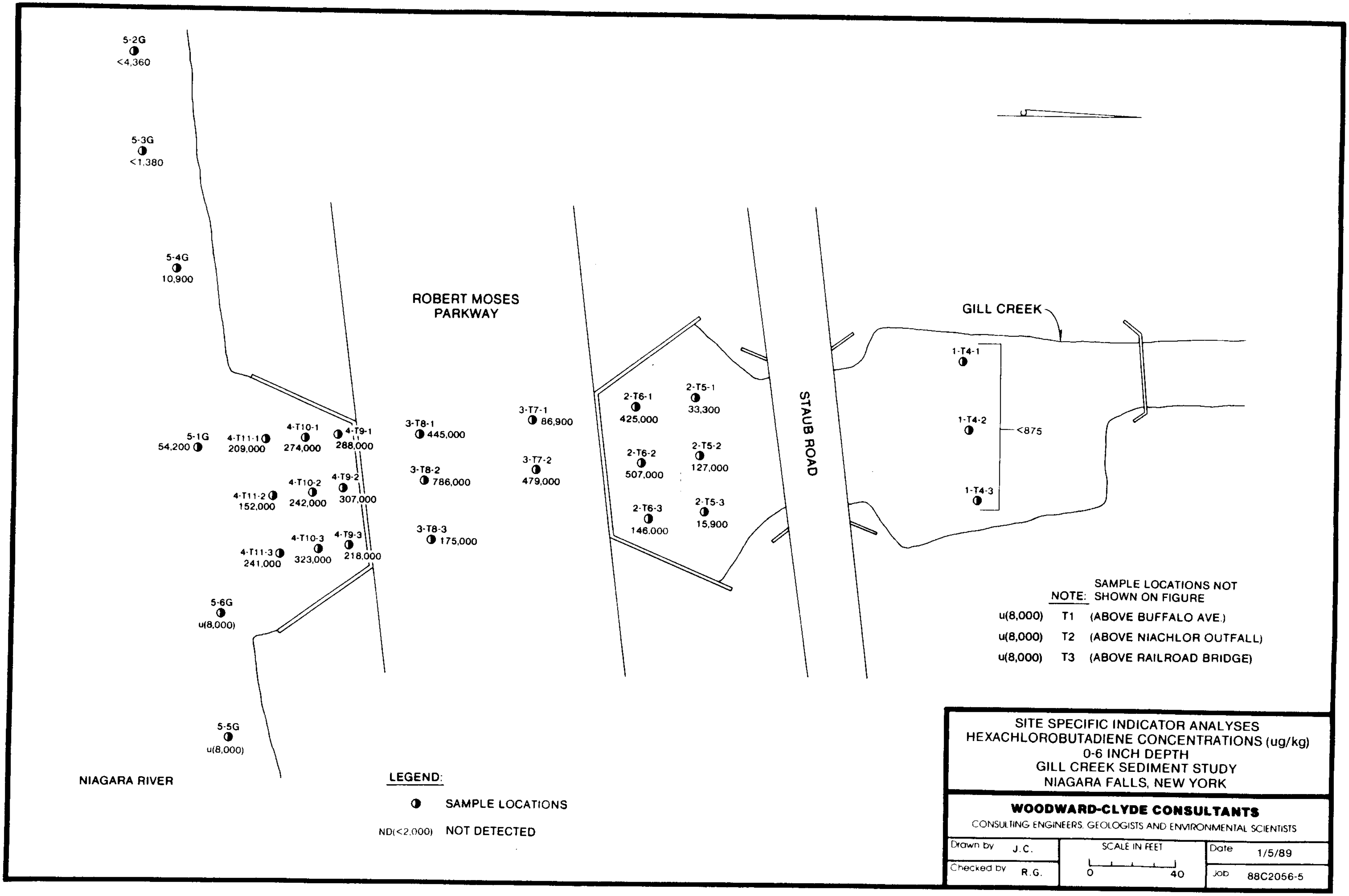
◑	SAMPLE LOCATIONS
NS	NO SAMPLE
ND(2,000)	NOT DETECTED

SITE SPECIFIC INDICATOR ANALYSES
PCB - 1248 CONCENTRATIONS (ug/kg)
DEEP SAMPLES
GILL CREEK SEDIMENT STUDY
NIAGARA FALLS, NEW YORK

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by J. C.	SCALE IN FEET 0 40	Date	1/5/89
Checked by R. G.		Job	88C2056-5

FIGURE 4-7

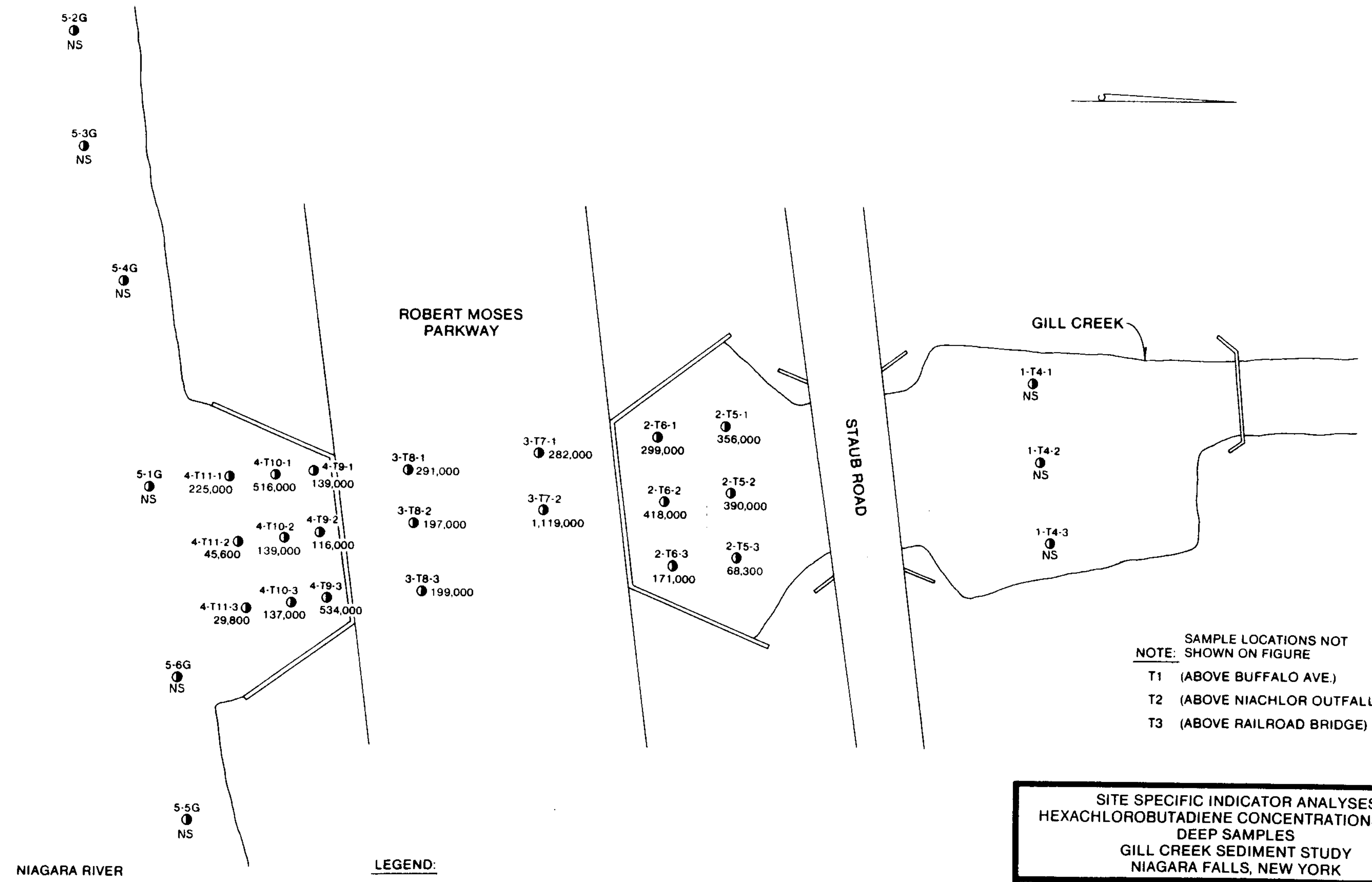


SITE SPECIFIC INDICATOR ANALYSES
HEXACHLOROBUTADIENE CONCENTRATIONS (ug/kg)
0-6 INCH DEPTH
GILL CREEK SEDIMENT STUDY
NIAGARA FALLS, NEW YORK

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by J.C.
Checked by R.G.
Date 1/5/89
Job 88C2056-5

FIGURE 4-8



NOTE: SAMPLE LOCATIONS NOT SHOWN ON FIGURE

T1	(ABOVE BUFFALO AVE.)
T2	(ABOVE NIACHLOR OUTFALL)
T3	(ABOVE RAILROAD BRIDGE)

LEGEND:

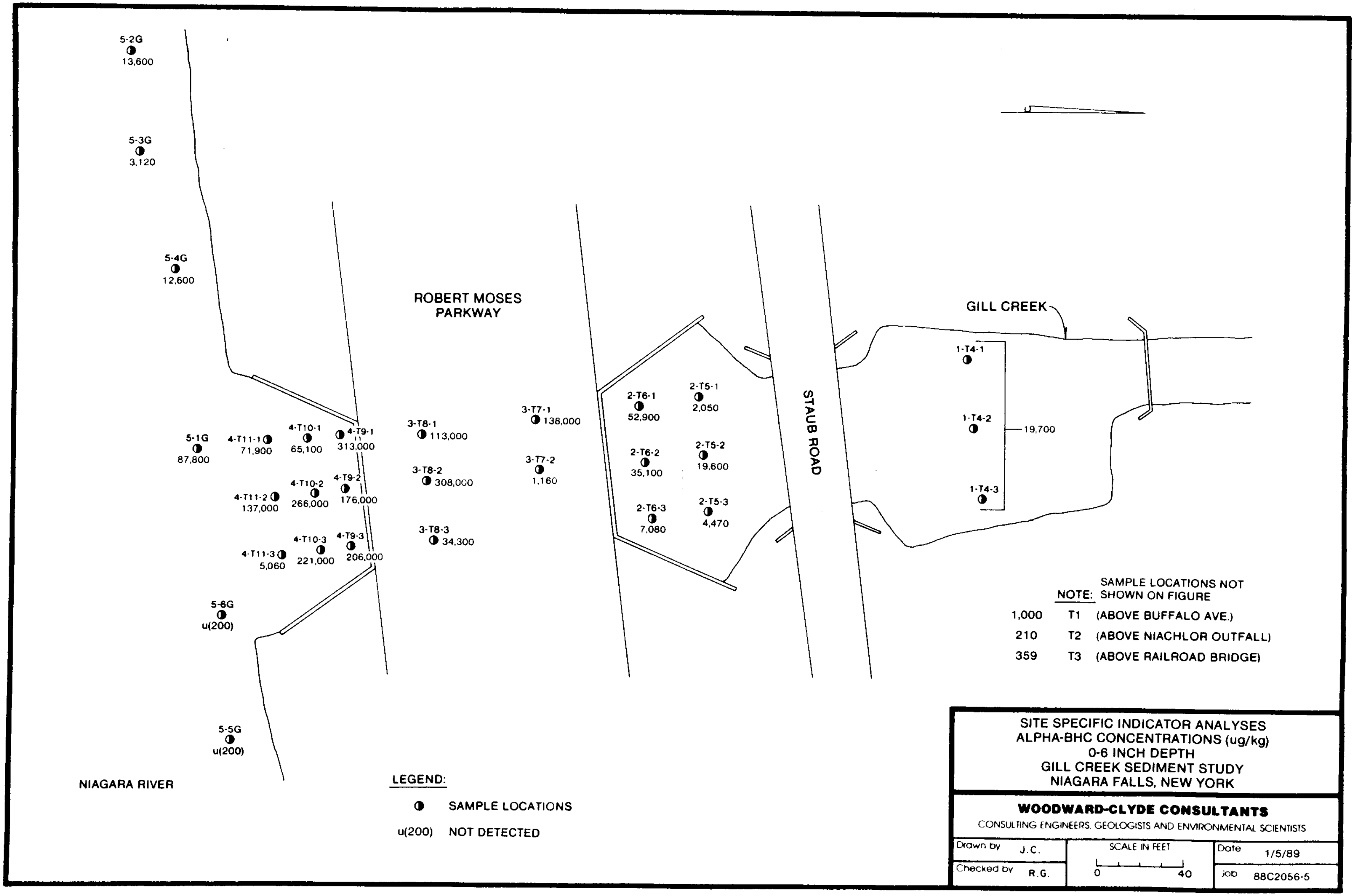
◑	SAMPLE LOCATIONS
NS	NO SAMPLE
u (2,000)	NOT DETECTED

SITE SPECIFIC INDICATOR ANALYSES
HEXACHLOROBUTADIENE CONCENTRATIONS (ug/kg)
DEEP SAMPLES
GILL CREEK SEDIMENT STUDY
NIAGARA FALLS, NEW YORK

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by J.C.	SCALE IN FEET 0 40	Date	1/5/89
Checked by R.G.		Job	88C2056-5

FIGURE 4-9



NOTE: SAMPLE LOCATIONS NOT SHOWN ON FIGURE

1,000	T1	(ABOVE BUFFALO AVE.)
210	T2	(ABOVE NIACHLOR OUTFALL)
359	T3	(ABOVE RAILROAD BRIDGE)

LEGEND:

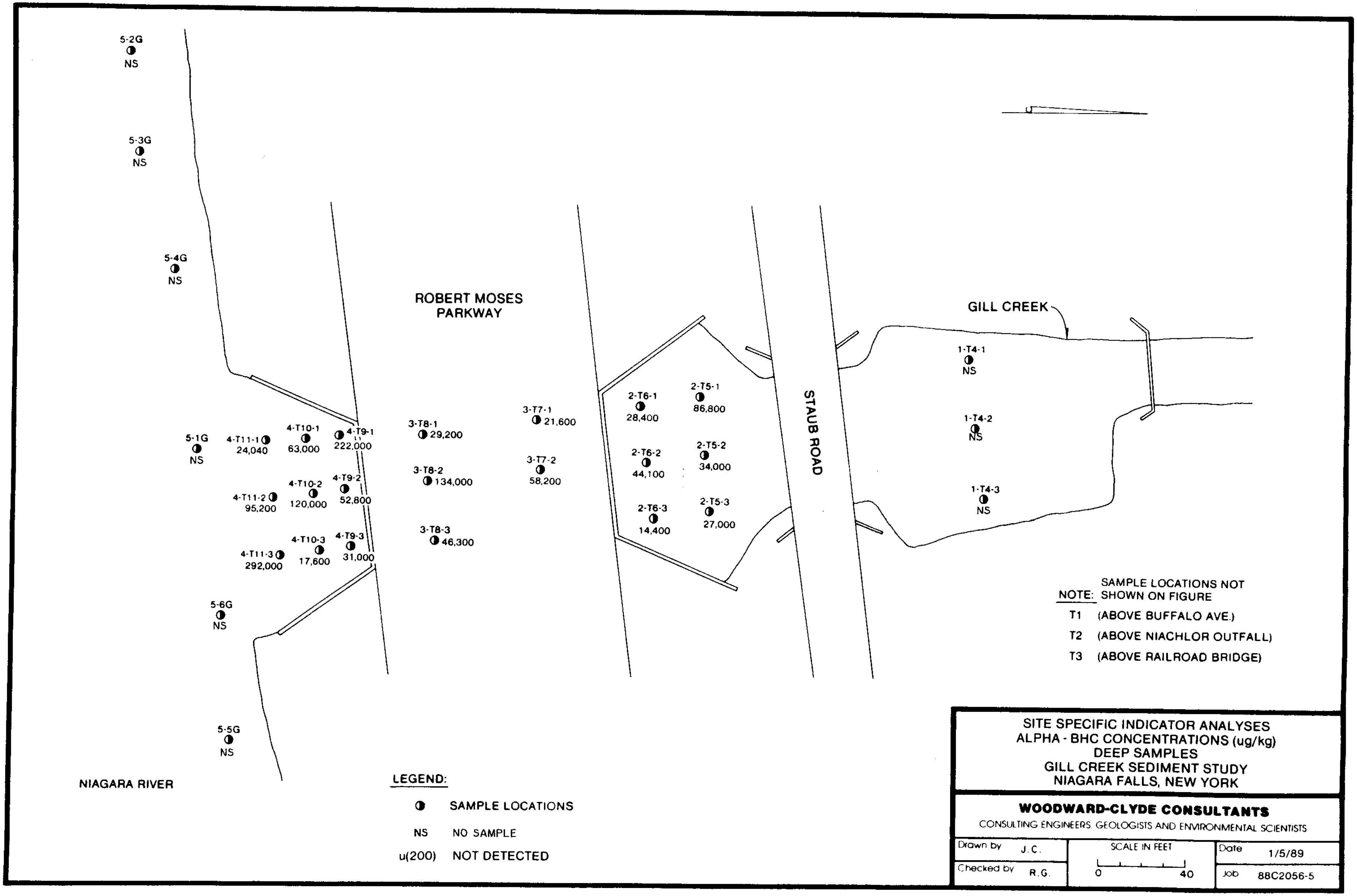
◑	SAMPLE LOCATIONS
u(200)	NOT DETECTED

SITE SPECIFIC INDICATOR ANALYSES
ALPHA-BHC CONCENTRATIONS (ug/kg)
0-6 INCH DEPTH
GILL CREEK SEDIMENT STUDY
NIAGARA FALLS, NEW YORK

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by J.C.
Checked by R.G.
Date 1/5/89
Job 88C2056-5

FIGURE 4-10

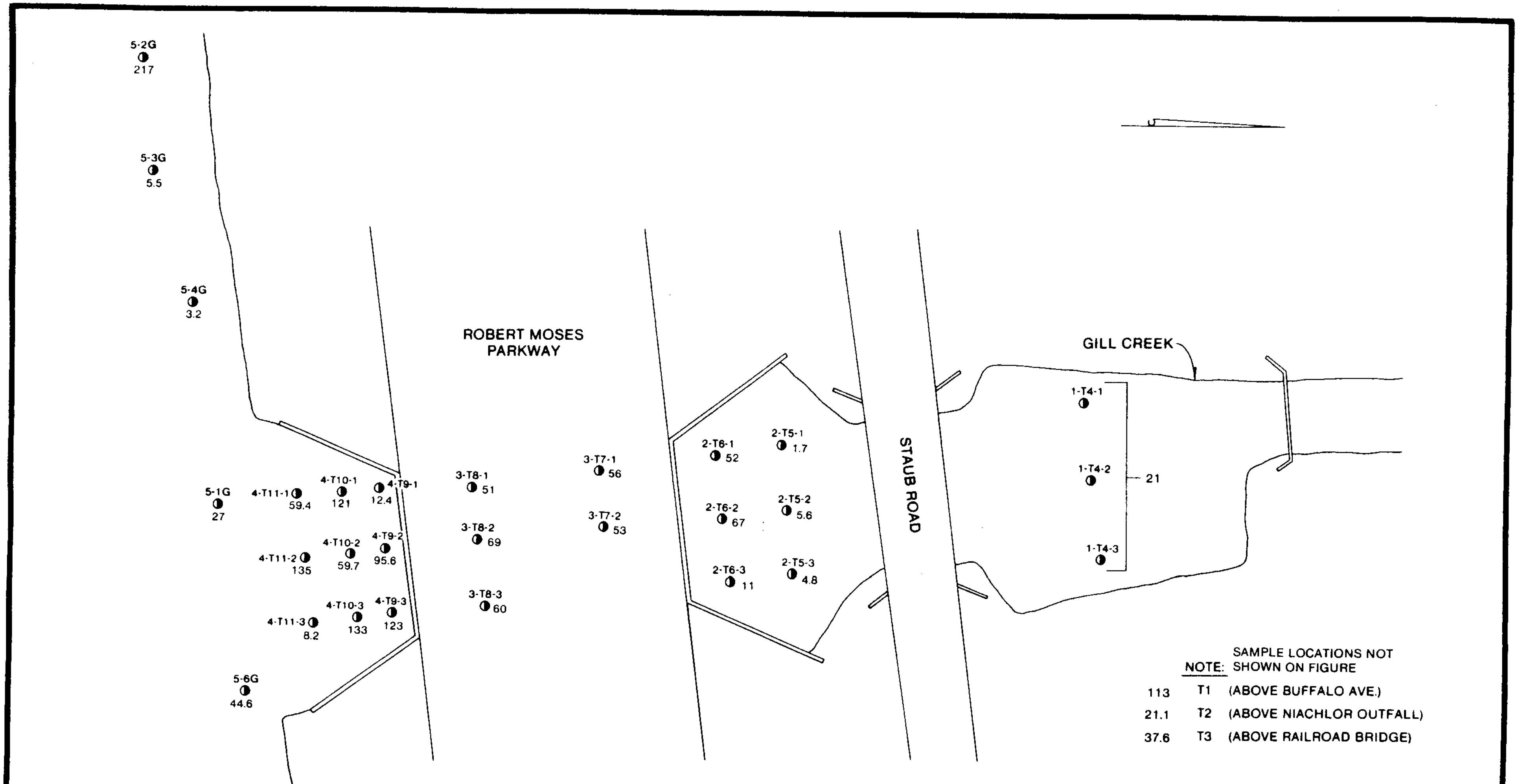


SITE SPECIFIC INDICATOR ANALYSES
ALPHA - BHC CONCENTRATIONS (ug/kg)
DEEP SAMPLES
GILL CREEK SEDIMENT STUDY
NIAGARA FALLS, NEW YORK

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by J.C.	SCALE IN FEET	Date	1/5/89
Checked by R.G.	0 40	Job	88C2056-5

FIGURE 4-11



NOTE: SAMPLE LOCATIONS NOT SHOWN ON FIGURE

113	T1	(ABOVE BUFFALO AVE.)
21.1	T2	(ABOVE NIACHLOR OUTFALL)
37.6	T3	(ABOVE RAILROAD BRIDGE)

LEGEND:

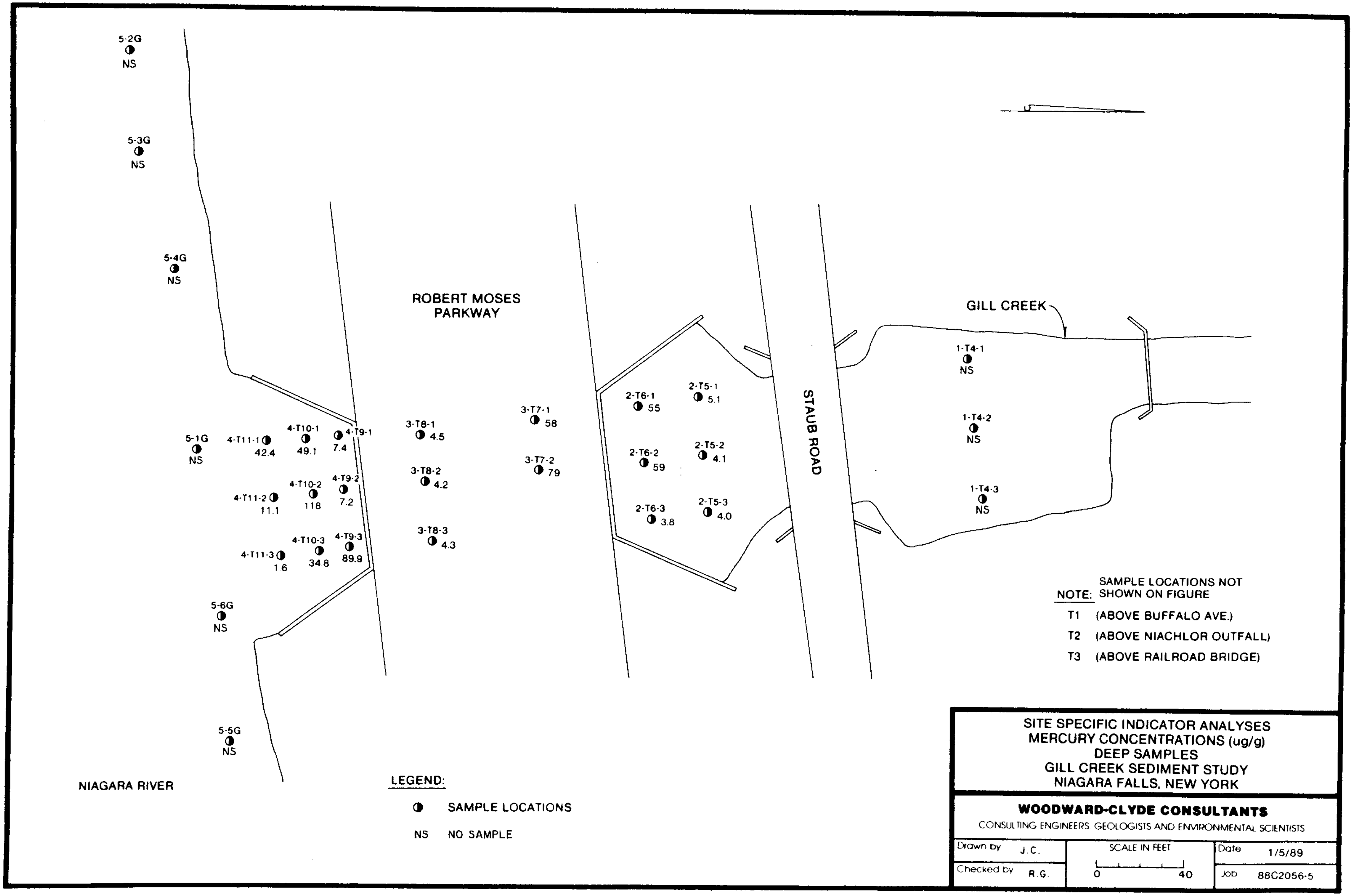
◐ SAMPLE LOCATIONS

SITE SPECIFIC INDICATOR ANALYSES
MERCURY CONCENTRATIONS (ug/g)
0-6 INCH DEPTH
GILL CREEK SEDIMENT STUDY
NIAGARA FALLS, NEW YORK

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by J.C.	SCALE IN FEET 0 40	Date	1/5/89
Checked by R.G.		Job	88C2056-5

FIGURE 4-12

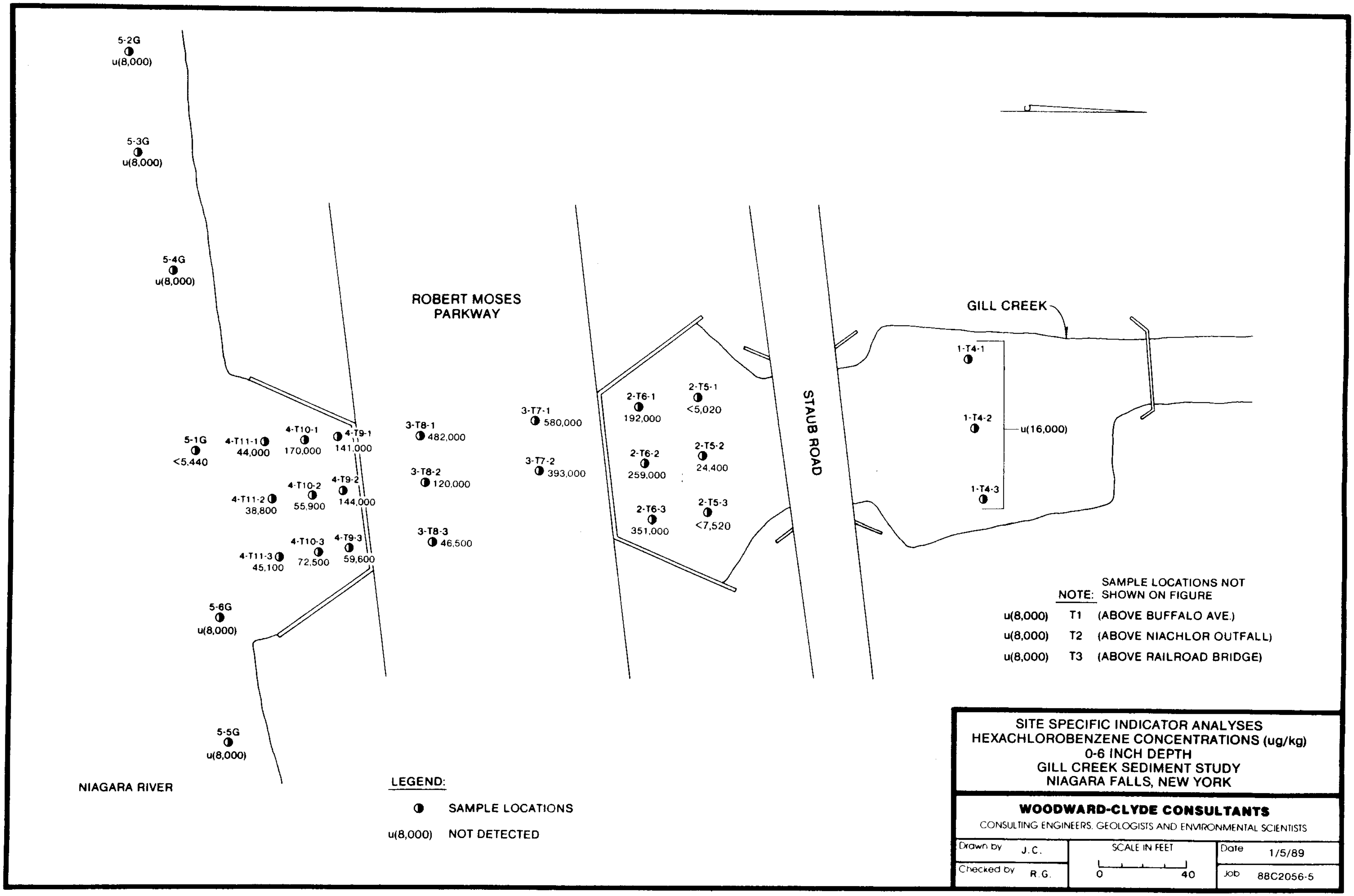


SITE SPECIFIC INDICATOR ANALYSES
MERCURY CONCENTRATIONS (ug/g)
DEEP SAMPLES
GILL CREEK SEDIMENT STUDY
NIAGARA FALLS, NEW YORK

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by J.C.	SCALE IN FEET 0 40	Date	1/5/89
Checked by R.G.		Job	88C2056-5

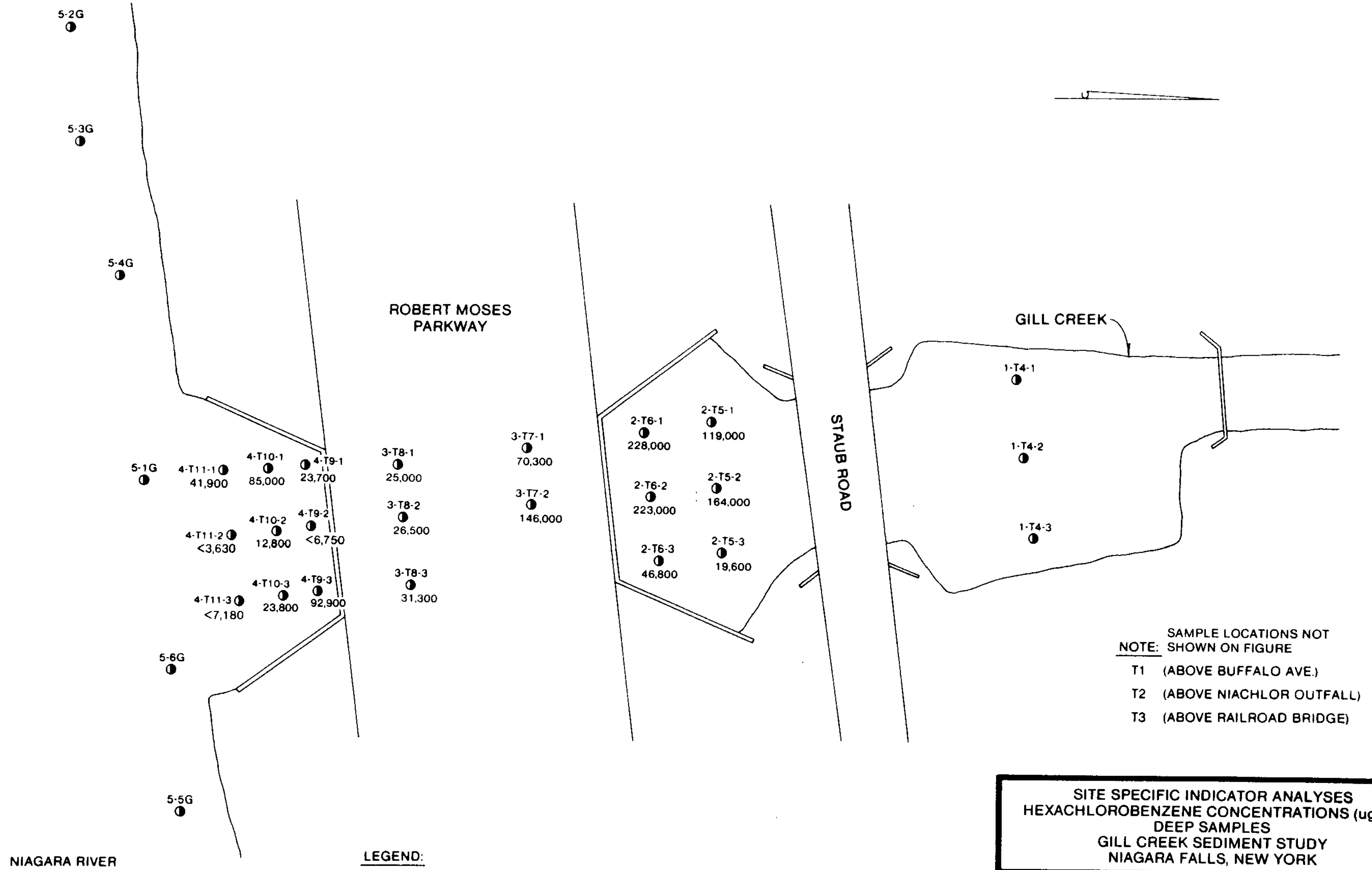
FIGURE 4-13



SITE SPECIFIC INDICATOR ANALYSES
HEXACHLOROBENZENE CONCENTRATIONS (ug/kg)
0-6 INCH DEPTH
GILL CREEK SEDIMENT STUDY
NIAGARA FALLS, NEW YORK

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

FIGURE 4-14



NOTE: SAMPLE LOCATIONS NOT SHOWN ON FIGURE

T1 (ABOVE BUFFALO AVE.)

T2 (ABOVE NIACHLOR OUTFALL)

T3 (ABOVE RAILROAD BRIDGE)

LEGEND:

◑ SAMPLE LOCATIONS

u(8,000) NOT DETECTED

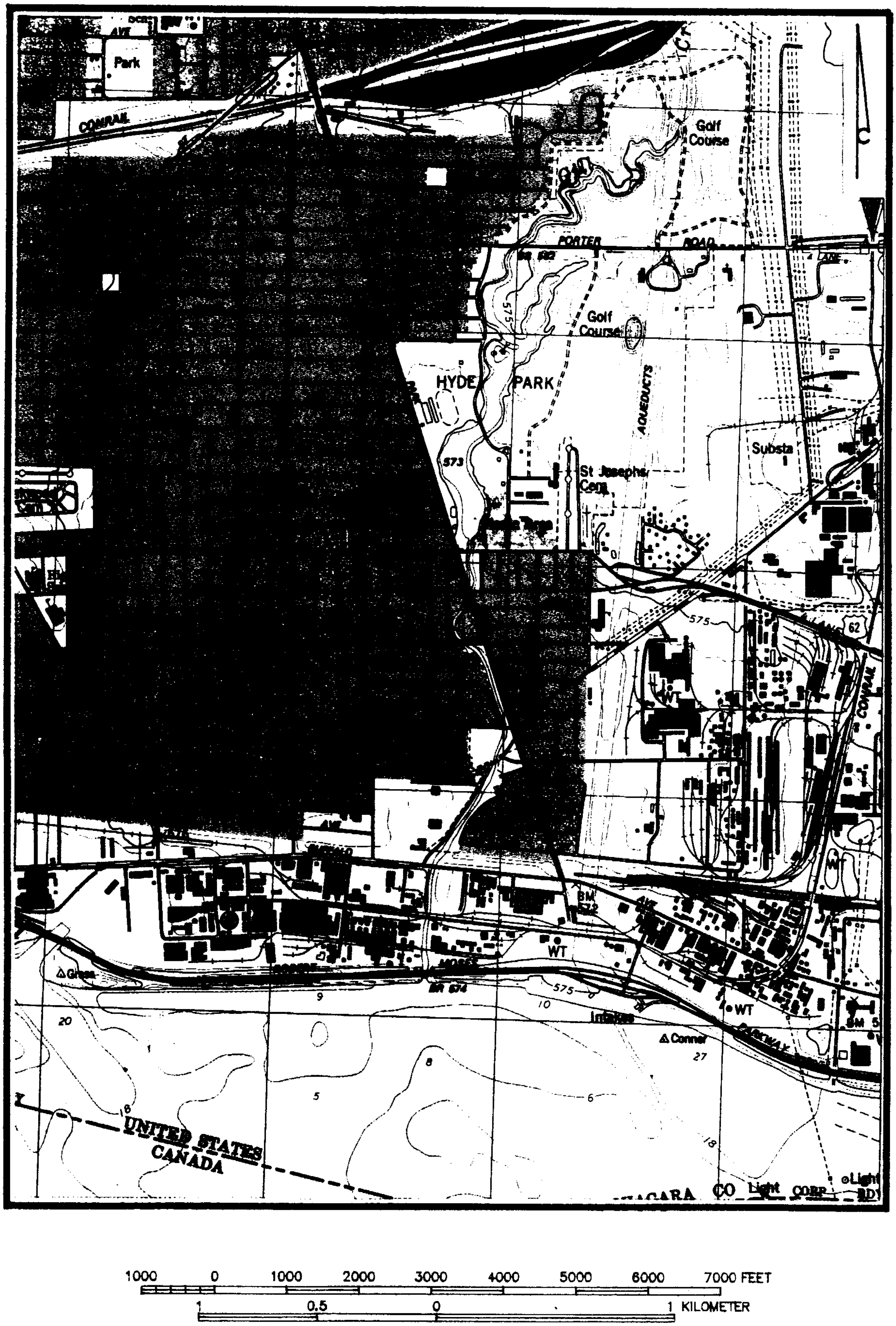
SITE SPECIFIC INDICATOR ANALYSES
HEXACHLOROBENZENE CONCENTRATIONS (ug/kg)
DEEP SAMPLES
GILL CREEK SEDIMENT STUDY
NIAGARA FALLS, NEW YORK

WOODWARD-CLYDE CONSULTANTS

CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

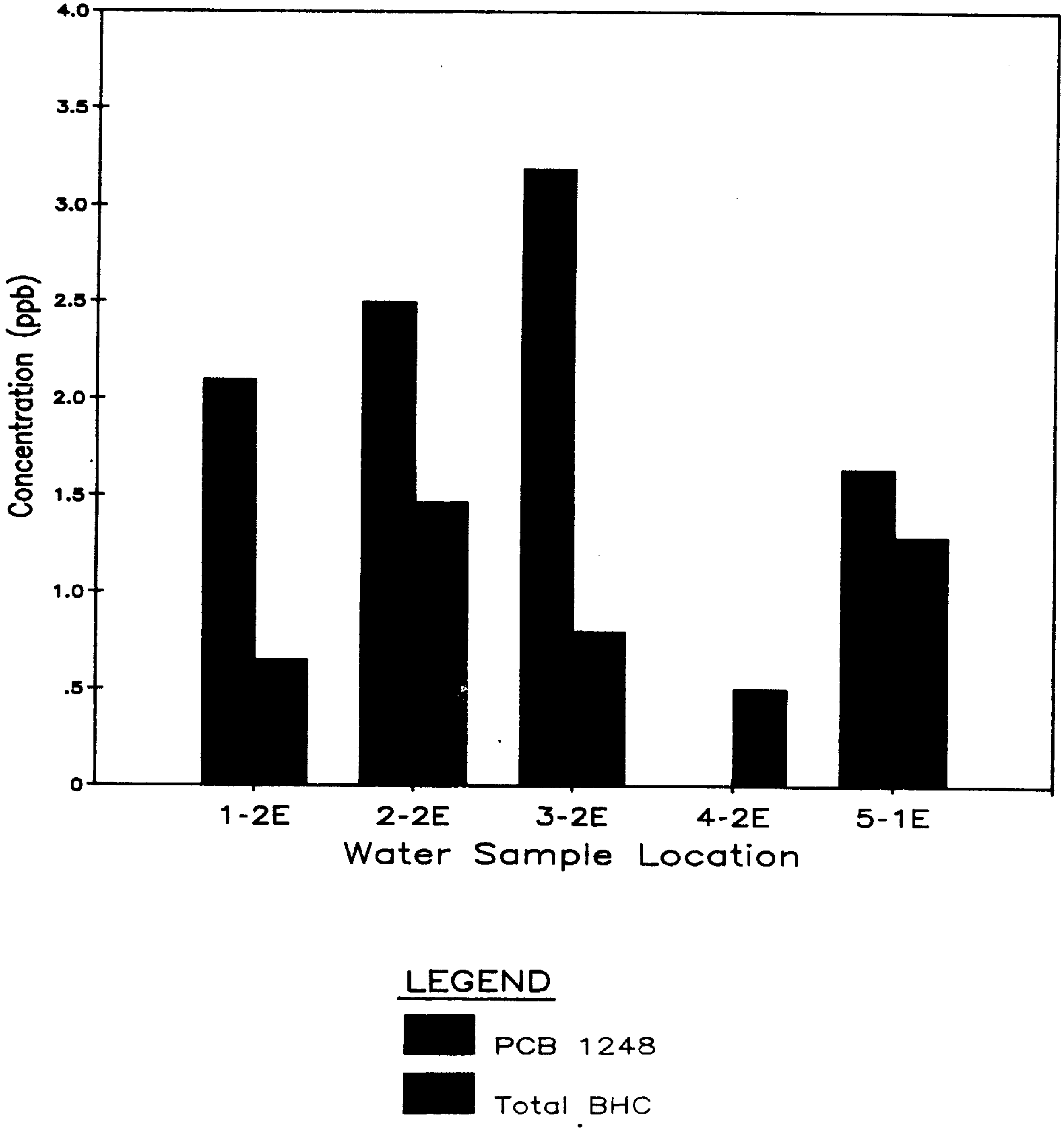
Drawn by J.C.	SCALE IN FEET 0 40	Date	1/5/89
Checked by R.G.		Job	88C2056-5

FIGURE 4-15



REGIONAL LOCATION PLAN

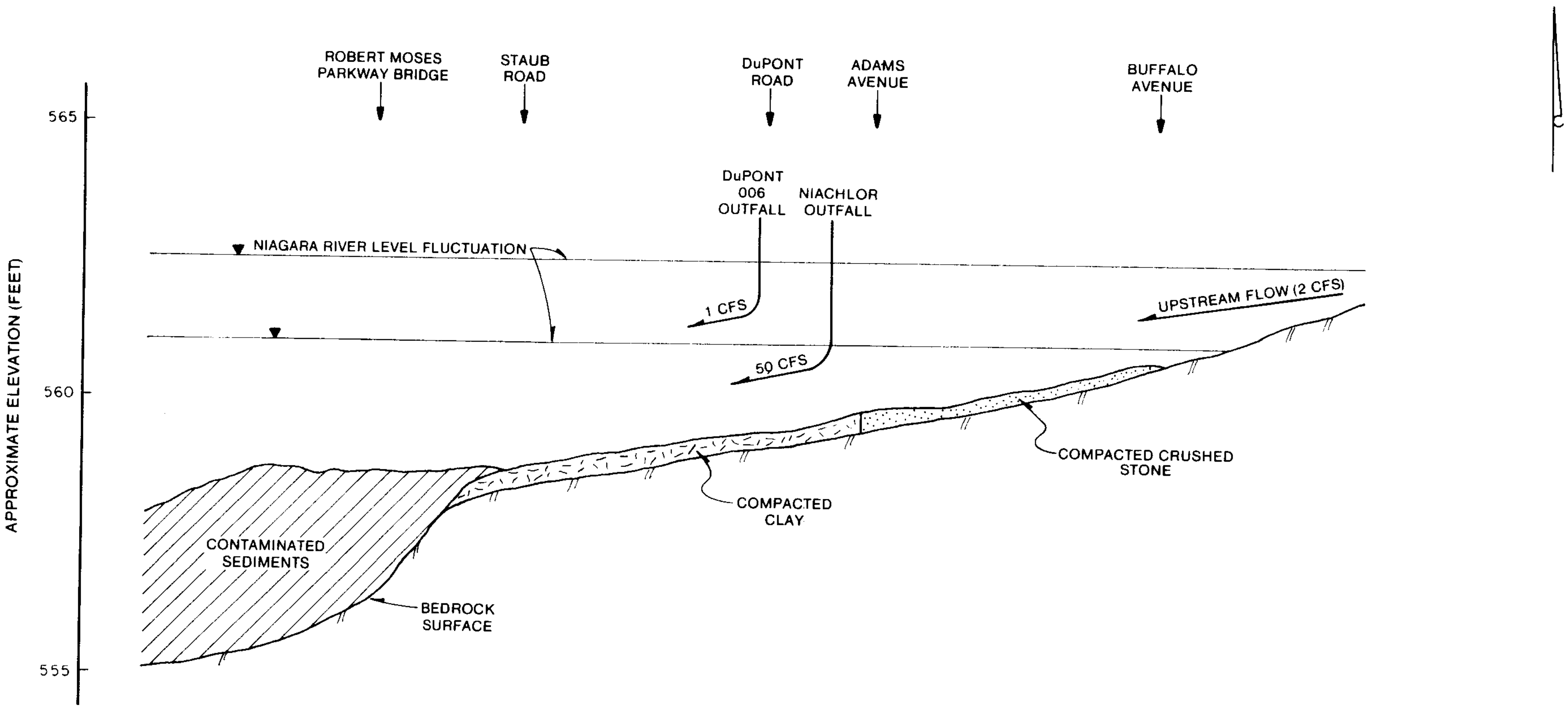
FIGURE 1-3



SURFACE WATER RESULTS
PCB-1248 AND BHC'S
GILL CREEK SEDIMENT STUDY
NIAGARA FALLS, NEW YORK

Drawn by J. C.	SCALE IN FEET	Date: 1/9/89
Checked by: R.G.	N.T.S.	Job 88C2056-5

FIGURE 4-16

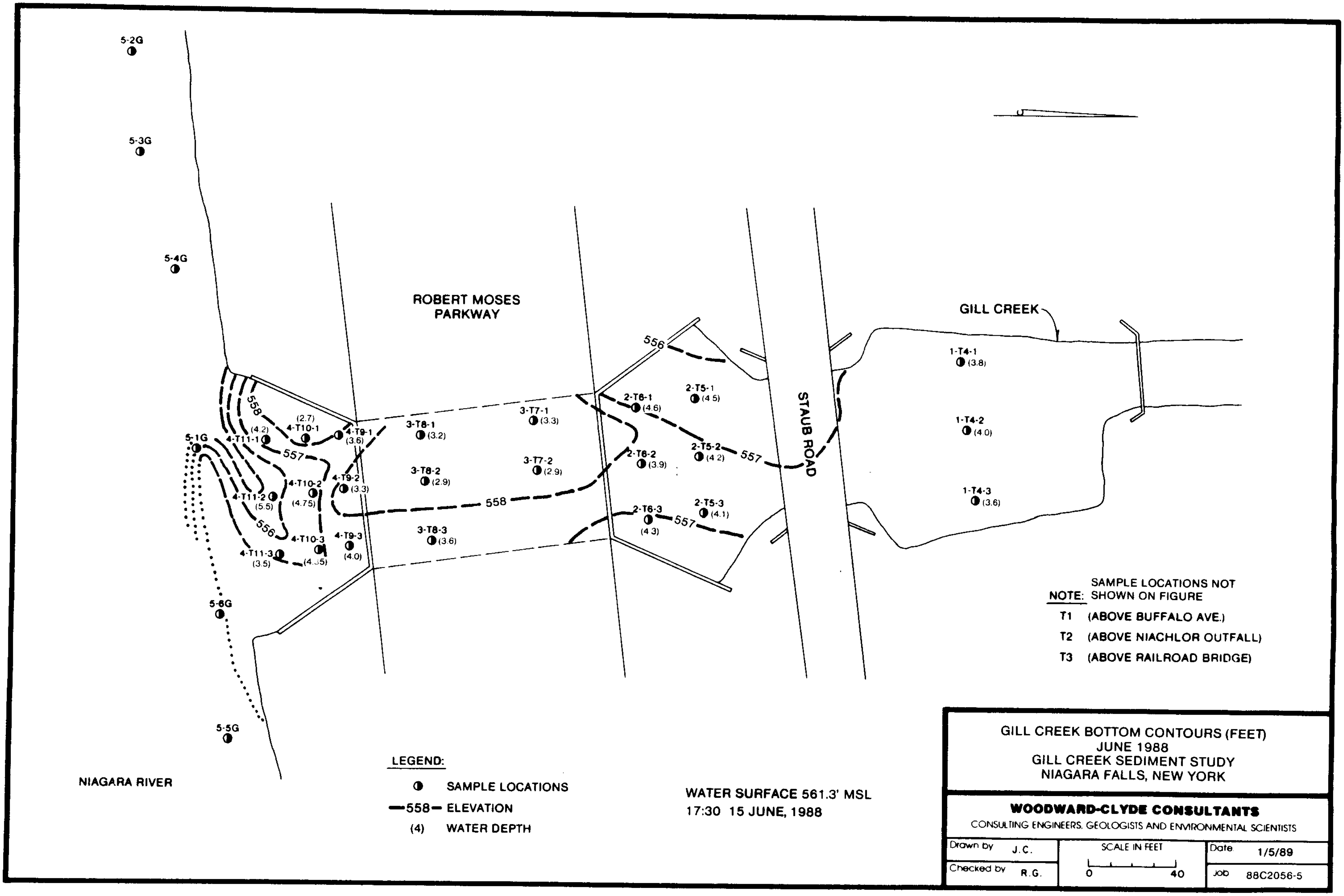


GILL CREEK SEDIMENT STUDY
NIAGARA FALLS, NEW YORK

WOODWARD-CLYDE CONSULTANTS
Consulting Engineers, Geologists and Environmental Scientists

CONCEPTUAL GILL CREEK CROSS-SECTION

Job No.: 88C2056-5	Drawing No.	Date: 3/15/89
Checked by: R.G.	Rev. No.:	FIGURE 4-17
Scale: NOT TO SCALE		



NOTE: SAMPLE LOCATIONS NOT SHOWN ON FIGURE

T1	(ABOVE BUFFALO AVE.)
T2	(ABOVE NIACHLOR OUTFALL)
T3	(ABOVE RAILROAD BRIDGE)

LEGEND:

◑	SAMPLE LOCATIONS
—558—	ELEVATION
(4)	WATER DEPTH

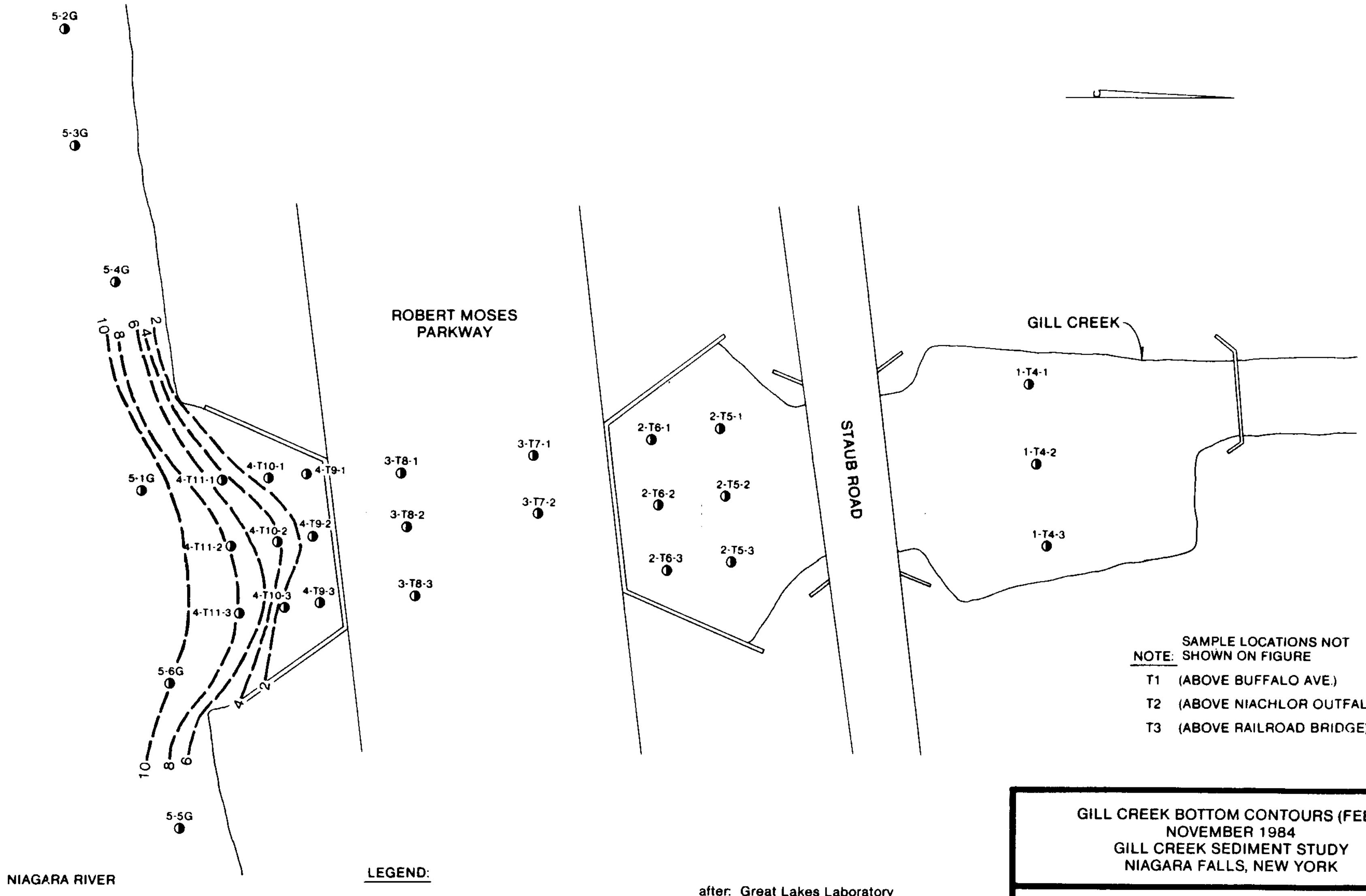
WATER SURFACE 561.3' MSL
17:30 15 JUNE, 1988

GILL CREEK BOTTOM CONTOURS (FEET)
JUNE 1988
GILL CREEK SEDIMENT STUDY
NIAGARA FALLS, NEW YORK

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by J.C.	SCALE IN FEET 0 40	Date	1/5/89
Checked by R.G.		Job	88C2056-5

FIGURE 4-18



NOTE: SAMPLE LOCATIONS NOT SHOWN ON FIGURE

T1 (ABOVE BUFFALO AVE.)
T2 (ABOVE NIACHLOR OUTFALL)
T3 (ABOVE RAILROAD BRIDGE)

LEGEND:

◑ SAMPLE LOCATIONS
— — DEPTH CONTOUR (FEET)

after: Great Lakes Laboratory
Survey November 14, 1984.

GILL CREEK BOTTOM CONTOURS (FEET)
NOVEMBER 1984
GILL CREEK SEDIMENT STUDY
NIAGARA FALLS, NEW YORK

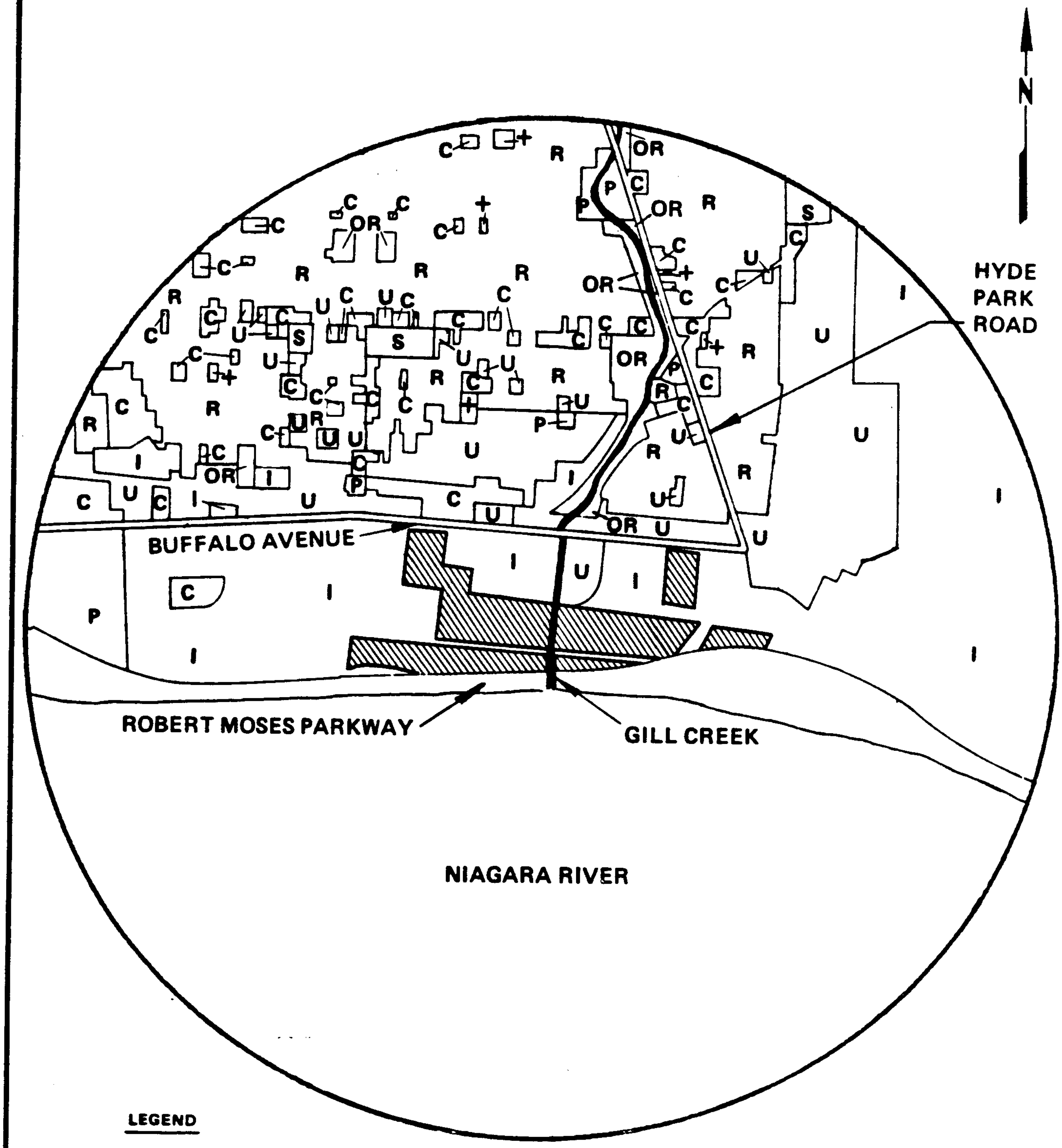
WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by J.C.	SCALE IN FEET 0 40	Date	1/5/89
Checked by R.G.		Job	88C2056-5

FIGURE 4-19

513472

Woodward-Clyde Consultants



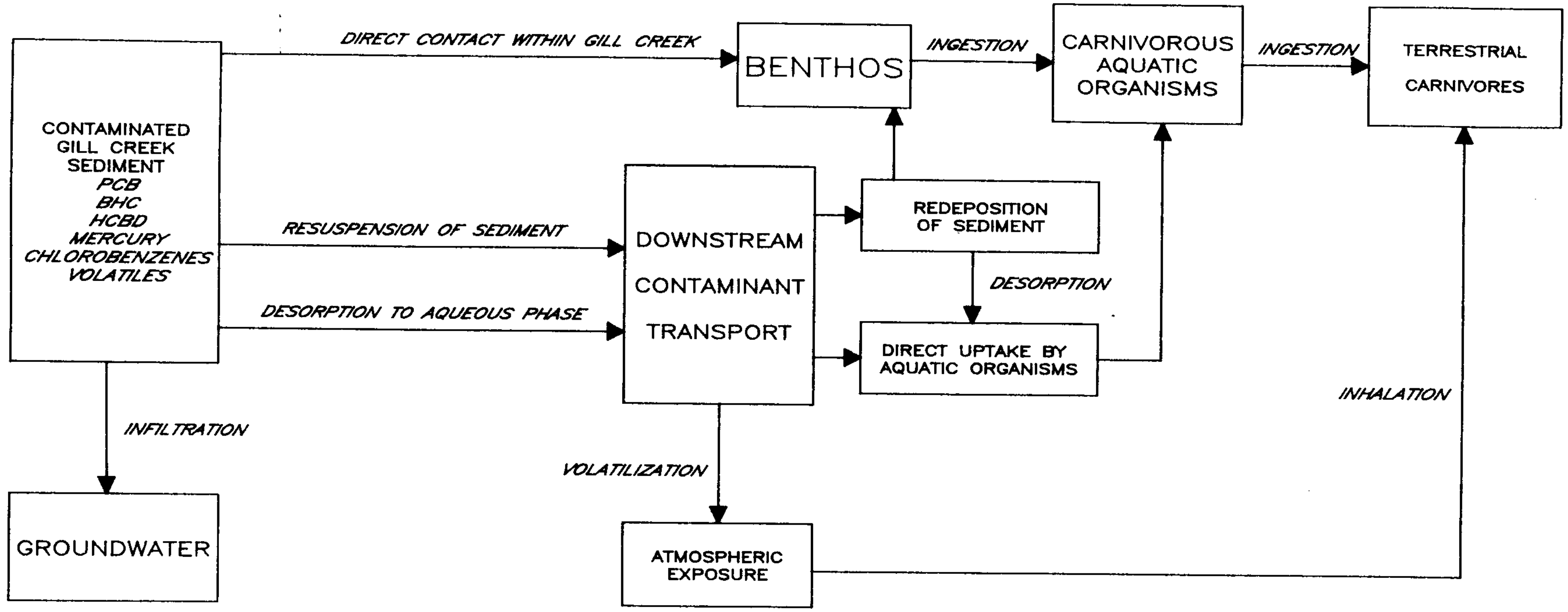
LEGEND

R	RESIDENTIAL
C	COMMERCIAL
I	INDUSTRIAL
OR	OUTDOOR RECREATION
S	SCHOOL
+	CHURCH
P	PUBLIC FACILITIES
U	URBAN–INACTIVE
▨	NIAGARA PLANT

LAND USE
GILL CREEK SEDIMENT STUDY
NIAGARA FALLS, NEW YORK

Drawn by J.C.	SCALE IN FEET 0 1500	Date: 1/9/89
Checked by: R.G.		Job 88C2056-5

FIGURE 5-1

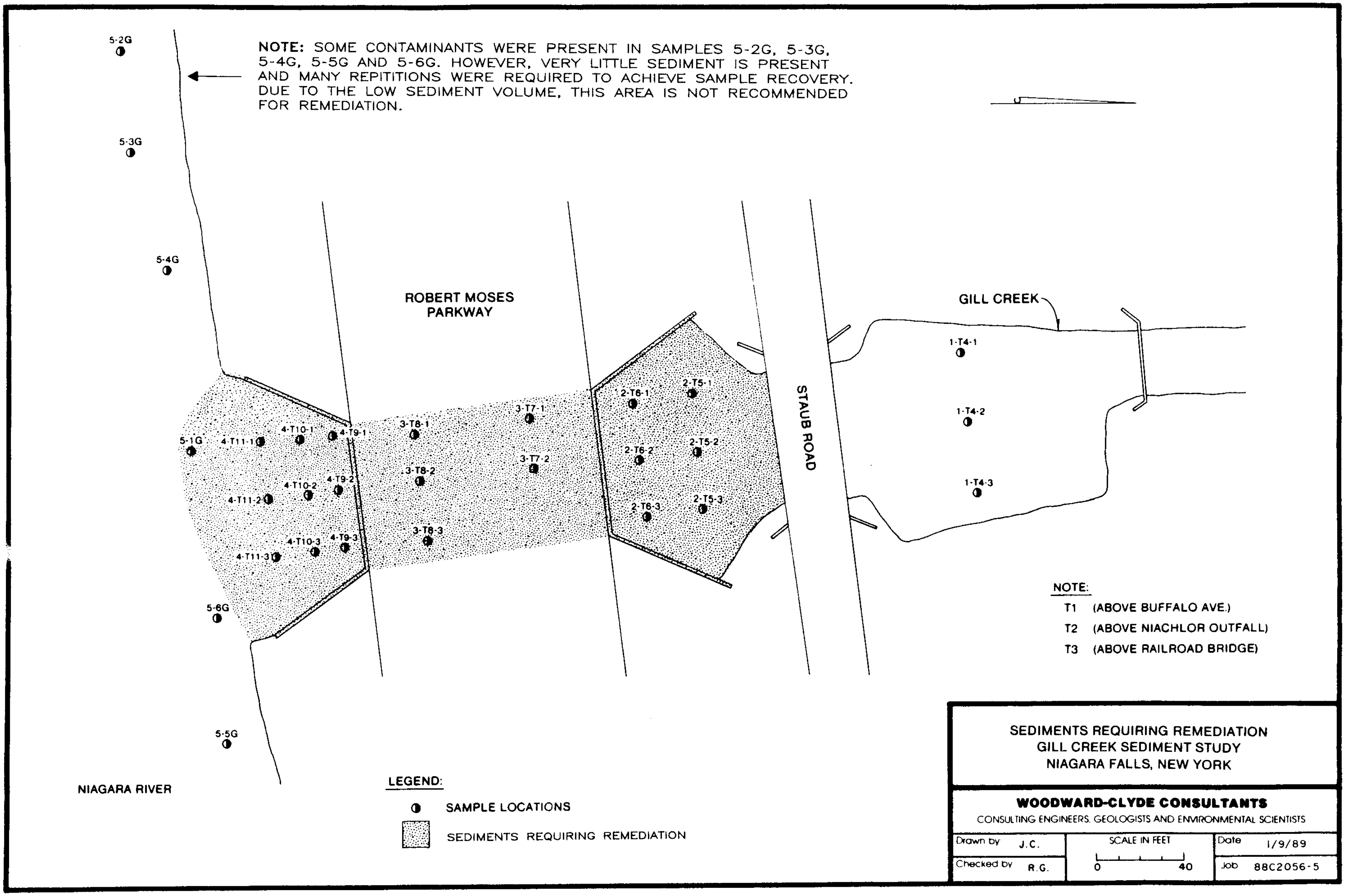


TRANSPORT/EXPOSURE PATHWAYS ANALYSIS
GILL CREEK SEDIMENT STUDY
NIAGARA FALLS, NEW YORK

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by J.C.	SCALE IN FEET	Date 1/9/89
Checked by R.G.	N.T.S.	Job 88C2056-5

FIGURE 5-2



NOTE: SOME CONTAMINANTS WERE PRESENT IN SAMPLES 5-2G, 5-3G, 5-4G, 5-5G AND 5-6G. HOWEVER, VERY LITTLE SEDIMENT IS PRESENT AND MANY REPITITIONS WERE REQUIRED TO ACHIEVE SAMPLE RECOVERY. DUE TO THE LOW SEDIMENT VOLUME, THIS AREA IS NOT RECOMMENDED FOR REMEDIATION.

NOTE:

T1 (ABOVE BUFFALO AVE.)

T2 (ABOVE NIACHLOR OUTFALL)

T3 (ABOVE RAILROAD BRIDGE)

LEGEND:

◑ SAMPLE LOCATIONS

▨ SEDIMENTS REQUIRING REMEDIATION

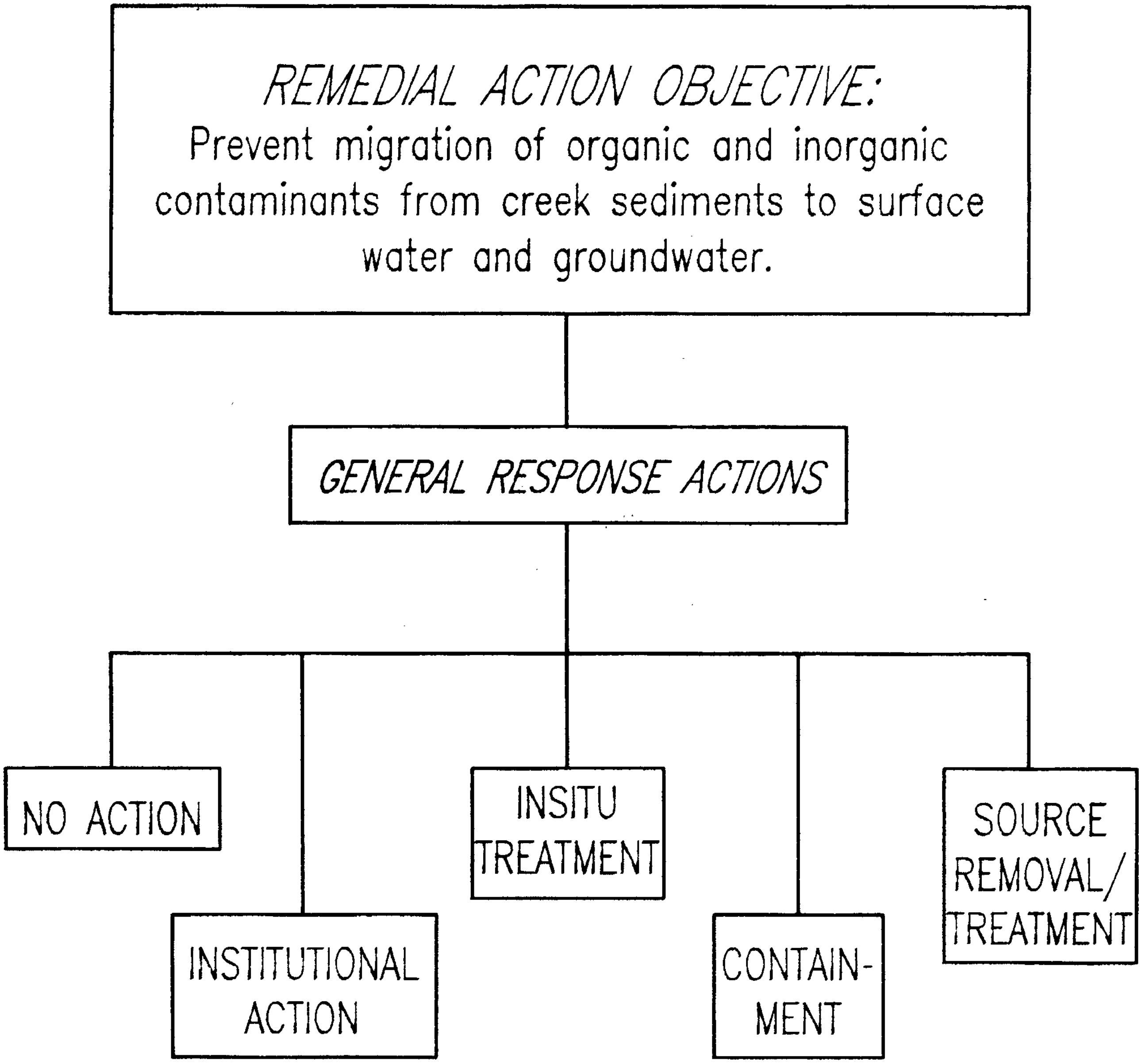
SEDIMENTS REQUIRING REMEDIATION
GILL CREEK SEDIMENT STUDY
NIAGARA FALLS, NEW YORK

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by J.C.	SCALE IN FEET	Date	1/9/89
Checked by R.G.	0 40	Job	88C2056-5

FIGURE 6-1

513472

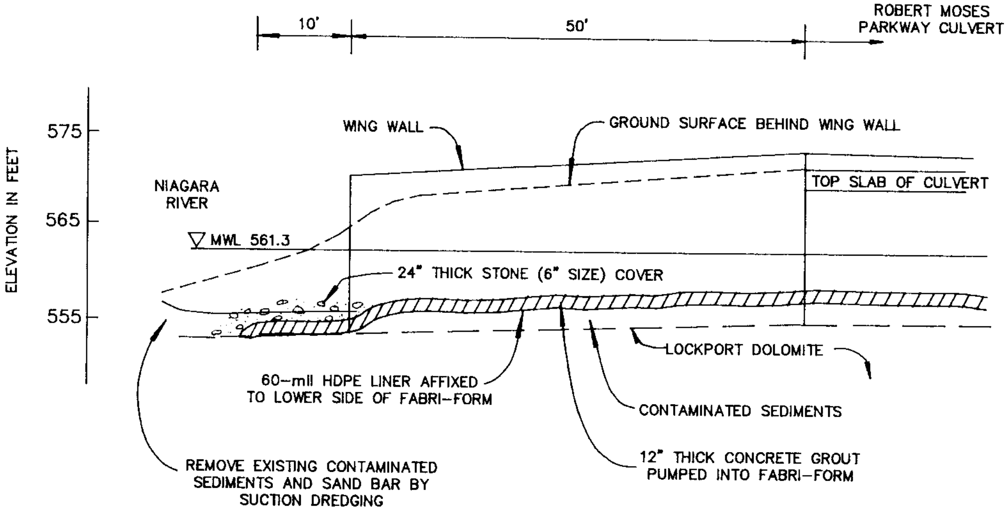


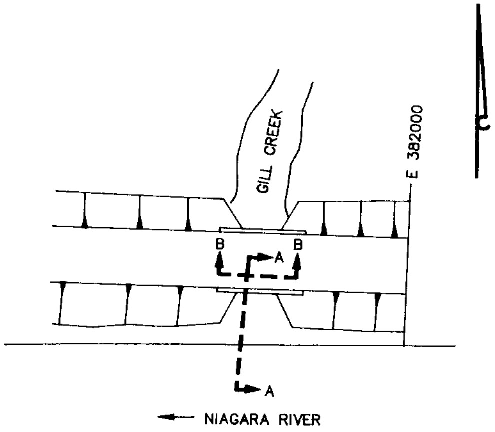
IDENTIFICATION OF RESPONSE ACTIONS
GILL CREEK SEDIMENT STUDY
NIAGARA FALLS, NEW YORK

Drawn by J.C.	SCALE IN FEET	Date 1/9/89
Checked by R.G.	N.T.S.	Job 88C2056-5

FIGURE 6-2

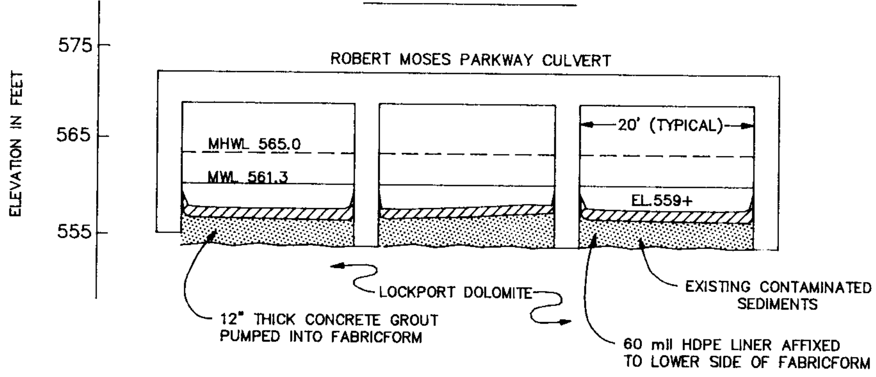
CROSS SECTION A–A'





PLAN VIEW

CROSS–SECTION B–B'



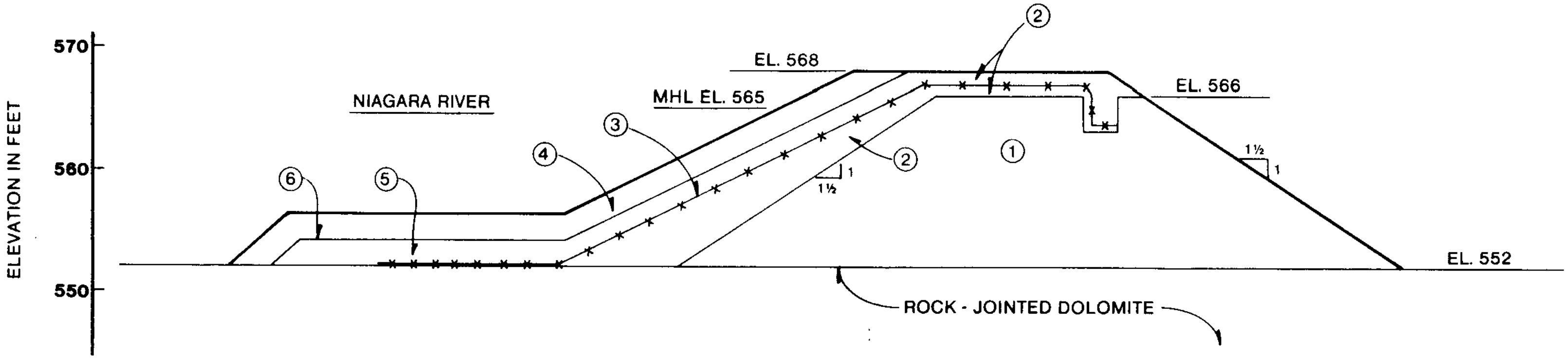
CONTAINMENT COVER ALTERNATIVE
TYPICAL PROFILE
GILL CREEK SEDIMENT STUDY
NIAGARA FALLS, NEW YORK

WOODWARD–CLYDE CONSULTANTS
Consulting Engineers, Geologists and Environmental Scientists

Drawn by: T.P.	Scale in Feet	Date: 1/9/89
Checked by: R.T.G.	N.T.S.	Job No.: 88C2056-5

FIGURE 6-3

PRELIMINARY



LEGEND:

① DUMPED ROCK FILL (SIZE LESS THAN 12")

② SAND AND GRAVEL (SIZE LESS THAN 3")

③ GEOMEMBRANE: HDPE 60 ml

④ DUMPED ROCK FILL (MINIMUM SIZE 6")

⑤ MIXTURE OF SAND, SILT AND CLAY
(SIZE LESS THAN #4 SIEVE) BLANKET

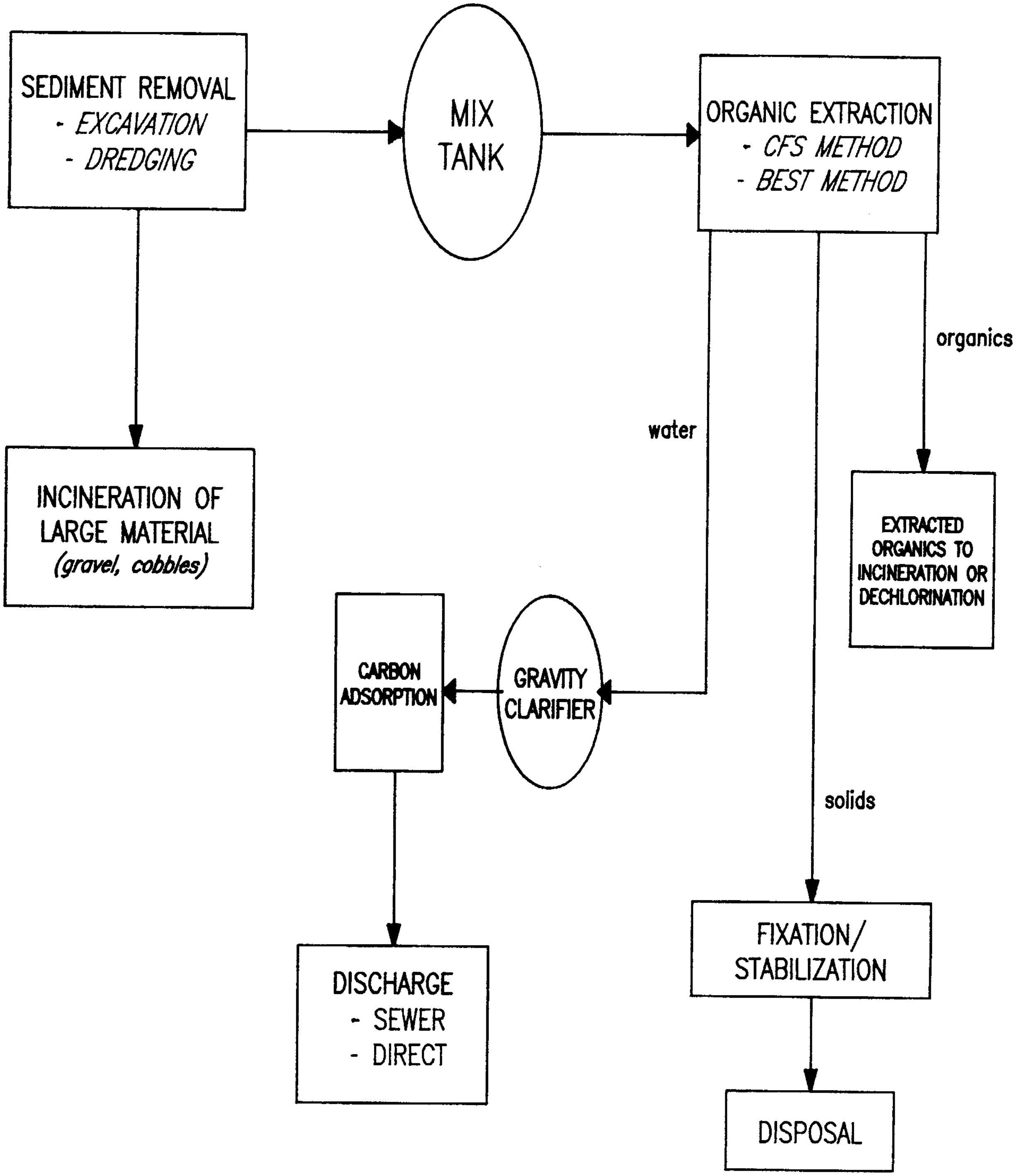
⑥ FILTER FABRIC

CROSS-SECTION RIVER DIKE
GILL CREEK SEDIMENT STUDY
NIAGARA FALLS, NEW YORK

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by D.E.G.	SCALE IN FEET 0 5 10	Date 10/31/88	
Checked by R.T.G.		Job 88C2056-5	

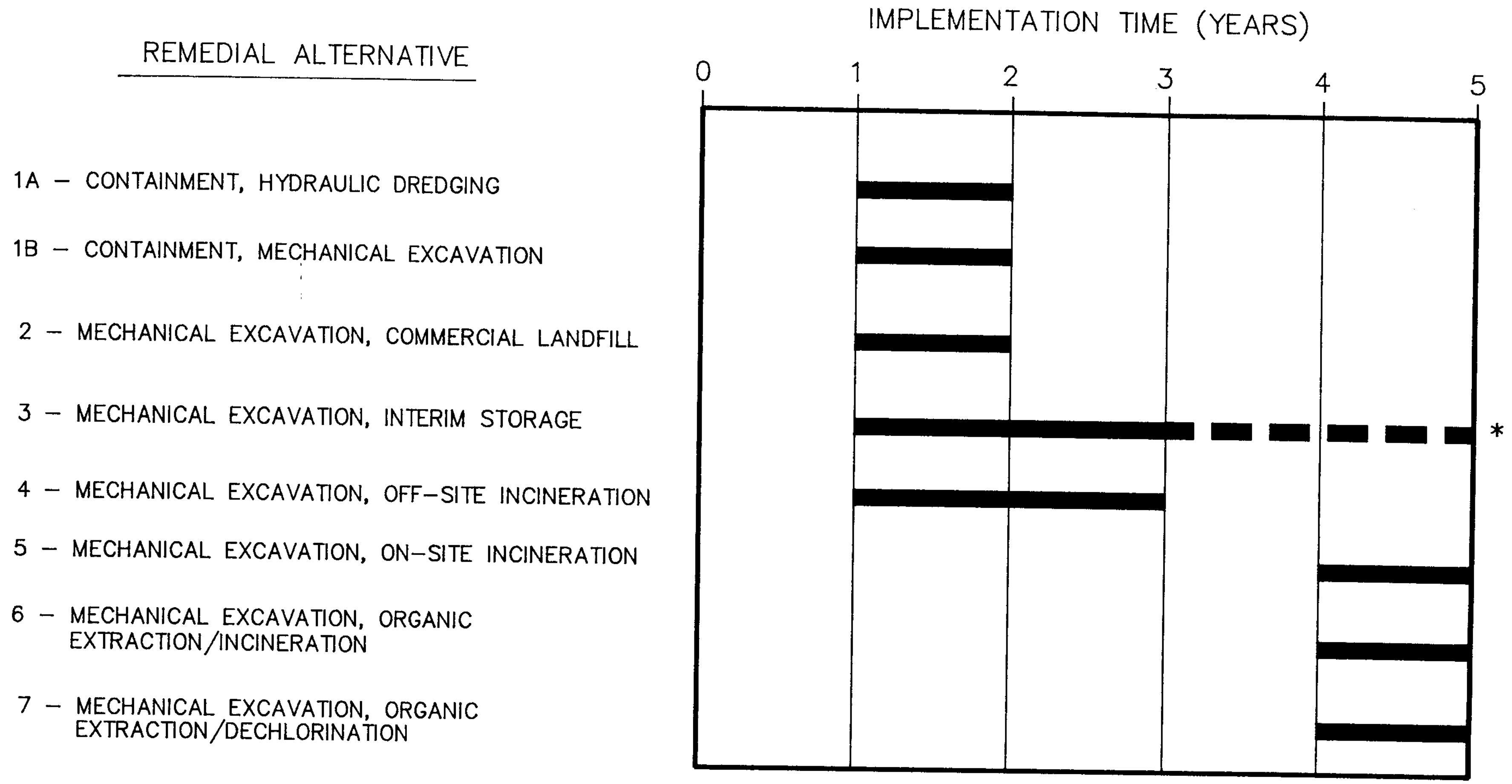
FIGURE 6-4



REMEDIAL ALTERNATIVES EMPLOYING
INNOVATIVE TECHNOLOGY
GILL CREEK SEDIMENT STUDY
NIAGARA FALLS, NEW YORK

Drawn by J.C.	SCALE IN FEET	Date 1/9/89
Checked by R.G.	N.T.S.	Job 88C2056-5

FIGURE 6-5

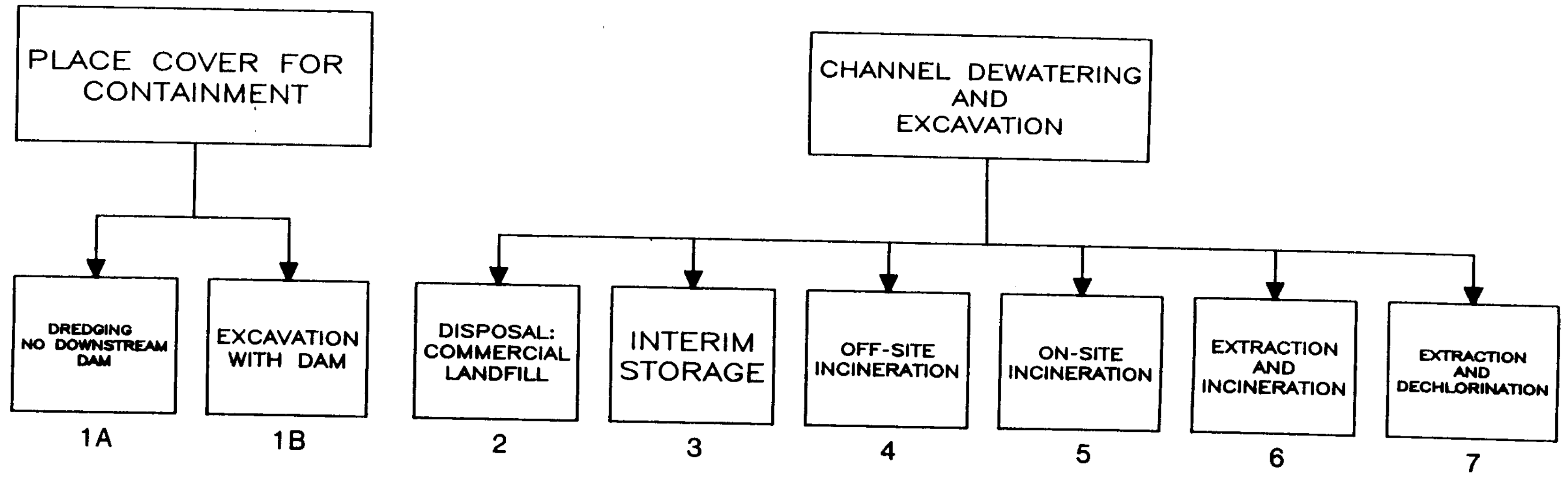


* ADDITIONAL IMPLEMENTATION TIME IF RCRA PERMIT IS REQUIRED FOR STORAGE FACILITY.

IMPLEMEMTATION TIME REQUIREMENTS
FOR REMEDIAL ALTERNATIVES
GILL CREEK SEDIMENT STUDY
NIAGARA FALLS, NEW YORK

FIGURE 6–6

REMEDIAL ALTERNATIVES



LIMITING FACTORS:

1)DOES NOT REDUCE CONTAMINANT MIGRATION TO NEAR ZERO
2) RELEASE DURING DREDGING
3)LONG TERM UTILITY IS QUESTIONABLE

1)DOES NOT REDUCE CONAMINANT MIGRATION TO NEAR ZERO
2)LONG TERM UTILITY IS QUESTIONABLE

1)LAND BAN
2)LIABILITY

1) NOT A PERMANENT SOLUTION

1)OFF SITE COMPANIES MAY BE RELUCTANT TO TREAT THIS WASTE; SPECIAL PERMITS MUST BE OBTAINED
2)ASH DISPOSAL

1)PERMITTING
2)ASH DISPOSAL
3)SMALL VOLUME RESULTS IN HIGH UNIT COST

1) RELATIVELY UNPROVEN TECHNOLOGIES
2) PERMITTING
3) RESIDUE DISPOSAL

REMEDIAL ALTERNATIVES SUMMARY
GILL CREEK SEDIMENT STUDY
NIAGARA FALLS, NEW YORK

WOODWARD-CLYDE CONSULTANTS
CONSULTING ENGINEERS, GEOLOGISTS AND ENVIRONMENTAL SCIENTISTS

Drawn by J.C.	SCALE IN FEET	Date 1/9/89
Checked by R.G.	N.T.S.	Job 88C2056-5

FIGURE 6-7

V. Erk

5120 Butler Pike
Plymouth Meeting
Pennsylvania 19462
215-825-3000
Fax 215-834-0234

Woodward-Clyde Consultants

June 12, 1989
88C2056-5

E. I. du Pont de Nemours and Company, Inc.
26th Street and Buffalo Avenue
Niagara Falls, New York 14302

Attention: Mr. David Wright

Olin Corporation
Lower River Road
Charleston, Tennessee 37310

Attention: Mr. Blaine Butaud

Gentlemen:

Upon review of the report entitled "Gill Creek Sediment Study, Niagara Falls, New York, April 7, 1989," by the New York State Department of Environmental Conservation (NYSDEC), an error was noted in Appendix A. In Appendix A, which summarizes the analytical results from the WCC sampling program, incorrect units were presented for sediment moisture content and HSL metals. Moisture content was reported as ug/g and should actually be reported in percent. HSL metals were reported in ug/kg but should actually be reported in ug/g. These errors were restricted to the database in Appendix A and do not affect any of the data summary tables or text in the main body of the report. Enclosed are copies of the revised Appendix A with the corrected units for distribution.

If there are any additional questions, please do not hesitate to contact us. Thank you for allowing us to serve your consulting needs for this project.

Very truly yours,

WOODWARD-CLYDE CONSULTANTS

Robert G. Gib

Robert G. Gibson
Project Manager

RGG/vbg/WM-WM-39

Enclosure

cc: Frank S. Waller, P.E.

Consulting Engineers, Geologists
and Environmental Scientists

Offices in Other Principal Cities

APPENDIX A

ANALYTICAL RESULTS

1. Site Specific Compound List Sediment Data
2. Hazardous Substance List Sediment Data
3. Site Specific Compound List Surface Water Data
4. Site Specific Compound List Elutriate Data

The following qualifiers are utilized in the data reporting format:

U = Indicates compound was analyzed for but not detected.

J = Indicates an estimated concentration.

B = Indicates that the compound was detected in the blank as well as the sample.

AREA 1

CATEGORY	PARAMETER	UNITS	SAMPLE NUMBER 1-T1-C CONCENTRATION	SAMPLE NUMBER 1-T2-C CONCENTRATION	SAMPLE NUMBER 1-T3-C CONCENTRATION	SAMPLE NUMBER 1-T4-SC CONCENTRATION
SITE-SPECIFIC						
	SAMPLE DATE		06/13/88	06/13/88	06/13/88	06/15/88
	TOTAL VOLATILE SOLIDS	%	32.6	4.5	5.7	16.5
	MOISTURE CONTENT	%	43.5	19.6	17.6	28.3
	MERCURY	ug/g	113.0	21.1	37.6	29.0
	ALPHA-BHC	ug/kg	1000.0	210.0	359.0	19700.0
	BETA-BHC	ug/kg	476.0	u200.0	u200.0	5980.0
	GAMMA-BHC (LINDANE)	ug/kg	u200.0	u200.0	u200.0	u2000.0
	HEPTACHLOR	ug/kg	u200.0	u200.0	u200.0	u2000.0
	DELTA-BHC	ug/kg	u200.0	u200.0	u200.0	u2000.0
	ALDRIN	ug/kg	u200.0	u200.0	u200.0	u2000.0
	HEPTACHLOREPOXIDE	ug/kg	u200.0	u200.0	u200.0	u2000.0
	ALPHA-ENDOSULFAN	ug/kg	u200.0	u200.0	u200.0	u2000.0
	4,4'-DDE	ug/kg	u200.0	u200.0	u200.0	u2000.0
	DIELDRIN	ug/kg	u200.0	u200.0	u200.0	u2000.0
	ENDRIN	ug/kg	u200.0	u200.0	u200.0	u2000.0
	4,4'-TDE (DDD)	ug/kg	u200.0	u200.0	u200.0	u2000.0
	BETA-ENDOSULFAN	ug/kg	u400.0	u400.0	u400.0	u4000.0
	4,4'-DDT	ug/kg	u400.0	u400.0	u400.0	u4000.0
	ENDRIN ALDEHYDE	ug/kg	u400.0	u400.0	u400.0	u4000.0
	ENDOSULFAN SULFATE	ug/kg	u400.0	u400.0	u400.0	u4000.0
	MIREX	ug/kg	u800.0	u800.0	u800.0	u8000.0
	METHOXYCHLOR	ug/kg	u800.0	u800.0	u800.0	u8000.0
	CHLORDANE	ug/kg	u800.0	u800.0	u800.0	u8000.0
	TOXAPHENE	ug/kg	u4000.0	u4000.0	u4000.0	u40000.0
	PCB 1216	ug/kg	u4000.0	u4000.0	u4000.0	u40000.0
	PCB 1221	ug/kg	u4000.0	u4000.0	u4000.0	u40000.0
	PCB 1232	ug/kg	u4000.0	u4000.0	u4000.0	u40000.0
	PCB 1242	ug/kg	u2000.0	u2000.0	u2000.0	u20000.0
	PCB 1248	ug/kg	u2000.0	u2000.0	25500.0	45800.0
	PCB 1254	ug/kg	u2000.0	u2000.0	u2000.0	u20000.0
	PCB 1260	ug/kg	u2000.0	u2000.0	u2000.0	u20000.0
	CHLOROBENZENE	ug/kg	u20.0	u20.0	67.6	17700.0
	1,3-DICHLOROBENZENE	ug/kg	u8000.0	u8000.0	u8000.0	u16000.0
	1,4-DICHLOROBENZENE	ug/kg	u8000.0	u8000.0	u8000.0	u16000.0
	1,2-DICHLOROBENZENE	ug/kg	u8000.0	u8000.0	u8000.0	u16000.0
	HEXACHLOROETHANE	ug/kg	u8000.0	u8000.0	u8000.0	u16000.0
	1,3,5-TRICHLOROBENZENE	ug/kg	u8000.0	u8000.0	u8000.0	u16000.0
	1,2,4-TRICHLOROBENZENE	ug/kg	u8000.0	u8000.0	u8000.0	j4000.0
	1,2,3-TRICHLOROBENZENE	ug/kg	u8000.0	u8000.0	u8000.0	u16000.0
	HEXACHLORBUTADIENE	ug/kg	u8000.0	u8000.0	u8000.0	j875.0
	1,2,3,5-TETRACHLOROBENZENE	ug/kg	u8000.0	u8000.0	u8000.0	u16000.0
	1,2,3,4-TETRACHLOROBENZENE	ug/kg	u8000.0	u8000.0	u8000.0	u16000.0
	PENTACHLOROBENZENE	ug/kg	u8000.0	u8000.0	u8000.0	u16000.0
	HEXACHLOROBENZENE	ug/kg	u8000.0	u8000.0	u8000.0	u16000.0

AREA 2

CATEGORY	PARAMETER	UNITS	SAMPLE NUMBER 2-T5-1D CONCENTRATION	SAMPLE NUMBER 2-T5-1D(DUP) CONCENTRATION	SAMPLE NUMBER 2-T5-1S CONCENTRATION	SAMPLE NUMBER 2-T5-2D CONCENTRATION	SAMPLE NUMBER 2-T5-2D(DUP) CONCENTRATION	SAMPLE NUMBER 2-T5-2S CONCENTRATION	SAMPLE NUMBER 2-T5-3D CONCENTRATION	SAMPLE NUMBER 2-T5-3S CONCENTRATION	SAMPLE NUMBER 2-T6-1D CONCENTRATION
SITE-SPECIFIC											
	SAMPLE DATE		06/14/88	06/14/88	06/14/88	06/14/88	06/14/88	06/14/88	06/14/88	06/14/88	06/14/88
	TOTAL VOLATILE SOLIDS	%	19.1	14.5	6.7	17.0	15.6	13.2	7.3	6.5	14.5
	MOISTURE CONTENT	%	17.4	23.0	23.1	29.7	23.2	24.0	29.8	39.6	37.8
	MERCURY	ug/g	5.1	5.2	1.7	4.1	5.5	5.6	4.0	4.8	55.0
	ALPHA-BHC	ug/kg	86800.0	63500.0	2050.0	34000.0	40900.0	19600.0	27000.0	4470.0	28400.0
	BETA-BHC	ug/kg	88900.0	84800.0	u2000.0	12400.0	12800.0	11300.0	13500.0	16500.0	12100.0
	GAMMA-BHC (LINDANE)	ug/kg	2730.0	u20000.0	u2000.0	u20000.0	u20000.0	u2000.0	u20000.0	u20000.0	u20000.0
	HEPTACHLOR	ug/kg	u20000.0	u20000.0	u2000.0	u20000.0	u20000.0	u2000.0	u20000.0	u20000.0	u20000.0
	DELTA-BHC	ug/kg	u20000.0	u20000.0	u2000.0	u20000.0	u20000.0	u2000.0	u20000.0	u20000.0	u20000.0
	ALDRIN	ug/kg	u20000.0	u20000.0	u2000.0	u20000.0	u20000.0	u2000.0	u20000.0	u20000.0	u20000.0
	HEPTACHLOREPOXIDE	ug/kg	u20000.0	u20000.0	u2000.0	u20000.0	u20000.0	u2000.0	u20000.0	u20000.0	u20000.0
	ALPHA-ENDOSULFAN	ug/kg	u20000.0	u20000.0	u2000.0	u20000.0	u20000.0	u2000.0	u20000.0	u20000.0	u20000.0
	4,4'-DDE	ug/kg	u20000.0	u20000.0	u2000.0	u20000.0	u20000.0	u2000.0	u20000.0	u20000.0	u20000.0
	DIELDRIN	ug/kg	u20000.0	u20000.0	u2000.0	u20000.0	u20000.0	u2000.0	u20000.0	u20000.0	u20000.0
	ENDRIN	ug/kg	u20000.0	u20000.0	u2000.0	u20000.0	u20000.0	u2000.0	u20000.0	u20000.0	u20000.0
	4,4'-TDE (DDD)	ug/kg	u20000.0	u20000.0	u2000.0	u20000.0	u20000.0	u2000.0	u20000.0	u20000.0	u20000.0
	BETA-ENDOSULFAN	ug/kg	u40000.0	u40000.0	u4000.0	u40000.0	u40000.0	u4000.0	u40000.0	u40000.0	u40000.0
	4,4'-DDT	ug/kg	u40000.0	u40000.0	u4000.0	u40000.0	u40000.0	u4000.0	u40000.0	u40000.0	u40000.0
	ENDRIN ALDEHYDE	ug/kg	u40000.0	u40000.0	u4000.0	u40000.0	u40000.0	u4000.0	u40000.0	u40000.0	u40000.0
	ENDOSULFAN SULFATE	ug/kg	u40000.0	u40000.0	u4000.0	u40000.0	u40000.0	u4000.0	u40000.0	u40000.0	u40000.0
	MIREX	ug/kg	u80000.0	u80000.0	u8000.0	u80000.0	u80000.0	u8000.0	u80000.0	u80000.0	u80000.0
	METHOXYCHLOR	ug/kg	u80000.0	u80000.0	u8000.0	u80000.0	u80000.0	u8000.0	u80000.0	u80000.0	u80000.0
	CHLORDANE	ug/kg	u80000.0	u80000.0	u8000.0	u80000.0	u80000.0	u8000.0	u80000.0	u80000.0	u80000.0
	TOXAPHENE	ug/kg	u400000.0	u400000.0	u40000.0	u400000.0	u400000.0	u40000.0	u400000.0	u400000.0	u400000.0
	PCB 1216	ug/kg	u400000.0	u400000.0	u40000.0	u400000.0	u400000.0	u40000.0	u400000.0	u400000.0	u400000.0
	PCB 1221	ug/kg	u400000.0	u400000.0	u40000.0	u400000.0	u400000.0	u40000.0	u400000.0	u400000.0	u400000.0
	PCB 1232	ug/kg	u400000.0	u400000.0	u40000.0	u400000.0	u400000.0	u40000.0	u400000.0	u400000.0	u400000.0
	PCB 1242	ug/kg	u200000.0	u200000.0	u20000.0	u200000.0	u200000.0	u20000.0	u200000.0	u200000.0	u200000.0
	PCB 1248	ug/kg	2610000.0	1910000.0	20200.0	189000.0	1780000.0	360000.0	287000.0	404000.0	3210000.0
	PCB 1254	ug/kg	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	PCB 1260	ug/kg	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	CHLOROBENZENE	ug/kg	1900.0	1180.0	27.6	8280.0	11100.0	1410.0	19700.0	6180.0	4830.0
	1,3-DICHLOROBENZENE	ug/kg	j2200.0	j1080.0	u8000.0	j1080.0	j667.0	u8000.0	j442.0	u8000.0	j2040.0
	1,4-DICHLOROBENZENE	ug/kg	j7020.0	j3450.0	u8000.0	j2850.0	j2330.0	u8000.0	j2400.0	u8000.0	8020.0
	1,2-DICHLOROBENZENE	ug/kg	j1780.0	j921.0	u8000.0	j1150.0	j815.0	u8000.0	j692.0	u8000.0	j5040.0
	HEXACHLOROETHANE	ug/kg	265000.0	u8000.0	j3890.0	22000.0	8630.0	u8000.0	u8000.0	u8000.0	7020.0
	1,3,5-TRICHLOROBENZENE	ug/kg	u8000.0	u8000.0	u8000.0	u8000.0	u8000.0	u8000.0	u8000.0	u8000.0	u8000.0
	1,2,4-TRICHLOROBENZENE	ug/kg	23200.0	14800.0	u8000.0	8150.0	10000.0	u8000.0	11600.0	u8000.0	17400.0
	1,2,3-TRICHLOROBENZENE	ug/kg	j7740.0	j5270.0	u8000.0	j2300.0	j3020.0	u8000.0	j4060.0	u8000.0	j4980.0
	HEXACHLORBUTADIENE	ug/kg	356000.0	439000.0	33300.0	390000.0	352000.0	127000.0	68300.0	15900.0	299000.0
	1,2,3,5-TETRACHLOROBENZENE	ug/kg	j6150.0	j3860.0	u8000.0	j2230.0	j2560.0	u8000.0	j2100.0	u8000.0	j4190.0
	1,2,3,4-TETRACHLOROBENZENE	ug/kg	j3200.0	j2390.0	u8000.0	j943.0	j1440.0	u8000.0	j1210.0	u8000.0	j2090.0
	PENTACHLOROBENZENE	ug/kg	19000.0	12100.0	u8000.0	8980.0	9240.0	u8000.0	j4020.0	u8000.0	12400.0
	HEXACHLOROBENZENE	ug/kg	119000.0	75500.0	j5020.0	164000.0	169000.0	24400.0	19600.0	j7520.0	228000.0

AREA 2

CATEGORY	PARAMETER	UNITS	SAMPLE NUMBER 2-T6-1S CONCENTRATION	SAMPLE NUMBER 2-T6-2D CONCENTRATION	SAMPLE NUMBER 2-T6-2S CONCENTRATION	SAMPLE NUMBER 2-T6-3D CONCENTRATION	SAMPLE NUMBER 2-T6-3S CONCENTRATION
SITE-SPECIFIC							
	SAMPLE DATE		06/14/88	06/14/88	06/14/88	06/14/88	06/14/88
	TOTAL VOLATILE SOLIDS	%	16.7	16.5	12.2	5.0	14.1
	MOISTURE CONTENT	%	33.1	35.4	53.9	16.1	16.3
	MERCURY	ug/g	52.0	59.0	67.0	3.8	11.0
	ALPHA-BHC	ug/kg	52900.0	44100.0	35100.0	14400.0	7080.0
	BETA-BHC	ug/kg	12400.0	8700.0	13300.0	4330.0	u2000.0
	GAMMA-BHC (LINDANE)	ug/kg	u20000.0	u20000.0	u20000.0	u20000.0	u2000.0
	HEPTACHLOR	ug/kg	u20000.0	u20000.0	u20000.0	u20000.0	u2000.0
	DELTA-BHC	ug/kg	u20000.0	u20000.0	u20000.0	u20000.0	u2000.0
	ALDRIN	ug/kg	u20000.0	u20000.0	u20000.0	u20000.0	u2000.0
	HEPTACHLOREPOXIDE	ug/kg	u20000.0	u20000.0	u20000.0	u20000.0	u2000.0
	ALPHA-ENDOSULFAN	ug/kg	u20000.0	u20000.0	u20000.0	u20000.0	u2000.0
	4,4'-DDE	ug/kg	u20000.0	u20000.0	u20000.0	u20000.0	u2000.0
	DIELDRIN	ug/kg	u20000.0	u20000.0	u20000.0	u20000.0	u2000.0
	ENDRIN	ug/kg	u20000.0	u20000.0	u20000.0	u20000.0	u2000.0
	4,4'-TDE (DDD)	ug/kg	u20000.0	u20000.0	u20000.0	u20000.0	u2000.0
	BETA-ENDOSULFAN	ug/kg	u40000.0	u40000.0	u40000.0	u40000.0	u4000.0
	4,4'-DDT	ug/kg	u40000.0	u40000.0	u40000.0	u40000.0	u4000.0
	ENDRIN ALDEHYDE	ug/kg	u40000.0	u40000.0	u40000.0	u40000.0	u4000.0
	ENDOSULFAN SULFATE	ug/kg	u40000.0	u40000.0	u40000.0	u40000.0	u4000.0
	MIREX	ug/kg	u80000.0	u80000.0	u80000.0	u80000.0	u8000.0
	METHOXYCHLOR	ug/kg	u80000.0	u80000.0	u80000.0	u80000.0	u8000.0
	CHLORDANE	ug/kg	u80000.0	u80000.0	u80000.0	u80000.0	u8000.0
	TOXAPHENE	ug/kg	u400000.0	u400000.0	u400000.0	u400000.0	u40000.0
	PCB 1216	ug/kg	u400000.0	u400000.0	u400000.0	u400000.0	u40000.0
	PCB 1221	ug/kg	u400000.0	u400000.0	u400000.0	u400000.0	u40000.0
	PCB 1232	ug/kg	u400000.0	u400000.0	u400000.0	u400000.0	u40000.0
	PCB 1242	ug/kg	<200000.0	u200000.0	u200000.0	u200000.0	u20000.0
	PCB 1248	ug/kg	1450000.0	2490000.0	3300000.0	863000.0	592000.0
	PCB 1254	ug/kg	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	PCB 1260	ug/kg	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	CHLOROBENZENE	ug/kg	4700.0	13000.0	3950.0	1510.0	1220.0
	1,3-DICHLOROBENZENE	ug/kg	j1410.0	j1260.0	j1330.0	u8000.0	u8000.0
	1,4-DICHLOROBENZENE	ug/kg	j5570.0	j5750.0	j6450.0	j1310.0	j887.0
	1,2-DICHLOROBENZENE	ug/kg	j2740.0	j4380.0	j3840.0	u8000.0	j359.0
	HEXACHLOROETHANE	ug/kg	j1980.0	17700.0	j7220.0	u8000.0	u8000.0
	1,3,5-TRICHLOROBENZENE	ug/kg	u8000.0	u8000.0	u8000.0	u8000.0	u8000.0
	1,2,4-TRICHLOROBENZENE	ug/kg	13400.0	11200.0	15200.0	j3980.0	j1940.0
	1,2,3-TRICHLOROBENZENE	ug/kg	j3910.0	j3660.0	j4700.0	j1190.0	j2300.0
	HEXACHLORBUTADIENE	ug/kg	425000.0	418000.0	507000.0	171000.0	146000.0
	1,2,3,5-TETRACHLOROBENZENE	ug/kg	j3350.0	j3400.0	j4020.0	j1040.0	u8000.0
	1,2,3,4-TETRACHLOROBENZENE	ug/kg	j1480.0	j1380.0	j2040.0	j944.0	u8000.0
	PENTACHLOROBENZENE	ug/kg	8700.0	9960.0	11900.0	j2900.0	j1400.0
	HEXACHLOROBENZENE	ug/kg	192000.0	223000.0	259000.0	46800.0	35100.0

CATEGORY	PARAMETER	UNITS	SAMPLE NUMBER 3-T7-1D CONCENTRATION	SAMPLE NUMBER 3-T7-1D (DUP) CONCENTRATION	SAMPLE NUMBER 3-T7-1S CONCENTRATION	SAMPLE NUMBER 3-T7-2D CONCENTRATION	SAMPLE NUMBER 3-T7-2D(DUP) CONCENTRATION	SAMPLE NUMBER 3-T7-2S CONCENTRATION	SAMPLE NUMBER 3-T8-1D CONCENTRATION	SAMPLE NUMBER 3-T8-1D(DUP) CONCENTRATION	SAMPLE NUMBER 3-T8-1S CONCENTRATION
SITE-SPECIFIC											
	SAMPLE DATE		06/15/88	06/15/88	06/15/88	06/15/88	06/15/88	06/15/88	06/15/88	06/15/88	06/15/88
	TOTAL VOLATILE SOLIDS	%	21.3	16.2	14.0	17.9	15.0	10.2	14.5	11.1	14.6
	MOISTURE CONTENT	%	37.1	45.3	35.2	58.3	52.7	30.4	44.7	49.8	41.5
	MERCURY	ug/g	3.5	58.0	56.0	79.0	76.0	53.0	4.5	70.0	51.0
	ALPHA-BHC	ug/kg	21600.0	83700.0	138000.0	58200.0	49100.0	1160.0	29200.0	80200.0	113000.0
	BETA-BHC	ug/kg	11700.0	9850.0	12800.0	8090.0	u20000.0	u20000.0	5000.0	18000.0	14100.0
	GAMMA-BHC (LINDANE)	ug/kg	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	HEPTACHLOR	ug/kg	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	DELTA-BHC	ug/kg	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	ALDRIN	ug/kg	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	HEPTACHLOREPOXIDE	ug/kg	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	ALPHA-ENDOSULFAN	ug/kg	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	4,4'-DDE	ug/kg	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	DIELDRIN	ug/kg	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	ENDRIN	ug/kg	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	4,4'-TDE (DDD)	ug/kg	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	BETA-ENDOSULFAN	ug/kg	u40000.0	u40000.0	u40000.0	u40000.0	u40000.0	u40000.0	u40000.0	u40000.0	u40000.0
	4,4'-DDT	ug/kg	u40000.0	u40000.0	u40000.0	u40000.0	u40000.0	u40000.0	u40000.0	u40000.0	u40000.0
	ENDRIN ALDEHYDE	ug/kg	u40000.0	u40000.0	u40000.0	u40000.0	u40000.0	u40000.0	u40000.0	u40000.0	u40000.0
	ENDOSULFAN SULFATE	ug/kg	u40000.0	u40000.0	u40000.0	u40000.0	u40000.0	u40000.0	u40000.0	u40000.0	u40000.0
	MIREX	ug/kg	u80000.0	u80000.0	u80000.0	u80000.0	u80000.0	u80000.0	u80000.0	u80000.0	u80000.0
	METHOXYCHLOR	ug/kg	u80000.0	u80000.0	u80000.0	u80000.0	u80000.0	u80000.0	u80000.0	u80000.0	u80000.0
	CHLORDANE	ug/kg	u80000.0	u80000.0	u80000.0	u80000.0	u80000.0	u80000.0	u80000.0	u80000.0	u80000.0
	TOXAPHENE	ug/kg	u400000.0	u400000.0	u400000.0	u400000.0	u400000.0	u400000.0	u400000.0	u400000.0	u400000.0
	PCB 1216	ug/kg	u400000.0	u400000.0	u400000.0	u400000.0	u400000.0	u400000.0	u400000.0	u400000.0	u400000.0
	PCB 1221	ug/kg	u400000.0	u400000.0	u400000.0	u400000.0	u400000.0	u400000.0	u400000.0	u400000.0	u400000.0
	PCB 1232	ug/kg	u400000.0	u400000.0	u400000.0	u400000.0	u400000.0	u400000.0	u400000.0	u400000.0	u400000.0
	PCB 1242	ug/kg	u200000.0	u200000.0	u200000.0	u200000.0	u200000.0	u200000.0	u200000.0	u200000.0	u200000.0
	PCB 1248	ug/kg	1220000.0	5380000.0	7530000.0	u4290000.0	8340000.0	6670000.0	449000.0	1240000.0	3230000.0
	PCB 1254	ug/kg	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u200000.0	u20000.0	u20000.0	u20000.0
	PCB 1260	ug/kg	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u200000.0	u20000.0	u20000.0	u20000.0
	CHLOROBENZENE	ug/kg	13700.0	16900.0	15200.0	3130.0	6740.0	4400.0	12800.0	16000.0	16800.0
	1,3-DICHLOROBENZENE	ug/kg	j901.0	j1600.0	j2220.0	j6980.0	j5710.0	j2220.0	j1550.0	j2210.0	j3290.0
	1,4-DICHLOROBENZENE	ug/kg	j2800.0	j4920.0	j7140.0	j13960.0	j11600.0	j7400.0	j3980.0	j5480.0	12200.0
	1,2-DICHLOROBENZENE	ug/kg	j2920.0	j1230.0	j1880.0	j3020.0	j2100.0	j2020.0	j1420.0	j1980.0	10500.0
	HEXACHLOROETHANE	ug/kg	u8000.0	72900.0	351000.0	1260000.0	1250000.0	314000.0	u8000.0	149000.0	257000.0
	1,3,5-TRICHLOROBENZENE	ug/kg	u8000.0	u8000.0	u8000.0	u16000.0	u8000.0	u8000.0	u8000.0	j698.0	u8000.0
	1,2,4-TRICHLOROBENZENE	ug/kg	9560.0	21700.0	25300.0	390000.0	31800.0	20900.0	12300.0	24900.0	28600.0
	1,2,3-TRICHLOROBENZENE	ug/kg	j3310.0	j7610.0	j7140.0	j8490.0	j7050.0	j6670.0	j4430.0	8750.0	8750.0
	HEXACHLORBUTADIENE	ug/kg	282000.0	337000.0	86900.0	1190000.0	1740000.0	479000.0	291000.0	374000.0	445000.0
	1,2,3,5-TETRACHLOROBENZENE	ug/kg	j3440.0	8100.0	9370.0	j6220.0	j5900.0	j6940.0	j3660.0	j7390.0	8150.0
	1,2,3,4-TETRACHLOROBENZENE	ug/kg	j2200.0	j3920.0	j2780.0	j2830.0	j5520.0	j6410.0	j1980.0	j4340.0	j2740.0
	PENTACHLOROBENZENE	ug/kg	17400.0	19300.0	33900.0	25500.0	25100.0	j7400.0	8080.0	13500.0	28300.0
	HEXACHLOROBENZENE	ug/kg	70300.0	129000.0	580000.0	146000.0	146000.0	393000.0	25000.0	46000.0	482000.0

AREA 3

CATEGORY	PARAMETER	UNITS	SAMPLE NUMBER 3-T8-2D CONCENTRATION	SAMPLE NUMBER 3-T8-2M CONCENTRATION	SAMPLE NUMBER 3-T8-2S CONCENTRATION	SAMPLE NUMBER 3-T8-3D CONCENTRATION	SAMPLE NUMBER 3-T8-3S CONCENTRATION
SITE-SPECIFIC							
	SAMPLE DATE		06/15/88	06/15/88	06/15/88	06/15/88	06/15/88
	TOTAL VOLATILE SOLIDS	%	15.7	11.9	18.4	12.8	14.4
	MOISTURE CONTENT	%	42.8	50.0	52.0	44.8	70.0
	MERCURY	ug/g	4.2	46.0	69.0	4.3	60.0
	ALPHA-BHC	ug/kg	134000.0	106000.0	308000.0	46300.0	34300.0
	BETA-BHC	ug/kg	103000.0	24500.0	53300.0	15300.0	9520.0
	GAMMA-BHC (LINDANE)	ug/kg	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	HEPTACHLOR	ug/kg	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	DELTA-BHC	ug/kg	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	ALDRIN	ug/kg	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	HEPTACHLOREPOXIDE	ug/kg	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	ALPHA-ENDOSULFAN	ug/kg	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	4,4'-DDE	ug/kg	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	DIELDRIN	ug/kg	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	ENDRIN	ug/kg	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	4,4'-TDE (DDD)	ug/kg	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	BETA-ENDOSULFAN	ug/kg	u40000.0	u40000.0	u40000.0	u20000.0	u40000.0
	4,4'-DDT	ug/kg	u40000.0	u40000.0	u40000.0	u40000.0	u40000.0
	ENDRIN ALDEHYDE	ug/kg	u40000.0	u40000.0	u40000.0	u40000.0	u40000.0
	ENDOSULFAN SULFATE	ug/kg	u40000.0	u40000.0	u40000.0	u40000.0	u40000.0
	MIREX	ug/kg	u80000.0	u80000.0	u80000.0	u80000.0	u80000.0
	METHOXYCHLOR	ug/kg	u80000.0	u80000.0	u80000.0	u80000.0	u80000.0
	CHLORDANE	ug/kg	u80000.0	u80000.0	u80000.0	u80000.0	u80000.0
	TOXAPHENE	ug/kg	u400000.0	u400000.0	u400000.0	u400000.0	u400000.0
	PCB 1216	ug/kg	u400000.0	u400000.0	u400000.0	u400000.0	u400000.0
	PCB 1221	ug/kg	u400000.0	u400000.0	u400000.0	u400000.0	u400000.0
	PCB 1232	ug/kg	u400000.0	u400000.0	u400000.0	u400000.0	u400000.0
	PCB 1242	ug/kg	u200000.0	u200000.0	u200000.0	u200000.0	u200000.0
	PCB 1248	ug/kg	149000.0	4630000.0	3380000.0	319000.0	1660000.0
	PCB 1254	ug/kg	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	PCB 1260	ug/kg	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	CHLOROBENZENE	ug/kg	7540.0	8090.0	14700.0	7920.0	2060.0
	1,3-DICHLOROBENZENE	ug/kg	12600.0	j2910.0	u16000.0	j1140.0	j840.0
	1,4-DICHLOROBENZENE	ug/kg	24300.0	9560.0	j13200.0	j4210.0	j2520.0
	1,2-DICHLOROBENZENE	ug/kg	j7050.0	j2940.0	j10600.0	j1160.0	j1540.0
	HEXACHLOROETHANE	ug/kg	j1550.0	107000.0	u16000.0	u8000.0	u8000.0
	1,3,5-TRICHLOROBENZENE	ug/kg	j879.0	u8000.0	u16000.0	u8000.0	j1440.0
	1,2,4-TRICHLOROBENZENE	ug/kg	65000.0	30900.0	44000.0	22800.0	j7960.0
	1,2,3-TRICHLOROBENZENE	ug/kg	19700.0	10000.0	j12000.0	j7630.0	j2140.0
	HEXACHLORBUTADIENE	ug/kg	197000.0	257000.0	786000.0	199000.0	175000.0
	1,2,3,5-TETRACHLOROBENZENE	ug/kg	9200.0	j5780.0	j8400.0	j5220.0	j1640.0
	1,2,3,4-TETRACHLOROBENZENE	ug/kg	j5360.0	j2780.0	j5000.0	j2940.0	j520.0
	PENTACHLOROBENZENE	ug/kg	11700.0	13900.0	j4200.0	j5040.0	j1780.0
	HEXACHLOROBENZENE	ug/kg	26500.0	142000.0	120000.0	31300.0	46500.0

AREA 4

			SAMPLE NUMBER 4-T10-1D	SAMPLE NUMBER 4-T10-1S	SAMPLE NUMBER 4-T10-2D	SAMPLE NUMBER 4-T10-2S	SAMPLE NUMBER 4-T10-3D	SAMPLE NUMBER 4-T10-3M	SAMPLE NUMBER 4-T10-3S	SAMPLE NUMBER 4-T11-1D	SAMPLE NUMBER 4-T11-1M
CATEGORY	PARAMETER	UNITS	CONCENTRATION	CONCENTRATION	CONCENTRATION	CONCENTRATION	CONCENTRATION	CONCENTRATION	CONCENTRATION	CONCENTRATION	CONCENTRATION
SITE-SPECIFIC											
	SAMPLE DATE		06/11/88	06/11/88	06/11/88	06/11/88	06/11/88	06/11/88	06/11/88	06/10/88	06/10/88
	TOTAL VOLATILE SOLIDS	%	13.1	13.5	14.2	18.2	14.7	15.5	21.6	17.1	13.0
	MOISTURE CONTENT	%	43.0	52.2	35.4	24.6	31.0	41.6	24.9	33.9	61.8
	MERCURY	ug/g	49.1	121.0	118.0	59.7	34.8	274.0	133.0	42.4	199.0
	ALPHA-BHC	ug/kg	63000.0	65100.0	120000.0	266000.0	17600.0	41700.0	221000.0	24040.0	32100.0
	BETA-BHC	ug/kg	8590.0	21700.0	34100.0	60000.0	11900.0	11900.0	64500.0	107000.0	3810.0
	GAMMA-BHC (LINDANE)	ug/kg	<20000.0	u20000.0	3320.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	HEPTACHLOR	ug/kg	<20000.0	u20000.0	u2000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	DELTA-BHC	ug/kg	<20000.0	u20000.0	u2000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	ALDRIN	ug/kg	<20000.0	u20000.0	u2000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	HEPTACHLOREPOXIDE	ug/kg	<20000.0	u20000.0	u2000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	ALPHA-ENDOSULFAN	ug/kg	<20000.0	u20000.0	u2000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	4,4'-DDE	ug/kg	<20000.0	u20000.0	u2000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	DIELDRIN	ug/kg	<20000.0	u20000.0	u2000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	ENDRIN	ug/kg	<20000.0	u20000.0	u2000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	4,4'-TDE (DDD)	ug/kg	<20000.0	u20000.0	u2000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	BETA-ENDOSULFAN	ug/kg	<40000.0	u40000.0	u4000.0	u40000.0	u40000.0	u40000.0	u40000.0	u40000.0	u40000.0
	4,4'-DDT	ug/kg	<40000.0	u40000.0	u4000.0	u40000.0	u40000.0	u40000.0	u40000.0	u40000.0	u40000.0
	ENDRIN ALDEHYDE	ug/kg	<40000.0	u40000.0	u4000.0	u40000.0	u40000.0	u40000.0	u40000.0	u40000.0	u40000.0
	ENDOSULFAN SULFATE	ug/kg	<40000.0	u40000.0	u4000.0	u40000.0	u40000.0	u40000.0	u40000.0	u40000.0	u40000.0
	MIREX	ug/kg	<80000.0	u80000.0	u8000.0	u80000.0	u80000.0	u80000.0	u80000.0	u80000.0	u80000.0
	METHOXYCHLOR	ug/kg	<80000.0	u80000.0	u8000.0	u80000.0	u80000.0	u80000.0	u80000.0	u80000.0	u80000.0
	CHLORDANE	ug/kg	<80000.0	u80000.0	u8000.0	u80000.0	u80000.0	u80000.0	u80000.0	u80000.0	u80000.0
	TOXAPHENE	ug/kg	<400000.0	u400000.0	u40000.0	u400000.0	u400000.0	u400000.0	u400000.0	u400000.0	u400000.0
	PCB 1216	ug/kg	<400000.0	u400000.0	u40000.0	u400000.0	u400000.0	u400000.0	u400000.0	u400000.0	u400000.0
	PCB 1221	ug/kg	<400000.0	u400000.0	u40000.0	u400000.0	u400000.0	u400000.0	u400000.0	u400000.0	u400000.0
	PCB 1232	ug/kg	<400000.0	u400000.0	u40000.0	u400000.0	u400000.0	u400000.0	u400000.0	u400000.0	u400000.0
	PCB 1242	ug/kg	<200000.0	u200000.0	u20000.0	u200000.0	u200000.0	u200000.0	u200000.0	u200000.0	u200000.0
	PCB 1248	ug/kg	5600000.0	5900000.0	96400.0	2130000.0	400000.0	3060000.0	3110000.0	1190000.0	1620000.0
	PCB 1254	ug/kg	<20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	PCB 1260	ug/kg	<20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u200000.0	u20000.0	u20000.0
	CHLOROBENZENE	ug/kg	3300.0	18900.0	37600.0	10600.0	4310.0	5790.0	10050.0	2950.0	7480.0
	1,3-DICHLOROBENZENE	ug/kg	j3240.0	j4540.0	j1980.0	j4430.0	j200.0	j755.0	j4160.0	j275.0	j1800.0
	1,4-DICHLOROBENZENE	ug/kg	9500.0	41000.0	j7620.0	29100.0	j1470.0	j2740.0	26500.0	j1330.0	j1680.0
	1,2-DICHLOROBENZENE	ug/kg	j2220.0	30900.0	j7900.0	17500.0	j291.0	j641.0	14900.0	j254.0	j1740.0
	HEXACHLOROETHANE	ug/kg	368000.0	u8000.0	u8000.0	u8000.0	u8000.0	u8000.0	u8000.0	u8000.0	u8000.0
	1,3,5-TRICHLOROBENZENE	ug/kg	<8000.0	j653.0	j860.0	j930.0	u8000.0	u8000.0	u8000.0	j412.0	u8000.0
	1,2,4-TRICHLOROBENZENE	ug/kg	24000.0	66200.0	33100.0	50400.0	8780.0	9790.0	40400.0	j5000.0	j5950.0
	1,2,3-TRICHLOROBENZENE	ug/kg	8110.0	23700.0	10500.0	14800.0	j3040.0	j3360.0	11100.0	j1950.0	j1960.0
	HEXACHLORBUTADIENE	ug/kg	516000.0	274000.0	139000.0	242000.0	137000.0	278000.0	323000.0	225000.0	245000.0
	1,2,3,5-TETRACHLOROBENZENE	ug/kg	j3930.0	9120.0	j652.0	10800.0	j2340.0	j2490.0	j6270.0	j1550.0	j1100.0
	1,2,3,4-TETRACHLOROBENZENE	ug/kg	j2020.0	j4770.0	j2860.0	j7500.0	j1380.0	j1130.0	j3600.0	j550.0	j1020.0
	PENTACHLOROBENZENE	ug/kg	9500.0	11000.0	j6400.0	j3300.0	j3200.0	9370.0	j2240.0	j3760.0	j2360.0
	HEXACHLOROBENZENE	ug/kg	85000.0	170000.0	12800.0	55900.0	23800.0	160000.0	72500.0	41900.0	71400.0

AREA 4

CATEGORY	PARAMETER	UNITS	SAMPLE NUMBER 4-T11-1S CONCENTRATION	SAMPLE NUMBER 4-T11-2D CONCENTRATION	SAMPLE NUMBER 4-T11-2S CONCENTRATION	SAMPLE NUMBER 4-T11-3D CONCENTRATION	SAMPLE NUMBER 4-T11-3D(DUP) CONCENTRATION	SAMPLE NUMBER 4-T11-3S CONCENTRATION	SAMPLE NUMBER 4-T9-1D CONCENTRATION	SAMPLE NUMBER 4-T9-1M CONCENTRATION	SAMPLE NUMBER 4-T9-1S CONCENTRATION
SITE-SPECIFIC											
	SAMPLE DATE		06/10/88	06/09/88	06/09/88	06/11/88	06/11/88	06/11/88	06/10/88	06/10/88	06/10/88
	TOTAL VOLATILE SOLIDS	%	26.1	17.6	15.7	6.4	7.8	13.8	17.7	23.8	11.1
	MOISTURE CONTENT	%	46.1	40.4	45.1	39.3	37.9	30.1	43.0	30.7	29.0
	MERCURY	ug/g	59.4	11.1	135.0	1.6	190.0	8.2	7.4	75.0	12.4
	ALPHA-BHC	ug/kg	71900.0	95200.0	137000.0	292000.0	312000.0	5060.0	222000.0	79200.0	313000.0
	BETA-BHC	ug/kg	18000.0	28800.0	31400.0	84800.0	57700.0	4810.0	142000.0	39600.0	130000.0
	GAMMA-BHC (LINDANE)	ug/kg	u20000.0	3240.0	u20000.0	u20000.0	u20000.0	u2000.0	9680.0	u20000.0	u20000.0
	HEPTACHLOR	ug/kg	u20000.0	u2000.0	u20000.0	u20000.0	u20000.0	u2000.0	u2000.0	u20000.0	u20000.0
	DELTA-BHC	ug/kg	u20000.0	u2000.0	u20000.0	u20000.0	u20000.0	u2000.0	u2000.0	u20000.0	u20000.0
	ALDRIN	ug/kg	u20000.0	u2000.0	u20000.0	u20000.0	u20000.0	u2000.0	u2000.0	u20000.0	u20000.0
	HEPTACHLOREPOXIDE	ug/kg	u20000.0	u2000.0	u20000.0	u20000.0	u20000.0	u2000.0	u2000.0	u20000.0	u20000.0
	ALPHA-ENDOSULFAN	ug/kg	u20000.0	u2000.0	u20000.0	u20000.0	u20000.0	u2000.0	u2000.0	u20000.0	u20000.0
	4,4'-DDE	ug/kg	u20000.0	u2000.0	u20000.0	u20000.0	u20000.0	u2000.0	u2000.0	u20000.0	u20000.0
	DIELDRIN	ug/kg	u20000.0	u2000.0	u20000.0	u20000.0	u20000.0	u2000.0	u2000.0	u20000.0	u20000.0
	ENDRIN	ug/kg	u20000.0	u2000.0	u20000.0	u20000.0	u20000.0	u2000.0	u2000.0	u20000.0	u20000.0
	4,4'-TDE (DDD)	ug/kg	u20000.0	u2000.0	u20000.0	u20000.0	u20000.0	u2000.0	u2000.0	u20000.0	u20000.0
	BETA-ENDOSULFAN	ug/kg	u40000.0	u4000.0	u40000.0	u40000.0	u40000.0	u4000.0	u40000.0	u40000.0	u40000.0
	4,4'-DDT	ug/kg	u40000.0	u4000.0	u40000.0	u40000.0	u40000.0	u4000.0	u4000.0	u40000.0	u40000.0
	ENDRIN ALDEHYDE	ug/kg	u40000.0	u4000.0	u40000.0	u40000.0	u40000.0	u4000.0	u4000.0	u40000.0	u40000.0
	ENDOSULFAN SULFATE	ug/kg	u40000.0	u4000.0	u40000.0	u40000.0	u40000.0	u8000.0	u4000.0	u40000.0	u40000.0
	MIREX	ug/kg	u80000.0	u8000.0	u80000.0	u80000.0	u80000.0	u8000.0	u8000.0	u80000.0	u80000.0
	METHOXYCHLOR	ug/kg	u80000.0	u8000.0	u80000.0	u80000.0	u80000.0	u8000.0	u8000.0	u80000.0	u80000.0
	CHLORDANE	ug/kg	u80000.0	u8000.0	u80000.0	u80000.0	u80000.0	u8000.0	u8000.0	u80000.0	u80000.0
	TOXAPHENE	ug/kg	u400000.0	u40000.0	u400000.0	u400000.0	u400000.0	u40000.0	u40000.0	u400000.0	u400000.0
	PCB 1216	ug/kg	u400000.0	u40000.0	u400000.0	u400000.0	u400000.0	u40000.0	u40000.0	u400000.0	u400000.0
	PCB 1221	ug/kg	u400000.0	u40000.0	u400000.0	u400000.0	u400000.0	u40000.0	u40000.0	u400000.0	u400000.0
	PCB 1232	ug/kg	u400000.0	u40000.0	u400000.0	u400000.0	u400000.0	u40000.0	u40000.0	u400000.0	u400000.0
	PCB 1242	ug/kg	u200000.0	u20000.0	u200000.0	u200000.0	u200000.0	u20000.0	u20000.0	u200000.0	u200000.0
	PCB 1248	ug/kg	2000000.0	30300.0	1780000.0	1690000.0	1720000.0	105000.0	62800.0	5060000.0	1880000.0
	PCB 1254	ug/kg	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	PCB 1260	ug/kg	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	CHLOROBENZENE	ug/kg	14500.0	6120.0	21000.0	6340.0	5110.0	8510.0	1480.0	4120.0	6200.0
	1,3-DICHLOROBENZENE	ug/kg	j582.0	j1610.0	j2130.0	j2290.0	j1600.0	j3370.0	j2990.0	j5390.0	j1480.0
	1,4-DICHLOROBENZENE	ug/kg	j2790.0	j7020.0	10000.0	j1350.0	j1000.0	14000.0	21200.0	13000.0	9540.0
	1,2-DICHLOROBENZENE	ug/kg	j2260.0	j2060.0	j6280.0	j500.0	j377.0	j7800.0	j6960.0	j3220.0	j6780.0
	HEXACHLOROETHANE	ug/kg	u8000.0	u8000.0	u8000.0	u8000.0	u8000.0	u8000.0	u8000.0	355000.0	28400.0
	1,3,5-TRICHLOROBENZENE	ug/kg	j463.0	j350.0	j1020.0	j4580.0	j5570.0	j2280.0	u8000.0	j302.0	u8000.0
	1,2,4-TRICHLOROBENZENE	ug/kg	10700.0	21000.0	22700.0	11300.0	8260.0	33200.0	61600.0	27500.0	28800.0
	1,2,3-TRICHLOROBENZENE	ug/kg	j4020.0	9070.0	j7800.0	j1160.0	8200.0	8800.0	18700.0	9510.0	12100.0
	HEXACHLORBUTADIENE	ug/kg	209000.0	45600.0	152000.0	29800.0	22500.0	241000.0	139000.0	342000.0	288000.0
	1,2,3,5-TETRACHLOROBENZENE	ug/kg	j2940.0	j3570.0	8260.0	j2240.0	j1850.0	8900.0	j7700.0	j6150.0	9090.0
	1,2,3,4-TETRACHLOROBENZENE	ug/kg	j1590.0	j1960.0	j4240.0	j210.0	j245.0	j3610.0	j4010.0	j3090.0	j5500.0
	PENTACHLOROBENZENE	ug/kg	j2330.0	j3500.0	j2740.0	j1820.0	j1340.0	j3740.0	11100.0	12100.0	8330.0
	HEXACHLOROBENZENE	ug/kg	44000.0	j3630.0	38800.0	j7180.0	j7790.0	45100.0	23700.0	75300.0	141000.0

AREA 4

CATEGORY	PARAMETER	UNITS	SAMPLE NUMBER 4-T9-2D CONCENTRATION	SAMPLE NUMBER 4-T9-2D(DUP) CONCENTRATION	SAMPLE NUMBER 4-T9-2S CONCENTRATION	SAMPLE NUMBER 4-T9-3D CONCENTRATION	SAMPLE NUMBER 4-T9-3D(DUP) CONCENTRATION	SAMPLE NUMBER 4-T9-3S CONCENTRATION
SITE-SPECIFIC								
	SAMPLE DATE		06/10/88	06/10/88	06/10/88	06/11/88	06/11/88	06/11/88
	TOTAL VOLATILE SOLIDS	%	12.6	13.6	14.6	15.1	13.4	14.8
	MOISTURE CONTENT	%	46.0	48.2	24.7	46.6	47.6	26.9
	MERCURY	ug/g	7.2	5.2	95.6	89.9	133.0	123.0
	ALPHA-BHC	ug/kg	52800.0	112000.0	176000.0	31000.0	47700.0	206000.0
	BETA-BHC	ug/kg	21800.0	33400.0	54800.0	u20000.0	15200.0	73200.0
	GAMMA-BHC (LINDANE)	ug/kg	u2000.0	3480.0	u20000.0	u20000.0	u20000.0	u20000.0
	HEPTACHLOR	ug/kg	u2000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	DELTA-BHC	ug/kg	u2000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	ALDRIN	ug/kg	u2000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	HEPTACHLOREPOXIDE	ug/kg	u2000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	ALPHA-ENDOSULFAN	ug/kg	u2000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	4,4'-DDE	ug/kg	u2000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	DIELDRIN	ug/kg	u2000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	ENDRIN	ug/kg	u2000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	4,4'-TDE (DDD)	ug/kg	u2000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	BETA-ENDOSULFAN	ug/kg	u4000.0	u40000.0	u40000.0	u20000.0	u40000.0	u40000.0
	4,4'-DDT	ug/kg	u4000.0	u40000.0	u40000.0	u20000.0	u40000.0	u40000.0
	ENDRIN ALDEHYDE	ug/kg	u4000.0	u40000.0	u40000.0	u20000.0	u40000.0	u40000.0
	ENDOSULFAN SULFATE	ug/kg	u4000.0	u40000.0	u40000.0	u40000.0	u40000.0	u40000.0
	MIREX	ug/kg	u8000.0	u80000.0	u80000.0	u40000.0	u80000.0	u80000.0
	METHOXYCHLOR	ug/kg	u8000.0	u80000.0	u80000.0	u40000.0	u80000.0	u80000.0
	CHLORDANE	ug/kg	u8000.0	u80000.0	u80000.0	u40000.0	u80000.0	u80000.0
	TOXAPHENE	ug/kg	u40000.0	u400000.0	u400000.0	u400000.0	u400000.0	u400000.0
	PCB 1216	ug/kg	u40000.0	u400000.0	u400000.0	u400000.0	u400000.0	u400000.0
	PCB 1221	ug/kg	u40000.0	u400000.0	u400000.0	u400000.0	u400000.0	u400000.0
	PCB 1232	ug/kg	u40000.0	u400000.0	u400000.0	u400000.0	u400000.0	u400000.0
	PCB 1242	ug/kg	u20000.0	u200000.0	u200000.0	u200000.0	u200000.0	u200000.0
	PCB 1248	ug/kg	106000.0	244000.0	4710000.0	2220000.0	3420000.0	2100000.0
	PCB 1254	ug/kg	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	PCB 1260	ug/kg	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0	u20000.0
	CHLOROBENZENE	ug/kg	30600.0	8140.0	16700.0	7190.0	2960.0	4270.0
	1,3-DICHLOROBENZENE	ug/kg	j3020.0	j2120.0	j2760.0	j2310.0	j3350.0	j2290.0
	1,4-DICHLOROBENZENE	ug/kg	9870.0	j7330.0	13500.0	j5310.0	j7400.0	13800.0
	1,2-DICHLOROBENZENE	ug/kg	j2770.0	j1940.0	j7290.0	j1270.0	j1890.0	10300.0
	HEXACHLOROETHANE	ug/kg	j6720.0	j4430.0	25600.0	j803.0	j870.0	j647.0
	1,3,5-TRICHLOROBENZENE	ug/kg	u8000.0	u8000.0	j387.0	u8000.0	u8000.0	u8000.0
	1,2,4-TRICHLOROBENZENE	ug/kg	38400.0	37200.0	31600.0	12600.0	19000.0	33300.0
	1,2,3-TRICHLOROBENZENE	ug/kg	12800.0	15600.0	9660.0	j4160.0	j6460.0	11200.0
	HEXACHLORBUTADIENE	ug/kg	116000.0	93500.0	307000.0	534000.0	434000.0	218000.0
	1,2,3,5-TETRACHLOROBENZENE	ug/kg	j4600.0	j5180.0	j6160.0	j2760.0	u8000.0	8550.0
	1,2,3,4-TETRACHLOROBENZENE	ug/kg	j2550.0	j3040.0	j3060.0	j902.0	u8000.0	j5180.0
	PENTACHLOROBENZENE	ug/kg	j2830.0	j3840.0	8370.0	j7310.0	13800.0	j2370.0
	HEXACHLOROBENZENE	ug/kg	6750.0	j7250.0	144000.0	92900.0	148000.0	59600.0

AREA 5

CA RY	PARAMETER	UNITS	SAMPLE NUMBER 5-1G CONCENTRATION	SAMPLE NUMBER 5-2G CONCENTRATION	SAMPLE NUMBER 5-3G CONCENTRATION	SAMPLE NUMBER 5-4G CONCENTRATION	SAMPLE NUMBER 5-5G CONCENTRATION	SAMPLE NUMBER 5-6G CONCENTRATION
SITE-SPECIFIC								
	SAMPLE DATE		06/13/88	06/11/88	06/10/88	06/10/88	06/13/88	06/13/88
	TOTAL VOLATILE SOLIDS	%	14.4	11.9	7.7	5.5	12.4	3.7
	MOISTURE CONTENT	%	14.9	17.2	9.7	14.4	18.0	19.2
	MERCURY	ug/g	27.0	217.0	5.5	3.2	183.0	44.6
	ALPHA-BHC	ug/kg	87800.0	13600.0	3120.0	12600.0	u200.0	u200.0
	BETA-BHC	ug/kg	31800.0	2210.0	2110.0	6320.0	u200.0	u200.0
	GAMMA-BHC (LINDANE)	ug/kg	u20000.0	u2000.0	u2000.0	u2000.0	u200.0	u200.0
	HEPTACHLOR	ug/kg	u20000.0	u2000.0	u2000.0	u2000.0	u200.0	u200.0
	DELTA-BHC	ug/kg	u20000.0	u2000.0	u2000.0	u2000.0	u200.0	u200.0
	ALDRIN	ug/kg	u20000.0	u2000.0	u2000.0	u2000.0	u200.0	u200.0
	HEPTACHLOREPOXIDE	ug/kg	u20000.0	u2000.0	u2000.0	u2000.0	u200.0	u200.0
	ALPHA-ENDOSULFAN	ug/kg	u20000.0	u2000.0	u2000.0	u2000.0	u200.0	u200.0
	4,4'-DDE	ug/kg	u20000.0	u2000.0	u2000.0	u2000.0	u200.0	u200.0
	DIELDRIN	ug/kg	u20000.0	u2000.0	u2000.0	u2000.0	u200.0	u200.0
	ENDRIN	ug/kg	u20000.0	u2000.0	u2000.0	u2000.0	u200.0	u200.0
	4,4'-TDE (DDD)	ug/kg	u20000.0	u2000.0	u2000.0	u2000.0	u200.0	u200.0
	BETA-ENDOSULFAN	ug/kg	u40000.0	u4000.0	u4000.0	u4000.0	u400.0	u400.0
	4,4'-DDT	ug/kg	u40000.0	u4000.0	u4000.0	u4000.0	u400.0	u400.0
	ENDRIN ALDEHYDE	ug/kg	u40000.0	u4000.0	u4000.0	u4000.0	u400.0	u400.0
	ENDOSULFAN SULFATE	ug/kg	u40000.0	u4000.0	u4000.0	u4000.0	u400.0	u400.0
	MIREX	ug/kg	u80000.0	u8000.0	u8000.0	u8000.0	u800.0	u800.0
	METHOXYCHLOR	ug/kg	u80000.0	u8000.0	u8000.0	u8000.0	u800.0	u800.0
	CHLORDANE	ug/kg	u80000.0	u8000.0	u8000.0	u8000.0	u800.0	u800.0
	TOXAPHENE	ug/kg	u400000.0	u40000.0	u40000.0	u40000.0	u4000.0	u4000.0
	PCB 1216	ug/kg	u400000.0	u40000.0	u40000.0	u40000.0	u4000.0	u4000.0
	PCB 1221	ug/kg	u400000.0	u40000.0	u40000.0	u40000.0	u4000.0	u4000.0
	PCB 1232	ug/kg	u400000.0	u40000.0	u40000.0	u40000.0	u4000.0	u4000.0
	PCB 1242	ug/kg	u200000.0	u20000.0	u20000.0	u20000.0	u2000.0	u2000.0
	PCB 1248	ug/kg	423000.0	79600.0	31300.0	143000.0	u2000.0	u2000.0
	PCB 1254	ug/kg	u20000.0	u20000.0	u2000.0	u20000.0	u2000.0	u2000.0
	PCB 1260	ug/kg	u20000.0	u20000.0	u2000.0	u20000.0	u2000.0	u2000.0
	CHLOROBENZENE	ug/kg	124.0	37.4	u20.0	24.7	u20.0	u20.0
	1,3-DICHLOROBENZENE	ug/kg	j346.0	u8000.0	u8000.0	j1160.0	u8000.0	u8000.0
	1,4-DICHLOROBENZENE	ug/kg	j3190.0	u8000.0	j226.0	j6500.0	u8000.0	u8000.0
	1,2-DICHLOROBENZENE	ug/kg	j2060.0	u8000.0	u8000.0	j7190.0	u8000.0	u8000.0
	HEXACHLOROETHANE	ug/kg	u8000.0	u8000.0	u8000.0	u8000.0	u8000.0	u8000.0
	1,3,5-TRICHLOROBENZENE	ug/kg	u8000.0	u8000.0	u8000.0	u8000.0	u8000.0	u8000.0
	1,2,4-TRICHLOROBENZENE	ug/kg	9730.0	u8000.0	u8000.0	9210.0	u8000.0	u8000.0
	1,2,3-TRICHLOROBENZENE	ug/kg	j2770.0	u8000.0	u8000.0	j1950.0	u8000.0	u8000.0
	HEXACHLORBUTADIENE	ug/kg	54200.0	j4360.0	j1380.0	10900.0	u8000.0	u8000.0
	1,2,3,5-TETRACHLOROBENZENE	ug/kg	j1520.0	u8000.0	u8000.0	j650.0	u8000.0	u8000.0
	1,2,3,4-TETRACHLOROBENZENE	ug/kg	j1400.0	u8000.0	u8000.0	j596.0	u8000.0	u8000.0
	PENTACHLOROBENZENE	ug/kg	u8000.0	u8000.0	u8000.0	u8000.0	u8000.0	u8000.0
	HEXACHLOROBENZENE	ug/kg	j5440.0	u8000.0	u8000.0	u8000.0	u8000.0	u8000.0

S[illegible] [illegible]REA 1

CATEGORY	PARAMETER	UNITS	SAMPLE NUMBER 1-T1-C CONCENTRATION	SAMPLE NUMBER 1-T4-SC CONCENTRATION
HSL VOLATILES				
	SAMPLE DATE		06/13/88	06/15/88
	CHLOROMETHANE	ug/kg	u100.0	u10000.0
	BROMOETHANE	ug/kg	u100.0	u10000.0
	VINYL CHLORIDE	ug/kg	u100.0	u10000.0
	CHLOROETHANE	ug/kg	u100.0	u10000.0
	METHYLENE CHLORIDE	ug/kg	u50.0	u5000.0
	ACETONE	ug/kg	u500.0	56000.0
	CARBON DISULFIDE	ug/kg	u200.0	u10000.0
	VINYL ACETATE	ug/kg	u500.0	u50000.0
	1,1-DICHLOROETHENE	ug/kg	u50.0	u5000.0
	1,1-DICHLOROETHANE	ug/kg	u50.0	u5000.0
	1,2-DICHLOROETHENE (TOTAL)	ug/kg	u50.0	16000.0
	CHLOROFORM	ug/kg	u50.0	u5000.0
	2-BUTANONE (MEK)	ug/kg	u500.0	113000.0
	1,2-DICHLOROETHANE	ug/kg	u50.0	u5000.0
	1,1,1-TRICHLOROETHANE	ug/kg	u50.0	u5000.0
	CARBON TETRACHLORIDE	ug/kg	u50.0	u5000.0
	BROMODICHLOROMETHANE	ug/kg	u50.0	u5000.0
	1,2-DICHLOROPROPANE	ug/kg	u50.0	u5000.0
	1,3-DICHLOROPROPENE (TRANS)	ug/kg	u50.0	u5000.0
	TRICHLOROETHENE	ug/kg	u50.0	16200.0
	DIBROMOCHLOROMETHANE	ug/kg	u50.0	u5000.0
	1,1,2-TRICHLOROETHANE	ug/kg	u50.0	u5000.0
	BENZENE	ug/kg	u50.0	u5000.0
	1,3-DICHLOROPROPENE (CIS)	ug/kg	u50.0	u5000.0
	BROMOFORM	ug/kg	u50.0	u5000.0
	4-METHYL-2-PENTANONE (MIBK)	ug/kg	u500.0	u50000.0
	2-HEXANONE	ug/kg	u500.0	u50000.0
	TETRACHLOROETHENE	ug/kg	u50.0	16200.0
	1,1,1,2-TETRACHLOROETHANE	ug/kg	u50.0	u5000.0
	TOLUENE	ug/kg	u50.0	u5000.0
	CHLOROBENZENE	ug/kg	u50.0	13400.0
	ETHYLBENZENE	ug/kg	u50.0	u5000.0
	STYRENE	ug/kg	u50.0	u5000.0
	XYLENE (TOTAL)	ug/kg	u50.0	u5000.0

SAMPLE AREA 2

CATEGORY	PARAMETER	UNITS	SAMPLE NUMBER 2-T6-MC CONCENTRATION	SAMPLE NUMBER 2-T6-SC CONCENTRATION
HSL VOLATILES				
	SAMPLE DATE		06/14/88	06/14/88
	CHLOROMETHANE	ug/kg	u10000.0	u10000.0
	BROMOETHANE	ug/kg	u10000.0	u10000.0
	VINYL CHLORIDE	ug/kg	u10000.0	j8900.0
	CHLOROETHANE	ug/kg	u10000.0	u10000.0
	METHYLENE CHLORIDE	ug/kg	8980.0	u50000.0
	ACETONE	ug/kg	u50000.0	u50000.0
	CARBON DISULFIDE	ug/kg	u10000.0	u10000.0
	VINYL ACETATE	ug/kg	u50000.0	u10500.0
	1,1-DICHLOROETHENE	ug/kg	u5000.0	u5000.0
	1,1-DICHLOROETHANE	ug/kg	u5000.0	u5000.0
	1,2-DICHLOROETHENE(TOTAL)	ug/kg	184000.0	278000.0
	CHLOROFORM	ug/kg	5140.0	6400.0
	2-BUTANONE (MEK)	ug/kg	120000.0	112000.0
	1,2-DICHLOROETHANE	ug/kg	u5000.0	u5000.0
	1,1,1-TRICHLOROETHANE	ug/kg	u5000.0	8030.0
	CARBON TETRACHLORIDE	ug/kg	u5000.0	u5000.0
	BROMODICHLOROMETHANE	ug/kg	u5000.0	12000.0
	1,2-DICHLOROPROPANE	ug/kg	u5000.0	u5000.0
	1,3-DICHLOROPROPENE(TRANS)	ug/kg	u5000.0	u5000.0
	TRICHLOROETHENE	ug/kg	1870000.0	2940000.0
	DIBROMOCHLOROMETHANE	ug/kg	u5000.0	u5000.0
	1,1,2-TRICHLOROETHANE	ug/kg	u5000.0	u5000.0
	BENZENE	ug/kg	u5000.0	u5000.0
	1,3-DICHLOROPROPENE(CIS)	ug/kg	u5000.0	u5000.0
	BROMOFORM	ug/kg	u5000.0	u5000.0
	4-METHYL-2-PENTANONE(MIBK)	ug/kg	u50000.0	u50000.0
	2-HEXANONE	ug/kg	u50000.0	u50000.0
	TETRACHLOROETHENE	ug/kg	4980000.0	8040000.0
	1,1,1,2-TETRACHLOROETHANE	ug/kg	100000.0	181000.0
	TOLUENE	ug/kg	u5000.0	u5000.0
	CHLOROBENZENE	ug/kg	u5000.0	j4380.0
	ETHYLBENZENE	ug/kg	u5000.0	u5000.0
	STYRENE	ug/kg	u5000.0	u5000.0
	XYLENE(TOTAL)	ug/kg	u5000.0	u5000.0

SAMPLE AREA 3

CATEGORY	PARAMETER	UNITS	SAMPLE NUMBER 3-T8-MC CONCENTRATION	SAMPLE NUMBER 3-T8-SC CONCENTRATION
HSL VOLATILES				
	SAMPLE DATE		06/15/88	06/15/88
	CHLOROMETHANE	ug/kg	u10000.0	u10000.0
	BROMOETHANE	ug/kg	u10000.0	u10000.0
	VINYL CHLORIDE	ug/kg	71000.0	27000.0
	CHLOROETHANE	ug/kg	u10000.0	u10000.0
	METHYLENE CHLORIDE	ug/kg	5100.0	u5000.0
	ACETONE	ug/kg	j39000.0	u50000.0
	CARBON DISULFIDE	ug/kg	u10000.0	u10000.0
	VINYL ACETATE	ug/kg	u50000.0	u50000.0
	1,1-DICHLOROETHENE	ug/kg	u5000.0	u5000.0
	1,1-DICHLOROETHANE	ug/kg	u5000.0	u5000.0
	1,2-DICHLOROETHENE(TOTAL)	ug/kg	7500.0	586000.0
	CHLOROFORM	ug/kg	u5000.0	6640.0
	2-BUTANONE (MEK)	ug/kg	118000.0	117000.0
	1,2-DICHLOROETHANE	ug/kg	u5000.0	u5000.0
	1,1,1-TRICHLOROETHANE	ug/kg	21000.0	11000.0
	CARBON TETRACHLORIDE	ug/kg	u5000.0	u5000.0
	BROMODICHLOROMETHANE	ug/kg	u5000.0	u5000.0
	1,2-DICHLOROPROPANE	ug/kg	u5000.0	u5000.0
	1,3-DICHLOROPROPENE(TRANS)	ug/kg	u5000.0	u5000.0
	TRICHLOROETHENE	ug/kg	580000.0	3460000.0
	DIBROMOCHLOROMETHANE	ug/kg	u5000.0	u5000.0
	1,1,2-TRICHLOROETHANE	ug/kg	u5000.0	u5000.0
	BENZENE	ug/kg	u5000.0	u5000.0
	1,3-DICHLOROPROPENE(CIS)	ug/kg	u5000.0	u5000.0
	BROMOFORM	ug/kg	u5000.0	u5000.0
	4-METHYL-2-PENTANONE(MIBK)	ug/kg	u50000.0	u50000.0
	2-HEXANONE	ug/kg	u50000.0	u50000.0
	TETRACHLOROETHENE	ug/kg	2560000.0	11600000.0
	1,1,1,2-TETRACHLOROETHANE	ug/kg	u5000.0	u5000.0
	TOLUENE	ug/kg	u5000.0	u5000.0
	CHLOROBENZENE	ug/kg	u5000.0	5910.0
	ETHYLBENZENE	ug/kg	u5000.0	u5000.0
	STYRENE	ug/kg	u5000.0	u5000.0
	XYLENE(TOTAL)	ug/kg	u5000.0	u5000.0

SAMPLE AREA 4

CATEGORY	PARAMETER	UNITS	SAMPLE NUMBER 4-T10-MC	SAMPLE NUMBER 4-T10-SC
			CONCENTRATION	CONCENTRATION
HSL VOLATILES				
	SAMPLE DATE		06/11/88	06/11/88
	CHLOROMETHANE	ug/kg	u10000.0	u10000.0
	BROMOETHANE	ug/kg	u10000.0	u10000.0
	VINYL CHLORIDE	ug/kg	168000.0	64800.0
	CHLOROETHANE	ug/kg	u10000.0	u10000.0
	METHYLENE CHLORIDE	ug/kg	7260.0	u5000.0
	ACETONE	ug/kg	u50000.0	81600.0
	CARBON DISULFIDE	ug/kg	u20000.0	u20000.0
	VINYL ACETATE	ug/kg	u50000.0	u50000.0
	1,1-DICHLOROETHENE	ug/kg	11800.0	u5000.0
	1,1-DICHLOROETHANE	ug/kg	u5000.0	u5000.0
	1,2-DICHLOROETHENE(TOTAL)	ug/kg	2300000.0	1230000.0
	CHLOROFORM	ug/kg	u5000.0	u5000.0
	2-BUTANONE (MEK)	ug/kg	330000.0	185000.0
	1,2-DICHLOROETHANE	ug/kg	u5000.0	u5000.0
	1,1,1-TRICHLOROETHANE	ug/kg	u5000.0	u5000.0
	CARBON TETRACHLORIDE	ug/kg	u5000.0	u5000.0
	BROMODICHLOROMETHANE	ug/kg	u5000.0	u5000.0
	1,2-DICHLOROPROPANE	ug/kg	u5000.0	u5000.0
	1,3-DICHLOROPROPENE(TRANS)	ug/kg	u5000.0	u5000.0
	TRICHLOROETHENE	ug/kg	5400.0	433000.0
	DIBROMOCHLOROMETHANE	ug/kg	u5000.0	u5000.0
	1,1,2-TRICHLOROETHANE	ug/kg	u5000.0	u5000.0
	BENZENE	ug/kg	5280.0	10200.0
	1,3-DICHLOROPROPENE(CIS)	ug/kg	u5000.0	u5000.0
	BROMOFORM	ug/kg	u5000.0	u5000.0
	4-METHYL-2-PENTANONE(MIBK)	ug/kg	u50000.0	u50000.0
	2-HEXANONE	ug/kg	u50000.0	u50000.0
	TETRACHLOROETHENE	ug/kg	47900.0	2400000.0
	1,1,1,2-TETRACHLOROETHANE	ug/kg	u5000.0	7260.0
	TOLUENE	ug/kg	u5000.0	u5000.0
	CHLOROBENZENE	ug/kg	u5000.0	24700.0
	ETHYLBENZENE	ug/kg	u5000.0	u5000.0
	STYRENE	ug/kg	u5000.0	u5000.0
	XYLENE(TOTAL)	ug/kg	u5000.0	u5000.0

SAMPLE AREA 5

CATEGORY	PARAMETER	UNITS	SAMPLE NUMBER 5-4G CONCENTRATION	SAMPLE NUMBER 5-4G(DUP) CONCENTRATION	SAMPLE NUMBER 5-5G CONCENTRATION
HSL VOLATILES					
	SAMPLE DATE		06/09/88	06/09/88	06/13/88
	CHLOROMETHANE	ug/kg	u100.0	u100.0	u100.0
	BROMOETHANE	ug/kg	u100.0	u100.0	u100.0
	VINYL CHLORIDE	ug/kg	u100.0	u100.0	u100.0
	CHLOROETHANE	ug/kg	u100.0	u100.0	u100.0
	METHYLENE CHLORIDE	ug/kg	173.0	109.0	u50.0
	ACETONE	ug/kg	4850.0	u500.0	u200.0
	CARBON DISULFIDE	ug/kg	u200.0	u200.0	u200.0
	VINYL ACETATE	ug/kg	u500.0	u500.0	u500.0
	1,1-DICHLOROETHENE	ug/kg	u50.0	u50.0	u50.0
	1,1-DICHLOROETHANE	ug/kg	u50.0	u50.0	u50.0
	1,2-DICHLOROETHENE(TOTAL)	ug/kg	290.0	181.0	u50.0
	CHLOROFORM	ug/kg	u50.0	u50.0	u50.0
	2-BUTANONE (MEK)	ug/kg	7430.0	u500.0	u500.0
	1,2-DICHLOROETHANE	ug/kg	u50.0	u50.0	u50.0
	1,1,1-TRICHLOROETHANE	ug/kg	u50.0	u50.0	u50.0
	CARBON TETRACHLORIDE	ug/kg	u50.0	u50.0	u50.0
	BROMODICHLOROMETHANE	ug/kg	u50.0	u50.0	u50.0
	1,2-DICHLOROPROPANE	ug/kg	u50.0	u50.0	u50.0
	1,3-DICHLOROPROPENE(TRANS)	ug/kg	u50.0	u50.0	u50.0
	TRICHLOROETHENE	ug/kg	u50.0	u50.0	u50.0
	DIBROMOCHLOROMETHANE	ug/kg	u50.0	u50.0	u50.0
	1,1,2-TRICHLOROETHANE	ug/kg	u50.0	u50.0	u50.0
	BENZENE	ug/kg	u50.0	u50.0	u50.0
	1,3-DICHLOROPROPENE(CIS)	ug/kg	u50.0	u50.0	u50.0
	BROMOFORM	ug/kg	u50.0	u50.0	u50.0
	4-METHYL-2-PENTANONE(MIBK)	ug/kg	u500.0	u500.0	u500.0
	2-HEXANONE	ug/kg	u500.0	u500.0	u500.0
	TETRACHLOROETHENE	ug/kg	u50.0	u50.0	u50.0
	1,1,1,2-TETRACHLOROETHANE	ug/kg	u50.0	u50.0	u50.0
	TOLUENE	ug/kg	u50.0	u50.0	u50.0
	CHLOROBENZENE	ug/kg	u50.0	u50.0	u50.0
	ETHYLBENZENE	ug/kg	u50.0	u50.0	u50.0
	STYRENE	ug/kg	u50.0	u50.0	u50.0
	XYLENE(TOTAL)	ug/kg	60.1	u50.0	u50.0

SAMPLE AREA 1

CATEGORY	PARAMETER	UNITS	SAMPLE NUMBER 1-T1-C CONCENTRATION	SAMPLE NUMBER 1-T4-SC CONCENTRATION
BASE/NEUTRAL				
	SAMPLE DATE		06/13/88	06/15/88
	BIS(2-CHLOROETHYL)ETHER	ug/kg	u6600.0	u2000.0
	1,3-DICHLOROBENZENE	ug/kg	u6600.0	u2000.0
	1,4-DICHLOROBENZENE	ug/kg	u6600.0	u2000.0
	1,2-DICHLOROBENZENE	ug/kg	u6600.0	u2000.0
	BIS(2-CHLOROISOPROPYL)ETHER	ug/kg	u6600.0	u2000.0
	N-NITROSO-DI-N-PROPYLAMINE	ug/kg	u6600.0	u2000.0
	HEXACHLOROETHANE	ug/kg	u6600.0	u2000.0
	NITROBENZENE	ug/kg	u6600.0	u2000.0
	ISOPHORONE	ug/kg	u6600.0	u2000.0
	BIS(2-CHLOROETHOXY)METHANE	ug/kg	u6600.0	u2000.0
	1,2,4-TRICHLOROBENZENE	ug/kg	u6600.0	u2000.0
	NAPHTHALENE	ug/kg	u6600.0	u2000.0
	HEXACHLOROBUTADIENE	ug/kg	u6600.0	u2000.0
	HEXACHLOROCYCLOPENTADIENE	ug/kg	u6600.0	u2000.0
	2-CHLORONAPHTHALENE	ug/kg	u6600.0	u2000.0
	DIMETHYL PHTHALATE	ug/kg	u6600.0	u2000.0
	ACENAPHTHYLENE	ug/kg	u6600.0	u2000.0
	ACENAPHTHENE	ug/kg	u6600.0	u2000.0
	2,4-DINITROTOLUENE	ug/kg	u6600.0	u2000.0
	2,6-DINITROTOLUENE	ug/kg	u6600.0	u2000.0
	DIETHYL PHTHALATE	ug/kg	u6600.0	u2000.0
	4-CHLOROPHENYL-PHENYLETHER	ug/kg	u6600.0	u2000.0
	FLUORENE	ug/kg	u6600.0	u2000.0
	N-NITROSODIPHENYLAMINE	ug/kg	u6600.0	u2000.0
	4-BROMOPHENYL-PHENYLETHER	ug/kg	u6600.0	u2000.0
	HEXACHLOROBENZENE	ug/kg	u6600.0	u2000.0
	PHENANTHRENE	ug/kg	4590.0	u2000.0
	ANTHRACENE	ug/kg	u6600.0	u2000.0
	DI-N-BUTYL PHTHALATE	ug/kg	u6600.0	u2000.0
	FLUORANTHENE	ug/kg	4660.0	u2000.0
	PYRENE	ug/kg	u6600.0	u2000.0
	BUTYL BENZYL PHTHALATE	ug/kg	u6600.0	u2000.0
	3,3'-DICHLOROBENZIDINE	ug/kg	u6600.0	u2000.0
	BENZO(A)ANTHRACENE	ug/kg	u6600.0	u2000.0
	BIS(2-ETHYLHEXYL)PHTHALATE	ug/kg	u6600.0	b9520.0
	CHRYSENE	ug/kg	u6600.0	u2000.0
	DI-N-OCTYL PHTHALATE	ug/kg	5980.0	u2000.0
	BENZO(B)FLUORANTHENE	ug/kg	u6600.0	u2000.0
	BENZO(K)FLUORANTHENE	ug/kg	u6600.0	u2000.0
	BENZO(A)PYRENE	ug/kg	u6600.0	u2000.0
	INDENO(1,2,3-CD)PYRENE	ug/kg	u6600.0	u2000.0
	DIBENZO(A,H)ANTHRACENE	ug/kg	u6600.0	u2000.0
	BENZO(G,H,I)PERYLENE	ug/kg	u6600.0	u2000.0
	BENZYL ALCOHOL	ug/kg	u6600.0	u2000.0
	4-CHLOROANALINE	ug/kg	u6600.0	u2000.0
	2-METHYL NAPHTHALENE	ug/kg	u6600.0	u2000.0
	2-NITROANALINE	ug/kg	u6600.0	u2000.0
	3-NITROANALINE	ug/kg	u6600.0	u2000.0
	DIBENZOFURAN	ug/kg	u6600.0	u2000.0
	4-NITROANALINE	ug/kg	u33200.0	u10000.0

SAMPLE AREA 2

CATEGORY	PARAMETER	UNITS	SAMPLE NUMBER 2-T6-MC CONCENTRATION	SAMPLE NUMBER 2-T6-SC CONCENTRATION
BASE/NEUTRAL				
	SAMPLE DATE		06/14/88	06/14/88
	BIS(2-CHLOROETHYL)ETHER	ug/kg	u10000.0	u10000.0
	1,3-DICHLOROBENZENE	ug/kg	u10000.0	u10000.0
	1,4-DICHLOROBENZENE	ug/kg	u10000.0	u10000.0
	1,2-DICHLOROBENZENE	ug/kg	u10000.0	u10000.0
	BIS(2-CHLOROISOPROPYL)ETHER	ug/kg	u10000.0	u10000.0
	N-NITROSO-DI-N-PROPYLAMINE	ug/kg	u10000.0	u10000.0
	HEXACHLOROETHANE	ug/kg	u10000.0	u10000.0
	NITROBENZENE	ug/kg	u10000.0	u10000.0
	ISOPHORONE	ug/kg	u10000.0	u10000.0
	BIS(2-CHLOROETHOXY)METHANE	ug/kg	u10000.0	u10000.0
	1,2,4-TRICHLOROBENZENE	ug/kg	u10000.0	u10000.0
	NAPHTHALENE	ug/kg	u10000.0	u10000.0
	HEXACHLOROBUTADIENE	ug/kg	269000.0	147000.0
	HEXACHLOROCYCLOPENTADIENE	ug/kg	u10000.0	u10000.0
	2-CHLORONAPHTHALENE	ug/kg	u10000.0	u10000.0
	DIMETHYL PHTHALATE	ug/kg	u10000.0	u10000.0
	ACENAPHTHYLENE	ug/kg	u10000.0	u10000.0
	ACENAPHTHENE	ug/kg	u10000.0	u10000.0
	2,4-DINITROTOLUENE	ug/kg	u10000.0	u10000.0
	2,6-DINITROTOLUENE	ug/kg	u10000.0	u10000.0
	DIETHYL PHTHALATE	ug/kg	u10000.0	u10000.0
	4-CHLOROPHENYL-PHENYLETHER	ug/kg	u10000.0	u10000.0
	FLUORENE	ug/kg	u10000.0	u10000.0
	N-NITROSODIPHENYLAMINE	ug/kg	u10000.0	u10000.0
	4-BROMOPHENYL-PHENYLETHER	ug/kg	u10000.0	u10000.0
	HEXACHLOROBENZENE	ug/kg	84600.0	43900.0
	PHENANTHRENE	ug/kg	u10000.0	u10000.0
	ANTHRACENE	ug/kg	u10000.0	u10000.0
	DI-N-BUTYL PHTHALATE	ug/kg	u10000.0	u10000.0
	FLUORANTHENE	ug/kg	u10000.0	u10000.0
	PYRENE	ug/kg	u10000.0	u10000.0
	BUTYL BENZYL PHTHALATE	ug/kg	u10000.0	u10000.0
	3,3'-DICHLOROBENZIDINE	ug/kg	u10000.0	u10000.0
	BENZO(A)ANTHRACENE	ug/kg	u10000.0	u10000.0
	BIS(2-ETHYLHEXYL)PHTHALATE	ug/kg	u10000.0	u10000.0
	CHRYSENE	ug/kg	u10000.0	u10000.0
	DI-N-OCTYL PHTHALATE	ug/kg	u10000.0	40000.0
	BENZO(B)FLUORANTHENE	ug/kg	u10000.0	u10000.0
	BENZO(K)FLUURANTHENE	ug/kg	u10000.0	u10000.0
	BENZO(A)PYRENE	ug/kg	u10000.0	u10000.0
	INDENO(1,2,3-CD)PYRENE	ug/kg	u10000.0	u10000.0
	DIBENZO(A,H)ANTHRACENE	ug/kg	u10000.0	u10000.0
	BENZO(G,H,I)PERYLENE	ug/kg	u10000.0	u10000.0
	BENZYL ALCOHOL	ug/kg	u10000.0	u10000.0
	4-CHLOROANALINE	ug/kg	u10000.0	u10000.0
	2-METHYL NAPHTHALENE	ug/kg	u10000.0	u10000.0
	2-NITROANALINE	ug/kg	u10000.0	u10000.0
	3-NITROANALINE	ug/kg	u10000.0	u10000.0
	DIBENZOFURAN	ug/kg	u10000.0	u10000.0
	4-NITROANALINE	ug/kg	u50000.0	u50000.0

SAMPLE AREA 3

CATEGORY	PARAMETER	UNITS	SAMPLE NUMBER 3-T8-MC CONCENTRATION	SAMPLE NUMBER 3-T8-SC CONCENTRATION
BASE/NEUTRAL				
	SAMPLE DATE		06/15/88	06/15/88
	BIS(2-CHLOROETHYL)ETHER	ug/kg	u10000.0	u10000.0
	1,3-DICHLOROBENZENE	ug/kg	u10000.0	u10000.0
	1,4-DICHLOROBENZENE	ug/kg	u10400.0	u10000.0
	1,2-DICHLOROBENZENE	ug/kg	u10000.0	u10000.0
	BIS(2-CHLOROISOPROPYL)ETHER	ug/kg	u10000.0	u10000.0
	N-NITROSO-DI-N-PROPYLAMINE	ug/kg	u10000.0	u10000.0
	HEXACHLOROETHANE	ug/kg	u449000.0	20000.0
	NITROBENZENE	ug/kg	u10000.0	u10000.0
	ISOPHORONE	ug/kg	u10000.0	u10000.0
	BIS(2-CHLOROETHOXY)METHANE	ug/kg	u10000.0	u10000.0
	1,2,4-TRICHLOROBENZENE	ug/kg	17100.0	10700.0
	NAPHTHALENE	ug/kg	u10000.0	u10000.0
	HEXACHLOROBUTADIENE	ug/kg	424000.0	236000.0
	HEXACHLOROCYCLOPENTADIENE	ug/kg	u10000.0	u10000.0
	2-CHLORONAPHTHALENE	ug/kg	u10000.0	u10000.0
	DIMETHYL PHTHALATE	ug/kg	10000.0	u10000.0
	ACENAPHTHYLENE	ug/kg	u10000.0	u10000.0
	ACENAPHTHENE	ug/kg	u10000.0	u10000.0
	2,4-DINITROTOLUENE	ug/kg	u10000.0	u10000.0
	2,6-DINITROTOLUENE	ug/kg	u10000.0	u10000.0
	DIETHYL PHTHALATE	ug/kg	u10000.0	u10000.0
	4-CHLOROPHENYL-PHENYLETHER	ug/kg	10000.0	u10000.0
	FLUORENE	ug/kg	u10000.0	u10000.0
	N-NITROSODIPHENYLAMINE	ug/kg	u10000.0	u10000.0
	4-BROMOPHENYL-PHENYLETHER	ug/kg	u10000.0	u10000.0
	HEXACHLOROBENZENE	ug/kg	75400.0	68100.0
	PHENANTHRENE	ug/kg	u10000.0	u10000.0
	ANTHRACENE	ug/kg	u10000.0	u10000.0
	DI-N-BUTYL PHTHALATE	ug/kg	u10000.0	u10000.0
	FLUORANTHENE	ug/kg	u10000.0	u10000.0
	PYRENE	ug/kg	u10000.0	u10000.0
	BUTYL BENZYL PHTHALATE	ug/kg	u10000.0	u10000.0
	3,3'-DICHLOROBENZIDINE	ug/kg	u10000.0	u10000.0
	BENZO(A)ANTHRACENE	ug/kg	u10000.0	u10000.0
	BIS(2-ETHYLHEXYL)PHTHALATE	ug/kg	b21300.0	u10000.0
	CHRYSENE	ug/kg	u10000.0	u10000.0
	DI-N-OCTYL PHTHALATE	ug/kg	u10000.0	u10000.0
	BENZO(B)FLUORANTHENE	ug/kg	u10000.0	u10000.0
	BENZO(K)FLUORANTHENE	ug/kg	u10000.0	u10000.0
	BENZO(A)PYRENE	ug/kg	u10000.0	u10000.0
	INDENO(1,2,3-CD)PYRENE	ug/kg	u10000.0	u10000.0
	DIBENZO(A,H)ANTHRACENE	ug/kg	u10000.0	u10000.0
	BENZO(G,H,I)PERYLENE	ug/kg	u10000.0	u10000.0
	BENZYL ALCOHOL	ug/kg	u10000.0	u10000.0
	4-CHLOROANALINE	ug/kg	u10000.0	u10000.0
	2-METHYL NAPHTHALENE	ug/kg	u10000.0	u10000.0
	2-NITROANALINE	ug/kg	u10000.0	u10000.0
	3-NITROANALINE	ug/kg	u10000.0	u10000.0
	DIBENZOFURAN	ug/kg	u10000.0	u10000.0
	4-NITROANALINE	ug/kg	u50000.0	u50000.0

SAMPLE AREA 4

CATEGORY	PARAMETER	UNITS	SAMPLE NUMBER 4-T10-MC CONCENTRATION	SAMPLE NUMBER 4-T10-SC CONCENTRATION
BASE/NEUTRAL				
	SAMPLE DATE		06/11/88	06/11/88
	BIS(2-CHLOROETHYL)ETHER	ug/kg	u6600.0	u6600.0
	1,3-DICHLOROBENZENE	ug/kg	u6600.0	u6600.0
	1,4-DICHLOROBENZENE	ug/kg	u3320.0	12500.0
	1,2-DICHLOROBENZENE	ug/kg	u6600.0	7260.0
	BIS(2-CHLOROISOPROPYL)ETHER	ug/kg	u6600.0	u6600.0
	N-NITROSO-DI-N-PROPYLAMINE	ug/kg	u6600.0	u6600.0
	HEXACHLOROETHANE	ug/kg	53900.0	u6600.0
	NITROBENZENE	ug/kg	u6600.0	u6600.0
	ISOPHORONE	ug/kg	u6600.0	u6600.0
	BIS(2-CHLOROETHOXY)METHANE	ug/kg	u6600.0	u6600.0
	1,2,4-TRICHLOROBENZENE	ug/kg	u12300.0	21700.0
	NAPHTHALENE	ug/kg	u6600.0	u6600.0
	HEXACHLOROBUTADIENE	ug/kg	148000.0	150000.0
	HEXACHLOROCYCLOPENTADIENE	ug/kg	u6600.0	u6600.0
	2-CHLORONAPHTHALENE	ug/kg	u6600.0	u6600.0
	DIMETHYL PHTHALATE	ug/kg	u6600.0	u6600.0
	ACENAPHTHYLENE	ug/kg	u6600.0	u6600.0
	ACENAPHTHENE	ug/kg	u6600.0	u6600.0
	2,4-DINITROTOLUENE	ug/kg	u6600.0	u6600.0
	2,6-DINITROTOLUENE	ug/kg	u6600.0	u6600.0
	DIETHYL PHTHALATE	ug/kg	u6600.0	u6600.0
	4-CHLOROPHENYL-PHENYLETHER	ug/kg	u6600.0	u6600.0
	FLUORENE	ug/kg	u6600.0	u6600.0
	N-NITROSODIPHENYLAMINE	ug/kg	u6600.0	u6600.0
	4-BROMOPHENYL-PHENYLETHER	ug/kg	u6600.0	u6600.0
	HEXACHLOROBENZENE	ug/kg	25900.0	23200.0
	PHENANTHRENE	ug/kg	u6600.0	u6600.0
	ANTHRACENE	ug/kg	u6600.0	u6600.0
	DI-N-BUTYL PHTHALATE	ug/kg	u6600.0	u6600.0
	FLUORANTHENE	ug/kg	u6600.0	u6600.0
	PYRENE	ug/kg	u6600.0	u6600.0
	BUTYL BENZYL PHTHALATE	ug/kg	u6600.0	u6600.0
	3,3'-DICHLOROBENZIDINE	ug/kg	u6600.0	u6600.0
	BENZO(A)ANTHRACENE	ug/kg	u6600.0	u6600.0
	BIS(2-ETHYLHEXYL)PHTHALATE	ug/kg	u6600.0	u6600.0
	CHRYSENE	ug/kg	u6600.0	u6600.0
	DI-N-OCTYL PHTHALATE	ug/kg	u6600.0	u6600.0
	BENZO(B)FLUORANTHENE	ug/kg	u6600.0	u6600.0
	BENZO(K)FLUORANTHENE	ug/kg	u6600.0	u6600.0
	BENZO(A)PYRENE	ug/kg	u6600.0	u6600.0
	INDENO(1,2,3-CD)PYRENE	ug/kg	u6600.0	u6600.0
	DIBENZO(A,H)ANTHRACENE	ug/kg	u6600.0	u6600.0
	BENZO(G,H,I)PERYLENE	ug/kg	u6600.0	u6600.0
	BENZYL ALCOHOL	ug/kg	u6600.0	u6600.0
	4-CHLOROANALINE	ug/kg	u6600.0	u6600.0
	2-METHYL NAPHTHALENE	ug/kg	u6600.0	u6600.0
	2-NITROANALINE	ug/kg	u6600.0	u6600.0
	3-NITROANALINE	ug/kg	u6600.0	u6600.0
	DIBENZOFURAN	ug/kg	u6600.0	u6600.0
	4-NITROANALINE	ug/kg	u33200.0	u33200.0

SAMPLE AREA 5

CATEGORY	PARAMETER	UNITS	SAMPLE NUMBER 5-4G CONCENTRATION	SAMPLE NUMBER 5-4G(DUP) CONCENTRATION	SAMPLE NUMBER 5-5G CONCENTRATION
BASE/NEUTRAL					
	SAMPLE DATE		06/09/88	06/09/88	06/13/88
	BIS(2-CHLOROETHYL)ETHER	ug/kg	u6600.0	u6600.0	u6600.0
	1,3-DICHLOROBENZENE	ug/kg	u6600.0	u6600.0	u6600.0
	1,4-DICHLOROBENZENE	ug/kg	u6600.0	u6600.0	u6600.0
	1,2-DICHLOROBENZENE	ug/kg	u6600.0	u6600.0	u6600.0
	BIS(2-CHLOROISOPROPYL)ETHER	ug/kg	u6600.0	u6600.0	u6600.0
	N-NITROSO-DI-N-PROPYLAMINE	ug/kg	u6600.0	u6600.0	u6600.0
	HEXACHLOROETHANE	ug/kg	u6600.0	u6600.0	u6600.0
	NITROBENZENE	ug/kg	u6600.0	u6600.0	u6600.0
	ISOPHORONE	ug/kg	u6600.0	u6600.0	u6600.0
	BIS(2-CHLOROETHOXY)METHANE	ug/kg	u6600.0	u6600.0	u6600.0
	1,2,4-TRICHLOROBENZENE	ug/kg	u6600.0	u6600.0	u6600.0
	NAPHTHALENE	ug/kg	u6600.0	u6600.0	u6600.0
	HEXACHLOROBUTADIENE	ug/kg	5940.0	10300.0	u6600.0
	HEXACHLOROCYCLOPENTADIENE	ug/kg	u6600.0	u6600.0	u6600.0
	2-CHLORONAPHTHALENE	ug/kg	u6600.0	u6600.0	u6600.0
	DIMETHYL PHTHALATE	ug/kg	6090.0	u6600.0	u6600.0
	ACENAPHTHYLENE	ug/kg	u6600.0	u6600.0	u6600.0
	ACENAPHTHENE	ug/kg	u6600.0	u6600.0	u6600.0
	2,4-DINITROTOLUENE	ug/kg	u6600.0	u6600.0	u6600.0
	2,6-DINITROTOLUENE	ug/kg	u6600.0	u6600.0	u6600.0
	DIETHYL PHTHALATE	ug/kg	20800.0	u6600.0	u6600.0
	4-CHLOROPHENYL-PHENYLETHER	ug/kg	u6600.0	u6600.0	u6600.0
	FLUORENE	ug/kg	u6600.0	u6600.0	u6600.0
	N-NITROSODIPHENYLAMINE	ug/kg	u6600.0	u6600.0	u6600.0
	4-BROMOPHENYL-PHENYLETHER	ug/kg	u6600.0	u6600.0	u6600.0
	HEXACHLOROBENZENE	ug/kg	u6600.0	u6600.0	u6600.0
	PHENANTHRENE	ug/kg	u6600.0	u6600.0	u6600.0
	ANTHRACENE	ug/kg	u6600.0	u6600.0	u6500.0
	DI-N-BUTYL PHTHALATE	ug/kg	u6600.0	u6600.0	u6600.0
	FLUORANTHENE	ug/kg	u6600.0	u6600.0	u6600.0
	PYRENE	ug/kg	u6600.0	u6600.0	u6600.0
	BUTYL BENZYL PHTHALATE	ug/kg	u6600.0	u6600.0	u6600.0
	3,3'-DICHLOROBENZIDINE	ug/kg	u6600.0	u6600.0	u6600.0
	BENZO(A)ANTHRACENE	ug/kg	u6600.0	u6600.0	u6600.0
	BIS(2-ETHYLHEXYL)PHTHALATE	ug/kg	u6600.0	u6600.0	u6600.0
	CHRYSENE	ug/kg	u6600.0	u6600.0	u6600.0
	DI-N-OCTYL PHTHALATE	ug/kg	u6600.0	u6600.0	5220.0
	BENZO(B)FLUORANTHENE	ug/kg	u6600.0	u6600.0	u6600.0
	BENZO(K)FLUORANTHENE	ug/kg	u6600.0	u6600.0	u6600.0
	BENZO(A)PYRENE	ug/kg	u6600.0	u6600.0	u6600.0
	INDENO(1,2,3-CD)PYRENE	ug/kg	u6600.0	u6600.0	u6600.0
	DIBENZO(A,H)ANTHRACENE	ug/kg	u6600.0	u6600.0	u6600.0
	BENZO(G,H,I)PERYLENE	ug/kg	u6600.0	u6600.0	u6600.0
	BENZYL ALCOHOL	ug/kg	u6600.0	u6600.0	u6600.0
	4-CHLOROANALINE	ug/kg	u6600.0	u6600.0	u6600.0
	2-METHYL NAPHTHALENE	ug/kg	u6600.0	u6600.0	u6600.0
	2-NITROANALINE	ug/kg	u6600.0	u6600.0	u6600.0
	3-NITROANALINE	ug/kg	u6600.0	u6600.0	u6600.0
	DIBENZOFURAN	ug/kg	u6600.0	u6600.0	u6600.0
	4-NITROANALINE	ug/kg	u33200.0	u33200.0	u33200.0

SAMPLE AREA 1

CATEGORY	PARAMETER	UNITS	SAMPLE NUMBER 1-T1-C CONCENTRATION	SAMPLE NUMBER 1-T4-SC CONCENTRATION
HSL ACIDS				
	SAMPLE DATE		06/13/88	06/15/88
	PHENOL	ug/kg	u660.0	u1000.0
	2-CHLOROPHENOL	ug/kg	u660.0	u1000.0
	2-NITROPHENOL	ug/kg	u660.0	u1000.0
	2,4-DIMETHYLPHENOL	ug/kg	u660.0	u1000.0
	2,4-DICHLOROPHENOL	ug/kg	u660.0	u1000.0
	4-CHLORO-3-METHYLPHENOL	ug/kg	u660.0	u1000.0
	2,4,6-TRICHLOROPHENOL	ug/kg	u660.0	u1000.0
	2,4-DINITROPHENOL	ug/kg	u3320.0	u5000.0
	4-NITROPHENOL	ug/kg	u3320.0	u5000.0
	2-METHYL-4,6-DINITROPHENOL	ug/kg	u3320.0	u5000.0
	PENTACHLOROPHENOL	ug/kg	u3320.0	u5000.0
	2-METHYL PHENOL	ug/kg	u660.0	u1000.0
	4-METHYL PHENOL	ug/kg	u660.0	u1000.0
	BENZOIC ACID	ug/kg	u3320.0	u5000.0
	2,4,5-TRICHLOROPHENOL	ug/kg	u660.0	u1000.0

SAMPLE AREA 2

CATEGORY	PARAMETER	UNITS	SAMPLE NUMBER 2-T6-MC CONCENTRATION	SAMPLE NUMBER 2-T6-SC CONCENTRATION
HSL ACIDS				
	SAMPLE DATE		06/14/88	06/14/88
	PHENOL	ug/kg	u1000.0	u1000.0
	2-CHLOROPHENOL	ug/kg	u1000.0	u1000.0
	2-NITROPHENOL	ug/kg	u1000.0	u1000.0
	2,4-DIMETHYLPHENOL	ug/kg	u1000.0	u1000.0
	2,4-DICHLOROPHENOL	ug/kg	u1000.0	u1000.0
	4-CHLORO-3-METHYLPHENOL	ug/kg	u1000.0	u1000.0
	2,4,6-TRICHLOROPHENOL	ug/kg	u1000.0	u1000.0
	2,4-DINITROPHENOL	ug/kg	u5000.0	u5000.0
	4-NITROPHENOL	ug/kg	u5000.0	u5000.0
	2-METHYL-4,6-DINITROPHENOL	ug/kg	u5000.0	u5000.0
	PENTACHLOROPHENOL	ug/kg	u5000.0	u5000.0
	2-METHYL PHENOL	ug/kg	u1000.0	u1000.0
	4-METHYL PHENOL	ug/kg	u1290.0	u1000.0
	BENZOIC ACID	ug/kg	u5000.0	u5000.0
	2,4,5-TRICHLOROPHENOL	ug/kg	u1000.0	u1000.0

SAMPLE AREA 3

CATEGORY	PARAMETER	UNITS	SAMPLE NUMBER 3-T8-MC CONCENTRATION	SAMPLE NUMBER 3-T8-SC CONCENTRATION
HSL ACIDS				
	SAMPLE DATE		06/15/88	06/15/88
	PHENOL	ug/kg	u1000.0	u1000.0
	2-CHLOROPHENOL	ug/kg	u1000.0	u1000.0
	2-NITROPHENOL	ug/kg	u1000.0	u1000.0
	2,4-DIMETHYLPHENOL	ug/kg	u1000.0	u1000.0
	2,4-DICHLOROPHENOL	ug/kg	u1000.0	u1000.0
	4-CHLORO-3-METHYLPHENOL	ug/kg	u1000.0	u1000.0
	2,4,6-TRICHLOROPHENOL	ug/kg	u1000.0	u1000.0
	2,4-DINITROPHENOL	ug/kg	u5000.0	u5000.0
	4-NITROPHENOL	ug/kg	u5000.0	u5000.0
	2-METHYL-4,6-DINITROPHENOL	ug/kg	u5000.0	u5000.0
	PENTACHLOROPHENOL	ug/kg	u5000.0	u5000.0
	2-METHYL PHENOL	ug/kg	u1000.0	u1000.0
	4-METHYL PHENOL	ug/kg	5390.0	u1000.0
	BENZOIC ACID	ug/kg	u5000.0	u5000.0
	2,4,5-TRICHLOROPHENOL	ug/kg	u1000.0	u1000.0

SAMPLE AREA 4

CATEGORY	PARAMETER	UNITS	SAMPLE NUMBER 4-T10-MC CONCENTRATION	SAMPLE NUMBER 4-T10-SC CONCENTRATION
HSL ACIDS				
	SAMPLE DATE		06/11/88	06/11/88
	PHENOL	ug/kg	u660.0	u660.0
	2-CHLOROPHENOL	ug/kg	u660.0	u660.0
	2-NITROPHENOL	ug/kg	u660.0	u660.0
	2,4-DIMETHYLPHENOL	ug/kg	u660.0	u660.0
	2,4-DICHLOROPHENOL	ug/kg	u660.0	u660.0
	4-CHLORO-3-METHYLPHENOL	ug/kg	u660.0	u660.0
	2,4,6-TRICHLOROPHENOL	ug/kg	u660.0	u660.0
	2,4-DINITROPHENOL	ug/kg	u3320.0	u3320.0
	4-NITROPHENOL	ug/kg	u3320.0	u3320.0
	2-METHYL-4,6-DINITROPHENOL	ug/kg	u3320.0	u3320.0
	PENTACHLOROPHENOL	ug/kg	u3320.0	u3320.0
	2-METHYL PHENOL	ug/kg	u660.0	u660.0
	4-METHYL PHENOL	ug/kg	5520.0	u660.0
	BENZOIC ACID	ug/kg	u3320.0	u3320.0
	2,4,5-TRICHLOROPHENOL	ug/kg	u660.0	u660.0

SAMPLE AREA 5

CATEGORY	PARAMETER	UNITS	SAMPLE NUMBER 5-4G CONCENTRATION	SAMPLE NUMBER 5-4G(DUP) CONCENTRATION	SAMPLE NUMBER 5-5G CONCENTRATION
HSL ACIDS					
	SAMPLE DATE		06/09/88	06/09/88	06/13/88
	PHENOL	ug/kg	u660.0	u660.0	u660.0
	2-CHLOROPHENOL	ug/kg	u660.0	u660.0	u660.0
	2-NITROPHENOL	ug/kg	u660.0	u660.0	u660.0
	2,4-DIMETHYLPHENOL	ug/kg	u660.0	u660.0	u660.0
	2,4-DICHLOROPHENOL	ug/kg	u660.0	u660.0	u660.0
	4-CHLORO-3-METHYLPHENOL	ug/kg	u660.0	u660.0	u660.0
	2,4,6-TRICHLOROPHENOL	ug/kg	u660.0	u660.0	u660.0
	2,4-DINITROPHENOL	ug/kg	u3320.0	u3320.0	u3320.0
	4-NITROPHENOL	ug/kg	u3320.0	u3320.0	u3320.0
	2-METHYL-4,6-DINITROPHENOL	ug/kg	u3320.0	u3320.0	u3320.0
	PENTACHLOROPHENOL	ug/kg	u3320.0	u3320.0	u3320.0
	2-METHYL PHENOL	ug/kg	u660.0	u660.0	u660.0
	4-METHYL PHENOL	ug/kg	u660.0	u660.0	u660.0
	BENZOIC ACID	ug/kg	u3320.0	u3320.0	u3320.0
	2,4,5-TRICHLOROPHENOL	ug/kg	u660.0	u660.0	u660.0

SAMPLE AREA 1

CATEGORY	PARAMETER	UNITS	SAMPLE NUMBER 1-T1-C CONCENTRATION	SAMPLE NUMBER 1-T4-SC CONCENTRATION
PESTICIDES				
	SAMPLE DATE		06/13/88	06/15/88
	ALPHA-BHC	ug/kg	u50.0	37500.0
	BETA-BHC	ug/kg	u50.0	10200.0
	GAMMA-BHC (LINDANE)	ug/kg	u50.0	u1000.0
	HEPTACHLOR	ug/kg	u50.0	u1000.0
	DELTA-BHC	ug/kg	u50.0	u1000.0
	ALDRIN	ug/kg	u50.0	u1000.0
	HEPTACHLOROEPOXIDE	ug/kg	u50.0	u1000.0
	ALPHA-ENDOSULFAN	ug/kg	u50.0	u1000.0
	4,4'-DDE	ug/kg	u50.0	u1000.0
	DIELDRIN	ug/kg	u50.0	u1000.0
	ENDRIN	ug/kg	u50.0	u1000.0
	4,4'-TDE (DDD)	ug/kg	u50.0	u1000.0
	BETA-ENDOSULFAN	ug/kg	u100.0	u2000.0
	4,4'-DDT	ug/kg	u100.0	u2000.0
	ENDRIN ALDEHYDE	ug/kg	u100.0	u2000.0
	ENDOSULFAN SULFATE	ug/kg	u100.0	u2000.0
	MIREX	ug/kg	u200.0	u4000.0
	METHOXYCHLOR	ug/kg	u200.0	u4000.0
	CHLORDANE	ug/kg	u200.0	u4000.0
	TOXAPHENE	ug/kg	u1000.0	u20000.0
	PCB 1016	ug/kg	u1000.0	u20000.0
	PCB 1221	ug/kg	u1000.0	u20000.0
	PCB 1232	ug/kg	u1000.0	u20000.0
	PCB 1242	ug/kg	u500.0	u10000.0
	PCB 1248	ug/kg	880.0	30800.0
	PCB 1254	ug/kg	u500.0	u10000.0
	PCB 1260	ug/KG	u500.0	u10000.0

SAMPLE AREA 2

CATEGORY	PARAMETER	UNITS	SAMPLE NUMBER 2-T6-MC CONCENTRATION	SAMPLE NUMBER 2-T6-SC CONCENTRATION
PESTICIDES				
	SAMPLE DATE		06/14/88	06/14/88
	ALPHA-BHC	ug/kg	155000.0	117000.0
	BETA-BHC	ug/kg	u100000.0	u100000.0
	GAMMA-BHC (LINDANE)	ug/kg	u100000.0	u100000.0
	HEPTACHLOR	ug/kg	u100000.0	u100000.0
	DELTA-BHC	ug/kg	u100000.0	u100000.0
	ALDRIN	ug/kg	u100000.0	u100000.0
	HEPTACHLOROEPOXIDE	ug/kg	u100000.0	u100000.0
	ALPHA-ENDOSULFAN	ug/kg	u100000.0	u100000.0
	4,4'-DDE	ug/kg	u100000.0	u100000.0
	DIELDRIN	ug/kg	u100000.0	u100000.0
	ENDRIN	ug/kg	u100000.0	u100000.0
	4,4'-TDE (DDD)	ug/kg	u100000.0	u100000.0
	BETA-ENDOSULFAN	ug/kg	u200000.0	u200000.0
	4,4'-DDT	ug/kg	u200000.0	u200000.0
	ENDRIN ALDEHYDE	ug/kg	u200000.0	u200000.0
	ENDOSULFAN SULFATE	ug/kg	u200000.0	u200000.0
	MIREX	ug/kg	u400000.0	u400000.0
	METHOXYCHLOR	ug/kg	u400000.0	u400000.0
	CHLORDANE	ug/kg	u400000.0	u400000.0
	TOXAPHENE	ug/kg	u2000000.0	u2000000.0
	PCB 1016	ug/kg	u2000000.0	u2000000.0
	PCB 1221	ug/kg	u2000000.0	u2000000.0
	PCB 1232	ug/kg	u2000000.0	u2000000.0
	PCB 1242	ug/kg	u1000000.0	u1000000.0
	PCB 1248	ug/kg	10700000.0	7620000.0
	PCB 1254	ug/kg	u1000000.0	u1000000.0
	PCB 1260	ug/KG	u1000000.0	u1000000.0

SAMPLE AREA 3

CATEGORY	PARAMETER	UNITS	SAMPLE NUMBER 3-T8-MC CONCENTRATION	SAMPLE NUMBER 3-T8-SC CONCENTRATION
PESTICIDES				
	SAMPLE DATE		06/15/88	06/15/88
	ALPHA-BHC	ug/kg	102000.0	440000.0
	BETA-BHC	ug/kg	u100000.0	u100000.0
	GAMMA-BHC (LINDANE)	ug/kg	u100000.0	u100000.0
	HEPTACHLOR	ug/kg	u100000.0	u100000.0
	DELTA-BHC	ug/kg	u100000.0	u100000.0
	ALDRIN	ug/kg	u100000.0	u100000.0
	HEPTACHLOROEPOXIDE	ug/kg	u100000.0	u100000.0
	ALPHA-ENDOSULFAN	ug/kg	u100000.0	u100000.0
	4,4'-DDE	ug/kg	u100000.0	u100000.0
	DIELDRIN	ug/kg	u100000.0	u100000.0
	ENDRIN	ug/kg	u100000.0	u100000.0
	4,4'-TDE (DDD)	ug/kg	u100000.0	u100000.0
	BETA-ENDOSULFAN	ug/kg	u200000.0	u200000.0
	4,4'-DDT	ug/kg	u200000.0	u200000.0
	ENDRIN ALDEHYDE	ug/kg	u200000.0	u200000.0
	ENDOSULFAN SULFATE	ug/kg	u200000.0	u200000.0
	MIREX	ug/kg	u400000.0	u400000.0
	METHOXYCHLOR	ug/kg	u400000.0	u400000.0
	CHLORDANE	ug/kg	u400000.0	u400000.0
	TOXAPHENE	ug/kg	u2000000.0	u2000000.0
	PCB 1016	ug/kg	u2000000.0	u2000000.0
	PCB 1221	ug/kg	u2000000.0	u2000000.0
	PCB 1232	ug/kg	u2000000.0	u2000000.0
	PCB 1242	ug/kg	u1000000.0	u1000000.0
	PCB 1248	ug/kg	7830000.0	10200000.0
	PCB 1254	ug/kg	u1000000.0	u1000000.0
	PCB 1260	ug/KG	u1000000.0	u1000000.0

SAMPLE AREA 4

CATEGORY	PARAMETER	UNITS	SAMPLE NUMBER 4-T10-MC CONCENTRATION	SAMPLE NUMBER 4-T10-SC CONCENTRATION
PESTICIDES				
	SAMPLE DATE		06/11/88	06/11/88
	ALPHA-BHC	ug/kg	u5000.0	u5000.0
	BETA-BHC	ug/kg	u5000.0	u5000.0
	GAMMA-BHC (LINDANE)	ug/kg	u5000.0	u5000.0
	HEPTACHLOR	ug/kg	u5000.0	u5000.0
	DELTA-BHC	ug/kg	u5000.0	u5000.0
	ALDRIN	ug/kg	u5000.0	u5000.0
	HEPTACHLOROEPOXIDE	ug/kg	u5000.0	u5000.0
	ALPHA-ENDOSULFAN	ug/kg	u5000.0	u5000.0
	4,4'-DDE	ug/kg	u5000.0	u5000.0
	DIELDRIN	ug/kg	u5000.0	u5000.0
	ENDRIN	ug/kg	u5000.0	u5000.0
	4,4'-TDE (DDD)	ug/kg	u5000.0	u5000.0
	BETA-ENDOSULFAN	ug/kg	u10000.0	u10000.0
	4,4'-DDT	ug/kg	u10000.0	u10000.0
	ENDRIN ALDEHYDE	ug/kg	u10000.0	u10000.0
	ENDOSULFAN SULFATE	ug/kg	u10000.0	u10000.0
	MIREX	ug/kg	u100000.0	u20000.0
	METHOXYCHLOR	ug/kg	u20000.0	u20000.0
	CHLORDANE	ug/kg	u20000.0	u20000.0
	TOXAPHENE	ug/kg	u100000.0	u100000.0
	PCB 1016	ug/kg	u100000.0	u100000.0
	PCB 1221	ug/kg	u100000.0	u100000.0
	PCB 1232	ug/kg	u100000.0	u100000.0
	PCB 1242	ug/kg	u50000.0	u50000.0
	PCB 1248	ug/kg	2600000.0	1810000.0
	PCB 1254	ug/kg	u50000.0	u50000.0
	PCB 1260	ug/KG	u50000.0	u50000.0

SAMPLE AREA 5

			SAMPLE NUMBER 5-4G	SAMPLE NUMBER 5-4G(DUP)	SAMPLE NUMBER 5-5G
CATEGORY	PARAMETER	UNITS	CONCENTRATION	CONCENTRATION	CONCENTRATION
PESTICIDES					
	SAMPLE DATE		06/09/88	06/09/88	06/13/88
	ALPHA-BHC	ug/kg	u50.0	u50.0	u50.0
	BETA-BHC	ug/kg	u50.0	u50.0	u50.0
	GAMMA-BHC (LINDANE)	ug/kg	u50.0	u50.0	u50.0
	HEPTACHLOR	ug/kg	u50.0	u50.0	u50.0
	DELTA-BHC	ug/kg	u50.0	u50.0	u50.0
	ALDRIN	ug/kg	u50.0	u50.0	u50.0
	HEPTACHLOROEPOXIDE	ug/kg	u50.0	u50.0	u50.0
	ALPHA-ENDOSULFAN	ug/kg	u50.0	u50.0	u50.0
	4,4'-DDE	ug/kg	u50.0	u50.0	u50.0
	DIELDRIN	ug/kg	u50.0	u50.0	u50.0
	ENDRIN	ug/kg	u50.0	u50.0	u50.0
	4,4'-TDE (DDD)	ug/kg	u50.0	u50.0	u50.0
	BETA-ENDOSULFAN	ug/kg	u100.0	u100.0	u100.0
	4,4'-DDT	ug/kg	u100.0	u100.0	u100.0
	ENDRIN ALDEHYDE	ug/kg	u100.0	u100.0	u100.0
	ENDOSULFAN SULFATE	ug/kg	u100.0	u100.0	u100.0
	MIREX	ug/kg	u200.0	u200.0	u200.0
	METHOXYCHLOR	ug/kg	u200.0	u200.0	u200.0
	CHLORDANE	ug/kg	u200.0	u1000.0	u200.0
	TOXAPHENE	ug/kg	u1000.0	u1000.0	u1000.0
	PCB 1016	ug/kg	u1000.0	u1000.0	u1000.0
	PCB 1221	ug/kg	u1000.0	u1000.0	u1000.0
	PCB 1232	ug/kg	u1000.0	u1000.0	u1000.0
	PCB 1242	ug/kg	u500.0	u500.0	u500.0
	PCB 1248	ug/kg	36600.0	45600.0	4040.0
	PCB 1254	ug/kg	u500.0	u500.0	u500.0
	PCB 1260	ug/KG	u500.0	u500.0	u500.0

SAMPLE AREA 1

CATEGORY	PARAMETER	UNITS	SAMPLE NUMBER 1-T1-C CONCENTRATION	SAMPLE NUMBER 1-T4-SC CONCENTRATION
HSL METALS				
	SAMPLE DATE		06/13/88	06/15/88
	CYANIDE, TOTAL	ug/g	u1.1	0.6
	ALUMINUM	ug/g	11800.0	5000.0
	ANTIMONY	ug/g	u4.6	u2.8
	ARSENIC	ug/g	5.5	2.2
	BARIUM	ug/g	189.0	167.0
	BERYLLIUM, TOTAL	ug/g	u1.2	u0.7
	CADMIUM, TOTAL	ug/g	u1.2	u0.7
	CALCIUM, TOTAL	ug/g	206000.0	135000.0
	CHROMIUM, TOTAL	ug/g	62.4	26.4
	COBALT, TOTAL	ug/g	u11.6	u7.0
	COPPER, TOTAL	ug/g	53.1	26.4
	IRON, TOTAL	ug/g	21000.0	8620.0
	LEAD, TOTAL	ug/g	125.0	57.0
	MAGNESIUM, TOTAL	ug/g	11100.0	52800.0
	MANGANESE, TOTAL	ug/g	346.0	417.0
	MERCURY, TOTAL	ug/g	14.6	44.5
	NICKEL, TOTAL	ug/g	27.7	20.8
	SELENIUM, TOTAL	ug/g	u0.5	u0.3
	POTASSIUM, TOTAL	ug/g	1730.0	945.0
	SILVER, TOTAL	ug/g	u2.3	u1.4
	SODIUM, TOTAL	ug/g	231.0	361.0
	THALLIUM, TOTAL	ug/g	u57.8	u34.8
	TIN, TOTAL	ug/g	u2.3	u1.4
	VANADIUM, TOTAL	ug/g	u57.8	u34.8
	ZINC, TOTAL	ug/g	323.0	236.0

SAMPLE AREA 2

CATEGORY	PARAMETER	UNITS	SAMPLE NUMBER 2-T6-MC CONCENTRATION	SAMPLE NUMBER 2-T6-SC CONCENTRATION
HSL METALS				
	SAMPLE DATE		06/14/88	06/14/88
	CYANIDE, TOTAL	ug/g	1.2	2.0
	ALUMINUM	ug/g	5400.0	4830.0
	ANTIMONY	ug/g	u3.1	u2.5
	ARSENIC	ug/g	5.4	4.6
	BARIUM	ug/g	246.0	572.0
	BERYLLIUM, TOTAL	ug/g	u0.8	u0.6
	CADMIUM, TOTAL	ug/g	u0.8	u0.6
	CALCIUM, TOTAL	ug/g	125000.0	94000.0
	CHROMIUM, TOTAL	ug/g	52.4	39.4
	COBALT, TOTAL	ug/g	u7.7	u6.4
	COPPER, TOTAL	ug/g	493.0	254.0
	IRON, TOTAL	ug/g	21600.0	12700.0
	LEAD, TOTAL	ug/g	120.0	267.0
	MAGNESIUM, TOTAL	ug/g	23100.0	29200.0
	MANGANESE, TOTAL	ug/g	277.0	279.0
	MERCURY, TOTAL	ug/g	60.1	49.5
	NICKEL, TOTAL	ug/g	43.1	29.2
	SELENIUM, TOTAL	ug/g	u0.2	u0.2
	POTASSIUM, TOTAL	ug/g	1540.0	724.0
	SILVER, TOTAL	ug/g	u2.2	u6.4
	SODIUM, TOTAL	ug/g	200.0	165.0
	THALLIUM, TOTAL	ug/g	u38.5	u31.8
	TIN, TOTAL	ug/g	u1.5	u1.3
	VANADIUM, TOTAL	ug/g	u38.5	u31.8
	ZINC, TOTAL	ug/g	1060.0	876.0

SAMPLE AREA 3

CATEGORY	PARAMETER	UNITS	SAMPLE NUMBER 3-T8-MC CONCENTRATION	SAMPLE NUMBER 3-T8-SC CONCENTRATION
HSL METALS				
	SAMPLE DATE		06/15/88	06/15/88
	CYANIDE, TOTAL	ug/g	7.8	2.4
	ALUMINUM	ug/g	6150.0	3230.0
	ANTIMONY	ug/g	u4.1	u4.6
	ARSENIC	ug/g	6.2	7.6
	BARIUM	ug/g	180.0	485.0
	BERYLLIUM, TOTAL	ug/g	u1.0	u1.2
	CADMIUM, TOTAL	ug/g	u1.0	u1.2
	CALCIUM, TOTAL	ug/g	104000.0	76200.0
	CHROMIUM, TOTAL	ug/g	80.0	60.1
	COBALT, TOTAL	ug/g	u10.2	u11.6
	COPPER, TOTAL	ug/g	451.0	231.0
	IRON, TOTAL	ug/g	308000.0	20300.0
	LEAD, TOTAL	ug/g	113.0	192.0
	MAGNESIUM, TOTAL	ug/g	15200.0	10200.0
	MANGANESE, TOTAL	ug/g	348.0	171.0
	MERCURY, TOTAL	ug/g	53.3	69.3
	NICKEL, TOTAL	ug/g	51.2	39.3
	SELENIUM, TOTAL	ug/g	u0.4	u0.5
	POTASSIUM, TOTAL	ug/g	1110.0	693.0
	SILVER, TOTAL	ug/g	u6.6	3.5
	SODIUM, TOTAL	ug/g	267.0	196.0
	THALLIUM, TOTAL	ug/g	u51.3	u57.8
	TIN, TOTAL	ug/g	u2.0	u2.3
	VANADIUM, TOTAL	ug/g	u51.3	u57.8
	ZINC, TOTAL	ug/g	1970.0	2170.0

SAMPLE AREA 4

CATEGORY	PARAMETER	UNITS	SAMPLE NUMBER 4-T10-MC CONCENTRATION	SAMPLE NUMBER 4-T10-SC CONCENTRATION
HSL METALS				
	SAMPLE DATE		06/11/88	06/11/88
	CYANIDE, TOTAL	ug/g	15.2	<0.5
	ALUMINUM	ug/g	7030.0	4090.0
	ANTIMONY	ug/g	u3.8	u2.8
	ARSENIC	ug/g	6.6	5.4
	BARIUM	ug/g	361.0	536.0
	BERYLLIUM, TOTAL	ug/g	u1.0	u0.7
	CADMIUM, TOTAL	ug/g	1.6	1.3
	CALCIUM, TOTAL	ug/g	116000.0	76100.0
	CHROMIUM, TOTAL	ug/g	78.0	46.5
	COBALT, TOTAL	ug/g	u9.5	u7.1
	COPPER, TOTAL	ug/g	342.0	197.0
	IRON, TOTAL	ug/g	30400.0	18300.0
	LEAD, TOTAL	ug/g	135.0	286.0
	MAGNESIUM, TOTAL	ug/g	18000.0	14100.0
	MANGANESE, TOTAL	ug/g	342.0	226.0
	MERCURY, TOTAL	ug/g	8.0	40.9
	NICKEL, TOTAL	ug/g	62.7	32.4
	SELENIUM, TOTAL	ug/g	u0.4	u0.3
	POTASSIUM, TOTAL	ug/g	1080.0	713.0
	SILVER, TOTAL	ug/g	u1.9	u1.4
	SODIUM, TOTAL	ug/g	247.0	381.0
	THALLIUM, TOTAL	ug/g	u48.0	u35.2
	TIN, TOTAL	ug/g	u1.9	u1.4
	VANADIUM, TOTAL	ug/g	u48.0	u35.2
	ZINC, TOTAL	ug/g	1520.0	1690.0

SAMPLE AREA 5

CATEGORY	PARAMETER	UNITS	SAMPLE NUMBER 5-4G CONCENTRATION	SAMPLE NUMBER 5-4G(DUP) CONCENTRATION	SAMPLE NUMBER 5-5G CONCENTRATION
HSL METALS					
	SAMPLE DATE		06/09/88	06/09/88	06/13/88
	CYANIDE, TOTAL	ug/g	u0.5	u0.5	u0.5
	ALUMINUM	ug/g	2440.0	2580.0	1900.0
	ANTIMONY	ug/g	u2.2	u2.2	u2.1
	ARSENIC	ug/g	2.1	1.9	1.5
	BARIUM	ug/g	25.5	105.0	28.6
	BERYLLIUM, TOTAL	ug/g	u0.6	u0.6	u0.5
	CADMIUM, TOTAL	ug/g	u0.6	5.3	u0.5
	CALCIUM, TOTAL	ug/g	65500.0	65000.0	90100.0
	CHROMIUM, TOTAL	ug/g	7.2	41.4	6.7
	COBALT, TOTAL	ug/g	<45.6	u5.6	u5.3
	COPPER, TOTAL	ug/g	14.4	15.7	9.1
	IRON, TOTAL	ug/g	11100.0	7730.0	5720.0
	LEAD, TOTAL	ug/g	15.5	90.7	11.7
	MAGNESIUM, TOTAL	ug/g	26600.0	23500.0	36000.0
	MANGANESE, TOTAL	ug/g	488.0	314.0	456.0
	MERCURY, TOTAL	ug/g	3.8	5.3	3.4
	NICKEL, TOTAL	ug/g	17.8	13.0	11.0
	SELENIUM, TOTAL	ug/g	u0.2	u0.2	u0.2
	POTASSIUM, TOTAL	ug/g	231.0	616.0	307.0
	SILVER, TOTAL	ug/g	u1.1	u1.1	1.1
	SODIUM, TOTAL	ug/g	74.4	123.0	127.0
	THALLIUM, TOTAL	ug/g	u27.8	u27.8	u26.0
	TIN, TOTAL	ug/g	u1.1	u1.1	u1.1
	VANADIUM, TOTAL	ug/g	u27.8	u27.8	u26.0
	ZINC, TOTAL	ug/g	92.1	258.0	56.2

CATEGORY	PARAMETER	UNITS	SAMPLE NUMBER 1-2E CONCENTRATION	SAMPLE NUMBER 2-2E CONCENTRATION	SAMPLE NUMBER 3-2E CONCENTRATION	SAMPLE NUMBER 4-2E CONCENTRATION	SAMPLE NUMBER 5-1E CONCENTRATION
SURFACE WATER							
	SAMPLE DATE		06/16/88	06/16/88	06/16/88	06/16/88	06/13/88
	MERCURY	ug/l	0.6	0.4	U0.2	u0.2	0.5
	ALPHA-BHC	ug/l	0.42	1.26	0.69	0.29	0.08
	BETA-BHC	ug/l	0.09	0.05	u0.05	0.07	1.08
	DELTA-BHC	ug/l	u0.05	u0.05	u0.05	u0.05	u0.05
	GAMMA-BHC(LINDANE)	ug/l	u0.05	u0.05	u0.05	u0.05	0.05
	HEPTACHLOR	ug/l	u0.05	u0.05	u0.05	u0.05	u0.05
	ALDRIN	ug/l	u0.05	u0.05	u0.05	u0.05	u0.05
	HEPTACHLOREPOXIDE	ug/l	u0.05	u0.05	u0.05	u0.05	u0.05
	ALPHA-ENDOSULFAN	ug/l	u0.05	u0.05	u0.50	u0.05	u0.05
	DIELDRIN	ug/l	u0.05	u0.05	u0.05	u0.05	u0.05
	4,4'-DDE	ug/l	u0.05	u0.05	u0.05	u0.05	u0.05
	ENDRIN	ug/l	u0.05	u0.05	u0.05	u0.05	u0.10
	BETA-ENDOSULFAN	ug/l	u0.10	u0.10	u0.10	u0.10	u0.05
	4,4'-DDD	ug/l	u0.05	u0.05	u0.05	u0.05	u0.10
	ENDOSULFAN SULFATE	ug/l	u0.10	u0.10	u0.10	u0.10	u0.10
	4,4'-DDT	ug/l	u0.10	u0.10	u0.10	u0.10	u0.20
	METHOXYCHLOR	ug/l	u0.20	u0.20	u0.20	u0.20	u0.20
	ENDRIN KETONE	ug/l	u0.20	u0.20	u0.20	u0.20	u0.20
	ALPHA-CHLORDANE	ug/l	u0.20	u0.20	u0.20	u0.20	u0.20
	GAMMA-CHLORDANE	ug/l	u0.20	u0.20	u0.20	u0.20	u0.20
	TOXAPHENE	ug/l	u1.00	u1.00	u1.00	u1.00	u1.00
	PCB 1216	ug/l	u1.00	u1.00	u1.00	u1.00	u1.00
	PCB 1221	ug/l	u1.00	u1.00	u1.00	u1.00	u1.00
	PCB 1232	ug/l	u1.00	u1.00	u1.00	u1.00	u1.00
	PCB 1242	ug/l	u0.50	u0.50	u0.50	u0.50	u0.50
	PCB 1248	ug/l	2.10	2.50	3.19	u0.50	1.64
	PCB 1254	ug/l	u0.50	u0.50	u0.50	u0.50	u0.50
	PCB 1260	ug/l	u0.50	u0.50	u0.50	u0.50	u0.50
	CHLOROBENZENE	ug/l	u2.0	u2.0	u2.0	u2.0	u2.0
	1,3-DICHLOROBENZENE	ug/l	u8.0	u8.0	u8.0	u8.0	u8.0
	1,4-DICHLOROBENZENE	ug/l	u8.0	u8.0	u8.0	u8.0	u8.0
	1,2-DICHLOROBENZENE	ug/l	u8.0	u8.0	u8.0	u8.0	u8.0
	HEXACHLOROETHANE	ug/l	u8.0	u8.0	u8.0	u8.0	u8.0
	1,3,5-TRICHLOROBENZENE	ug/l	u8.0	u8.0	u8.0	u8.0	u8.0
	1,2,4-TRICHLOROBENZENE	ug/l	u8.0	u8.0	u8.0	u8.0	j1.0
	1,2,3-TRICHLOROBENZENE	ug/l	u8.0	u8.0	u8.0	u8.0	u8.0
	HEXACHLORBUTADIENE	ug/l	u8.0	u8.0	u8.0	u8.0	u8.0
	1,2,3,5-TETRACHLOROBENZENE	ug/l	u8.0	u8.0	u8.0	u8.0	u8.0
	1,2,3,4-TETRACHLOROBENZENE	ug/l	u8.0	u8.0	u8.0	u8.0	u8.0
	PENTACHLOROBENZENE	ug/l	u8.0	u8.0	u8.0	u8.0	u8.0
	HEXACHLOROBENZENE	ug/l	u8.0	u8.0	u8.0	u8.0	j2.4

CATEGORY	PARAMETER	UNITS	SAMPLE NUMBER 1-2E CONCENTRATION	SAMPLE NUMBER 2-2E CONCENTRATION	SAMPLE NUMBER 3-2E CONCENTRATION	SAMPLE NUMBER 4-2E CONCENTRATION	SAMPLE NUMBER 5-1E CONCENTRATION
ELUTRIATE							
	SAMPLE DATE		06/16/88	06/16/88	06/16/88	06/16/88	06/13/88
	MERCURY	ug/l	u0.2	u0.2	U0.2	u0.2	0.6
	ALPHA-BHC	ug/l	352.0	1500.0	1380.0	1280.0	168.0
	BETA-BHC	ug/l	58.4	20.3	172.0	161.0	62.9
	DELTA-BHC	ug/l	3.36	u0.50	1.72	u0.50	u0.50
	GAMMA-BHC(LINDANE)	ug/l	0.5	u0.9	25.0	2.2	0.7
	HEPTACHLOR	ug/l	u0.5	u0.5	u1.0	u0.5	u0.5
	ALDRIN	ug/l	u0.5	u0.5	u1.0	u0.5	u0.5
	HEPTACHLOREPOXIDE	ug/l	u0.5	u0.5	u1.0	u0.5	u0.5
	ALPHA-ENDOSULFAN	ug/l	u0.5	u0.5	u1.0	u0.5	u0.5
	DIELDRIN	ug/l	u0.5	u0.5	u1.0	u0.5	u0.5
	4,4'-DDE	ug/l	u0.5	u0.5	u1.0	u0.5	u0.5
	ENDRIN	ug/l	u0.5	u0.5	u1.0	u0.5	u0.5
	BETA-ENDOSULFAN	ug/l	u1.0	u1.0	u2.0	u1.0	u1.0
	4,4'-DDD	ug/l	u0.5	u0.5	u1.0	u0.5	u0.5
	ENDOSULFAN SULFATE	ug/l	u1.0	u1.0	u2.0	u1.0	u1.0
	4,4'-DDT	ug/l	u1.0	u1.0	u2.0	u1.0	u1.0
	METHOXYCHLOR	ug/l	u2.0	u2.0	u4.0	u1.0	u2.0
	ENDRIN KETONE	ug/l	u2.0	u2.0	u4.0	u2.0	u2.0
	ALPHA-CHLORDANE	ug/l	u2.0	u2.0	u4.0	u2.0	u2.0
	GAMMA-CHLORDANE	ug/l	u2.0	u2.0	u4.0	u2.0	u2.0
	TOXAPHENE	ug/l	u10.0	u10.0	u20.0	u10.0	u10.0
	PCB 1216	ug/l	u10.0	u10.0	u20.0	u10.0	u10.0
	PCB 1221	ug/l	u10.0	u10.0	u20.0	u10.0	u10.0
	PCB 1232	ug/l	u10.0	u10.0	u20.0	u10.0	u10.0
	PCB 1242	ug/l	u5.0	u5.0	u10.0	u5.0	u5.0
	PCB 1248	ug/l	u5.0	u5.0	u10.0	81.3	u5.0
	PCB 1254	ug/l	u5.0	u5.0	u10.0	u5.0	u5.0
	PCB 1260	ug/l	u5.0	u5.0	u10.0	u5.0	u5.0
	CHLOROBENZENE	ug/l	62.7	42.5	950.0	54.7	38.6
	1,3-DICHLOROBENZENE	ug/l	j1.3	j0.5	31.4	j3.5	u8.0
	1,4-DICHLOROBENZENE	ug/l	j3.2	j1.4	204.0	25.0	j3.4
	1,2-DICHLOROBENZENE	ug/l	j2.4	j0.7	276.0	24.3	j2.8
	HEXACHLOROETHANE	ug/l	u8.0	u8.0	u16.0	u8.0	u8.0
	1,3,5-TRICHLOROBENZENE	ug/l	u8.0	u8.0	u16.0	u8.0	u8.0
	1,2,4-TRICHLOROBENZENE	ug/l	j1.7	u8.0	109.0	11.0	j1.6
	1,2,3-TRICHLOROBENZENE	ug/l	j1.3	u8.0	57.2	j5.1	j1.8
	HEXACHLORBUTADIENE	ug/l	u8.0	63.5	52.0	21.6	j9.6
	1,2,3,5-TETRACHLOROBENZENE	ug/l	u8.0	u8.0	j2.6	u8.0	u8.0
	1,2,3,4-TETRACHLOROBENZENE	ug/l	u8.0	u8.0	j2.8	u8.0	u8.0
	PENTACHLOROBENZENE	ug/l	u8.0	u8.0	u16.0	u8.0	u8.0
	HEXACHLOROBENZENE	ug/l	u8.0	u8.0	u16.0	j2.3	u8.0

APPENDIX B

SEDIMENT SAMPLING PROGRAM DATA

1. Vibracore Logs
2. Ponar Dredge and Piston Core Sample Descriptions
3. Grain Size Data
4. Depositional Environment Summary

/WM-39

Log of Vibracorer Samples

DATE 6/14/88 SURFACE ELEVATION 556.8 LOCATION 2-T5-1

DEPTH, ft.	SAMPLES	SECTION LOG	DESCRIPTION	ELEVATION	
0		2-T5-15	Red-brown clay, little silt, with crushed stone, firm		
			Black silt, with crushed stone, oily, liquified		
1		2-T5-1D	Dark to medium gray silt and clay, laminated, with organic matter		
2					
3					

Completion Depth 2.3 Feet Water Depth 4.5 Feet Date 6/14/88

Project Name Gill Creek Sediment Study Project Number 88C2056-2

Woodward-Clyde Consultants

Log of Vibracorer Samples

DATE 6/14/88 SURFACE ELEVATION 557.1 LOCATION 2-T5-2

DEPTH, ft.	SAMPLES	SECTION LOG	DESCRIPTION	ELEVATION	
0		2-T5-2S	Medium brown to gray silt, some fine sand, with crushed stone fragments, saturated		
			Medium brown clay, trace silt, plastic, firm		
1			Medium gray silty clay, some fine sand, with crushed stone, very soft		
		2-T5-2D			
2					
3					

Completion Depth 2.5 Feet Water Depth 4.2 Feet Date 6/14/88

Project Name Gill Creek Sediment Study Project Number 88C2056-2

Woodward-Clyde Consultants

Log of Vibracorer Samples

DATE 6/14/88 **SURFACE ELEVATION** 557.2 **LOCATION** 2-T5-3

DEPTH, ft.	SAMPLES	SECTION LOG	DESCRIPTION	ELEVATION
0		2-T5-3S	Black silt, some fine sand, trace clay, oily sheen liquified	
			Medium brown clay, trace silt, firm	
1		2-T5-3D	Black silty clay, some fine sand, oily sheen	
2				

Completion Depth 1.4 Feet Water Depth 4.1 Feet Date 6/14/88

Project Name Gill Creek Sediment Study Project Number 88C2056-2

Woodward-Clyde Consultants

Log of Vibracorer Samples

DATE 6/14/88 SURFACE ELEVATION 556.7 LOCATION 2-T6-1

DEPTH, ft.	SAMPLES	SECTION LOG	DESCRIPTION	ELEVATION	
0		2-T6-1S 2-T6-SC (HSL)	Dark gray silt, some clay, trace fine sand, with roots, liquified		
			Dark gray clay and silt, some roots, very soft		
1					
2		2-T6-MC (HSL)			
		2-T6-1D			
3					

Completion Depth 3.5 Feet Water Depth 4.6 Feet Date 6/14/88

Project Name Gill Creek Sediment Study Project Number 88C2056-2

Woodward-Clyde Consultants

Log of Vibracorer Samples

DATE 6/14/88 SURFACE ELEVATION 557.4 LOCATION 2-T6-2

DEPTH, ft.	SAMPLES	SECTION LOG	DESCRIPTION	ELEVATION
0		2-T6-2S 2-T6-SC (HSL)	Medium brown to gray silt with some medium to fine sand, trace clay, crushed stone fragments	
1		2-T6-2D 2-T6-MC (HSL)	Medium brown silty clay, trace fine sand, with crushed stone fragments	
2				

Completion Depth 2.0 Feet Water Depth 3.9 Feet Date 6/22/88

Project Name Gill Creek Sediment Study Project Number 88C2056-2

Woodward-Clyde Consultants

Log of Vibracorer Samples

DATE 6/14/88 SURFACE ELEVATION 557.0 LOCATION 2-T6-3

DEPTH, ft.	SAMPLES	SECTION LOG	DESCRIPTION	ELEVATION	
0		2-T6-3S 2-T6-SC (HSL) 2-T6-3D 2-T6-MC (HSL)	Medium gray to brown silt, some fine sand, some clay, with crushed stone, liquified		
1					
2					

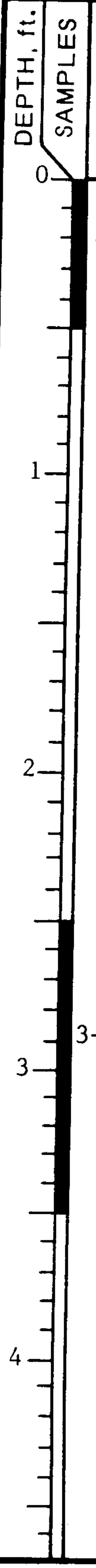
Completion Depth 1.1 Feet Water Depth 4.3 Feet Date 6/14/88

Project Name Gill Creek Sediment Study Project Number 88C2056

Woodward-Clyde Consultants

Log of Vibracorer Samples

DATE 6/15/88 SURFACE ELEVATION 558.1 LOCATION 3-T7-1



DEPTH, ft.	SECTION LOG	DESCRIPTION	ELEVATION
0	3-T7-1S	Black silt, some gravel , liquified -becoming solid, with brick fragments -with soft white sand-sized particles	
2	3-T7-1D	Black silty clay, oily sheen, soft	
3		Medium brown to gray clay, some silt, with laminated light gray layers, firm	

Completion Depth 3.5 Feet Water Depth 3.3 Feet Date 6/15/88
Project Name Gill Creek Sediment Study Project Number 88C2056-2

Woodward-Clyde Consultants

Log of Vibracorer Samples

DATE 6/15/88 **SURFACE ELEVATION** 558.4 **LOCATION** 3-T7-2

DEPTH, ft.	SAMPLES	SECTION LOG	DESCRIPTION	ELEVATION	
0	■	3-T7-25	Black silt, some gravel, with shell fragments, oily sheen liquified		
1			Black clay, some silt, with isolated crushed stone and gravel		
2	■	3-T7-2D			
3					

Completion Depth 2.6 Feet Water Depth 2.9 Feet Date 6/15/88

Project Name Gill Creek Sediment Study Project Number 88C2056-2

Woodward-Clyde Consultants

WCC ... 2

Log of Vibracorer Samples

DATE 6/15/88 SURFACE ELEVATION 558.2 LOCATION 3-T8-1

DEPTH, ft.	SAMPLES	SECTION LOG	DESCRIPTION	ELEVATION
0	3-T8-1S 3-T8-SC (HSL)		Black silt, some fine sand and gravel	
			Dark gray silt, some clay, isolated gravel and crushed stone, soft	
1				
2	3-T8-1D 3-T8-MC (HSL)			
3				

Completion Depth 2.8 Feet Water Depth 3.1 Feet Date 6/15/88

Project Name Gill Creek Sediment Study Project Number 88C2056-2

Woodward-Clyde Consultants

Log of Vibracorer Samples

DATE 6/15/88 SURFACE ELEVATION 558.5 LOCATION 3-T8-2

DEPTH, ft.	SAMPLES	SECTION LOG	DESCRIPTION	ELEVATION
0	■	3-T8-2S 3-T8-SC (HSL)	Medium to dark gray silt and fine sand, some fine gravel, oily sheen, saturated	
1			Black silty clay, with organic matter	
	■		-gravelly layer	
2	■	3-T8-MC (HSL)		
	■		-gravelly layer	
3				
	■		-becoming medium gray-black laminated	
	■	3-T8-2D		
4	■		Medium brown to gray clayey silt with some fine gravel	

Completion Depth 4.4 Feet Water Depth 2.8 Feet Date 6/15/88

Project Name Gill Creek Sediment Study Project Number 88C2056-2

Woodward-Clyde Consultants

Log of Vibracorer Samples

DATE 6/15/88 **SURFACE ELEVATION** 557.7 **LOCATION** 3-T8-3

DEPTH, ft.	SAMPLES	SECTION LOG	DESCRIPTION	ELEVATION	
0		3-T8-3S 3-T8-5C (HSL)	Black silt, some fine sand and clay, with shell fragments, liquified		
			Black clay, some silt, oily appearance, soft, with roots		
1					
2		3-T8-MC (HSL)			
3		3-T8-3D			
			Medium brown clay, trace silt, soft, with organic matter (roots, stems)		
4					

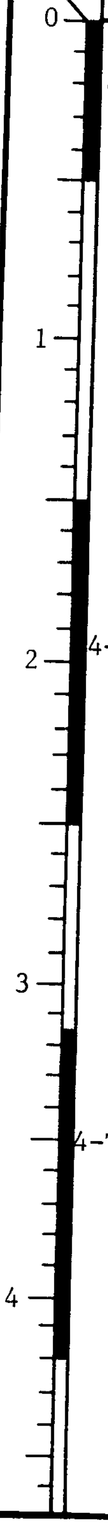
Completion Depth 3.9 Feet Water Depth 3.6 Feet Date 6/15/88

Project Name Gill Creek Sediment Study Project Number 88C2056-2

Woodward-Clyde Consultants

Log of Vibracorer Samples

DATE 6/10/88 **SURFACE ELEVATION** 557.7 **LOCATION** 4-T9-1



SECTION LOG	DESCRIPTION	ELEVATION	
4-T9-1S	Black fine sand with some silt trace clay, some roots, some shell fragments, saturated		
	-increasing clay		
4-T9-1S	-becoming oily		
4-T9-1D	Light to medium gray clay, some silt, firm		
	Medium brown to gray silt, trace fine sand		

Completion Depth 4.2 Feet Water Depth 3.6 Feet Date 6/10/88

Project Name Gill Creek Sediment Study Project Number 88C2056-2

Woodward·Clyde Consultants

Log of Vibracorer Samples

DATE 6/10/88 **SURFACE ELEVATION** 558 **LOCATION** 4-T9-2

DEPTH, ft.	SAMPLES	SECTION LOG	DESCRIPTION	ELEVATION
0	4-T9-2S		Black silt with trace fine sand and clay, oily, liquified	
1				
2				
3	4-T9-2D		Medium gray sand and clay, with organic matter (roots, stems)	
4				

Completion Depth 3.5 Feet Water Depth 3.3 Feet Date 6/10/88

Project Name Gill Creek Sediment Study Project Number 88C2056-2

Woodward-Clyde Consultants

WCC nr 2

Log of Vibracorer Samples

DATE 6/11/88 **SURFACE ELEVATION** 557.3 **LOCATION** 4-T9-3

DEPTH, ft.	SAMPLES	SECTION LOG	DESCRIPTION	ELEVATION	
0		4-T9-3S	Black silty sand, with shell fragments, twigs, roots, liquified		
			Black clay, some silt, oily		
1		4-T9-3D	-1-inch medium brown clay, firm		
2					

Completion Depth 1.7 Feet Water Depth 4.0 Feet Date 6/11/88

Project Name Gill Creek Sediment Study Project Number 88C2056-2

Woodward-Clyde Consultants

Log of Vibracorer Samples

DATE 6/11/88 SURFACE ELEVATION 558.6 LOCATION 4-T10-1

DEPTH, ft.	SAMPLES	SECTION LOG	DESCRIPTION	ELEVATION	
0		4-T10-1S 4-T10-SC (HSL)	Black silt with medium to fine sand, occasional small mollusk (living)		
1					
		4-T10-1D 4-T10-MC (HSL)	Black clayey silt with root fibers, oily sheen		
2					
3					

Completion Depth 2.5 Feet Water Depth 2.7 Feet Date 6/11/88

Project Name Gill Creek Sediment Study Project Number 88C2056-2

Woodward-Clyde Consultants

WCC-HP 2

Log of Vibracorer Samples

DATE 6/11/88 SURFACE ELEVATION 556.6 LOCATION 4-T10-2

DEPTH, ft.	SAMPLES	SECTION LOG	DESCRIPTION	ELEVATION
0	4-T10-2S 4-T10-SC (HSL)		Black silt with some fine sand, little clay, with shell fragments and trace gravel, some roots -no shell fragments	
1				
	4-T10-MC (HSL)		Black silty clay, some laminated light gray layers	
2				
	4-T10-20			
3			Light brown silty clay, firm	

Completion Depth 3.25 Feet Water Depth 4.7 Feet Date 6/11/88
Project Name Gill Creek Sediment Study Project Number 88C2056-2

Woodward-Clyde Consultants

Log of Vibracorer Samples

DATE 6/11/88 **SURFACE ELEVATION** 557.0 **LOCATION** 4-T10-3

DEPTH, ft.	SAMPLES	SECTION LOG	DESCRIPTION	ELEVATION	
0	4-T10-3S 4-T10-SC (HSL)		Black silty sand, with shell fragments, roots, saturated		
			Black clayey silt with organic matter (roots, stems)		
1			-light gray layer		
			Dark gray clay, some silt, firm		
	4-T10-MC				
2					
			-becoming medium gray		
	4-T10-3M				
3					
	4-T10-3D				
4					

Completion Depth 4.4 Feet Water Depth 4.3 Feet Date 6/11/88

Project Name Gill Creek Sediment Study Project Number 88C2056-2

Woodward-Clyde Consultants

Log of Vibracorer Samples

DATE 6/10/88 **SURFACE ELEVATION** 557.1 **LOCATION** 4-T11-1

DEPTH, ft.	SAMPLES	SECTION LOG	DESCRIPTION	ELEVATION
0	4-T11-1S		Dark gray silty clay, little fine gravel, trace fine sand, with organic matter (roots, stems), isolated small bivalve mollusks (living)	
1				
2	4-T11-1M		-less gravel	
3	4-T11-1 D			
			Light to medium gray clay, trace silt, laminated	
4				

Completion Depth 4.0 Feet Water Depth 4.2 Feet Date 6/10/88

Project Name Gill Creek Sedimant Study Project Number 88C2056-2

Woodward-Clyde Consultants

Log of Vibracorer Samples

DATE 6/9/88 SURFACE ELEVATION 555.8 LOCATION 4-T11-2

DEPTH, ft.	SAMPLES	SECTION LOG	DESCRIPTION	ELEVATION
0	▮	4-T11-2S	Dark gray to black silty sand with some small gravel, saturated	
1			Dark gray silty clay, some lighter gray laminated layers, plastic	
2	▮	4-T11-2D		
	▮		Medium brown clay, some silt, firm	
3				
4				

Completion Depth 3.0 Feet Water Depth 5.5 Feet Date 6/9/88

Project Name Gill Creek Sediment Study Project Number 88C2056-2

Woodward-Clyde Consultants

Log of Vibracorer Samples

DATE 6/11/88 SURFACE ELEVATION 557.8 LOCATION 4-T11-3

DEPTH, ft.	SAMPLES	SECTION LOG	DESCRIPTION	ELEVATION	
0	4-T11-3S		Black silt, some fine sand, little clay, shell fragments, twigs, liquified		
1					
			Black silt, some clay, very soft		
2					
			-increasing clay		
	4-T11-3D				
3					
4					

Completion Depth 3.5 Feet Water Depth 3.5 Feet Date 6/11/88

Project Name Gill Creek Sediment Study Project Number 88C2056-2

Woodward-Clyde Consultants

SAMPLE DESCRIPTIONS
GILL CREEK STUDY

Sample No.	Method	Description
1-T1-C	Grab Sample	Dark gray to black SILT and CLAY, with organic matter (roots, vegatative material), some cobbles and gravel.
1-T2-C	Piston Corer	Medium brown CLAY, some silt, very firm 4 to 5 inches recovery on three samples.
1-T3-C	Piston Corer	Medium brown to gray CLAY, some silt, little fine sand, very firm.
1-T4-C	Vibra Corer	Medium gray SILT, with sand and clay, saturated very loose, overlying medium brown CLAY, very firm. Recovery 3 to 10 inches.
5-1G	Ponar	Gravelly coarse SAND, with some silt (black).
5-2G	Ponar	Medium brown coarse to medium SAND, trace silt, with large cobbles and gravel.
5-3G	Ponar	Medium brown coarse to medium SAND, trace silt, with large cobbles and gravel.
5-4G	Ponar	Medium brown SAND, trace silt, with large gravel and cobbles.
5-5G	Ponar	Gravelly sand, brown.
5-6G	Ponar	Gravelly sand, brown.

/WM-39

EMPIRE
SOILS INVESTIGATIONS INC.

August 12, 1988

Ms. Karen Bunker
GENERAL TESTING CORPORATION
710 Exchange St.
Rochester, NY 14608

REFERENCE: Particle Size Analysis
Sediment Samples, Gill Creek, Niagara Falls, NY
Job Reference R88/1810

Dear Ms. Bunker:

Transmitted herewith are two (2) copies of Particle Size Analysis Reports performed on Samples No. R88/1810-001 through R88/1810-005, inclusive. The tests were performed in general conformance with ASTM Designation D422. The major deviation from this standard regards the sample size recommended on basis of the maximum particle size present. Thus, the distribution curve for Sample No. R88/1810-002 may not be statistically representative of the total material gradation at this location.

It should be noted that Sample No. R88/1810-003, after drying, contained a rubbery substance in a variety of particle sizes. It is possible that this material is a residue from oils contained in the sample and its presence may have influenced the mineral grain size distribution. We decided against washing the sample with solvent, since this would have caused a loss of mineral fines.

Since oil contamination could be a recurrent problem in testing of contaminated soils I am currently researching the ASTM Standards for a suitable solvent distillation process which can be performed without altering the grain size composition of the sample. Such a standard is available for extraction of asphalt from pavement core samples for verification of aggregate composition. I shall keep you informed of the results of my research and let you know of our time frame for having this capability available in our laboratory.

The waste materials generated through the test procedures, as well as the coolers and untested portions of the samples are ready for pickup as previously arranged.

Very truly yours,

EMPIRE SOILS INVESTIGATIONS, INC.

Jørgen F. Christiansen

Jorgen F. Christiansen, PE
Director, Geotechnical Testing

pl
Enc.

140 TELEGRAPH ROAD, P.O. BOX 297, MIDDLEPORT, NEW YORK 14105 716-735-3502

EMPIRE
SOILS INVESTIGATIONS INC.

GILL CREEK PROJECT

E. I. DuPont de Nemours & Company, Inc.

Niagara Falls, New York

For

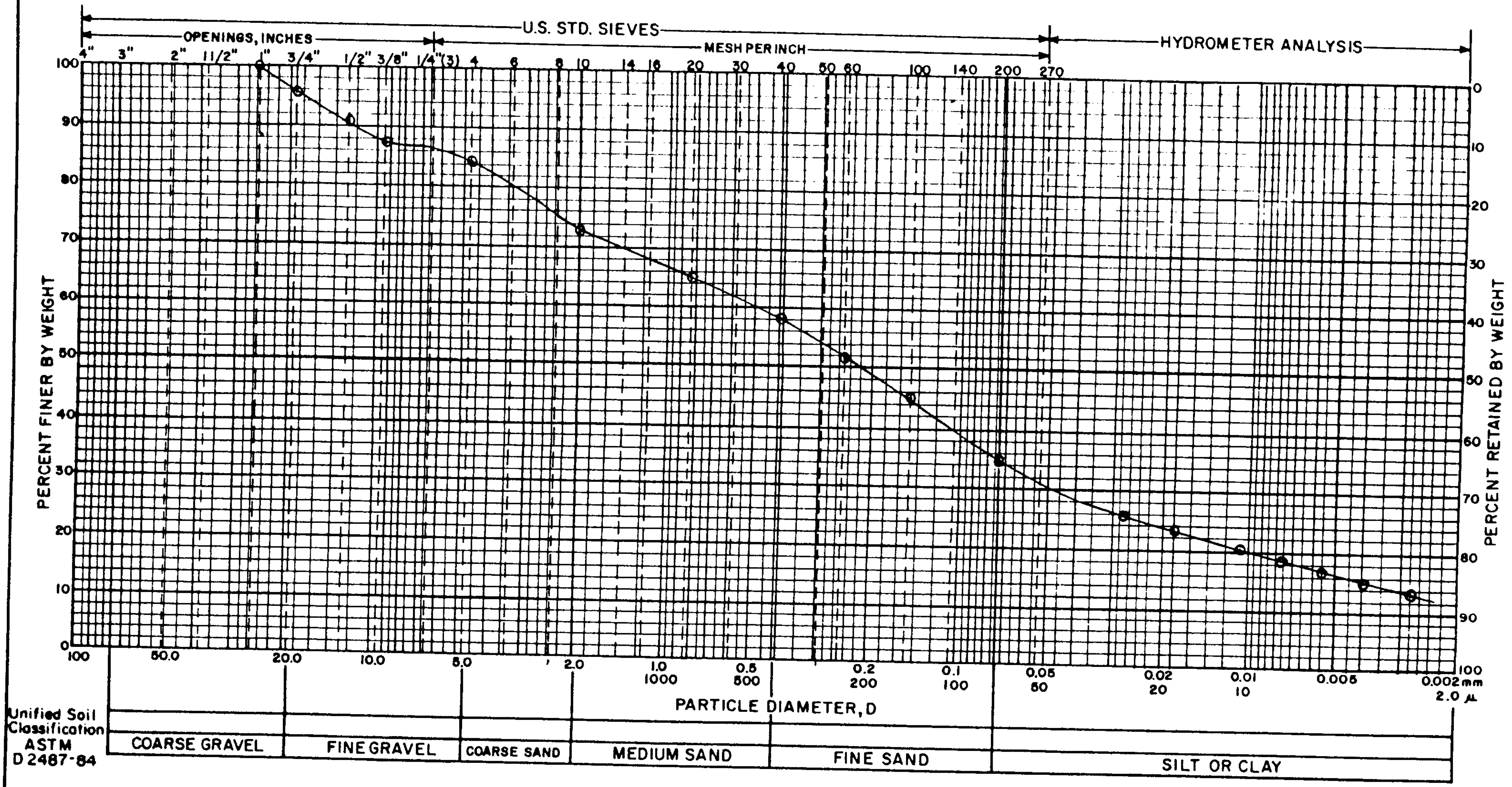
GENERAL TESTING CORPORATION

Rochester, New York

File No. G001.001

August, 1988

PARTICLE SIZE DISTRIBUTION CURVE



SAMPLE INFORMATION: SAMPLE NO. R88/1810-001 WCC 5-1E

STREAM BOTTOM SEDIMENT

☐ **Insufficient Sample Size per ASTM D 422**

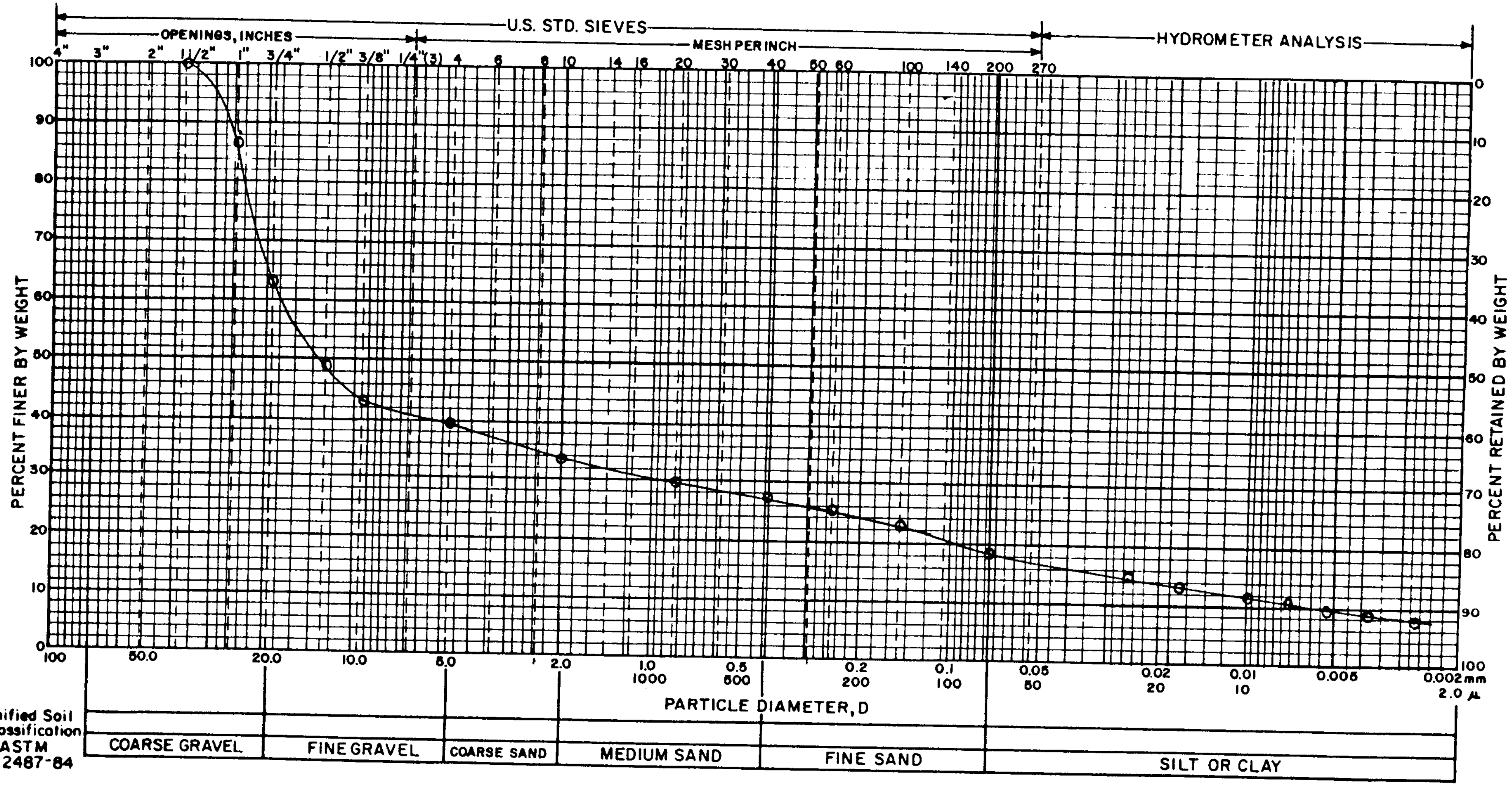
EMPIRE
SOILS INVESTIGATIONS INC.

PARTICLE SIZE ANALYSIS

GILL CREEK PROJECT
E. I. DuPont de Nemours
Niagara Falls, New York

DR. BY:	CK'D. JRC	DATE:	PROJ. NO. G001.001

PARTICLE SIZE DISTRIBUTION CURVE



SAMPLE INFORMATION: SAMPLE NO. R88/1810-002 WCC 1-2E

STREAM BOTTOM SEDIMENT

Note: Sample contained alot of oversize gravel particles which were excluded from the analysis.

☒ **Insufficient Sample Size per ASTM D 422**

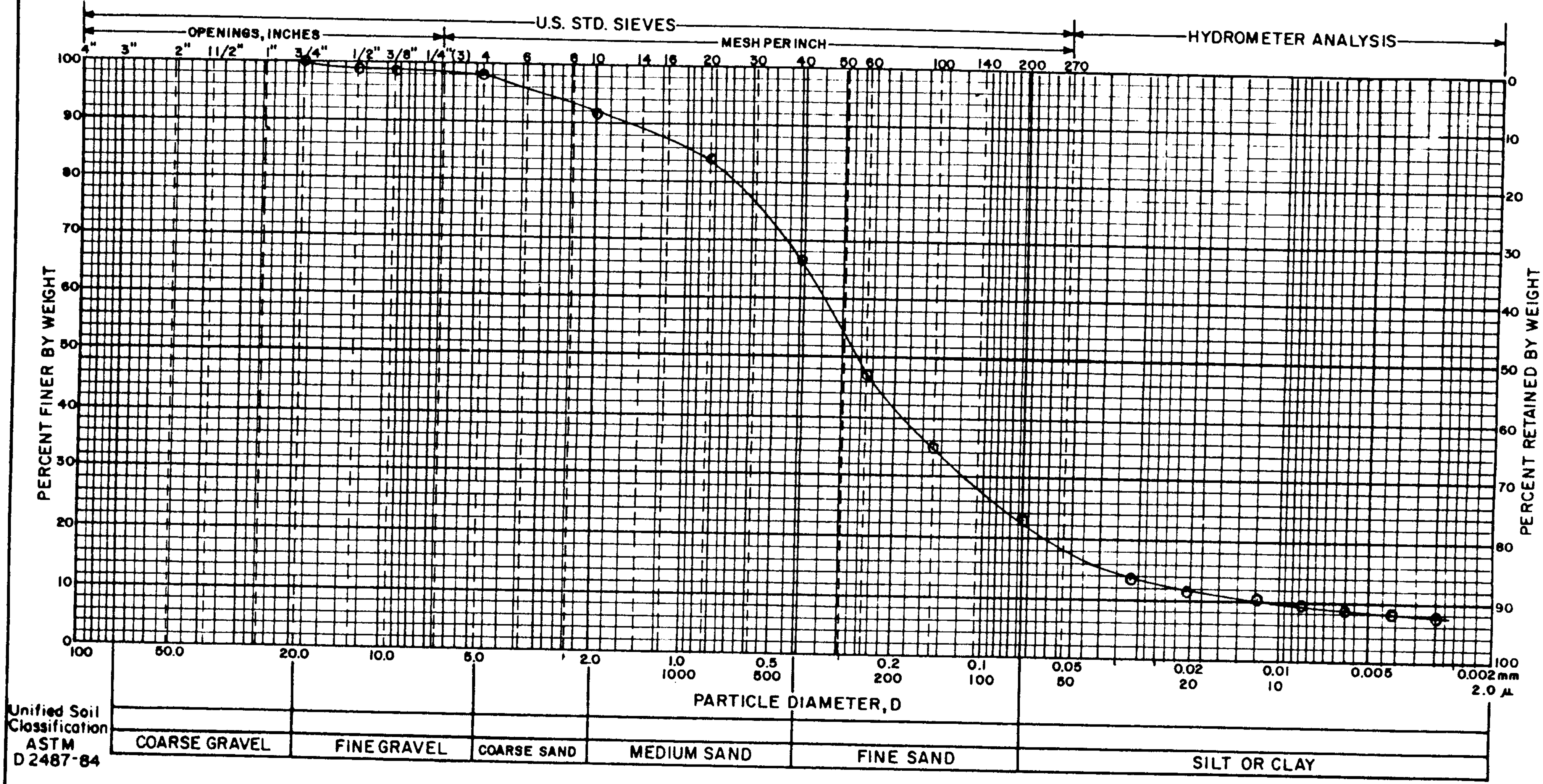
EMPIRE
SOILS INVESTIGATIONS INC.

PARTICLE SIZE ANALYSIS

GILL CREEK PROJECT
E. I. DuPont de Nemours
Niagara Falls, New York

DR. BY:	CK'D. JFC	DATE:	PROJ. NO. G001.001

PARTICLE SIZE DISTRIBUTION CURVE



SAMPLE INFORMATION: SAMPLE NO. R88/1810-003 WCC 2-2E

STREAM BOTTOM SEDIMENT

Note: During sample preparation following drying pieces of rubbery material was observed. Whether this material is rubber or residue from oils contained in the sample was not determined. We opted not to wash the sample with solvent, for fear that a loss of fines would occur.

☐ **Insufficient Sample Size per ASTM D 422**

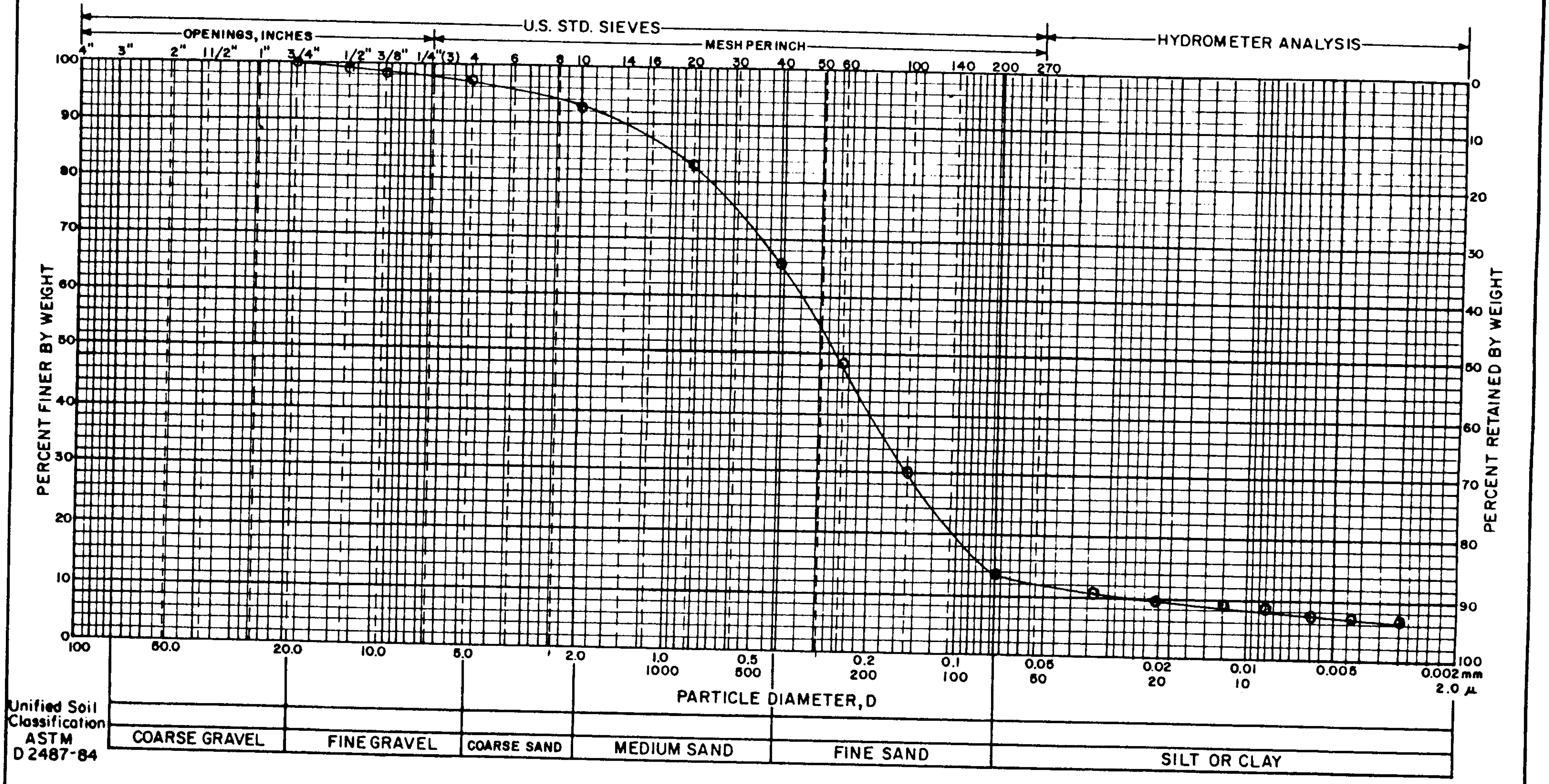
EMPIRE
SOILS INVESTIGATIONS INC.

PARTICLE SIZE ANALYSIS

GILL CREEK PROJECT
E. I. DuPont de Nemours
Niagara Falls, New York

DR. BY:	CK'D. JFC	DATE:	PROJ. NO. G001.001

PARTICLE SIZE DISTRIBUTION CURVE



SAMPLE INFORMATION: SAMPLE NO. R88/1810-004 WCC 3-2E

☐ **Insufficient Sample Size per ASTM D 422**

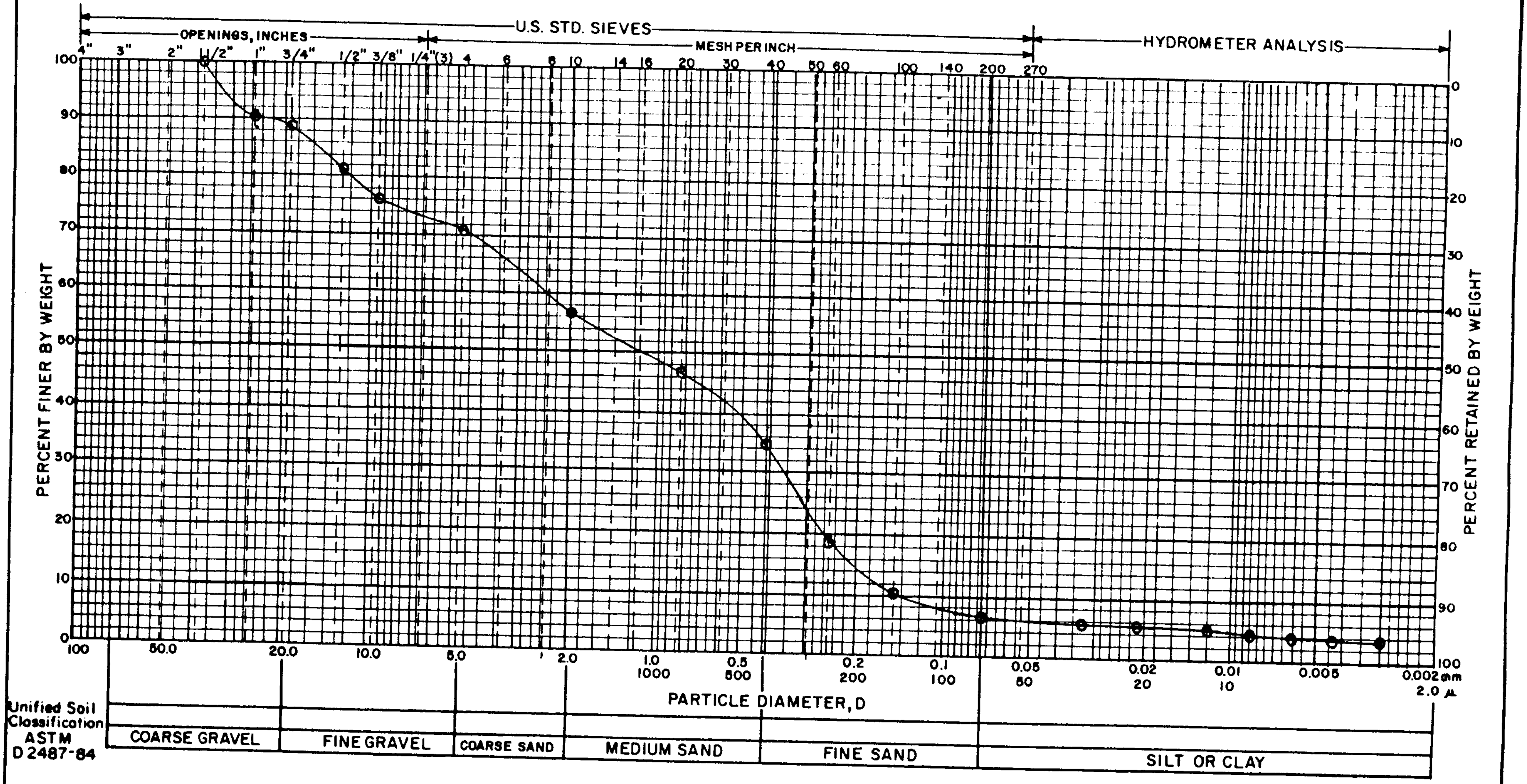
EMPIRE SOILS INVESTIGATIONS INC.

PARTICLE SIZE ANALYSIS

GILL CREEK PROJECT
E. I. DuPont de Nemours
Niagara Falls, New York

DR. BY: NS	CK'D. JFC	DATE: 8/5/88	PROJ. NO. G001.001

PARTICLE SIZE DISTRIBUTION CURVE



SAMPLE INFORMATION: SAMPLE NO. R88/1810-005 WCC 4-2E

☐ **Insufficient Sample Size per ASTM D 422**

EMPIRE
SOILS INVESTIGATIONS INC

PARTICLE SIZE ANALYSIS

GILL CREEK PROJECT
E. I. DuPont de Nemours
Niagara Falls, New York

DR. BY:	CK'D. JFC	DATE:	PROJ. NO. G001.001

APPENDIX B

SEDIMENTARY ENVIRONMENTS

The information described briefly above, along with relevant field observations, was evaluated in an effort to characterize the sedimentary setting of each of the sampling zones (Areas 1 - 5).

AREA 1

This area extends from north of Buffalo Avenue to south of Staub Road. Most of this area was remediated in the 1981 project. Very little sediment accumulation on top of the firm clay liner was observed in piston cores from T2 and T3, and in vibracores from T4. The stretch of Gill Creek between Buffalo and Adams Avenues was not sampled. Therefore no conclusions can be drawn. It is probable that little sediment is settling in the rest of this area south of Adams Avenue. It appears that few particulates enter the stream via the Niachlor outfall, thus little source for sediments exists in this area. The clay liner material appears to provide a poor substrate for aquatic plants as few were observed. Area 1 south of Adams Avenue can be described as a sediment starved area.

AREA 2

Area 2 includes transects T5 and T6 between the Staub Road and RMP Bridges. This is the area which contained the temporary earth dam at the downstream end of the 1981 remediation project. The water depth is the same as the T4 area north of Staub Road but greater vibracore recoveries of 1.1 to 3.5 feet were achieved. Grain-size analysis from a T6 sample indicates that surficial sediments are silty sands with very little gravel. The bathymetry suggests that since the removal of the dam, sands and silts have been deposited primarily in the eastern half of this area. Area 2 is essentially unaffected by waves from the Niagara River except in the immediate vicinity of the culvert mouths. It is a calm settling area both for any clay scoured from the upstream liner and for fine sands and silts passing upstream through the culverts from the south.

AREA 3

Areas 3 includes transects T7 and T8 under the RMP Bridge. The shallowest waters outside of Area 1 were combined here with the highest core recovery (2.6 to 4.4 feet). None of this area was excavated in the 1981 project. It is presumed, however that most of the unconsolidated sediment column found in this section has accumulated since the RMP Bridge was built in 1963. Grain-size analysis of a T8 sample was similar to that for T6 except that the sample was sandier with less clay. The three north-south oriented culverts now appear to function as channels for sand-sized materials to be moved north by shoaling and breaking waves entering from the Niagara River.

Before the culverts became so shallow, the conduits appear to have been locations for quiet settling of finer-grained materials including organic plant debris from the submerged grassbeds along the Niagara River bank and from upstream Gill Creek. The corsening upward sequence observed in T7 and T8 cores may also reflect a decrease in fine-grained sediment input from the creek watershed. Such a decrease would be the expected consequence of the progressive channelization and bank stabilization work conducted on the creek over the past 25 years.

It is more difficult to explain the presence of sizeable cobbles along the entire length of the east wall of the east culvert. Cobbles so armor the bottom of this culvert on its northern end that it was not possible to obtain a core at location 3-T7-3. These cobbles are too large to be moved by any waves that could be locally generated, therefore it is likely that some combination of winds and ice are responsible for their transport.

AREA 4

Area 4 includes transect T9, T10, and T11 located in the creek mouth between the south wing-walls of the RMP Bridge. The presence of significant gravel layers resulted in variable core recoveries ranging from 1.5 to 4.2 feet. Grain-size analysis of a T10 sample shows that the median surficial sediment size in this area is a medium sand, considerably coarser than that found under the RMP Bridge. Until the very recent development of the bar across the creek mouth, this area was exposed to significant wave action. As with the Area 3 section under the RMP Bridge, it appears that earlier deposition in this area was finer-grained and included more organic matter washed in from the submerged grass beds which occur along the Niagara River bank and offshore of the mouth of Gill Creek. As the creek mouth area has filled, sedimentation in the shallows has been increasingly affected by waves. Waves act to rework the sediments and winnow out the finer clay and organic fraction. These tend to be transported offshore to the Niagara River while the coarser sands remain behind.

Ice action appears to have played a very important role in recent years (at least since 1984) in modifying the hydrography of the creek mouth. Ice grounding on the shoreline has pushed large pieces of shot-rock plucked from the adjacent fill into a bar which now obstructs 60 percent of the entrance. A smaller cobble accumulation has grown from the west wing-wall such that now the entrance of the creek is quite constricted. It is likely that these developments will restrict future transport of sands into the creek. Fine-grained sediment deposition will, however, continue to occur as wave action is diminished in the lee of the bar.

AREA 5

Area 5 includes grab sample locations in the Niagara River up and downstream from the creek entrance and, in the case of location 5-1G, just offshore of the mouth. These samples were taken with a Ponar sampler and typically required numerous attempts to acquire the sand-sized or smaller material required for the analytical work. The difficulties encountered in sampling reflect the paucity of sediment within this area. Currents in this area are on the order of 1 foot per second and 10 foot depths are reached within 25 feet of shore. The river bottom is well scoured and sediments consist primarily of gravel with sands found only where trapped by small stands of submerged vegetation or large cobbles.

The grain-size sample (5-1G) obtained to characterize this area was collected from a scour hole located at the end of the "shot rock" bar which extends across the mouth of the Gill Creek entrance. It cannot be considered representative of the nearshore Niagara River setting. Nearly 25 percent of this sample consisted of sediment finer than sand-sized, and gravel constituted only 16 percent. This hole appears to have been scoured to its present depth under conditions more energetic than observed during the May sampling and was accumulating fine-grained material at the time of collection. Drogues (neutrally bouyant floats) released both upstream on the Niagara River and from within Gill Creek itself were observed to be temporarily trapped in a vortex of dead water above this hole created by the end of the bar.

APPENDIX C

TOXICITY PROFILES

1. Polychlorinated Biphenyls (PCB)
2. Hexachlorocyclohexane (BHC)
3. Hexachlorobutadiene
4. Hexachlorobenzene
5. Mercury
6. Vinyl Chloride
7. Tetrachloroethene
8. Trichloroethene
9. 1,1,2,2-Tetrachloroethane

/WM-39

POLYCHLORINATED BIPHENYLS

1.0 GENERAL

Polychlorinated biphenyls (PCBs) are a class of organic compounds characterized by two linked phenyl rings that are chlorinated at from 2 to 10 sites. PCBs were first described in the late 19th century by Schmidt and Schultz (1881) and have been in general use since 1930. They were manufactured in the United States exclusively by Monsanto Corporation under the trade name Aroclor from 1929 until 1977 (Limburg, 1986).

Each Aroclor product is a mixture of chlorinated biphenyl congeners. In the name Aroclor 12XX, the 12 indicates 12 carbon atoms, and the XX denotes the percentage of chlorination (by weight) of the mixture. For example, Aroclor 1248 is a mixture of six PCB congeners with 48 percent chlorine, overall. An exception to the nomenclature is Aroclor 1016 which has 12 carbons and is 42 percent chlorine.

As a class of compounds, PCBs are extremely stable, slow to physically transform, chemically or biochemically degrade. PCBs are now distributed worldwide, with measurable concentrations reported in polar bears of the Canadian Arctic, marine organisms in the Atlantic and Pacific oceans, birds and fish of the Great Lakes, and up to 90 percent of the adult human population of the United States. PCBs have been linked to reproductive failure, birth defects, tumors, and at elevated concentrations, death. Their toxicity is enhanced by their tendency to bioaccumulate and with some species, biomagnify due to extremely high liposolubility (Eisler, 1986).

2.0 AROCLOR 1248

Based on analytical results of Gill Creek sediment cores collected by the New York State Department of Environmental Conservation (NYSDEC), the PCB congener mixture detected was closest to Aroclor 1248 (Litten, 1987). According to Webb and McCall (1973), Aroclor 1248 contains the following: 1% dichloro biphenyls, 23% trichloro biphenyls, 50% tetrachloro biphenyls, 20% pentachloro biphenyls, and 1% hexachloro biphenyls. Others (Mieure et al., 1976; Hutzinger et al., 1974) have reported slightly different congener mixtures for Aroclor 1248. A listing of the Aroclors and their chlorinated biphenyl congener composition is presented in Table 1.

2.1 PHYSICAL AND CHEMICAL PROPERTIES

Commercial PCB mixtures, including Aroclor 1248, were typically produced by the chlorination of the biphenyl ring with anhydrous chlorine. Iron filings or ferric chloride was used as a catalyst. The extent of chlorination was determined by the ratio of chlorine to biphenyl, the catalyst, and the temperature of the reaction. The crude products were then purified into a complex mixture of chlorinated biphenyl congeners (US EPA, 1980).

PCBs are characterized by chemical stability, high heat capacity, and low dielectric constants. Individual PCB congeners are usually solids at room temperature, while the Aroclor mixtures are generally viscous liquids or resins. Aroclors generally do not crystalize upon heating or cooling, but at a specific "pour point" temperature, they change into a resinous state.

As shown in Table 2, the physical properties of PCBs change with increasing chlorination (i.e., - Aroclor 1221 through 1260). The vapor pressure and evaporative loss both decrease with increasing chlorination. For Aroclor 1248 the vapor pressure is 4.9×10^{-4} mm Hg, and the evaporation loss is 0 to 0.3% at 100°C for 6 hours. The solubilities of Aroclors decrease rapidly with greater chlorination; the solubility of Aroclor 1248 in water (25°C) is 54 ug/l. PCB octanol/water partition coefficients (K_{ow}) range between 130,000 for dichlorinated biphenyls to over 11,000,000 for hexachlorinated biphenyls (US EPA, 1988). The Aroclor 1248 Log K_{ow} is estimated to be 5.75 to 6.2 (562,000 to 1,585,000) (Versar, 1979). These high partition coefficients correlate well with PCB bioaccumulation in fatty tissues of aquatic organisms and with incorporation into sediments containing a high organic or clay content (NAS, 1979).

2.2 IMPURITIES

Toxic materials other than chlorinated biphenyls have been found in commercial PCB mixtures. Polychlorinated dibenzofurans (PCDF) at concentrations of 0.8 to 33 mg/kg have been found in several domestic and foreign PCB mixtures (US EPA, 1980). Aroclor 1016 and 1242 are very similar mixtures of PCB congeners with an overall chlorination of 41 to 42 percent. However, one major difference between the two is the relative amounts of PCDF contamination. Aroclor 1016 virtually lacks contamination, while Aroclor 1242 contains approximately 1.5 to 2.0 ug PCDF/g PCB (Buckley In: Limburg 1985). According to Bowes et al. (1975), there would appear to be no authenticated reports of polychlorinated dibenzodioxins (PCDDs) in commercial PCD mixtures. However, tetrachlorodi-benzofuran (TCDF) and tetrachlorodibenzodioxin (TCDD), toxic contaminants and byproducts of PCBs, were reportedly found at a concentration of 2.0 ppm in Aroclor 1248 (NAS, 1979).

3.0 ENVIRONMENTAL FATE

The environmental fate of PCBs was summarized by Versar, Inc. (1979) in their document describing the fate of 129 priority pollutants. More recent fate summaries for PCBs have been prepared by the U.S. EPA (1980) and the U.S. Fish and Wildlife Service (Eisler, 1986).

PCBs are environmentally stable compounds and are found in soils, sediments, water, air, and biota. The physical characteristics of the PCBs help determine relative concentrations in the various matrices. Especially important in determining their environmental fate are the physical characteristics of volatility, solubility in water, and the octanol/water partition coefficient (K_{ow}) all of which are listed in Table 2.

Environmental processes potentially involved in transforming or transferring PCBs between matrices include: oxidation, hydrolysis, photolysis, volatilization, sorption, bioaccumulation, and biotransformation/biodegradation. Oxidation and hydrolysis are not important as environmental fate processes since PCBs are very resistent to these reactions (Versar, 1979).

Photolysis. Experimental evidence shows that PCBs are slowly degraded by photolysis or photodegradation. Further, it appears that the more highly chlorinated congeners (hexa- and octachloro biphenyls) are more photo-reactive than the tetrachlorobiphenyls. While the rate of photodegradation is low, it may be environmentally significant since other fate processes (e.g., volatilization and biodegradation) act more rapidly on the less-chlorinated congeners. In addition to the photochemical dechlorination of PCBs, experimental evidence suggests that PCBs may be phototechnically transformed to PCDFs at rates slightly higher than those naturally occurring (US EPA, 1980).

Volatilization. Volatilization and/or aerosol dispersion of PCBs are thought to account for their world-wide distribution. MacKay and Leinonen (1975) calculated theoretical evaporative half-lives of various Aroclors and predicted very rapid vaporization rates. The volatilization half-life of Aroclor 1248 in 25°C water 1 meter deep was 9.5 hours. However, volatilization of Aroclors from natural water has been found to be much slower, perhaps due to the presence of sediments that tend to adsorb the PCBs (Versar, 1979; US EPA, 1980). Sawhney (1986) found that the rate of volatilization of environmental samples is greatly reduced when PCBs are adsorbed onto sediments. Although empirical evidence shows that volatilization is slow under natural conditions, the lack of destructive processes for the more highly-chlorinated biphenyls indicates that volatilization is an important transport process. The persistence of these compounds, along with the transport afforded them by volatilization, is probably the major factor in their widespread distribution.

Sorption. Adsorption to sediments is the major non-destructive environmental process affecting polychlorinated biphenyls after introduction to the aquatic environment. The combination of low water solubility (2.7 to 200 ug/l) and high octanol/water partition coefficient (Log K_{ow}) of 2.8-6.9 (Table 2) indicates that PCBs have a high affinity for suspended solids, especially those high in organic carbon and/or microparticulates (Versar, 1979; US EPA, 1980). Partition coefficients between water and a variety of bacteria, seston, and sediment were found to be only an order of magnitude less than the corresponding octanol/water partition coefficient (Paris et al., 1978). As a result, PCBs are usually found at much higher concentrations in sediments than in the overlying water (US EPA, 1980).

The preferential sorption of PCBs on the organic fraction of suspended solids coupled with the entrance of these suspended solids into the sediments is thought to be a major mechanism for the immobilization of PCBs in aquatic systems. When contamination becomes sufficiently high, however, sediments may serve as a reservoir for resolution of PCBs directly or through resuspension of contaminated sediments (Versar, 1979).

Bioaccumulation. Bioaccumulation of individual PCBs from aqueous solution are influenced primarily by two factors: the partition coefficient (K_{ow}) of the compounds and steric factors resulting from different patterns of chlorine substitution. The product of Log K_{ow} and the steric effect coefficient has been found by Shaw and Connell (1982) to be directly related to bioaccumulation. Log K_{ow} values for various congeners of the Aroclors are high, varying from 4.0 to

9.4, indicating high uptake potential. Steric effect coefficients are based on the number of chlorine atoms and their arrangement in the biphenyl molecule.

Thus, maximum uptake was found with penta- and hexachlorobiphenyls predominant in Aroclor 1254, which have high values for Log K_{ow} and for steric effect coefficients. Comparatively less uptake was found with di-, tri-,and tetrachlorobiphenyls, typical of Aroclor 1242, which have lower values for Log K_{ow}, and with hepta- and octachlorobiphenyls, predominant in Aroclor 1260, which have lower steric effect coefficients (Shaw and Connell, 1982). Aroclor 1248, with its high log K_{ow} of 5.75 to 6.2 and its biphenyl mixture which includes a high percentage of penta- and hexachlorbiphenyls, is expected to have an uptake potential that is close to that of Aroclor 1254. Higher-chlorinated biphenyls also tend toward greater bioaccumulation rates because they are more resistant to biodegradation (Versar, 1979).

PCBs are typically taken up by animals and stored in tissues high in lipid content such as fat and skin. Patterns of higher chlorinated biphenyls in marine clams, worms, sediment, and water indicate that uptake was from diet or from sediments (Duinker et al., 1983). In freshwater fishes, direct partitioning across the gill membrane of the blood:water interface controls PCB accumulation; however, dietary PCBs may significantly affect accumulation and exchange rates at the gill membrane (Rohrer et al., 1982). In the Hudson River, a strong correlation between PCB and lipid concentrations was seen for all resident fish (Brown et al., 1985).

Numerous authors have published the concentrations of polychlorinated biphenyls in various aquatic and terrestrial organisms. Although the ambient concentrations are not often reported along with the in vivo concentrations, it is suggested that bioaccumulation factors are usually on the order of 10^4 -10^6. Nadeau and Davis (1974) reported bioaccumulation rates for Aroclor 1248 and 1254 in fish and gastropods of the upper Hudson River as being 10^3 and greater.

Verschueren (1983) lists a bioaccumulation factor of 1.2×10^5 for Aroclor 1248 in fathead minnows.

Although diet has been shown to be an important route of PCB transfer (McKim and Johnson, 1983), biomagnification (sequential bioaccumulation up through the food chain) may not be a controlling factor in attaining the levels found in aquatic organisms (Metcalf et al., 1975; Clayton et al., 1977). Scura and Theilacker (1977) found that the partition coefficient for each organism in an aquatic food chain determined the ultimate level, not the food chain itself. However, within the Lake Ontario food chain, PCB biomagnification is very evident in empirical data. PCB residue levels in gulls average 51 mg/kg, lake trout average over 5.0 mg/kg, rainbow smelt and sculpin (i.e., forage species) have 1.5 mg/kg, while lower planktonic forms average less than 0.4 mg/kg (GLWQB, 1987).

Biodegradation and Biotransformation. The individual PCB congeners vary widely in their susceptibility to biodegradation. The mono-, di-, and tri-chlorinated biphenyls can be degraded by an array of organisms although microoganisms are thought to be the principal participant. PCBs with four chlorines are degraded to a smaller degree, while the penta- and hexa-chlorinated biphenyls are only minimally bio-degraded if at all.

The biodegradation process under environmental conditions appears to be quite complex and is not fully understood. Microorganisms have been observed to catabolize PCBs, through hydroxylation, dechlorination, and ring clevage. Chlorobenzenes, especially chlorobenzoic acids, were the most common metabolic product found (Furakawa, 1986).

Rates of biodegradation vary widely, depending upon the degree of chlorination, position of the chlorine molecules, composition of the biota, availability of alternative nutrients, and temperature, among others. Tucker et al. (1975) reported biodegradation rates of 81 percent for Aroclor 1221 to 19 percent for Aroclor 1254 during a 48-hour exposure to an activated sludge mixture. This range of degradation rates is in basic agreement with Furakawa and Matsumura (1976) who found complete degradation of the lower chlorinated biphenyls (1 to 3 chlorines) within 20 hours. In contrast, Tulp and Hutzinger (1978) found that biodegradation of a dichlorobiphenyl was almost completely suppressed by alternative nutrient sources similar to those found in the environment.

To review, more highly chlorinated PCB congeners are more soluble in lipids, more resistant to degradation (except photodegradation), less volatile, and more persistent in the environment. In a comparison of the relative concentrations of Aroclor 1016 to 1254 in selected biological samples collected during a multi-year period from the Hudson River, the ratio of Aroclor 1016 to 1254 declined primarily because of a loss of the less chlorinated PCB congeners (Brown et al., 1985). A summary of the environmental fate of PCBs is presented in Table 3.

4.0 CRITERIA

Criteria have been established for PCB concentrations in water, sediment, and edible portions of fish and shellfish. The ambient water quality criteria as established by the US EPA (1980, 1986) for fresh water is 0.014 ug/l as a 24-hour average. Acute toxicity to aquatic organisms is expected at water concentrations of 2.0 ug/l or higher. For the maximum protection of human health from carcinogenic effects through ingestion of PCB-contaminated water and aquatic organisms, the ambient water concentration should be zero. Since zero concentrations may not be attainable at this time, PCB criteria of 0.79 ng/l, 0.079 ng/l, and 0.0079 ng/l corresponding to incremental increases of cancer risk of 10^{-5}, 10^{-6}, and 10^{-7}, respectively have been set for ambient water (US EPA, 1980; 1986). A water concentration of 1 ng PCB/l is an objective of the 1978 Great Lakes Water Quality Agreement (GLWQB, 1987).

Interim sediment criteria for PCBs were recently established by the US EPA (1988). The criteria were developed using the Equilibrium Partitioning Approach.

This uses the ambient water quality criteria (chronic), and the organic carbon normalized partition coefficient (K_{OC}). K_{OC} is calculated from the K_{OW} for Aroclor 1254. Sediment criteria for Aroclor 1254 of 0.195 mg/kg and 1.95 mg/kg have been calculated for sediment with 1 percent and 10 percent organic carbon, respectively. Site-specific sediment PCB criteria can be calculated using the methodology described in the criteria document and available organic carbon data.

The interim sediment criteria of Aroclor 1254 were developed based upon the tolerance level of 5 mg/kg for PCBs in edible portions of fish and shellfish and bioaccumulation factors measured in the laboratory. Subsequently, the FDA lowered this tolerance level (i.e., criteria) to 2 ppm (mg/kg) (21 CFR Part 109.30). As a consequence, the interim sediment criteria for PCBs will very likely be revised downward following review by the US EPA's Science Advisory Board later in 1988 (US EPA, 1988; Zarba, 1988). The 1978 Great Lakes Water Quality Agreement includes a tissue residue objective of 0.1 mg/kg for PCBs in whole fish (GLWQB, 1987).

5.0 BACKGROUND LEVELS

PCB levels have been measured in water, sediment, and fish in the Great Lakes over the past several years. Levels of PCBs in the waters of both Lake Erie and Lake Ontario as measured in 1986 and 1985, respectively, ranged from 0.3 to 3.0 ng/l. The highest PCB concentrations were found in the western areas of both lakes coinciding with inputs from the Detroit and Niagara rivers. PCB levels in Lake Michigan were from 1.2 to 3.5 ng/l with the highest levels found nearshore and in Green Bay. Lake Huron had the lowest water concentrations at 0.07 to 0.4 ng/l (GLQWB, 1987).

PCB levels in sediments of Lake Ontario followed the general pattern of the highest maximum levels in harbor and river-mouth areas. Overall, the range of sediment concentrations during 1970-1984 was 0.001 to 4.4 mg/kg with a "background" sample from >9 cm depth being 0.8 mg/kg (GLWQB, 1987).

Fish tissue samples of rainbow smelt (forage species) and lake trout (predator species) have been collected from open-water areas of the Great Lakes since 1977. In most lakes, PCB levels decreased during the 1970s but showed no clear trend during the 1980s. Overall levels were highest in Lake Ontario. In those lakes and years where both rainbow smelt and lake trout were collected, rainbow smelt PCB levels were always lower than those in lake trout. In 1985, PCB levels averaged 0.55 mg/kg in smelt and 2.8 mg/kg in lake trout. Much of this apparent difference in PCB tissue levels could be due to the significantly higher lipid percentages in lake trout. Young-of-year spotail shiners collected from four locations in Lakes Erie and Ontario showed a general decrease in PCB levels from 1975 through 1985 (GLWQB, 1987).

6.0 TOXICITY

Acute toxicity (LC_{50}) values for freshwater invertebrates and fish subjected to various Aroclors varied from 3 to >50,000 ug/l during exposure of 4 to 30 days (Table 4). In general, toxicity increased with increasing exposure, crustaceans and younger developmental stages were the most sensitive groups tested, and lower chlorinated biphenyls were more toxic than higher chlorinated biphenyls over the same exposure period. In most toxicity tests, mortality patterns in PCB-exposed fish did not stabilize within 30 days (Johnson and Finley, 1980). For example, Aroclor 1248 LC_{50} values for rainbow trout decreased from 54 ug/l to 3.4 ug/l as the exposure period was extended from 5 to 25 days. Aroclor 1248 LC_{50} values for bluegills were 136 and 78 ug/l for 5 and 30 days' exposure, respectively, (De Foe et al., 1978).

Chronic toxicity values for PCBs have been determined for selected freshwater species based upon induced growth, reproductive, and metabolic effects. Maximum Acceptable Toxicant Concentration (MATC) values bracket the chronic toxicity values and extend from the "no effect" to the "measurable effect" levels. MATC values for selected Aroclors varied from 0.1 to 5.4 ug/l for the no effect level, and from 0.4 to 15.0 ug/l for measurable effects (Table 5). The data indicate that Aroclor 1248 was more chronically toxic than other PCBs tested.

TABLE 1
APPROXIMATE COMPOSITION OF AROCLORS (PERCENT)

Chlorobiphenyl	Aroclor:	1221		1232	1016	1242			1248		1254		1260	
	Ref:	1	2	2	1	1	2	3	2	1	4	2	3	2
$C_{12}H_{10}$		11	7	6	Tr	Tr	-	-	-	Tr	-	-	-	-
$C_{12}H_9Cl$		51	51	26	1	1	1	Tr	-	Tr	-	-	-	-
$C_{12}H_8Cl_2$		32	38	29	20	16	17	4	1	0.5	2	-	-	-
$C_{12}H_7Cl_3$		4	3	24	57	49	40	39	23	1	18	-	0.5	-
$C_{12}H_6Cl_4$		2	-	15	21	25	32	42	50	21	40	16	36	-
$C_{12}H_5Cl_5$		0.5	-	0.5	1	8	10	14	20	48	36	60	45	12
$C_{12}H_4Cl_6$		-	-	-	Tr	1	0.5	-	1	23	4	23	18	46
$C_{12}H_3Cl_7$		-	-	-	-	Tr	-	-	-	6	-	1	1	36
$C_{12}H_2Cl_8$		-	-	-	-	-	-	-	-	-	-	-	-	6

Tr - Trace (<0.1 percent)

Ref: [1] Mieure _et_ _al_. (1976)

[2] Webb and McCall (1973)

[3] Hirwe _et_ _al_. (1974)

[4] Hutzinger _et_ _al_. (1974)

Source: U.S. EPA (1980)

TABLE 2
PHYSICAL PROPERTIES OF AROCLORS

Property	1221	1232	1242	1248	1254	1260
Appearance	Clear, mobile oil	Clear mobile oil	Clear, mobile oil	Clear, mobile oil	Light-yellow, viscous liquid	Light-yellow, sticky resin
Mean molecular wt.	192	221	261	288	327	372
Mean No. Cl atoms/ molecular	1.15	2.04	3.10	3.90	4.96	6.30
Percent Chlorine	20.5-21.5	31.4-32.5	42	48	54	60
Specific Gravity	1.182-1.192 (25°/15.5°C)	1.270-1.280 (25°/15.5°C)	1.391-1.392 (25°/15.5°C)	1.405-1.415 (65°/15.5°C)	1.495-1.555 (65°/15.5°C)	1.555-1.566 (90°/15.5°C)
Distillation Range °C Corrected	275-320	290-325	325-366	340-375	365-390	385-420
Vapor Pressure (mm/Hg)	6.7×10^{-3}	4.06×10^{-3}	4.06×10^{-4}	4.94×10^{-4}	7.71×10^{-5}	4.05×10^{-5}
Evaporation loss (%) 100°C 6 hr.	1.0-1.5	1.0-1.5	0-0.4	0-0.3	0-0.2	0-0.1
ASTM D-6 Mod. 160°C, 5 hr.	-	-	3.0-3.6	3.0-4.0	1.1-1.3	0.5-0.8
Pour Point °C (ASTM E-97)	1 (Crystals)	-35.5	-19	-7	10	31
Water Solubility at 25°C (ug/l)	200	-	240	54	12	2.7
Log K_{ow}	2.8-4.1	3.2-4.6	6.10	5.75-6.2	6.25	6.94

Sources: Eisler (1986)
US EPA (1980, 1986, 1988)
Versar (1979)

TABLE 3

SUMMARY OF AQUATIC FATE OF POLYCHLORINATED BIPHENYLS

Environmental Process	Summary Statement	Rate	Confidence of Data
Photolysis	May result in destruction of highly-chlorinated PCBs.	Slow	Low
Oxidation	PCBs are stable to oxidation.	Near zero	High
Hydrolysis	PCBs are stable to hydrolysis.	Near zero	High
Volatilization	Important mechanism for transport. Volatility depressed by presence of organic solids.	Varies widely	Medium
Sorption	PCBs strongly adsorbed by solids, especially with high organic content.	Typically rapid	High
Bioaccumulation	Bioaccumulation factors range from about 10^4 to 10^6.	Typically rapid	High
Biotransformation/ Biodegradation	The only proven mode of destruction of PCBs, but only important for those with fewer than 4 chlorines per molecule.	Varies widely	High

Source: Adapted from Versar (1979).

TABLE 4
ACUTE TOXICITIES OF AROCLORS

Organism Aroclor	Exposure period (days)	LC_{50} (ug/l)	Reference
Invertebrates			
Crayfish, <u>Orconectes</u> <u>nais</u>			
1242	7	30	NAS (1979)
1254	7	80-100	NAS (1979)
Scud, <u>Gammarus</u> <u>pseudolimnaeus</u>			
1242	4	10	NAS (1979)
1242	10	5	NAS (1979)
1248	4	52	NAS (1979)
1254	4	2,400	NAS (1979)
Glass Shrimp, <u>Palaemonetes</u> <u>kadiakensis</u>			
1254	7	3	NAS (1979)
Damselfly, <u>Ischnura</u> <u>verticalis</u>			
1242	4	400	Johnson and Finley (1980)
1254	4	200	Johnson and Finley (1980)
Dragonfly, <u>Macromia</u> sp.			
1242	4	800	Johnson and Finley (1980)
1254	5	800	Johnson and Finley (1980)
Cladoceran, <u>Daphnia</u> <u>magna</u>			
1254	14	1.8-24.0	EPA (1980)
1254	21	1.3	EPA (1980)
Stonefly, <u>Pteronarcella</u> <u>badia</u>			
1016	4	424-878	Johnson and Finley (1980)
Fish			
Rainbow trout, <u>Salmo</u> <u>gairdneri</u>			
1016	4	114-159	Johnson and Finley (1980)
1242	5	67	Johnson and Finley (1980)
1248	5	54	Johnson and Finley (1980)
1254	5	142	Johnson and Finley (1980)
1254	10	8	NAS (1979)
1260	20	21	NAS (1979)

Table 4 (continued)

Organism Aroclor	Exposure period (days)	LC_{50} (ug/l)	Reference
Cutthroat trout, *Salmo clarki*			
1221	4	1,170	Johnson and Finley (1980)
1232	4	2,500	Johnson and Finley (1980)
1242	4	5,420	Johnson and Finley (1980)
1248	4	5,750	Johnson and Finley (1980)
1254	4	42,500	Johnson and Finley (1980)
1260	4	60,900	Johnson and Finley (1980)
1262	4	>50,000	Johnson and Finley (1980)
1268	4	>50,000	Johnson and Finley (1980)
Yellow perch, *Perca flavescens*			
1016	4	240	Johnson and Finley (1980)
1242	4	>150	Johnson and Finley (1980)
1248	4	>100	Johnson and Finley (1980)
1254	4	>150	Johnson and Finley (1980)
1260	4	>200	Johnson and Finley (1980)
Bluegill, *Lepomis macrochirus*			
1016	4	390-540	Johnson and Finley (1980)
1242	5	125	Johnson and Finley (1980)
1242	15	54	NAS (1979)
1248	20	10	NAS (1979)
1254	25	54	NAS (1979)
1260	30	150	NAS (1979)
Channel catfish, *Ictalurus punctatus*			
1016	4	340-560	Johnson and Finley (1980)
1242	15	110	NAS (1979)
1248	15	130	NAS (1979)
1254	15	740	NAS (1979)
1260	30	140	NAS (1979)

Source: Adapted from Eisler (1986).

TABLE 5
MAXIMUM ACCEPTABLE TOXICANT CONCENTRATION (MATC) AND CHRONIC TOXICITY VALUES OF AROCLORS

Organism Aroclor	MATC (ug/l)	Chronic Value (ug/l)	Reference
Cladoceran, *Daphnia magna*			
1248	2.5-7.5	4.3	Nebeker and Puglisi (1974)
1254	1.2-3.5	2.1	Nebeker and Puglisi (1974)
Amphipod, *Gammarus pseudolimnaeus*			
1242	2.8-8.7	4.9	Nebeker and Puglisi (1974)
1248	2.2-5.1	3.3	Nebeker and Puglisi (1974)
Insect (midge), *Tanytarsus dissimilis*			
1254	0.5-1.2	0.8	Nebeker and Puglisi (1974)
Brook Trout, *Salvelinus fontinalis*			
1254	0.7-1.5	1.0	Mauck *et al*. (1978)
Fathead minnow, *Pimephales promelas*			
1242	5.4-15.0	9.0	Nebeker *et al*. (1974)
1248	0.1-0.4	0.2	De Foe *et al*. (1978)
1254	1.8-4.6	2.9	Nebeker *et al*. (1974)
1260	1.3-4.0	2.3	De Foe *et al*. (1978)

Note: Tests based on life cycle or partial life cycle.

Source: Adapted from US EPA (1980)

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HEXACHLOROCYCLOHEXANE

1.0 GENERAL

Hexachlorocyclohexane (BHC) is a broad spectrum insecticide of the group of cyclic chlorinated hydrocarbons called organochlorine insecticides. It consists of a mixture of five configurational isomers and was introduced in 1942 as a contact insecticide under the trade names BHC, benzene hexachloride, and 666. Since its introduction both the used and production volume of technical grade BHC have undergone dramatic changes as a result of the discovery that virtually all of the insecticidal activity of BHC resides with its γ-isomer (lindane). By voluntary action the principal domestic producer of technical grade BHC requested cancellations of its BHC registrations on 1 September 1976. As of 21 July 1978, all registrants of pesticide products containing BHC voluntarily cancelled their registrations or switched their former BHC products to lindane formulations. On the other hand, significant commercial use of the purified γ-isomer of BHC (lindane) continues (U.S. EPA, 1980).

BHC is the common name approved by the International Standards Organization for the mixed configurational isomers of 1,2,3,4,5,6-hexachlorocyclohexane although the terms BHC and benzene hexachloride are misnomers for this aliphatic compound and should not be confused with aromatic compounds of similar structure such as the aromatic compound hexachlorobenzene (Int. Agency Res. Cancer, 1974). Lindane is the common name approved by the International Standards Organization for the γ-isomer of 1,2,3,4,5,6-hexachlorocyclohexane.

BHC is synthesized by direct action of chlorine on benzene in the presence of ultraviolet light (Hardie, 1972). Technical grade BHC contains the hexachlorocyclohexane isomers in the following ranges: α-isomer, 60 to 70 percent; β-isomer, 5 to 12 percent; γ-isomer, 10 to 15 percent; δ-isomer, 6 to 10 percent; ε-isomer, 3 to 4 percent (U.S. EPA, 1980). The actual content of the isomers in technical grade BHC varies depending on the manufacturing conditions. Since the γ-isomer (lindane) has been shown to be the insecticidally active ingredient in technical grade BHC (Hardie, 1972), technical grade BHC now has limited use commercially except as the raw material from which the purified γ-isomer is extracted by a process of selective crystallization. Technical grade lindane is composed of 99 to 100 percent pure γ-BHC isomer and has a melting point of at least 112°C.

2.0 PHYSICAL AND CHEMICAL PROPERTIES

BHC is a brownish-to-white crystalline solid with a phosgene-like odor, a molecular formula of $C_6H_6Cl_6$, a molecular weight of 290.85, a melting point of 65°C, and a solubility in water of 10 to 32 mg/L (Hardie, 1972; Christensen, 1976; Matsumura, 1975). The physical properties of the α, β, and γ isomers of BHC are presented in Table 1.

3.0 ENVIRONMENTAL FATE

Photolysis. Kawahara (1972) reported that the rates of disappearance of the BHC isomers were in the order $\alpha > \gamma > \beta > \delta$ when dissolved in water at concentrations 0.01 to 5.0 ppm and exposed to sunlight; half-lives ranging from four to six days for α-BHC to 10-22 days for δ-BHC were reported. These data are highly suspect, however, because experimental details were lacking. The BHC isomers are not expected to photolyze rapidly in sunlight because of the slight, if any, light absorption coefficients above 290 nm. Roburn (1963) reported that the four isomers of BHC gave no reaction products after photolysis with a 254 nm light source for 2-3 hours. Roburn's experiments and the expected low absorbance of the BHC isomers suggest that photolysis will not be an important process in the environment; the reported photolysis of BHC are likely due to adventitious processes such as volatilization, sorption on glass, or photoreaction caused by impurities in the BHC used (Versar, 1979).

Oxidation. No information was obtained concerning oxidation of any BHC isomer in the aquatic environment. By analogy to limited studies on the oxidation of lindane by Hoffman and Eichelsdoerfer (1971) and Leigh (1969), the other BHC isomers should be quite stable to oxidation.

Hydrolysis. No data are available on hydrolysis rates of the individual BHC isomers although information from one paper does indicate that the BHC (all isomers together) has a half-life for hydrolysis of more than two years.

Eichelberger and Lichtenberg (1971) examined the persistence of BHC for eight weeks in water samples from the Little Miami River and in distilled water; the pH of the river water varied from 7.3 to 8.0 during the eight-week period. No change in BHC concentration was found during this time. Assuming a maximum analytical error of 2.5 percent (recoveries reported were rounded off to nearest 5 percent), the half-life for BHC under these conditions must be at least four years, indicating that the BHC isomers are quite stable to hydrolysis.

Volatilization. There are no reliable data with which to estimate a half-life for volatilization of BHC isomers from aquatic environments. Although loss of BHC through volatilization has been addressed by several research groups investigating biotransformation or bioaccumulation of BHC isomers, the information obtained cannot be directly compared or even used to decide whether volatilization of BHC can be an important process in aquatic environments (Versar, 1979).

Sorption. Only one paper (King et al., 1969) on the sorption of the individual BHC isomers to sediments was found. Based upon data for the γ-BHC isomer, BHC should not be sorbed extensively onto biota and sediments. Because of the lack of chemical and biological transformation in aerobic systems, however, sorption onto particulates with subsequent deposition and transformation in anerobic systems may be the most important fate for BHC (Versar, 1979).

King et al. (1969), studied the sorption of lindane on two species of algae and three soils of different characteristics. The authors note that lindane equilibrium between soil and solution was attained in an hour and that greater sorption was found on soils with higher organic content as clay content.

Bioaccumulation. Information available on the bioaccumulation of α-, β-, and δ-BHC is similar to that for γ-BHC and indicates that BHC isomers are not extensively bioaccumulated in organisms. Concentration factors vary among the four BHC isomers in the range of about 10 to 500, depending on the isomer and organism.

Schimmel *et al.* (1977), reported that pink shrimp, pinfish, and oysters accumulated BHC to concentrations that were 80, 480 and 130 times, respectively, the concentrations of BHC in water. Ernst (1977) reported concentration factors in mussels of 106 and 100 for α-BHC and lindane, respectively.

Gakstatter and Weiss (1967) found that fish exposed to lindane reached equilibrium within a few hours, and the lindane was eliminated in less than two days after the fish were transferred to clean water. Based on this information and their work, Hamelink *et al.* (1977), suggest that lindane may undergo exchange between fish and water with half-lives of three to six hours.

Biotransformation and Biodegradation. Very little information is available to assess biotransformation of α- or β-BHC. However, biotransformation of lindane may be a significant source of α-BHC in the environment. Benezet and Matsumura (1973) showed that lindane is transformed to γ-TCCH, γ-PCCH, and the α-BHC isomer in the laboratory by a *Pseudomonas* ssp. culture. α-BHC was also formed in an oceanic sediment treated with lindane.

Steinwandter and Schluter (1978) have reported that β-BHC is a product of γ-BHC (lindane) metabolism in grass via the intermediacy of α-BHC. Interconversion of BHC isomers may also be occurring in aquatic environments and may complicate conclusions on the fate of individual BHC isomers in such systems.

Other Reactions. No processes other than those listed above have been indicated as important in the fate of BHC in aquatic environments. No information was found to indicate that isomerization of BHC isomers occur spontaneously in the aquatic environment (Versar, 1979) other than the biotransformation discussed above.

A summary of the aquatic fate of BHC is presented in Table 2.

4.0 CRITERIA

According to the U.S. EPA (1986), criteria for the protection of aquatic life are as follows:

> "The available data for a mixture of isomers of BHC indicate that acute toxicity to freshwater aquatic life occurs at concentrations as low as 100 ug/L and would occur at lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of a mixture of isomers of BHC to sensitive freshwater aquatic life."
>
> "For the gamma isomer of BHC (lindane), the criterion to protect freshwater aquatic life as derived using the guidelines is 0.080 ug/L as a 24-hour average and the concentration should not exceed 2.0 ug/L at any time."

Human health criteria for BHC (U.S. EPA, 1986) are as follows:

> "For the maximum protection of human health from the potential carcinogenic effects of exposure to α-BHC through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentrations should be zero, based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding recommended criteria are 92 ng/L, 9.2 ng/L, and 0.92 ng/L, respectively. If these estimates are made for consumption of aquatic organisms

> only, excluding consumption of water, the levels are 310 ng/L, 31.0 ng/L, and 3.10 ng/L, respectively."
>
> "For the maximum protection of human health from the potential carcinogenic effects of exposure to β-BHC through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentrations should be zero, based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding recommended criteria are 163 ng/L, 16.3 ng/L, and 1.63 ng/L, respectively. If these estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 547 ng/L, 54.7 ng/L, and 5.47 ng/L, respectively."

As a basis for comparison, the human health criteria for lindane, as stated by the U.S. EPA (1986), is:

> "For the maximum protection of human health from the potential carcinogenic effects due to exposure of γ-hexachlorocyclohexane through ingestion of contaminated water and contaminated aquatic organisms, the ambient water concentrations should be zero, based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result in incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding recommended criteria are 186 ng/L, 18.6 ng/L, and 1.86 ng/L, respectively. If these estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 625 ng/L, 62.5 ng/L, and 6.25 ng/L, respectively."

The 1978 Great Lakes Water Quality Agreement objective level for lindane in water is 10 ng/L (GLWQB, 1987).

5.0 BACKGROUND LEVELS

Alpha-BHC was found in Lake Erie waters during 1986 at concentrations of 7.17 to 5.48 ng/L (n = 23). In Lake Ontario during 1985, α-BHC ranged from 4.36 to 8.81 (n = 14). No sediment data for α-BHC was presented. The γ isomer of BHC (lindane) was detected at 0.49 to 2.14 ng/L in Lake Erie (1986) and 0.81 to 1.85 ng/L in Lake Ontario (1985) (GLWQB, 1987).

No significant loading increases were seen for α-BHC or γ-BHC in water or suspended sediments passing through the Niagara River. However, levels of both isomers in both media increased slightly from Fort Erie to Ontario on-the-lake during the 1983 to 1986 period of study (Data Interpretation Group, 1986).

6.0 TOXICITY

Acute values (96-hour LC_{50}) for lindane with 15 freshwater fish species range from 2 to 141 µg/l for brown trout and goldfish, respectively. These values represent differences among species in their response to lindane exposure. Generally, the warmwater fish species appear to be more tolerant of lindane than do the coldwater salmonid species; this is also shown in fish acute data for BHC. Acute values for BHC (i.e., mixture of isomers) range from 200 for coho salmon to 15,000 for goldfish and fathead minnows (U.S. EPA, 1980).

Chronic data for lindane are available for three freshwater invertebrate species. Chronic values for Daphnia magna, Gammarus fasciatus, and Chironomus tentans are 14.5, 6.1 and 3.3 µg/l, respectively. A chronic value fo 14.6 µg/l was calculated for the fathead minnow. This compares to an estimated acute toxicity value of 110 µg/l (U.S. EPA, 1980). No chronic toxicity values for α-BHC or β-BHC were presented for any invertebrate or fish species.

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TABLE 1

PHYSICAL PROPERTIES OF BHC ISOMERS

	Alpha	Beta	Gamma
CAS No.	319-84-6	319-85-7	58-89-9
Molecular Weight (Verschueren, 1983)	290.85	Same	Same
Melting Point (°C)			
(Gunther, 1971)	157-158	309	
(Martin, 1972)			112.9
Boiling Point	NO DATA FOUND		
Vapor Pressure (torr at 20°C)			
(Balson, 1947)	2.5×10^{-5}	2.8×10^{-7}	
(Benchmark, 1975)			$2.1\text{-}3.3 \times 10^{-4}$
Solubility in Water (mg/L at 28°C) (Kawahara et al., 1973)	1.2-2.0	0.1-0.2	5.8-7.4
Log K_{ow} at 25°C (Kawahara et al., 1973)	3.81	3.80	3.72

Adapted from Versar (1979)

TABLE 2

SUMMARY OF AQUATIC FATE OF HEXACHLOROCYCLOHEXANE

Environmental Process	Summary Statement	Rate	Half-Life	Confidence of Data
Photolysis	Not an important process.	--	--	Medium
Oxidation	Not an important process.	--	--	Medium
Hydrolysis	Not an important process.	--	--	Medium
Volatilization	Information contradictory as to how important process is.	--	--	--
Sorption	Important for transport to anaerobic sediments.	--	--	Low
Bioaccumulation	Not an important process.	--	--	Low
Biotransformation/ Biodegradation	Important process that varies with environment.	--	--	Low

There is insufficient information in the reviewed literature to permit assessment of a most probable fate.
Source: Versar (1979).

HEXACHLOROBATADIENE

1.0 GENERAL

Hexachlorobutadiene (HCBD; C_4Cl_6) is produced deliberately in the United States as a by-product of the manufacture of chlorinated hydrocarbons such as tetrachloroethylene, trichloroethylene, and carbon tetrachloride. Secondary production estimates range from 7.3 to 14.5 million pounds per year. In 1974, approximately 0.5 million pounds were imported into the U.S. (U.S. EPA, 1975).

HCBD is used as a solvent for many organic substances; its relatively low vapor pressure gives it a distinct advantage over some other chlorohydrocarbons for this purpose. The largest domestic users to HCBD are chlorine producers, who use it to recover chlorine from "snift" gas which is cleaned by passage through HCBD. Other applications of HCBD include its use as an intermediate in the manufacture of rubber compounds and lubricants and as a fluid for gyroscopes (U.S. EPA, 1975).

2.0 PHYSICAL AND CHEMICAL PROPERTIES

The general properties of HCBD, a colorless liquid with a faint turpentine - like odor, are as follows:

Molecular weight (Weast, 1977)	260.76
Specific gravity (Verschueren, 1977)	1.675

Melting point (Weast, 1977)	-21°C
Boiling point at 760 torr (Weast, 1977)	215°C
Vapor pressure at 20°C (Pearson and McConnel, 1975)	0.15 torr
Vapor Pressure at 100°C (Hawley, 1977)	22 mm Hg
Solubility in water at 20°C (Pearson and McConnel, 1975)	2 mg/l
Log octanol/water partition coefficient (Log K_{ow}) (Versar, 1979)	3.74

3.0 ENVIRONMENTAL FATE

Hexachlorobutadiene is a very persistent environmental pollutant. Although the literature reviewed indicates that adsorption onto sediments is an important aquatic transport process for this compound, the potential contribution of bioaccumulation, volatilization, and other processes should not be neglected (Versar, 1979). Phototysis of HCBD is thought to be unimportant in the aquatic environment (U.S. EPA, 1980a). No information is available on the effects of oxidation and hydrolysis of HCBD (Versar, 1979).

Sorption. Recent literature, which contains an appreciable amount of information pertaining to the adsorption of HCBD onto sediments, indicates that sorption may be an important process for HCBD. The calculated log K_o

(octanol/water partition coefficient) of 3.74 implies that HCBD should be strongly adsorbed by humus material.

In a study of the Mississippi Delta region it was found that the level of HCBD water was less than 2 ug/l while the concentration of HCBD in mud or soil samples exceeded 200 ug/l (Lasater et al., 1976). In this same study, water samples from the waste of an industrial company in Geismar, Louisiana, was found to contain from <0.1 ug/l to 4.5 ug/l HCBD. Levels of HCBD in the mud, however, reached a maximum of 2,370 ug/l, indicating selective concentration of several orders of magnitude. Leeuwangh et al. (1975) found that the concentration of HCBD in uncontaminated sediment after equilibration with water that contained HCBD was 100 x that found in the water. McConnell et al. (1975) noted that coarse gravels have little adsorptive capacity for chlorinated aliphatics, whereas sediments rich in organic detritus have a much higher adsorptive capacity.

Volatilization. Although no specific rate data found for HCBD, volatilization may be an important transport process for this compound in aqueous systems. This assessment is based on the fact that hexachloroethane, which is structurally somewhat similar to HCBD and exhibits a vapor pressure of 0.4 torr at 20°C (Verschueren, 1977) in comparison to 0.15 torr for HCBD (Pearson and McConnel, 1975), appears to be volatilized rather rapidly from water. However, in view of the lower vapor pressure of HCBD, it may not volatilize rapidly from the aqueous environment to the atmosphere (Versar, 1979).

Bioaccumulation. The log control/water partition coefficient (log K_o) of 3.74, calculated using the method of Tute (1971), indicates that HCBD may bioaccumulate significantly. However, results of a study conducted for the U.S. EPA by Laseter et al. (1976) showed that HCBD did not accumulate to high levels in test animals and that rates of uptake were irregular. They obtained bioconcentration factors for an algal species, a crayfish species, and largemouth bass of 160, 60, and 29, respectively over a 7-10 day exposure period. Results of this study suggest that KCBD is not significantly biomagnified up the food chain.

Bioconcentration factors ranging from 920 to 2,300 were determined for goldfish over a 49-day exposure period by Leeuwangh et al. (1975).

4.0 CRITERIA

According to the U.S. EPA (1980a):

> "The available data for hexachlorobutadiene indicate that acute and chronic toxicity to freshwater aquatic life occur at (water) concentrations as low as 90 and 9.3 ug/l, respectively, and would occur at lower concentrations among species that are more sensitive than those tested."

For the maximum protection of human health from the potential carcinogenic effects of HCBD through ingestion of contaminated water and aquatic organisms, the ambient water concentrations should be zero based on the non-threshold assumption for this chemical. However, zero level may not be attainable at the present time. The recommend criteria for HCBD in water are 4.47 ug/l, 0.45 ug/l, and 0.045 ug/l which may result in incremental increases of cancer risk over the lifetime of 10^{-5}, 10^{-6}, and 10^{-7}, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels are 500 ug/l, 50 ug/l, and 5.0 ug/l, respectively (U.S. EPA, 1980a).

5.0 BACKGROUND LEVELS

Data on hexachlorobutadine levels in water, sediment, and biota of the Great Lakes and Niagara River are very limited. HCBD data were not available from the latest report on Great Lakes water quality (GLWQB, 1987). HCBD data were, however, reported in terms of loadings to the Niagara River water and suspended sediments by the Data Interpretation Group (1986). At Fort Erie (upstream location), mean water and suspended sediment loadings were 0.2 and 0.002 kg/day, respectively. At Niagara on the Lake (downstream), mean water and sediment loadings were 0.52 and 0.03 kg/day, respectively. It was determined that significant loading increases occurred in the suspended sediment phase only. Mean daily increases of HCBD in sediment through the Niagara River were 0.001 to near 0.1 kg/day (90% C.I.) (Data Interpretation Group, 1986).

6.0 TOXICITY

The acute toxicity (LC_{50}) values for the goldfish, fathead minnow, rainbow trout, and bluegill are 90, 102, 320, and 326 ug/l, respectively. A freshwater snail Lymnaea stagnalis was exposed to HCBD, and the 96-hour LC_{50} was found to be 210 ug/l. All the tested species, both fish and invertebrate, demonstrated a relatively narrow range of sensitivity (Leeuwangh et al., 1975; U.S. EPA, 1980b).

A chronic toxicity value for HCBD of 9.3 ug/l was determined by the U.S. EPA (1980b) for an early life stages of the fathead minnow.

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HEXACHLOROBENZENE

1.0 GENERAL

Chlorination of benzene yields 12 different compounds: monochlorobenzene (C_6H_5Cl), three dichlorobenzene ($C_6H_4Cl_2$) isomers (1,2-;1,3-;1,4-), three trichlorobenzene ($C_6H_3Cl_3$) isomers (1,2,3-; 1,2,4-; 1,3,5-), two tetrachlorobenzene ($C_6H_2Cl_4$) isomers (1,2,3,5-;1,2,4,5-), pentchlorobenzene (C_6HCl_5), and hexachlorobenzene (C_6Cl_6). In the mid-1970's, over 650,000 kkg of chlorinated benzenes were produced annually in the U.S. (U.S. EPA, 1975; West and Ware, 1977). The chlorinated benzenes are used as intermediates for herbicides, insecticides, and dyestuffs; dye carriers, deodorants, lubricants, and dielectric/heat transfer mediums.

In 1972, hexachlorobenzene (HCB) was used as a fungicide (23 percent) to control wheat bunt and smut on seed grains. Other industrial uses (77 percent) included dye manufacturing, an intermediate in organic synthesis, porosity controller in the manufacturing of electrodes, a wood preservative, and an additive in pyrotechnic compositions for the military (U.S. EPA, 1975).

In recent years, HCB has become a concern because of its widespread distribution as an environmental contaminant and a contaminant of food products used for human consumption. Production and use of chlorinated benzenes results in approximately 1,500 kkg of tetra-, penta-, and hexa-chlorinated benzenes entering the aquatic environment yearly. Annually, 1,628 kkg of hexachlorobenzene contaminate solid wastes (West and Ware, 1977). The occurrence and effects of HCB have been reported in many organisms, e.g., birds (Vos et al., 1971; Cromartie et al., 1975), rats (Medline et al., 1973), man (Cam and Nigogosyan, 1963) and fish (Holden, 1970; Johnson, et al., 1974; Zitko, 1971). Magnification in the natural food chain is suggested by Gilbertson and Reynolds' (1972) observation of HCB in the eggs of common terns, which had apparently eaten contaminated fish. This compound has also been found in samples of ocean water, and its persistence in the environment has been acknowledged (Seltzer, 1975).

2.0 PHYSICAL AND CHEMICAL PROPERTIES

All of the chlorinated benzenes are colorless liquids or solids with a pleasant aroma. All are heat-stable; HCB is nonflammable. Among the several physical properties listed in Table 1, the vapor pressure, solubility in water, and log octanol water partition coefficient (Log K_{ow}) most directly affect the compounds' aquatic environmental fate. As chlorination increases from mono- to hexa-, vapor pressure decreases, solubility decreases, and Log K_{ow} increases. Consequently, HCB is the most environmentally-persistent compound and the one most apt to accumulate in ecosystems. The following discussions will therefore emphasize hexachlorobenzene.

3.0 ENVIRONMENTAL FATE

None of the destructive processes studied, which include photolysis, oxidation, hydrolysis, and biodegradation, appear to exert an appreciable effect on the fate of HCB in the aquatic environment. Some investigators believe that naturally-occurring complex organic compounds present in rivers and streams may serve as photosensitizers and thus enhance the degradation of organic pollutants; however, the photolysis of HCB in the presence of such possible photosensitizers has not been studied. Due to the very low volatility, only limited amounts of HCB are expected to enter the atmosphere where sort wavelength light may convert it into other compounds (Versar, 1979).

The stability of HCB is such that it is resistant to oxidation except under the most extreme conditions (Fieser and Fieser, 1956). Consequently, oxidation of HCB would not be expected to be an important fate under ambient conditions. Further, Leoni and D'Arca (1976) report that HCB is chemically very inert at room temperature and reacts with caustic alkalis to form the corresponding pentachlorophenolates only at 130°-200°C. Patai (1973) reported that the minimum conditions necessary for the conversion of HCB to a pentachlorophenyl derivative were the presence of aqueous ammonia and a temperature of 250°C. Thus, HCB would not be expected to undergo hydrolysis at an appreciable rate under environmental conditions.

According to Ware and West (1977), the more highly halogenated a compound becomes, the more resistant it is to biodegradation. Experimental evidence has been found indicating that chlorobenzene is a persistent compound (Lu and Metcalf, 1975) and is not readily biodegraded unless the microorganisms present are already growing on another hydrocarbon source (Gibson _et_ _al_., 1968). Since HCB is more highly chlorinated than chlorobenzene, it would presumably biodegrade more slowly than chlorobenzene under similar conditions of exposure to microorganisms.

Lu and Metcalf (1975) reported a value for the biodegradability index of HCB of 0.377 in mosquito fish (_Gambusia_ _affinis_) within an aquatic model ecosystem. The biodegradability index is defined by Lu and Metcalf as the ratio of polar products of degradation to the nonpolar products. A low value for the biodegradability index indicates that a compound resists biodegradation. Comparison of the biodegradability index of HCB with that of some more-widely studied persistent pollutants such as DDT and aldrin gives a better idea of the significance of this value. Lu and Metcalf (1975) reported biodegradability indices for DDT and aldrin of 0.012 and 0.015, respectively, compared to a value of 0.377 for HCB in mosquito fish.

Volatilization. Because of its relatively high boiling point (322°C) and correspondingly low vapor pressure at ambient temperature (1.09 x 10^{-5} mm Hg), HCB might be expected to exhibit very slow rates of volatilization from water. However, calculations by Mackay and Leinonen (1975) predict a half-life of about 8 hours for evaporation from a water column 1 m deep. Although such an estimate does not include environmentally important parameters such as adsorption by sediment and variable mixing rates, it does suggest that transport by volatilization might be important in the absence of other processes.

Sorption. Laseter et al. (1976) conducted an experiment in which a soil sample was exposed to a regular flow of water with a concentration of 8.3 ug/l HCB. After one day of exposure to this concentration, the soil sample had a concentration of 332 ug/l of HCB, a concentration factor of 40X. Four days after initiation of the test, the concentration of HCB in the soil was 269 ug/l. Depuration was initiated on the fourth day of exposure, and after four days of depuration the sample of sediment had a concentration of 303 ug/l of HCB, a concentration almost as high as that measured on the first day of exposure. It was concluded that bottom sediment accumulated proportionately less HCB than did organisms, but retained it longer.

Bioaccumulation. The bioaccumulation potential of HCB has been studied using radiotracer techniques in three model aquatic ecosystems (Metcalf et al., 1973; Lu and Metcalf, 1975; Isensee et al., 1976). In all studies, HCB was found to be a highly persistent compound as demonstrated by the bioaccumulation ratios.

In the study by Isensee et al., (1976), three replicates each of a control soil and soils treated with HCB at concentrations of 0.1, 1, and 10 mg/l were placed in tanks to which was added aqueous solutions with concentrations of 0, 10, 100, and 1000 ug/l of HCB, respectively. Twenty-four hours later, approximately 100 daphnids (Daphnia magna), eight snails (Helisoma sp.), a few strands of an alga (Oedogonium cardiacum), and 10 ml of old aquarium water which contained various diatoms, protozoa, and rotifers were added. Water lost by evaporation was replenished as needed. At 30 days, daphnids were sampled for analysis (20 to 30 mixed age organisms per sample) and two 0.15 - 0.25g mosquito fish (Gambusia affinis) were added. Three days later all organisms were harvested and two 2.0 - 2.5g fingerling channel catfish (Ictalurus punctatus) were added to each tank and exposed for 8 days.

Based on their results, Isensee et al. (1976) concluded that HCB is very persistent in aquatic systems. They also found that the amounts of HCB accumulated by all studied aquatic model food chain organisms increased as the treatment concentrations increased. In addition, these researchers found that, for any given treatment concentration, higher food chain organisms (such as snails and mosquito fish) always contained 1.5 to 2 times more HCB than lower food chain organisms such as algae and daphnids. Furthermore, catfish, being the highest food chain organism in the model aquatic ecosystem, accumulated 10 times more HCB than did any other organisms. Isensee et al. (1976) theorize that either biomagnification within the food chain and/or a species-specific response was important in contributing to the observed accumulation patterns.

Due to the experimental design used by Isensee et al. (1976), it is difficult to assess whether biomagnification through food chains was, in fact, occurring, since there is no evidence that the bioaccumulation ratios measured were quantitatively evaluated at equilibrium concentrations.

In a study by Laseter et al. (1976), an experiment was carried out for a duration of one week to determine the difference in uptake of HCB between sunfish (Lepomis macrochirus) held in water free of HCB and fed sailfin mollies (Poecilia latipinna) contaminated with HCB and sunfish held in water having a concentration of 2.7 ug/l of HCB and fed contaminated sailfin mollies. The mean concentrations of HCB in the two groups of sunfish at the end of the experiment were 594 and 3,578 ug/l, respectively. From these results, it appeared that aqueous sources contributed far more to the sunfish body burden of HCB than did dietary sources. Other experiments conducted by Laseter et al. (1976) on uptake and depuration HCB by various aquatic organisms showed that this chemical was depurated quite rapidly.

The findings of Laseter et al. (1976) support the contention that HCB bioaccumulates but does not biomagnify in aquatic food chains. It must be noted, however, that there is no evidence that the relative contributions of aqueous and dietary sources of HCB were measured at equilibrium conditions. It is also uncertain whether predators of fish such as aquatic birds will ultimately biomagnify this compound.

In addition to experimental evidence, there is empirical evidence that HCB has a high potential for accumulation in organisms. Neely et al. (1974) and Metcalf et al. (1973) have shown that the log octanol/water partition coefficient (log K_{ow}) correlates well with the ability of a compound to accumulate in the lipids of tissues of living organisms. The high log K_{ow} value of 6.18 (Neely et al., 1974) indicates that the bioaccumulation potential of HCB by aquatic organisms at pollutant concentrations anticipated in environmental waters is very high.

Summary. Data found concerning the processes for removal of HCB are insufficient to allow designation of almost probable fate pathway for this compound. HCB has a high affinity for lipophilic materials; consequently, sorption and bioaccumulation are anticipated to occur quite readily. It appears that the major portion of HCB found in aquatic organisms is from aqueous rather than dietary sources. Furthermore, experimentally determined rates of depuration of HCB appear to be substantially more rapid than rates of depuration for other persistent chemicals such as DDT (Versar, 1979). Consequently, biomagnification of HCB through aquatic food chains may not occur. Not enough data, however, is available to determine if this statement is true where birds are the predators of fish.

4.0 CRITERIA

Criterion for the protection of aquatic life from chlorobenzenes are as follows according to the U.S.EPA (1980):

> "The available data for chlorinated benzenes indicates that acute toxicity to freshwater aquatic life occurs at concentrations as low as 250 ug/l and would occur at

> lower concentrations among species that are more sensitive than those tested. No data are available concerning the chronic toxicity of the more toxic of the chlorinated benzenes to sensitive freshwater aquatic life but toxicity occurs at concentrations as low as 50 ug/l for a fish species exposed for 7.5 days."

Human health criteria for HCB as stated by the U.S.EPA (1980) are as follows:

> "For the maximum protection of human health from the potential carcinogenic effects due to exposure of hexachlorobenzene through ingestion of contaminated water and contaminated aquatic organisms, the ambient waer concentration should be zero based on the nonthreshold assumption for this chemical. However, zero level may not be attainable at the present time. Therefore, the levels which may result n incremental increase of cancer risk over the lifetime are estimated at 10^{-5}, 10^{-6}, and 10^{-7}. The corresponding recommended criteria are 7.2 ng/l, 0.72 ng/l, and 0.072 ng/l, respectively. If the above estimates are made for consumption of aquatic organisms only, excluding consumption of water, the levels of 7.4 ng/l, 0.74 ng/l, and 0.074 ng/l, respectively."

It should be noted that these human health criteria for HCB are several orders-of-magnitude lower than those for any of the other chlorinated benzenes.

5.0 BACKGROUND LEVELS

Levels of chlorobenzenes in both water and sediments of the Great Lakes have been compiled and reported by the Great Lakes Water Quality Board (1987) and are presented in Table 2. In Lake Erie, levels of HCB in water ranged from less than 0.002 to 0.218 ng/l in 23 samples collected in 1986. Five Lake Erie sediment samples collected in 1980 had HCB levels of 0.7 to 12.0 ug/kg. In Lake Ontario, 14 water samples collected in 1985 had HCB levels of 0.017 to 0.103

ng/l. Lake sediment levels were 9 to 320 ug/kg with a mean of 97 ug/kg as seen in 11 samples collected in 1980 (GLWQB, 1987).

In a long-term (November 1983 to May 1986) study of contaminant loadings fro the Niagara River to Lake Ontario, significant increases were noted for several chlorobenzenes by the Data Interpretation Group (1986). Statistically significant increases were noted for 1,2,3,4-tetrachlorobenzene (water and suspended sediments), pentachlorobenzene (water and suspended sediments), and hexachlorobenzene (suspended sediment only). HCB suspended sediment loadings increased from a mean of 0.0039 kg/day at Fort Erie to 0.1318 kg/day at Niagara-on-the-Lake, the mouth of the Niagara River. HCB water loadings showed an increasing tendency with mean values of 0.0538 kg/day (Fort Erie) and 0.972 kg/day (Niagara-on-the-Lake). Thirty-four samples were collected at each location; detection levels were 0.05 ng/l for water and 0.001 ug/gm for suspended sediments (Data Interpretation Group, 1986).

6.0 TOXICITY

There is a diversity of toxicological data with numerous species, and there is a consistent direct relationship between toxicity and bioconcentration and degree of chlorination for the organisms tested. The acute toxicity of HCB is difficult to ascertain since acute mortality for a variety of species (e.g., midge, rainbow trout, fathead minnows) appears to occur a or above its water solubility of 6.0 ug/l. However, the USEPA (1978) reported 96-hour LC_{50} values for bluegill exposed to chlorobenzene, 1,2,4-trichlorobenzene, 1,2,3,5-tetrachlorobenzene, 1,2,4,5-tetrachlorobenzene, and pentachlorobenzene to be 15,900, 3,360, 6,420, 1,550 and 250 ug/l, respectively. Only the 1,2,3,5-tetrachlorobenzene LC_{50} value of 6,420 ug/l is an apparent anomaly in the trend of increasing toxicity with increasing chlorination (U.S.EPA, 1980).

Chronic toxicity data, like acute toxicity data for HCB, are not available. Chronic values for the fathead minnow exposed to tri- and tetrachlorobenzene were 705 and 286 ug/l, respectively (U.S.EPA, 1978).

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TABLE 1

PHYSICAL PROPERTIES OF CHLORINATED BENZENES

Compound	MW	MP(°C)	BP(°C)	Density	Vapor Pressure (mm Hg)	Solubility in Water (mg/l)	Log K_{ow}
Monochlorobenzene	112.56	-45.6	131-132	1.11	60	488	2.83
Dichlorobenzenes	147.01	-53- -17.6	172-179	1.25-1.30	0.4-5	80-145	3.37-3.44
Trichlorobenzenes	181.45	17-63.4	213.5-208	1.57	3-4.4	5.8-19	4.23
Tetrachlorobenzenes	215.90	47.5-140	243-254	1.46-1.86	2	0.3-3.5	4.93
Pentachlorobenzene	250.34	86	277	1.61	-	0.24	5.63
Hexachlorobenzene	284.79	230	322	2.04	1.09×10^{-5}	0.006	6.18

Sources: Hampel and Hawsley (1973), Neely et al. (1974), U.S. EPA (1978), Verschueren (1983), Weast (1977).

TABLE 2

CHLORONATED BENZENES IN LAKE ERIE AND LAKE ONTARIO WATERS AND SEDIMENTS

	Lake Erie			Lake Ontario		
Compound	Water^1 (ng/l)	Sediment^2 (ug/kg)	($\overline{X}$)	Water^3 (ng/l)	Sediment^4 (ug/kg)	($\overline{X}$)
1,2-Dichlorobenzene	0.030-0.982	1-4	(2)	ND	4-27	(11)
1,3-Dichlorobenzene	0.280-4.182	1-9	(4)	ND	15-250	(74)
1,4-Dichlorobenzene	0.051-0.464	3-20	(9)	ND	22-210	(94)
1,2,3-Trichlorobenzene	ND-0.065	0.1-1	(.4)	0.008-0.672	1-16	(7)
1,2,4-Trichlorobenzene	0.043-0.600	1-9	(3)	0.022-1.360	20-200	(94)
1,3,5-Trichlorobenzene	ND-0.136	0.1-5	(1)	ND-0.079	7-250	(60)
1,2,3,4-Tetrachlorobenzene	ND-0.059	0.2-2	(.7)	ND-0.572	4-86	(33)
1,2,3,5-Tetrachlorobenzene	-	0.1-0.9	(.3)	-	1-13	(6)
1,2,4,5-Tetrachlorobenzene	-	0.3-4	(1)	-	6-160	(52)
Pentachlorobenzene	ND-0.070	0.3-3	(1)	-	3-84	(32)
Hexachlorobenzene	ND-0.218	0.7-12	(3)	0.017-0.103	9-320	(97)

Notes:

[1] 23 samples in 1986
[2] 5 samples in 1980
[3] 14 samples in 1985
[4] 11 samples in 1980

Source: GLWQB (1987)

MERCURY

1.0 GENERAL

Mercury (Hg) has long been recognized as one of the most toxic of the heavy metals and is identified as a serious pollutant in the aquatic environment. Mercury levels in river, lake, and estuarine sediments have increased 2 to 5 times the precultural levels due to human activities. Some of the activities that contribute to the global input include: burning of fossil fuels; mining and processing of gold, copper and lead; and the operation of chloralkali plants (NRC, 1978). The major use of mercury in the United States has been as a cathode in the preparation of chlorine and caustic. In 1968, this use accounted for roughly 1/3 of the U.S. consumption (US EPA, 1980). Mercury also enters the aquatic environment from natural sources as a vapor, in solution, and in particulate form (e.g., cinnabar-the mercuric sulfide ore). Mercury and its compounds serve no known biological function; their presence in living organisms at any level is undesirable and potentially hazardous (Eisler, 1987).

2.0 PHYSICAL AND CHEMICAL PROPERTIES

Within the aquatic environment, mercury can exist in three oxidation states: elemental mercury (Hg^o), mercurous ion (Hg_2^{2+}), and mercuric ion (Hg^{2+}). Elemental mercury has a melting point of -38.87^oC and a density of 13.53. It is very volatile with a vapor pressure of 2×10^{-3} mm at 25°C. It's solubility in water is 0.056 mg/l; in benzene, solubility is 2.387 mg/l (Merck, 1983; Eisler, 1987). Movements of mercury within the aquatic environment are governed by both physico-chemical conditions present and by the biological influences (i.e., the biological mercury cycle).

Inorganic mercury compounds found in water vary depending on pH, redox potential (Eh), alkalinity, temperature, pressure, and the anionic species present.

The mercury forms present can be liquid, solid, or aqueous with a wide variety of solubilities and electrical charges. Figure 1 shows the solid and liquid forms of mercury that would be stable under a normal range of aqueous Eh and pH conditions. Figure 2 shows the predominant aqueous mercury species.

Superimposed upon the inorganic dynamics of mercury in the aquatic environment is the biological mercury cycle (Figure 3). The interconversions shown maintain a dynamic equilibrium of organic mercury species including methyl mercury (CH_3Hg^+) in the water and sediments. Under naturally occurring conditions of pH and temperature, mercury may be methylated by biological and/or chemical processes (Eisler, 1987), although the extent of chemical (i.e., abiological) methylation is thought to be quite limited (Callister and Winfrey, 1986); Boudou and Ribeyre, 1983). Mercury methylation in ecosystems depends on mercury loadings, microbial activity, nutrient content, pH and redox condition, suspended sediment load, sedimentation rates, and other variables (Eisler, 1987). This process can occur under both aerobic and anaerobic conditions (Beijer and Jernlov, 1979; Clarkson et al, 1984), but appears to favor an anaerobic setting (Olson and Cooper, 1976). A change in pH can change the balance of the biological mercury cycle resulting in elevated methylation rates. For example, Clarkson et al. (1984) found that the acidification of natural bodies of freshwater is statistically associated with elevated concentrations of methyl mercury in the edible tissues of predatory fishes. Methylation also occurs at the organism level by way of mucus, intestinal bacteria, and enzymatic processes, but these pathways are not as important as diet in the bioaccumulation process (Huckabee et al., 1979; Boudou and Ribeyre, 1983).

Bacteria decompose methyl mercury as well as form it. Demethylation proceeds through two phases, resulting in elemental mercury (Hg^0) which can dissolve in water to a limited extent or be released to the atmosphere in a vapor phase (Clarkson et al, 1984). Organomercury compounds other than methyl mercury decompose rapidly in the environment and behave much like inorganic mercury compounds (Beijer and Jernelov, 1979).

3.0 ENVIRONMENTAL FATE

The environmental fate of mercury has been reviewed by NRC (1978), Versar (1979) and Eisler (1987). Mercury is strongly adsorbed onto inorganic and organic particulates which settle on to bottom sediments. Once in the sediments, mercury can precipitate as HgS or be mobiled by biomethylization. Due to its high volatility and low water solubility, mercury can be lost from the aquatic system by volatilization. Mercury as methyl mercury is strongly bioaccumulated from both water and diet; it may also be biomagnified in top predatory fish species.

Photolysis. Photolysis may be important to the breakdown of methyl mercury in the atmosphere and perhaps in surface waters. As shown in Figure 3, dimethyl mercury may be transformed into methyl mercury and/or elemental mercury (Johnson and Bramen, 1974; Berjen and Jemelov, 1979). However, due to the limited amount of data available, the importance of photolysis to the overall fate of mercury is unclear.

Chemical Speciation. As described in Section 2.0, mercury in the aquatic environment can be found in three oxidation states, the predominance of which is controlled by both the physical (inorganic) and biological ambient conditions. The thermodynamic and biological effects are shown in Figures 1 through 3. Generally, in a mildly oxydizing environment above pH 5, the predominant mercury species will be elemental mercury. Under mildly reducing conditions which are commonly found in sediments, mercury may be precipitated as the sulfide (HgS), a solid of very low solubility. Mercury also forms a wide variety of complexes with chloride, sulfhydryls, and alkyls. As concluded by Boudou and Ribeyre (1983), chemical speciation of mercury is probably the most important variable influencing the ecotoxicology of mercury. Biological methylation of mercury also influences the mercury species found under a given set of conditions.

Sorption. Mercury is known to have a strong affinity to adsorb onto surfaces. In fact, Versar (1979) concludes that adsorption onto sediments is probably the most important process determining the fate of mercury in the aquatic environment. It appears that sediment binding capacity for mercury is directly related to its organic content (Ramamoorthy and Rust, 1976), a tendency confirmed by Reimers and Krenkel (1974). Carr and Wilkness (1972) found that adsorbed mercury is probably not in the form of methylated mercury compounds.

Biotransformation. Mercury, as an element, is not intrinsically altered by transformation processes; however, mercury does take part in biologically-mediated reactions which significantly alter its mobility and toxicity (Versar, 1979). The most widely studied biotransformation of mercury is methylation, although Wood (1974) demonstrated that a biochemical equilibria exits among dimethyl mercury, $(CH_3)_2$ Hg, methyl mercuric ion, Hg^{2+}, and mercurous ion, $Hg_2{}^{2+}$. Methylation of mercury is favored by elevated levels of inorganic mercury, lowered pH, organic sediments, anaerobic conditions, and the abundance of bacteria (Versar, 1979). Conversion of inorganic and organic forms of mercury into the highly toxic and bioavailable methyl mercury via dynamic equilbria reactions makes it evident that any form of mercury in the environment is hazardous (US EPA, 1980; 1985). Additional discussion of the biotransformation is found in Section 2.0.

Bioaccumulation. The relative rates of uptake and depuration determine the net bioaccumulation rate. Methyl mercury is the form of mercury present in most fish tissue, and it is the most readily accumulated and retained form of mercury in aquatic biota. Methyl mercury is readily accumulated by fish both from their food and through the water. Although conflicting evidence exists regarding the relative importance of these two sources of mercury to fish, most reports suggest that both sources can be significant. Since methyl mercury is very slow to be eliminated once it has entered the biological system, bioconcentration factors (BCFs) are high for most fish (Versar, 1979). The relative importance of the two mercury sources varies with tropic level, water temperature, and ambient mercury concentrations, among others. However, mercury contributions from the water and food have been found to be additive with food uptake accounting for up to 10 times that of water (Lock, 1975).

Bioconcentration factors (BCFs), the ratio of the chemical concentration in fish tissue to the concentration in the ambient water, have been calculated for a wide variety of fish species, water temperatures, and mercury concentrations. McKim et al. (1976) found BCFs of 11,000 to 33,000 for brook trout muscle at water levels of 0.93 to 0.03 ug/l (methyl mercury). Olson et al. (1975) determined BCFs for fathead minnows to be higher at 44,000 to 81,700 with water concentrations of 0.25 to 0.02 ug/l (methyl mercury), possibly due to browsing of attached algae by the minnows. Miimi and Lowe-Jinde (1984) calculated BCFs of 4,100 to 85,700 based on direct and food-ingestion uptake. A listing of selected BCFs for fish is presented in Table 1.

In an examination of mercury bioaccumulation studies for evidence of biomagnification, Kay (1984) concluded that mercury may be biomagnified in top predatory fish species collected from areas of known mercury contamination. Results of the numerous studies reviewed were not in agreement on the potential for biomagnification, however. Work by Cherry and Guthrie (1977) suggests a lack of magnification; results of a study by Phillips and Bukler (1978) suggest biomagnification of methyl mercury; while studies by Potter et al. (1975), Akielaszek and Haines (1981), and May and McKinney (1981) all showed higher tissue levels of mercury in predatory fish species than in forage species.

4.0 CRITERIA

Criteria have been established for mercury levels in surface waters and edible portions of fish and shellfish. The US EPA (1985) has set the ambient surface water criteria for mercury as follows:

> "... freshwater aquatic organisms and their uses should not be affected unacceptably if the four-day average concentration of mercury does not exceed 0.012 ug/l more than once every three years on the average and if the one-hour average concentration does not exceed 2.4 ug/l more than once every three years on the average..."

In other words, freshwater organisms will be protected from chronic effects if mercury levels do not exceed 0.012 ug/l (four-day average) and from acute effects if levels do not exceed 2.4 ug/l (one-hour average). This freshwater criteria of 0.012 ug/l is termed a Final Residue Value since it is derived from the Food and Drug Administration (FDA) action level of 1.0 mg/kg for fish tissue and the BCF of 81,700 for methyl mercury in the fathead minnow (Olson et al., 1975). The Final Residue Value is quite conservative since it is considerably lower than a Final Chronic Value, that level of mercury in water that would be expected to cause statistically significant effects on fish life. These criteria should be applied to "total recoverable mercury, although the US EPA (1985) feels that the "acid soluble" mercury fraction would be a more scientifically correct basis on which to set the criteria.

For the protection of human health from the toxic properties of mercury ingested through water and contaminated aquatic organisms, the ambient water criterion is determined to be 144 ng/l. For the protection of human health from the toxic properties of mercury ingested through contaminated aquatic organisms alone, the ambient water criterion is determined to be 146 ng/l. These values include the consumption of freshwater, estuarine, and marine species (US EPA, 1986).

The FDA has established an Action Level (Guideline) of 1.0 mg/kg for methyl mercury in edible portions of fish and shellfish in their Compliance Policy Guides. The 1978 Great Lakes Water Quality Agreement objective level for mercury is 0.5 mg/kg in whole fish (GLWQB, 1987).

5.0 BACKGROUND LEVELS

Levels of mercury and other metals have been measured in the waters of the Great Lakes during recent (1980-1983) years. Open lake total metals concentrations were low in all lakes. However, in nearshore areas and in areas near identified areas of concern, levels of many metals exceeded the 1978 Great Lakes Water Quality Agreement objectives which address the potential toxicity of metal mixtures. Median mercury levels were 0.033 ug/l in Lake Erie and <0.01 ug/l in Lake Ontario (GLWQB, 1987).

Mercury levels in Lake Ontario sediments have been measured in depositional basins, non-depositional zones, and harbor/river mouths. In depositional areas, mercury levels were 0.40 to 3.95 mg/kg in surface sediments and 0.03 to 0.09 mg/kg at >9 cm depth. In non-depositional areas, surface sediments had <0.01 to 7.76 mg/kg mercury, while background levels (>9 cm depth) were 0.40 to 0.70 mg/kg. Surface sediments in harbors and river mouths had mercury levels of <0.01 to 7.0 mg/kg (GLWQB, 1987).

Water and suspended sediment were sampled at Fort Erie (head of the Niagara River) and at Niagara-on-the-Lake (mouth of Niagara River) during 1982 through 1984. Based on results of unfiltered water and suspended sediment analyses, loadings of 300-700 tons/day of mercury were added to the suspended sediments passing through the Niagara River. Unfiltered water samples had average loadings of 8,100 and 11,800 tons/day at Fort Erie and Niagara-on-the-lake, respectively. Suspended sediment mercury loadings during the same period averaged 500 and 900 tons/day at the same two locations (Data Interpretation Group, 1986).

Fish tissue samples of rainbow smelt and lake trout from the Great Lakes were collected during 1984-85 and analyzed for mercury. Concentrations of mercury in these two open-water predator and forage fishes throughout the Great lakes were below the Agreement objective of 0.5 mg/kg. Levels exceeded the objective in nearshore regions and connecting rivers. In 1985, average mercury levels in rainbow smelt were 0.04 to 0.05 mg/kg, while levels in lake trout were 0.05 to 0.14 mg/kg. Tissue analyses for mercury in Lake Ontario plankton, mysid shrimp, sculpins, smelt, lake trout, and herring gulls revealed biomagnification of mercury through the food chain (GLWQB, 1987).

6.0 TOXICITY

Among metals tested, mercury has been the most toxic to aquatic organisms (Eisler, 1981). For all organisms tested, early developmental stages were the most sensitive, and organomercury compounds--especially methyl mercury--were more toxic than inorganic forms. In general, toxicity of mercury was higher at elevated temperatures (Armstrong, 1979) and in the presence of other metals such as zinc and lead (Parker, 1979). Toxic concentrations of mercury salts ranged from <0.1 ug/l to more than 200 ug/l for representative species of freshwater organisms. The lower toxic concentrations of <2.0 ug/l were usually associated with early developmental stages, long exposures, and flowthrough tests (Eisler, 1981). Table 2 lists mercury toxicities to representative freshwater organisms.

Signs of acute mercury poisoning in fish included flaring of gill covers, increased frequency of respiratory movements, loss of equilibrium, and sluggishness. Signs of chronic mercury poisoning included emaciation (due to appetite loss), brain lesions, cataracts, diminished response to change in light intensity, inability to capture food, abnormal motor coordination, and various erratic behaviors. Mercury residues in severly poisoned fish that died soon thereafter ranged (in mg/kg fresh weight) from 26 to 68 in liver, 16 to 20 in brain, and 5 to 7 in whole body (Armstrong, 1979; Hawryshyn et al., 1982).

TABLE 1
BIOACCUMULATION OF MERCURY BY FRESHWATER FISH

Species	Tissue	Chemical	Duration (days)	BCF*	Reference
		Mercury^{2+}			
Rainbow trout, *Samo gairdneri*	Whole body	Mercuric chloride	60	1,800	Boudou and Ribeyre (1984)
Fathead minnow, *Pimephales promelas*	Whole body	Mercuric chloride	287	4,994	Snarski and Olson (1982)
		Methylmercury			
Rainbow trout, *Salmo gairdneri*	Whole body	Methylmercuric chloride	60	11,000	Boudou and Ribeyre (1984)
Rainbow trout, *Salmo gairdneri*	Whole body	Methylmercuric chloride	75	4,077-85,000	Niimi and Lowe-Jinde (1984)
Brook trout, *Salvelinus fontinalis*	Muscle	Methylmercuric chloride	273	11,000-33,000	McKim *et al.* (1976)
Brook trout, *Salvelinus fontinalis*	Whole body	Methylmercuric chloride	273	10,000-23,000	McKim *et al.* (1976)
Brook trout, *Salvelinus fontinalis*	Muscle and whole body	Methylmercuric chloride	756	12,000	McKim *et al.* (1976)
Fathead minnow, *Pimephales promelas*	Whole body	Methylmercuric chloride	336	44,130-81,670	Olson *et al.* (1975)

* Bioconcentration Factor

Source: US EPA (1985).

TABLE 2
TOXICITIES OF INORGANIC AND ORGANIC MERCURY COMPOUNDS TO AQUATIC ORGANISMS

Chemical species, taxonomic group, species	Effect*	Concentration (ug Hg/l)	Reference
INORGANIC MERCURY			
Crustaceans			
Crayfish, Orconectes limosus	LC-50 (30 d)	2.0	US EPA (1980)
Cladoceran, Daphnia magna	LC-50 (96 h)	5.0	US EPA (1980)
Cladoceran, Daphnia magna	LC-50 (LT)	1.3-1.8	US EPA (1980)
Scud, Gammarus pseudolimnaeus	LC-50 (96 h)	10.0	US EPA (1980)
Fish			
Rainbow trout, Salmo gairdneri			
Juveniles	LC-50 (96 h)	155.0-200.0	US EPA (1980)
Embryo-larva			
Static test	LC-50 (28 d)	4.7	Birge et al. (1979)
Flowthrough test	LC-50 (28 d)	>0.1	Birge et al. (1979)
Channel catfish, Ictalurus punctatus			
Embryo-larva			
Static test	LC-50 (10 d)	30.0	Birge et al. (1979)
Flowthrough test	LC-50 (10 d)	0.3	Birge et al. (1979)
Largemouth bass, Micropterus salmoides			
Embryo-larva			
Static test	LC-50 (8 d)	140.0	Birge et al. (1979)
Flowthrough test	LC-50 (8 d)	5.3	Birge et al. (1979)
Brook trout, Salvelinus fontinalis	LC-50 (LT)	0.3-0.9	US EPA (1980)

TABLE 2
TOXICITIES OF INORGANIC AND ORGANIC MERCURY COMPOUNDS TO AQUATIC ORGANISMS

Chemical species, taxonomic group, species	Effect*	Concentration (ug Hg/l)	Reference
INORGANIC MERCURY			
Crustaceans			
Crayfish, *Orconectes limosus*	LC-50 (30 d)	2.0	US EPA (1980)
Cladoceran, *Daphnia magna*	LC-50 (96 h)	5.0	US EPA (1980)
Cladoceran, *Daphnia magna*	LC-50 (LT)	1.3-1.8	US EPA (1980)
Scud, *Gammarus pseudolimnaeus*	LC-50 (96 h)	10.0	US EPA (1980)
Fish			
Rainbow trout, *Salmo gairdneri*			
Juveniles	LC-50 (96 h)	155.0-200.0	US EPA (1980)
Embryo-larva			
Static test	LC-50 (28 d)	4.7	Birge *et al.* (1979)
Flowthrough test	LC-50 (28 d)	>0.1	Birge *et al.* (1979)
Channel catfish, *Ictalurus punctatus*			
Embryo-larva			
Static test	LC-50 (10 d)	30.0	Birge *et al.* (1979)
Flowthrough test	LC-50 (10 d)	0.3	Birge *et al.* (1979)
Largemouth bass, *Micropterus salmoides*			
Embryo-larva			
Static test	LC-50 (8 d)	140.0	Birge *et al.* (1979)
Flowthrough test	LC-50 (8 d)	5.3	Birge *et al.* (1979)
Brook trout, *Salvelinus fontinalis*	LC-50 (LT)	0.3-0.9	US EPA (1980)

TABLE 2 (Continued)

Chemical species, taxonomic group, species	Effect*	Concentration (ug Hg/l)	Reference
ORGANIC MERCURY			
Planarians			
Flatworm, Dugesia dorotocephala			
Adult	LC-0 (10 d)	200.0	Best et al. (1981)
Adult	LC-100 (5 d)	500.0	Best et al. (1981)
Crustaceans			
Cladoceran, Daphnia magna	LC-50 (LT)	0.9-3.2	US EPA (1980)
Fish			
Rainbow trout, Salmo gairdneri			
Larva	LC-50 (96 h)	24.0	US EPA (1980)
Juvenile	LC-50 (96 h)	5.0-42.0	US EPA (1980)
Brook trout, Salvelinus fontinalis			
Yearling	LC-50 (96 h)	65.0	US EPA (1980)

*LT = lifetime exposure
h = hours
d = days

Source: Eisler (1987)

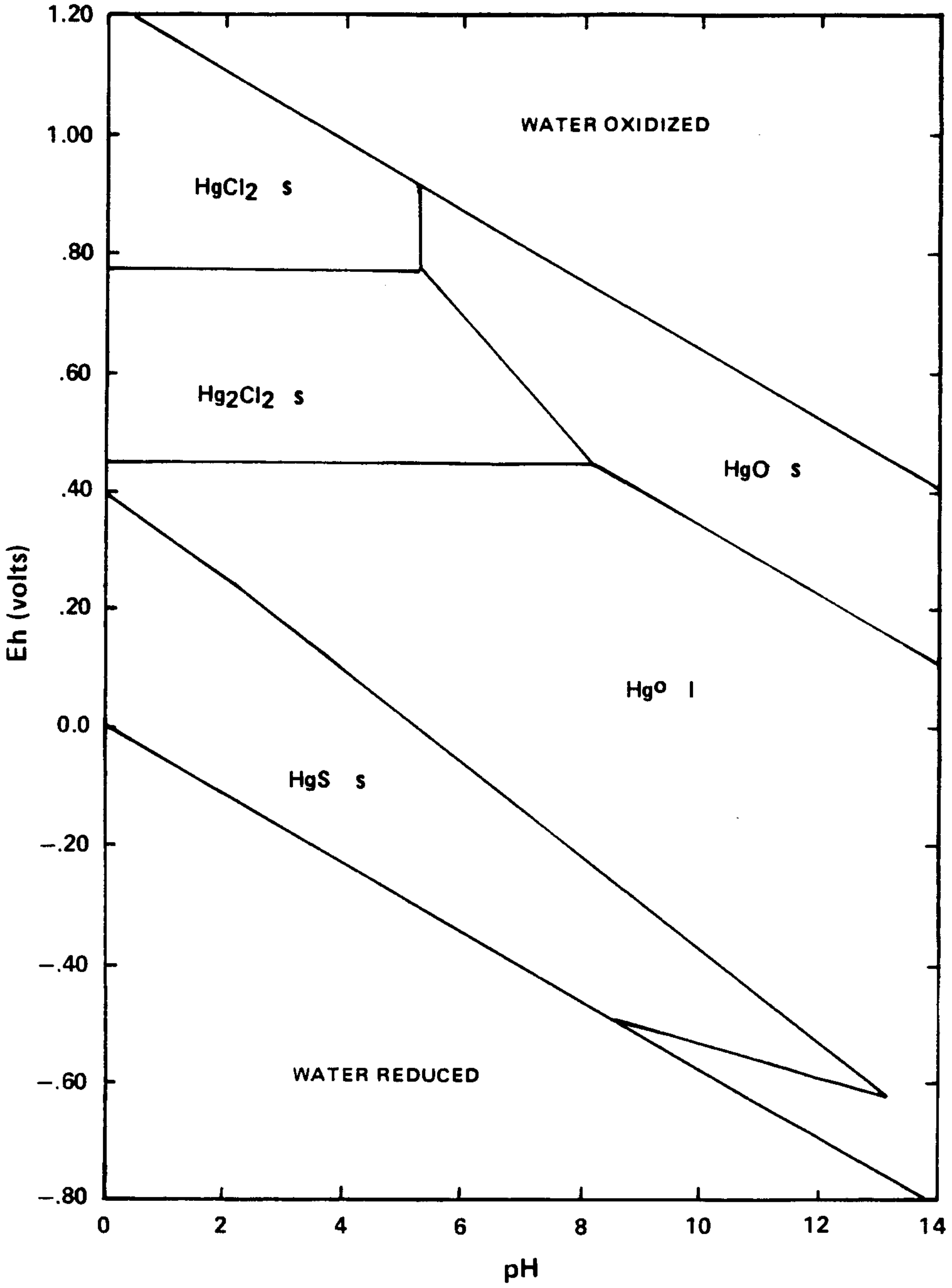

FIGURE 1 – FIELDS OF STABILITY FOR SOLID (S) AND LIQUID (L) MERCURY SPECIES AT 25°C AND 1 ATMOSPHERE PRESSURE. WATER CONTAINS 36 PPM CHLORINE AND 96 PPM SULFER AS SO_4^{2-} (HEM, 1970).

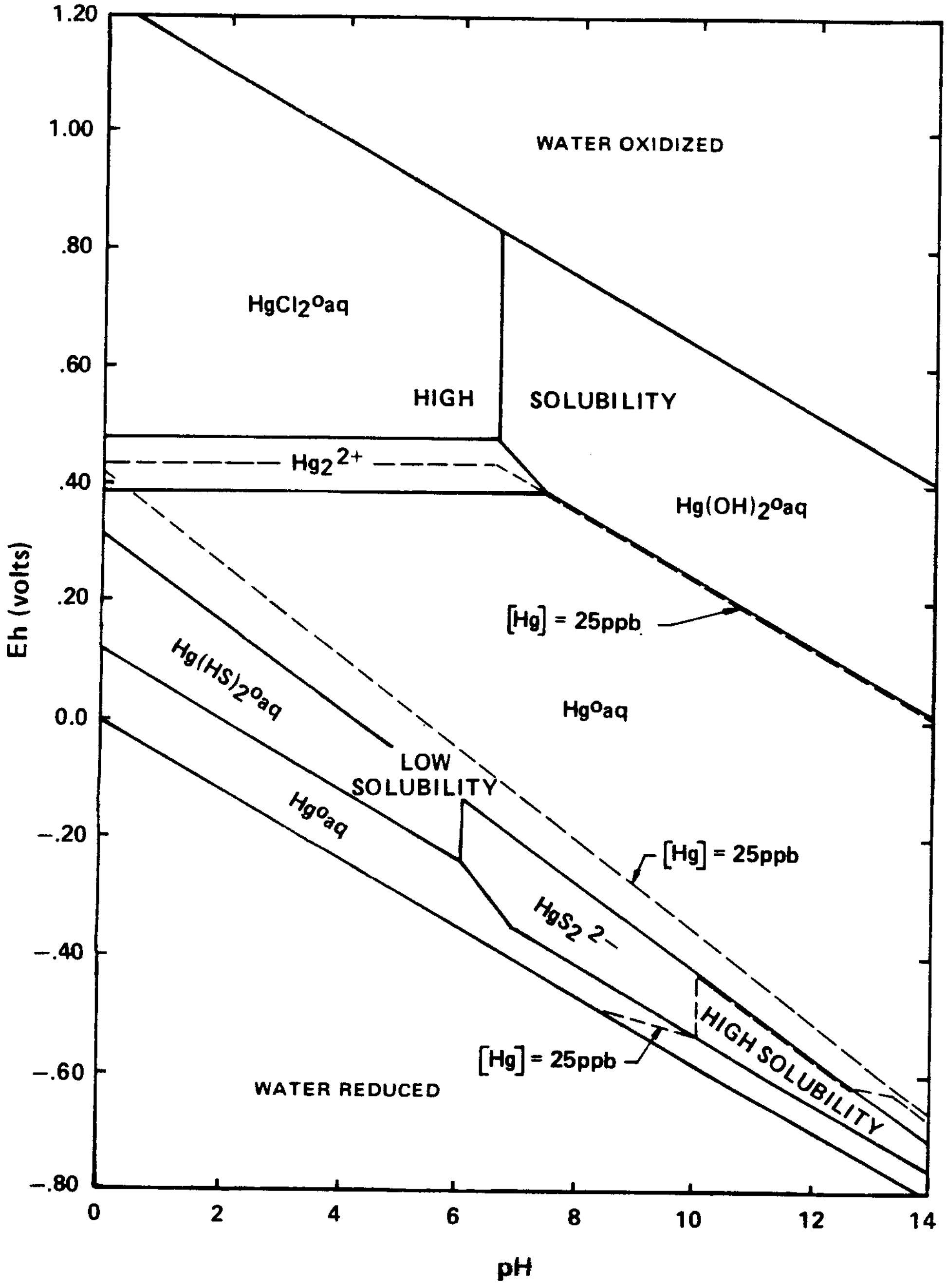

FIGURE 2 -- FIELDS OF STABILITY FOR AQUEOUS MERCURY SPECIES AT 25°C AND 1 ATMOSPHERE PRESSURE. WATER CONTAINS 36 PPM CHLORINE AND 56 PPM SULFER AS SO_4^{2-} (HEM, 1970).

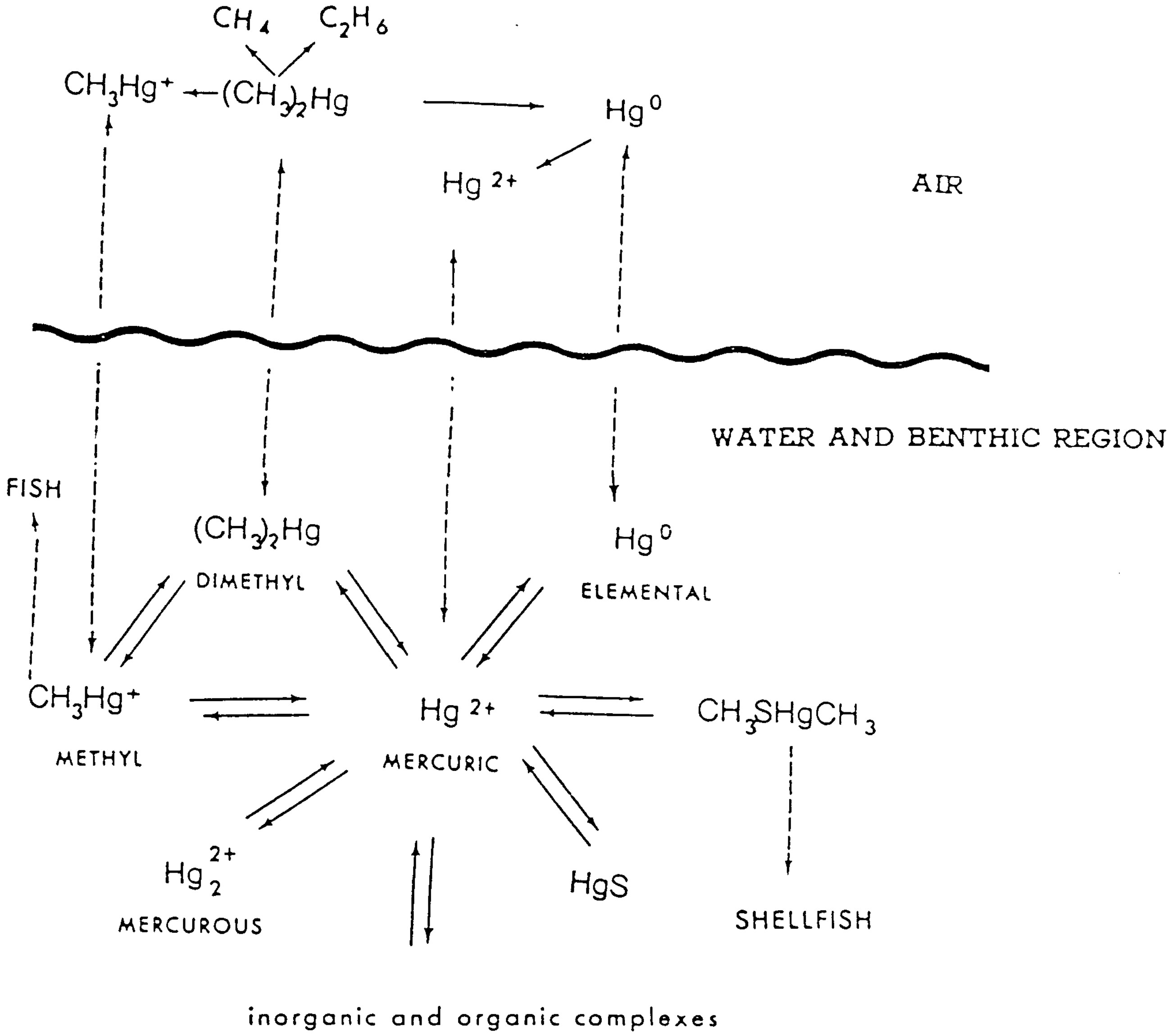

FIGURE 3 – BIOLOGICAL MERCURY CYCLE.
(MODIFIED FROM BEIJER AND JERNELOV, 1979)

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VINYL CHLORIDE

1.0 GENERAL

Vinyl chloride is an unsaturated halogenated hydrocarbon. Most of the vinyl chloride produced in the United States is used to make polyvinyl chloride (PVC), which is a material used to manufacture a variety of plastic and vinyl products. It includes pipes, wire and cable coatings, packaging materials, furniture and automobile upholstery, wall coverings, housewares, and automotive parts. To a lesser extent, vinyl chloride is used as a refrigerant gas and in the manufacture of other chlorinated compounds. Limited quantities of vinyl chloride were at one time used in the United States as an aerosol propellant and as an ingredient of drug and cosmetic products; however, these practices have been discontinued (EPA 1985b).

During 1986, an estimated 8.5 to 8.6 billion pounds of vinyl chloride was produced in the United States (C&EN 1987). It is made commercially by thermal cracking of ethylene dichloride which is synthesized by either direct chlorination of ethylene, using liquid chlorine, or oxychlorination of ethylene using dry hydrochloric acid and oxygen (Cowfer and Magistro 1985). Vinyl chloride is usually supplied as a liquid under pressure (IARC 1979). The technical grade product is available in 99.9 percent purity (Sax and Lewis 1987).

2.0 PHYSICAL AND CHEMICAL PROPERTIES

Chemical Name	Chloroethene
Synonyms and trade names	Vinyl chloride, chloroethylene, ethylene monochloride, monochloroethylene, VC, VCM, vinyl C monomer
Chemical formula	C_2H_3Cl
Identification numbers	
CAS Registry No.	75-01-4
NIOSH RTECS No.	KU9625000
EPA Hazardous Waste No.	U043
DOT/UN/NA/IMCO Shipping No.	1086

Property	Value
Molecular weight	62.5
Color	Colorless
Physical state	Gas
Odor	Mild, sweet
Odor threshold	
Water	3.4 ppm (w/v)
Air	3000 ppm (v/v)
Melting point	-153.8°C
Boiling point	-13.4°C
Autoignition temperature	472.22°C
Solubility	
Water	2763 mg/L at 25°C 1100 mg/L at 25°C
Organic solvents	Soluble in hydrocarbons, oil, alcohol, chlorinated solvents, and most common organic liquids
Density, g/cm^3	0.969 (-14.2°C)
Vapor density (air = 1)	2.15
Stability	May produce peroxides
Specific gravity	0.9121
Partition Coefficients	
Log octanol - water	1.36
Organic carbon	5.70
Vapor pressure	2660 mm Hg at 25°C
Ionization Potential	9.995 ev
Henry's Law constant	1.2 (atm-m^3)/mol at 10°C
Refractive index	1.3700 at 20°C
Flashpoint	-77.75 (open cup)
Flammability limits	4 - 22 vol percent
Conversion factors	
ppm (v/v) to mg/m^3 in air	ppm (v/v) = 2.60 mg/m^3
mg/m^3 to ppm (v/v) in air	mg/m^3 = 0.39 ppm (v/v)
ppm (w/v) to mg/L in water	ppm (w/v) = mg/L = ug/L
ppm (w/w) to mg/kg in solid matrices	ppm (w/w) = mg/kg = ug/g

3.0 ENVIRONMENTAL FATE

3.1 VOLATILIZATION

The primary loss process for vinyl chloride in natural water systems is volatilization into the atmosphere. The half-life for vinyl chloride volatilization from a typical pond, river, and lake has been estimated to be 43.3, 8.7, and 34.7 hour, respectively (EPA 1985b). Volatilization of vinyl chloride also occurs quite rapidly from soil surfaces. The effective half-life due to volatilization of vinyl chloride placed 10 cm deep in dry soil in predicted to be 12 hours (EPA 1985b). When released to the atmosphere, essentially all vinyl chloride exists in vapor form (Verschueren 1983). Removal from the atmosphere by dry or wet depositions are unlikely to occur.

3.2 SORPTION

The soil adsorption coefficient (K_{OC}) for vinyl chloride has been estimated to range between 17 and 131, and suggests that the compound would be highly mobile in soil. Therefore, vinyl chloride has the potential to leach into the groundwater.

3.3 PHOTOLYSIS

Direct photolysis of vinyl chloride in the atmosphere is a relatively insignificant degradation mechanism (EPA 1985b). In contrast, waters containing photosensitizers such as humic materials, would cause photogegradation of vinyl chloride and be a significant removal mechanism (HSDB 1987).

3.4 PHOTOCHEMICAL HYDROLYSIS

In the atmosphere, reaction of vinyl chloride vapor with photochemically generated hydroxyl radicals is predicted to be the primary degradation mechanism for this compound. The half-life for this reaction in the atmosphere is estimated to be 1.5 to 1.8 days (EPA 1985b) forming HCl, formaldehyde, formyl chloride, carbon monoxide, carbon dioxide, chloroacetaldehyde, acetylene, chloroethylene, chloroacetylchloranil, and H_2O. In photochemical smog, the reaction half-life is 3 to 7 hours (HSDB 1987). Reaction with ozone has a half-life between 4.2 and 33 days (EPA 1985b).

In water systems and soil, chemical hydrolysis of vinyl chloride does not appear to be a significant fate process.

3.5 BIODEGRADATION

Vinyl chloride in soil or water systems are believed resistent to microbial biodegradation under aerobic conditions.

3.6 BIOACCUMULATION

Vinyl chloride is not expected to bioaccumulate significantly in aquatic organisms (HSDB 1987).

4.0 CRITERIA

Air: The OSHA (1983) regulations for vinyl chloride state that a worker must not be exposed to greater than 1 ppm over any 8 hour period, and that a worker must not be exposed to greater than 5 ppm for any period of time exceeding 15 minutes. Direct contact with liquid vinyl chloride is prohibited. EPA (1982) has established emission standards for vinyl chloride released to the atmosphere by vinyl chloride and polyvinyl chloride plants. Emissions are not to exceed 10 ppm. ACGIH recommends a Threshold Limit Value - Time Weighted Average (TLV-TWA) for vinyl chloride of 5 ppm along with the notation of A1 recognizing the compound as a confirmed human carcinogen. NIOSH (1975) concluded that a TLV for vinyl chloride was inappropriate because of its carcinogencity. NIOSH recommended that any workers exposed to vinyl chloride should wear an air-supplied respirator.

Water: Effective January 9, 1989, EPA (1987) established as part of the Safe Drinking Water Act a maximum contaminant level (MCL) for vinyl chloride of 0.002 mg/L, equivalent to an estimated cancer risk of 10^{-5}. This regulation applies to all community drinking water systems that regularly serve the same 25 persons for at least 8 months/year. The Recommended Drinking Water contaminant level (RMCL) for vinyl chloride is 0.

The EPA derived Ambient Water Quality Criteria for Protection of Human Health (EPA - 1980).

Carcinogenicity Protection associated with a cancer risk of 10^{-6} and assuming a daily ingestion of 2 L water and 6.5 g fish and shellfish, is 2 ppb for protection against ingested water and organisms and 525 ppb for protection against the ingestion of organisms only.

The New York State Department of Environmental Conservation recommends a vinyl chloride ambient water quality guidance level of 5 ppb when the source of the potable water supply's fresh groundwater (NYSDEC 1985).

More recently EPA (1985a, 1987) estimated cancer risks of 10^{-4}, 10^{-5}, 10^{-6} would result from daily consumption of drinking water containing vinyl chloride at 1.5, 0.15, and 0.015 ppb, respectively. The agency promulgated the following health advisories for vinyl chloride in drinking water: a 10-day health advisory of 2.6 mg/L a longer term health advisory of 0.013 mg/L for a 10 kg child, and a term health advisory of 0.046 mg/l for an adult.

5.0 BACKGROUND LEVELS

Vinyl chloride in the atmosphere is not detectable in most parts of the United States. In areas near vinyl chloride and polyvinyl chloride manufacturers, concentrations of vinyl chloride may range from trace levels to 1 ppm. Average daily intake of vinyl chloride by inhalation for people living in the vicinity of emission sources range from trace amounts to 2.1 mg per day.

The majority of drinking water supplies in the United States contain no detectable levels of vinyl chloride (HSDB 1987), however, persons who have inadequately treated PVC water pipes may ingest 0.06 to 2.8 microgram per day vinyl chloride monomer. Data on concentrations of vinyl chloride in the soil was not reported in the literature.

6.0 TOXICITY

Because vinyl chloride is a gas, the only significant route of toxic exposure is inhalation. If it is confined on the skin in a liquid, a relatively small amount is absorbed.

Likelihood of acute effects is not nearly as significant as are excessive repeated exposures which are most likely to result in liver injury, angiosarcoma, and acroosteolysis.

Vinyl chloride primarily affects the central nervous system with symptoms including dizziness and disorientation. It is a known human carcinogen listed by IARC, NIOSH, NTP, and ACGIH, and has been demonstrated weakly mutagenic in the Salmonella test.

Experimental toxicity data include estimation of the LD50 (oral) in rats at 500 mg/kg and LC10 in guinea pigs at 20 ppm per 30 minutes.

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TETRACHLOROETHYLENE

1.0 GENERAL

Tetrachloroethylene (PCE) is a commercially important chlorinated hydrocarbon and chemical intermediate. It is widely used as a dry-cleaning and textile processing solvent (replacing carbon tetrachloride) and for vapor degreasing in metal cleaning operations. Approximately 0.5 billion pounds of PCE is produced annually.

2.0 PHYSICAL AND CHEMICAL PROPERTIES

Chemical Name	Ethene, tetrachloro-
Synonyms	1,1,2,2-Tetrachloroethylene; tetrachloroethylene; perchloroethylene; perc; carbon bichloride; carbon dichloride; ethylene tetrachloride; per; perchlor; perchloroethylene; perk
Chemical formula	C_2Cl_4
Identification numbers	
CAS Registry No.	127-18-4
NIOSH RTECS No.	KX3850000
EPA Hazardous Waste No.	U210

Property	Value
Molecular weight	165.83
Color	Colorless
Physical state	Liquid (at room temperature)
Odor	Ether-like odor
Melting point	-22.7°C
Boiling point	121.2°C (at 760 mm Hg)
Autoignition temperature	Unknown
Solubility	
Water	150 mg/L at 25°C
Organic solvents	Miscible with ethanol, diethyl ether, and oils in all proportions
Specific gravity	1.62260 (20/4°C)
Partition coefficients	
Log octanol-water	2.88

Property	Value
Vapor pressure	14 mm Hg at 20°C 24 mm Hg at 30°C
Ionization potential	9.32 ev
Henry's law constant	0.82 unitless
Refractive index	1.5029 at 25°C
Flash point	None
Flammable limits	Nonflammable
Conversion factors	
Air	1 ppm = 6.89 mg/m^3 (20°C) 1 mg/m^3 = 0.15 ppm
Water	1 ppm (w/v) = 1 mg/L = 1 ug/mL

3.0 ENVIRONMENTAL FATE

3.1 VOLATILIZATION

PCE is rapidly volatilized from water. Its estimated volatilization half-life for a pond, river, and lake are 7, 1.4, and 5.6 days, respectively. Because of its high vapor pressure, significant evaporation of PCE from dry surfaces is predicted to occur.

3.2 SORPTION

Experimentally measured soil sorption coefficients (K_{oc}) for PCE indicate a medium-to-high soil mobility. Several groundwater monitoring studies have confirmed PCE's leachability.

3.3 BIOACCUMULATION

PCE has low bioaccumulation potential with an experimentally measured fish bioconcentration factor of 31.

3.4 HYDROLYSIS

PCE in the atmosphere is primarily transformed as the result of reaction with photochemically produced hydroxyl radicals. Reaction degradation products include phosgene and chloroacetylchlorides. The half-life of PCE in air of approximately 96 days indicates long range global transport of PCE is likely. The hydrolysis half-life of PCE in water at room temperature is approximately 9 months (Dilling et. al., 1975).

3.5 BIODEGRADATION

PCE is resistant or only slowly biodegraded under anaerobic conditions with acclimated microorganisms (Wilson 1983).

4.0 CRITERIA

Air: The OSHA permissible exposure limit (PEL) for PCE is 100 ppm for an 8 hour time-weighted average (TWA), 200 ppm acceptable ceiling concentration, and 300 ppm maximum peak above the ceiling concentration for a maximum duration of 5 minutes in any 3 hour period. NIOSH designated PCE as a carcinogen and recommends that occupational exposure be limited to the lowest feasible limit. ACGIH recommends for PCE a threshold limit value (TLV) TWA of 50 ppm and a TLV short term exposure limit (STEL) of 200 ppm.

Water: No Maximum Contaminant Level (MCL) has been established for PCE in water, however, the Recommended Maximum Contaminant Level (RMCL) is 0.

EPA (1987) developed the following guidance levels for PCE in water:

1 day child = 2.0 mg/L
10 day child - 2.0 mg/L
longer term child = 1.4 mg/L
longer term adult = 5.0 mg/L
drinking water equivalent level (DWEL) = 0.5 mg/L

The World Health Organization drinking water guidance level for PCE is 0.01 mg/L.

The New York State Department of Environmental Conservation guideline for PCE in a fresh groundwater potable supply is 0.7 ppb (NYSDEC 1985).

The EPA derived Ambient Water Quality Criteria Protection of Human Health (EPA 1980) - Carcinogenicity Protection associated with a cancer risk of 10^{-6} and assuming a daily ingestion of 2L water and 6.5 g fish and shellfish, is 0.8 ppb for protection against ingested water and organisms and 8.85 ppb for protection against the ingestion of organisms only.

5.0 BACKGROUND

EPA (1985a) has estimated the average background level of PCE in the air to be 50 ppt in the northern hemisphere and an average unban level of PCE of -800 ppt. Rural and remote areas tend to have one fourth the ambient PCE levels estimated in urban/surburban areas.

The concentration of PCE in open oceans may be indicative of the environmental background levels in water. Average concentrations of 0.12 to 0.5 ppt have been detected in the North Atlantic (Pearson and McConnell 1975, Murray and Riley 1975). In drinking water, median concentrations of 0.3 and 3.0 ppb were found from 180 U.S. cities using surface water supplies and 36 cities using groundwater supplies, respectively (Coniglio et. al., 1980).

PCE was positively detected in 5 percent of 359 nationwide sediment observation stations with median levels less than 5 ng/g (Staples et. al., 1985).

6.0 TOXICITY

PCE causes central nervous system depression and liver damage. Symptions include dizziness, "inebriation," and staggered gait. Prolonged exposure has caused impaired memory, numbness of the extremities, and peripheral neutropathy including impaired vision.

In human experiments, 7-hour inhalation exposures at 100 ppm resulted in mild irritation of the eyes, nose, and throat, flushing of the face and neck headache, drowsiness, and slurred speech. Direct contact of PCE placed on the skin for 40 minutes results in a progressively severe buring sensation, beginning within 5 to 10 minutes and marked erythema, which subsided after 1 to 2 hours (Steward et. al., 1970).

Some experimental toxicity results are as follows:

Man	TCLo = 600 ppm/10 min
	TCLo = 96 ppm/7 hr
Rat	LCLo = 4000 ppm/4 hr
	LD_{50} (oral) = 8850 mg/kg
Rabbit	eye irit 162 mg: mild
	skin irrit 810 mg/24 hr: severe

The lowest concentrations of PCE in water causing toxicity in fish are:

Water	Exposure Length	Concentration
fresh	acute	5.28 mg/L
fresh	chronic	0.84 mg/L
salt	acute	1.02 mg/L
salt	chronic	0.45 mg/L

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TRICHLOROETHYLENE

1.0 GENERAL

Trichloroethylene (TCE) is a halogenated aliphatic hydrocarbon widely used as an industrial solvent. Eighty percent of its consumption is as a solvent for the vapor degreasing of fabricated metal parts in the automotive and metal industries. Other applications include its use as a chemical intermediate and as a heat-transfer media. Last reported production volume of TCE in the U.S. was 258.2 million pounds in 1981 (USITC 1982).

2.0 PHYSICAL AND CHEMICAL PROPERTIES

Chemical Name	Ethylene, trichloro-
Synonyms	Acetylene trichloride; 1-chloro-2,2-dichloroethylene; 1,1-dichloro-2-chloroethylene; ethinyl trichloride; ethylene trichloride; TCE; Tri; trichloroethylene; 1,1,2-trichloroethylene
Chemical formula	C_2HCl_3
Identification numbers	
CAS Registry No.	79-01-6
NIOSH RTECS No.	KX4550000
EPA Hazardous Waste No.	U228
DOT/UN/NA/IMCO No.	UN1710

Property	Value
Molecular weight	131.40
Color	Clear; colorless
Physical state	Liquid (at room temperature)
Odor	Ethereal; chloroform-like; sweet
Melting point	-87.1°C
Boiling point	86.7°C
Autoignition temperature	None
Solubility	
Water	1.366 mg/L at 25°C 1.070 mg/kg at 20°C
Organic solvents	Miscible with many common organic solvents (such as either, alcohol, and chloroform)

Property	Value
Density/specific gravity	1.465 (20/4°C)
Partition coefficients	
log octanol-water	2.42
organic carbon	126.0
Vapor pressure	74 mm Hg at 25°C 59 mg Hg at 20°C
Ionization potential	9.47 ev
Henry's law constant	0.020 atm-m^3/mol at 20°C 0.011 atm-m^3/mol at 25°C
Refractive index (n_D)	1.4782 at 20°C
Flash point	None
Flammability limits (exposive limits) (vol % in air)	8.0-10.5 at 25°C
Conversion factors	
Air (20°C)	1 mg/m^3 = 0.18 ppm 1 ppm = 5.46 mg/m^3
Water	1 ppm (w/v) = 1 mg/L = 1 u/mL

3.0 ENVIRONMENTAL FATE

3.1 VOLATILIZATION

TCE rapidly volatilizes from surface waters on soil surfaces. The major route of TCE from water is volatilization. Estimated volatilization half-lives from a typical pond, lake and river are 11, 4-12, and 1-12 days, respectively (EPA 1985a).

3.2 SORPTION

The soil sorption coefficient (K_{oc}) for TCE of 126 ml/g indicates high soil mobility. The leachability of TCE has been demonstrated in several groundwater monitoring studies.

3.3 PHOTOLYSIS

Direct photolysis of TCE in both water and the air is not a significant degradation process.

3.4 PHOTOCHEMICAL HYDROLYSIS

Atmospheric degradation of TCE is primarily via reaction with sunlight-produced hydroxyl radicals. The half-life is estimated to be 6.8 days. Reaction products include phosgene, bischloroacetyl chloride, and formyl chloride. Reaction of TCE with ozone in the atmosphere is too slow to be environmentally significant. In water, hydrolysis and oxidation of TCE are not important environmental processes.

3.5 BIOACCUMULATION

The potential for bioaccumulation of TCE in fish is relatively low. The estimated fish bioconcentration factor is 10.6.

3.6 BIODEGRADATION

Slow biodegradation of TCE occurs under anaerobic conditions. Dichloroethylene and, to a lesser extent, vinyl chloride are the biodegradation products. Due to the limited biodegradation, TCE may be relatively persistent in regions where volatilization is not viable.

4.0 CRITERIA

Air: The OSHA (1985) permissible exposure level for an 8-hour time weighted average (PEL-TWA) for TCE is 100 ppm. The acceptable ceiling/concentration is 200 ppm. Exposure may also be permitted up to 300 ppm for a maximum duration of 5 minutes every 2-hour period (OSHA 1985). The ACGIH threshold limit value (TLV) is 50 ppm and TLV short term exposure limit (STEL) is 200 ppm. The NIOSH recommended exposure limit (REL) TWA is 25 ppm.

Water: Effective January 9, 1989, the maximum contaminant level for TCE in water (MCL) is 5 ug/L. The recommended maximum contaminant level (RMCL) is 0.

The EPA derived Ambient Water Quality Criteria for Protection of Human Health (EPA 1980) - Carcinogenicity Protection associated with a cancer risk of 10^{-6} assuming a daily ingestion of 2 L water and 6.5 g fish and shellfish, is 2.7 ppb for protection against ingested water and organisms and 80.7 ppb for protection against the ingestion of organisms only.

The New York State Department of Environmental Conservation recommends a TCE ambient water quality guidance level of 0.01 mg/L when the source of the potable water supply is fresh groundwater (NYSDEC 1985).

5.0 BACKGROUND LEVELS

The average background level of TCE in the air is 11-30 ppt in the northern hemisphere (EPA 1985a). Water levels of TCE in open areas of the Gulf of Mexico are less than 1 ppt. In the northeastern Atlantic, average levels of 7 ppt were found. Typical concentrations of TCE in United States drinking waters are less than 1 ppb, and concentrations in soil are at less than 5 ppb.

6.0 TOXICITY

TCE is a central nervous system depressant and a mild irritant of the respiratory tract. Symptoms of exposure include drowsiness and eye and throat irritation. Injury to the cardiovascular system, gastrointestinal system, the liver, and the kidneys have also been observed. The liquid can penetrate the skin and prolonged contact may cause irritation, and repeated immersion of hands in the liquid has caused paralysis of the fingers.

NIOSH lists TCE as a carcinogen while IARC, the National Toxicology Program (NTP), and ACGIH do not.

The following TCE toxicity data have been determined experimentally:

Algae	600 mg/L
Arthropods (Daphia)	LD_{100}± 600 mg/L, 40 hr
	NOEL ± 100 mg/L
Fish (Fathead Minnow)	96 hr LC_{50} (flow through) = 40.7 mg/L
	96 hr LC_{50} (static) = 66.8 mg/L
Mouse	LC_{50} = 49,000 ppm, 30 min
	LC_{50} = 8,450 ppm, 4 hr
Rat	LD_{50} = 7193 mg/kg
Man	CNS effects = 27 ppm
	LCL_o = 2900 ppm
	LCL_o (oral) = 7 g/kg
	TCL_o = 160 ppm/83 min
Rabbit	skin irrit - 500 mg/24 hr: severe
	eye irrit - 29 gm/24 hr: severe

In fish, the lowest concentration of TCE in a acute exposure that causes toxicity in fresh water is 45 mg/L. Acute toxicity of fish in salt water occurs at 2 mg/L.

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1,1,2,2-TETRACHLOROETHANE

1.0 GENERAL

1,1,2,2-Tetrachloroethane was widely used as a solvent principally for cleaning and extraction processes, and as a chemical intermediate, primarily in the manufacture of trichloroethylene and tetrachloroethylene. Due to its toxicity, the manufacture and use has greatly diminished.

2.0 CHEMICAL AND PHYSICAL

Chemical Name	1,1,2,2-tetrachloroethane
Synonyms	sym-tetrachloroethane, acetylene tetrachloride; cellon; bonoform; 1,1-dichloro-2,2-dichloroethane
Chemical formula	$C_2H_2Cl_4$
Identification numbers	
CAS Registry No.	79-34-5
NIOSH RTECS No.	K18575000
EPA Hazardous Waste No.	U209
DOT/UN/INCO Shipping No.	UN1702
Natl. Cancer Inst. No.	CO3554

Property	Value
Molecular Wt.	167.86
Color	Colorless
Physical state	Liquid
Odor	3 ppm, chloroform-like odor
Melting point	-42.5°C
Boiling point	146.4°C
Solubility	
water	2,900 mg/L at 20°C
organic solvents	soluble in alcohol and ether
Specific gravity	1.6 (20/4°C)
Partition coefficients	2.39
Vapor density	5.79
Vapor pressure	5 mm at 20°C 8.5 mm at 30°C

Property	Value
Ionization potential	11.1 ev
Henry's law constant	3.81×10^{-4}
Refractive Index	1.4918
Flash point	None
Flammable limits	non-flammable
Corrosivity	Strong

3.0 ENVIRONMENTAL FATE

3.1 VOLATILIZATION

Since the vapor pressure of this compound is reasonable high, volatilization probably serves as the primary transport process for removal from aquatic systems (NTIS 1979). The half-life was determined experimentally to be on the order of 55 minutes to several hours. A 1 ppm solution of 1,1,2,2-tetrachloroethane at 25°C will evaporate 50 percent after 56 minutes (Verschueren 1983).

3.2 SORPTION

The data are inconclusive relative to sorption or mobility of 1,1,2,2-tetrachloroethane.

3.3 PHOTOLYSIS

Photolysis is probably not significant in aquatic systems but is significant in the atmosphere.

3.4 OXIDATION/PHOTOCHEMICAL HYDROLYSIS

1,1,2,2-tetrachloroethane is thought to undergo a photo-oxidation reaction with hydroxyl radicals once in the atmosphere with a half-life estimated as a few years.

3.5 HYDROLYSIS

1,1,2,2-tetrachloroethane undergoes hydrolysis at a rate corresponding to a half-life of several months to a few years. This process occurs too slowly to be of any significance.

3.6 BIOACCUMULATION

The log octanol/water partition coefficient indicates that bioaccumulation of 1,1,2,2-tetrachloroethane is possible, but its significance is unknown at present.

3.7 BIODEGRADATION

The biodegradation of 1,1,2,2-tetrachloroethane probably occurs at a low rate, if at all.

4.0 CRITERIA

Water: 1,1,2,2-tetrachloroethane has no drinking water standard. For the protection of human health, the EPA derived ambient water quality criteria for carcinogenicity protection (10^{-6} risk) against the ingestion of water and organisms and carcinogenicity protection against ingestion of organisms alone are 2.8 and 31.1 mg/L, respectively.

Air: The OSHA Permissible Exposure Limit (PEL) is 5 ppm. ACGIH recommends a Threshold Limit Value (TLV) of 1 ppm and a Short Term Exposure Limit (STEL) of 5 ppm. The compound has a notation for its ease of direct skin absorption.

5.0 TOXICITY

Exposure to 1,1,2,2-tetrachlroethane can depress the central nervous system and cause liver toxicity. Gastrointestinal irritation such as nausea, vomiting and abdominal pain are acute symptoms of exposure. More severe exposure may result in liver involvement, tender nephritis, and tremors of the hands and eyelids. Contact dermatitis may result from a direct skin exposure.

NIOSH lists 1,1,2,2 as a carcinogen while IARC, the National Toxicology Program (NTP), and ACGIH do not.

Some experimental toxicity results are as follows:

Man	TDLo (oral) = 30 mg/kg TCLo = 1000 mg/m^3/30 min
Rat	LD_{50} (oral) = 800 mg/kg LCLo = 1000 ppm/4 hr
Guppy (poecilia raticulata)	LC_{50} = 37 ppm, 7 day

The lowest concentrations of 1,1,2,2-tetrachloroethane found to cause toxicity in fish are 9.32, 2.40, and 9.02 mg/L for fresh water acute exposure, fresh water chronic exposure, and salt water acute exposure, respectively.

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