

**INDIANA HARBOR AND CANAL MAINTENANCE
DREDGING AND DISPOSAL ACTIVITIES – DESIGN
DOCUMENTATION REPORT**

MONITORING PROGRAM INCLUDING RCRA/TSCA

APPENDIX G

U.S. Army Corps of Engineers, Chicago District
Hydraulics and Environmental Engineering Branch

MONITORING PROGRAM INCLUDING RCRA/TSCA

APPENDIX G

TABLE OF CONTENTS

PURPOSE	1
GENERAL GOALS OF THE PLANS	1
RCRA CLOSURE/POST-CLOSURE PLANS AND TSCA PERMIT	2
CONTENTS OF THE CLOSURE PLAN AND POST-CLOSURE PLAN	3
General Facility Information.....	3
Facility History.....	3
DESCRIPTION OF RCRA ACTIVITIES	4
Closure Design Proposal.....	5
Confined Disposal Facility.....	5
CONSTRUCTION PLANS	7
CONTENTS OF THE CONSTRUCTION PLANS	7
CONSTRUCTION QUALITY ASSURANCE PLANS	7
Components addressed in the CQA Program.....	8
OTHER PLANS FOR CONSTRUCTION.....	8
OPERATIONAL PLANS.....	8
DREDGING.....	9
Plans and Specifications	9
Equipment and Operation.....	9
Surface Water Monitoring During Dredging.....	10
Control of Oil	10
REHANDLING OF DREDGED MATERIAL.....	10
AIR MONITORING PROGRAM FOR OPERATIONAL ACTIVITIES	11
Background	11
Air Monitoring Plan.....	11
GROUNDWATER MONITORING OF THE GRADIENT CONTROL SYSTEM.....	11
Groundwater Monitoring Plan for the Gradient Control System.....	12
EFFLUENT MONITORING.....	12
MAINTENANCE PLANS.....	13
VEGETATION AND WILDLIFE MANAGEMENT	13
SITE SECURITY.....	13
ENVIRONMENTAL PROTECTION PLAN	13
HEALTH AND SAFETY PLANS	13
HEALTH AND SAFETY DURING CONSTRUCTION.....	14
PREPAREDNESS AND PREVENTION	14
HEALTH AND SAFETY DURING OPERATION	14
Monitoring Activities	14
Personal Protective Equipment (PPE).....	15
Decontamination.....	15
INSPECTION AND CONTINGENCY PLANS.....	15

GENERAL INSPECTION REQUIREMENTS	15
MAINTENANCE INSPECTIONS.....	15
CONSTRUCTION INSPECTIONS.....	15
REHANDLING INSPECTIONS.....	16
DREDGING EQUIPMENT INSPECTIONS.....	16
CONTINGENCY PLAN AND EMERGENCY PROCEDURES	16
PERSONNEL TRAINING PLANS.....	16
GENERAL PERSONNEL TRAINING REQUIREMENTS.....	16
DATA MANAGEMENT PLANS	16
OPERATION RECORD	16
AVAILABILITY, RETENTION, AND DISPOSITION OF RECORDS.....	17
CONSTRUCTION RECORDS.....	18
DREDGING RECORDS.....	18
MAINTENANCE RECORDS.....	18
SUBMITTAL OF DATA.....	18
RCRA POST-CLOSURE APPLICATION	19
OPERATION AND MAINTENANCE (O&M) MANUAL.....	19

LIST OF PLATES

Plate G-1. ECI Property Parcels.....	20
Plate G- 2. ECI Refinery Structures.....	21
Plate G-3. CDF Plan View.....	22
Plate G-4. CDF Cross Section.....	23
Plate G-5. Dredging and Monitoring stations	24
Plate G-6. Plan View of Rehandling Area.....	25

LIST OF ATTACHMENTS

- ATTACHMENT G-1 - LABORATORY ASSESSMENT OF VOLATILIZATION
OF INDIANA HARBOR SEDIMENT

- ATTACHMENT G-2 - INDIANA HARBOR VOLATILIZATION AND ODOR
ANALYSIS

- ATTACHMENT G-3 - GENERAL DECONTAMINATION SCHEMES AND
EQUIPMENT

PURPOSE

1. This appendix describes the general contents of the plans that will be developed for monitoring during dredging; monitoring during the construction, operation, maintenance, closure, and post-closure care of the CDF on Parcels IIA and IIB; and monitoring during the construction of the cap, closure, and post-closure of Parcel I of the ECI facility at Indiana Harbor. This appendix is a revision of Appendix N (Monitoring Plan) which was co-written with the U.S. Environmental Protection Agency, Region V (USEPA) and was included in Volume 2 of the CMP. The owner of the site is the East Chicago Waterway Management District (ECWMD) and the operator is the Chicago District, U.S. Army Corps of Engineers (USACE). For the purposes of this appendix, the term "owner/operator" will be used.
2. The plans described in this appendix are intended to provide sufficient detail for the project Design Documentation Report (DDR). The specific details will be provided in the Regulatory Requirements Report. Given the unique nature of this project, which is regulated by multiple environmental regulations including RCRA, TSCA, and the CWA, a memorandum of understanding is currently being developed with USEPA and Indiana Department of Environmental Management (IDEM). This memorandum will outline the regulatory framework to which the project will adhere. During initial coordination with USEPA and IDEM, the following permits or approvals will be necessary, at a minimum: TSCA, Section 402 of the CWA, and Facility Construction.
3. The bottom sediments in Indiana Harbor and Canal are polluted with heavy metals and organics, such as PAHs and PCBs. As a result, dredged materials will be disposed in a confined disposal facility (CDF). Following is a list of information which can be found in the Comprehensive Management Plan (CMP) and Final Environmental Impact Statement (FEIS). The characteristics of the sediment are discussed in Appendix E, Sediment Quality. The recommended dredging methods and water quality impacts of dredging are described in Appendix H, Dredging Technologies and Impact. The water quality impacts of the operation of the CDF and the environmental controls are described in Appendix F, Environmental Engineering.

General Goals of the Plans

4. The construction, operation, monitoring, maintenance, closure, and post-closure care of the project will be performed for several purposes, including:
 - a. To assure compliance with RCRA closure/corrective action and TSCA requirements for containment, operation, closure and post-closure care of the CDF and the underlying portions of the ECI facility.
 - b. To assure that completion of all activities associated with the project are in accordance with the Corps' plans and specifications, and compliance with all

applicable Federal, State, and local requirements, including RCRA closure/corrective action and TSCA permitting.

- c. To assure that any adverse impacts of construction, dredging or disposal do not occur or are minimized, to the extent practicable, and to prevent releases of contaminants from the areas which underlie the project.
- d. To assure that the integrity and performance of the project are maintained, and to assure compliance with all applicable Federal, State, and local standards.
- e. To provide information which will enable the owner/operator to identify changing conditions and/or alter CDF operations to enhance the overall effectiveness of the facility.
- f. To ensure the safety of workers.

5. The implementation of the various plans described here will be the responsibility of the owner/operator and will be executed by the owner/operator and its contractors. Modifications to any of the plans described in this appendix will be made as site conditions, operations, and design modification(s) warrant. Changes to the plans will be coordinated with the following agencies, according to the applicable regulatory requirements of the Resource Conservation and Recovery Act (RCRA), the Toxic Substances Control Act (TSCA), the Clean Air Act, the Clean Water Act, and, as appropriate:

U.S. Environmental Protection Agency, Region 5
Indiana Department of Environmental Management

Reports of monitoring results will be submitted to the above agencies as required. These reports will also be submitted to other federal, state, and local agencies and the public for information upon request.

RCRA CLOSURE/POST-CLOSURE PLANS AND TSCA PERMIT

6. A Memorandum of Understanding (MOU) is currently being developed between IDEM; USEPA; the East Chicago Waterway Management District (ECWMD); and the U.S. Army Corps of Engineers, Chicago District (USACE). This MOU is designed to provide the overall legal and technical framework by which the parties will construct the CDF; complete the dredging; place the dredged material in the CDF; and upon completion of the project, close and monitor the CDF in accordance with all applicable legal requirements. In lieu of a Solid Waste Permit, this MOU will serve to delineate the aspects of RCRA closure/corrective action requirements. The details of these activities will be incorporated into the Regulatory Requirements Report. The plans will cover the closure and post-closure care of the RCRA hazardous waste units that were located on Parcel I, and corrective action activities associated with Parcels II A and II B. The plans will also address TSCA issues associated with the project.

Contents of the Closure Plan and Post-Closure Plan

7. This section describes information concerning the facility history and activities that that have been completed by the previous owner/operator(s). It also describes the construction, maintenance, and monitoring of the cap, cutoff wall, groundwater gradient control system, the treatment system, and any other equipment and structures associated with the closure aspects of the facility. A discussion of financial assurance, a requirement of RCRA will be included in the Regulatory Requirements Report.

General Facility Information

8. The entire ECI site is made up of separate parcels of land numbered from I to VII as shown on Plate G-1. The Lake George Branch of the Indiana Harbor Canal extends east west across the site, geographically dividing various parcels north of the canal. Thin strips of land owned by different railroad companies separate many of the individual parcels from each other.

9. The CDF will be located on parcels IIA and IIB. Parcel I contains the two former underground oil refinery structures which presently have open RCRA status. Plate G-2 shows the oil refinery structures on these three parcels prior to their demolition in response to the bankruptcy court order in the late 1980's. The refinery operations included the production of mineral spirits, propane, and unleaded gasoline, fuel oil, kerosene, asphalt and asphalt products, liquefied petroleum gas, grease, lubricating oils, paraffin wax, phenols, and sulfur.

Facility History

10. The ECI notified the USEPA, Region 5 of hazardous waste activity on this site on July 1, 1980. The ECI subsequently submitted a Part A permit application required by RCRA regulations on November 13, 1980. The permit application indicated hazardous waste storage in tanks and treatment by incineration. The hazardous wastes listed were slop oil emulsion solids from the petroleum refining industry (K049) and American Petroleum Institute (API) separator sludge from the petroleum industry (K051). While the ECI facility's RCRA application indicated the incinerator was intended for hazardous waste disposal, the company insists that there is no evidence that the incinerator had been used for hazardous waste treatment.

11. The facility had RCRA interim status for the storage and treatment of hazardous waste when ECI filed for reorganization under Chapter 11 bankruptcy in 1981. ECI later attempted to abandon the property, but the United States Bankruptcy Court, Northern District of Illinois, Eastern Division, ordered the facility to close in an environmentally sound manner and allocated funds to accomplish this task. However, the court-approved demolition of the plant did not include the closure of the hazardous waste units as required under RCRA and did not address the RCRA corrective action requirements. The court-ordered demolition activities occurred in the mid-1980's and all buildings and above ground structures were razed. The hazardous wastes identified for removal by the

contractor during the court ordered closure activities were: 600 cubic yards and two tanks containing a total of 2,558 barrels of API separator sludge; two tanks totaling 61 barrels of slop oil emulsion solid; six drums of tetraethyl lead waste; and 7,000 barrels of waste gasoline. In addition to the tanks, storage containers, and incinerator on-site, there were several pits, sumps, and spill areas. Pumps were removed from lead pump pits and then the pits were filled. There was no testing of residuals that remained in the pits. After the above ground structures were removed, the site was graded and several inches of clean topsoil were placed on the site.

12. In 1989, the city of East Chicago became the owner of the ECI site as payment for back taxes owed by ECI. In assuming ownership without approved corrective and closure actions in place, the City of East Chicago also assumed the liability for the site. In 1994, the property was transferred to the East Chicago Waterway Management District and is currently a responsible party for the site.

Description of RCRA Activities

13. The IDEM has determined that RCRA closure will be required on parcel I, which contained the hazardous waste management units. Due to soil and groundwater contamination, which may have come from these units, this parcel is also subject to post-closure permitting requirements. Closure/post-closure requirements focus on two main actions: (1) an in-place closure cap system including a cutoff wall, and (2) a groundwater gradient control system that will prevent contamination from leaving the site.

14. The USEPA has concluded that parcels IIA and IIB require RCRA corrective action due to apparent extensive on-site surface and groundwater contamination. Based on site characterization studies, corrective action can range from excavation and proper disposal of isolated contaminants to providing an in-place cap system and a groundwater gradient control system. A complete site characterization study of parcels IIA and IIB would be very costly. In lieu of such an expensive study, the USEPA determined that a worst case corrective action approach was warranted, including construction of an in-place clay cap system with a cutoff wall around the perimeter of the site, and implementation of a groundwater gradient control system. In addition an effort was initiated to optimize a plan to combine the required RCRA closure and corrective actions with construction of a CDF on parcels IIA and IIB. The objective of the discussions was to develop a combined plan that (1) was cost-effective and environmentally sound; (2) met regulatory requirements; and (3) resulted in significant cost savings for both Federal and non-Federal interests by undertaking a joint effort.

Closure Design Proposal

15. RCRA-Related CDF Aspects The CDF plan is shown on Figures G-3 and G-4. Parcel I of the ECI site previously housed the RCRA hazardous waste units. IDEM determined that closure in-place would be most appropriate for Parcel I. The in-situ closure design for parcel I will include 1) a cutoff wall with hydraulic conductivity of 10^{-7} cm/sec tied into the underlying clay unit, 2) a gradient control system consisting of groundwater extraction wells to maintain groundwater flow into the site, and 3) an overlying 3-foot compacted clay cap with a hydraulic conductivity of 10^{-7} cm/s. The compacted clay cap will be placed on the existing surface and will overlie parcel I. The USEPA has determined that construction of these components would also address the corrective action requirements for parcel I. These RCRA closure and corrective action components have been incorporated into the CDF design. Even though the cap will be constructed on parcel I at the beginning of the project, parcel I will not be subject to the RCRA post-closure care and permitting requirements applicable to hazardous waste units for maintenance and monitoring until the CDF is capped. The post-closure care requirements under RCRA will be integrated into the maintenance and monitoring requirements for the CDF.

16. The CDF will overlie ECI site parcels IIA and IIB. Unlike Parcel I, these parcels never housed hazardous waste units and are not subject to the RCRA closure requirements. However, these parcels are subject to the RCRA corrective action requirements, which address releases associated with waste handling practices to the environment. During the initial design phase of the project the implementation of corrective action within the State of Indiana was the responsibility of the USEPA. Given the apparent widespread contamination of these parcels, both the USEPA and IDEM determined that an acceptable corrective action condition for these parcels would be similar to the corrective action outlined above for parcel I. This will consist of the cutoff wall and the groundwater gradient control system. The final cap for this site will be accomplished at the same time as final closure of the CDF. The corrective action maintenance and monitoring requirements for these parcels will be integrated into the maintenance and monitoring requirements of the CDF.

17. The features to create an inward hydraulic gradient and provide for treatment of groundwater collected within the cutoff walls will include installation of extraction wells with pumps to provide the inward gradient. The wells will be located within the perimeter of the cutoff wall and around parcels I, IIA, and IIB. Contaminated groundwater collected in connection with the gradient control system will be discharged to the canal after treatment at an on-site wastewater treatment plant. The pore water and precipitation run-off within the CDF will also be treated in the treatment plant.

Confined Disposal Facility

18. The CDF will be constructed on parcels IIA and IIB, as shown on Plate G-3. A single-track railroad spur currently separates the two parcels but will be re-routed to the north side of the site. The CDF will occupy 83 of the 115 acres of parcel IIA, located south of the track, and 45 of the 53 acres of parcel IIB, located north of the track. The

CDF will be constructed as three separate cells, two in the southern portion of the site and one in the northern portion. The west cell in the southern portion of the site will be isolated and used for the disposal of the TSCA level PCB-contaminated sediment. The CDF design incorporates those elements necessary for risk-based TSCA approval. TSCA maintenance and monitoring requirements will be integrated into the maintenance and monitoring requirements for the CDF.

19. The CDF will have a capacity of approximately 4.8 million CY. The initial 15-foot lift will have a capacity of approximately 2.3 million CY. Construction of the second lift of 15-feet will increase the CDF capacity to 4.83 million CY.

20. Plate G-4 shows a cross-section through the CDF. The CDF dikes will be constructed in two stages in incremental lifts of 15 feet. The first stage earthen dikes will be constructed using off-site clean fill materials. The second stage dikes will be constructed of off-site materials beginning approximately 9 years after initial dike construction. The dikes will be constructed on top of a 3-foot layer of compacted clay tied into the cutoff wall. The interior side slopes of the dikes will be lined with a 3-foot layer of compacted clay tied into the bottom clay layer. On-site materials will be used to construct the initial 10-foot lift of the interior center dike separating the two cells of parcel IIA. Dried dredged material will be used to continue subsequent construction of the cross dike.

21. The final 6 feet (cap) of the second stage lift will consist of clay, sand, clean fill and seeded topsoil. The clay will seal the CDF and provide for the RCRA capping of parcels IIA and IIB. The sand will provide for drainage of precipitation off of the CDF. The exterior side slopes of the dikes will also be covered with topsoil, seeded, and landscaped as the dikes are constructed to control erosion and enhance their visual appearance.

22. Construction and operation of the CDF will require an on-site treatment plant to provide treatment of the precipitation run-off within the CDF, pore water from the disposed sediment, and groundwater collected from the gradient control system.

CONSTRUCTION PLANS

23. Contractors working under contract to the owner/operator will construct the CDF. These contractors will construct the CDF disposal cells, cutoff wall, treatment facility, rehandling area, and groundwater extraction wells in strict accordance with the plans and specifications prepared by the owner/operator, and approved by the appropriate agencies. As part of the quality assurance program, the owner/operator will require documentation by the contractor on all aspects of construction. The plans described in this section are intended to provide sufficient detail for the project DDR, specific details will be provided in the Regulatory Requirements Report.

Contents of the Construction Plans

24. Prior to the construction, the owner/operator will prepare Construction Plans addressing:

- a. The RCRA closure cap for Parcel I;
- b. The cutoff wall and groundwater extraction system for Parcels I, IIA, and IIB;
- c. The treatment system for groundwater collected from the gradient control system, pore water from the dredged material, and precipitation run-off within the CDF;
- d. A rehandling area for transfer of dredged material from barges to the trucks, or other waste management transportation equipment (conveyors, pipelines); and
- e. The CDF disposal cells (including dikes, run-off controls) and a final cap.

25. The Construction Plans shall include, but not be limited to: Plans and Specifications; descriptions of the activities and performance standards; a Construction Quality Assurance Plan (CQA Plan); a Health and Safety Plan; and an Environmental Protection Plan.

26. The Plans and Specifications and detailed descriptions of the construction of the facility structures shall provide information regarding the materials and methods to be used in construction, and the applicable performance standards that the designs and operations will meet.

Construction Quality Assurance Plans

27. The owner/operator prepares a Construction Quality Assurance Plan (CQA Plan) that identifies the level of inspection and testing necessary to construct or install a RCRA cap, cutoff wall, groundwater extraction wells, treatment system, rehandling area, and the CDF disposal cell specifications used in the designs.

28. The CQA officer, a registered professional engineer, develops the CQA plan. The CQA officer will ensure that the constructed units meet or exceed all design criteria and specifications in the RCRA closure and post-closure plans and the TSCA permit as defined in the MOU.

Components addressed in the CQA Program

29. The owner/operator shall develop and implement a written CQA Plan. The CQA Plan will identify steps that will be used to monitor and document the quality of materials and placement and to remedy any construction not meeting the requirements of the Plans and Specifications.

30. The CQA Plan involves inspecting, monitoring, and sampling and testing to ensure that construction materials and methods meet the contract plans and specifications. This plan will meet the criteria in the quality assurance plan prepared by the owner/operator, and any applicable regulatory requirements. During construction, the contractor prepares daily quality control reports, which are reviewed by quality assurance representatives of the owner/operator on a regular basis.

31. The following components of the project will require a CQA program for installation:

- a. The CDF disposal cells (including dikes, run-off controls, and low-permeability soils); and final cap on CDF and Parcel I;
- b. The cutoff wall (possibly including materials; cutoff; geomembranes; and backfill mixing facilities) and groundwater extraction system;
- c. The rehandling area; and
- d. The wastewater treatment system (including tanks, filters, etc.).

32. A certification package will be completed by the CQA officer that the approved CQA plan has been successfully carried out and that the components of the project meet the requirements of the RCRA closure and post-closure plans and the TSCA permit. The certification and supporting documentation will be made available to the appropriate agencies.

Other Plans for Construction

33. The owner/operator (or contractor) will also prepare the following: a Health and Safety Plan and an Environmental Protection Plan, specific to construction activities.

OPERATIONAL PLANS

34. The operation of the CDF and the containment and collection systems involves a number of separate, but coordinated functions (see Appendix E for a detailed discussion).

These include dredging, rehandling, placement of dredged material, dewatering, operating the groundwater gradient control system, and collecting and treating the wastewater. The operation monitoring described below will occur during and after each dredging and disposal event. An individual dredging operation may last about four to six months and is usually performed in the non-winter months. The frequency of dredging operations may occur every year or once every several years. The operation of the gradient control system and wastewater treatment plant will be year round to maintain the inward gradient into the site and to treat the CDF effluent and groundwater from the gradient control system, respectively. Monitoring of the effluent treatment system and gradient control system will occur on a regular basis.

35. These activities could be conducted by a private contractor or by one or more subcontractors. The plans described in this section are intended to provide sufficient detail for the project DDR, specific details will be provided the Regulatory Requirements Report.

Dredging

36. It is proposed that the maintenance dredging of the Indiana Harbor and Canal be performed by a mechanical dredge using a closed-bucket clamshell. This method will be used in order to minimize turbidity from the resuspension of sediments to the water column, to minimize spillage of dredged material, and to minimize quantities of water from the dredged material requiring treatment.

Plans and Specifications

37. The plans and specifications are written by the Corps and are the design documents that the contractor follows for construction and dredging. Prior to commencing work, all contractors will be required to prepare plans for quality control, health and safety, contingencies, and environmental protection as described in this appendix. Corps representatives will provide quality assurance oversight (construction management and quality assurance) of the dredging and disposal activities.

38. A Quality Assurance (QA) Plan associated with the dredging operation shall identify the procedures of dredging, equipment used and quality assurance of the equipment, and quality assurance aspects for the dredging itself to ensure that procedures are followed properly.

Equipment and Operation

39. The general type of equipment to be used and the method of dredging are described in Appendix H, Dredging Technologies and Impacts of the CMP. Spillage will be minimized during the dredging and rehandling operations. The volume of dredged material placed in the transport barge or scow shall not exceed the barge's capacity to hold the material without overflowing or spilling while either in motion or at rest.

40. The skill of a dredge operator can have as much effect on reducing resuspension and turbidity as the type of dredge used. Certain practices, such as dropping the dredge bucket "free-fall", dragging the bucket on the bottom, and opening the bucket too high over the barge will not be allowed.

Surface Water Monitoring During Dredging

41. The owner/operator shall monitor the impact of the dredging operation upon the surface water in the vicinity of the dredge. This plan shall monitor for the parameters of suspended solids (or turbidity) and ammonia nitrogen. The specific frequency for monitoring, action levels, and locations will be developed in the Regulatory Requirements Report. If the performance goals established in the plans are not met, the contractor will be required to modify the operation.

42. A brief description of the monitoring plan follows. During the dredging operation, two fixed stations will be monitored along with stations around the dredge. The fixed stations will be at the upstream limit of the navigation channel (141st Street at the Calumet Branch) and in the approach channel (see Plate G-5). The other three stations around the dredge will be located 200 feet upstream and 200 and 500 feet downstream of the dredge. These latter stations will move with the dredge.

Control of Oil

43. If determined to be necessary by the occurrence of visible floating oil, an oil boom shall be deployed around the dredge in such a manner as to control any floating oils generated as a result of the dredging operation. Sorbants will be used to collect the oil contained by the oil boom.

44. The sorbant materials will be collected as they become saturated with oil. All oil-saturated sorbant materials shall be collected, stored, and disposed of within the CDF. It is not anticipated that the concentration of PCBs in the sorbant material will approach 50 ppm; however, if the sorbant materials exceed 50 ppm PCBs, then these materials will be disposed of in accordance with appropriate Federal and State regulations.

Rehandling of Dredged Material

45. Rehandling is the transfer of dredged material from the barges to the CDF. The dredged material will be transferred from the barges/scows for transportation to the CDF. Barges will be unloaded from a rehandling area at the ECI property along the Lake George Branch of the Canal. The transfer occurs in the rehandling area and, then the dredged material is transported into the CDF via haul roads constructed on top of the dikes.

46. The details for the rehandling operation will be provided in the Regulatory Requirements Report. However, it is likely that some type of small crane system will be used to transfer the dredged material from the barge/scows into trucks. Plate G-6 shows a

plan view of the rehandling area. The contractor will be required to provide any appropriate safeguards to prevent leakage or spillage into the canal.

Air Monitoring Program for Operational Activities

Background

47. An air monitoring program will be developed to ensure the protection of workers on-site; protection of the environment; and the evaluation and mitigation of off-site releases. As part of the Comprehensive Management Plan (CMP) for the project, a “screening level” analysis was completed to estimate the loss of contaminant losses through the air pathway. However, during the timeframe of this investigation there was little information available relating estimated fluxes, using mathematical models, to measured fluxes from laboratory or pilot scale experiments. Therefore, a laboratory experiment was conducted in order to determine measured contaminant fluxes under various conditions and confirm the conservative nature of the mathematical models. The experiment was conducted by the Corps’ Waterways Experiment Station (WES) and consisted of conducting five runs in laboratory scale flux chambers. The results of the experiment are documented in a Report titled Laboratory Assessment of Volatilization from Indiana Harbor Sediment dated September 23, 1997. In addition the Chicago District wrote a summary report that analyzed the results of the WES report and compared the laboratory or experimental fluxes to the modeled fluxes. This report is titled Indiana Harbor Volatilization and Odor Analysis and is dated December 1998. Both of these reports are attached to this Appendix.

Air Monitoring Plan

48. The contaminants of concern for this project include PCBs, PAHs, ammonia, and hydrogen sulfide. The specific locations, frequency, action levels and data evaluation for the monitoring plan will be determined in the Regulatory Requirements Report. This program will be submitted to the appropriate agencies for review and comment. Final approval of the worker safety aspects of the plan will be made by the Safety Officer for the Corps.

49. There will be two types of air monitoring. Ambient air sampling will be conducted using high-volume samplers positioned around the perimeter of the site. The purpose is to provide “fence-line” concentrations, so that the potential for any off-site impact can be determined and rectified. Personal/equipment sampling will be conducted to determine if the on-site workers are being adequately protected. It is expected that Level C dress-out (e.g., protective coveralls, gloves and a face respirator) may be required for all workers involved in sediment dredging, hauling, truck unloading, and processing operations.

Groundwater Monitoring of the Gradient Control System

50. The CDF resides on the site of a former petroleum refinery in a heavily industrialized area. The groundwater flow may be influenced by groundwater pumping (extraction) at adjacent industries; infiltration to local sewers; and by the Lake George

Branch of the Canal. The soil and groundwater at the site, and adjacent to the site, are believed to be contaminated with petroleum products and metals. These conditions may result in high background concentrations for a number of constituents, and limit the ability to detect groundwater impacts from the project. For this reason, an inward gradient will be established. Monitoring of the water level shall be performed to ensure that the extraction system (i.e. the wells and pumps) does not fail.

51. The two types of wells installed for the gradient control system will be extraction and monitoring wells. Groundwater extraction wells will be used to collect groundwater from inside the area surrounded by the cutoff wall and to measure the water level. Extraction wells for the project shall be installed within the perimeter of the cutoff wall around Parcels I, IIA and IIB. Monitoring wells will be used to measure the water level in the area outside the cutoff wall.

Groundwater Monitoring Plan for the Gradient Control System

52. The monitoring program will address the gradient control system. Water level monitoring of the groundwater will be conducted, in order to assure that an inward gradient is maintained and to ensure that groundwater will flow towards the site, preventing the release of groundwater contamination. Also contingency plans shall be prepared in case a failure should occur that would result in groundwater levels within the site exceeding groundwater levels beyond the property boundaries, thereby allowing the potential for groundwater contamination to move off-site.

Effluent Monitoring

53. Effluent will consist of precipitation run-off within the CDF, pore water from the disposed sediment, and groundwater collected from the gradient control system. The run-off and pore water are variable over time. The groundwater collection systems will be maintained and operated during the operating life and the post-closure care period.

54. The surface run-off and pore water release will be collected in sumps within the CDF disposal unit and ponded within the CDF. An onsite wastewater treatment plant (WTP) will process this effluent before being discharged to the Lake George Branch of the canal.

55. Gradient control system pumping will occur when the water elevation difference between the inside and outside of the cutoff wall is less than 1-2 feet. Subsurface pumping to control the groundwater gradient will be initiated before disposal operations commence to create an inward gradient into the subsurface of the project. The inward gradient control around the perimeter of Parcels I, IIA, and IIB will continue throughout the operation and post-closure period.

56. The discharged effluent from the WTP will be monitored in accordance with permit requirements issued by the IDEM. Additional information on aspects of the design of the WTP can be found in Appendix D.

MAINTENANCE PLANS

57. Maintenance of the project includes a number of activities, such as management of vegetation and wildlife and maintaining site security. These activities will be performed by the owner/operator and its contractors. Although the detailed schedule for these activities has not been established, the frequency will be greater during the active life of the project and less frequent during the post-closure care period. The plans described in this section are intended to provide sufficient detail for the project DDR, specific details will be provided in the Regulatory Requirements Report.

Vegetation and Wildlife Management

58. The dredged material and vegetation at the site has the potential to become an attractive habitat for wildlife. Plans will be developed in consultation with United States Department of Agriculture, United States Fish and Wildlife Service, and Indiana Department of Natural Resources to biologically monitor the site and provide activities to reduce, minimize, or eliminate impacts to wildlife.

Site Security

59. Site security measures will be required to minimize the possibility for the unauthorized entry of persons onto the facility at any time. The project will be completely surrounded by a chain link fence. There will be a means to control entry through gates or other entrances to the active portion of the facility. Warning signs instructing unauthorized personnel to keep out will be posted at each entrance and at other locations in sufficient numbers to be seen from any approach to the active portion of the facility. Only owner/operator personnel and authorized visitors will be given access to the site. The owner/operator shall report to the appropriate agencies of any violators intruding the facility, and an evaluation shall be made to determine if any changes in security are necessary.

ENVIRONMENTAL PROTECTION PLAN

60. For a given activity, a contractor will be required to develop an Environmental Protection Plan (EPP). The EPP will document how all applicable federal, state, and local environmental laws and regulations will be followed. The plan will describe ways in which to safeguard the environment from damage or potential impacts resulting from construction, operational, and maintenance activities.

HEALTH AND SAFETY PLANS

61. The plans described in this section are intended to provide sufficient detail for the project DDR, specific details will be provided in the Regulatory Requirements Report.

Health and Safety During Construction

62. The contractor will prepare a Health and Safety Plan which detail methods designed to reduce and ameliorate accidents, which could occur during construction. This plan consists of two components. The administrative safety plan identifies personnel responsible for ensuring that on-site safety precautions are implemented. A hazard analysis is also performed on site conditions that may pose safety hazards and ways to avoid accidents. The Health and Safety Plan shall also address medical emergency response procedures, and potential exposure to contaminants from any on-site source. Accident prevention measures must meet or exceed the requirements of the Corps Engineer Manual EM 385-1-1 Safety and Health Requirements, and any other federal, state and local requirements (e.g. OSHA).

Preparedness and Prevention

63. The facility will be designed, constructed, maintained, and operated to minimize the possibility of a fire, explosion, or any other unplanned sudden or non-sudden release of hazardous waste constituents to the air, soil, or surface water which could threaten human health or the environment.

Health and Safety During Operation

Monitoring Activities

64. Various monitoring activities will have to be undertaken in connection with the dredging and disposal operations. The sediment to be dredged contains chemical compounds in concentrations, which could be harmful to workers either through skin contact or inhalation of released vapors or dusts. Therefore, an appropriate project safety and health program will be established and implemented. This program will be based upon the analysis of environmental data collected in the project area, which should include:

- 1) Representative sampling and chemical analysis of the sediment shall be performed so that worker protection alternatives are confirmed to be appropriate.
- 2) High-volume air sampling conducted at various locations throughout the project area to determine "work zones", as well as to measure the potential for effect of operations on the surrounding community.
- 3) Personal air monitoring to identify work assignments that pose the highest risk to worker health and safety. In addition, the results of personal air monitoring will indicate the level of protection required for any particular task on the site, or at which times levels of protection must be tightened or may be relaxed.

Personal Protective Equipment (PPE)

65. It is considered that Level C dress-out (e.g., protective coveralls, gloves and a face respirator) will be required during the initial stages of the project for all workers involved in sediment dredging, hauling, truck unloading, and processing operations. Acceptable air quality monitoring results could lead to the relaxation of respirator requirements. However, the protective coverall requirement will not be relaxed for those workers subject to contact with the sediment. A very limited probability exists that Level B dress-out (e.g., self-contained breathing apparatus) may be required at some time during the project.

Decontamination

66. All workers who enter a “hot” zone must be decontaminated prior to exiting the site. Teams who are wearing PPE at a level equal to that of the site worker they are assisting carry out decontamination. Decontamination team members become contaminated during the course of their duties and must decontaminate themselves prior to entry into lesser-contaminated areas. Attachment G-3 illustrates typical decontamination schemes and provides a list of equipment needed to support the decontamination process.

67. As with personnel, all tools, vehicles, and other equipment entering a contaminated area must be decontaminated prior to being released into non-contaminated areas.

INSPECTION AND CONTINGENCY PLANS

General Inspection Requirements

68. An Inspection Plan will be created as part of the Regulatory Requirements Report. The owner/operator or its representative shall inspect the facility for malfunctions and deterioration, operator errors, and discharges, which may cause - or may lead to - a release of hazardous waste constituents to the environment, or a threat to human health.

Maintenance Inspections

69. Inspection areas shall include the gradient control system, the wastewater treatment facility, the CDF, the rehandling area, and the RCRA cap for Parcel I.

Construction Inspections

70. Construction representatives from the Corps are present on-site during construction and dredging, operating from a temporary field office. These inspectors report directly to administrative staff at the District. Any changes in construction methods or materials are first reviewed by District engineers and environmental staff, and the appropriate regulatory agencies are contacted if necessary.

Rehandling Inspections

71. Appropriate safeguards shall be employed to prevent the spillage of dredged material into the canal. If the dredged material is transported via a pipeline or conveyor system, the Corps will inspect the integrity of the pipeline or conveyor system prior to disposal. Daily inspections for any leaks at the trucks, pipeline, or conveyor system will be conducted during disposal operation.

Dredging Equipment Inspections

72. Dredging equipment and barges/scows used to transport the dredged material will be inspected by the Corps prior to the start of work to assure that they meet the requirements of the approved plans and specifications, and inspected periodically during dredging. All barges/scows must be watertight. Overfilling of barges will not be allowed. If problems arise with the equipment, a contingency plan shall be implemented to correct any environmental releases, and correct the equipment problems.

Contingency Plan and Emergency Procedures

73. The owner/operator will have a Contingency Plan prepared for the facility. The Contingency Plan will be designed to minimize hazards to human health or the environment from any unplanned sudden or slow release of hazardous waste constituents to the air, soil, or surface water.

PERSONNEL TRAINING PLANS

General Personnel Training Requirements

74. The owner/operator will create a training program, which complies with any applicable requirements of RCRA, TSCA and OSHA. The Regulatory Requirements Report will describe a training program to be used at the facility, including worker health & safety, and a brief description of how the training program is designed to meet actual job tasks. Facility personnel must successfully complete a program of classroom instruction or on-the-job training that teaches them to perform their duties in a way that ensures the facility's compliance with any applicable requirements of RCRA, TSCA, and any other laws or rules.

DATA MANAGEMENT PLANS

Operation Record

75. The owner/operator shall maintain a written operating record at the facility. The following information shall be recorded, as it becomes available, and maintained in the operating record until closure of the facility:

- a. A description and the quantity of the dredging materials received, and the method(s), and date(s) of its disposal at the facility;

- b. For the CDF disposal unit, the reach number and quantity of dredged material will be recorded and the location of disposal will be shown on a map or diagram of the cell. A log should be maintained cross-referencing the location of the dredged material in the canal to the location in the CDF disposal unit where the material is disposed;
- c. the quantity of groundwater collected;
- d. Records and results of any dredged material or effluent analysis performed;
- e. Summary reports and details of all incidents that require implementing the Contingency Plan;
- f. Records and results of inspections;
- g. Monitoring, testing, or analytical data, and corrective action required for groundwater gradient system and air;
- h. All closure and post-closure cost estimates;
- i. Waste minimization records;
- j. Any applicable RCRA land ban record keeping;
- k. Any RCRA corrective action records; and
- l. Any applicable TSCA record keeping.

Availability, Retention, and Disposition of records

76. All records, including plans, required under RCRA and TSCA, and any other applicable regulations, will be furnished upon request, and made available at all reasonable times for inspection, by any officer, or representative of the USEPA or IDEM.

77. The retention period for all records required under RCRA and TSCA is extended during the course of any unresolved enforcement action regarding the facility or as requested by the USEPA or IDEM.

78. The retention period for all RCRA corrective action records is for the three years after the completion of all corrective action activities at the facility. This includes implementation and long-term monitoring.

79. A copy of records of material disposal locations and quantities shall be submitted to the USEPA, IDEM, and the local land authority upon closure of the facility.

Construction Records

80. The results of monitoring conducted in association with construction activities will be compiled into a report by the owner/operator or its contractor. This report will describe the as-built engineering diagrams and descriptions of the CDF disposal unit, the rehandling area, the wastewater treatment plant and any other ancillary equipment or handling units; the draft and final CQA reports; and any field data.

81. The reports of construction activities will be completed in a timely manner, after the conclusion of an individual construction operation.

Dredging Records

82. The results of monitoring conducted in association with an individual dredging and disposal operation will be compiled into a report by the owner/operator or its contractor. This report will describe the areas dredged, total quantities of materials dredged and disposed, methods of dredging. The results of turbidity monitoring around the dredge will be presented.

83. The reports of operational monitoring will be completed in a timely manner, after the conclusion of an individual dredging operation.

Maintenance Records

84. Maintenance activities and the monitoring associated with it are at regular and continuous intervals and not limited to times when dredging occurs. An annual report of maintenance activities and monitoring results will be prepared by the owner/operator or its contractors and include descriptions of site inspections and maintenance activities, groundwater gradient monitoring data, effluent monitoring, air monitoring, and surveys of vegetation and wildlife at the project.

85. The maintenance monitoring report will be prepared and distributed to the same agencies receiving the operation monitoring reports.

Submittal of Data

86. The data described in this appendix shall be furnished to the following agencies as part of RCRA, TSCA and Clean Water Act compliance:

U.S. Environmental Protection Agency, Region V
Indiana Department of Environmental Management

The reports will also be furnished for information upon request, including the following agencies:

U.S. Fish and Wildlife Service
Indiana Department of Natural Resources

Lake County Health Department

Other groups and individuals will be sent copies of these reports upon written request.

RCRA POST-CLOSURE APPLICATION

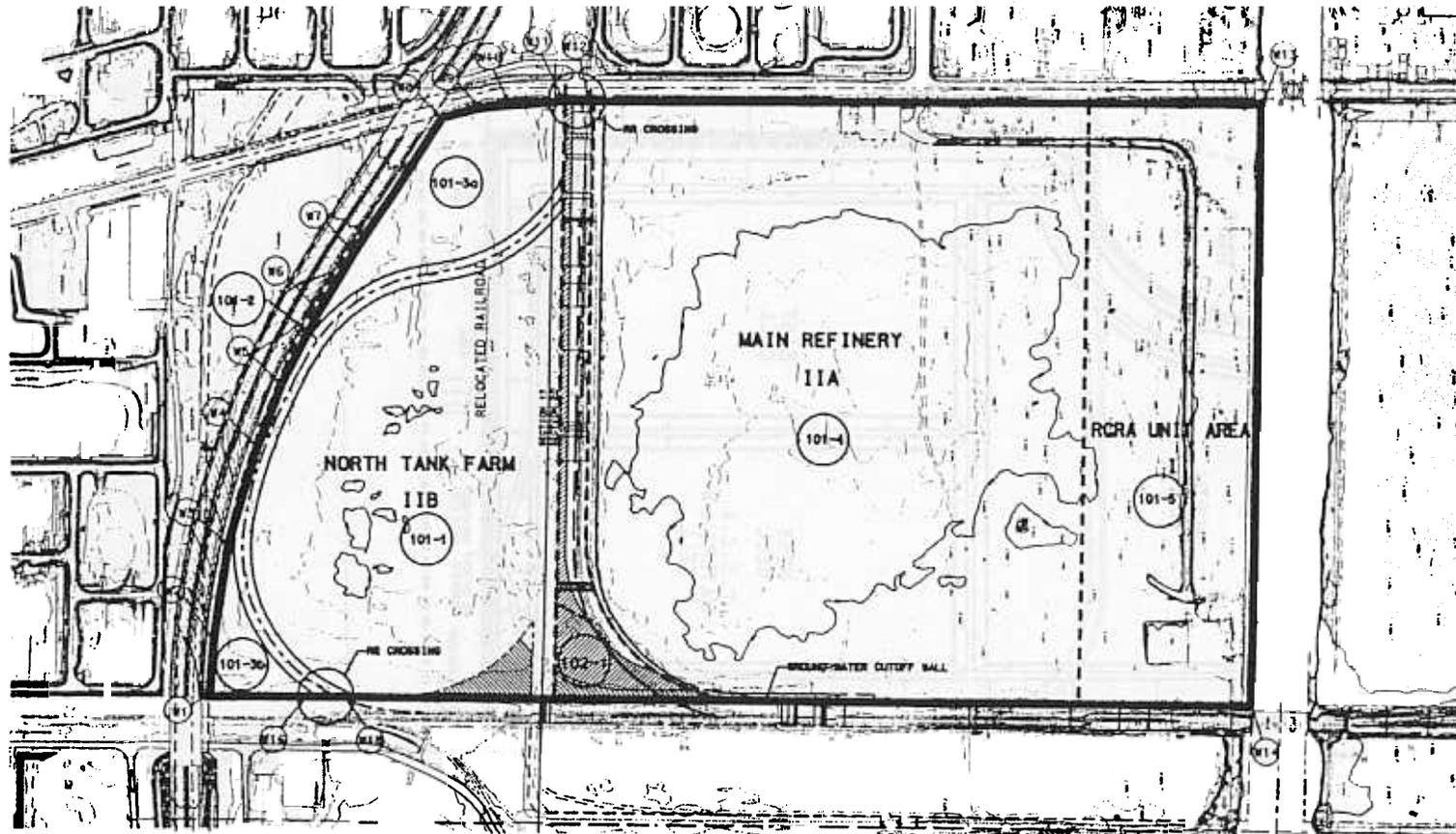
87. A RCRA post-closure permit application from the owner and operator of the ECI facility will be required. The post-closure permit application shall address the post-closure requirements for the project and corrective action requirements for all property parcels contiguous to the CDF. The requirements for a post-closure permit application are outlined in 40 CFR Parts 270 and 264. The USEPA and IDEM shall review the application, and propose to approve or deny the post-closure permit application. At that time public participation requirements of 40 CFR Part 124 shall take place. After public participation is completed (the end of the public comment period), the USEPA and IDEM shall make a final decision. If a post-closure permit is issued, the post-closure care period will take place for a minimum of 30 years, and the permit shall be renewed every 5 to 10 years.

OPERATION AND MAINTENANCE (O&M) MANUAL

88. The Corps produces an Operation and Maintenance (O&M) Manual for all CDF projects. The O&M manual for this CDF will contain descriptions of operations and maintenance activities. Most of the O&M activities will be in the nature of maintenance rather than operations.

89. Maintenance is divided into 1) maintenance of the channel and 2) maintenance of the CDF. Maintenance of the channel includes all costs for maintenance dredging including dredging and transporting the dredged material and soundings. It includes the costs to obtain necessary environmental permissions to perform the associated dredging. In general, maintenance of the CDF includes placement of the dredged material in the CDF, management of dredged material within the CDF to promote drying and consolidation of the dredged material (i.e. trenching, placing underdrainage system with additional lifts), and running the effluent treatment system and gradient control system.

90. The only operations activities are the activities regarding operational maintenance of the CDF. These are the activities that are of a recurring nature. It includes activities such as custodial services; removing snow and trash; relamping light fixtures; placing signs; painting of guard rails; and wildlife and vegetation management (i.e. mowing grass, cutting down vegetation).



PERMANENT EASEMENT		
NUMBER	NORTHING	EASTING
W1	1,514,487.0	389,213.8
W2	1,514,452.8	389,413.8
W3	1,514,404.2	389,758.8
W4	1,514,501.0	390,103.5
W5	1,514,215.8	390,322.0
W6	1,514,080.8	390,577.5
W7	1,513,957.1	390,773.8
W8	1,513,843.1	391,256.2
W9	1,513,506.5	391,290.7
W10	1,513,286.2	391,300.5
W11	1,513,207.8	391,315.3
W12	1,513,123.8	391,314.8
W13	1,510,731.1	391,304.9
W14	1,510,747.5	389,187.4
W15	1,513,985.8	389,214.4
W16	1,514,128.9	389,214.4

REA ESTATE LEGEND

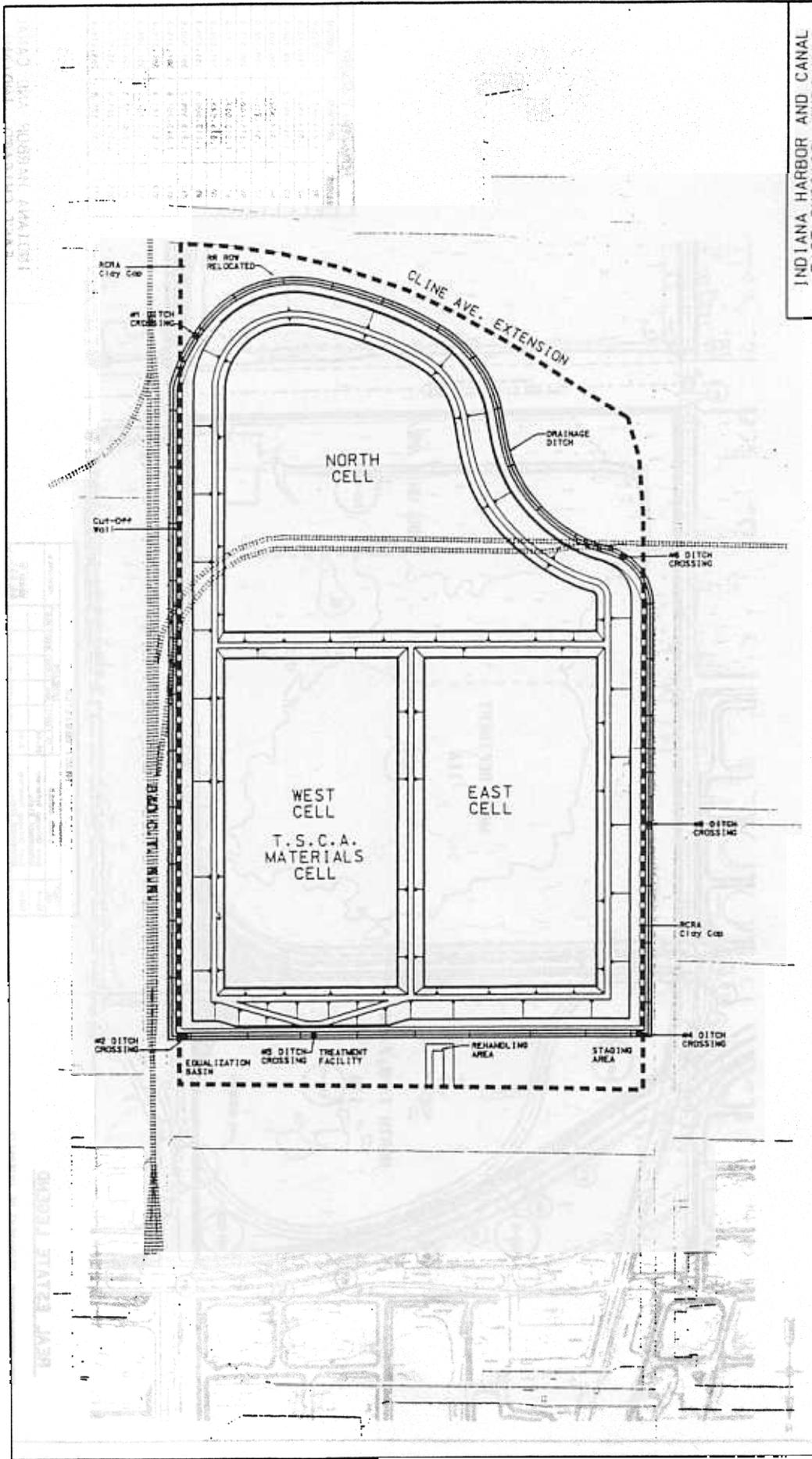
- PERMANENT RE INTERESTS
- CANAL CENTERLINE
- ROAD CENTERLINE
- PROPERTY BOUNDARY

TRACT REGISTER							
TRACT NO.	LAND OWNER	EASEMENT					REMARKS
		NO.	DATE	TYPE	STATUS	REMARKS	
101-1	East Chicago Refinery Management Dist.	38-04					
101-2	East Chicago Refinery Management Dist.	3-44					SUBJECT TO E.S. 8-2
101-3a	East Chicago Refinery Management Dist.	6-04					
101-3b	East Chicago Refinery Management Dist.	1-74					
101-4	East Chicago Refinery Management Dist.	05-02					
101-5	East Chicago Refinery Management Dist.	20-08					
102-1			6-98				EXISTING E.S. 8-20

INDIANA HARBOR AND CANAL
EAST CHICAGO, INDIANA
DESIGN DOCUMENTATION REPORT

REAL ESTATE MAP

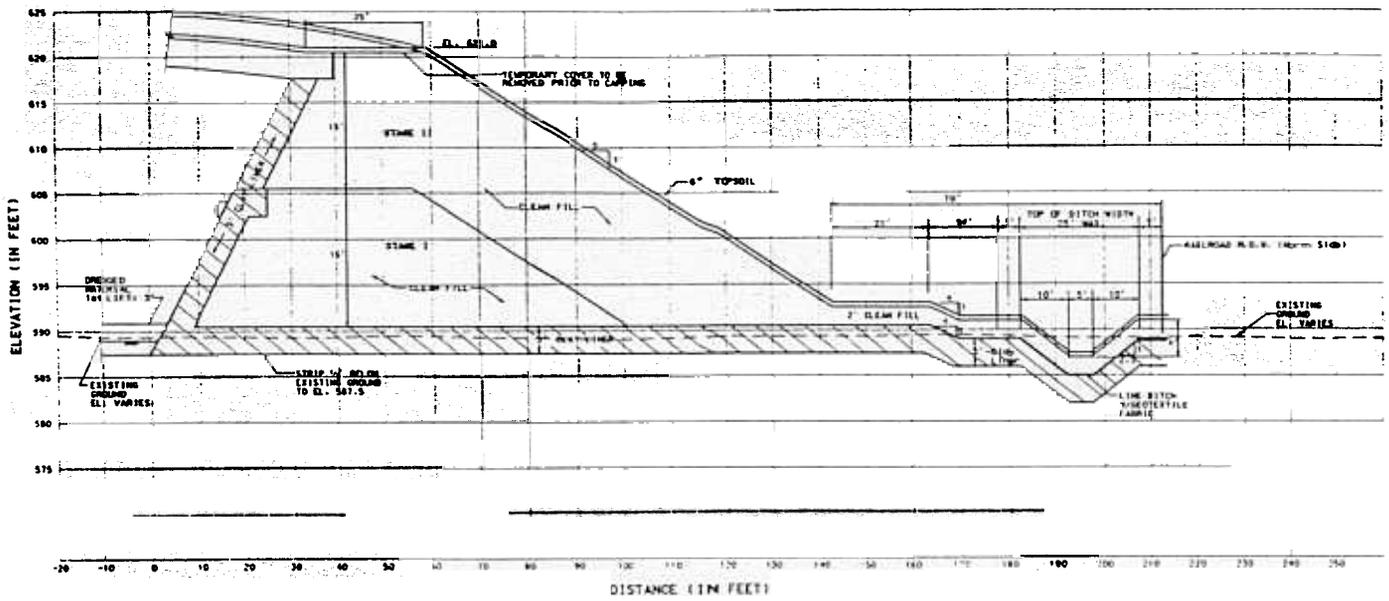
Scale AS SHOWN	Date DEC	1999	Drawing PLATE_01.DGN
----------------	----------	------	----------------------



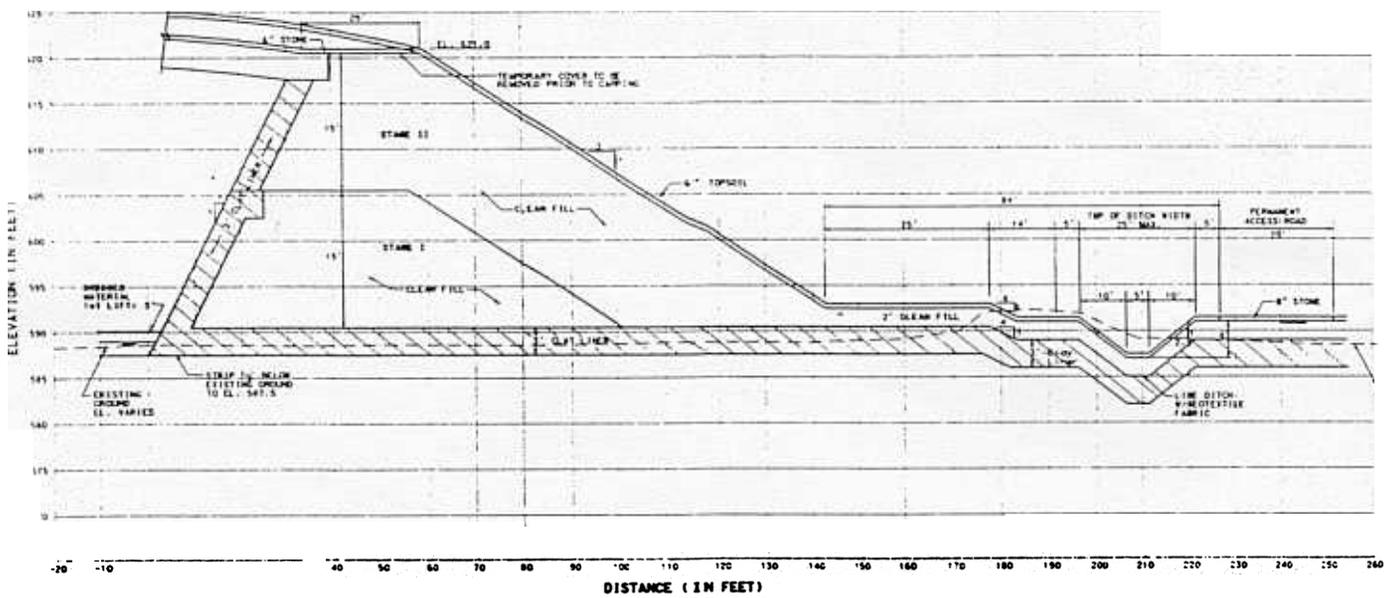
INDIANA HARBOR AND CANAL
 EAST CHICAGO, INDIANA
 DESIGN DOCUMENTATION REPORT

CDF PLAN VIEW

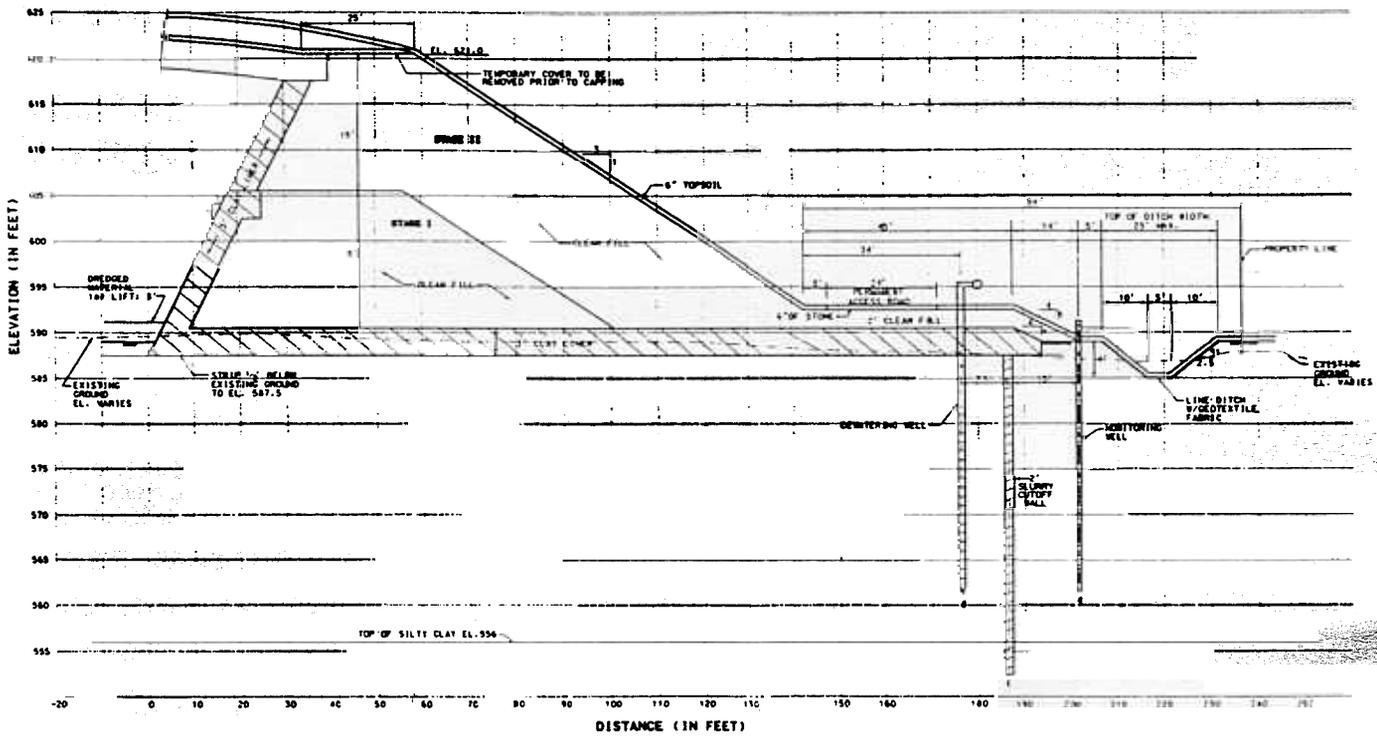
Scale: AS SHOWN Date: DECEMBER 1999 Drawing: PLATE.G3.DGN



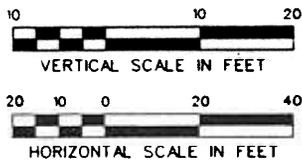
NORTH SIDE
TYPICAL DIKE & DITCH SECTION



SOUTH SIDE
TYPICAL DIKE & DITCH SECTION



EAST AND WEST SIDES
TYPICAL DIKE & DITCH CROSS SECTION

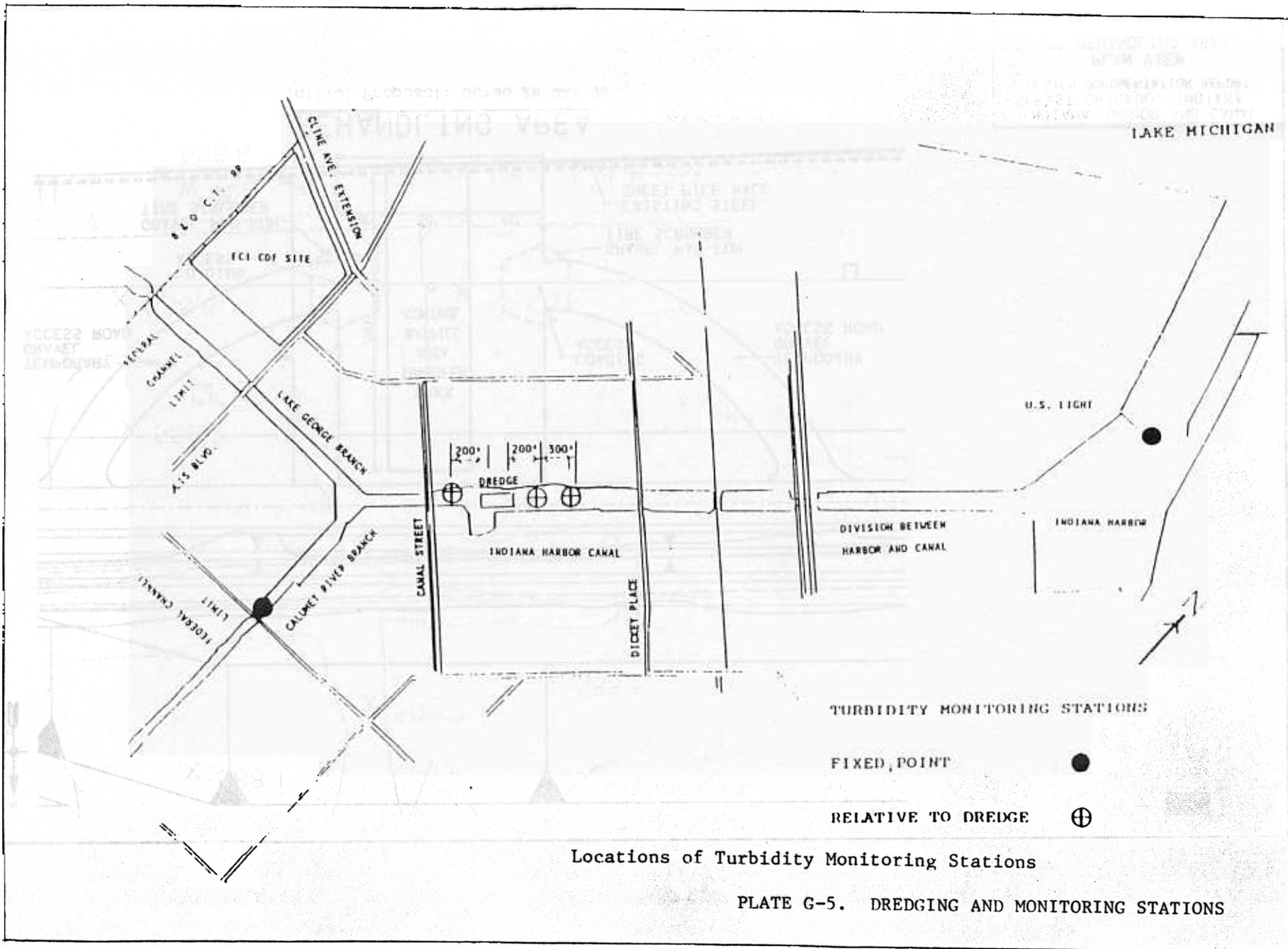


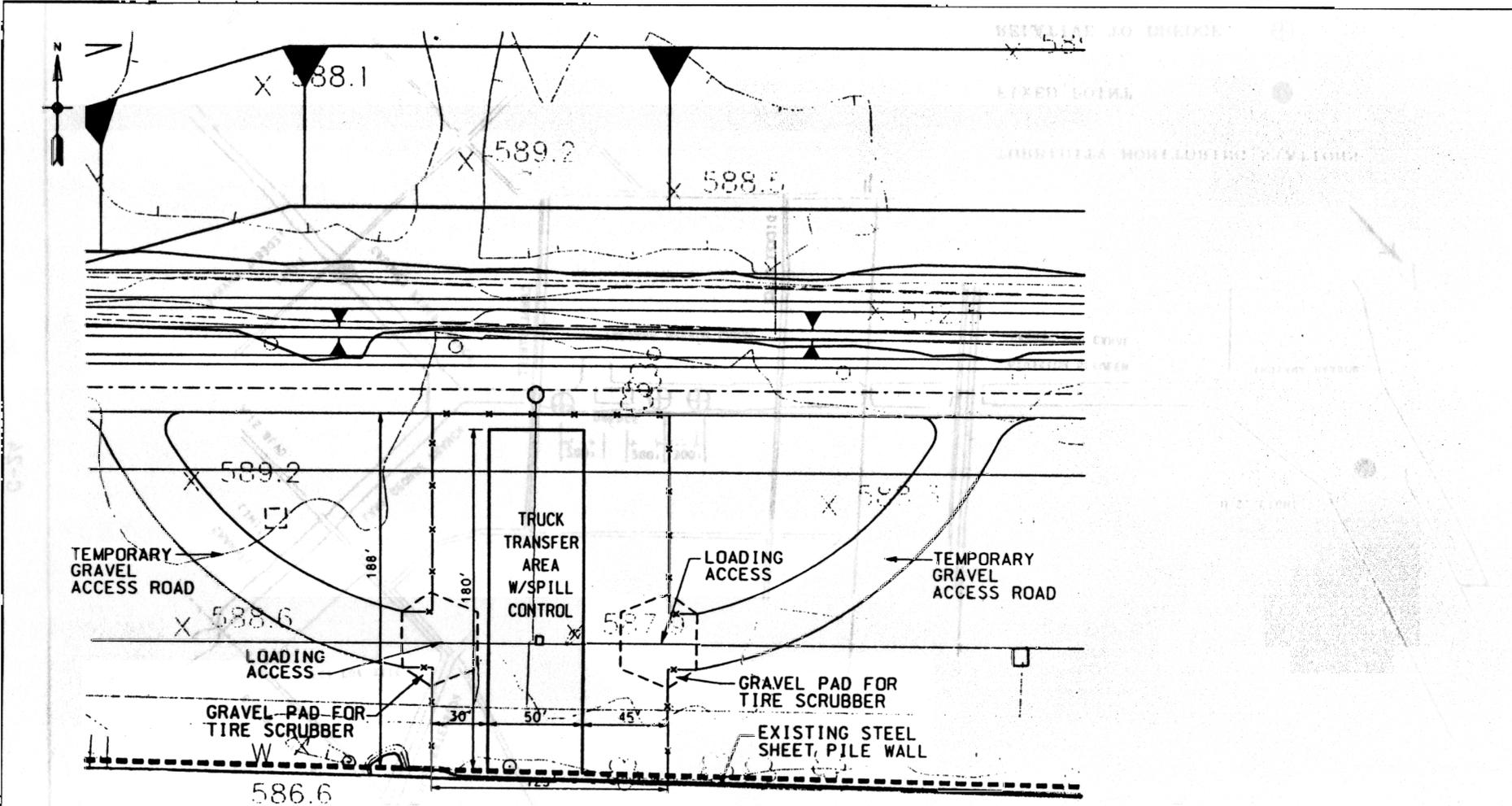
INDIANA HARBOR AND CANAL
EAST CHICAGO, INDIANA
DESIGN DOCUMENTATION REPORT

CDF CROSS SECTION

Scale AS SHOWN	Date DECEMBER 1999	Drawing PLATE_G4.DGN
-------------------	-----------------------	-------------------------

G-24





REHANDLING AREA

Initial Proposal: Dated 28 MAY 98

INDIANA HARBOR AND CANAL
 EAST CHICAGO, INDIANA
 DESIGN DOCUMENTATION REPORT
**PLAN VIEW
 OF REHANDLING AREA**

Scale AS SHOWN	Date DECEMBER 1999	Drawing PLATE_G6.DGN
-------------------	-----------------------	-------------------------

ATTACHMENT G-1
LABORATORY ASSESSMENT OF VOLATILIZATION
OF INDIANA HARBOR SEDIMENT



DEPARTMENT OF THE ARMY
 WATERWAYS EXPERIMENT STATION, CORPS OF ENGINEERS
 3809 HALLS FERRY ROAD
 VICKSBURG, MISSISSIPPI 39180-6199

C. Price
mail 9/23/97
Y

REPLY TO
 ATTENTION OF

CEWES-ES-P (70-1r)

23 SEP 1997
23 Sep 97

MEMORANDUM FOR Commander, U.S. Army Engineer District, Chicago,
 ATTN: CENCC-ED-HE (Mr. Jay Semmier), 111 N.
 Canal, Chicago, IL 60606-7206

SUBJECT: Transmittal of Report Entitled "Laboratory Assessment of
 Volatilization From Indiana Harbor Sediment"

1. In accordance with the Scope of Work entitled "Laboratory Testing and Evaluations for the Indiana Harbor ECI CDF," I am enclosing a copy of the subject final report.
2. If you have any questions or require additional information, my point of contact is Ms. Cynthia B. Price, 601-634-2802.

Encl

Robert W. Whalin
 ROBERT W. WHALIN, PhD, PE
 Director

COASTAL AND HYDRAULICS
 LABORATORY

GEOTECHNICAL
 LABORATORY

STRUCTURES
 LABORATORY

ENVIRONMENTAL
 LABORATORY

INFORMATION TECHNOLOGY
 LABORATORY

Laboratory Assessment of Volatilization From Indiana Harbor Sediment

Introduction

The loss of volatile contaminants from dredged sediments is an increasingly recognized environmental problem. For example, previous laboratory investigations with New Bedford Harbor sediment showed large amounts of volatile organic compounds (VOCs) emitted when the dredged material was disturbed and exposed to air as when placed in a CDF (Brannon 1989). Dredging and storage operations in confined disposal facilities (CDFs) can increase the potential opportunity for VOC emission. In a CDF sediments are subject to wet and dry cyclic conditions, variations in the relative humidity of the air above the sediment, and temperature fluctuations. Moisture content has also been shown to affect the sorptive capacity of sediments for VOCs (Valsaraj and Thibodeaux 1988).

The U.S. Army Engineer District, Chicago (CENCC) has requested assistance with evaluating various construction and management practices, including volatile emissions, for the Indiana Harbor ECI upland CDF project. Volatile emissions of organic contaminants and other odorous compounds that potentially reduce air quality are a concern due to (1) the proximity of a high school, and (2) potential adverse health impacts on the safety of site personnel. The USAEWES, in conjunction with Louisiana State University (LSU) (Dept. of Chemical Engineering), Baton Rouge, LA, has completed laboratory investigations that measure volatile emissions of polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), total recoverable petroleum hydrocarbons (TRPHs), ammonia, methyl mercaptans, and hydrogen sulfide from Indiana Harbor sediment.

This "memorandum for record" summarizes the laboratory results. Emphasis is on trends in volatile emissions as a function of evaporative sediment drying, "wet/dry" cycles, and sediment disturbance. A comparison of measured laboratory fluxes of selected PAH compounds with those predicted by theoretical models and emissions from spiked sediment are also presented in an attached paper prepared at LSU using laboratory data generated at the WES.

Methods

Flux Chambers

Tests were conducted using VOC flux chambers designed by LSU and constructed at WES (Figure 1). The two-piece anodized aluminum chambers were devised to hold sediment at a depth of 10 cm with a surface area of 375 cm². The top portion of the flux chamber was designed with channels to distribute airflow uniformly across the sediment surface. A glass window was provided to visually monitor drying of the sediment surface. The chambers were sealed with an O-ring and threaded fasteners for an airtight fit. Initial sediment contaminant concentrations were determined by HPLC analysis (EPA method 8270) and sediment moisture

content was measured prior to and following the test.

Experimental Design

Flux chambers were filled with a known volume (wet weight) of Indiana Harbor sediment and sealed. Air was passed over the sediment surface at 1.7 L/min. This rate was based upon earlier investigations conducted with flow rates in the flux chambers (Valsaraj et al. 1997). The flow rate was chosen to eliminate fluxes controlled by air-side resistance, thereby maximizing contaminant fluxes. Increasing the flow rate did not result in increased flux rates signifying that sediment-side resistance became the controlling factor. If air-side resistance dominates, fluxes would be low and at a constant rate; whereas, with sediment-side resistance fluxes show high initial values (maximum flux) followed by steady decreases. The relative humidity was maintained by using an in-line bubble trap as needed. A thermohygrometer (Cole-Parmer) was connected to the exit port to monitor air temperature and relative humidity.

Contaminant specific sampling tubes (Supelco Inc., PA) were attached to the chamber exit ports. TRPH's/PAH's and PCB's were trapped on XAD-2 glass sampling tubes (Orbo-44), and analyses were performed according to EPA method 8270 and 8081 respectively. Ammonia was trapped on H₂SO₄-coated silica gel (Orbo 554), and analyzed by OSHA method 6015. Hydrogen sulfide was trapped on specially treated, activated coconut charcoal (Orbo 34), and analyzed according to NIOSH method 6013. Mercuric acetate-coated A/E glass fiber filters (Orbo 826) enclosed in cassettes were used for detection of methyl mercaptan. Analyses were performed according to OSHA method 2542.

The experiment was designed to provide information on maximum contaminant fluxes expected under different air humidity, sediment moisture and site management conditions which might occur during CDF operations. The sample schedule consisted of five continuous runs simulating various conditions.

Runs I and II gave maximum initial contaminant fluxes from wet sediment under dry and humid air conditions. Dry air was passed over the sediment surface for two weeks (336 hours) for Run I. Samples were taken at 6, 24, 72, 168, 240 and 336 hours. The dry air was changed to humid air (98% RH) for Run II. Sampling times were 6, 24, 72 and 168 hours. For Run III the sediment was rewet to near field capacity to simulate a rainfall event. Dry air was passed over the sediment for 14 days. Samples were taken at 6, 24, 72, 168, 240 and 336 hours. Run IV consisted of reworking the sediment to represent the addition to or mixing of sediment during CDF operations. The sediment was reworked inside sealed glove bags equipped with sampling tubes to trap contaminants released during mixing. Contaminant fluxes trapped during mixing of the sediment were assayed (Table 1). Dry air was passed over the sediment surface for seven days. Samples were taken at 6, 24, 72 and 168 hours. The sediment was rewet to near field capacity for run V. Dry air was passed over the sediment for seven days. Samples were taken at 6, 24, 72 and 168 hours.

Results and Discussion

A sample of consolidated Indiana Harbor sediment was used. The sediment was contaminated with PAHs/TRPHs, PCBs (arochlors and congeners¹), ammonia, and hydrogen sulfide (Tables 2, 3, and 4 respectively). Indiana Harbor sediment is a silty-sand containing approximately 0.9% oil and grease, with an initial moisture content of 56%.

PAH Fluxes

Most of the hydrocarbons exhibited initial sharp decreases in flux rate within the first 72 hours following passage of dry air over the sediment surface in Run I (Table 4, Figure. 2). No increase in flux of any of the hydrocarbons was noted until test Run IV when the sediment was reworked. At that time flux rates showed a sharp increase to approximately that of the initial rate followed by a sharp decrease. The 0.9% oil and grease may have produced a thin oil-film layer on the sediment surface. Quick evaporation of this layer could account for the observed flux (Valsaraj 1997, attached paper). No increase in flux rates were noted when humid air was passed over the sediment in Run II as experienced in earlier investigations with laboratory-spiked sediment (Valsaraj et al. 1997). Sediment moisture fluxes which were monitored during the course of the test, showed no decrease in relative humidity which could account for the lack of an increase in flux rates when humid air was passed over the sediment. The sorptive capacity of sediments is strongly affected by sediment moisture; decreasing sediment moisture increases sediment sorptive capacity (Valsaraj et al. 1988). Naphthalene and acenaphthene showed the highest initial volatilization rates of 50 and 6.7 ng/cm²/hr, respectively. The third highest flux rate was 5.8 ng/cm²/hr for 2-methylnaphthalene. All other detectable PAH compounds showed initial volatilization rates of less than 3 ng/cm²/hr. Pyrene fluxes remained relatively stable over the course of the experiment.

TRPH Flux

The TRPH flux rate decreased from 500 to 175 ng/cm²/hr in 168 hours followed by an increase in rate to 867 ng/cm²/hr at the start of test Run II when humid air was passed over the sediment (Table 5). The increased flux of TRPHs suggests that the factors affecting TRPH differ fundamentally from those affecting PAHs. The response to humid air by TRPH fluxes indicated that the change in relative humidity of the carrier air in Run II may have decreased the sediment sorptive capacity for TRPHs allowing for increased volatilization. A large flux of TRPHs apparently occurred during reworking of the sediment. Approximately 34,000 ng/cm²/hr TRPHs volatilized during a 20 minute mixing interval. A second, much larger increase in flux 4938 ng/cm²/hr, occurred after remixing of the sediment at Run IV. This increase was followed by a sharp decrease, indicating the rapid evaporation of the surface oil-film which would have reestablished after mixing (Figure 3).

¹ Numbering for PCB congeners is given in Appendix A

Ammonia Flux

Ammonia fluxes showed an initial decrease in rate from 471 to 94 ng/cm²/hr in the first 72 hours during Run I, followed by an increase in rate to 631 ng/cm²/hr at 240 hours (Table 6). Emission rates fell at the beginning of Run II when humid air was applied, and did not show an increase until Run IV, when the increase was slight, only to 80 ng/cm²/hr. This increase was followed by a sharp decrease (Figure 3). These data indicate that high ammonia fluxes will prevail only during the initial stages of sediment exposure.

Hydrogen Sulfide Flux

Hydrogen sulfide fluxes remained relatively constant (< 0.54 ng/cm²/hr) over the course of the test with the exception of a large increase at the beginning of Run V when the sediment moisture content was increased and dry air was passed over the sediment surface (Table 7, Figure 3). During remixing, hydrogen sulfide flux approached 100 ng/cm²/hr. Apparently, the available hydrogen sulfide volatilized during reworking and was not released until the sediment sorptive capacity was decreased with the increased moisture content.

PCB Fluxes

PCB 1248 was the only arochlor detected during the experiment (Table 8). Initial flux rates in Run I decreased to 0.06 ng/cm²/hr at 240 hours of sampling and had increased to 0.101 ng/cm²/hr by 336 hours. Addition of humid air, resulted in an increased flux rate of arochlor 1248 at 24 hours in Run II even though sediment moisture flux was unchanged (Figure 4). As observed for PAH fluxes, Run IV showed a large initial increase in emission rate followed by a decrease. Flux rates for most congeners showed trends similar to those for PAH emissions. Volatilization rates of all detected PCBs decreased during Run I and peaked again at the beginning of Run IV after sediment was remixed (Figure 4). Increasing sediment moisture content and subsequent application of dry air over the sediment resulted in an increased flux for arochlor 1248 during Run V. Congeners appeared to follow arochlor flux patterns. Increasing relative humidity of the carrier air slightly increased flux rates at the beginning of Run II. Increased sediment moisture followed by the addition of dry air also increased fluxes in Run V.

Conclusions

Results of this investigation showed the highest contaminant fluxes occur with initial loading and mechanical disturbance of the sediment. Results imply that wetting of the sediment will not drastically increase emission rates and that diffusion of volatiles through the sediment will be at a slower rate than those rates observed for laboratory spiked sediments

Measured fluxes were orders of magnitude lower than model predictions and than in a comparable study conducted with laboratory-spiked sediment (Valsaraj et al. 1997). Sediment physical and chemical characteristics, such as aging, porosity, and percent oil and grease

probably decreased fluxes.

Flux rates for PAHs will be highest during initial sediment exposure (after placement) and after reworking activities which exposes underlying material. Changes in relative air humidity or sediment moisture following rainfall will not increase fluxes. TRPH fluxes will also be highest during and after re-working of the sediment. Increases in relative humidity of air will increase flux rates for a short period. Ammonia fluxes will be significant during initial exposure stages not during reworking or changes in relative air humidity and sediment moisture. Hydrogen sulfide fluxes will be highest during reworking of the sediment. Fluxes may also be evident during initial exposure, but may be dependent on environmental conditions. Fluxes for PCBs will be highest during initial exposure and after reworking. Increases in relative air humidity will result in a slight increase in PCB and TRPH flux rates.

References

Brannon, James M. 1989. "Laboratory Assessment of Volatilization from New Bedford Harbor Sediment," Memorandum for Record, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

K. T. Valsaraj and L. J. Thibodeaux, 1988. "Equilibrium adsorption of chemical vapors on surface soils, landfills and landfarms - a Review," *J. Haz. Mater.* 19 (1988) 79.

K. T. Valsaraj, B. Choy, R. Ravikrishna, D. D. Reible, L. J. Thibodeaux, C. B. Price, J. M. Brannon, and T. E. Myers, "Air Emissions from Exposed, Contaminated Sediments and Dredged Materials. I. Experimental Data in Laboratory Microcosms and Mathematical Modeling," *J. Haz. Mater.* (In Press).

K. T. Valsaraj, 1997. "Assessment of Air Emissions of Volatile and Semi-Volatile Organic Compounds From Contaminated Sediments and Dredged Materials," Research Progress Report, Dept. of Chemical Engineering, Louisiana State University, Baton Rouge, LA.

Table 1. Flux (ng/cm²/hr) for Contaminants Trapped During Reworking of the Sediment

Parameter	Flux (ng/cm²/hr)*
PAHs	<2.50
TRPHs	34000
Ammonia	<1.00
Hydrogen Sulfide	100
Arochlors	<2.00
Congeners	<0.03
Methyl Mercaptans	<4.0

Less than values indicate total ug trapped

Table 2. Indiana Harbor PAH and TRPH Initial Sediment Concentrations		
Parameter	Abbreviation	Concentration, mg/kg
Naphthalene	Napth	38.25
Acenaphthylene	Acenay	1.54
Acenaphthene	Acenap	26.75
Fluorene	Fluore	18.00
Phenanthrene	Phenan	50.95
Anthracene	Antrac	10.70
Fluoranthene	Flanthe	50.70
Pyrene	Pyrene	59.20
Chrysene	Chryse	40.30
Benzo(a)Anthracene	Baanthr	26.50
Benzo(b)Fluoranthene	Bbflant	19.40
Benzo(k)Fluoranthene	Bkflant	14.00
Benzo(a)Pyrene	Bapyre	21.65
Indeno(1,2,3-C,D)Pyrene	I123pyr	14.65
Dibenzo(A,H)Anthracene	Dbahant	0.98
Benzo(G,H,I)Perylene	B-ghi-py	15.70
2-Methylnaphthalene	2Menaph	11.40
Total Recoverable Hydrocarbons	TRPH	12790

Table 3. Indiana Harbor Initial PCB Sediment Concentrations, mg/kg									
Arochlor	PCB 1016	PCB 1221	PCB 1232	PCB 1242	PCB 1248	PCB 1254	PCB 1260		
	<1.63	<1.63	<1.63	<1.63	4.10	<1.63	<1.63		
Congener	PCB 7	PCB 8	PCB 15	PCB 18	PCB 28	PCB 31	PCB 40	PCB 44	PCB 49
	0.0028J	0.033	0.022	0.129	0.077	0.159	0.017	0.069	0.059
Congener	PCB 50	PCB 52	PCB 54	PCB 60	PCB 70	PCB 77	PCB 82	PCB 86	PCB 87
	0.008	0.094	0.004	0.019	0.058	0.049	0.019	<0.003	0.023
Congener	PCB 97	PCB 101	PCB 103	PCB 105	PCB 114	PCB 118	PCB 121	PCB 128	PCB 129
	0.016	0.036	0.014	0.020	0.0018J	0.034	<0.003	0.007	0.0025J
Congener	PCB 136	PCB 137	PCB 138	PCB 141	PCB 143	PCB 151	PCB 153	PCB 154	PCB 156
	<0.003	<0.003	0.008	0.004	0.006	0.036	0.012	0.036	0.0031J
Congener	PCB 159	PCB 170	PCB 171	PCB 173	PCB 180	PCB 182	PCB 183	PCB 185	PCB 187
	0.0012J	0.005	0.0032J	<0.003	0.010	0.0025J	0.0017J	0.0011J	0.006
Congener	PCB 189	PCB 191	PCB 194	PCB 195	PCB 196	PCB 199	PCB 201	PCB 202	PCB 203
	<0.003	<0.003	0.0021J	0.0014J	0.006	0.004	0.0025J	<0.003	0.005
Congener	PCB 205	PCB 206	PCB 207	PCB 208	PCB 66	PCB 155	PCB 184		
	<0.003	0.0016J	<0.003	<0.003	0.082	<0.003	0.004		

Table 4. Indiana Harbor Initial Sediment Concentrations for Total Organic Carbon, Ammonia, Methyl Mercaptan, and Hydrogen Sulfide

Parameter	Concentration, mg/kg
Total Organic Carbon	26100
Ammonia	700
Methyl Mercaptan	<8.0
Hydrogen Sulfide	20.45

Table 5									
Flux (ng/cm²/hr) for TRPHs and PAHs in Experiments Conducted with Indiana Harbor Sediment*									
Run I (dry air over wet sediment for 14 days)									
Sample Time	TRPH	Napth	Acenay	Acenap	Fluore	Phenan	Antrac	Flanthe	Pyrene
6 hours	502	50.1	0.404	6.98	2.46	0.991	0.151	0.071	0.053
24 hours	312	18.5	0.273	4.85	2.33	1.15	0.187	0.121	0.104
72 hours	155	0.707	0.120	2.56	1.03	0.538	0.137	0.116	0.100
7 days	175	0.018	0.005	0.140	0.031	0.018	0.009	0.051	0.081
10 days	100	0.034	<2.5	0.035	0.007	0.008	<2.5	0.013	0.064
14 days	50	0.025	0.006	0.023	0.011	0.013	<2.5	0.014	0.095
Run II (humid air over sediment for 7 days)									
6 hours	867	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	0.067
24 hours	326	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	0.062
72 hours	294	0.008	<2.5	0.008	<2.5	0.007	<2.5	<2.5	0.042
7 days	111	0.009	<2.5	0.006	0.004	0.006	<2.5	0.007	0.042

*Less than values indicate total ug trapped

Table 5 (continued)									
Run III (rewet sediment and apply dry air over sediment for 14 days)									
Sample Time	TRPH	Napth	Acenay	Acenap	Fluore	Phenan	Antrac	Flanthe	Pyrene
6 hours	<10	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	0.058
24 hours	<10	.016	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	0.056
72 hours	11.1	.014	<2.0	.008	<2.0	0.007	<2.0	0.009	0.058
7 days	50.0	.053	.006	.013	0.007	0.006	<2.0	0.008	0.053
10 days	24.1	.119	.009	.038	0.011	0.007	<2.0	0.007	0.053
14 days	500	.045	<2.0	.029	0.011	0.008	<2.0	0.007	0.052
Run IV (rework sediment and pass dry air over for 7 days)									
6 hours	622	54.3	0.409	7.08	2.16	0.791	0.129	<2.5	<2.5
24 hours	407	7.70	0.258	5.17	1.73	0.729	0.130	0.069	0.074
72 hours	4938	0.566	0.082	2.13	0.466	0.302	0.068	0.075	0.084
7 days	2640	0.077	<2.5	0.283	0.101	0.145	0.024	0.044	0.072
Run V (pass humid air over sediment for 7 days)									
6 hours	1333	<2.5	<2.5	0.182	<2.5	0.120	<2.5	<2.5	<2.5
24 hours	437	<2.5	<2.5	0.101	0.049	0.067	<2.5	<2.5	0.046
72 hours	292	0.042	<2.5	0.118	0.054	0.095	0.017	0.033	0.073
7 days	392	0.037	<2.5	0.164	0.054	0.071	0.014	0.031	0.060

*Less than values indicate total ug trapped

Table 5 (continued)									
Run I (dry air over wet sediment for 14 days)									
Sample Time	Chryse	Baanthr	Bbflant	Bkflant	Bapyre	I123pyr	Dbahant	B-ghi-py	2Menaph
6 hours	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	5.83
24 hours	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	2.64
72 hours	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	0.354
7 days	0.018	0.017	0.028	0.033	0.026	0.008	0.013	0.009	0.021
10 days	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	0.013
14 days	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	0.018
Run II (humid air over sediment for 7 days)									
6 hours	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5
24 hours	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5
72 hours	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	0.009
7 days	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	0.007

*Less than values indicate total ug trapped

Table 5 (continued)									
Run III (rewet sediment and apply dry air over sediment for 14 days)									
Sample Time	Chryse	Baanthr	Bbflant	Bkflant	Bapyre	I123pyr	Dbahant	B-ghi-py	2Menaph
6 hours	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
24 hours	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0
72 hours	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	0.017
7 days	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	0.023
10 days	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	0.044
14 days	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	<2.0	0.032
Run IV (rework sediment and pass dry air over for 7 days)									
6 hours	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	7.40
24 hours	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	2.31
72 hours	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	0.251
7 days	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	0.060
Run V (pass humid air over sediment for 7 days)									
6 hours	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5
24 hour	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5
72 hours	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	0.022
7 days	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	<2.5	0.038

*Less than values indicate total ug trapped

Table 6					
Ammonia Flux (ng/cm²/hr)					
Sample Time	Run I	Run II	Run III	Run IV	Run V
6 hours	471	188	4.76	80.0	4.03
24 hours	204	83.3	39.4	5.61	2.09
72 hours	93.9	20.3	12.8	16.9	1.17
7 days	287	2.43	0.130	2.53	0.520
10 days	631	na	0.010	na	na
14 days	625	na	0.740	na	na
Run I - pass dry air over wet sediment for 14 days					
Run II - pass humid air over sediment for 7 days					
Run III - rewet sediment and pass dry air over sediment for 14 days					
Run IV - rework sediment and pass dry air over sediment for 7 days					
Run V - pass humid air over sediment for 7 days					

Table 7
Hydrogen Sulfide (ng/cm²/hr)*

Sample Time	Run I	Run II	Run III	Run IV	Run V
6 hours	<1.3	<1.25	<1.25	<1.25	6.80
24 hours	0.53	<1.25	0.185	<1.25	<1.25
72 hours	0.197	<1.25	0.341	<1.25	<1.25
7 days	<1.3	0.035	0.111	<1.25	<1.25
10 days	0.050	na	<1.25	na	na
14 days	<1.3	Na	<1.25	na	na

Run I - pass dry air over wet sediment for 14 days

Run II - pass humid air over sediment for 7 days

Run III - rewet sediment and pass dry air over sediment for 14 days

Run IV - rework sediment and pass dry air over sediment for 7 days

Run V - rewet sediment and pass dry air over sediment for 7 days

*Less than values indicate total ug trapped

Table 8									
Flux (ng/cm²/hr) for PCB Arochlors and Congeners in Tests Conducted with Indiana Harbor Sediment									
Run I - (pass dry air over wet sediment for 14 days)									
Sample Time	PCB 1248	PCB 7	PCB 8	PCB 15	PCB 18	PCB 28	PCB 31	PCB 40	PCB 44
6 hours	0.231	0.028	0.020	0.018	0.107	0.019	0.053	<0.03	0.014
24 hours	0.222	0.005	0.016	0.003	0.077	0.018	0.044	0.003	0.012
72 hours	0.164	0.005	0.013	0.003	0.044	0.012	0.033	0.002	0.012
7 days	0.113	0.0008	0.006	0.008	0.013	0.009	0.009	0.0003	0.003
10 days	0.061	<0.03	0.002	0.002	0.007	0.004	0.004	<0.03	0.002
14 days	0.101	<0.03	0.005	0.006	0.011	0.003	0.003	0.0003	0.003
Run II - (pass humid air over sediment for 7 days)									
6 hours	<2.0	<0.03	<0.03	<0.03	0.008	<0.03	<0.03	<0.03	<0.03
24 hours	0.074	<0.03	0.002	<0.03	0.008	<0.03	<0.03	<0.03	0.003
72 hours	0.036	<0.03	0.002	<0.03	0.003	0.001	0.001	<0.03	0.001
7 days	0.029	<0.03	0.001	0.001	0.002	0.001	0.001	<0.03	0.001

*Less than values indicate total ug trapped

Table 8 (continued)**Run III - (rewet sediment and apply dry air over sediment for 14 days)**

Sample Time	PCB 1248	PCB 7	PCB 8	PCB 15	PCB 18	PCB 28	PCB 31	PCB 40	PCB 44
6 hours	<2.0	<0.03	<0.03	<0.03	0.005	<0.03	<0.03	<0.03	<0.03
24 hours	0.044	<0.03	0.002	<0.03	<0.03	0.002	0.002	<0.03	0.002
72 hours	0.054	<0.03	0.003	0.003	0.004	0.002	0.002	<0.03	0.003
7 days	0.037	<0.03	0.002	0.002	0.003	0.002	0.002	<0.03	0.002
10 days	0.043	<0.03	0.003	0.002	0.003	0.002	0.002	<0.03	0.002
14 days	0.047	<0.03	0.004	0.003	0.004	0.002	0.002	<0.03	0.002

Run IV - (rework sediment and pass dry air over sediment for 7 days)

6 hours	0.320	<0.03	0.024	<0.03	0.040	0.008	0.012	<0.03	<0.03
24 hours	0.228	<0.03	0.019	0.014	0.004	0.014	0.014	<0.03	0.003
72 hours	0.187	<0.03	0.013	0.019	0.022	0.007	0.011	0.003	0.004
7 days	0.129	<0.03	0.007	0.006	0.013	0.005	0.009	0.004	0.003

Run V - (pass humid air over sediment for 7 days)

6 hours	<2.0	<0.03	<0.03	<0.03	0.022	0.010	0.016	<0.03	0.004
24 hours	0.111	<0.03	0.005	<0.03	0.013	0.003	0.007	<0.03	0.003
72 hours	0.079	<0.03	0.005	0.005	0.013	0.006	0.008	<0.03	0.003
7 days	<2.0	<0.03	0.004	0.004	0.007	0.004	0.006	<0.03	0.002

*Less than values indicate total ug trapped

Table 8 (continued)									
Run I - (pass dry air over wet sediment for 14 days)									
Sample Time	PCB 49	PCB 50	PCB 52	PCB 54	PCB 60	PCB 70	PCB 77	PCB 82	PCB 86
6 hours	0.020	0.007	0.018	0.017	<0.03	<0.03	<0.03	<0.03	<0.03
24 hours	0.013	<0.03	0.017	0.009	0.002	0.002	0.003	<0.03	<0.03
72 hours	0.013	0.003	0.006	0.009	0.002	0.001	0.003	<0.03	0.0009
7 days	0.006	0.002	<0.03	0.002	<0.03	0.001	0.0003	0.0007	<0.03
10 days	0.003	0.0006	<0.03	0.0007	<0.03	0.0009	<0.03	<0.03	<0.03
14 days	0.006	0.002	<0.03	0.002	<0.03	0.001	<0.03	<0.03	<0.03
Run II - (pass humid air over sediment for 7 days)									
6 hours	<0.03	<0.03	0.010	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
24 hours	0.005	<0.03	<0.03	0.001	<0.03	<0.03	<0.03	<0.03	<0.03
72 hours	0.003	0.0006	0.006	0.0007	<0.03	<0.03	<0.03	<0.03	<0.03
7 days	0.003	0.0004	0.006	0.0006	<0.03	0.0005	<0.03	<0.03	<0.03

*Less than values indicate total ug trapped

Table 8 (continued)**Run III - (rewet sediment and apply dry air over sediment for 14 days)**

Sample Time	PCB 49	PCB 50	PCB 52	PCB 54	PCB 60	PCB 70	PCB 77	PCB 82	PCB 86
6 hours	<0.03	<0.03	0.014	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
24 hours	<0.03	<0.03	0.011	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
72 hours	<0.03	0.001	0.013	0.002	<0.03	0.0008	<0.03	<0.03	<0.03
7 days	<0.03	0.0007	0.009	0.0008	<0.03	0.0007	<0.03	<0.03	<0.03
10 days	<0.03	0.0008	0.010	0.001	<0.03	0.0008	<0.03	<0.03	<0.03
14 days	<0.03	0.0007	0.010	0.001	<0.03	0.0008	0.0004	0.0003	<0.03

Run IV - (rework sediment and pass dry air over sediment for 7 days)

6 hours	0.004	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
24 hours	0.006	0.004	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
72 hours	0.007	0.004	<0.03	0.002	<0.03	0.0008	<0.03	<0.03	<0.03
7 days	0.006	0.001	<0.03	0.0009	0.0004	0.0007	<0.03	<0.03	<0.03

Run V - (pass humid air over sediment for 7 days)

6 hours	0.008	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
24 hours	0.005	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
72 hours	0.005	0.001	<0.03	<0.03	<0.03	0.0006	<0.03	<0.03	<0.03
7 days	0.003	0.0009	<0.03	<0.03	0.0003	0.0004	<0.03	<0.03	<0.03

*Less than values indicate total ug trapped

Table 8 (continued)**Run I - (pass dry air over wet sediment for 14 days)**

Sample Time	PCB 87	PCB 97	PCB 101	PCB 103	PCB 105	PCB 114	PCB 118	PCB 121	PCB 138
6 hours	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	0.012	<0.03
24 hours	<0.03	<0.03	<0.03	0.001	<0.03	0.002	<0.03	0.021	<0.03
72 hours	0.0009	<0.03	0.0008	0.0008	0.002	<0.03	0.0006	0.014	0.0008
7 days	0.0007	0.0006	<0.03	0.0004	<0.03	<0.03	<0.03	0.0006	<0.03
10 days	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	0.0004	<0.03
14 days	0.0005	0.0007	<0.03	0.0004	0.0003	<0.03	<0.03	<0.03	<0.03

Run II - (pass humid air over sediment for 7 days)

6 hours	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
24 hours	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
72 hours	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
7 days	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03

*Less than values indicate total ug trapped

Table 8 (continued)

Run III - (rewet sediment and apply dry air over sediment for 14 days)

Sample Time	PCB 87	PCB 97	PCB 101	PCB 103	PCB 105	PCB 114	PCB 118	PCB 121	PCB 138
6 hours	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
24 hours	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
72 hours	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
7 days	0.0003	0.0003	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
10 days	0.0004	0.0004	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
14 days	0.0004	0.0004	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03

Run IV - (rework sediment and pass dry air over sediment for 7 days)

6 hours	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
24 hours	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
72 hours	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
7 days	<0.03	<0.03	0.0005	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03

Run V - (pass humid air over sediment for 7 days)

6 hours	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
24 hours	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
72 hours	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
7 days	<0.03	<0.03	0.0003	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03

*Less than values indicate total ug trapped

Table 8 (continued)**Run I - (pass dry air over wet sediment for 14 days)**

Sample Time	PCB 154	PCB 159	PCB 180	PCB 183	PCB 66	PCB 155	PCB 184
6 hours	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
24 hours	<0.03	<0.03	0.002	<0.03	0.009	0.002	<0.03
72 hours	0.0007	0.001	<0.03	0.0008	0.006	0.002	0.00007
7 days	0.0008	0.0009	<0.03	<0.03	0.001	0.0008	<0.03
10 days	0.0004	<0.03	<0.03	<0.03	0.0009	0.0004	<0.03
14 days	<0.03	<0.03	<0.03	<0.03	0.001	0.0009	<0.03

Run II - (pass humid air over sediment for 7 days)

6 hours	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
24 hours	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
72 hours	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
7 days	<0.03	<0.03	<0.03	<0.03	0.0005	<0.03	<0.03

*Less than values indicate total ug trapped

Table 8 (continued)							
Run III - (rewet sediment and apply dry air over sediment for 14 days)							
Sample Time	PCB 154	PCB 159	PCB 180	PCB 183	PCB 66	PCB 155	PCB 184
6 hours	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
24 hours	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
72 hours	<0.03	<0.03	<0.03	<0.03	0.0008	<0.03	<0.03
7 days	<0.03	<0.03	<0.03	<0.03	0.0007	0.0003	<0.03
10 days	<0.03	<0.03	<0.03	<0.03	0.0008	0.0004	<0.03
14 days	<0.03	<0.03	<0.03	<0.03	0.0008	0.0004	<0.03
Run IV - (rework sediment and pass dry air over sediment for 7 days)							
6 hours	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
24 hours	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
72 hours	<0.03	<0.03	<0.03	<0.03	<0.03	0.0006	<0.03
7 days	<0.03	<0.03	<0.03	<0.03	0.002	0.0006	<0.03
Run V - (pass humid air over sediment for 7 days)							
6 hours	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
24 hours	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03	<0.03
72 hours	<0.03	<0.03	<0.03	<0.03	0.002	<0.03	<0.03
7 days	0.0004	<0.03	<0.03	<0.03	0.001	<0.03	<0.03

*Less than values indicate total ug trapped

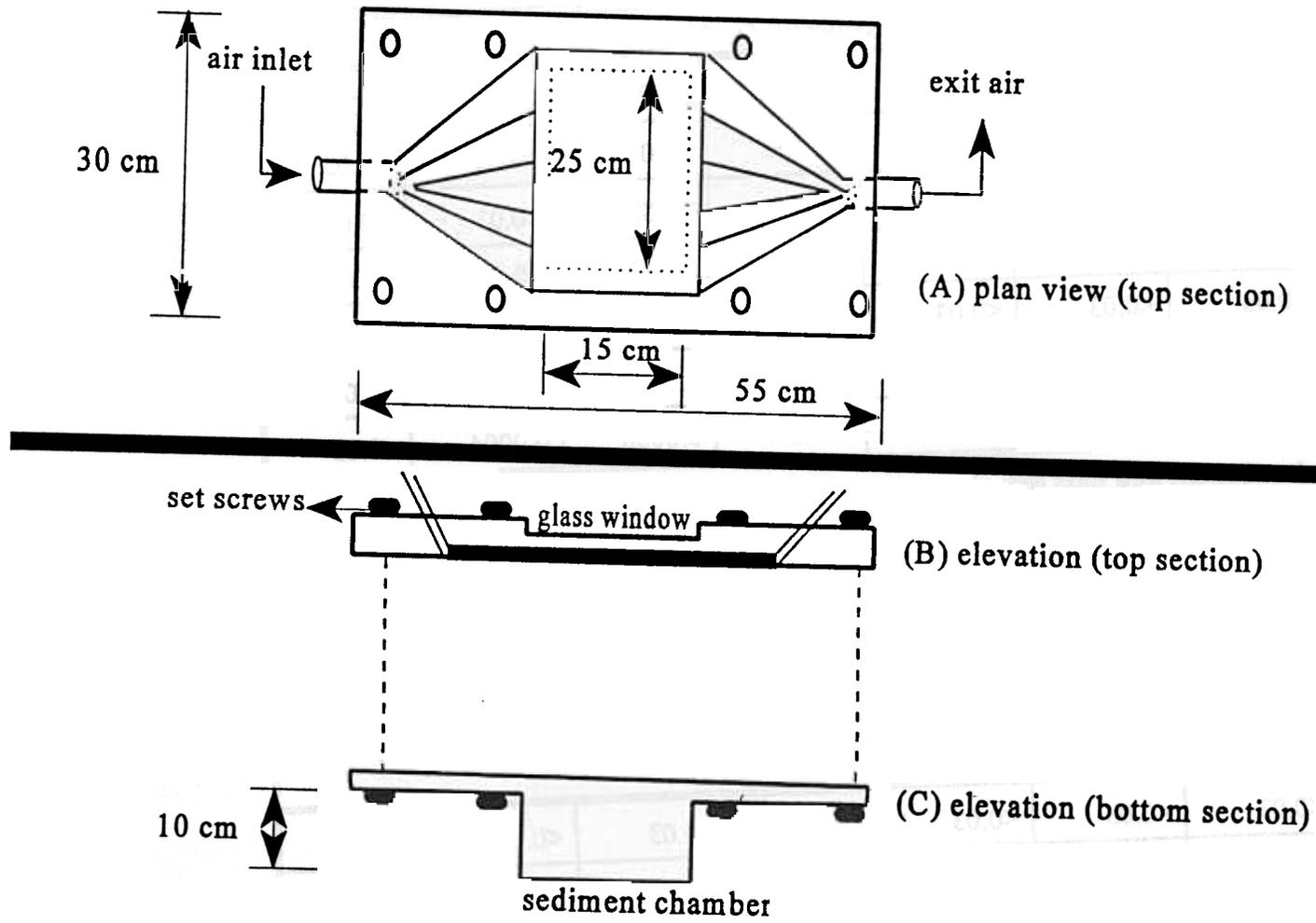
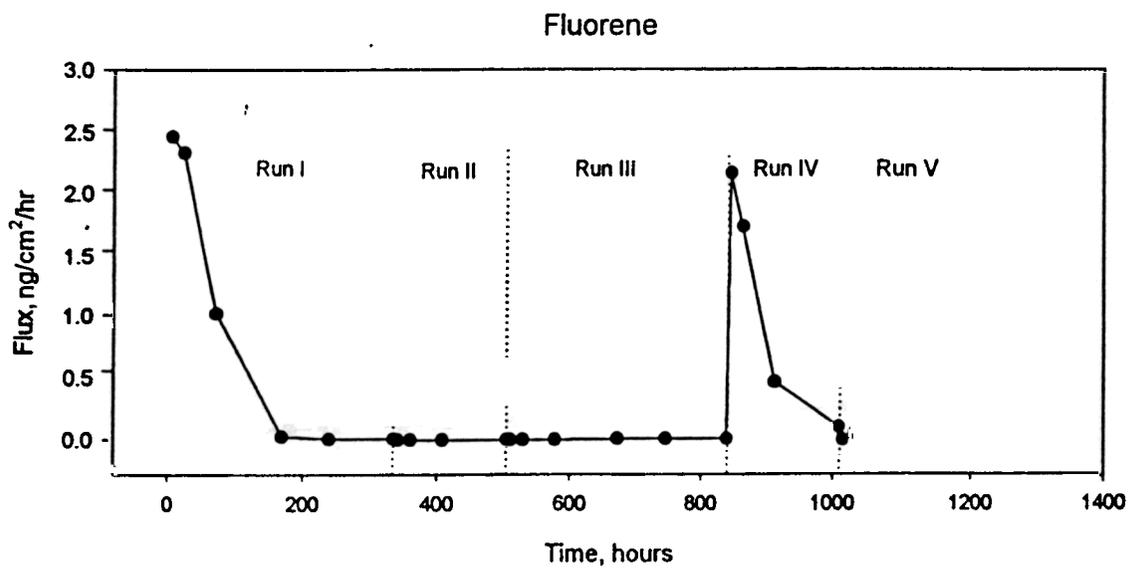
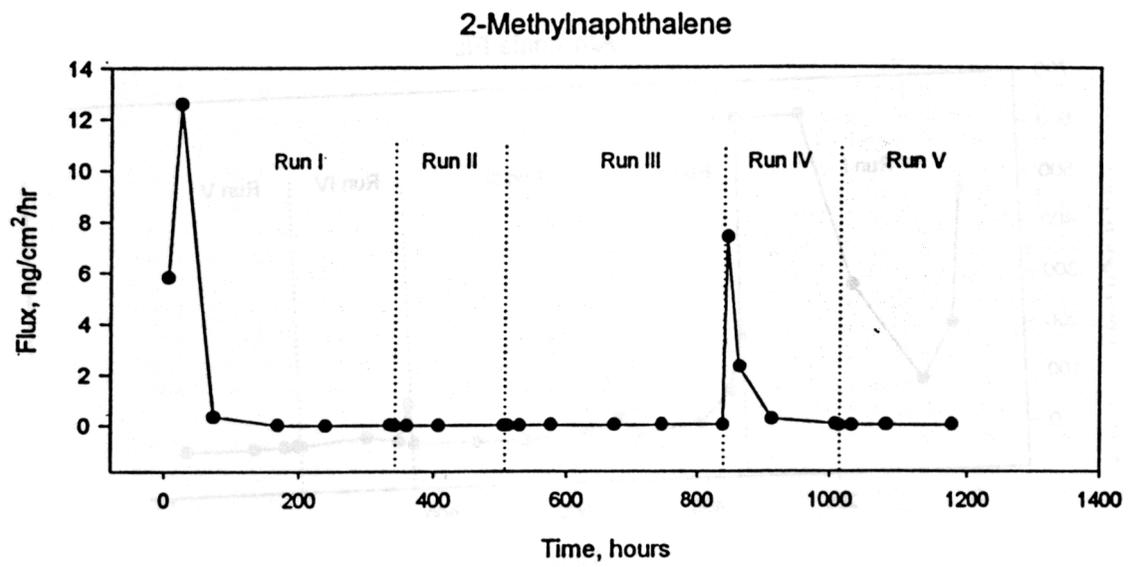
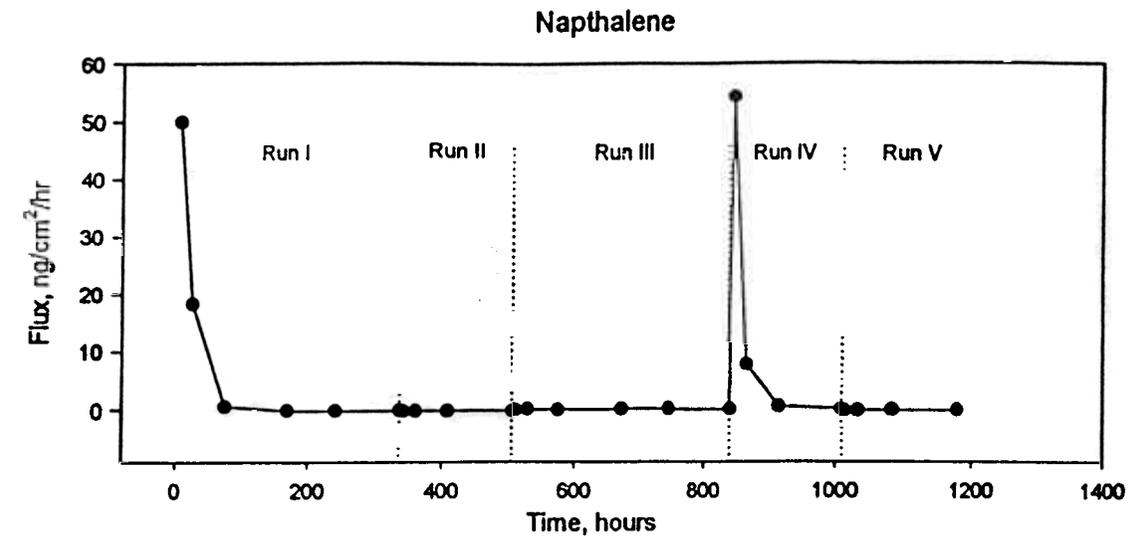
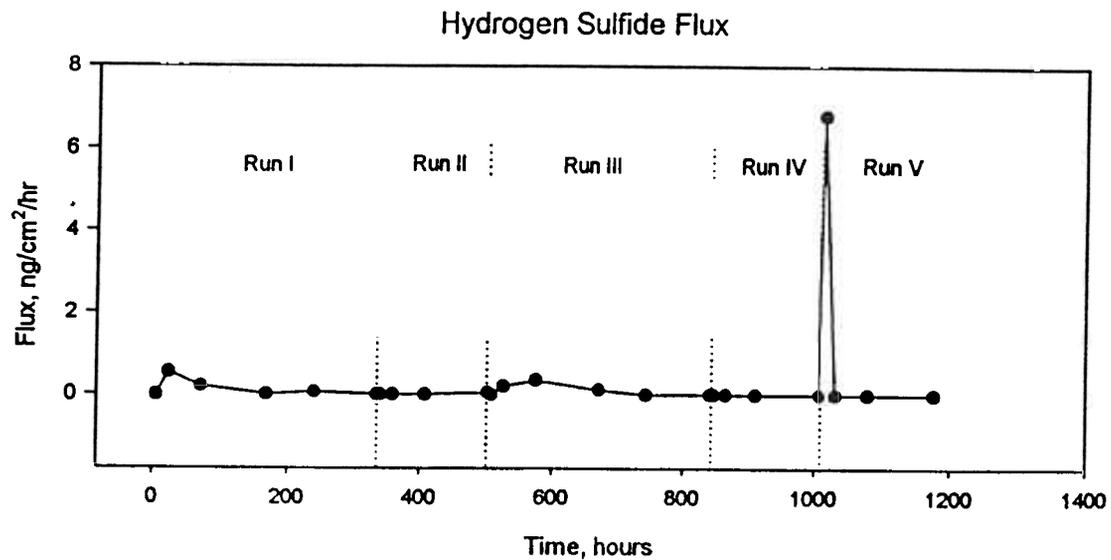
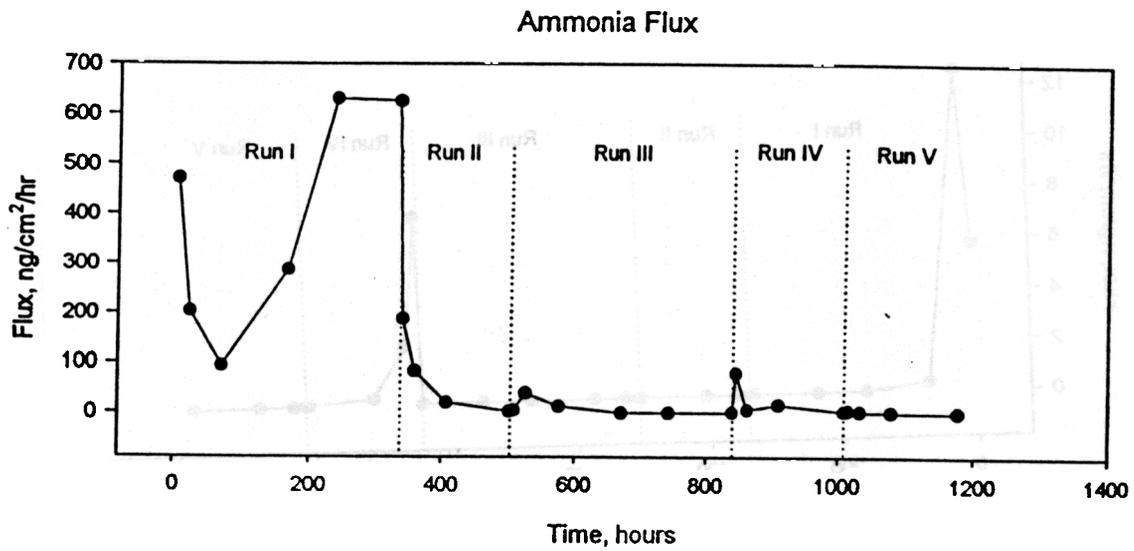
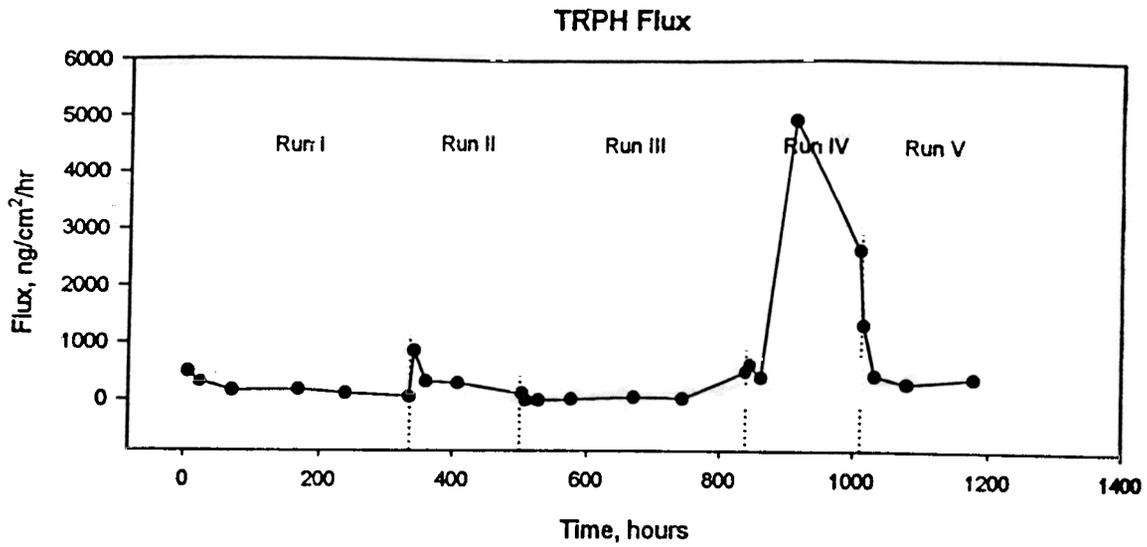


Fig 1



Run I	dry air for 14 days
Run II	humid air for 7 days
Run III	rewet sediment followed by dry air for 14 days
Run IV	rework sediment followed by dry air for 7 days
Run V	humid air for 7 days

Fig 2



Run I	dry air for 14 days
Run II	humid air for 7 days
Run III	rewet sediment followed by dry air for 14 days
Run IV	rework sediment followed by dry air for 7 days
Run V	humid air for 7 days

Fig 3

INDIANA HARBOR VOLATILIZATION AND ODOR ANALYSIS

Indiana Harbor Volatilization and Odor Analysis

December, 1998

Prepared by USACE, Chicago District

Introduction

Indiana Harbor sediment contains high concentrations of such organics as polycyclic aromatic hydrocarbons (PAHs), polychlorinated biphenyls (PCBs), and petroleum products. Volatilization of these organic contaminants and other odorous compounds, such as ammonia, is a concern because of the proximity of a high school (1/4 mile), health and safety of on-site workers, and impacts on air quality. Maximum volatile fluxes and odor creation will occur as the fresh dredged material is placed and spread. If the material did not require reworking, volatile fluxes and odor creation would rapidly decrease and cease to be a concern until the next filling operation. Renewed volatilization and odor creation is likely as material is reworked and spread to completely cover the bottom of the confined disposal facility and enhance dewatering and consolidation. Information is therefore needed on probable maximum fluxes of organic contaminants and odor-causing compounds and the significance of the fluxes associated with spreading and reworking the material.

As part of the Environmental Impact Statement (EIS) for the Indiana Harbor and Canal maintenance dredging and disposal activities, a General Conformity Determination and Odor Analysis was completed. In order to estimate the volatile organic compound (VOC) emissions from the dredged material, mathematical models were used (Thibodeaux, 1989; Semmler, 1990; Meyers, et al, 1994). The aforementioned references describe the movement of chemicals through the environmental media (soil, sediment, water, and air). These "screening level" models are based on conservative assumptions which are meant to overestimate the actual flux of contaminant losses. In this sense, the results will indicate if further evaluation and possibly some type of engineering controls would be required to mitigate losses. However, to date there is little information available relating estimated fluxes using mathematical models, to measured fluxes from laboratory or pilot scale experiments. Therefore, a laboratory experiment was conducted in order to determine measured contaminant fluxes under various conditions and confirm the conservative nature of the mathematical models. The experiment was conducted by the Corps' Waterways Experiment Station (WES) and consisted of conducting five runs in laboratory scale flux chambers. The experiments were conducted to eliminate fluxes controlled by air-side resistance, thereby maximizing contaminant fluxes.

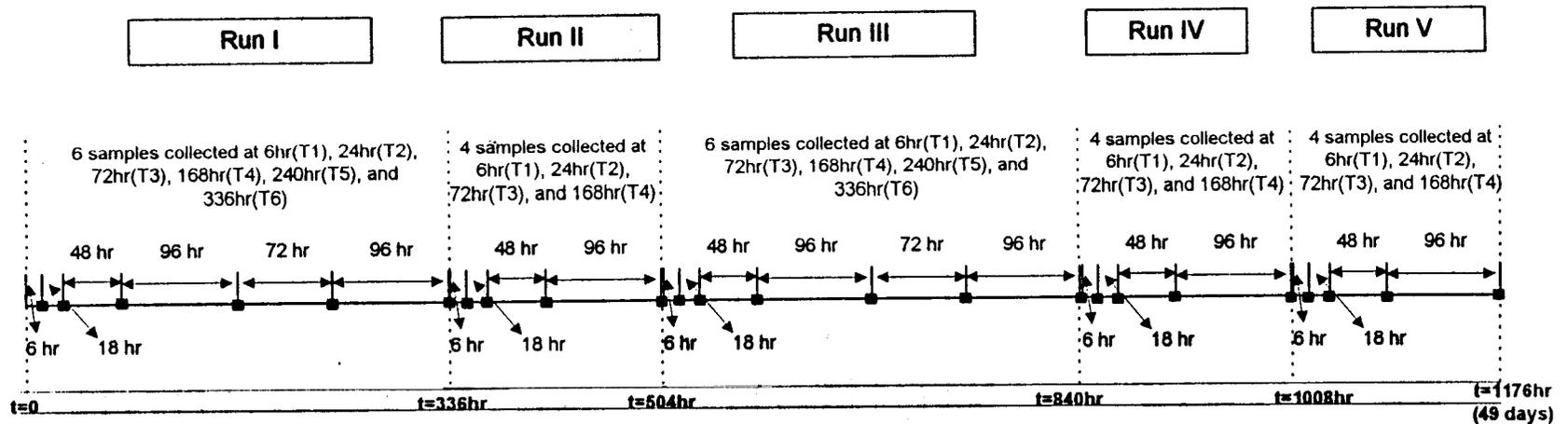
A total of five runs were conducted representing different field conditions anticipated throughout the filling life of the CDF. The sediment used in the experiment was taken from Indiana Harbor and was collected to be representative of the material to be dredged. The contaminants of concern included: polycyclic aromatic hydrocarbons (PAHs),

Table 1 - Initial Sediment Chemistry

Compound		Sediment Concentration mg/kg	Compound	Sediment Concentration mg/kg
PAHS			PCB Congeners	
ACENAP	Acenaphthlene	26.8	PCB 7	j 0.0028
	Acenaphthylene	1.54	PCB 8	0.0325
ANTRAC	Anthracene	10.7	PCB 15	0.0215
BAANTHR	Benzo(a)Anthracene	26.5	PCB 18	0.129
BAPYRE	Benzo(a)Pyrene	21.7	PCB 28	0.077
BBFLANT	Benzo(b)Fluoranthene	19.4	PCB 31	0.159
B-GHI-PY	Benzo(G,H,I)Perylene	15.7	PCB 40	0.017
BKFLANT	Benzo(k)Fluoranthene	14	PCB 44	0.0685
CHRYSE	Chrysene	40.3	PCB 49	0.0585
DBAHANT	Dibenzo (A,H)Anthracene	0.98	PCB 50	0.0081
FLUORE	Florene	18	PCB 52	0.0935
FLANTHE	Fluoranthene	50.7	PCB 54	0.0044
8123PYR	Indeno (1,2,3-C,D)Pyrene	14.7	PCB 60	0.019
2MENAPH	Methlynaphthalene-2	11.4	PCB 70	0.058
NAPHTH	Naphthalene	38.3	PCB 77	0.049
PHENAN	Phenanthrene	51	PCB 82	0.019
PYRENE	Pyrene	59.2	PCB 86	< 0.0033
			PCB 87	0.023
			PCB 97	0.016
NH3-N	Ammonia-Nitrogen	711.8	PCB 101	0.036
H2S	Hydrogen Sulfide	20.45	PCB 103	0.0135
Met Mer	Methyl mercaptan	< 8	PCB 105	0.02
O&G	Oil & Grease	8710	PCB 114	j 0.0018
TRPH	TRPH	12790	PCB 118	0.0335
			PCB 121	< 0.0033
			PCB 128	0.0072
			PCB 129	j 0.0025
PCB Arochlors				
	PCB 1016	< 1.63	PCB 136	< 0.0033
	PCB 1221	< 1.63	PCB 137	< 0.0033
	PCB 1232	< 1.63	PCB 138	0.0078
	PCB 1242	< 1.63	PCB 141	0.0041
	PCB 1248	4.1	PCB 143	0.0056
	PCB 1254	< 1.63	PCB 151	0.036
	PCB 1260	< 1.63	PCB 153	0.012
			PCB 154	0.036
			PCB 156	j 0.0031
			PCB 159	j 0.0021
			PCB 170	0.0045
			PCB 171	j 0.0032
			PCB 173	j 0.0033
			PCB 180	0.0102
			PCB 182	j 0.0025
			PCB 183	j 0.0017
			PCB 185	j 0.0011
			PCB 187	0.0059
			PCB 189	< 0.0033
			PCB 191	< 0.0033
			PCB 194	j 0.0021
			PCB 195	j 0.0014
			PCB 196	0.0055
			PCB 199	0.0043
			PCB 201	j 0.0025
			PCB 202	< 0.0033
			PCB 203	0.0045
			PCB 205	< 0.0033
			PCB 206	j 0.0016
			PCB 207	< 0.0033
			PCB 208	< 0.0033

"j" = Estimated value below the method detection limit. Value is resolved on chromatogram but below the method detection limit. "<" = concentration that is below the method detection limit.

Figure 1 Flow Chart for sample collection



Run I Wet sediment with dry air flow

Provide maximum initial fluxes from wet sediment under dry condition

Run II Air flow switched to 97% relative humidity

Provide maximum initial fluxes under humid conditions

Run III Sediment rewetted to initial water content (field capacity)

Provide a measure of flux expected after rain event

Run IV Sediment remixed with dry air flow

Provide a measure of flux from reworked sediment under dry conditions

Run V Sediment rewetted to field capacity

Provide a measure of flux from rewetted sediment under dry conditions

As an example, both methods are used to calculate a flux for naphthalene (Run I) as shown in Table 2.

Table 2 - Comparison of Flux rates for Naphthalene

Naphthalene area = 375 cm ²	Time step (T _i)	Quantity (M _i) (ng)	flux-running avg (ng/cm ² *hr)	flux-incremental (ng/cm ² *hr)
	6hr(T1)	112,700	50.1	50.1
	24hr(T2)	124,600	26.3	18.5
	72hr(T3)	12,730	9.3	0.71
	168hr(T4)	640	4.0	0.02
	240hr(T5)	930	2.8	0.03
	336hr(T6)	890	2.0	0.02

For this experiment a total of 2,184 analyses were completed (91 compounds at 24 separate time intervals). From the total number of analyses completed there were 266 (12%) that were detectable and 226 (10%) estimated but below the detection limit (J-values). The J-values were treated as actual values, however, because using the estimated values in this manner could overestimate the actual flux from the experiment. In addition, any J-value concentration derived early in the experiment would be compounded throughout the time intervals since any contaminant released in a preceding time interval is additive to latter time intervals for calculating an average running flux. In most cases the modeled fluxes exceeded the measured fluxes confirming the conservative nature of the model.

Modeled fluxes exceeded measured fluxes on average by 16 times for PCB congeners, and 30 times for PAHs. However, a total of 25 (5.1%) of the 492 (266+226) detectable and estimated values produced measured fluxes which exceeded calculated fluxes as shown in Tables 3 and 4. The PCB congeners (54, 114, 121, and 159) and the PAHs {benzo(a)pyrene, benzo(g,h,i)perylene, benzo(k)fluoranthene, chrysene, naphthalene, and pyrene} in which the measured flux exceeded the calculated flux are shown in Tables 3 and 4, respectively. It should be noted that more than half of these exceedances (13 of 25) are based on estimated (J-value) concentrations that could overestimate the actual amount of mass loss.

For all the exceedances, excluding naphthalene that will be discussed below, the percent mass loss relative is small compared to the total mass loss for PCB congeners or PAHs. For instance, 4.44% of the summation of PCB congeners is from PCB 54 (T1-T6), 4.43% for PCB 121(T1-T5), and 2.18% for all the PAHs is from Pyrene (T1 -- T6). In addition, the exceedances occurred only for small flux rates relative to other compounds. For the PCB congeners the flux rates were less than 0.02 ng/cm²*hr and for the PAHs (excluding naphthalene) the flux rates were less than 0.1 ng/cm²*hr.

Table 3 - Cases where measured flux exceeds calculated flux in Run I - PCB Congeners

Compound	¹ M/C	² j	Run	Run Duration (hrs)	³ Flux ng/cm ² *hr	⁵ Quantity trapped (ug)	⁴ % Mass Loss
PCB 54	M		T1	6	0.017	0.038	0.38%
	C				0.014		
	M		T2	18	0.011	0.058	0.59%
	C				0.007		
	M		T3	48	0.0098	0.17	1.72%
	C				0.0042		
PCB 114	M	j	T2	18	0.0017	0.015	0.15%
	C				0.0009		
	M	j	T1	6	0.012	0.028	0.28%
	C				0.0098		
	M		T2	18	0.019	0.14	1.42%
	C				0.005		
PCB 121	M		T3	48	0.016	0.26	2.63%
	C				0.0029		
	M	j	T5	72	0.0049	0.01	0.10%
	C				0.0016		
	M	j	T2	18	0.0011	0.01	0.10%
	C				0.00087		
PCB 159	M	j	T3	48	0.001	0.017	0.17%
	C				0.00051		

¹M = Measured concentration; C = Calculated concentration

²j = Flux values based on concentrations that are below detection limit and are an estimated value

³ The "M" value is based on average running flux

⁴ Represents the percent mass loss for the summation of the PCB congeners of each individual compound over the entire Run I (14 days). Total quantifiable PCB congener mass = 9.892 ug.

⁵ **Quantity Trapped** is the actual mass of the compound retained on the sorptive filters used in the experiment. This mass is used to calculate the flux rate given the duration of the experiment run and the surface area of the exposed sediment.

Table 4 - Cases where measured flux exceeds calculated flux in Run I - PAHs

Compound	¹ M/C	² j	Run	Run Duration (hrs)	³ Flux ng/cm ² *hr	⁵ Quantity Trapped (ug)	⁴ % Mass Loss
Benzo (a) Pyrene	M	j	T4	96	0.015	0.92	0.19%
	C				0.0004		
Benzo (g,h,i) Perylene	M	j	T4	96	0.0052	0.33	0.07%
	C				0.0023		
Benzo (k) Fluoranthene	M	j	T4	96	0.019	1.17	0.24%
	C				0.001		
Chrysene	M	j	T4	96	0.010	0.64	0.13%
	C				0.0004		
Naphthalene	M		T1	6	50	112.7	23%
	C				36		
	M		T2	18	26	124.6	26%
	C				19		
Pyrene	M	j	T1	6	0.053	0.12	0.02%
	C				0.003		
	M	j	T2	18	0.091	0.7	0.14%
	C				0.0027		
	M	j	T3	48	0.097	1.8	0.37%
	C				0.0027		
	M		T4	96	0.088	2.91	0.60%
	C				0.0026		
Pyrene	M	j	T5	72	0.081	1.72	0.35%
	C				0.0025		
	M		T6	96	0.085	3.41	0.70%
	C				0.0024		

¹M = Measured concentration; C = Calculated concentration

²j = Flux values based on concentrations that are below detection limit and are an estimated value

³ The "M" value is based on average running flux

⁴Represents the percent mass loss for the summation of the PAH compounds over the entire Run I (14 days). Total quantifiable PAH mass = 486.2 ug

⁵Quantity Trapped is the actual mass of the compound retained on the sorptive filters used in the experiment. This mass is used to calculate the flux rate given the duration of the experiment run and the surface area of the exposed sediment.

The compound naphthalene showed a higher mass loss than the other compounds in the PAH group at 23% in run T1 and 26% in run T2. The high mass loss for naphthalene was limited to the first two runs. The other PAHs exhibited mass loss of less than 1% for each of the runs. The measured flux rate for naphthalene exceeded the calculated flux rate in the first two runs only, and the level of exceedance was less than 35%. The measured and calculated flux rates for naphthalene are shown in Table 5. Since air resistance, as discussed earlier, was minimized in the measured runs which can not be simulated in the calculated values, the conservative nature of the modeled results is maintained.

Table 5 - Naphthalene flux for Run I (ng/cm² *hr)

Time step Cumulative time	T1 (6hr) 6 hr	T2 (18 hr) 24 hr	T3 (48 hr) 72 hr	T4 (96 hr) 168 hr (7 day)	T5 (72 hr) 240 hr (10 day)	T6(96hr) 336 hr (14 day)
Calculated	36	19	11.2	7.4	6.2	5.2
Measured	50	26	9.3	4.0	2.8	2.0

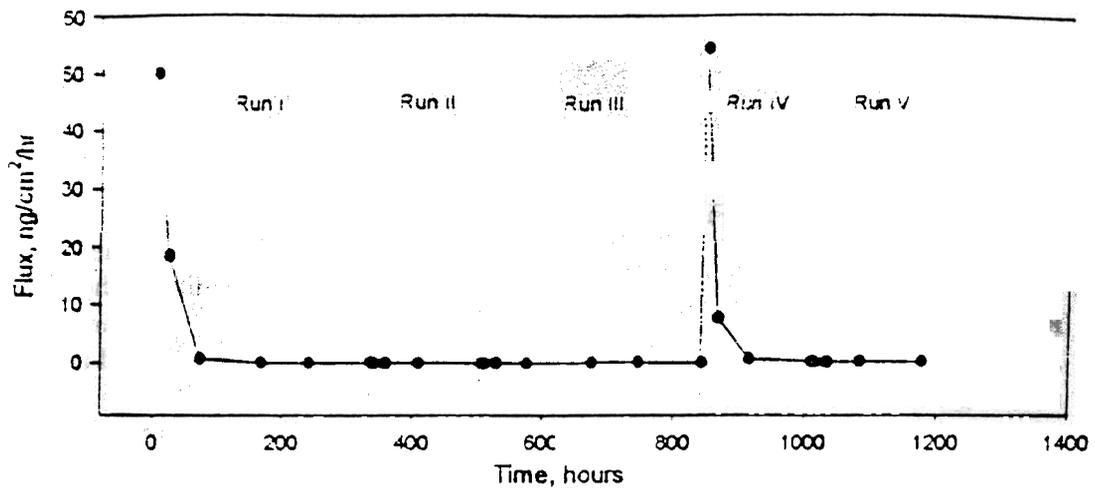
In summary, the comparison of measured flux to modeled flux indicates that the model is conservative in that it over estimates the actual flux. On average, these results showed an exceedance of at least 1 order of magnitude (10x). For a few compounds, at low flux rates the model underpredicted volatilization, and for naphthalene during the initial time steps the model slightly underpredicted volatilization. However, given that these differences, either occurred at very low rates or were only slightly lower, and the experimental design was set up to maximize flux, the model functioned well for a screening level estimate. Therefore, the flux rates used to estimate VOC emissions and complete the odor analysis provided in the EIS are expected to be conservatively high, providing worst case analysis and verified through these experimental results.

Discussion of Experimental Results

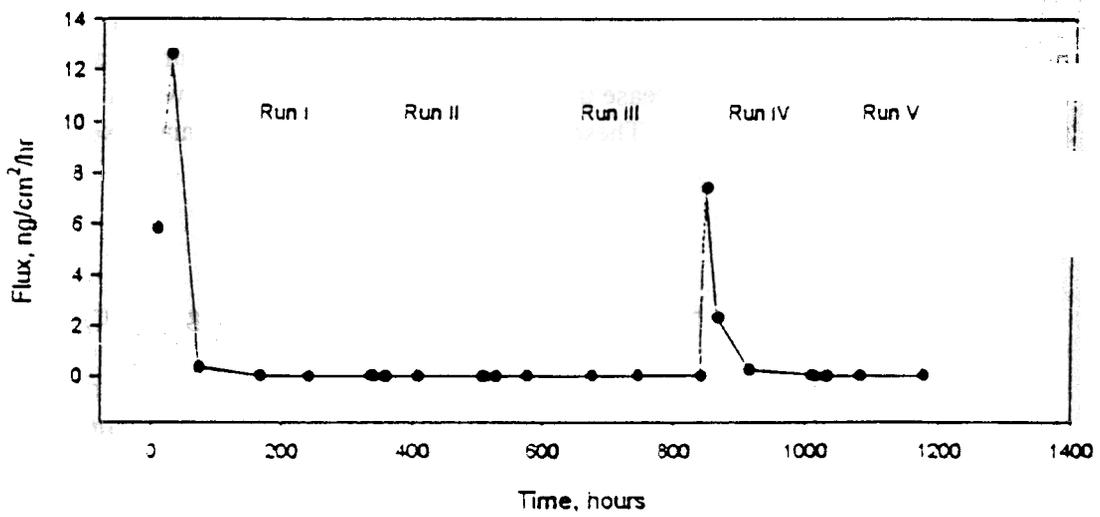
PAH Fluxes

Most of the hydrocarbons exhibited initial sharp decreases in flux rate within the first 72 hours following passage of dry air over the sediment surface in Run I (Figure 2). No increase in flux of any of the hydrocarbons was noted until test Run IV when the sediment was reworked. At that time flux rates showed a sharp increase to approximately that of the initial rate followed by a sharp decrease. No increase in flux rates were noted when humid air was passed over the sediment in Run II. Naphthalene and acenaphthene showed the highest initial volatilization rates of 50 and 6.7 ng/cm²/hr, respectively. The third highest flux rate was 5.8 ng/cm²/hr for 2-methylnaphthalene. All other detectable PAH compounds showed initial volatilization rates of less than 3 ng/cm²/hr.

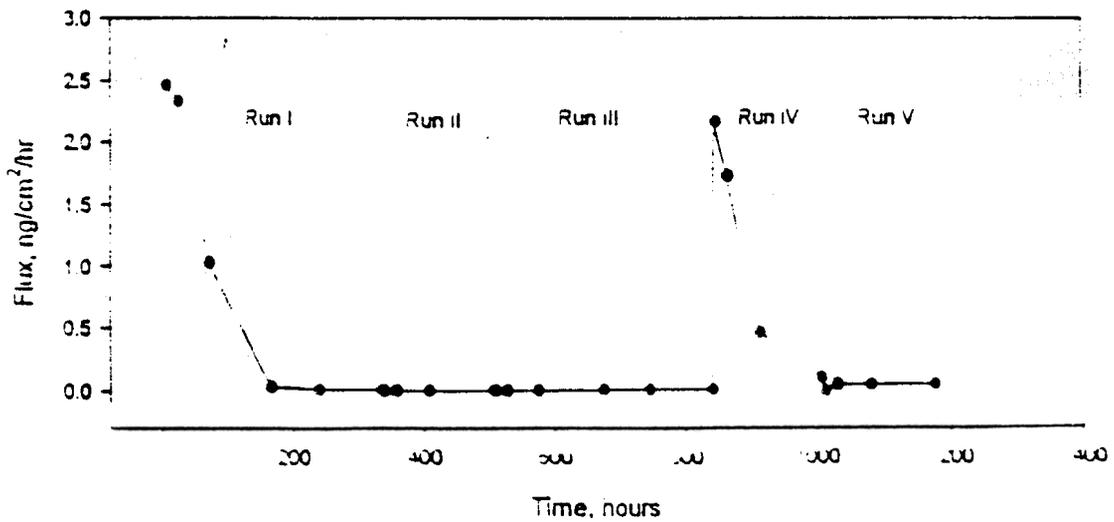
Napthalene



2-Methylnaphthalene



Fluorene



- Run I dry air for 14 days
- Run II humid air for 7 days
- Run III rewet sediment followed by dry air for 14 days
- Run IV rework sediment followed by dry air for 7 days
- Run V humid air for 7 days

TRPH Flux

The TRPH flux rate decreased from 500 to 175 ng/cm²/hr in 168 hours followed by an increase in rate to 867 ng/cm²/hr at the start of test Run II when the humid air was passed over the sediment (Figure 3). The increased flux of TRPHs suggests that the factors affecting TRPH differ fundamentally from those affecting PAHs. The response to humid air by TRPH fluxes indicated that the change in relative humidity of the carrier in Run II may have decreased the sediment sorptive capacity for TRPHs allowing for increased volatilization. A large flux of TRPHs of 4,900 ng/cm²/hr occurred after remixing of the sediment at Run IV.

Ammonia Flux

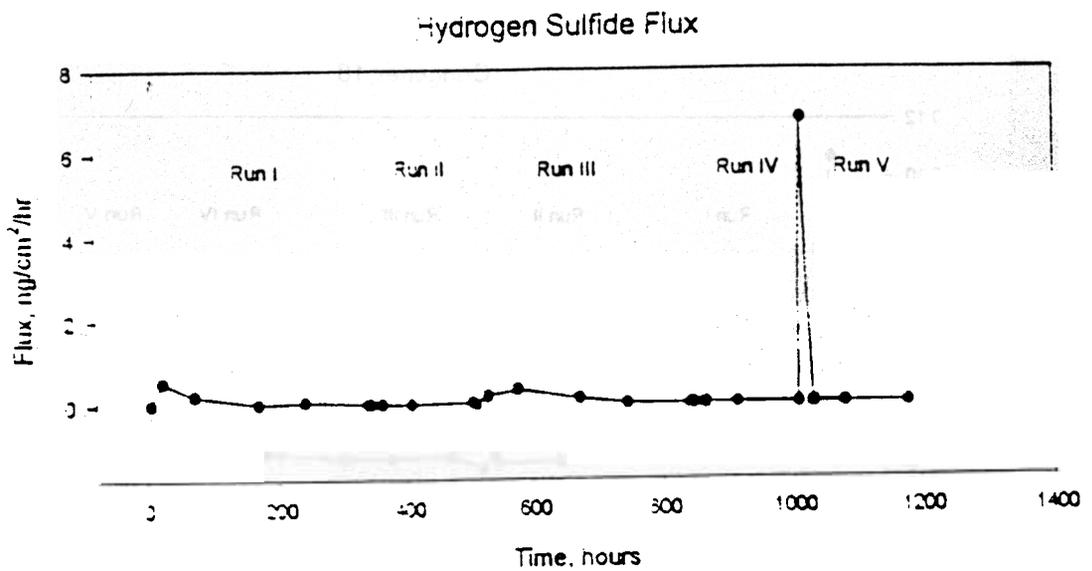
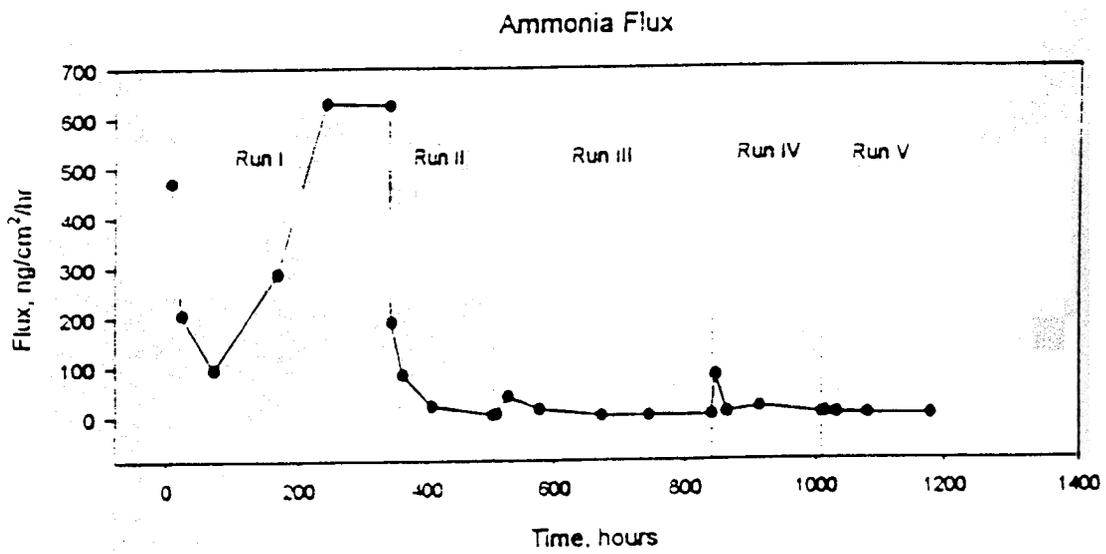
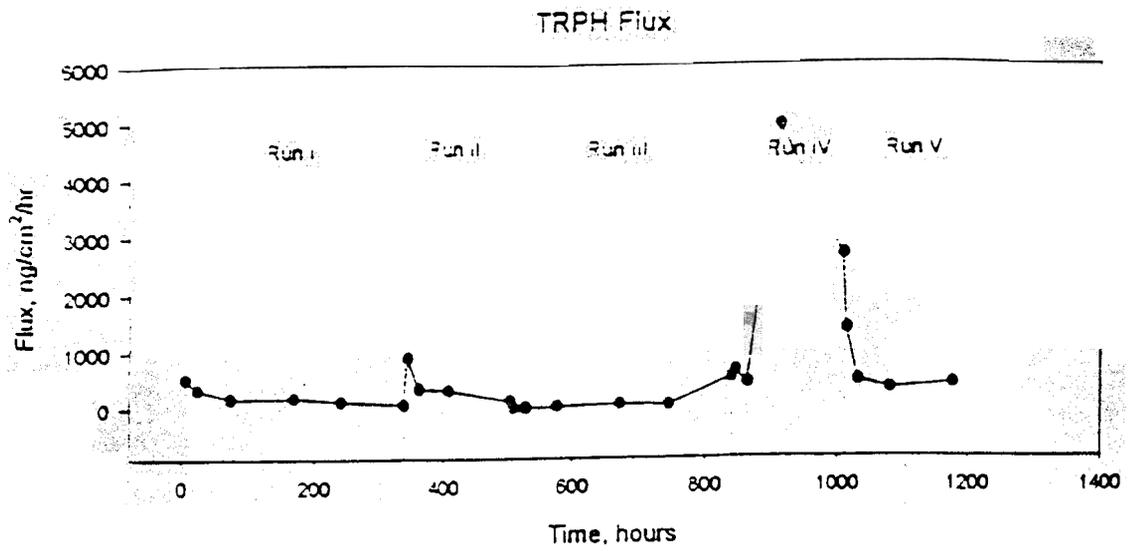
Ammonia flux rates showed an initial decrease in rate from 471 to 94 ng/cm²/hr in the first 72 hours during Run I, followed by an increase in rate to 631 ng/cm²/hr at 240 hours (Figure 3). Emission rates fell at the beginning of Run II when humid air was applied, and did not show an increase until Run IV, when the increase was slight and temporary, only to 80 ng/cm²/hr. These data indicate that high ammonia fluxes will prevail only during the initial stages of sediment exposure.

Hydrogen Sulfide Flux

Hydrogen sulfide fluxes remained relatively constant (<0.54 ng/cm²/hr) over the course of the test with the exception of a large increase to 6.8 ng/cm²/hr at the beginning of Run V when the air relative humidity was adjusted to 97% (Figure 3). During remixing of the sediment (prior to the start of Run IV), hydrogen sulfide flux approached 100 ng/cm²/hr. Apparently, the available hydrogen sulfide volatilized during reworking and was not released until the sorptive capacity of the sediment decreased when the air humidity increased.

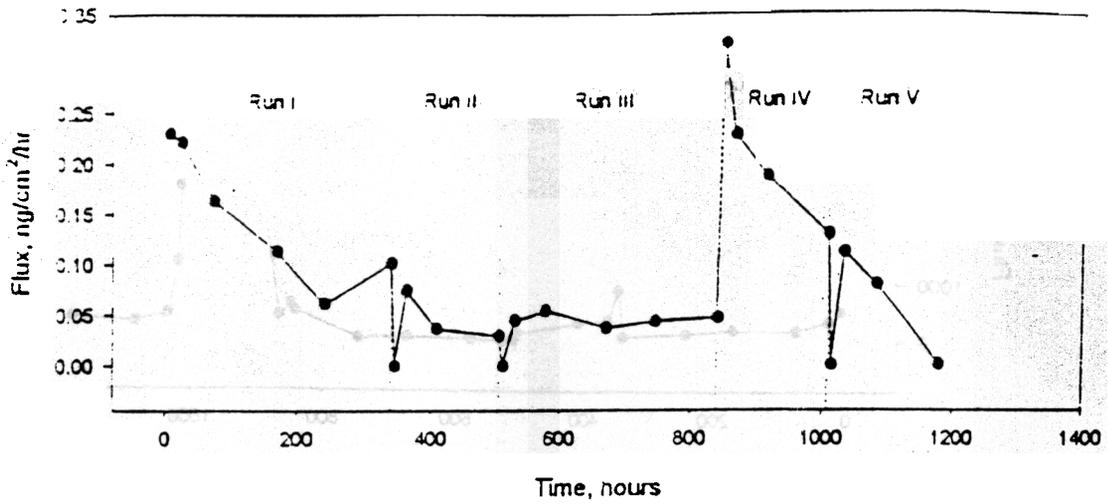
PCB Fluxes

PCB 1248 was the only arochlor detected during the experiment. Initial flux rates in Run I decreased to 0.06 ng/cm²/hr at 240 hours of sampling and had increased to 0.101 ng/cm²/hr by 336 hours (Figure 4). As observed for PAH fluxes, Run IV showed a large initial increase in emission rate followed by a decrease. Flux rates for most congeners showed trends similar to those for PAH emissions. Volatilization rates for all detected PCBs decreased during Run I and peaked again at the beginning of Run IV after sediment was remixed. Congeners appeared to follow arochlor flux patterns. Increasing relative humidity of the carrier air slightly increased flux rates at the beginning of Runs II and V.

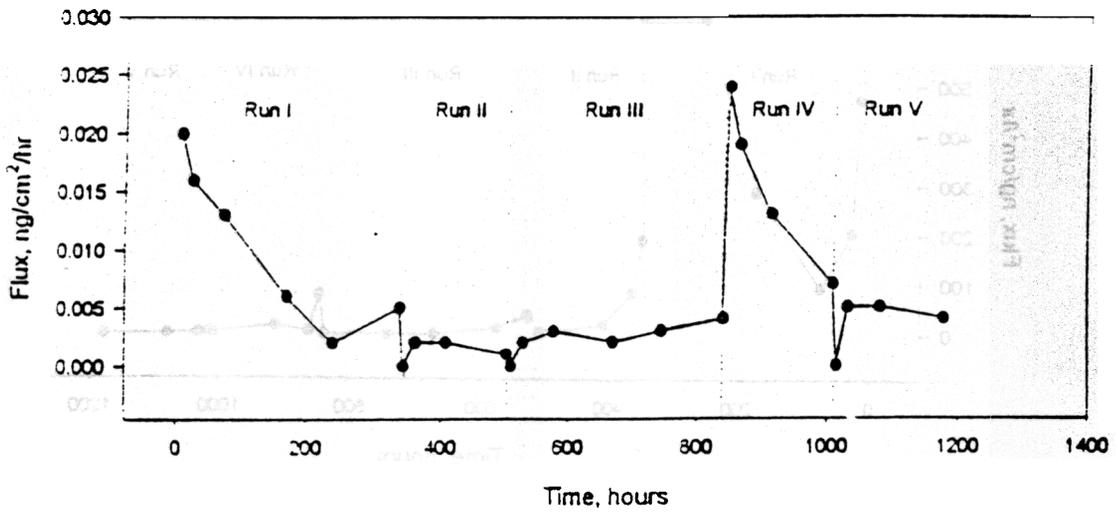


Run I dry air for 14 days
 Run II humid air for 7 days
 Run III rewet sediment followed by dry air for 14 days
 Run IV rework sediment followed by dry air for 7 days
 Run V humid air for 7 days

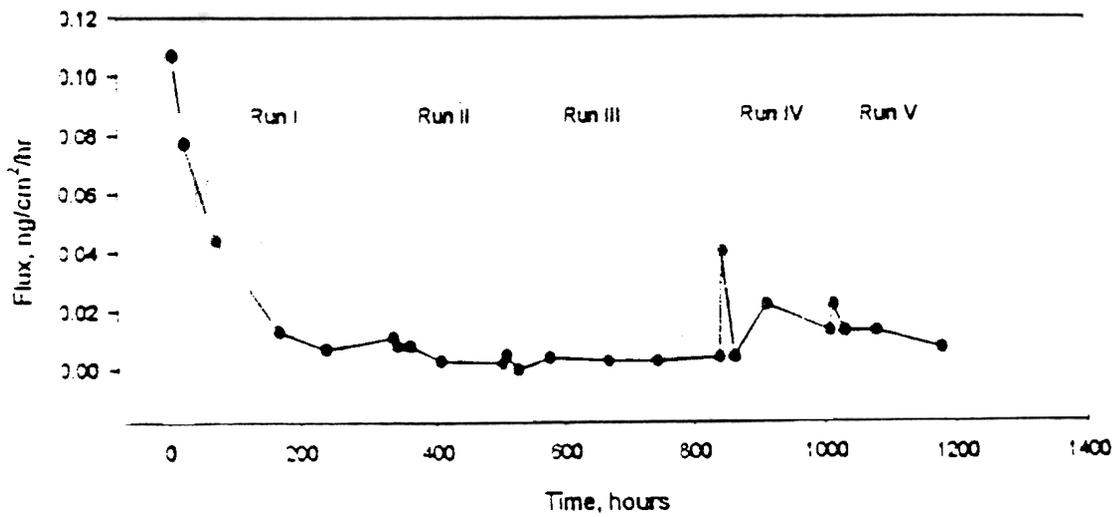
Arochlor 1248



Congener 8



Congener 18



- Run I dry air for 14 days
- Run II humid air for 7 days
- Run III rewet sediment followed by dry air for 14 days
- Run IV rework sediment followed by dry air for 7 days
- Run V humid air for 7 days

Fig 4

Methyl Mercaptan Flux

The sediment concentration of methyl mercaptan was below the method detection limit of 8 mg/kg. Also, during the experimental runs no methyl mercaptan was trapped. Therefore, any flux would be insignificant.

Odor Analysis for Ammonia, and Hydrogen Sulfide (PCB Risk Analysis)

The contaminants ammonia and hydrogen sulfide were evaluated in this experiment, but were not discussed in the EIS odor analysis. The mechanics for sorption are different for these parameters than the organics PAHs/PCBs previously discussed. As such the model could not be used to estimate a flux rate. In order to estimate air concentrations for these parameters a number of assumptions had to be made as discussed in Table 6.

Table 6 Assumptions used to develop contaminant air concentrations

Surface Area A1	Overall exposed surface area for sediment in CDF approximately 110 acres (445,000 m ²)
Surface Area A2	Exposed surface area for 8 days of sediment placement during dredging a high volume year. Assuming 250,000 yd ³ placed in CDF in 4 months (2083yd ³ /day*8 day =16,667 yd ³). Assuming 3' lift results in a exposed surface area of 150,000 ft ² (13,900m ²)
Flux (A1)	Contaminant flux rate from Area A1. Based on stabilized flux rate measured during experiment (see Figures 2-4). The time period to reach a stabilized flux rate ranged from <1day for hydrogen sulfide to about 8 days for PCB 1248
Flux (A2)	Contaminant flux rate from Area A2. Based on highest flux rate measured during experiment (see Figures 2-4)
Max onsite concentration	Based on a hypothetical rectangular storage facility, assuming highest flux rate measured during experiment over an 8 hour period. The storage facility is assumed 10' tall (Dike incremental height).

All of the assumptions provided in Table 6 are conservative. For instance the sediment within the CDF is represented by two locales (A1 & A2) which are both based on short term experimental conditions allowing for maximum flux. When in reality for any given time the majority of the exposed sediment will be in an aged and undisturbed state substantially reducing the composite flux from the CDF. The maximum onsite concentrations, derived for worker health and safety were very conservatively based on a box model assuming no washout from within the CDF occurring over a period of 8 hours. Table 7 provides the results for these parameters.

Table 7 - Odor results for Ammonia, and Hydrogen Sulfide (PCB Flux)

Compound	¹ Flux (g/m ² *s)	² Perimeter Modeled Conc. (ug/m ³)	³ Max Offsite Conc./distance (ug/m ³)	⁴ Odor (ug/m ³)	⁵ Max Onsite Modeled Conc. (ug/m ³)	⁶ OSHA/PEL (ug/m ³)
Ammonia	1.22E-07	12.6	13.8/148m	37-4,600	16,550	27,000
⁷ Hydrogen Sulfide	1.40E-09/ 9.50E-09	0.14	0.16/148m	0.47-4.7	2,600	14,000
PCB 1248	1.632E-10	-----	-----	-----	-----	-----



Neither ammonia nor hydrogen sulfide are expected to exceed odor thresholds offsite from the CDF. However, given a worst case scenario assuming stagnant atmospheric conditions for 8 hours, the concentrations of these parameters onsite could reach elevated levels, yet below OSHA PELs. The PCB 1248 flux value of $1.63\text{E-}10$ $\text{g/m}^2\cdot\text{s}$ is less than the modeled value used in the Inhalation Risk Analysis (Appendix T) completed in the EIS. The risk analysis used a value of $1.007\text{E-}09$ $\text{g/m}^2\cdot\text{s}$. Since the air dispersion model used for the Risk Analysis (U.S. EPA approved Industrial Source Complex Long Term Version 2) is much more sophisticated, and accurate, than the "screening level" (SCREEN3) model used here, no modeled air concentrations are provided.

Conclusions

Results of the experiment showed the highest contaminant fluxes occur with initial loading and mechanical disturbance of the sediment. Results imply that wetting of the sediment will not drastically increase emission rates. Measured fluxes were considerably lower (on average $>10\text{x}$) than modeled fluxes. Sediment physical and chemical characteristics, such as aging, porosity, and percent oil and grease probably decreased fluxes.

Flux rates for PAHs will be highest during initial sediment exposure (after placement) and after reworking activities which exposes underlying material. Changes in relative air humidity or sediment moisture following rainfall did not increase fluxes. TRPH fluxes will also be highest during and after re-working of the sediment. Increases in relative humidity of air increased flux rates for a short period. Ammonia fluxes will be highest during initial exposure stages. Hydrogen sulfide fluxes will be highest during reworking of the sediment. Fluxes may be evident during initial exposure, but may be dependent on environmental conditions. Fluxes for PCBs will be highest during initial exposure and after reworking. Increases in relative air humidity will result in a slight increase in PCB and TRPH flux rates.

The fluxes from the mathematical model overestimated the experimental fluxes. Based on this comparison, it is concluded that there will be no off-site odor impacts.

References

Semmler, Jay, A. 1990. "PCB Volatilization from Dredged Material, Indiana," Environmental Effects of Dredging Technical Notes, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Thibodeaux, Louis J. 1989. "Theoretical Models for Evaluation of Volatile Emissions to Air During Dredged Material Disposal with Applications to New Bedford Harbor, Massachusetts," Miscellaneous Paper EL-89-3, US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Price, Cindy 1997. "Memorandum on Laboratory Assessment of Volatilization From Indiana Harbor Sediment", US Army Engineer Waterways Experiment Station, Vicksburg, MS.

Addendum to Indiana Harbor Volatilization and Odor Analysis

To further assess the importance of the cases where the measured flux rates exceeded the calculated flux rates, the USEPA SCREEN3 air quality model was run to calculate a maximum air concentration associated with the measured flux rates. The air concentrations were generated using an area source with dimensions comparable to the proposed Indiana Harbor Confined Disposal (CDF) facility. The dimensions of the area source were 630m by 1,020m. The use of an area source implies that the entire area of the source will have an equal flux rate. This is much more conservative than the anticipated conditions at the actual CDF, since the actual CDF will consist of separate cells filled in sequence.

Conservative assumptions were used in the SCREEN3 model input parameters. The source height was assumed to be at ground level (0 meters). The receptor height was assumed to be 2 meters. The "urban" option was selected, for wind velocity profile. The default regulatory values for maximum mixing height (10,000 meters) and anemometer height (10 meters) were used. The full meteorology data set was used, and the model scanned directions to find the maximum air concentration. In addition, distances between 10 meters and 10,000 meters from the source were evaluated.

Maximum air concentration results were compared to the USEPA Risk Standards published in the USEPA Region 3 Risk-Based Concentration Table updated October 1998. The risk standards published in that table correspond to the concentrations which, when used with the USEPA Risk Assessment Guidance for Superfund (RAGS) Equations with default values, result in an increased lifetime cancer risk of 1×10^{-6} for carcinogens, or a Hazard Quotient (HQ) of 1 for non-carcinogens. These concentrations are typically used as a screening level evaluation, in lieu of a full risk assessment. The SCREEN3 maximum air concentrations were compared to the ambient air risk concentration standards found in the Risk-Based Concentration Tables.

A review of the comparison shows that the resultant maximum concentrations were lower than the ambient air risk standards for all cases except the naphthalene flux measured in run T1. For naphthalene, the EPA ambient air risk standard is 3.3 ug/m^3 . The resultant concentration generated using the using the experimentally measured flux from run T1 was 6.13 ug/m^3 . If the actual CDF operation sequence were used as input to the SCREEN3 model, the resultant maximum air concentration would almost certainly be lower than the risk standard. Furthermore, the conservative nature of the experiment (air-side resistance eliminated) indicates that actual field flux rates will be lower than the experimentally determined flux rate. Results are summarized in Table A-1.

Since naphthalene exceeded the risk standard for this screening level evaluation, it should be considered during future analyses of potential air impacts. Actual operation of the CDF will include air monitoring to protect on-site worker safety and to control off-site impacts. More detailed analyses of air quality impacts will likely be conducted during the design phase of this project. These analyses should include a more realistic representation of the

CDF filling operation that includes filling of specific cells rather than filling the entire CDF. These design phase analyses will identify the analytical parameters which require monitoring during the CDF filling operation.

It should be noted that for the PCB congeners, the resultant maximum air concentrations for each congener were compared to the EPA risk standard for Total PCBs. While this comparison is technically incorrect, a review of the Air Standards for the individual aroclors shows that the value of the air standard for each aroclor except 1016 is the same numerical value as the air standard for total PCBs. Logically, if ambient air contains PCBs at concentrations close to the risk standard for several aroclors, the total PCB concentration in that air would probably exceed the total PCB air standard. This demonstrates the screening level nature of the air standards, and suggests the comparison performed here between PCB congener concentrations and total PCB air standards is reasonable as a screening level assessment.

Table A-1. Comparison of Air Concentrations generated Using Experimental, Measured Flux Rates with USEPA Ambient Air Risk Standards.

Compound	Run	Run Time hrs	Flux		7RPD	Flux		SCREEN3 Air Concentration		7RPD	EPA Air Risk Standard ug/m3	Comparison
			measured ng/(cm2.hr)	calculated ng/(cm2.hr)		measured g/(m2.s)	calculated g/(m2.s)	Max Conc. 1 ug/m3	Max Conc. 2 ug/m3			
PCB 54	T1	6	0.017	0.014	19%	4.72E-11	3.89E-11	2.14E-03	1.77E-03	19%	3.10E-03	OK
	T2	18	0.011	0.007	44%	3.06E-11	1.94E-11	1.39E-03			3.10E-03	OK
	T3	48	0.0098	0.0042	80%	2.72E-11	1.17E-11	1.24E-03			3.10E-03	OK
	T4	96	0.0054	0.0027	67%	1.50E-11	7.50E-12	6.81E-04			3.10E-03	OK
	T5	72	0.004	0.0023	54%	1.11E-11	6.39E-12	5.04E-04			3.10E-03	OK
	T6	96	0.0035	0.0019	59%	9.72E-12	5.28E-12	4.41E-04			3.10E-03	OK
PCB 114	T2	18	0.0017	0.0009	62%	4.72E-12	2.50E-12	2.14E-04			3.10E-03	OK
PCB 121	T1	6	0.012	0.0098	20%	3.33E-11	2.72E-11	1.51E-03			3.10E-03	OK
	T2	18	0.019	0.005	117%	5.28E-11	1.39E-11	2.40E-03			3.10E-03	OK
	T3	48	0.016	0.0029	139%	4.44E-11	8.06E-12	2.02E-03	3.66E-04	139%	3.10E-03	OK
	T5	72	0.0049	0.0016	102%	1.36E-11	4.44E-12	6.17E-04			3.10E-03	OK
PCB 159	T2	18	0.0011	0.00087	23%	3.06E-12	2.42E-12	1.39E-04			3.10E-03	OK
	T3	48	0.001	0.00051	65%	2.78E-12	1.42E-12	1.26E-04			3.10E-03	OK
Benzo(a)Pyrene	T4	96	0.015	0.0004	190%	4.17E-11	1.11E-12	1.89E-03			2.00E-03	OK
Benzo(g,h,l)Perylene	T4	96	0.0052	0.0023	77%	1.44E-11	6.39E-12				Note 4	OK
Benzo(k)Fluoranthene	T4	96	0.019	0.001	180%	5.28E-11	2.78E-12	2.40E-03			8.60E-02	OK
Chrysene	T4	96	0.01	0.0004	185%	2.78E-11	1.11E-12	1.26E-03			8.60E-01	OK
Naphthalene	T1	6	50	36	33%	1.39E-07	1.00E-07	6.13E+00	4.54E+00	30%	3.30E+00	EXCEEDENCE
	T2	18	26	19	31%	7.22E-08	5.28E-08	3.28E+00			3.30E+00	OK
Pyrene	T1	6	0.053	0.003	179%	1.47E-10	8.33E-12	6.67E-03			1.10E+02	OK
	T2	18	0.091	0.0027	188%	2.53E-10	7.50E-12	1.15E-02			1.10E+02	OK
	T3	48	0.097	0.0027	189%	2.69E-10	7.50E-12	1.22E-02			1.10E+02	OK
	T4	96	0.088	0.0026	189%	2.44E-10	7.22E-12	1.11E-02			1.10E+02	OK
	T5	72	0.081	0.0025	188%	2.25E-10	6.94E-12	1.02E-02			1.10E+02	OK
	T6	96	0.085	0.0024	189%	2.36E-10	6.67E-12	1.07E-02			1.10E+02	OK

Notes:

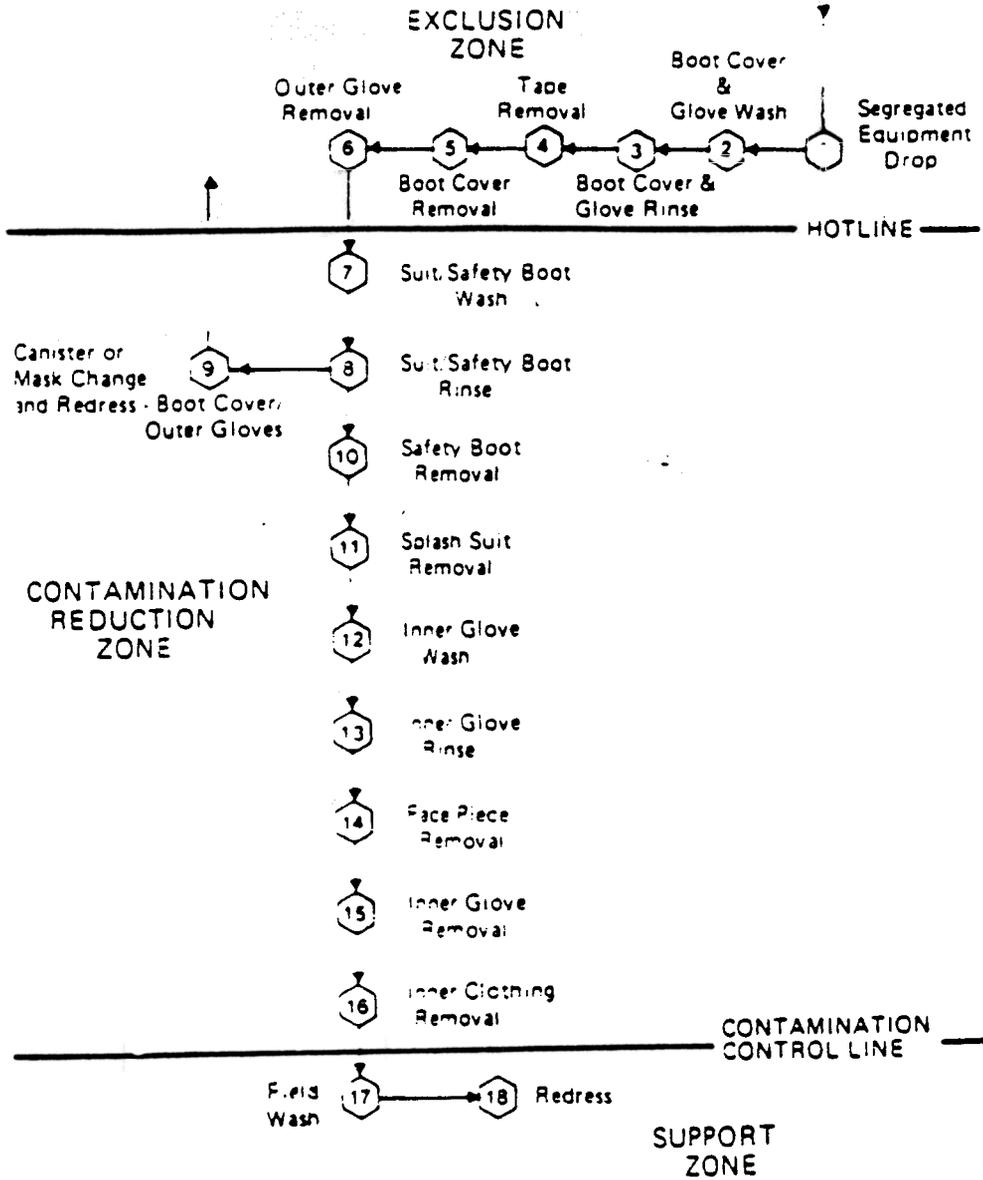
- 1 - Max Conc. 1 is the maximum concentration generated using the SCREEN3 Model using the MEASURED flux rate as input. See text for discussion.
- 2 - Max Conc. 2 is the maximum concentration generated using the SCREEN3 Model using the CALCULATED flux rate as input. See text for discussion.
- 3 - EPA Risk Standard is the ambient air concentration which when used in the EPA Superfund Risk Assessment Equations, results in a lifetime cancer risk of 1E-6 for carcinogens or a Hazard Quotient of 1 for non-carcinogens, as reported in the EPA Risk Based Concentration Table, dated October 1998. For reference, the PCB congeners and Benzo(a)pyrene, Benzo(k)fluoranthene, and Chrysene are considered carcinogens, and Naphthalene and Pyrene are considered non-carcinogens.
- 4 - No Risk Standard was published for Benzo(g,h,l)perylene in the above reference.
- 5 - Comparison shows the result of the comparison of the maximum concentration generated using the SCREEN3 Model using the MEASURED flux rate to the Risk Standard. If the Maximum Concentration was lower than the Risk Standard, the cell reads "OK". If the Maximum Concentration was greater than the Risk Standard, the cell reads "EXCEEDENCE".
- 6 - The PCB Air Standard is for Total PCBs, and is therefore not a completely appropriate comparison. However, examination of EPA Risk Standards shows that the air standard for each Aroclor except 1016 is the same value as the air standard for Total PCBs, therefore there is a precedence for using this value for a screening level evaluation.
- 7 - RPD = Relative Percent Difference

GENERAL DECONTAMINATION SCHEMES AND EQUIPMENT

PROCESS DECON PROCEDURES

MAXIMUM DECONTAMINATION LAYOUT

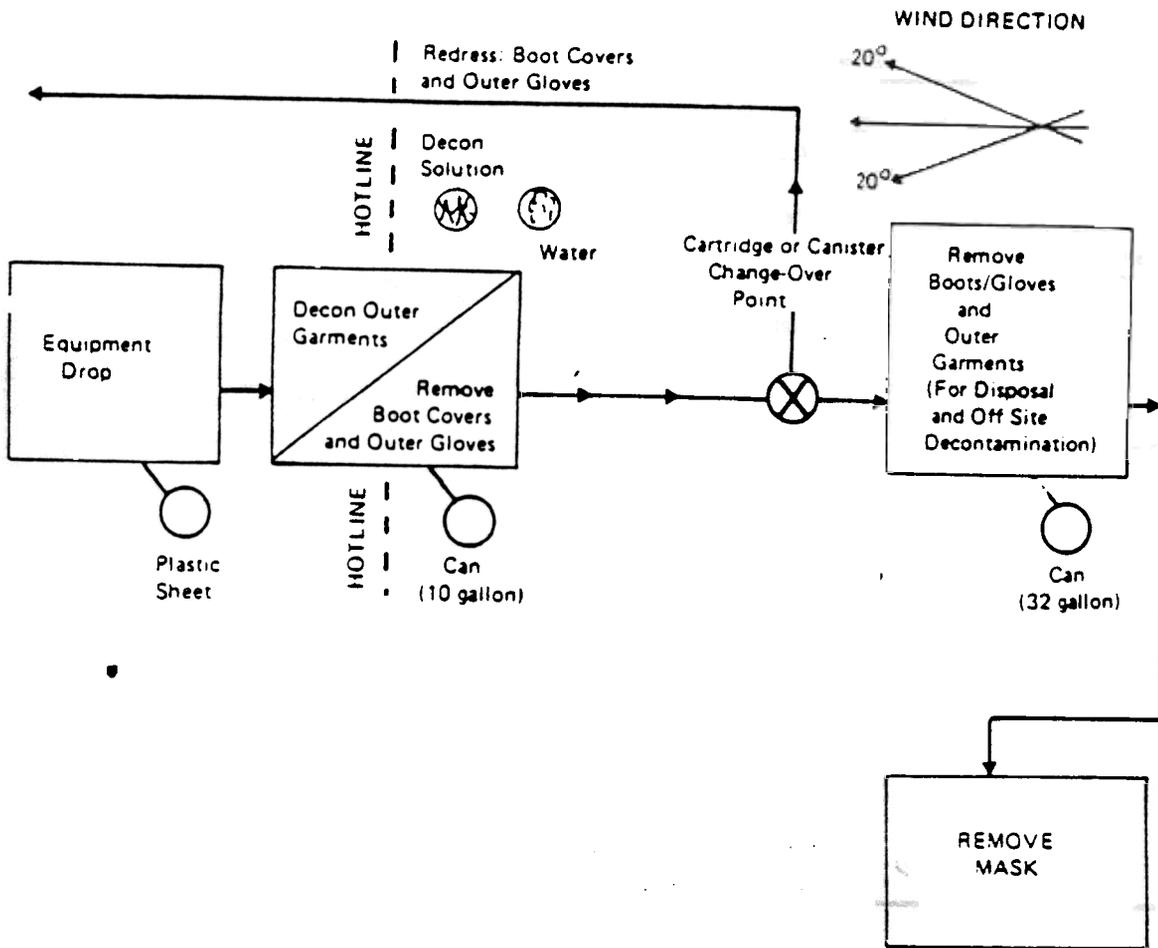
LEVEL C PROTECTION



Source: Excerpted from "Field Operating Procedures for the Decontamination of Response Personnel (FSOP 7)." EPA Office of Emergency and Remedial Response, Hazardous Response Support Division, Washington, D.C., January 1985.

MINIMUM DECONTAMINATION LAYOUT

LEVEL C PROTECTION



EQUIPMENT NEEDED TO PERFORM MAXIMUM DECONTAMINATION MEASURES FOR LEVELS A, B, AND C

- Station 1: a. Various Size Containers
b. Plastic Liners
c. Plastic Drop Cloths
- Station 2: a. Containers (20-30 Gallons)
b. Decon Solution or Detergent Water
c. 2-3 Long-Handled, Soft-Bristled Scrub Brushes
- Station 3: a. Containers (20-30 Gallons)
OR
High-Pressure Spray Unit
b. Water
c. 2-3 Long-Handled, Soft-Bristled Scrub Brushes
- Station 4: a. Containers (20-30 Gallons)
b. Plastic Liners
- Station 5: a. Containers (20-30 Gallons)
b. Plastic Liners
c. Bench or Stools
- Station 6: a. Containers (20-30 Gallons)
b. Plastic Liners
- Station 7: a. Containers (20-30 Gallons)
b. Decon Solution or Detergent Water
c. 2-3 Long-Handled, Soft-Bristled Scrub Brushes
- Station 8: a. Containers (20-30 Gallons)
OR
High-Pressure Spray Unit
b. Water
c. 2-3 Long-Handled, Soft-Bristled Scrub Brushes
- Station 9: a. Air Tanks or Face Masks and Cartridge Depending on Level
b. Tape
c. Boot Covers
d. Gloves

- Station 10: a. Containers (20-30 Gallons)
b. Plastic Liners
c. Bench or Stools
d. Boot Jack
- Station 11: a. Rack
b. Drop Cloths
c. Bench or Stools
- Station 12: a. Table
- Station 13: a. Basin or Bucket
b. Decon Solution
c. Small Table
- Station 14: a. Water
b. Basin or Bucket
c. Small Table
- Station 15: a. Containers (20-30 Gallons)
b. Plastic Liners
- Station 16: a. Containers (20-30 Gallons)
b. Plastic Liners
- Station 17: a. Containers (20-30 Gallons)
b. Plastic Liners
- Station 18: a. Water
b. Soap
c. Small Table
d. Basin or Bucket
e. Field Showers
f. Towels
- Station 19: a. Dressing Trailer is Needed in Inclement Weather
b. Tables
c. Chairs
d. Lockers
e. Cloths

EQUIPMENT NEEDED TO PERFORM MINIMUM DECONTAMINATION MEASURES FOR LEVELS A, B, AND C

- Station 1: a. Various Size Containers
b. Plastic Liners
c. Plastic Drop Cloths
- Station 2: a. Containers (20-30 Gallons)
b. Decon Solution
c. Rinse Water
d. 2-3 Long-Handled, Soft-Bristled Scrub Brushes
- Station 3: a. Containers (20-30 Gallons)
b. Plastic Liners
c. Bench or Stools

- Station 4: a. Air Tanks or Masks and Cartridges Depending Upon Level
b. Tape
c. Boot Covers
d. Gloves
- Station 5: a. Containers (20-30 Gallons)
b. Plastic Liners
c. Bench or Stools
- Station 6: a. Plastic Sheets
b. Basin or Bucket
c. Soap and Towels
d. Bench or Stools
- Station 7: a. Water
b. Soap
c. Tables
d. Wash Basin or Bucket