



CITY OF CAMBRIDGE
CAMBRIDGE, MASSACHUSETTS 02139

TEL 349-4300

FAX 349-4307

EXECUTIVE DEPARTMENT
ROBERT W. HEALY
City Manager

RICHARD C. ROSSI
Deputy City Manager

May 1, 1996

To The Honorable, The City Council:

As you are aware, a number of fact finding efforts have been underway over the last several months regarding a proposal for development of the W. R. Grace site for retail and hotel use. Efforts undertaken by the City to review current and future environmental conditions include: engaging the services of an independent environmental consultant, to advise us all of any potential health risks related to contamination from previous industrial activity at the site; ongoing review of Grace Site remediation and construction activities associated with both the MBTA facilities and Russell Field; working with the Massachusetts Department of Environmental Protection as they review the site classification and remediation under the Massachusetts Contingency Plan; and review of wetlands and floodplain concerns at the site. With respect to traffic issues, the City engaged the services of a traffic consultant, Rizzo Associates, Inc. to review the traffic impacts associated with the proposed use. All of this information has been recently discussed during the numerous meetings of the Grace Site Advisory Committee which was convened to identify and review issues, concerns and opportunities associated with the proposed retail/hotel development.

While the proposal for the supermarket, retail and hotel use has recently been withdrawn from consideration, the information gathered through these efforts remains useful. Enclosed you will please find the initial and final reports prepared by Dr. John D. Spengler, of Environmental Health & Engineering, Inc. and the Harvard School of Public Health, on public health issues associated with site contamination.

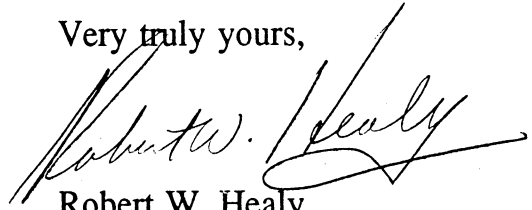
Dr. Spengler's report concludes that the contamination on site as a result of industrial activities does not present a risk to public health and recommends additional measures to further ensure this. His conclusions address the site under existing conditions, during construction (assuming implementation of a management plan as required by the Massachusetts Department of Environmental Protection) or during proposed,

redeveloped conditions. To further ensure protection against future risk; his report recommends the following actions to the developer and the City:

- monitor groundwater at site perimeter to detect potential migration of site contaminants.
- review and approval of soil remediation activities by Massachusetts Department of Environmental Protection.
- clarify whether contaminated soil from the W.R. Grace site was stored on Russell Field, and if any contamination remains.

The City Staff have already begun to work with the MBTA regarding use of Russell Field and the Massachusetts Department of Environmental Protection regarding Massachusetts Contingency Plan review of the W.R. Grace site. I will keep you informed of progress in implementation of these recommendations.

Very truly yours,

A handwritten signature in black ink, appearing to read "Robert W. Healy", with a stylized flourish at the end.

Robert W. Healy
City Manager

**Environmental
Health &
Engineering, Inc.**

March 20, 1996

Ms. Elizabeth Epstein
Deputy Director
Community Development Department
57 Inman Street
Cambridge, MA 02139

**RE: Public Health Risk Evaluation for W.R. Grace Site in Cambridge, Massachusetts,
(EH&E 95.415)**

Dear Ms. Epstein:

Environmental Health & Engineering, Inc. (EH&E) is pleased to present this summary of our review of public documents and data describing environmental measurements and risk assessments for the W.R. Grace site located at 62 Whittemore Avenue in Cambridge, Massachusetts. The site is a 27-acre, irregularly-shaped parcel of land that is directly east of the Alewife Brook Parkway and Route 2 interchange in Cambridge. Public health issues addressed for this evaluation included potential impacts of airborne compounds generated by excavation and movement of soil during site development, transport of site-related compounds through groundwater and surface water to the site and vicinity, and potential exposures related to the site as it currently exists.

BACKGROUND

The primary health concerns of the City of Cambridge regarding the proposed development of this site are based on its former use for chemical manufacturing and the compounds that remain on site as a result of these previous manufacturing activities. The site is currently listed with the Massachusetts Department of Environmental Protection (MADEP), based on 1984 and 1985 evaluations of subsurface and hydrogeological conditions that indicated the presence of volatile and semi-volatile organic compounds, petroleum products, and metals.

Environmental Health & Engineering, Inc.
60 Wells Avenue
Newton, MA 02159-3210
TEL (617) 964-8550 FAX (617) 964-8555
EMAIL EHE1@AOL.COM



The Dewey and Almy Chemical Company developed the site in 1919 for the manufacture of rubber products used for sealing compounds, drum and pail cover gaskets, and bottle cap gaskets. One of the major products manufactured on the site was naphthalene sulfonate (trade name DAXAD), a compound used to facilitate the dispersion of rubber in water. During the period of DAXAD manufacture, several lagoons on the site were used for settling ponds and sources of cooling water. This activity is the presumed major source for the continued presence of naphthalene in soils at the site. Evaluation of the map of the storage areas (Ref. H&A Public Involvement Plan) indicates storage of a number of chemical compounds, as well as fuel oils, on the site during the Dewey and Almy operations. Based on the 1988 health risk assessment by Meta Systems, Inc. and a 1994 update by the same company (now named Cambridge Environmental, Inc.), the compounds detected on the site at levels that indicate potential health concerns are naphthalene, formaldehyde, fluorene, and several petroleum-based compounds.

EH&E'S PUBLIC HEALTH RISK EVALUATION FOR W.R. GRACE SITE

EH&E's evaluation of the history and extensive database associated with this site, which was purchased by W.R. Grace in the early 1940s, involved several broad categories of activities.

- Evaluation of the sufficiency and adequacy of measurement data collected by Haley & Aldrich at the W.R. Grace site.
- Evaluation of the 1988 health risk assessment and its 1994 update.
- Evaluation of the groundwater model and the potential for transport of site-related compounds to neighboring properties.
- Evaluation of the hazardous materials management plan.
- Communication with the City and its advisory committee regarding the potential health impacts related to current and future conditions of the site.



- Discussions with staff members from Cambridge Environmental, Inc. and Haley & Aldrich regarding clarification of previous work related to the W.R. Grace site.

The following is a summary of our findings and recommendations. A draft report has been prepared and will be available for review in advance of the committee meeting scheduled for April 11, 1996.

RECOMMENDATIONS

1. Monitoring of groundwater should continue to provide long-term assurance to residents bordering the W.R. Grace site. The low levels of compounds reported in offsite well 604 near the Alewife Brook do not present a health risk. Results of multi-year monitoring from three wells along Whittemore Avenue indicated that site contaminants have not moved offsite in this northerly direction. However, direct monitoring rather than groundwater modeling can provide the best assurance that contaminants have not migrated toward residential areas.

Groundwater flow may be altered by development, repairs to the MBTA tunnel, variations in surface recharge rates, and other factors. Surveillance of groundwater for evidence of site-related compounds should continue after site development. Selection and use of analytical methods that detect very low levels of contaminants will provide adequate response time to ensure that public health and economic interests are protected.

2. Questions remain regarding how fast and in what directions the groundwater is moving. Quantifying the groundwater transport of site-related contaminants is uncertain based on current assessments. Modeling groundwater flow at this site is complicated by the MBTA tunnels and lack of hydrogeologic information east of the tunnel toward Clifton Street. Additional hydrogeological data and analysis is required. While groundwater movement toward Clifton Street is not expected, we could not confirm this based on the information provided. Additional data (groundwater elevations, permeability) collected east of the MBTA tunnel, along with measurements taken from existing wells, will determine direction and speed of hydrogeologic pressure driven groundwater flow with more certainty.

Following a review, recommendations about the extent and frequency of continued monitoring of groundwater could be reconsidered.

3. EH&E is satisfied that the chemical compounds identified on the site currently do not and will not (with anticipated construction and future site use) constitute a risk to public health. The risk assessment conducted for this site used conservative methods to examine both the cancer and non-cancer risks and determined them to be below levels of concern established by MADEP. Groundwater monitoring at the site boundary, the planned soil remediation, and the mitigation of construction impacts will further ensure that risks are maintained at acceptably low levels.
4. MADEP audit of the Tier Classification of the site is encouraged. A change in classification from the current II to a IA, IB, or IC would require varying degrees of State oversight or permitting. At a minimum, the State should review and approve soil remediation activities.
5. Although the issue concerning the storage of contaminated soil on Russell Field is only marginally related to the proposed development, the city (and/or MBTA) should resolve the remaining uncertainties. This may include sampling of surface or subsurface soils, groundwater, or providing verification from manifest records that contaminated soils were handled appropriately.

GENERAL FINDINGS

Extensive sampling of soil and groundwater was performed between 1984 and 1988 in anticipation of development plans for the site proposed in the late 1980s. Soil and water samples were analyzed for more than 125 analytes, including volatile organic compounds (VOCs), pesticides, polycyclic aromatic hydrocarbons (PAHs), metals, and polychlorinated biphenyls (PCBs) among others. The data set provided to us had 78 compounds listed as well as total cyanide, total sulfates, total phenol, and grease/oil. According to Haley & Aldrich, the remaining 47 compounds were never detected in any of the samples.

Sixteen of the compounds or metals tested in the soil exceeded reporting levels established by MADEP. Eighteen compounds or metals tested in the groundwater were at concentrations

above the MADEP-required reporting levels. The MADEP reporting levels used here simply as a reference, applies to soils and water at residential sites or sites with unrestricted access. All of these compounds exceeding the stricter reporting levels were included in the 1988 risk assessment. These compounds, plus oil, grease, petroleum hydrocarbons in the soil and formaldehyde and phenanthrene in the water, were examined statistically. Haley & Aldrich, Cambridge Environmental, W.R. Grace, and City employees were cooperative in providing us prompt access to data and documents as well as candid responses to our inquiries. The following are EH&E's general findings in support of the recommendations.

1. Provided that the proposed soil remediation and additional boundary line well monitoring takes place, EH&E does not foresee health impacts resulting from contaminants that originated from former industrial use of the site.
2. Data from soil samples, including the duplicates, suggest that the selected analytic methods were adequate to discriminate differences in concentrations between sampling locations and variations attributable to laboratory and sampling procedures. Evaluation of all soil sample duplicates, although limited in number, supports this conclusion.
3. Soil samples in the area of the proposed supermarket and parking lot show that contaminants are not uniformly distributed. Based on the distribution patterns, the locations identified for further remediation are apparent and those locations should be addressed during construction.
4. Soils in the vicinity of the proposed retail development on the eastern side of the parcel have not been surveyed as thoroughly as the rest of the site. While additional samples would be useful, we do not think they are absolutely necessary. Review of site plans and facility history suggests that chemicals were not stored, used, or deposited on this area. Oversight during construction should identify deposits of oil, grease, naphthalene, and perhaps other odorous compounds, if they exist. Only petroleum hydrocarbons appeared somewhat elevated in this area. The risk assessment anticipated a more extensive disruption of soils from the area where chemicals and fuels were stored and used than currently proposed. However, the exposure scenarios used conservative

methods to estimate assumed activities onsite and dispersion of materials offsite independent of a specific location. Therefore, results of the risk assessment would apply to the development of a sub-parcel on the eastern side of site, provided contaminants in the disturbed soils were similar to those reported.

5. Between 1984 and the present, 44 monitoring wells were drilled in and around the W.R. Grace property. Information about groundwater elevations and bulk water samples were collected from these sites. There were too few well and surface duplicate samples to draw conclusions about the analytic precision of these samples. Confidence in the well water methods was assessed by examining variability for those wells over time. Greater variability in concentrations across the property suggests that some wells were located in areas of higher concentrations, which was the intent. Furthermore, the monitoring methods were specific and sensitive enough to identify movement of contaminants offsite.

Nine monitoring wells were selected by Haley & Aldrich for trends monitoring: three were located along Whittemore Avenue to the north of the property, two wells were along the western border, three wells were near the eastern MBTA entrance and in the vicinity of known naphthalene deposits, and one well was across the road west of the property near Alewife Brook. Measurable concentrations of naphthalene were reported at the offsite well, which, from a hydrogeological perspective, indicates that naphthalene is moving from the site toward the Alewife Brook. While in absolute terms the concentrations were low (below MADEP-reporting values), they suggest that site-related contaminants are moving offsite.

6. The groundwater model was not sufficiently described or documented in reports to substantiate the claims that, "the simulated existing groundwater conditions reasonably reflected measured existing groundwater conditions."

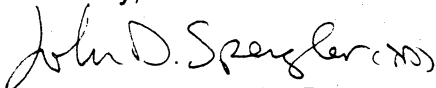
Uncertainties about the recharge rate of water from the surface and the influence of the MBTA tunnel and portals need to be resolved before specific inferences can be derived from the current analysis.

The rates at which contaminants were moving offsite can be inferred either from the modeling or the measurements. At this time we have greater confidence that materials have not left the site on the northern boundary (Whittemore Avenue), but this can not be said about the other directions because no direct evidence exists.

7. While improvements in the risk assessment could be suggested, over all we found it to be reasonable. Estimated health risks were below 1 in 100,000 for cancer and below the reference dose or concentration guidelines. Even assuming naphthalene is a possible human carcinogen and summing the impacts of all the PAHs, the likely risk to workers and neighbors would be small and within acceptable guidelines. When considering that contaminated soil will be remediated before construction, risk would be further reduced.
8. The MBTA tunnel is affecting groundwater flow; it is likely that some site contaminants enter the tunnel. Air and water emissions from MBTA facilities at Alewife do not pose health hazards to neighborhoods or future users of the site.
9. Questions related to storage of contaminated soil at Russell Field are separate from the issues specifically related to development of the W.R. Grace site. If modeling or monitoring indicate that groundwater is moving under Russell Field in the direction of homes on Clifton Street, then it would be another matter. Staged groundwater and possible soil tests are recommended to help resolve this issue.

We look forward to our continuing work on this project.

Sincerely,

A handwritten signature in black ink that reads "John D. Spengler" with a stylized flourish at the end.

John D. Spengler, Ph.D.
Principal

**FINAL DRAFT
PUBLIC HEALTH RISK EVALUATION FOR
W.R. GRACE SITE IN
CAMBRIDGE, MASSACHUSETTS**

Prepared For:

**Ms. Elizabeth Epstein
Deputy Director
Community Development Department
57 Inman Street
Cambridge, MA 02139**

Prepared By:

**Environmental Health & Engineering, Inc.
60 Wells Avenue
Newton, MA 02159-3210**

**EH&E Report # 95.415
April 23, 1996**

P:\95.415\FINLRPT2.DOC

**©1996 by Environmental Health & Engineering, Inc.
All rights reserved**

TABLE OF CONTENTS

1.0 EXECUTIVE SUMMARY.....	1
2.0 BACKGROUND	4
3.0 GENERAL FINDINGS.....	7
4.0 RECOMMENDATIONS.....	11
5.0 EVALUATION OF THE SUFFICIENCY AND ADEQUACY OF DATA FROM SOIL AND GROUNDWATER SAMPLES.....	12
5.1 THE DATA.....	12
5.2 METHODOLOGY	16
5.3 GENERAL FINDINGS	17
6.0 EVALUATION OF THE 1988 AND 1994 HEALTH RISK ASSESSMENTS.....	20
6.1 EXPOSURE SCENARIOS.....	22
6.2 GROUNDWATER.....	23
6.3 SOIL.....	23
6.4 EXPOSURE GROUPS	23
6.5 EXPOSURE PATHWAYS.....	24
6.6 EXPOSURE FACTORS.....	24
6.7 TOXICITY VALUES.....	25
6.8 CONCLUSIONS	26
7.0 EVALUATION OF HYDROGEOLOGIC DATA	28
8.0 RELATED ISSUES	31
8.1 TIER CLASSIFICATION.....	31
8.2 HAZARDOUS MATERIALS MANAGEMENT AND REMEDIAL ACTION.....	35
8.3 MBTA TUNNEL	36
8.4 RUSSELL FIELD	37
9.0 REFERENCES	39

LIST OF APPENDICES

Appendix A	Evaluation of Soil and Groundwater Samples
Appendix B	Supplemental Information - Soil and Groundwater Data: Spatial and Distributional Displays
Appendix C	Limitations

LIST OF TABLES

Table 5.1	Compounds included in the Cambridge Environmental Inc. risk assessment and those included in statistical analyses discussed in this report
Table A.1	Compounds included in the Cambridge Environmental Inc. risk assessment and those included in statistical analyses discussed in this report
Table A.2	Percent of differences less than zero for soil duplicate samples
Table A.3	Paired differences analysis for duplicate soil samples
Table A.4	Qualitative evaluation of soil duplicate samples based on detection category
Table A.5	Soil - Comparison of within duplicates and between duplicate variances
Table A.6	Comparison of variation in concentrations between sites and within sites for groundwater well samples-log transformed data
Table A.7	Number of samples, means, and standard deviations for samples with a measurable concentration of the compound for soil and groundwater samples
Table A.8	Comparison of variation in concentrations between sites and within sites for groundwater well samples-untransformed data
Table A.9	Soil samples - Summary of categorization of samples into non-detect, detect (detected, but concentration not quantified), and measurable (detected and concentration quantified)
Table A.10	Comparison of the distribution of soil concentrations to the MADEP Reporting Standard
Table A.11	Groundwater - Estimated probabilities for three categories non-detect, detect, and measurable for a sampling visit
Table A.12	Comparison of the distribution of groundwater concentrations to the MADEP Reporting Standard

Table A.13 Comparison of observed and estimated probability of measuring a compound at a groundwater well site

LIST OF FIGURES

Figure 1	Proposed Building Footprints
Figure A.1	Spatial Map and Empirical Distribution Function for Naphthalene in Soil
Figure A.2	Spatial Map and Empirical Distribution Function for Formaldehyde in Soil
Figure A.3	Spatial Map and Empirical Distribution Function for Naphthalene in Groundwater
Figure A.4	Spatial Map and Empirical Distribution Function for Formaldehyde in Groundwater

LIST OF ABBREVIATIONS & ACRONYMS

CO ₂	carbon dioxide
EH&E	Environmental Health & Engineering, Inc.
EPA	U.S. Environmental Protection Agency
IRIS	Integrated Risk Information System
MADEP	Massachusetts Department of Environmental Protection
MCP	Massachusetts Contingency Plan
MWRA	Massachusetts Water Resources Authority
NTP	National Toxicology Program
OHM	oil or hazardous materials
PAHs	polycyclic aromatic hydrocarbons
PCBs	polychlorinated biphenyls
ppb	parts of vapor or gas per billion parts of air by volume
ppm	parts of vapor or gas per million parts of air by volume

1.0 EXECUTIVE SUMMARY

Environmental Health & Engineering, Inc. (EH&E) is pleased to present this summary of our review of public documents and data describing environmental measurements and risk assessments for the W.R. Grace site located at 62 Whittemore Avenue in Cambridge, Massachusetts. The site is a 27-acre, irregularly-shaped parcel of land that is directly east of the Alewife Brook Parkway and Route 2 interchange in Cambridge. Redevelopment of this site to office or retail use as proposed by W.R. Grace, Inc. has been considered. Information considered include reports and data collected by Haley & Aldrich, Inc., consultants to W.R. Grace. Site development is likely to occur in coordination with further remediation of soils contaminated with petroleum products. Details of the soil remediation techniques were not considered but were presumed to be approved by the Massachusetts Department of Environmental Protection (MADEP). Hotel development on the former Liegh Metals site, which now belongs to W.R. Grace, was not considered. Public health issues addressed for this evaluation included potential impacts of airborne compounds generated by excavation and movement of soil during site development, transport of site-related compounds through groundwater and surface water to the site and vicinity, and potential exposures related to the site as it currently exists.

Based in available data there is no reason to consider the W.R. Grace site, as it currently exists, to be a health concern to the neighboring community, which includes residents and recreational users of the Russell Field Facilities. Redevelopment, conducted under proper precautions, should not cause unacceptable health risks from exposures to contaminants present on site. This includes slab-on-grade, as well as below-grade construction. Nevertheless, there are unresolved issues that warrant further investigation. Even if further investigation determines that conditions are other than what has been represented in this and previous assessments, remedial actions are available to safeguard the environment and the community. During construction and remediation on the site, implementation and enforcement of a comprehensive hazardous materials' management plan is required. Public participation in this

management plan should ensure neighbors that all public health risks are thoroughly considered.

The general findings and recommendations of EH&E's review are summarized as follows.

1. Monitoring of groundwater should continue to provide long-term assurance to residents bordering the W.R. Grace site regarding potential changes in the levels of contaminants. The low levels of compounds reported in offsite well 604 near the Alewife Brook do not present a health risk. Results of multi-year monitoring from three wells along Whittemore Avenue indicated that site contaminants have not moved offsite in this northerly direction. However, direct monitoring rather than groundwater modeling can provide the best assurance that contaminants have not migrated toward residential areas.

Groundwater flow may be altered by development, repairs to the MBTA tunnel, variations in surface recharge rates, and other factors. Surveillance of groundwater for evidence of site-related compounds should continue after site development. Selection and use of analytical methods that detect very low levels of contaminants will provide adequate response time to ensure that public health and economic interests are protected.

2. Questions remain regarding how fast and in what directions the groundwater is moving. Quantifying the groundwater transport of site-related contaminants is uncertain based on current assessments. Modeling groundwater flow at this site is complicated by the MBTA tunnels and lack of hydrogeologic information east of the tunnel toward Clifton Street. Additional hydrogeological data and analysis is required. While groundwater movement toward Clifton Street is not expected, we could not confirm this based on the information provided. Some Clifton Street residents attest that basement flooding has occurred more frequently since the MBTA tunnel was built. Additional data (groundwater elevations, permeability) collected east of the MBTA tunnel, along with measurements taken from existing wells, will determine with more certainty direction and speed of hydrogeologic

pressure driven groundwater flow. Following a review, recommendations about the extent and frequency of continued monitoring of groundwater could be reconsidered.

3. EH&E is satisfied that the chemical compounds identified on the site currently do not and will not (with anticipated construction and future site use) constitute a risk to public health. The risk assessments conducted for this site used conservative methods to examine both the cancer and non-cancer risks and determined them to be below levels of concern established by the MADEP. Groundwater monitoring at the site boundary, the planned soil remediation, and the mitigation of construction impacts will further ensure that risks are maintained at acceptably low levels.
4. MADEP audit of the Tier Classification of the site is underway. A change in classification from the current II to a IA, IB, or IC would require varying degrees of State oversight or permitting. At a minimum, the State should review and approve soil remediation activities.

Although the issue concerning the storage of contaminated soil on Russell Field is only marginally related to the proposed development, the city (and/or MBTA) should resolve the remaining uncertainties. This may include sampling of surface or subsurface soils, groundwater, or providing verification from manifest records that contaminated soils were handled appropriately.

2.0 BACKGROUND

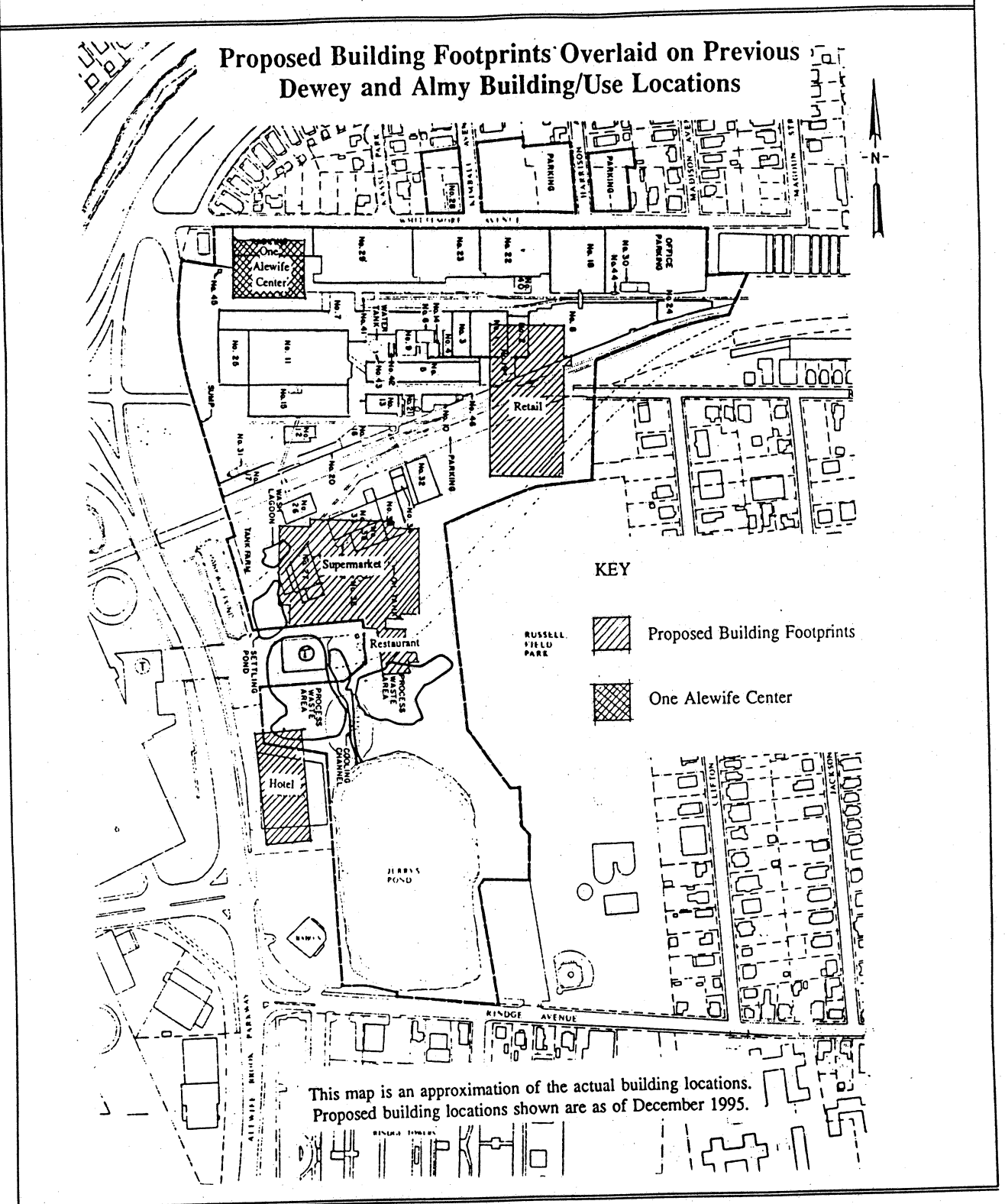
The primary health concerns of the City of Cambridge regarding the proposed development of the W.R. Grace site are based on its former use for chemical manufacturing and the compounds that remain on site as a result of these previous manufacturing activities. (See Figure 1) The site is currently listed with MADEP based on 1984 and 1985 evaluations of subsurface and hydrogeological conditions that indicated the presence of volatile and semi-volatile organic compounds, petroleum products, and metals.

The Dewey and Almy Chemical Company developed the site in 1919 for the manufacture of rubber products used for sealing compounds, drum and pail cover gaskets, and bottle cap gaskets. One of the major products manufactured on site was naphthalene sulfonate (trade name DAXAD), a compound used to facilitate the dispersion of rubber in water. During the period of DAXAD manufacture, several lagoons on the site were used for settling ponds and sources of cooling water. This activity is the presumed major source for the continued presence of naphthalene in soils at the site. Evaluation of the map of the storage areas (Haley & Aldrich 1995) indicates storage of a number of chemical compounds, as well as fuel oils, on the site during the Dewey and Almy operations. Based on the 1988 health risk assessment by Meta Systems, Inc. and a 1994 update by the same company now named Cambridge Environmental, Inc., the compounds detected on site at levels that pose potential health concerns are naphthalene, formaldehyde, fluorene, and several petroleum-based compounds.

EH&E's evaluation of the history and extensive database associated with this site, which was purchased by W.R. Grace in the early 1940s, involved several broad categories of activities.

- Evaluation of the sufficiency and adequacy of measurement data collected by Haley & Aldrich at the W.R. Grace site.

Figure 1 Proposed building footprints overlaid on previous Dewey and Almy Building/use locations



- Evaluation of the 1988 health risk assessment and its 1994 update.
- Evaluation of the groundwater model and the potential for transport of site-related compounds to neighboring properties.
- Evaluation of the hazardous materials management plan.
- Communication with representatives from the City of Cambridge, the community, and the Grace Site Advisory Committee regarding the potential health impacts related to current and future conditions at the site.

3.0 GENERAL FINDINGS

Extensive sampling of soil and groundwater was performed between 1984 and 1988 in anticipation of development plans for the site proposed in the late 1980s. Soil and water samples were analyzed for more than 125 analytes, including volatile organic compounds (VOCs), pesticides, polycyclic aromatic hydrocarbons (PAHs), metals, and polychlorinated biphenyls (PCBs) among others. The data set provided to EH&E had 78 compounds listed as well as total cyanide, total sulfates, total phenol, and grease/oil. According to Haley & Aldrich, the remaining 47 compounds were never detected in any of the samples.

Sixteen of the compounds or metals tested in the soil exceeded reporting levels established by MADEP. Eighteen compounds or metals tested in the groundwater were at concentrations above the MADEP-required reporting levels. The MADEP reporting levels, used here simply as a reference, apply to soils and water at residential sites or sites with unrestricted access. All of these compounds exceeding the stricter reporting levels were included in the 1988 risk assessment. These compounds, plus oil, grease, petroleum hydrocarbons in the soil, and formaldehyde and phenanthrene in the water, were examined statistically. Haley & Aldrich, Cambridge Environmental, Inc., W.R. Grace, and City employees were cooperative in providing us prompt access to data and documents as well as candid responses to our inquiries. The following are EH&E's general findings in support of the recommendations.

1. Considering that the proposed soil remediation and additional boundary line well monitoring takes place, EH&E does not foresee health impacts resulting from contaminants that originated from former industrial use of the site.
2. Data from soil samples, including the duplicates, suggest that the selected analytic methods were adequate to discriminate differences in concentrations between sampling locations and variations attributable to laboratory and sampling procedures. Evaluation of all soil sample duplicates, although limited in number, supports this conclusion.

3. Soil samples in the area of the proposed supermarket and parking lot show that contaminants are not uniformly distributed. Based on the distribution patterns, the locations identified for further remediation are apparent and those locations should be addressed during construction.
4. Soils in the vicinity of the proposed retail development on the eastern side of the parcel have not been surveyed as thoroughly as the rest of the site. While additional samples would be useful, we do not think they are absolutely necessary. Review of site plans and facility history suggests that chemicals were not stored, used, or deposited on this area. Oversight during construction should identify deposits of oil, grease, naphthalene, and perhaps other odorous compounds, if they exist. Only petroleum hydrocarbons appeared somewhat elevated in this area. The risk assessment anticipated a more extensive disruption of soils from the area where chemicals and fuels were stored and used than currently proposed. However, the exposure scenarios used conservative methods to estimate assumed activities onsite and dispersion of materials offsite independent of a specific location. Therefore, results of the risk assessment would apply to the development of a sub-parcel on the eastern side of site, provided contaminants in the disturbed soils were similar to those reported.
5. Between 1984 and the present, 44 monitoring wells were drilled in and around the W.R. Grace property. Information about groundwater elevations and bulk water samples were collected from these sites. There were too few well and surface water duplicate samples to draw conclusions about the analytic precision of these samples. Confidence in the well water methods was assessed by examining variability for those wells over time. Greater variability in concentrations across the property suggests that some wells were located in areas of higher concentrations, which was the intent. Furthermore, the monitoring methods were specific and sensitive enough to identify movement of contaminants offsite. This observation, if substantiated, is at variance with the speed of groundwater transport described in the model. It implies that

downgradient movement of contaminants might continue and warrant continued monitoring.

Nine monitoring wells were selected by Haley & Aldrich for trends monitoring: three were located along Whittemore Avenue to the north of the property, two wells were along the western border, three wells were near the eastern MBTA entrance and in the vicinity of known naphthalene deposits, and one well was across the road west of the property near Alewife Brook. Measurable concentrations of naphthalene were reported at the offsite well, which, from a hydrogeological perspective, indicates that naphthalene is moving from the site toward the Alewife Brook. While in absolute terms the concentrations were low (below MADEP-reporting values), they suggest that site-related contaminants are moving offsite.

6. The groundwater model was not sufficiently described or documented in reports to substantiate the claims that, "the simulated existing groundwater conditions reasonably reflected measured existing groundwater conditions."

Uncertainties about the recharge rate of water from the surface and the influence of the MBTA tunnel and portals need to be resolved before specific inferences can be derived from the current analysis. Changes in site development plans reduces the usefulness of the simplified hydrogeological model used.

The rates at which contaminants were moving offsite can be inferred either from the modeling or the measurements. At this time we have greater confidence that materials have not left the site on the northern boundary (Whittemore Avenue), but this can not be said about the other directions because no direct evidence exists.

7. Overall, we found the risk assessment to be reasonable and conservative. Estimated health risks were below 1 in 100,000 for cancer and below the reference dose or concentration guidelines. Even assuming naphthalene as a possible human carcinogen and summing the impacts of all the PAHs, the likely

risk to workers and neighbors would be small and within acceptable guidelines. The risk assessment considered below grade excavation of soils. When considering that some of the soil with higher amounts of petroleum hydrocarbons to other contaminants will be remediated before construction, risk would be further reduced.

8. The MBTA tunnel is affecting groundwater flow; it is likely that some site contaminants enter the tunnel. Air and water emissions from MBTA facilities at Alewife do not pose health hazards to neighborhoods or future users of the site.
9. Questions related to storage of contaminated soil at Russell Field are separate from the issues specifically related to development of the W.R. Grace site. If modeling or monitoring indicate that groundwater is moving under Russell Field in the direction of homes on Clifton Street, then it would be another matter. Staged groundwater and possible soil tests are recommended to help resolve this issue.

4.0 RECOMMENDATIONS

1. Groundwater well monitoring should continue in order to provide long-term protection of residents bordering the W.R. Grace site regarding possible changes in the concentrations of contaminants in the groundwater. Well B204 and at least two additional wells east of the MBTA tunnel should be included along with the nine previously established wells. Composite samples might be screened for the presence of potential site-related compounds as a less expensive strategy that provides greater spatial coverage.
2. A groundwater model reflecting the proposed development, drainage into the MBTA tunnel, and additional hydrogeological data is required to establish the rate, direction, and variations in flow. As an alternative approach, existing hydrogeological and chemical data along with additional permeability information could be used to assess groundwater flow. Following independent review of the results by a party selected by the City of Cambridge, the recommendation for expanded monitoring of groundwater contaminants could be reconsidered.
3. MADEP audit of the Tier Classification of the site is underway. A change in classification may require additional oversight by the State of Massachusetts. If the current Class II is changed to IA, IB, or IC, at a minimum, the MADEP should review and approve soil remediation activities.
4. While the issue of storage of contaminated soil on Russell Field is only marginally related to the proposed development, the city (and/or MBTA) should resolve the remaining uncertainties. This may include sampling of surface soils or providing verification of manifest records.

5.0 EVALUATION OF THE SUFFICIENCY AND ADEQUACY OF DATA FROM SOIL AND GROUNDWATER SAMPLES

This evaluation examined the patterns of chemical concentration measurements in soil and groundwater samples at the W.R. Grace site in Cambridge, Massachusetts. Specifically, EH&E has:

1. Examined the consistency of the data between samples and their duplicates
2. Summarized concentrations in relation to MADEP soil and groundwater standards
3. Mapped the spatial pattern of chemical concentrations on the site

5.1 THE DATA

The soil samples' data set contains the results of soil analyses collected mainly in 1986 and 1987 with a few preliminary samples from 1984 and 1985. There were 127 sites sampled in and around the W.R. Grace property. Each site was sampled only once, except for the collection of duplicates. However, many of the collected samples were fairly close to others collected at different times.

Groundwater samples were taken from 44 wells in and around the W.R. Grace property from 1984 to 1988 with the bulk of the samples taken in 1986 and 1987. From these wells, 29 were sampled two to four times during this time period. Sampling of nine wells continued through 1994 and each of these was sampled 10 and 15 times. The data set corresponding to the samples collected between 1990 and 1994 was not integrated into the main database. Instead, the data from these nine wells are discussed separately.

Samples collected from 1984 to 1988 were analyzed for 125 analytes and several other types of measurements, such as pH. The data sets (provided by Haley & Aldrich) were examined and found to contain 78 compounds, as well as other summary values. According to Haley & Aldrich the remaining 47 compounds were never detected in any of the samples. From these compounds, 59 were chosen for inclusion in risk assessment by Cambridge Environmental, Inc. and are listed in Table 5.1. The

groundwater samples collected between 1990 and 1994 were analyzed for VOCs and naphthalene only. A subset of these compounds found in the data files were selected for the statistical analysis described here. A further description of the methods for choosing the compounds for analysis is given in Section A.3 of Appendix A.

Table 5.1 Compounds included in the Cambridge Environmental, Inc. risk assessment and those included in statistical analyses discussed in this report

Compound	Risk assessment	Soil analysis		Groundwater
		Duplicate	Distribution	Duplicate and distribution
1,1,1-trichloroethane	1			
1,1-dichloroethene	1			1
1,2-dichloropropane	1			
2,4-dimethylphenol	1			
2-butanone	1			
2-hexanone	1			
4-methyl-2-pentanone	1		1	
Acenaphthene	1		2	
Acenaphthylene	1			
Acetone	1	1		
Anthracene	1			
Antimony	1			
Arsenic	1	1	2	
Barium	1		2	
Benzene	1	1		
Benzo (a) anthracene	1	1	1	1
Benzo (a) pyrene	1	1	1	1
Benzo (b,k) fluoranthene	1	1	1	1
Benzo (ghi) perylene	1		2	1
Beryllium	1		1	
Bis (2-ethylhexyl) phthalate	1			1
Butyl benzyl phthalate	1			
Cadmium	1		1	1
Carbon disulfide	1			
Carbon tetrachloride				1
Chlorobenzene	1			
Chromium	1	1		
Chrysene	1		1	1
Copper	1			
Di-n-butyl phthalate	1			
Di-n-octyl phthalate	1			
Dibenzo (a,h) anthracene	1		1	1
Diethyl phthalate	1		2	1
Ethylbenzene	1			
Fluoranthene	1	1		

Blank means not used, 1 means included in analysis, and 2 indicates compounds less than reporting limits, but larger than half the reporting limits.

Table 5.1 Continued

Compound	Risk assessment	Soil analysis		Groundwater
		Duplicate	Distribution	Duplicate and distribution
Fluorene	1			
Formaldehyde	1	1	1	1
Indeno (1,2,3-cd) pyrene	1		1	1
Iron	1			
Lead	1	1	1	1
Mercury	1	1		1
Methylene chloride	1	1	1	
n-Nitrosodiphenylamine	1			
Naphthalene	1	1	1	1
Nickel	1	1	1	1
Oil and grease		1	1	
p-Chloro-m-cresol	1			
Pentachlorophenol	1			
Petroleum hydrocarbons		1	1	
Phenanthrene	1		2	1
Phenol	1			
Pyrene	1	1		
Selenium	1			1
Silver	1			
Styrene	1			
Tetrachloroethene	1			
Toluene	1	1		
Total Cyanide	1			
Total Xylenes	1			
Trichloroethene	1		1	
Vinyl Acetate	1			
Zinc	1	1	1	1

Blank means not used, 1 means included in analysis, and 2 indicates compounds less than reporting limits, but larger than half the reporting limits.

Results of a sample's lab analysis can be placed in four categories:

1. Not available - compounds not analyzed for the sample.
2. Not detected - sample analyzed for compound, but value was below detection limits.
3. Detected, but not quantified - sample analyzed and compound detected, but not in amounts that can be reliably measured.

4. Detected and quantified - sample analyzed and compound detected in amounts that could be reliably measured.

The last three categories separate samples on the basis of the qualitative description of the presence of a compound at a site. Let these categories be represented by the sets A (absent), D (detected), and M (measurable), respectively. The response for samples that fall in the first two categories are non-numeric, but tell us a great deal about the concentration levels of a compound at a site.

5.2 METHODOLOGY

We were interested in determining the reliability of the monitoring data. A comprehensive evaluation would have included a review of laboratory records and chain of custody documentation for the samples. This could not be done because of time and expense involved and due to the fact that many of the samples were analyzed by laboratories no longer in existence. Therefore, we proceeded to examine the statistical behavior of the data.

Duplicate soil and water samples can be used to determine the precision of sampling and analysis methods. A small difference between the reported values of duplicate samples relative to the overall mean concentrations provides confidence that the methods are capable of detecting larger differences across sites and across time. Unfortunately, these analyses can not answer the question of accuracy. Displaying the distribution of concentrations can be used to compare reported values to expected distributional patterns. Plotting data spatially and examining the concentration patterns with knowledge about historic operations, chemical use, fuel storage, spills, settling ponds, and likely groundwater movement can also be useful. These techniques, along with trends analyses of samples collected over time, provide a sense that the sampling and analyses were comprehensive and provide a reasonable database for risk assessment.

5.3 GENERAL FINDINGS

A comprehensive description of the statistical analysis is included in Appendix A. The following is a summary of the general findings.

- The methods used both for field sampling and laboratory analyses are standard.
- The number of analytes evaluated is a comprehensive list that includes pesticides, PCBs, metals, and numerous other organic and inorganic compounds. Of the 125 analytes, only 78 were detected at least once at quantifiable levels. The other 47 were never detected. MADEP established reporting levels for soil, water, and air contamination. Using the most conservative MADEP reporting guidelines set for residential property use, there were 16 compounds or metals in the soil exceeding those levels. Eighteen compounds or metals tested in the groundwater were at concentrations above the MADEP-required reporting levels.
- Our analyses also included these compounds plus oil, grease, and petroleum hydrocarbons in the soil and formaldehyde and phenanthrene in the water.
- For the compounds found in the soil with a sufficient number of duplicates, the precision was 30% or better. The spatial differences between sites were substantially greater than 30%, so spots with higher concentrations are readily identified. This is important in order to have confidence that further soil remediation will be effective in removing soils with the higher concentrations.
- There were a few soil test pits dug in the area of the commercial/retail site proposed for the eastern side of the property. Only petroleum hydrocarbons were found in these samples. This is reasonable, based on historic use of the site.
- The higher concentrations of soil contaminants were reported for subsurface instead of surface samples.

- Unfortunately, there were not a sufficient number of groundwater duplicate samples to draw firm conclusions about precision. As an alternative, the multiple measurements collected at a well were used to calculate the within well variability. By comparing statistical variance of repeated measurements at a well to the variance obtained by contrasting concentrations reported for different wells, a degree of reliability for the overall analytical performance was obtained. We reached the conclusion that, because across well variance greatly exceeded the within-well variance, well data could be interpreted to show trends and spatial differences.
- Based on the above reasoning and examination of the data, we see groundwater contaminants in higher concentrations onsite in locations that reflect historic use.
- Except for small amounts of a few VOCs found in well water samples collected more than ten years ago, there is no contemporary evidence that site-related contaminants have moved offsite in the direction of Whittemore Avenue.
- The same can not be said about well 604 between the Parkway and Alewife Brook. Samples containing naphthalene suggest that site contaminants have or are being transported via groundwater. These values do not constitute a health risk. First, they are found in the groundwater at low levels and second, water and sediment samples found no trace of site-related contaminants.
- Because there is very limited data available for groundwater or soils east of the MBTA tunnel, we were unable to formulate findings relevant to the Clifton Street neighborhood.
- Haley & Aldrich prepared responses to comments and recommendations raised in our previous review in 1987. While Haley & Aldrich provided maps showing sewer and utility connections, there were no additional sampling data in response to the original concern. The plan to analyze samples along existing or historic sewer and utility lines during excavations and only from within the building footprint is not fully responsive to the original concerns. The point of the original comment relates to the possibility that contaminants could be leaving site by traveling both within and

adjacent to sewer and utility lines. It is our understanding that the MWRA has upgraded sewer and storm drains along sections of Whittemore Avenue since 1987. The City should examine construction records to determine the reported condition of the previous system and to establish the extent of repairs/replacement. Further, the location of all the groundwater wells along Whittemore Avenue should be determined with respect to their proximity to sewer and utility lines. If, as we suggested, groundwater monitoring is continued, an alternative set of wells may be more appropriate to safeguard the community.

Appendix A contains a more detailed evaluation of data. We have also included in Appendices A and B graphical presentations of the soil and groundwater well data. Concentrations are shown graphically as cumulative distributions. The reader should note that only values at quantified concentrations are included. Table A.9 shows in the last column the fraction of total samples that had measurable quantities. Table A.11 provides similar information for groundwater. It is from these fractions that the empirical or cumulative distributions were drawn. Where applicable, vertical lines are drawn on the empirical distribution graphs to indicate values used in the risk analyses (RA) and as the MADEP S1 reporting level.

Appendix B provides spatial maps and empirical distribution functions for selected contaminants found in soil and groundwater samples.

6.0 EVALUATION OF THE 1988 AND 1994 HEALTH RISK ASSESSMENTS

EH&E evaluated the appropriateness of the data and risk assessment methods used by Meta Systems, Inc. in their 1988 health risk assessment for the W.R. Grace site and a 1994 update by the same company, now named Cambridge Environmental, Inc. Since 1994, new development plans for this site have been presented and some new toxicological information regarding a few key compounds found on the site have been presented by MADEP and the U.S. Environmental Protection Agency (EPA). Therefore, the present analysis also evaluated the sufficiency of the original risk analysis calculations in light of recent changes in exposure methods, toxicological data, and planned development.

During the course of this review, a number of questions or points of clarification were raised. To address these questions and issues, Dr. Halük Özkaynak of EH&E met with Dr. Edmund Crouch, the scientist at Cambridge Environmental, Inc. who was responsible for the risk assessment performed for the W.R. Grace site. Many technical issues were resolved and an electronic file copy of the available onsite environmental and meteorological data used in the risk assessment was obtained.

In addition to a technical review of the risk assessment documents, we wanted to be responsive to citizens' concerns that were expressed during meetings with the Grace Site Advisory Committee regarding the potential toxicity of onsite contaminants. One such concern was the toxicity of naphthalene. Naphthalene is a white solid that evaporates easily and is found in several consumer products, including moth balls, moth flakes, and toilet deodorant blocks (ATSDR 1995). Fossil fuels, such as petroleum and coal, contain naphthalene and burning tobacco and wood can release naphthalene into the air. Naphthalene has a strong, distinctive odor that individuals can detect in the air at concentrations as low as 85 parts per billion (ppb). Once released into the air, moisture and sunlight can break down naphthalene within a day. MADEP currently lists an allowable ambient level (24-hour exposure) and threshold effects limit (annual average) of 2.72 ppb for naphthalene in outdoor air.

Naphthalene binds weakly to soils and, as a result, it can pass through sandy soils and reach groundwater. This groundwater can then flow into other areas along its flow patterns. However, microorganisms in healthy soils can help break down naphthalene into carbon dioxide (CO₂), thus reducing the amounts of naphthalene that enter groundwater supplies.

The EPA currently categorizes naphthalene in Class D, which indicates that it is not classifiable as to human carcinogenicity due to inadequate evidence. In an October 1995 draft report, the MADEP proposed a relative potency factor for naphthalene based on some recent evidence that inhaled naphthalene produced cancer in animals. Data from a 1992 National Toxicology Program (NTP) report indicated an increased tumor incidence in female mice that inhaled 30 parts per million (ppm) of naphthalene for two years (NTP 1992).

These issues were also discussed with Dr. Crouch, who was very familiar with NTP studies and their extrapolation to human populations. Further information on the most recent listing and carcinogenic potency value of this compound was solicited from Dr. Lauren Zeiss at the California Department of Health Services. In addition, an online toxicity profile search was performed using the EPA's Integrated Risk Information System (IRIS).

Finally, a limited re-analysis of the site-specific data using alternative (e.g., air quality dispersion) modeling techniques and exposure or chemical toxicity values was conducted to determine how sensitive the results of original risk analysis were to modifications to exposures or potency values.

We have organized our findings under several categories.

6.1 EXPOSURE SCENARIOS

1. The potential human exposures considered in the risk assessment included inhalation of dust and vapors both onsite and offsite, ingestion of soil, and groundwater seepage into basements. It should be recognized that these exposures are hypothetical and were most often designed to represent extreme conditions so that the maximal levels of risk could be assessed. The expectation is that actual health risks are substantially below these values.
2. Emissions or volatilization of VOCs from soil have been modeled using conservative assumptions that are consistent with upper bound estimates.
3. The pollution dispersion model (AVR) did not use site-specific meteorology, but assumed uniform winds in all directions. When we used representative meteorology and a recent EPA model (ISCLT), we could demonstrate that the techniques used by Dr. Crouch were quite conservative. The impacts predicted by Dr. Crouch were about ten times greater than using current models and actual Boston meteorology.
4. Excavation, soil storage, and windblown dust impacts have been modeled using reasonable physical models. Emission rates of soil-related contaminants had to be assumed (estimated). Recently, EPA has developed models of fugitive dust generated during construction. The emission rates estimated for W.R. Grace site development should be compared to those derived from the EPA methods. The analysis performed for workers incorporated conservative exposure assumptions and selected high soil concentrations. However, if the basic emission factor currently used by the EPA would result in risk and methodology estimates increasing by a factor of five or more, then previous risk assessments should be reconsidered.

The risk assessments reviewed did not address impacts of particulate emissions resulting from trucking activities over paved or unpaved surfaces. This may not be an important shortcoming, depending on truck routes and construction site dust suppression practice. Proper dust suppression practices during the course of construction should minimize potential dust exposures.

6.2 GROUNDWATER

1. An ingestion route was not considered in the risk assessment because groundwater will not be used as drinking water. In addition, dermal contact with surface water was not considered.
2. Inhalation of naphthalene originating from the groundwater was considered inside homes. The risk assessment assumed that the highest concentrations of naphthalene would be present in groundwater that intruded into basements. This was obviously a very conservative approach, because the highest levels were reported only in water samples from wells that were several hundred meters from the nearest home.

6.3 SOIL

The updated risk assessment estimated the risk to visitors who might ingest small quantities of soil/dust from the site. All values (detect and non-detect) were averaged together to estimate risks. This is a reasonable approach, particularly when considering additional remediation of soils that will take place. Although an upper 95th percentile value of the arithmetic mean could have been used, this factor should not appreciably change the conclusions.

6.4 EXPOSURE GROUPS

Exposure scenarios for most of the critical groups (e.g., neighborhood residents, construction workers, office workers, and transient visitors) have been addressed in the risk assessment. Trespassers during the construction were not considered in the risk analysis. Also, children and adult shopper scenarios might be examined by different age groups because assumptions about ingestion, length of visit, etc. would result in different estimates. This refinement could be addressed without extensive re-analysis or simply addressed by scaling potential impact that might result from using default inhalation and ingestion values and contaminant levels before and after soil remediation.

6.5 EXPOSURE PATHWAYS

Inhalation, soil ingestion, and dermal absorption pathways have all been considered as the primary routes of exposure. However, small exposures might occur due to ingestion of homegrown fruits and vegetables that may be contaminated by deposition of dusts from the site or absorption of groundwater transported offsite. In the unlikely event that contaminants intruded into basements, dermal contact could occur if building occupants touched the water. Similarly, dermal or ingestion uptake might occur if populations come in contact with contaminated surface water. However, although the data are limited, they do not suggest that these pathways would contribute substantially to human health risks.

We mention these omitted pathways for completion. If the risk assessment were to be updated, we encourage the qualitative discussion of these other pathways that present an upper bound to the relative importance. W.R. Grace has stated that during construction, chemical analyses of landscape soil around Jerry's Pond will be conducted. At this time, additional surface and sediment samples might be required by MADEP. Continued trends monitoring of groundwater wells along Whittemore Avenue will provide advanced indications that contaminants may be leaving the site.

6.6 EXPOSURE FACTORS

Risk assessments of this type have to make assumptions about the frequency and duration of dermal contact, inhalation, and ingestion. While the assumptions used appear quite reasonable, suggested current EPA default values, in some cases, are actually higher. It is quite easy to scale the risk since it will be proportional to the amount ingested or the time of dermal contact and assumed proportion absorbed. Using higher values will obviously increase the estimated risk.

6.7 TOXICITY VALUES

The risk assessment used published potency and reference dose values. We find no fault in the application of these values. However, since the first risk assessment in the 1980s, new information has been published on naphthalene. Also, MADEP has drafted guidelines for assessing the several PAH compounds that do not have established cancer potency values. In light of these developments, we have sought clarification about naphthalene and other PAHs.

According to EPA (IRIS) and the State of California, naphthalene is still not classified as a human carcinogen. However, in a review of the EPA/IRIS database in March 1996, the description of naphthalene includes the following note:

NOTE ADDED IN JULY 1995: Subsequent to the verification of this cancer assessment in 1990, the National Toxicology Program completed a two-year cancer bioassay (1991); its results suggest that naphthalene may be more appropriately classified as a possible human carcinogen (Group C under current EPA guidelines). The NTP concluded, "Under the conditions of these 2-year studies, there was no evidence of carcinogenic activity of naphthalene in male B6C3F1 mice exposed by inhalation to concentrations of 10 or 30 ppm for 6 hours daily, 5 days per week, for 103 weeks. There was some evidence of carcinogenic activity of naphthalene in female B6C3F1 mice, as pulmonary alveolar/bronchiolar adenomas."

Naphthalene, a chemical on this site, was treated in the Health Risk Assessments of 1988 and 1994 as a non-carcinogen based on contemporary evidence. To address concerns regarding a potential reclassification of naphthalene to Group C, possible human carcinogen, the relative potency factor for naphthalene proposed in the MADEP document concerning risk assessment for PAHs (October 2, 1995) was used by us to calculate human risk levels. Our evaluation indicated that the projected lifetime cancer risks for residents, mall visitors, and workers would still be below the 1 in 100,000 target limit set by MADEP.

There is inconsistent treatment of naphthalene at this time. Naphthalene is still not classified as a human carcinogen by EPA and the California Department of Health. It is not listed among the California Proposition 65 compounds. As of October 1995 MADEP

considered naphthalene as a potential carcinogen based on evidence of lung cancer in one gender of one animal species only. They use a conservative mouse-to-man extrapolation method to estimate potency in humans.

The existing risk assessments have adequately considered both the cancer and non-cancer risks from other PAHs. Recent revisions or modification to relative toxicity of PAHs should not affect the previous predictions that indicated a small contribution of the analyzed PAHs to total risks.

6.8 CONCLUSIONS

Estimated lifetime cancer risks of less than 1 in 100,000 and a total hazard index of less than 1 (*i.e.*, total exposures are below the reference concentrations or assumed safe limits for non-cancer effects) are projected. These projections are below the MADEP guidelines and other agency criteria for acceptability.

Analysis was done by a competent and experienced individual using available data and mostly new methods to predict concentrations. Methods were developed to predict concentrations and exposures prior to detailed guidance from EPA and MADEP. In general, however, either realistic or conservative assumptions were made to estimate exposures and risks.

It is usually desirable to update a risk assessment when new concentrations, exposures, or toxicity data are made available. In this case, given the conservativeness of the existing risk assessment methods and based on what we already know, it is unlikely that the predicted risks would change appreciably if updates were conducted. Recent proposed revisions or new information on naphthalene and PAH toxicity values are unlikely to increase either the cancer or non-cancer risk estimates above the acceptable limits.

New development plans for the site differ from the earlier version and include an area near the northeast corner of the site where there is limited soil and groundwater data. In absence of soil concentration data for this area, we took the upper (95th percentile) bound estimate based on the site-wide concentrations. Using this approach, the

projected risks (e.g., from naphthalene) could increase somewhat (by 40%) but not beyond the accepted MADEP target limits.

7.0 EVALUATION OF HYDROGEOLOGIC DATA

Hydrogeologic data collected at this site were assessed for quality and adequacy. Analytical methods selected for the water analysis at the site were EPA methods commonly used at hazardous waste sites. The quality of these data could be partially assessed as discussed earlier. General issues relating to environmental data are discussed in this section before considering the groundwater model in more detail.

Review of the series of long-term monitoring reports was completed. Based upon the review of this data, the following observations and recommendations are made.

Water and sediment data were collected primarily during the springtime when surface water levels would have been highest due to runoff. A better measure of worst case conditions could have been made during the summer or fall when conditions are drier. In addition, only one location at Jerry's Pond had been monitored on a regular basis. This may not adequately represent conditions at Jerry's Pond and, therefore, may affect scoring for Tier Classification, as discussed later.

Groundwater monitoring data indicated that flow patterns and direction displayed some variation over time at the site. Flow patterns to the east of the site, in the vicinity of the MBTA tunnel and Russell Field, have not been well characterized; this is the area where the greatest degree of variability was observed. No monitoring points were located east of the tunnel, which reportedly has a significant impact on flow.

The April 1988 Environmental Data Report (Volume 7 of 7) (Haley & Aldrich 1988) was reviewed to assess the groundwater modeling conducted at the site. Observations are general at this time and concerns might be resolved by discussions with the modelers and/or review of primary data. More specific comments would require a detailed analysis of site data and possibly additional field testing.

The model selected for evaluation of the previously planned development seems appropriate. The boundary conditions and orientation of the model were consistent with

site conditions. Grid spacing was sufficient for the project objectives and was within the model's limitations. Use of a steady-state, two-dimensional simulation, although a simplification, was nevertheless appropriate for assessing the impact of the proposed foundations of the original development plan. However, sensitivity analysis of the initial boundary conditions was not performed, as far as we could discern. Therefore, the influence of boundary conditions' assumptions could not be evaluated, and their impact on groundwater flow patterns could not be assessed.

The documents provided did not present sufficient information supporting model assumptions and applications to allow independent reassessment. For example, information that indicates how values for certain model parameters were determined was generally not provided in the documentation, nor was information provided on the error criterion for model closure.

Parameters that are of primary concern include the permeabilities assigned to the subway tunnel and the passageway nodes and the surface recharge rates. Since the sensitivity analyses indicated that the model was most sensitive to these parameters, justification for the values assigned should be provided. We have no current understanding of how the subway tunnel and passageway node permeabilities were calculated. In addition, our opinion is that the recharge rates seem much lower than would be expected for the site area.

Information contained in the well construction logs and methods used during the in-situ permeability tests could possibly be used to evaluate the representativeness of aquifer permeabilities used as model input. Given the descriptions of the aquifer material, the permeability used appears within the typical ranges commonly observed for sandy outwash material. Current methods generally employ a different analytical technique than Hvorslev's method (which was used) to estimate aquifer permeability from slug test data. Evaluation and re-analysis at this level of detail was not undertaken.

Without an understanding of how adjustments to the saturated thickness, permeability, and recharge rates were made from measured data, EH&E can form no opinion as to how accurately data represent site conditions during model calibration. We agree that

the comparison of the measured historical groundwater conditions with simulated conditions indicates only reasonable similarities, with notable differences in the upgradient area of the site. However, we believe that the simulated existing groundwater conditions do not reasonably reflect measured existing groundwater conditions. Finally, in order to support model verification, a mass balance calculation is typically reported. In the absence of these data, we can not form an opinion as to the accuracy of the calibration and verification runs.

In our opinion, comparison of the simulated future groundwater contour plan with the existing groundwater contour plan showed significant differences in the rate and direction of groundwater flow. We believe that, because the conclusion derived from the groundwater modeling was based on previous development plans, they can not be used to evaluate conditions under the current development proposal. We can not say with confidence that it is unlikely that groundwater flow directions or water table elevations will be significantly altered in the site vicinity or north of the development as a result of the newly proposed construction. However, if the new construction does not include significant alteration of the subsurface or recharge patterns, impacts to flow patterns and rates may not be as significant. Detailed analysis of construction plans would be necessary to assess potential impacts to groundwater flow. In addition, changes in groundwater flow directions and gradients that could result from the repair of the MBTA tunnel are potentially significant.

Additional characterization of site hydrogeology is necessary to resolve these questions. Installation of additional wells east of the MBTA tunnel, groundwater monitoring in this area, and additional assessment of groundwater flow rates across the site are recommended.

8.0 RELATED ISSUES

While the majority of EH&E's effort was involved with the review of the numerous documents previously prepared by Haley & Aldrich, several related items were mentioned at the citizen meetings and in written correspondences. We could not address all of these points, in fact the City, Haley & Aldrich, and others were more appropriate responders. However, we did consider the Tier Classification, MBTA Tunnel, Russell Field, and the recent data on naphthalene (previously discussed).

8.1 TIER CLASSIFICATION

We support the decision of MADEP to conduct an audit of the Tier Classification process for this site. We believe that the interests of the City, neighborhood, and the developer would be better served if site construction and further remediation were subject to some additional oversight by MADEP.

The following observations are offered to assist the audit process.

8.1.1 Surface Soil and Sediment

Surface soil in the zero- to six-inch zone reportedly had been sampled at 14 locations on the site (J1, J2, and SS1 through SS12). Sediment reportedly had been sampled at five locations in Jerry's Pond (Jerry's Pond, J3, and SD11 through SD13), two locations in Alewife Brook (SD6 and SD8), and one other location of apparent sediment accumulation (SD14). It has been assumed that the applicable reporting category for the site is RCS-1 due to the proximity of Russell Field Park, residences, and Jerry's Pond. Exceedances of the RCS-1 concentrations have been noted at locations SS1 through SS3, SS5, SS6, SS9, SS10, SS12, SD4, SD6, and SD8.

The Numerical Ranking System indicated that areas where surface soil or sediment concentrations of oil or hazardous materials (OHM) exceeded applicable reportable concentrations constituted a potential exposure pathway for soil (and sediment) as

defined in MADEP CMR 40.1512(1). The Tier Classification and Numerical Ranking submitted for the site indicates that the OHM is located beneath paved surfaces and at depths greater than six inches (due to pre-construction paving or re-grading that occurred subsequent to the collection of these data), thereby constituting evidence of contamination for soil (and sediment) as defined in MADEP regulations. Additional documentation of the regrading and paving was requested, but was not received at the time this report was prepared. The significance of this point is that if site conditions actually constitute a Potential Exposure Pathway rather than Evidence of Contamination, the Numerical Ranking Score would be increased by 85 points.

It was also noted that some of the greater exceedances of RCS-1 concentrations in subsurface soils in the test pit programs completed at the site were at locations where no surface soil samples were obtained. This may not be an issue if the remediation and construction plans include replacing top soil with clean material or covering the surface with a foundation and/or parking area.

The site-wide database should be reviewed to assess that samples of surface soil and sediment (*i.e.*, zero to six inch) were collected at a representative number of locations on the site, based upon site history and current knowledge of the nature, extent, and distribution of contamination.

A comparison of the locations where the RCS-1 exceedances noted were observed should be made with actual site conditions to verify that all these locations had been re-graded or paved over, including sediment sample locations. It should be determined if MADEP definitions refer to the sediment above and/or below water surfaces. We have been unable to obtain information from MADEP regarding this issue at the time this report was prepared.

8.1.2 Private Water Supply Well

A letter from a resident in the site vicinity, Mr. Edward Norberg, to Secretary Trudy Coxé of the Executive Office of Environmental Affairs, dated February 7, 1996, indicates that Mr. Norberg has a private water supply well for agricultural/residential (non-ingested)

use at his property. Subsequent conversations with Mr. Wesley Stimpson of Haley & Aldrich and receipt of a letter written by Haley & Aldrich to MADEP regarding this issue indicated that Mr. Norberg does not use this well at all and, in fact, does not have a pump in the well. This may be a non-issue as long as the well is never activated.

The Numerical Ranking System indicates that when a private *drinking* water well is located within 500 feet of any portion of a disposal site where OHM has been identified in groundwater at concentrations equal to or exceeding applicable risk-based concentrations promulgated in MADEP regulations, this constitutes a Potential Exposure Pathway for groundwater as defined in the regulations. Such exceedances were reported in the Numerical Ranking Score determined for the site. However, the Numerical Ranking indicated that no *drinking* water wells were known to exist in the site vicinity at the time the Numerical Ranking Score was determined, thereby constituting Evidence of Contamination in groundwater. Please note that Haley & Aldrich indicated that, based on prior experience in Massachusetts, an unpermitted well, as the Norberg well is reported to be, is not eligible for consideration in Numerical Ranking in the Massachusetts Contingency Plan (MCP). MADEP must make a firm determination on this matter. The significance of this point is that if site conditions actually constitute a Potential Exposure Pathway rather than Evidence of Contamination, the Numerical Ranking Score would be increased by 80 points.

8.1.3 Surface Water

The Numerical Ranking indicated that OHM has been identified in site surface water at concentrations constituting Evidence of Contamination. Part of the basis for the score provided for this section appears to be that the surface water indicating the presence of OHM is not used for drinking, boating, or swimming. MADEP regulations indicate that conditions constitute a Potential Exposure Pathway for surface water if it is known to be used for drinking, swimming, boating, or fishing. Information provided in historical reports for the site indicates that Jerry's Pond was used for swimming, boating, and fishing. It is not clear whether the locations where OHM was observed were used for any of these purposes. However, information provided in Section VI of the Numerical Ranking indicated that a Long-Term Monitoring Report, dated 1994, provided data

supporting the conclusion that surface water and sediment contamination do not exist in Jerry's Pond. However, the Long-Term Monitoring Report provides information at one location at Jerry's Pond once a year (springtime). These data may not adequately characterize conditions at Jerry's Pond. The significance of this point is that, if site conditions actually constitute a Potential Exposure Pathway rather than Evidence of Contamination, the Numerical Ranking Score would be increased by 80 points.

8.1.4 Disposal Site Characteristics

State regulations set forth methods for determination of scores in many categories. The sum of all the categories is the final Tier Classification score. It appears that the methods used to determine the OHM Toxicity Score (CMR 40.1511, Section III.A.) and the OHM Mobility and Persistence Score (CMR 40.1511, Section III.C.) do not include use of the methods defined and required by in the regulations, specifically, the Human Health-Based Toxicity Value Matrix (CMR 40.1513(3)) or the OHM Mobility and Persistence Factors (CMR 40.1514(4)) for site-related OHM are not found in the listed Human Toxicity Values (CMR 40.1513(2)) and Mobility and Persistence Scores (CMR 40.1514(2)) and (3)), respectively. The significance of these points is that it is possible that use of these methods could slightly increase the total site ranking and could potentially change the Tier Classification. However, the outcome would be uncertain until the procedures are completed.

8.1.5 Ecological Population

As with the Disposal Site Characteristics Scoring, a method defined in and required by the regulations was not used for the ecological population scoring. It appears that the methods used to determine the Environmental Toxicity Score did not include use of the Environmental Toxicity Value Matrix for site-related OHM not found in the listed Environmental Toxicity Values. The significance of this point is that it is possible that use of this method could slightly increase the total site ranking. However, the final outcome would be uncertain until the procedures are completed.

8.1.6 Mitigating Disposal Site-Specific Conditions

The first mitigating condition referenced in the Numerical Ranking indicated that, since no surface water or sediment contamination existed in Jerry's Pond, the score for the presence of a Fish Habitat under Ecological Population was reduced by 10 points.

The second mitigating condition referenced in the Numerical Ranking indicated that, since no surface water contamination existed in Alewife Brook and since there was no opportunity for surficial contamination from the site to impact Alewife Brook Reservation, the score for the presence of a Protected Open Space under Ecological Population was reduced by 10 points. Regional groundwater flow from the site toward the Reservation had been shown. Further, naphthalene and some VOCs had been reported for well 604, adjacent to Alewife Brook. The potential for site impact on Alewife Brook Reservation exists. However, EH&E does not believe that the numerical ranking should be changed because of lack of supportive evidence in surface and sediment samples.

8.2 HAZARDOUS MATERIALS MANAGEMENT AND REMEDIAL ACTION

In accordance with the MCP, this site must be remediated within five years of Tier Classification, that is, by the year 2000, with or without redevelopment of the site for any use. Remedial action plans have not yet been developed by Haley & Aldrich, but they will likely be incorporated into any redevelopment project. If the proposed shopping center is built on the site, limited soil excavation will be required for development and additional soils will be excavated for remediation. Management of hazardous materials will be necessary to minimize impacts to the surrounding community and onsite workers during remediation and construction.

Under the MCP, rigorous health and safety and contingency planning must be completed prior to the initiation of remediation and construction. Environmental oversight will be required during any construction that occurs concurrently with remediation. It is recommended that the City of Cambridge thoroughly review all plans governing hazardous materials management, remedial action, health and safety, and emergency contingencies at the site, when these documents become available. This

review will help ensure both the short-term and long-term site risks are minimized and that thorough remedial action is completed at the site.

8.3 MBTA TUNNEL

In February EH&E gained access to the MBTA tunnels at Alewife Station. Visual inspection of several hundred meters of tunnel both east and west of the passenger platform were made. It was obvious from the damage to the concrete retaining walls and ceiling that water seepage had been occurring for some time. The tunnel walls on both sides were wet and seeping water in numerous spots along the entire section.

A 1992 report by Stone & Webster, Inc. for the MBTA characterized the health risks for employees at this station. Drainage into the tunnel by groundwater was identified as the primary route for low level exposures to VOCs. The Stone & Webster, Inc. report referred to the 13-year history of investigations that had been carried out in an attempt to explain the reported objectionable odors and to resolve the health and safety fears of the employees. EH&E's review did not include monitoring nor could EH&E review the consultant reports referred to in the Stone & Webster, Inc. document, which were not provided, with the exception of the W.R. Grace reports prepared by Haley & Aldrich.

Presented here is EH&E's perspective. Based on the similarity between chemical compounds found in tunnel aqueous samples and those reported for soil and well water samples at the site, it is likely that the site is the origin. However, because oil and grease are used on switches and trains, and because various cleaning solvents are used on the trains and in the Alewife station, multiple sources for the contaminants are likely. A limited number of air measurements made in 1985 in the tunnel indicate low airborne concentrations of several compounds. During the tunnel inspection, we did not detect chemical odors in the air or when smelling the discolored surfaces. However, other individuals reported a chemical odor from the pump room on a previous visit.

Inspections by others, as recounted by Stone & Webster, Inc., reported that both the sewer sump and drain sump vented through a common vent, which could be responsible for sewer smells from the track drainage and floor drain system.

The relevance of the MBTA to the proposed development has to be put into perspective. The MBTA drainage system and air exhaust system would be the only avenues for contaminant exposure to the community. Routine and continuous monitoring of the Parkway Pond, where the subway pump empties, has not revealed contaminants, according to Haley & Aldrich, Inc. Limited air sampling in the tunnel conducted by GZA reported low concentrations of a few VOCs. VOCs volatilizing from the seeping groundwater would be greatly diluted both in the high volume airflow through the tunnels and upon dispersion in the outdoor air. As a result, this would not be an important exposure pathway.

The tunnels may have significantly altered the groundwater movement in the vicinity of the proposed development. The combined impact of development, paved surface areas, and new surface water drains needs to be assessed. It is conceivable that, as groundwater flow into the tunnels is reduced, aqueous concentrations of site contaminants could actually increase. Although this would have insignificant impact on the neighborhood, it could be important for MBTA employees.

8.4 RUSSELL FIELD

Environmental data is not currently available for the Russell Field area. This information is important from two perspectives.

First, groundwater quality and flow data in this area would provide a more complete understanding of potential groundwater impacts from the W.R. Grace site onto properties to the east (as discussed in Section 7.0). Based upon the available information, it appears that this area is largely uncharacterized.

Second, there are community concerns about past activities at Russell Field. Specifically, it has been reported by community members and in file documentation that contaminated excavate soil was stored on portions of the Russell Field property during excavation of the MBTA tunnel. Detailed information on the methods of excavation, materials handling, storage, and disposal has not been available for review. No

information on the chemical nature of contamination in the excavate has been available. In addition, records of the reported offsite disposal (hazardous waste manifests), which are required by Federal and State regulations, have not been available for review.

Given the many areas of uncertainty, it is recommended that an environmental investigation of this area be conducted. This should include characterization of soils and groundwater. It is estimated that a minimum of four to five wells would be necessary east of the tunnel to characterize flow in this area; actual locations should be selected based upon field conditions and a review of boring logs from the investigation of the W.R. Grace site. Permeability testing is recommended at selected representative wells. It is reported that clean fill was placed on top of existing materials at Russell Field. This should be verified by analyzing pooled soil samples obtained for the top few inches. In addition, subsurface soil should be characterized to assess any potential impacts of storage of contaminated excavate. While subsurface soils do not generally pose a direct exposure hazard (unless excavated), they can provide a source of contamination to groundwater. Therefore, there are two options: either analyze bulk water samples from new wells located between Russell Field and Clifton Street houses, or collect soil core samples down to the level of the original grade.

9.0 REFERENCES

Agency for Toxic Substances and Disease Registry. 1995. *Toxicological Profile for Naphthalene (Update)*. U.S. Department of Health and Human Services, Agency for Toxic Substances and Disease Registry: Atlanta, Georgia.

Cambridge Environmental, Inc. 1994. *Update of Health Risk Assessment for the W.R. Grace & Co. Property, Cambridge, Massachusetts* as prepared by Meta Systems, Inc. (same company, new name) in 1988.

Haley & Aldrich, Inc. 1988. *Environmental Data Report for the W.R. Grace & Co. Property in Cambridge, Massachusetts, Volumes 1-7*.

Haley & Aldrich, Inc. 1995. *Public Involvement Plan DEP RTN 3-0277 for W.R. Grace 62 Whittemore Avenue, Cambridge, Massachusetts*.

MADEP. October 1995. *Petroleum Hydrocarbon Toxicity Project Report: Polycyclic Aromatic Hydrocarbon Cancer Risk Evaluation Methods*. Massachusetts Department of Environmental Protection, Office of Research and Standards: Boston, Massachusetts.

Meta Systems, Inc. 1988. *Health Risk Assessment for the W.R. Grace & Co. Property, Cambridge, Massachusetts*.

NTP. 1992. *Toxicological Carcinogenesis Studies of Naphthalene (CAS No. 91-20-3) in B6C3F Mice Inhalation Studies*. Technical report series No. 410, NPH Publication No. 92-3141. National Toxicology Program, U.S. Department of Health and Human Services, Public Health Service, National Institute of Health: Research Triangle Park, NC.

APPENDIX A

**EVALUATION OF SOIL AND
GROUNDWATER SAMPLES**

EVALUATION OF SOIL AND GROUNDWATER SAMPLES

This evaluation examined the patterns of chemical concentration measurements in soil and groundwater samples at the W.R. Grace site in Cambridge, Massachusetts. Specifically, EH&E has:

1. Examined the consistency of the data between samples and their duplicates
2. Summarized concentrations in relation to MADEP soil and groundwater standards
3. Mapped the spatial pattern of chemical concentrations on the site

A.1 THE DATA

The soil samples' data set contains the results of soil analyses collected mainly in 1986 and 1987 with a few preliminary samples from 1984 and 1985. There were 127 sites sampled in and around the W.R. Grace property. Each site was sampled only once, except for the collection of duplicates. However, many of the collected samples were fairly close to others collected at different times.

Groundwater samples were taken from 44 wells in and around the W.R. Grace property from 1984 to 1988 with the bulk of the samples taken in 1986 and 1987. From these wells, 29 were sampled two to four times during this time period. Sampling of nine wells continued through 1994 and each of these was sampled 10 and 15 times. The data set corresponding to the samples collected between 1990 and 1994 was not integrated into the main database. Instead, the data from these nine wells are discussed separately.

Samples collected from 1984 to 1988 were analyzed for 125 analytes and several other types of measurements, such as pH. The data sets (provided by Haley & Aldrich) were examined and found to contain 78 compounds as well as other summary values. According to Haley & Aldrich the remaining 47 compounds, were never detected in any of the samples. From these compounds 59 were chosen for inclusion in risk assessment by Cambridge Environmental, Inc. and are listed in Table A.1. The groundwater samples collected between 1990 and 1994 were analyzed for VOCs and naphthalene only. A subset of these compounds found in the data files were selected for the

statistical analysis described here. A further description of the methods for choosing the compounds for analysis is given in Section A.3.

Table A.1 Compounds included in the Cambridge Environmental, Inc. risk assessment and those included in statistical analyses discussed in this report

Compound	Risk assessment	Soil analysis		Groundwater
		Duplicate	Distribution	Duplicate and distribution
1,1,1-trichloroethane	1			
1,1-dichloroethene	1			1
1,2-dichloropropane	1			
2,4-dimethylphenol	1			
2-butanone	1			
2-hexanone	1			
4-methyl-2-pentanone	1		1	
Acenaphthene	1		2	
Acenaphthylene	1			
Acetone	1	1		
Anthracene	1			
Antimony	1			
Arsenic	1	1	2	
Barium	1		2	
Benzene	1	1		
Benzo (a) anthracene	1	1	1	1
Benzo (a) pyrene	1	1	1	1
Benzo (b,k) fluoranthene	1	1	1	1
Benzo (ghi) perylene	1		2	1
Beryllium	1		1	
Bis (2-ethylhexyl) phthalate	1			1
Butyl benzyl phthalate	1			
Cadmium	1		1	1
Carbon disulfide	1			
Carbon tetrachloride				1
Chlorobenzene	1			
Chromium	1	1		
Chrysene	1		1	1
Copper	1			
Di-n-butyl phthalate	1			
Di-n-octyl phthalate	1			
Dibenzo (a,h) anthracene	1		1	1
Diethyl phthalate	1		2	1
Ethylbenzene	1			
Fluoranthene	1	1		

Blank means not used, 1 means included in analysis, and 2 indicates compounds less than reporting limits, but larger than half the reporting limits.

Table A.1 Continued				
Compound	Risk assessment	Soil analysis		Groundwater
		Duplicate	Distribution	Duplicate and distribution
Fluorene	1			
Formaldehyde	1	1	1	1
Indeno (1,2,3-cd) pyrene	1		1	1
Iron	1			
Lead	1	1	1	1
Mercury	1	1		1
Methylene chloride	1	1	1	
n-Nitrosodiphenylamine	1			
Naphthalene	1	1	1	1
Nickel	1	1	1	1
Oil and grease		1	1	
p-Chloro-m-cresol	1			
Pentachlorophenol	1			
Petroleum hydrocarbons		1	1	
Phenanthrene	1		2	1
Phenol	1			
Pyrene	1	1		
Selenium	1			1
Silver	1			
Styrene	1			
Tetrachloroethene	1			
Toluene	1	1		
Total Cyanide	1			
Total Xylenes	1			
Trichloroethene	1		1	
Vinyl Acetate	1			
Zinc	1	1	1	1
Blank means not used, 1 means included in analysis, and 2 indicates compounds less than reporting limits, but larger than half the reporting limits.				

Results of a sample's lab analysis can be placed in four categories:

1. Not available - compounds not analyzed for the sample.
2. Not detected - sample analyzed for compound, but value was below detection limits.
3. Detected, but not quantified - sample analyzed and compound detected, but not in amounts that can be reliably measured.

4. Detected and quantified - sample analyzed and compound detected in amounts that could be reliably measured.

The last three categories separate samples on the basis of the qualitative description of the presence of a compound at a site. Let these categories be represented by the sets A (absent), D (detected), and M (measurable), respectively. The response for samples that fall in the first two categories are non-numeric, but tell us a great deal about the concentration levels of a compound at a site.

A.2 THE MODEL

The model used for this type of mixed data can be described as follows. Let $X(\mathbf{s})$ be the true concentration level at a site. Given a random sample of the study area, define the probability that $X(\mathbf{s})$ is in one of the three categories as:

$$p_A = P(\text{non-detect})$$

$$p_D = P(\text{detected, but not quantified})$$

$$p_M = P(\text{detected and quantified})$$

Given that a sample is in one of these categories, the probability distribution of the true concentration level for samples within the category needs to be determined. The distribution of the sample depends on the category. Define the conditional cumulative distributions for the three categories to be F_A , F_D , and F_M respectively.

Estimates of the distributions for the non-detect and present categories are not possible since we can not get any measurements. We can assume without much loss of generality that the distribution F_A is Uniform on $[0, x_D]$, where x_D is the detection limits of the method of sample analysis and F_D is Uniform on $[x_D, x_M]$, where x_M is the limit of the method of sample analysis that produces reliable numerical results. The cumulative distribution F_M is estimated from the samples, but it is assumed $F_M(x) = 0$, for $x < x_M$. Now the distribution of $X(\mathbf{s})$ can be written as:

$$F(X(s) < x) = p_A F_A(x) + p_D F_D(x) + p_M F_M(x).$$

A.3 THE ANALYSIS

The statistical analysis of the soil and groundwater data from 1984 to 1988 is composed of three parts: duplicate analysis, univariate distribution estimation, and spatial mapping of concentrations. A brief discussion of the nature of the analysis and choice of compounds studied is given here.

There were 78 chemical compounds analyzed for at least one site. Subsets of these chemicals were chosen for duplicate and distribution analyses. Sixteen compounds that had a high number of samples with detectable concentrations were chosen for duplicate analysis for the soil samples. For distribution estimation, compounds were chosen if any samples had concentration values higher than the MADEP standards for groundwater (GW2) and soil (S1). Other compounds included were oil and grease and petroleum hydrocarbons for soil samples and phenanthrene and formaldehyde for groundwater samples. A total of 18 and 20 compounds were included in the soil and groundwater analyses, respectively. There was considerable overlap between compounds included in analyses of soil and groundwater distributions. A secondary list was developed for compounds that had maximum observed values less than the MADEP standards, but greater than half of the MADEP standards. For 47 of the 78 compounds studied, no samples had concentrations greater than half the MADEP standard reporting categories GW2 and S1. Table A.1 contains a list of the compounds included in the statistical analyses and in the Cambridge Environmental, Inc. risk assessment for the site.

Analysis of the duplicate sample data was conducted to determine the validity of the samples themselves. Two main questions were:

1. Do data from the duplicates indicate any sampling bias?
2. Is the variability between duplicates at a site relatively small compared to the variability in concentration levels between sites?

Only soil samples with 15 duplicates had a large enough sample size for true duplicate analysis to be performed. The number of duplicate samples for groundwater and surface water were eight and three, respectively.

Duplicate analysis, in which groundwater samples collected over time from the same site were treated as replicates, was conducted. Even for this strategy, only 13 compounds had enough replicates to perform the analysis. To overcome possible non-normality, analyses were also carried out on log transformed data.

Univariate distribution estimation included estimates of probability samples belonging to the three categories *A*, *D*, and *M*. Empirical distribution functions are given for the distribution of concentration values (*i.e.*, the empirical distribution function for F_M). Other relevant statistics, such as mean and variance, were also computed. Spatial distribution of concentration levels were also supplied.

A.4 DUPLICATE ANALYSIS

Duplicate samples were field duplicates and not lab duplicates. In this situation, duplicates were not necessarily expected to generate nearly identical results, particularly for soil samples, because soil composition can naturally vary even within a few inches. It is really a test to see how representative a sample may be of the neighboring area, particularly compared to the variability across the entire study site.

The number of soil, groundwater, and surface water samples that had duplicates was small. Maximum possible sample sizes were 15, 8, and 3, respectively. For many compounds, actual sample sizes were typically smaller because samples were not analyzed or did not have detectable levels for one of the samples in the duplicates. The number of soil duplicate pairs was just large enough to carry out a few basic analyses.

One assumption about the collection of field duplicates was that the samples were randomly selected at the site. To investigate this assumption let $d = X(\mathbf{s}) - X_d(\mathbf{s})$, where X_d is the duplicate sample at the site. Table A.2 states the frequency that d is less than

zero for each compound. Table A.3 gives the mean of d for each compound. If duplicates were taken randomly, the frequency in both tables should be around 50%. Looking over all compounds listed in Table A.2, the variability in these frequencies is in line with what occurs if samples were selected at random. The results show no indication of non-random sampling behavior.

Table A.2 Percent of differences less than zero for soil duplicate samples			
Compound	n	# $d < 0$	%($d < 0$)
Methylene chloride	5	2	0.40
Acetone	1	1	1.00
Benzene	1	1	1.00
Toluene	0	-	-
Fluoranthene	2	1	0.50
Naphthalene	6	5	0.83
Benzo (a) anthracene	2	2	1.00
Benzo (a) pyrene	1	1	1.00
Benzo (b,k) fluoranthene	2	2	1.00
Pyrene	3	2	0.67
Arsenic	15	5	0.33
Chromium	15	9	0.60
Mercury	9	3	0.33
Nickel	15	7	0.47
Lead	15	7	0.47
Zinc	14	5	0.36
Formaldehyde	7	5	0.71
Oil and grease	12	8	0.67
Petroleum hydrocarbons	14	8	0.57

Table A.3 Paired differences analysis for duplicate soil samples

Compound	Mean difference	Std. dev.(d)	Std. err. (d)	n	Mean rel diff.	Std. dev. rel. diff.
Methylene chloride	10.00	21.7	9.7	5	0.20	0.19
Acetone	-40.00	-	-	1	0.19	-
Benzene	-20.00	-	-	1	0.09	-
Toluene	-	-	-	0	-	-
Fluoranthene	11,120.00	19,629.3	13,880.0	2	1.07	0.21
Naphthalene	-1,532.83	6,126.3	2,501.0	6	0.21	0.22
Benzo (a) anthracene	-1,705.00	2,100.1	1,485.0	2	0.42	0.44
Benzo (a) pyrene	-2,835.00	-	-	1	0.97	-
Benzo (b,k) fluoranthene	-5,950.00	7,396.3	5,230.0	2	0.59	0.72
Pyrene	1,780.00	13,821.0	7,979.6	3	0.98	0.19
Arsenic	-0.52	3.0	0.8	15	0.20	0.14
Chromium	-0.71	2.5	0.6	15	0.10	0.09
Mercury	0.00	0.1	0.02	9	0.22	0.22
Nickel	4.77	20.5	5.3	15	0.17	0.30
Lead	-3.23	26.5	6.8	15	0.24	0.35
Zinc	-74.26	214.6	57.4	14	0.18	0.16
Formaldehyde	-48.09	118.3	44.7	7	0.40	0.49
Oil and grease	6,093.17	23,440.0	6,766.5	12	0.53	0.35
Petroleum hydrocarbons	-331.93	809.6	216.4	14	0.34	0.36

Besides mean difference, Table A.3 gives estimates of variability in measured differences, both in absolute terms and relative terms. The mean relative difference is the mean of the coefficient of variation for all duplicate pairs for a compound. The coefficient of variation for a particular pair can be written as $v_i = \sqrt{2}|x_i - x_{ir}|/(x_i + x_{ir})$. Then the mean relative difference is the mean of v_i over all duplicate pairs, etc. Absolute mean difference and its standard deviation show no indication that the mean difference is not zero. The decision on whether the variability within duplicates is high is a subjective one and left at the reader's discretion. The mean relative difference indicates that, for most of the compounds, the standard deviation was usually less than 30-40% of the mean. The largest mean relative errors also had very small sample sizes and were not reliable estimates. Of those compounds with larger sample sizes, formaldehyde and oil and grease had the highest mean relative difference and precision may be of concern for them.

Next, the duplicate pairs were identified by whether both pairs fell in the same detection category. This is a useful test for those compounds that have a high percentage of samples with no measurable concentrations. Clearly, if one sample shows no detectable amounts of a compound and the area is fairly homogeneous, the duplicate sample should also show no detectable amounts. Table A.4 gives the total sample size, the correct number of matches, and the percent correct. All results were over 67% and 15 of the 19 compounds matched on more than 80% of the samples. Metals had very high rates, while the other compounds had lower rates. Note that due to small sample sizes just one mismatch more or less causes about a 6% or 7% change in the correct categorization rate. These results were fairly subjective, but indicated that field samples were representative of the neighboring area, at least on a qualitative level.

Table A.4 Qualitative evaluation of soil duplicate samples based on detection category			
Compound	Total samples	# Correct matches	% Correct
Methylene chloride	14	13	0.93
Acetone	14	11	0.79
Benzene	14	13	0.93
Toluene	14	11	0.79
Fluoranthene	15	11	0.73
Naphthalene	15	13	0.87
Benzo (a) anthracene	15	12	0.80
Benzo (a) pyrene	15	10	0.67
Benzo (b,k) fluoranthene	15	12	0.80
Pyrene	15	13	0.87
Arsenic	15	15	1.00
Chromium	15	15	1.00
Mercury	15	14	0.93
Nickel	15	15	1.00
Lead	15	15	1.00
Zinc	14	14	1.00
Formaldehyde	14	13	0.93
Oil and grease	14	13	0.93
Petroleum hydrocarbons	14	14	1.00

For those duplicate pairs that had measurable concentrations in both samples, a simple analysis of variance was used to compare the variability between duplicate samples and the variability between sampling locations. Small variability within duplicates compared to variability between locations was another indication that samples were fairly

representative of the neighboring area. Let σ_w^2 and σ_b^2 be the within duplicates and between sampling location variances. Table A.5 contains estimates of these variances for all compounds with a suitable sample size. The ratio of variances for within duplicates and between sites can be used to get relative size of variances. Smaller p -values indicate the strength of the hypothesis when the ratios of the two variances is not equal to one, a p -value less than 0.05 is frequently used as a cut-off point. For compounds with a reasonable sample size, only nickel, formaldehyde, and oil and grease show within variability as large as between site variability. However, deletion of a questionable value for one of the duplicates for nickel changes its p -value to 2×10^{-11} . This analysis indicates that for compounds with a reasonable sample size, all but formaldehyde and oil and grease showed a much greater variation between sites than within a site. For many reasons, most notably non-normality and possible lack of independence of samples, it is not recommended to use the p -values given in the table as a true test statistic. However, they may still be used to judge relative variability. Results were carried out on log transformed data and results were qualitatively the same.

Table A.5 Soil - Comparison of within duplicates and between duplicate variances				
Compound	<i>n</i>	σ_w^2	σ_b^2	<i>p</i>-value
Methylene chloride	5	237.80	7,488.35	0.0001
Acetone	1	800.00	-	-
Benzene	1	200.00	-	-
Toluene	0	-	-	-
Fluoranthene	2	1.58E+08	1.53E+08	0.43
Naphthalene	6	1.68E+07	4.058E+08	0.001
Benzo (a) anthracene	2	2.56E+06	2.58E+06	0.42
Benzo (a) pyrene	1	4.02E+06	-	-
Benzo (b,k) fluoranthene	2	3.14E+07	532,900	0.90
Pyrene	3	6.53E+07	3.71E+07	0.62
Arsenic	15	4.388787	51.35	0.0000
Chromium	15	3.056	37.28	0.0000
Mercury	9	0.00167	0.0222	0.0004
Nickel*	15	208.0623	206.65	0.5
Lead	15	332.7477	26,635.6	0.0000
Zinc	14	2.41E+04	2.41E+06	0.0000
Formaldehyde	7	8,344.165	7,191.3	0.56
Oil and grease	12	2.7E+08	2.42E+08	0.56
Petroleum hydrocarbons	14	3.59E+05	1.31E+07	0.0000
* - <i>p</i> -value would be 3×10^{-6} if site SIT3 TP15 S2 is deleted				

Repeated measurements over time were used as replicates for groundwater in place of standard duplicate analysis to try and get an estimate of relative variability within and between sites. The results of this analysis is given in Tables A.6 and A.7 for the 10 compounds with enough samples for this analysis. Again, small *p*-values indicated that variability over time at a particular well was small compared to the variability between wells. The large *p*-values were not surprising for many of the compounds because of the small sample sizes involved. Except for naphthalene, there was general agreement in tests for untransformed and log transformed data. For naphthalene, the log transformed results were more appropriate. Most compounds with reasonable sample sizes indicated concentration levels varied across the property.

Table A.6 Comparison of variation in concentrations between sites and within sites for groundwater well samples-log transformed data

Compound	site d.f.	err. d.f.	MS(site)	MS(w/in)	p-value
Naphthalene	17	17	9.55	1.42	0.00
Benzo (b,k) fluoranthene	6	1	0.84	0.00	0.01
Chrysene	5	1	0.82	0.08	0.24
Phenanthrene	5	3	0.36	0.30	0.47
Cadmium	9	3	4.34	0.77	0.09
Nickel	14	3	1.43	1.07	0.46
Lead	14	2	1.31	0.87	0.47
Selenium	4	1	1.34	6.80	0.91
Zinc	35	18	4.31	1.60	0.01
Formaldehyde	14	6	4.60	0.81	0.02

Table A.7 Number of samples, means, and standard deviations for samples with a measurable concentration of the compound for soil and groundwater samples

Compound	Soil Sample Summary				Groundwater Summary			
	n	Mean	St. Dev.	Units	n	Mean	St. Dev.	Units
Methylene chloride	38	86.78	71.83	ppb	-	-	-	
1,1-dichloroethene	-	-	-		3	5.47	3.92	ppb
Trichloroethene	1	1,200.00	-	ppb	-	-	-	
Carbon tetrachloride	-	-	-		2	22.50	13.44	ppb
4- methyl-2-pentanone	4	333.00	579.92	ppb	-	-	-	
Naphthalene	43	11,265.8	24,985.8	ppb	35	2,838.21	5,596.53	ppb
Benzo (a) anthracene	35	4,404.46	8,704.15	ppb	5	8.00	4.98	ppb
Benzo (a) pyrene	20	3,140.75	5,490.82	ppb	4	17.10	18.04	ppb
Benzo (b,k) fluoranthene	41	9,073.00	29,079.4	ppb	8	13.68	13.07	ppb
Chrysene	15	4,734.67	6,649.04	ppb	7	9.30	11.97	ppb
Benzo (ghi) perylene	-	-	-		2	46.30	56.71	ppb
Phenanthrene	-	-	-		9	22.32	11.15	ppb
Dibenzo (a,h) anthracene	17	2,367.59	6,194.62	ppb	1	4.4	-	ppb
Indeno (1,2,3-cd) pyrene	27	6,008.74	18,753.5	ppb	3	30.47	38.57	ppb
Bis (2-ethylhexyl) phthalate	-	-	-		7	162.37	185.30	ppb
Beryllium	39	0.51	0.45	ppm	1	31	-	ppb
Cadmium	71	2.82	7.12	ppm	13	59.43	151.67	ppb
Mercury	-	-	-		2	0.75	0.64	ppb
Nickel	102	18.08	63.24	ppm	18	107.00	200.41	ppb
Lead	98	190.22	555.50	ppm	17	110.47	123.31	ppb
Selenium	-	-	-		6	113.33	158.20	ppb
Zinc	99	441.31	1,330.23	ppm	54	906.37	1,945.53	ppb
Formaldehyde	40	14.36	44.65	ppm	21	0.55	1.01	ppm
Oil and grease	70	7,871.39	14,237.6	ppm	-	-	-	
Petroleum hydrocarbons	74	789.69	1,321.12	ppm	-	-	-	

A.5 ANALYSIS OF RANGE OF COMPOUND CONCENTRATION LEVELS

As described previously, a complete description of the range or distribution of concentrations for each compound consists of two parts:

1. Estimating the probability that a sample has a detectable concentration of a compound.
2. For those samples with measurable amounts of a compound estimating the distribution or range of concentrations present.

Table A.8 gives estimates of the means and standard deviations for those compounds with a measurable quantity studied from the soil and groundwater samples. Tables A.8 and A.9 contain the probability of non-detect, detecting at non-measurable amounts, and detecting at measurable amounts of a compound for soil and groundwater samples, respectively. Most soil samples detected at least some amount of elemental compounds, while other compounds studied occurred in less than 40% of the samples. In descending order, zinc, naphthalene, formaldehyde, nickel, and lead were the most frequently occurring compounds in the groundwater samples. Nickel and lead were present in 25% of the samples. The overall mean can roughly be calculated as the probability a sample has a measurable concentration times the mean of those samples with a measurable concentration. This overall or grand mean is what is used in the Cambridge Environmental, Inc. risk assessment for soil analyses. Tables A.10 and A.11 contain the quintiles and maximum observed values for soil and groundwater samples respectively. For comparison these tables also contain the MADEP S1 and GW2 standards, respectively.

Table A.8 Comparison of variation in concentrations between sites and within sites for groundwater well samples-untransformed data

Compound	Site d.f.	Err. d.f.	MS(site)	MS(w/in)	P-value
Naphthalene	17	17	2.33E+07	3.93E+07	0.85
Benzo (b,k) fluoranthene	6	1	199.45	0.01	0.00
Chrysene	5	1	171.85	0.85	0.05
Phenanthrene	5	3	84.52	190.89	0.80
Cadmium	9	3	30,433.91	718.22	0.01
Nickel	14	3	21,267.21	128,358.3	0.99
Lead	14	2	16,287.16	7,625.00	0.36
Selenium	4	1	12,270.83	76,050.00	0.93
Zinc	35	18	5.58E+06	2.87E+05	0.00
Formaldehyde	14	6	1.31	0.37	0.06

MS(site) is variance between sites and MS(w/in) is variance within sites. P-value is for *F*-test. Results for log transformed data and untransformed data.

Table A.9 Soil samples - Summary of categorization of samples into non-detect, detect (detected, but concentration not quantified), and measurable (detected and concentration quantified)

Compound	Total n	Probability of		Measurable
		Non-detect	Detect	
Methylene chloride	101	0.62	0.00	0.38
Trichloroethene	101	0.98	0.01	0.01
4-methyl-2-pentanone	102	0.95	0.01	0.04
Naphthalene	117	0.50	0.14	0.37
Benzo (a) anthracene	112	0.48	0.21	0.31
Benzo (a) pyrene	112	0.62	0.21	0.18
Benzo (b,k) fluoranthene	112	0.42	0.21	0.37
Chrysene	112	0.64	0.22	0.13
Dibenzo (a,h) anthracene	112	0.72	0.13	0.15
Indeno (1,2,3-cd) pyrene	112	0.57	0.19	0.24
Beryllium	103	0.62	0.00	0.38
Cadmium	103	0.31	0.00	0.69
Nickel	103	0.01	0.00	0.99
Lead	103	0.05	0.00	0.95
Zinc	100	0.01	0.00	0.99
Formaldehyde	88	0.55	0.00	0.45
Oil and grease	78	0.10	0.00	0.90
Petroleum hydrocarbons	77	0.04	0.00	0.96

Table A.10 Comparison of the distribution of soil concentrations to the MADEP Reporting Standard

Compound	n	Quantiles for the following percentiles of F_N						MADEP S -1
		20th	40th	60th	80th	90th	Max.	Standard
Methylene chloride	38	19	47	76	160	200	250	100
Trichloroethene	1	1,200	1,200	1,200	1,200	1,200	1,200	400
4-methyl-2-pentanone	4	3	19	19	110	1,200	1,200	500
Naphthalene	43	680	1,640	4,800	14,000	20,000	150,000	4,000
Benzo (a) anthracene	35	610	980	1,480	4,000	8,700	41,000	700
Benzo (a) pyrene	20	570	660	1,100	3,000	6,700	24,000	700
Benzo (b,k) fluoranthene	41	480	950	1,630	8,740	13,000	182,900	700
Chrysene	15	800	940	2,900	7,200	10,000	26,000	7,000
Dibenzo (a,h) anthracene	17	151	331	500	1,410	2,000	25,700	700
Indeno (1,2,3-cd) pyrene	27	417	600	1,100	3,600	6,700	97,500	700
Beryllium	39	0.26	0.34	0.45	0.6	0.82	2.8	0.7
Cadmium	71	0.6	0.91	1.3	2.3	3.3	54	30
Nickel	102	6.1	7.8	10	14	19	640	300
Lead	98	8.5	22.9	78	260	351	4,900	300
Zinc	99	18.4	42	110	440	801	11,975	2,500
Formaldehyde	40	0.6	1.1	1.8	3.5	5.1	220	100
Oil and grease	70	527	1,580	4,950	9,930	18,700	81,700	-
Petroleum hydrocarbons	74	10	94	384	1,109	2,118	7,950	-

F_M computed from empirical distribution function. Reporting limits are given by the City of Cambridge

Table A.11 Groundwater - Estimated probabilities for three categories non-detect, detect, and measurable for a sampling visit

Compound	# Sampling visits	Probability of no detect	Probability of detect	Measurable
1,1-dichloroethene	101	0.97	0.00	0.03
Carbon tetrachloride	101	0.98	0.00	0.02
Naphthalene	94	0.56	0.06	0.37
Benzo (a) anthracene	94	0.90	0.04	0.05
Benzo (a) pyrene	94	0.88	0.07	0.04
Benzo (b,k) fluoranthene	94	0.85	0.06	0.09
Chrysene	94	0.87	0.05	0.07
Benzo (ghi) perylene	94	0.95	0.03	0.02
Phenanthrene	94	0.88	0.02	0.10
Dibenzo (a,h) anthracene	94	0.98	0.01	0.01
Indeno (1,2,3-cd) pyrene	94	0.93	0.04	0.03
Bis (2-ethylhexyl) phthalate	59	0.83	0.05	0.12
Diethyl phthalate	94	0.99	0.00	0.01
Cadmium	70	0.81	0.00	0.19
Mercury	70	0.97	0.00	0.03
Nickel	70	0.74	0.00	0.26
Lead	70	0.76	0.00	0.24
Selenium	67	0.91	0.00	0.09
Zinc	58	0.07	0.00	0.93
Formaldehyde	60	0.65	0.00	0.35

See Table A.12 for the probability that a well had at least one detect

Samples with measurable concentration levels can be used to estimate the frequency that concentration levels occurred at sampling locations. For groundwater, the average over time is used for wells with multiple samples. These estimates, called empirical distribution functions, are plotted in Figures A.1 through A.4 for soil and groundwater samples for naphthalene and formaldehyde.

Figure A.1 Spatial Map and Empirical Distribution Function for Naphthalene in Soil

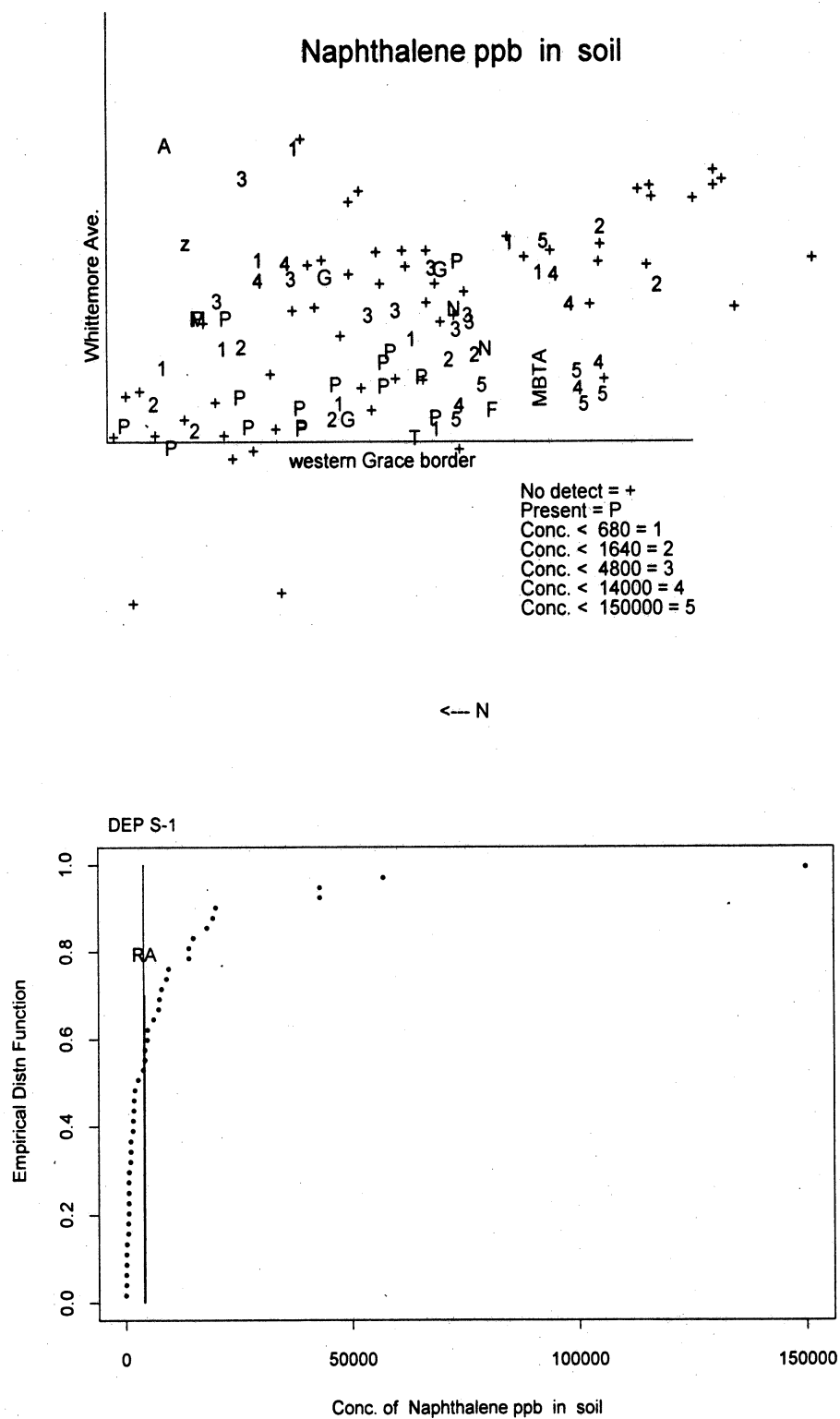


Figure A.2 Spatial Map and Empirical Distribution Function for Formaldehyde in Soil

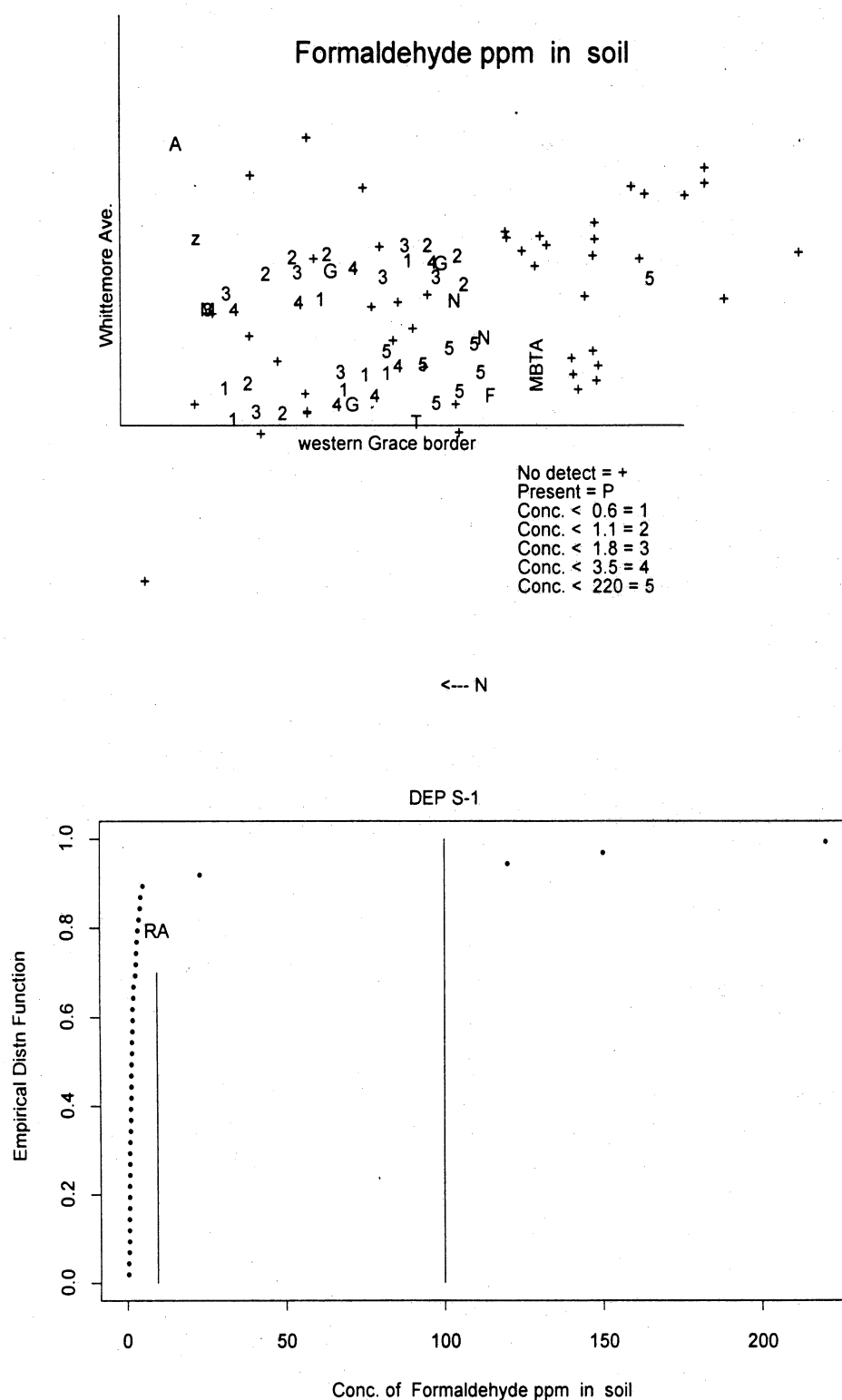


Figure A.3 Spatial Map and Empirical Distribution Function for Naphthalene in Groundwater

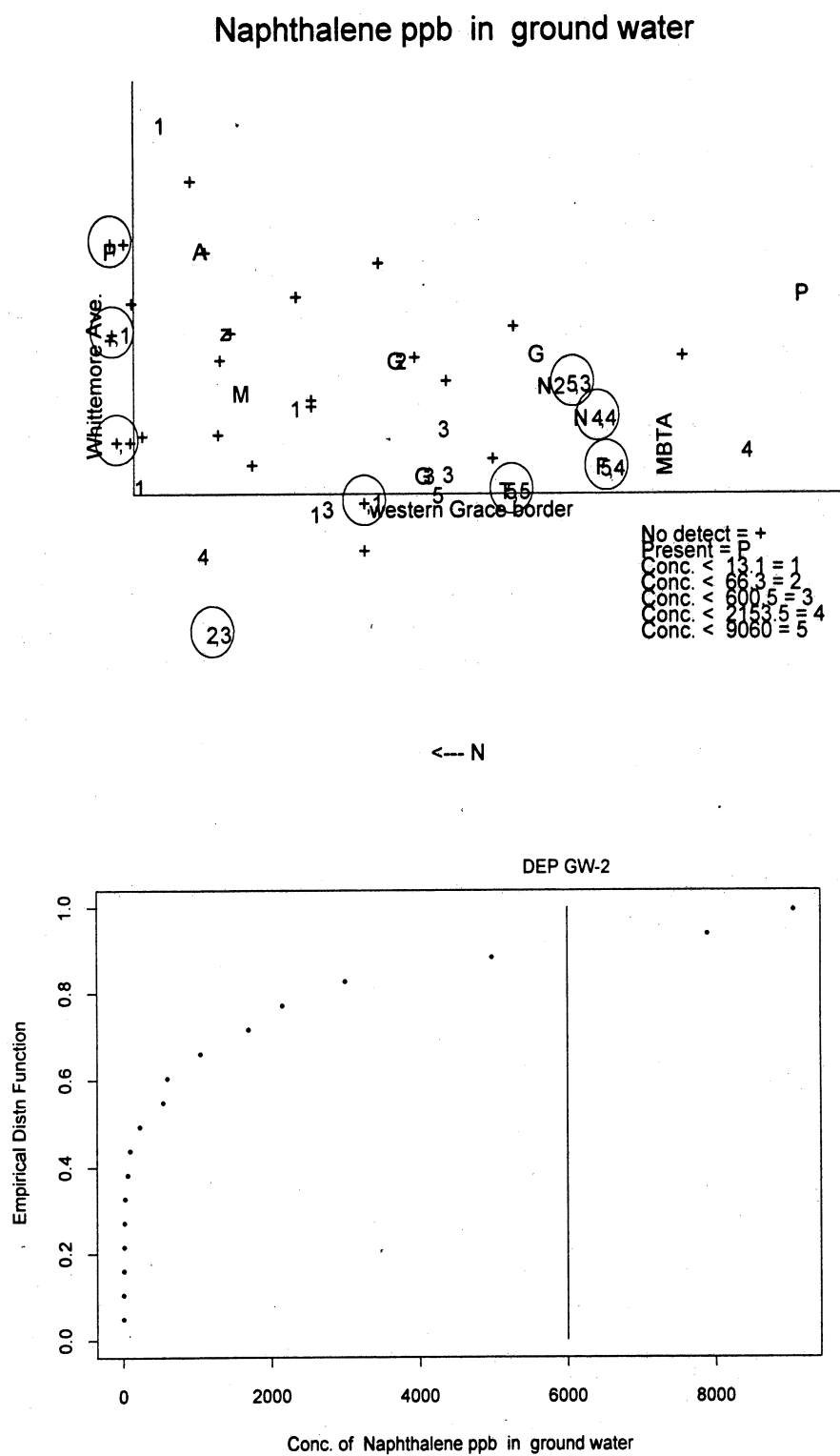
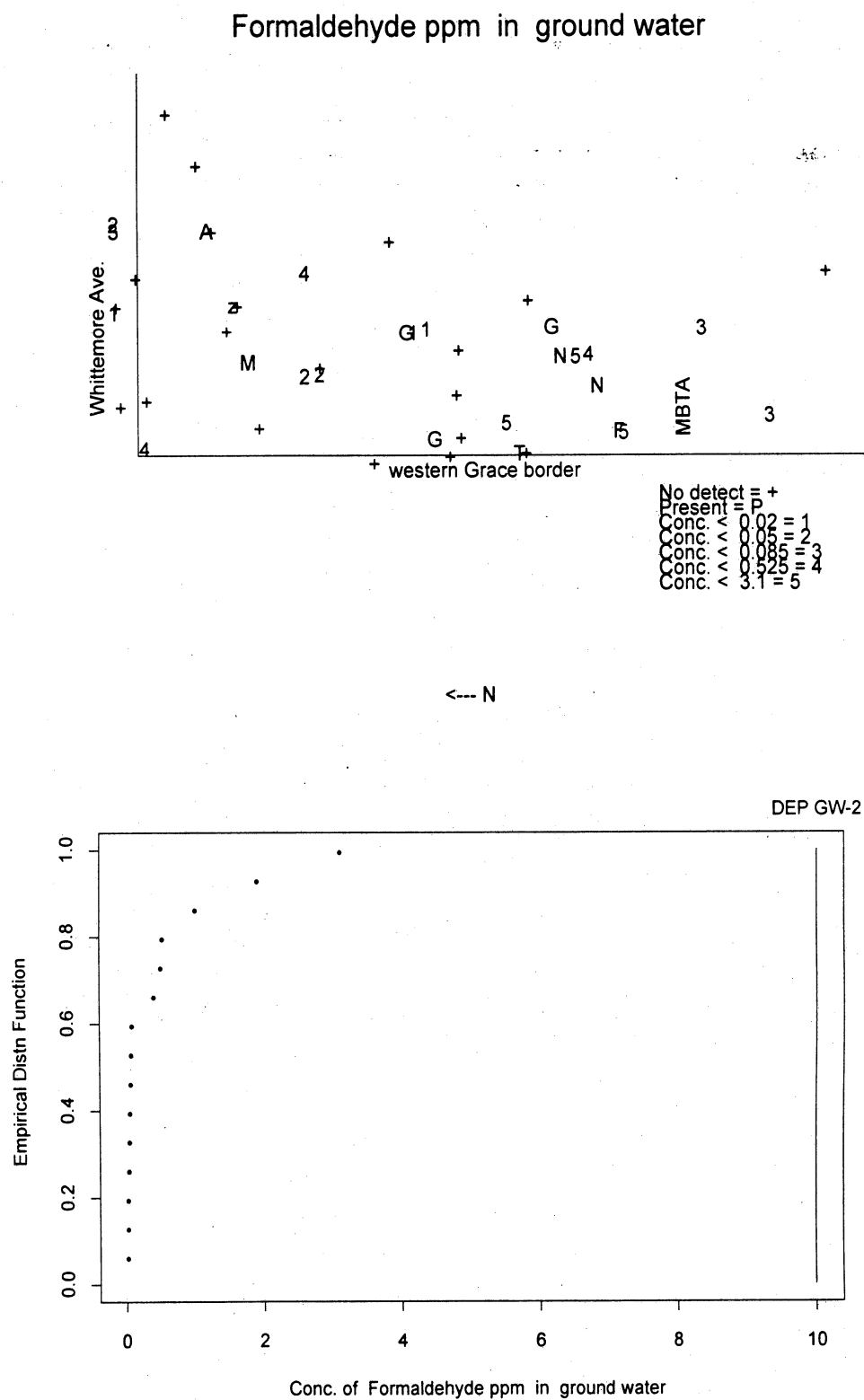


Figure A.4 Spatial Map and Empirical Distribution Function for Formaldehyde in Groundwater



A.6 SPATIAL AND TEMPORAL ANALYSES

Spatial maps of the concentration levels for groundwater and soil samples have been generated. Figures A.1 through A.4 show the maps for soil and groundwater samples for naphthalene and formaldehyde. The characters on the map represent the following: + is a non-detect, P is a detect, 1-5 indicate whether the measurable concentration value observed at the site is less than or between the 20th, 40th, 60th, 80th, or 100th percentile concentrations observed. Locations of storage facilities are also given. The codes for these are: A = acetone, M = methanol, F = formaldehyde, G = fuel, N = naphthalene, z = zinc, and T is for tanks that held a number of different compounds.

A simple representation of time trends is given in Figure A.3 for naphthalene in groundwater. The nine wells that were sampled from 1984 to 1994 are circled in Figure A.3. Inside these circles are a pair of numbers separated by a comma. The meaning of these numbers is the same as the others on the plot; however, the first number represents the mean of samples from 1984 to 1987 and the second number represents the mean of samples from 1990 to 1994. No samples were taken in 1988 and 1989. The two wells changed from non-detect to a 1, but this change was less than indicated. This is because there were only one or two samples at these wells in 1984-1987, but nine samples in 1990-1994, of which only two or three samples had detectable levels. If the earlier period had been sampled as frequently as the latter period, it is possible low concentration levels may have occurred.

The probability of at least one detection in repeated groundwater samples of the same wells can be used to indicate differences between wells. It is assumed that the probability of detection is equally likely at any well at any time. From this assumption, the expected probability a well had at least one detection can be computed using the estimate of the probability that a sample had a detectable level of a compound. If the observed probabilities were considerably less than the expected probabilities given in Table A.12, this indicated that samples with detectable concentrations were being observed at certain wells rather than randomly over the W.R. Grace property. This was another indication that concentration levels of these compounds were different across the W.R. Grace property.

Analysis of concentrations that were analyzed for VOCs and naphthalene over time were only available for nine well sites along the north and west borders of the W.R. Grace property from approximately 1985 to 1994. A total of 90 well samples were spread out fairly evenly among the nine well sites. Five compounds, benzene, ethyl benzene, naphthalene, methylene chloride, and total xylenes, had 26, 27, 49, 10, and 10 detects out of the 90 possible visits; all the rest had less than 10. Only naphthalene had observations above MADEP GW2 standards and the maximum concentrations observed for the other compounds were less than 10% of MADEP GW2 standards.

Naphthalene was consistently present in four of the nine sites: B212, B707, B708, and B604. Except B604, which is outside the W. R. Grace property (near the rotary), all sites were close to previous storage sites on the property. None of the sites showed any apparent time trends in concentration levels of naphthalene. It is possible there was an increase over time at well B604. However, one outlier and too few observations preclude a definite assessment. The fact that well B904 is between B604 and the others and showed no detectable concentration levels further weakens any migration hypothesis for naphthalene from the W.R. Grace property. The increase in concentration levels was slight, roughly 20 ppb per year and the maximum concentration level, 950 ppb at well B604, was considerably less than the MADEP GW2 standards (6,000 ppb).

Benzene and ethyl benzene also had a fair number of detects, but were scattered over many sites. Sites B212 and B604 had more detects than other sites, but detection was not consistent from one time to the next. No samples were above MADEP GW2 standards and there was an indication that concentrations were decreasing over time.

In summary, results from soil samples including duplicates indicate that the analytical methods were adequate to determine concentration differences among sites. However, this finding applies only to a few compounds due to the limited number of available data.

Table A.12 Comparison of the distribution of groundwater concentrations to the MADEP Reporting Standard

Compound	20th	40th	60th	80th	90th	Max.	MADEP GW2
Naphthalene (ppb)	13.1	66.3	600.5	2,153.5	4,983.33	9,060	6,000
Benzo (b,k) fluoranthene	3.9	8.7	10.6	21.9	21.9	42.4	7
Chrysene	3.25	4.8	5.7	6.5	6.5	36.3	3
Phenanthrene	5.9	19	23	27.67	27.67	29	50
Bis (2-ethylhexyl) phthalate	6.6	61	74	400	400	460	30
Cadmium	0.85	2.7	10	28	36.6667	560	10
Nickel	13	24	34	61	120	342.5	80
Lead	29	50	60	195	290	430	30
Zinc	48	130	380	850	2,900	9,600	900
Formaldehyde (ppm)	0.02	0.05	0.085	0.525	1.9	3.1	10

Only compounds with at least six sites with measurable concentrations are included. The mean value for each site does not include non-detects in estimates. Last column is the MADEP GW2 standards.

Table A.13 Comparison of observed and estimated probability of measuring a compound at a groundwater well site

Compounds	# Sites	Observed	Expected
1,1-dichloroethene	44	0.07	0.07
Carbon tetrachloride	44	0.05	0.04
Naphthalene	43	0.42	0.67
Benzo (a) anthracene	43	0.12	0.19
Benzo (a) pyrene	43	0.09	0.23
Benzo (b,k) fluoranthene	43	0.16	0.29
Chrysene	43	0.14	0.25
Benzo (ghi) perylene	43	0.05	0.11
Phenanthrene	43	0.14	0.23
Dibenzo (a,h) anthracene	43	0.02	0.05
Indeno (1,2,3-cd) pyrene	43	0.07	0.15
Bis (2-ethylhexyl) phthalate	36	0.19	0.25
Diethyl phthalate	43	0.02	0.02
Cadmium	38	0.26	0.30
Mercury	38	0.05	0.05
Nickel	38	0.39	0.40
Lead	38	0.39	0.38
Selenium	38	0.13	0.15
Zinc	37	0.97	0.96
Formaldehyde	35	0.43	0.49

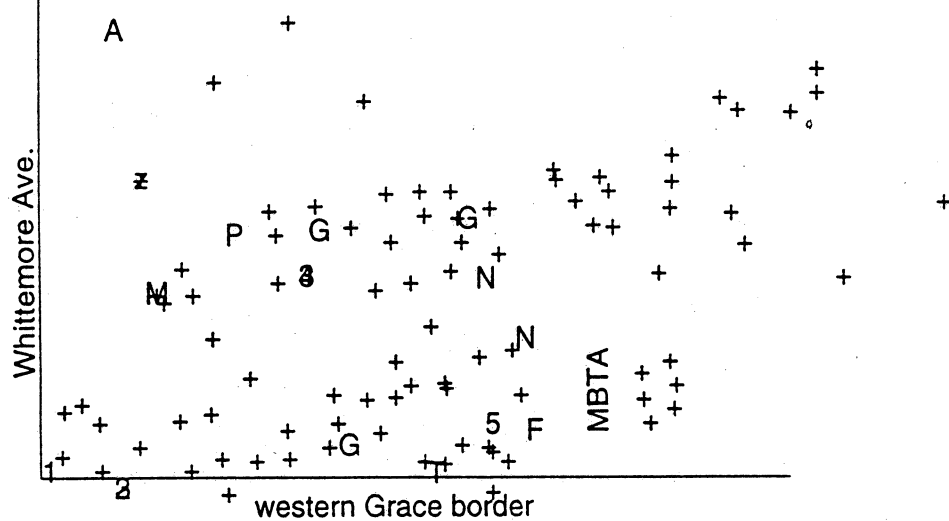
First column is the number of wells that had at least one sample over time sampled for the compound. Second column is the observed probability that a well had at least one detect. The last column is the expected probabilities based on random distribution, when observed was less than expected indicating non-random spatial distribution of compound across the site.

APPENDIX B

SUPPLEMENTAL INFORMATION

**SOIL AND GROUNDWATER DATA: SPATIAL AND
DISTRIBUTIONAL DISPLAYS**

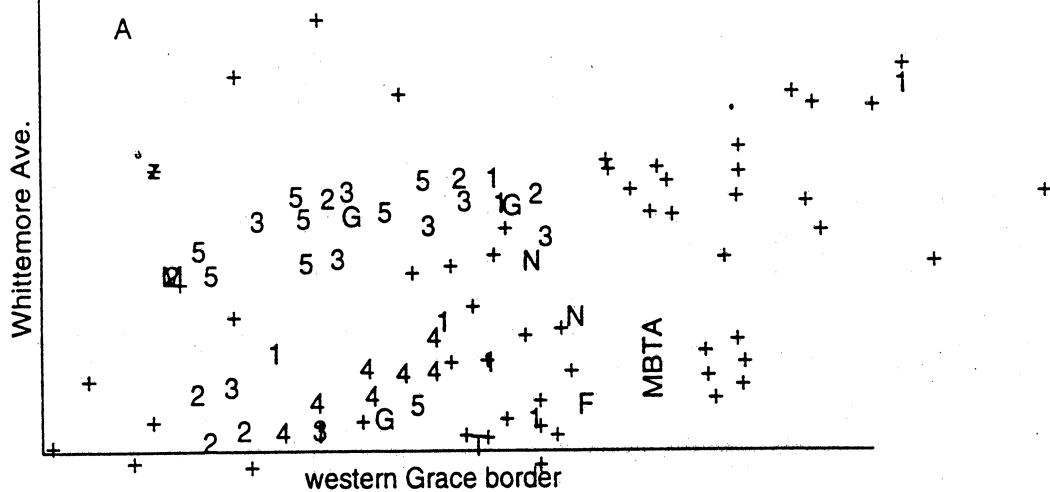
4-Methyl-2-Pentanone ppb in soil



No detect = +
 Present = P
 Conc. < 3 = 1
 Conc. < 19 = 2
 Conc. < 19 = 3
 Conc. < 110 = 4
 Conc. < 1200 = 5

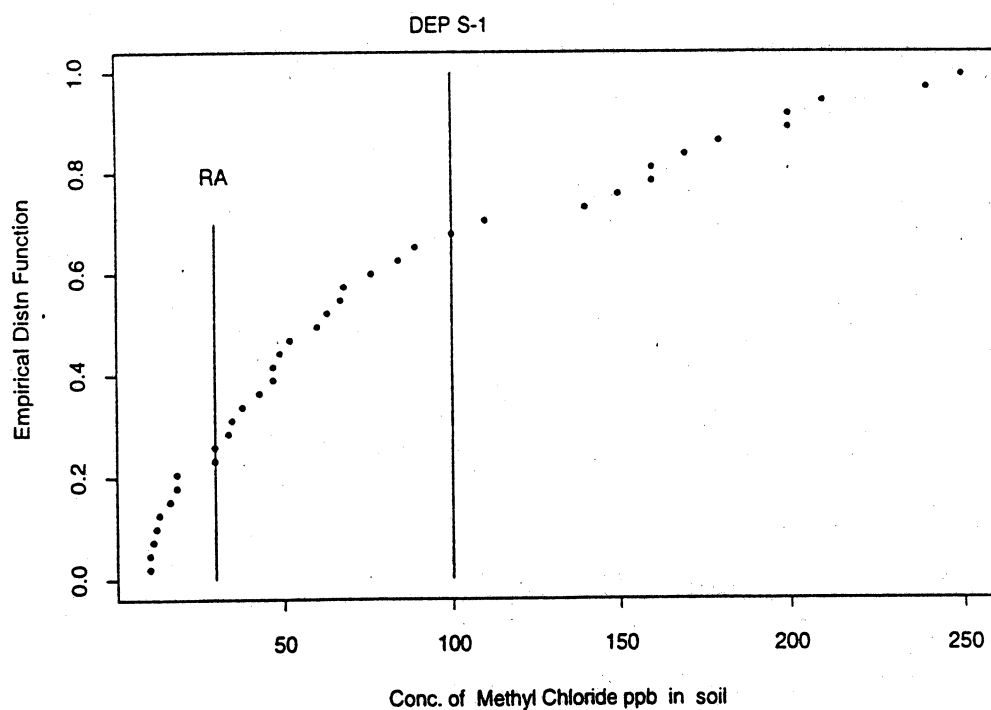
<--- N

Methyl Chloride ppb in soil

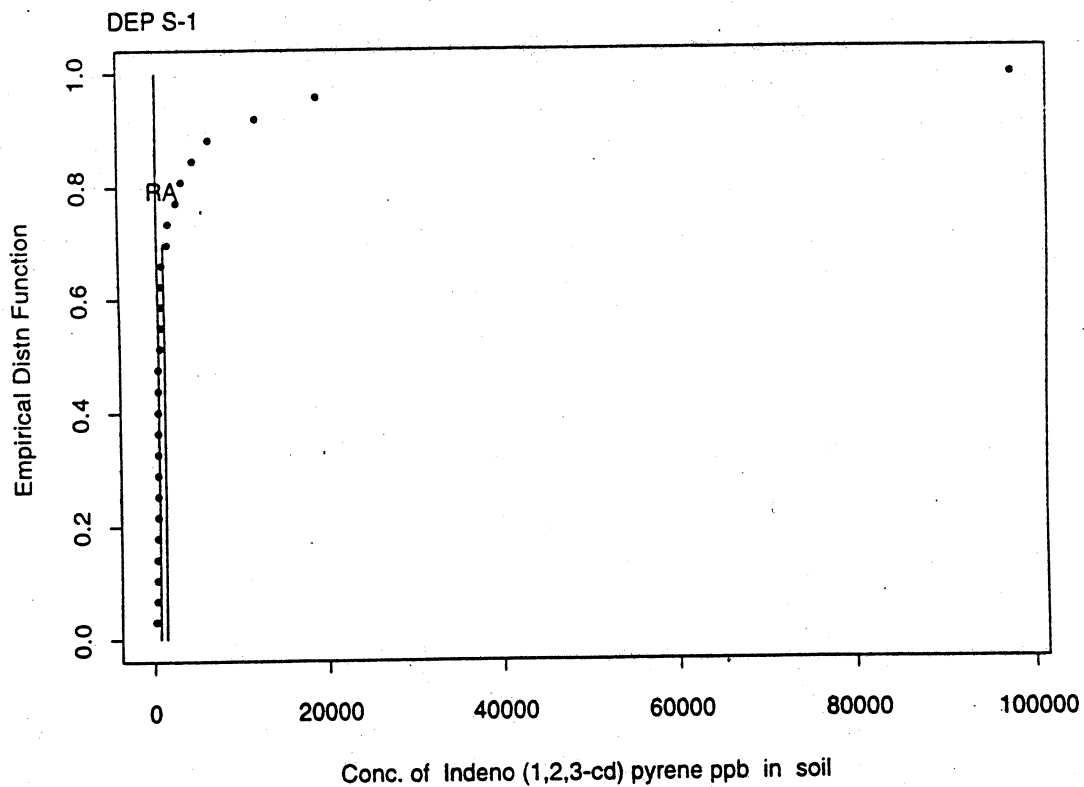
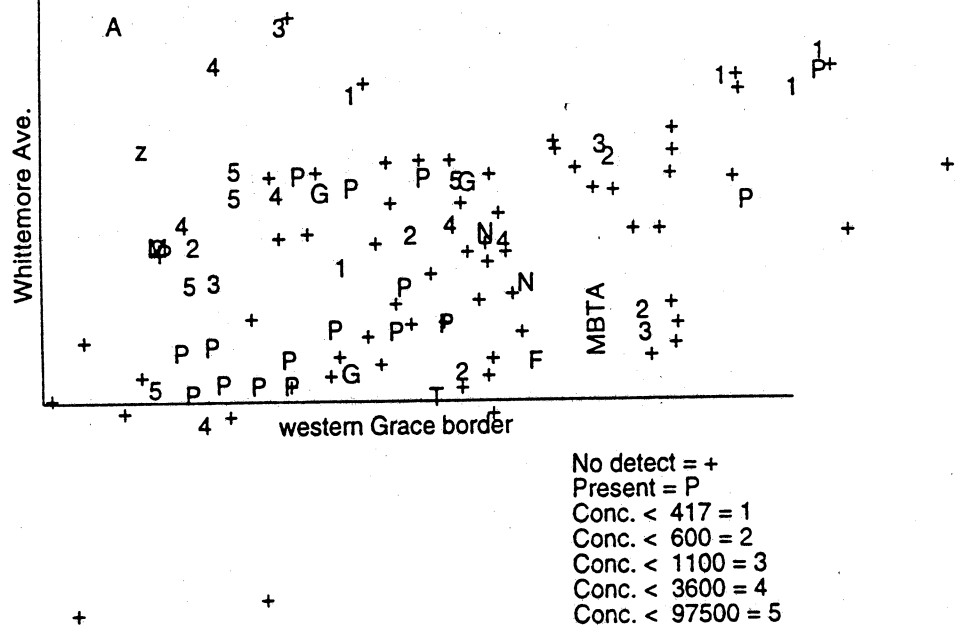


No detect = +
 Present = P
 Conc. < 19 = 1
 Conc. < 47 = 2
 Conc. < 76 = 3
 Conc. < 160 = 4
 Conc. < 250 = 5

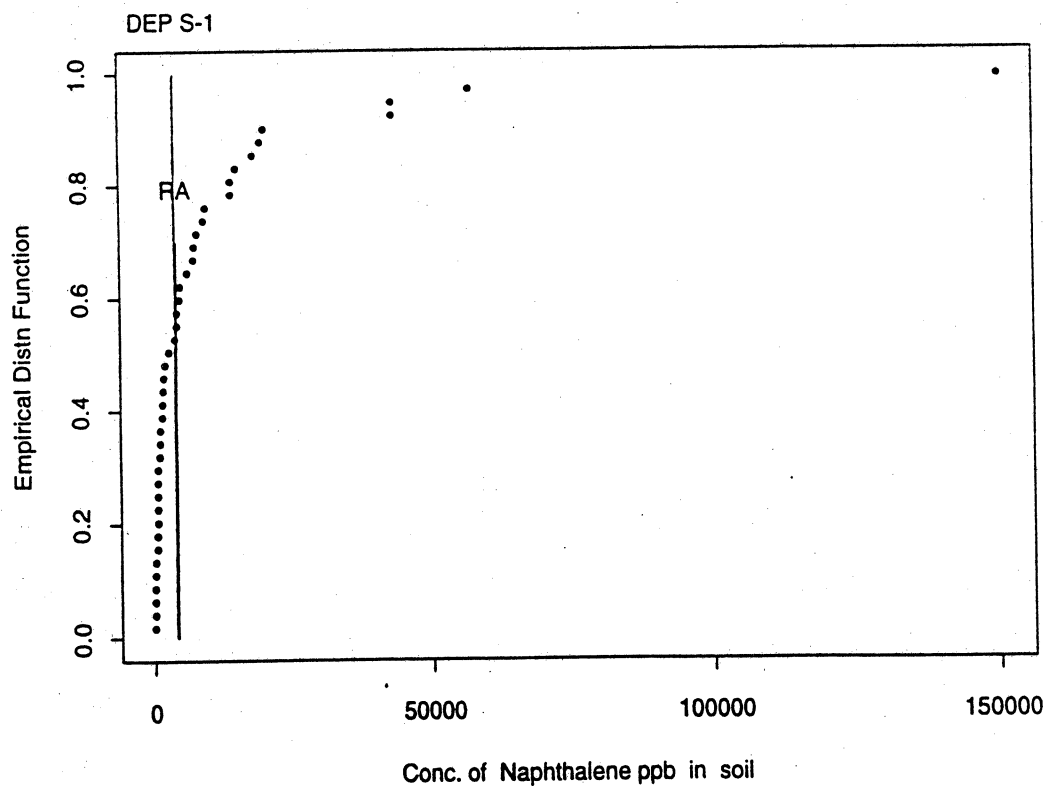
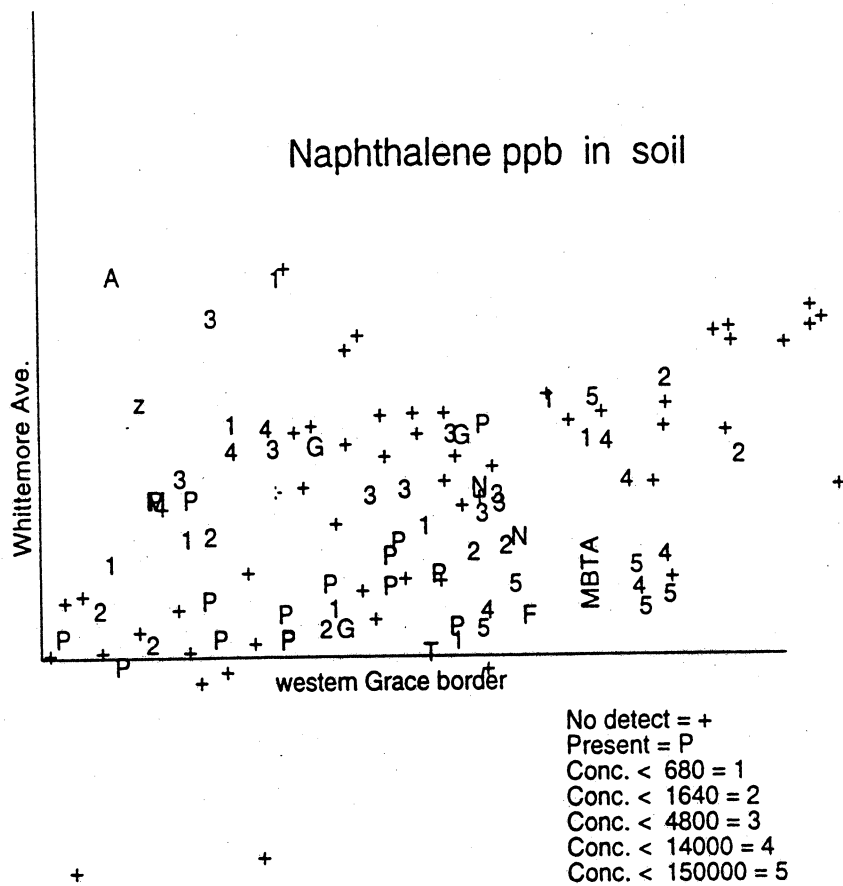
<-- N



Indeno (1,2,3-cd) pyrene ppb in soil



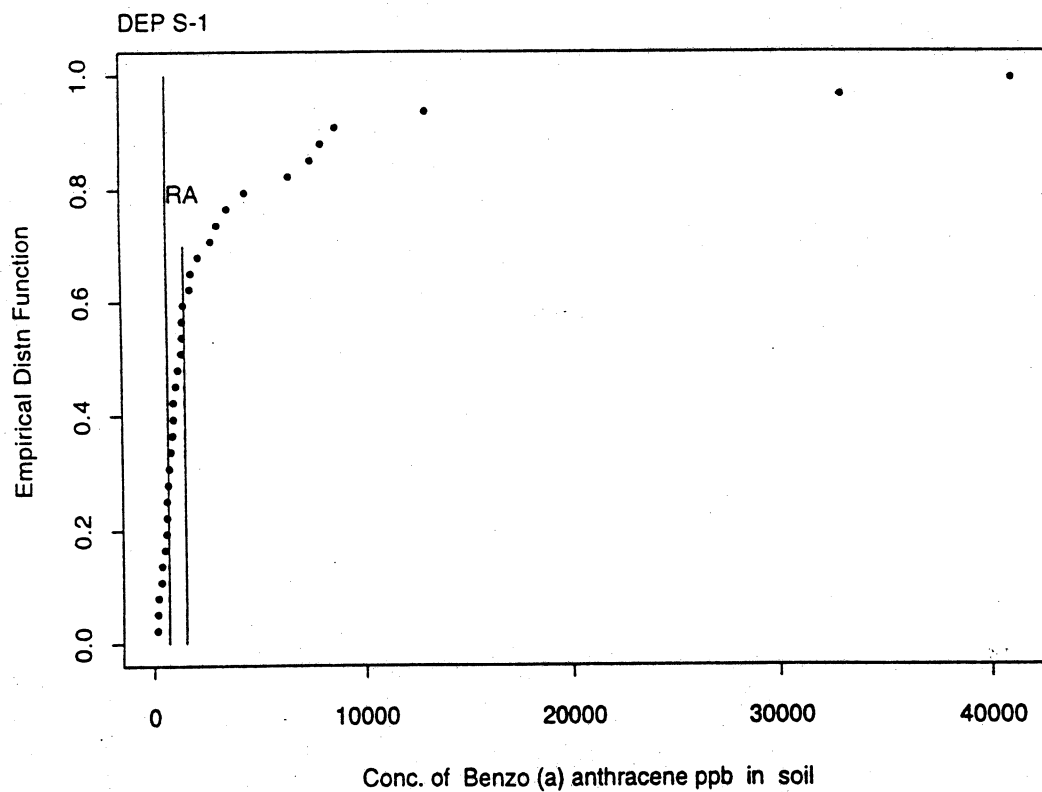
Naphthalene ppb in soil

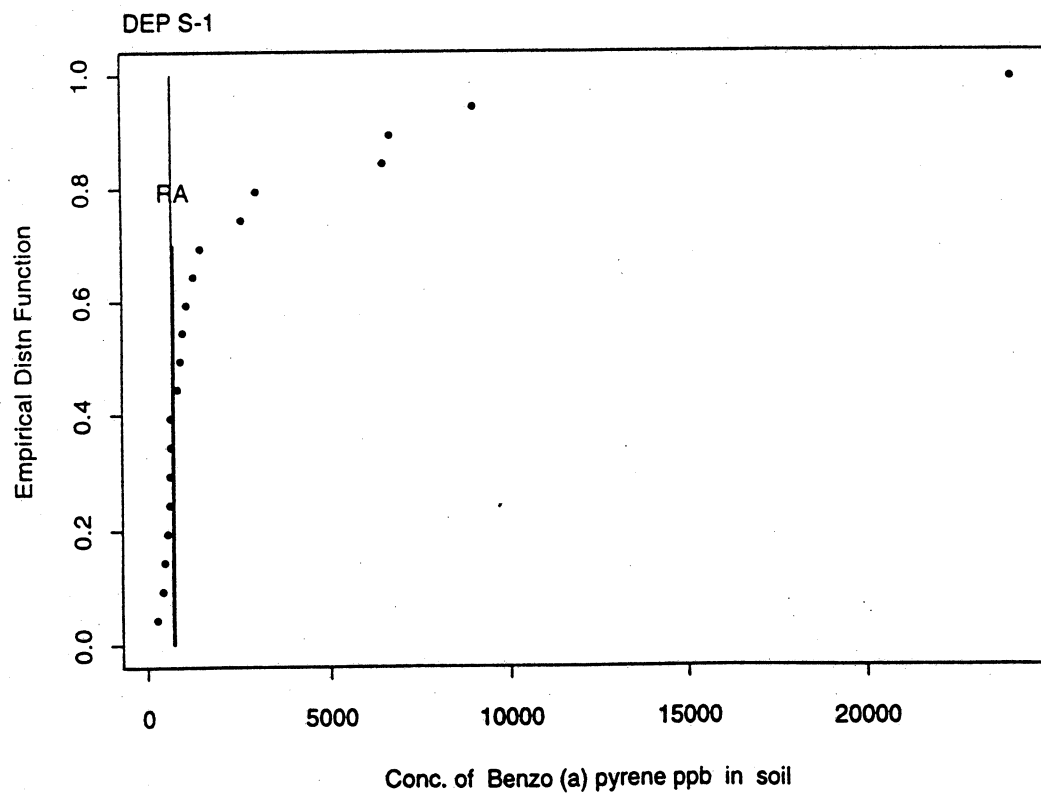
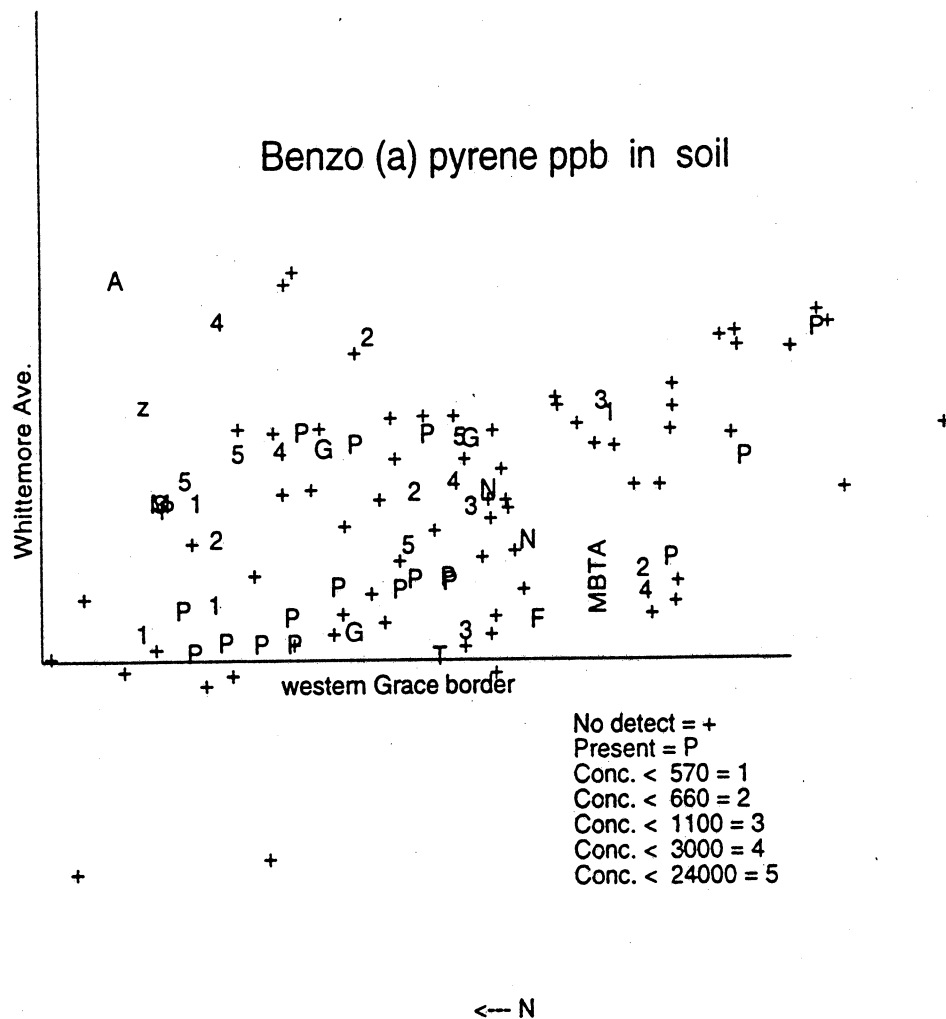


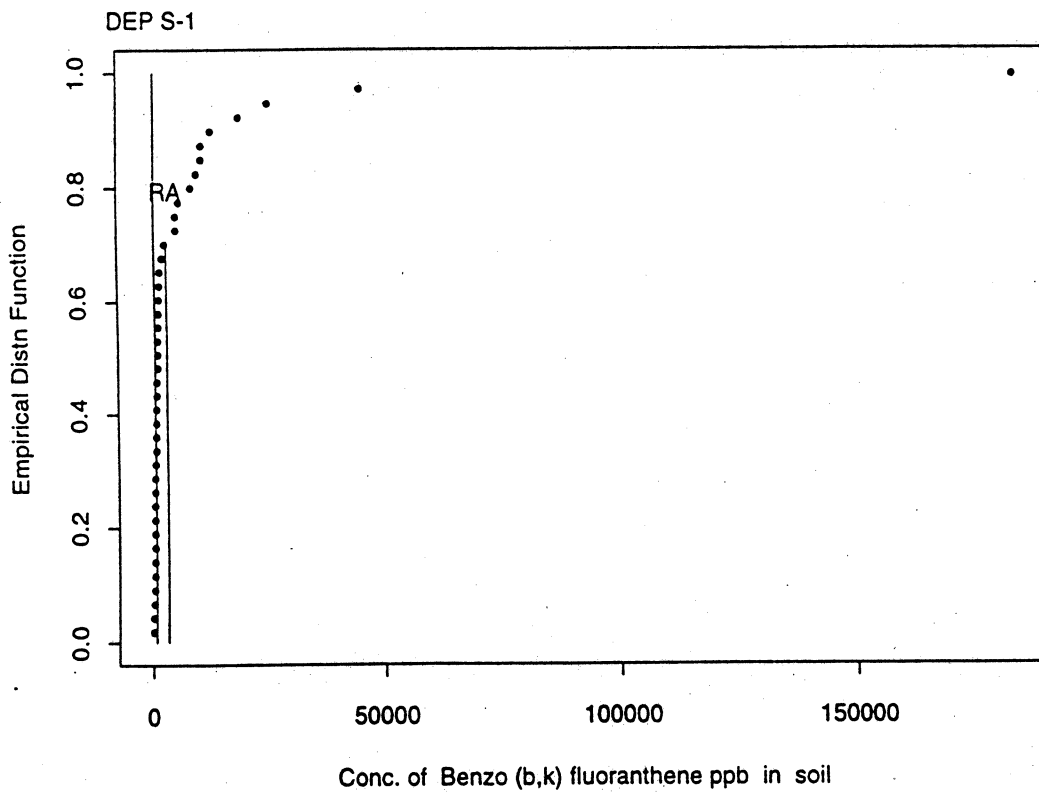
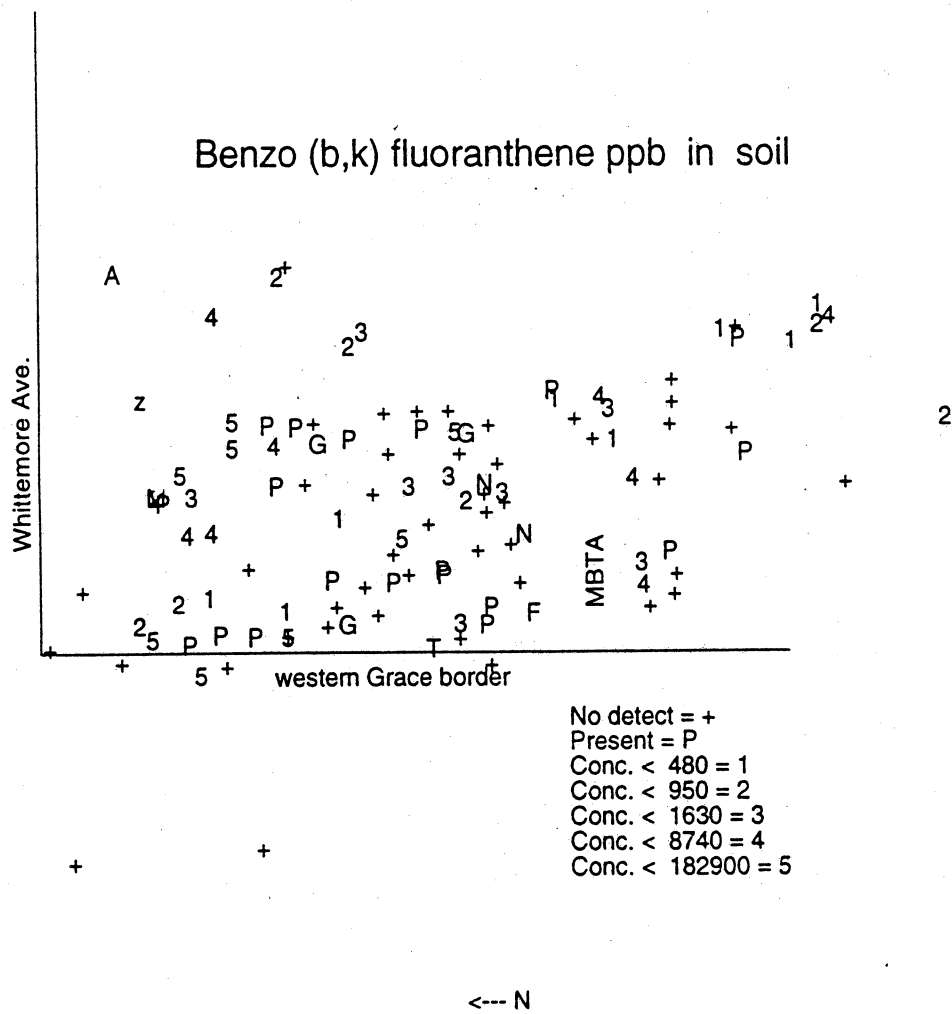
The map displays sampling locations along Whittemore Ave. and the western Grace border. Data points are labeled with numbers 1 through 5, representing concentration levels, and letters A through Z, representing specific sites. The legend indicates:

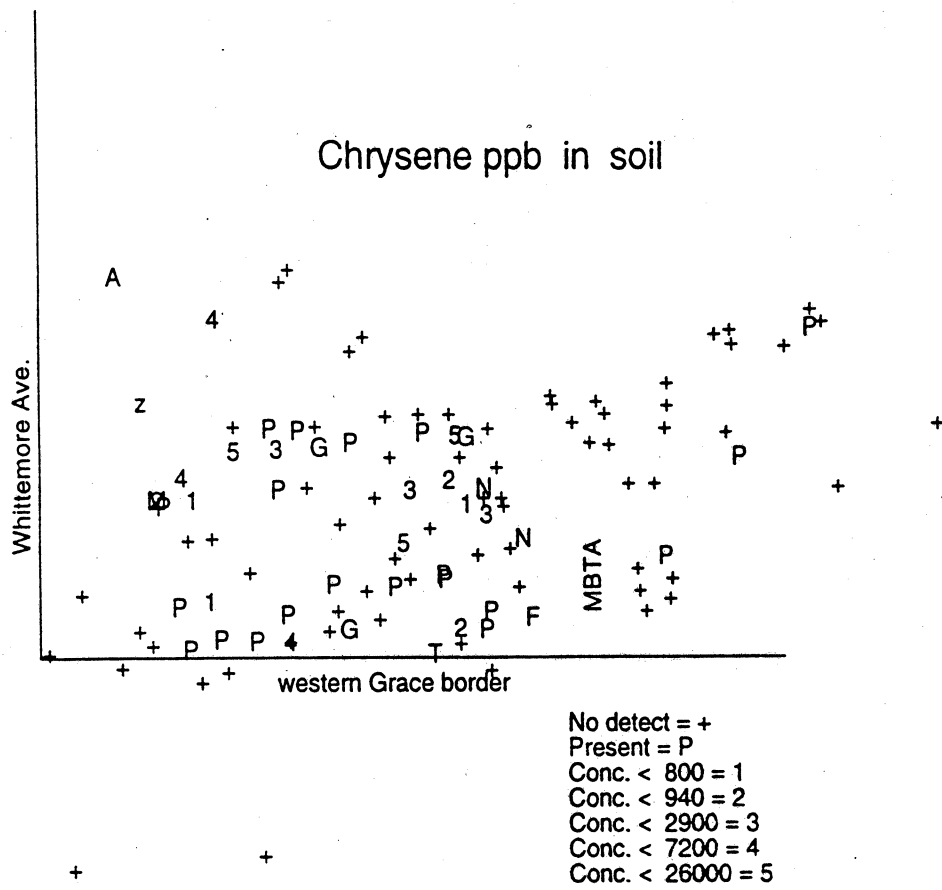
- No detect = +
- Present = P
- Conc. < 610 = 1
- Conc. < 980 = 2
- Conc. < 1480 = 3
- Conc. < 4400 = 4
- Conc. < 41000 = 5

A north arrow points towards the top right of the page.

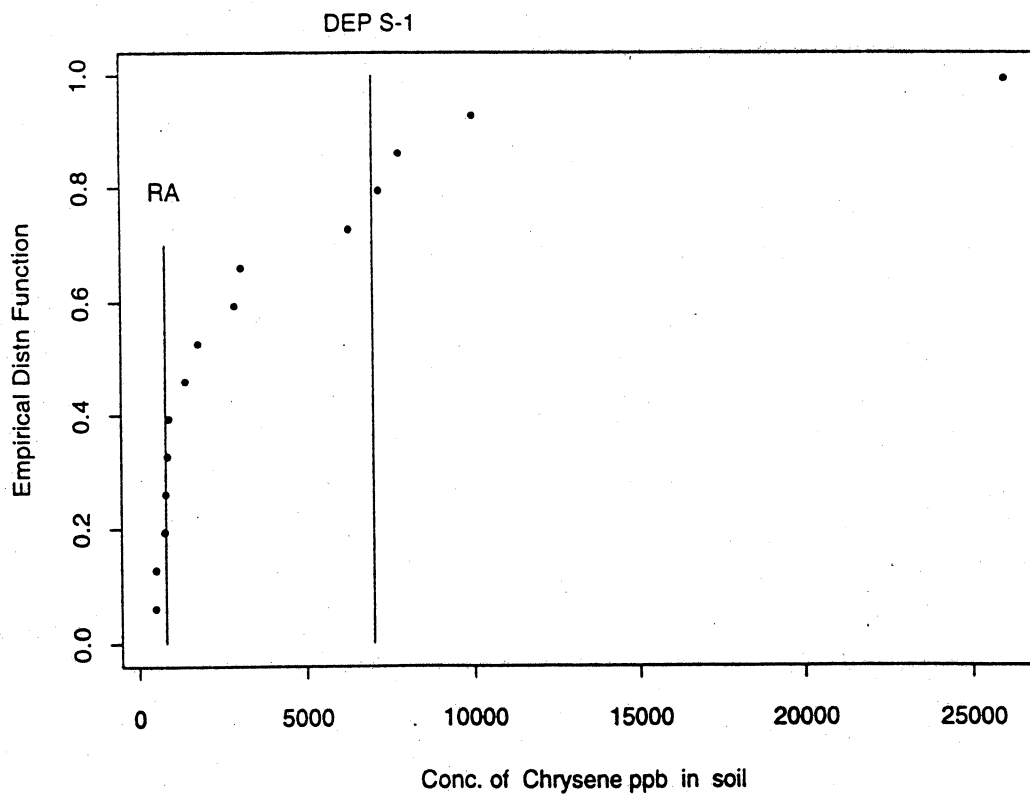


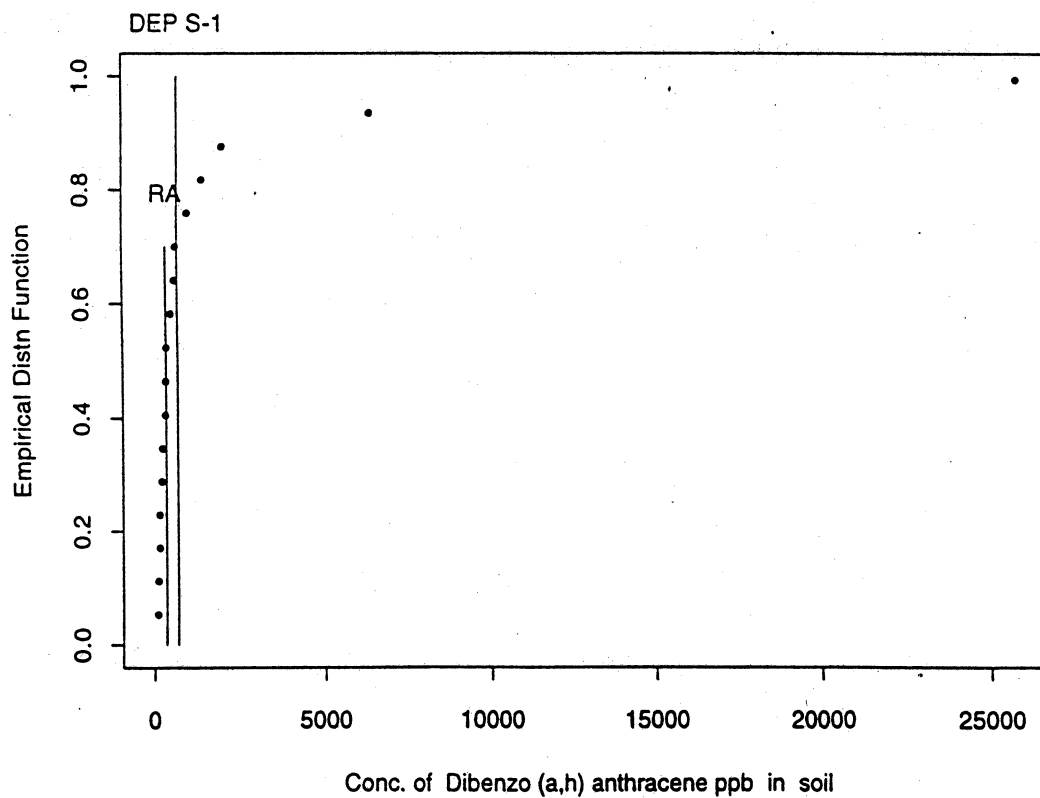
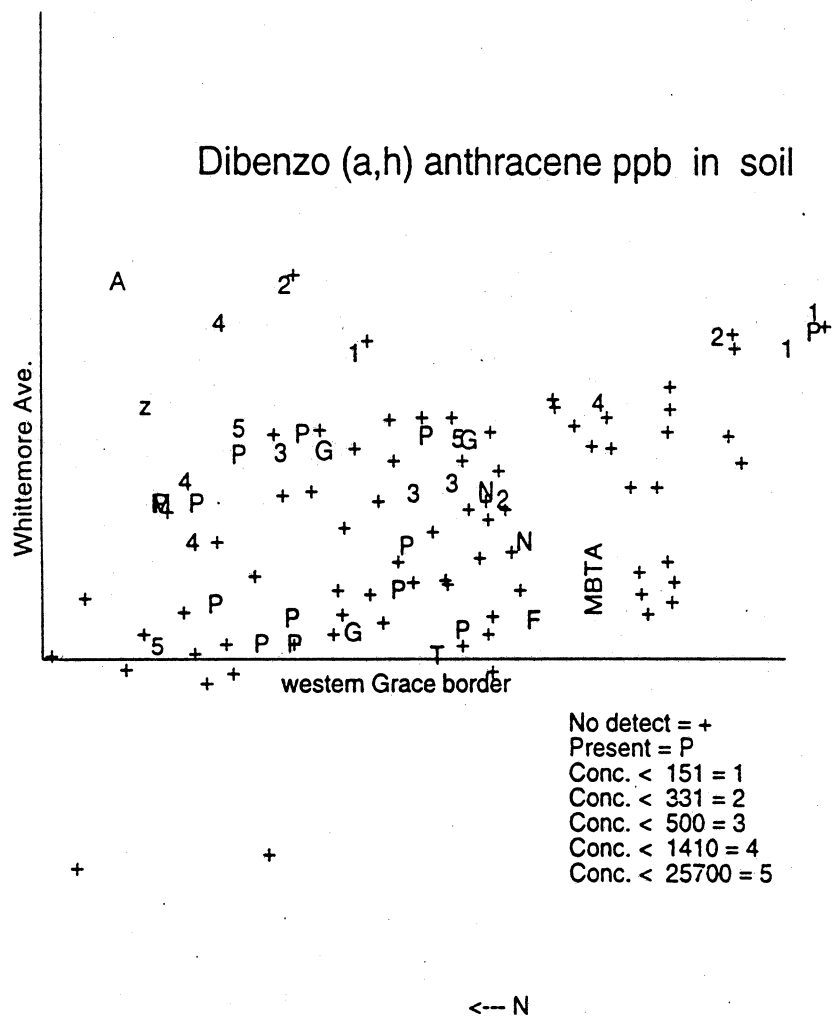


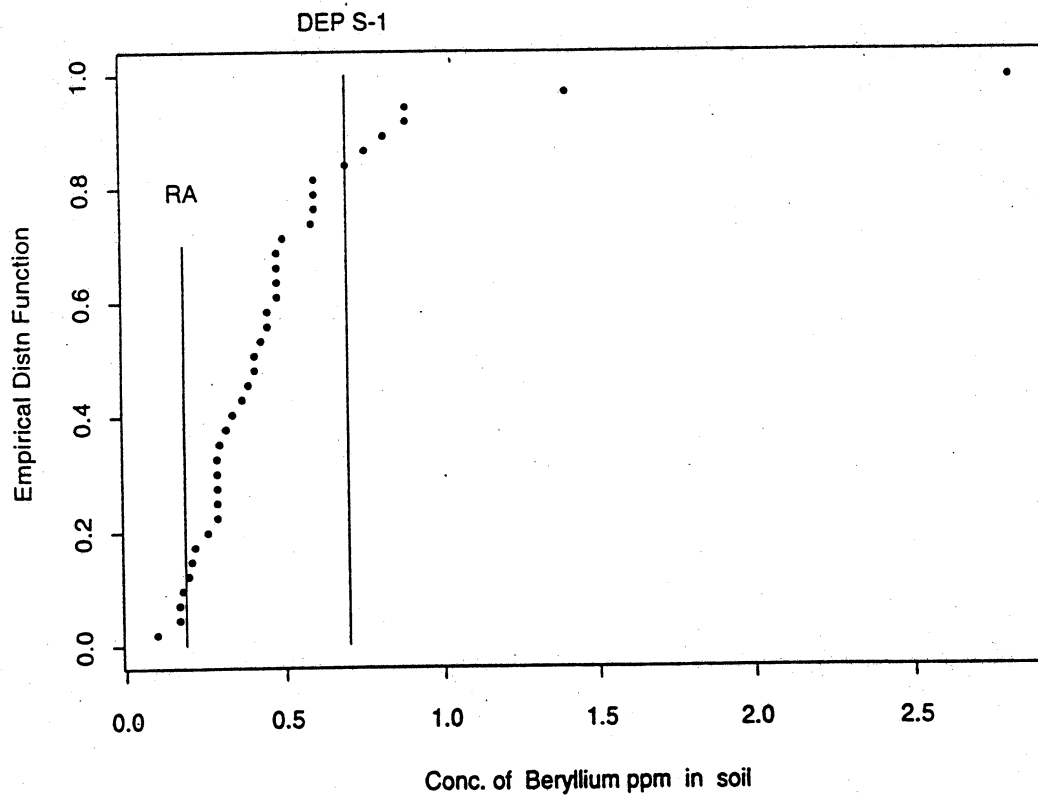
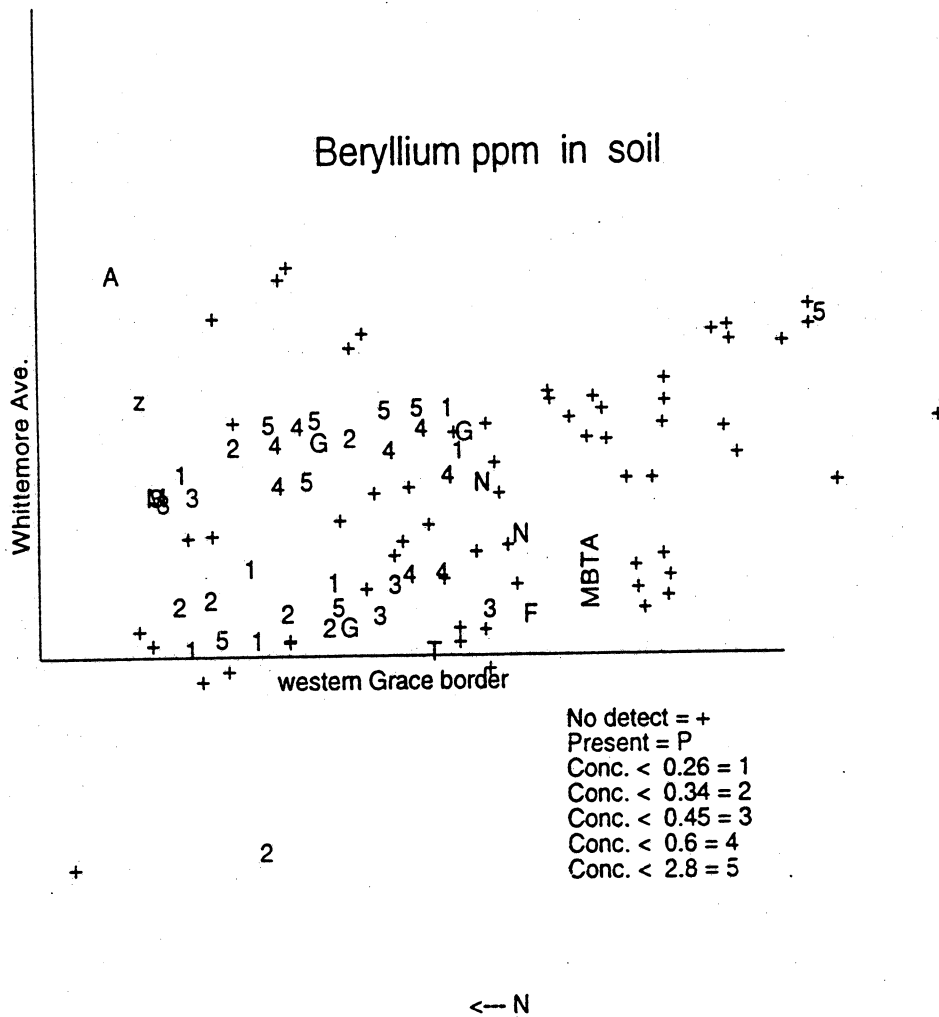


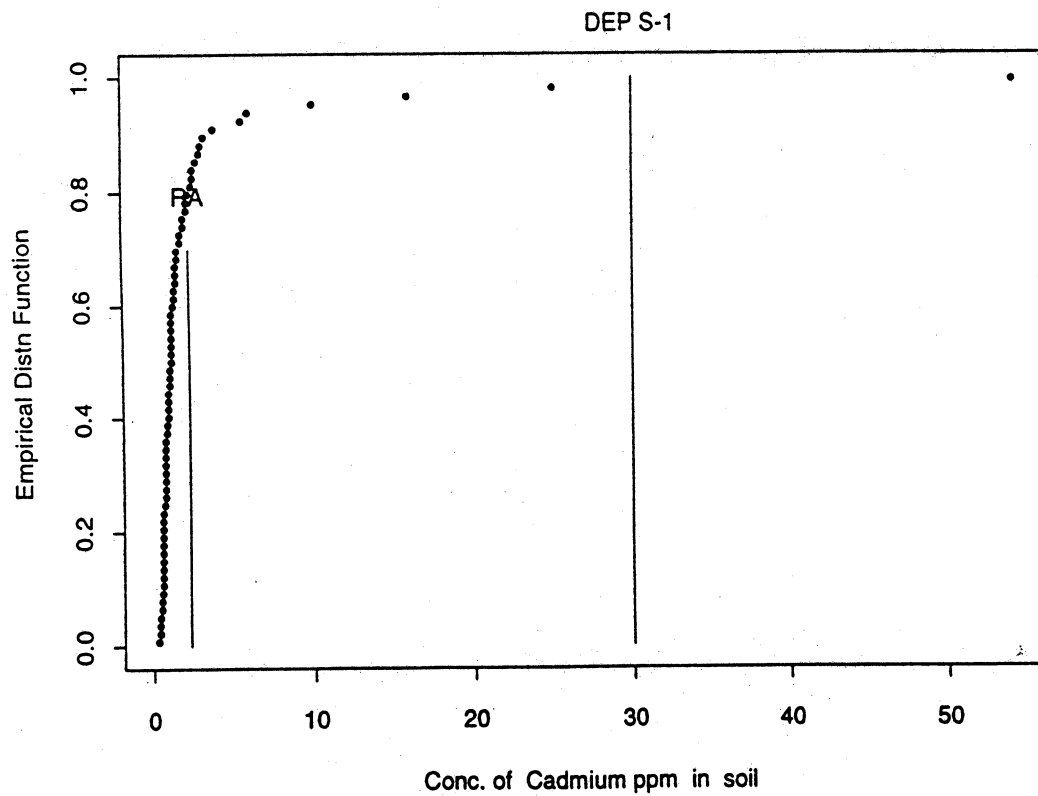
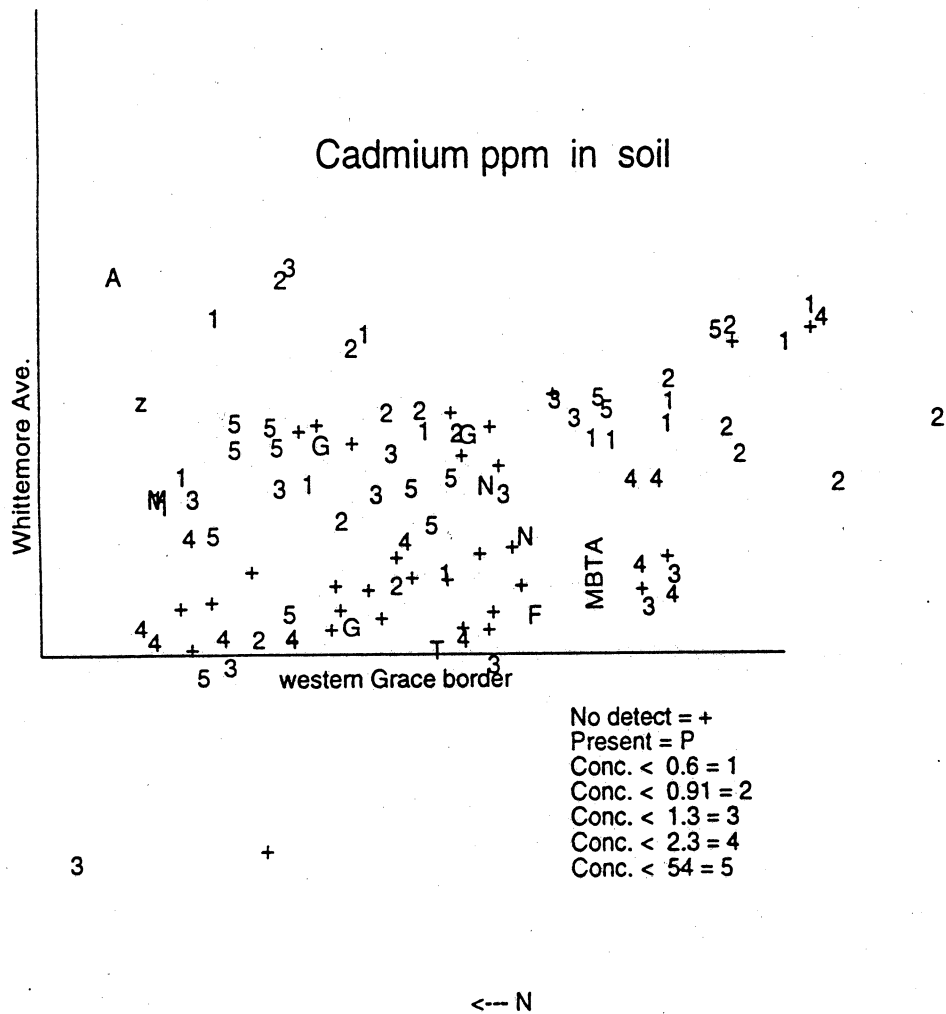


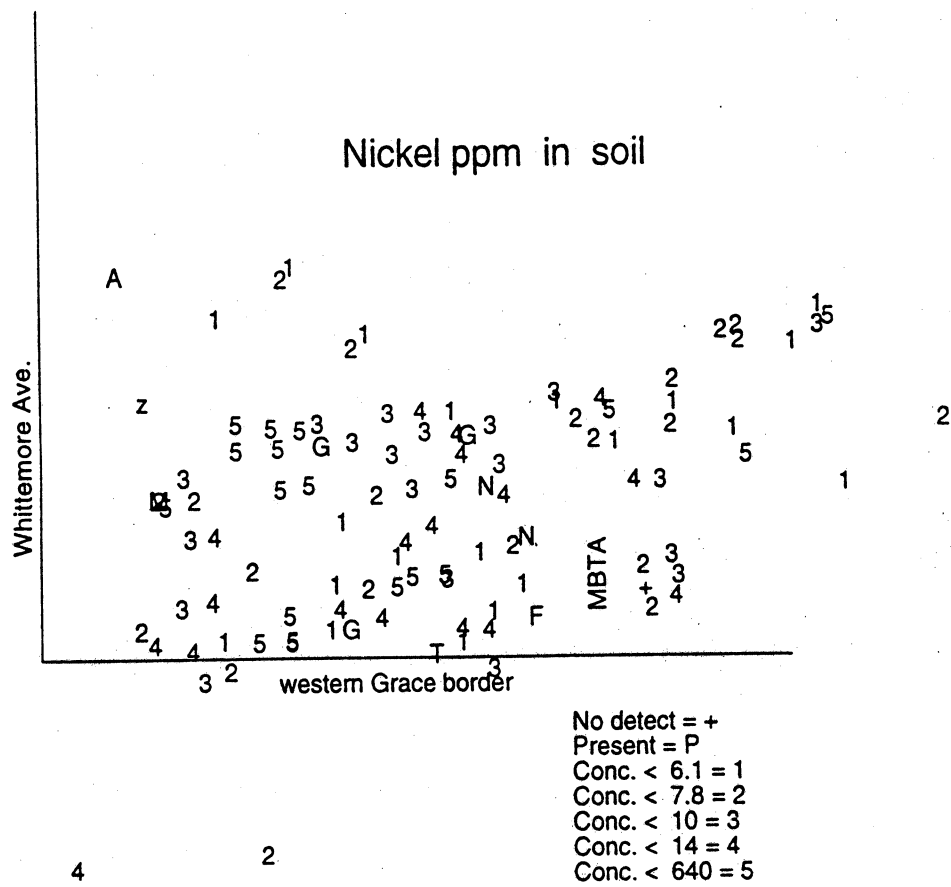
<-- N



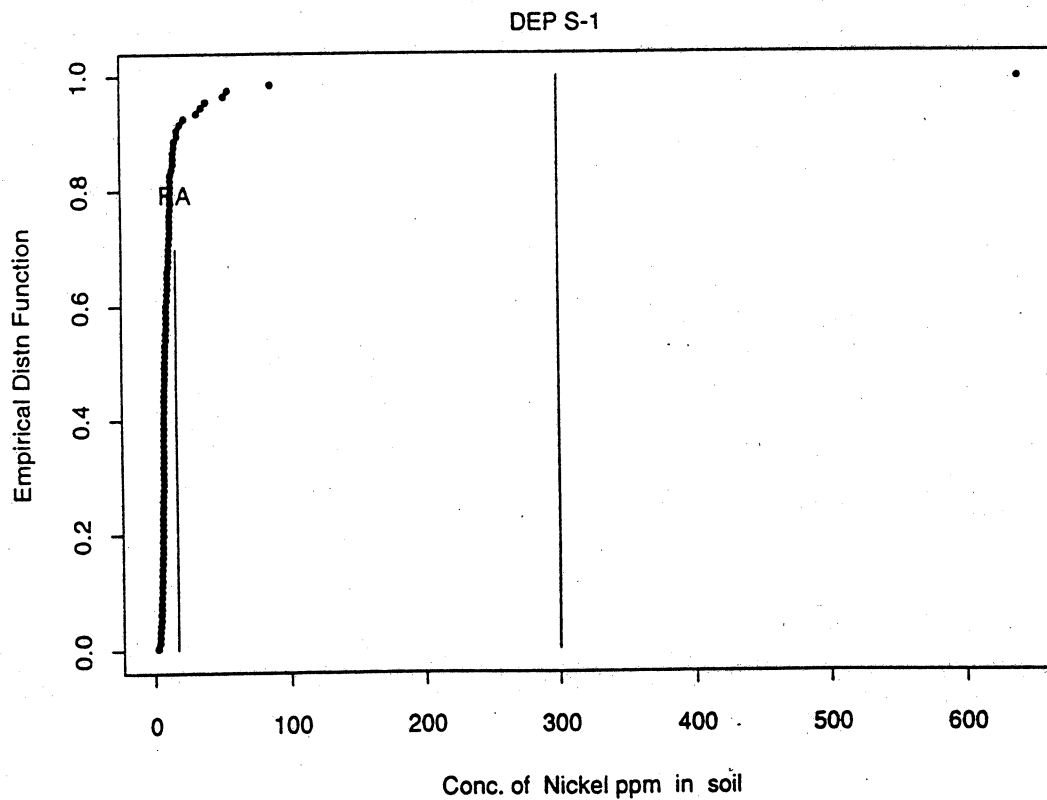


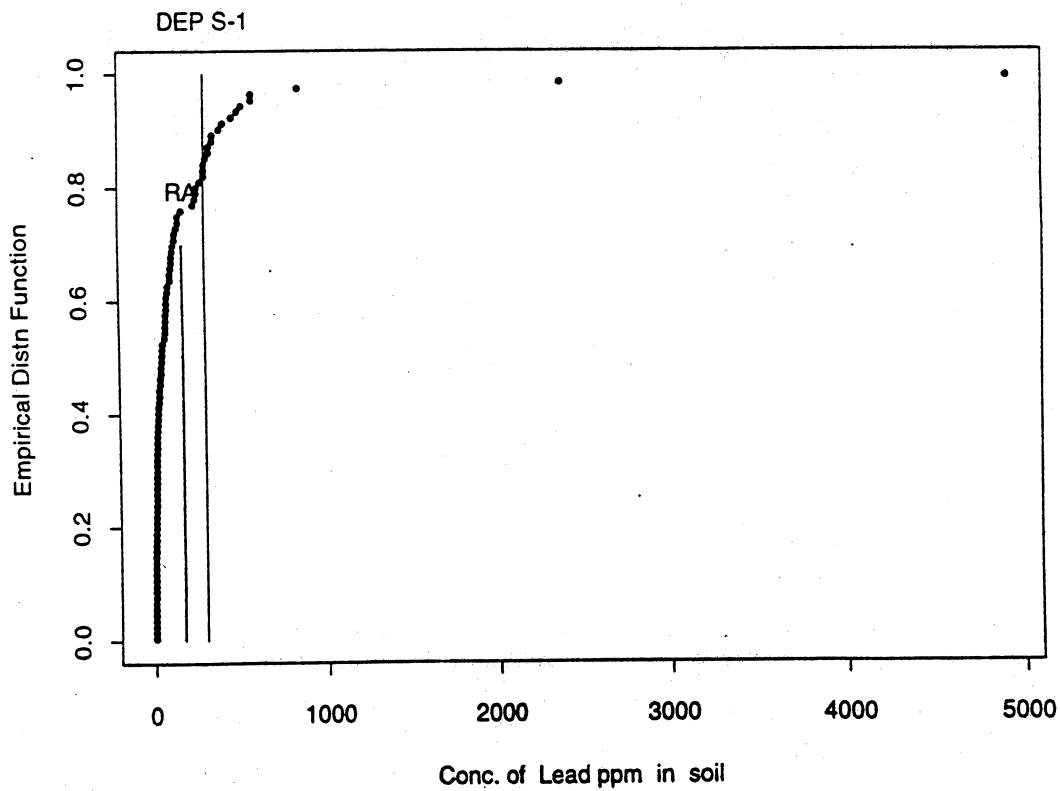
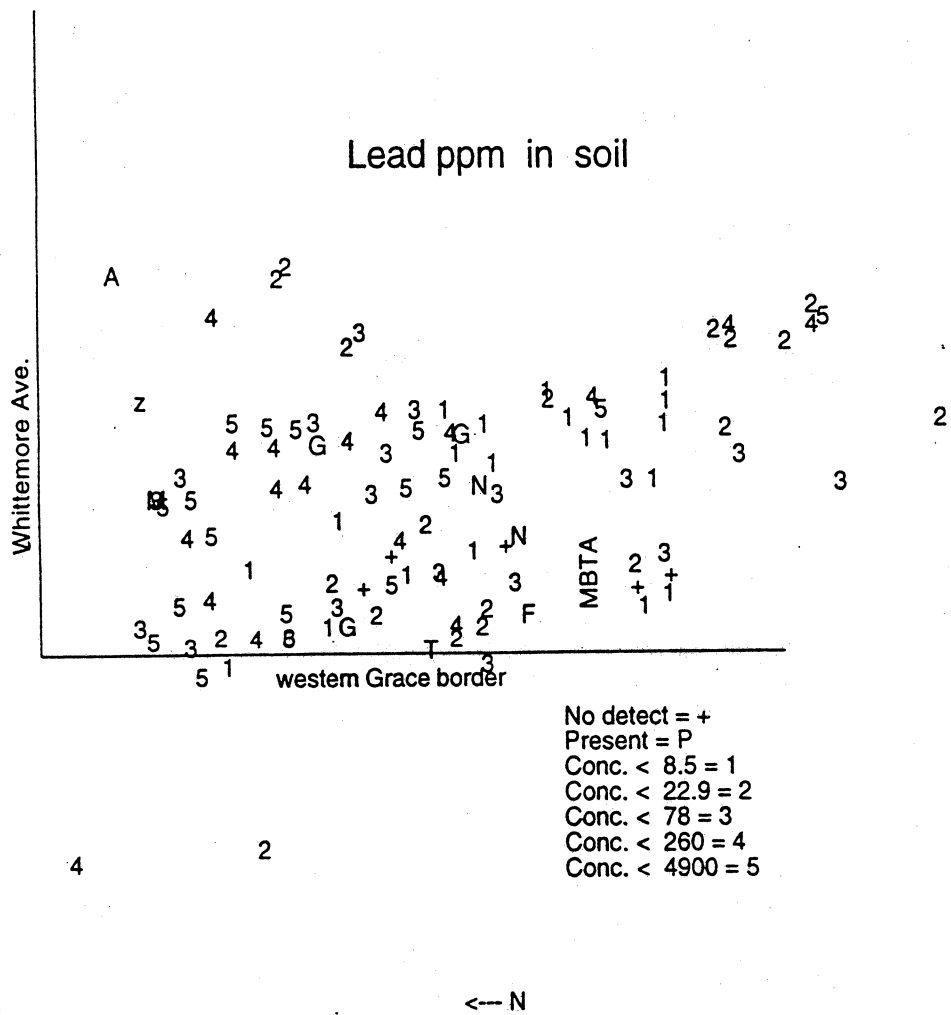


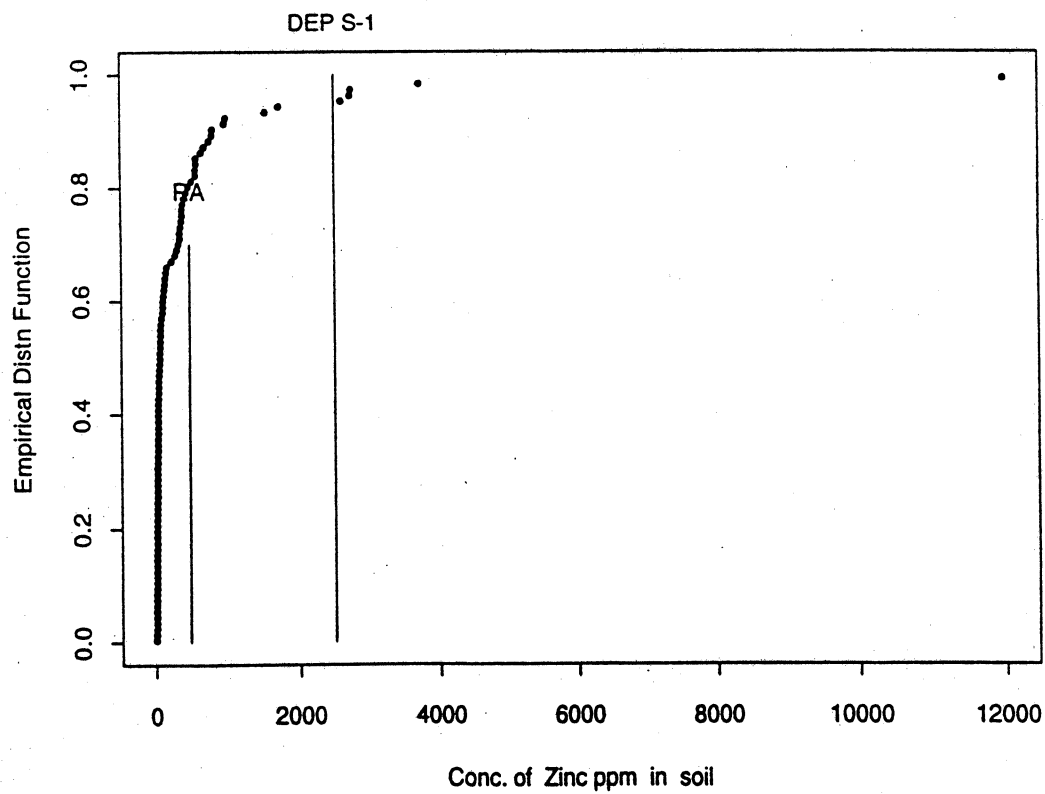
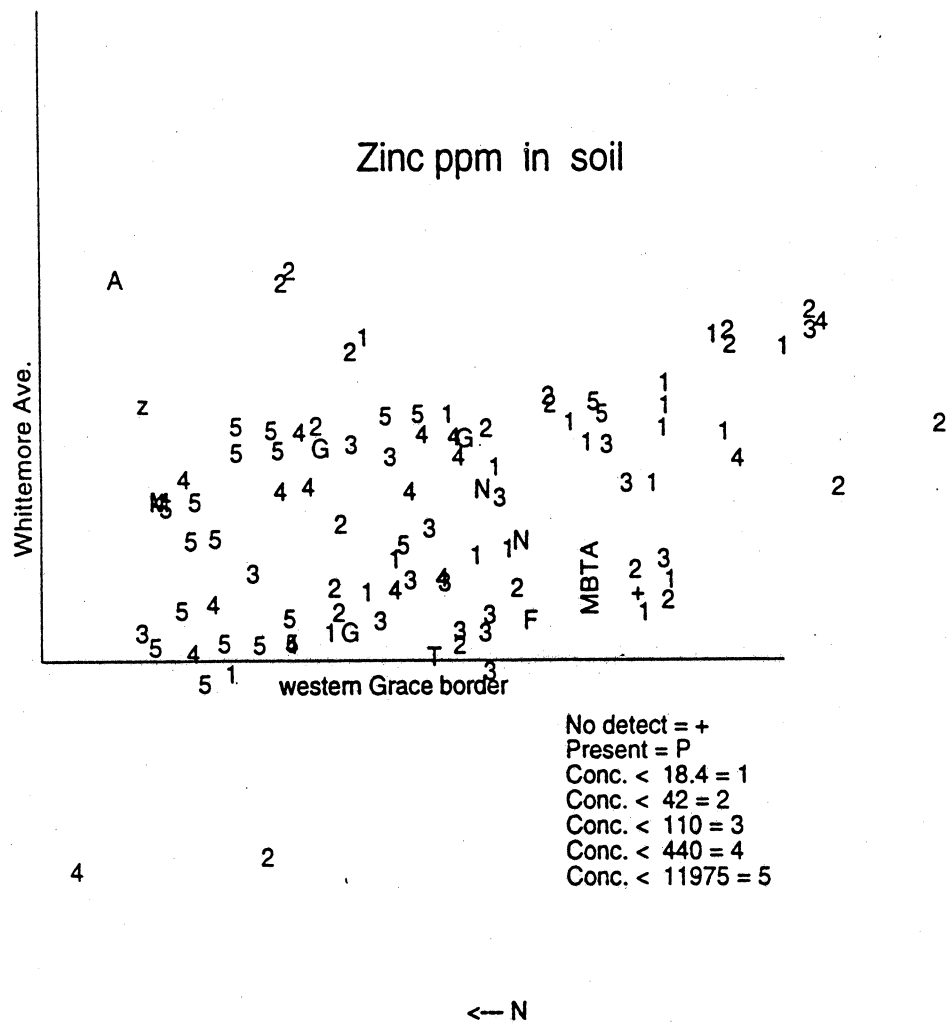


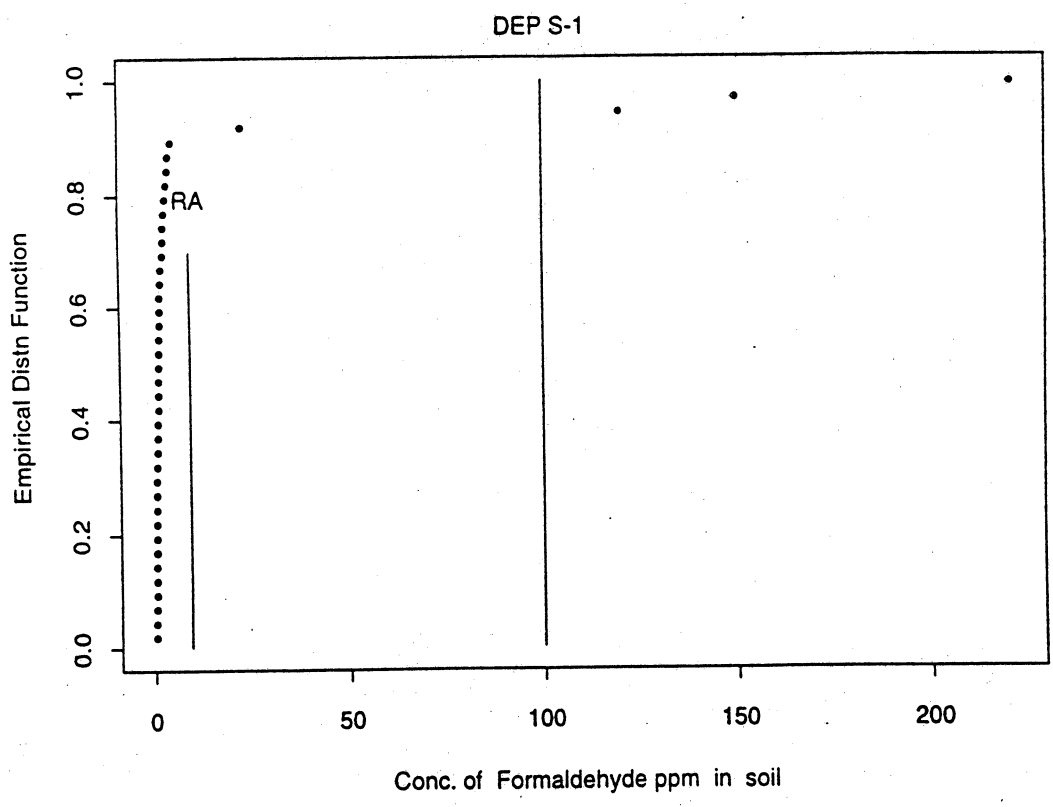
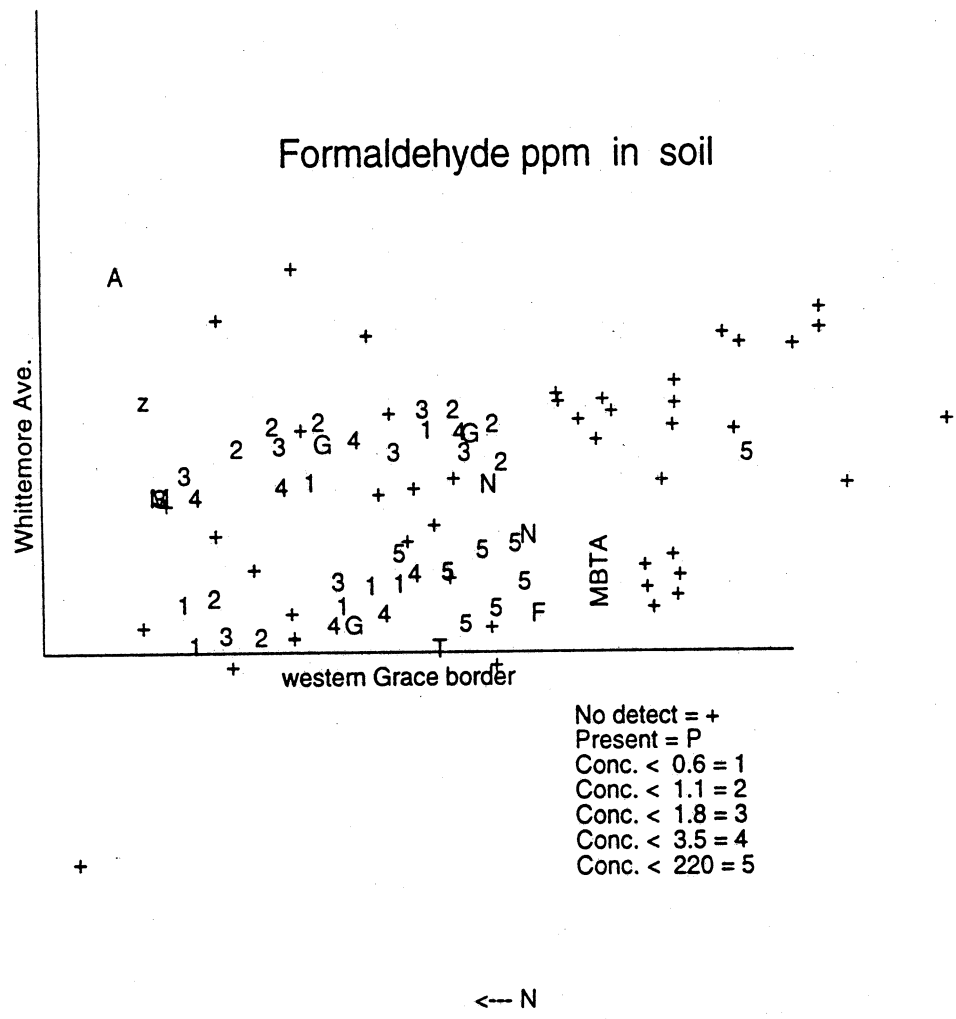


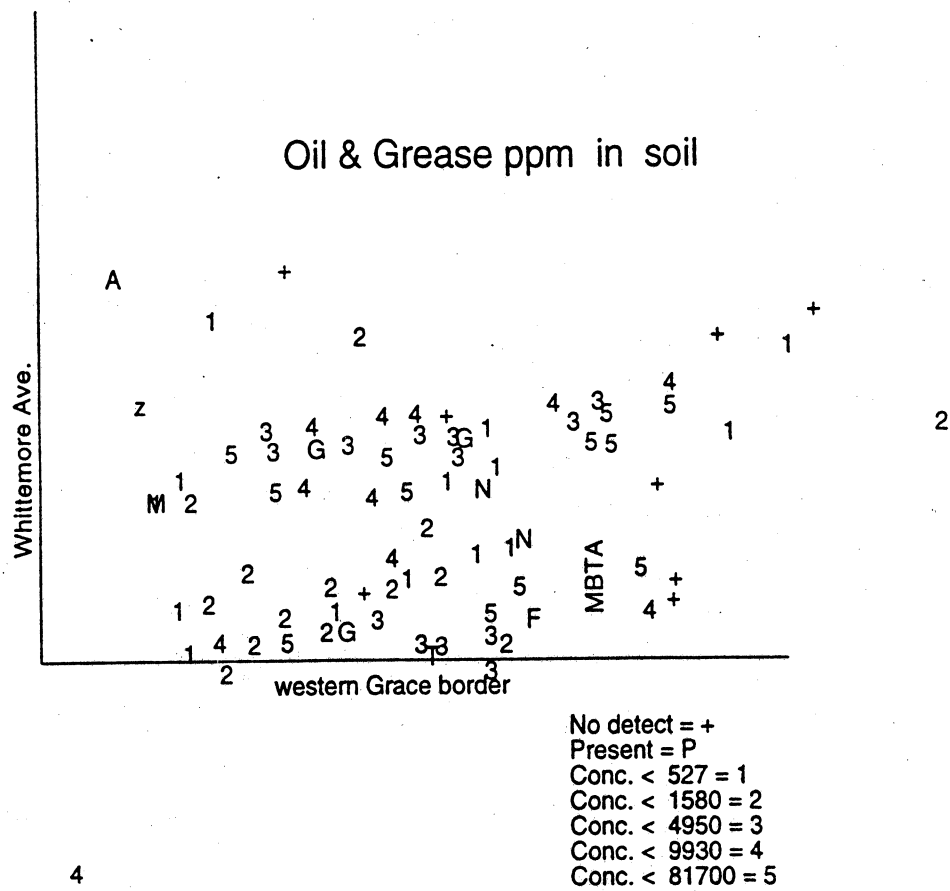
<--- N



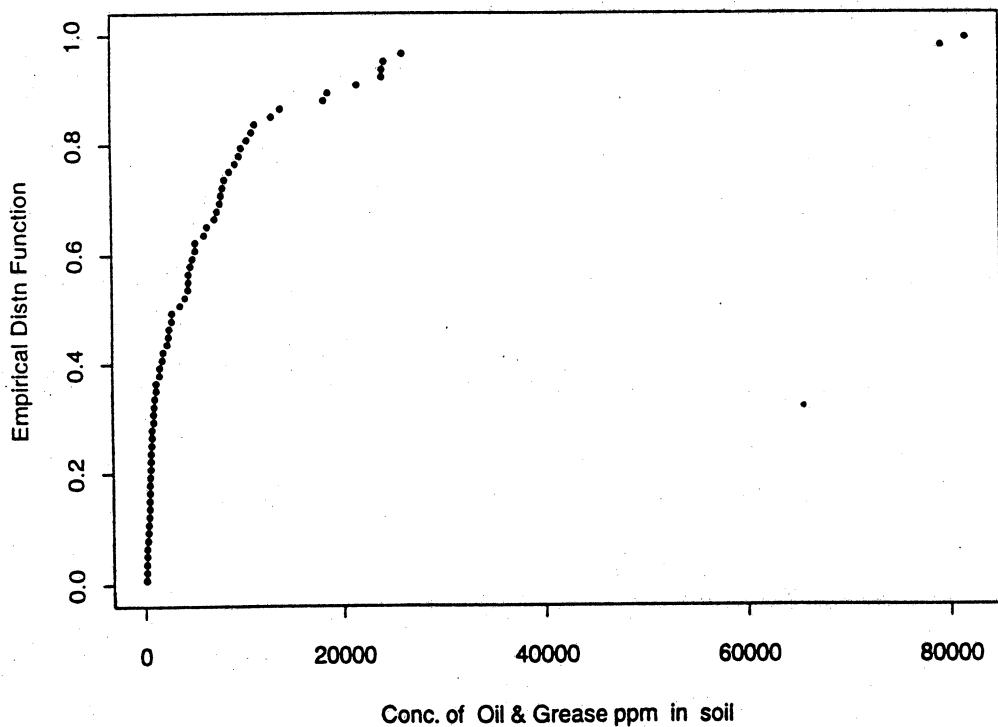




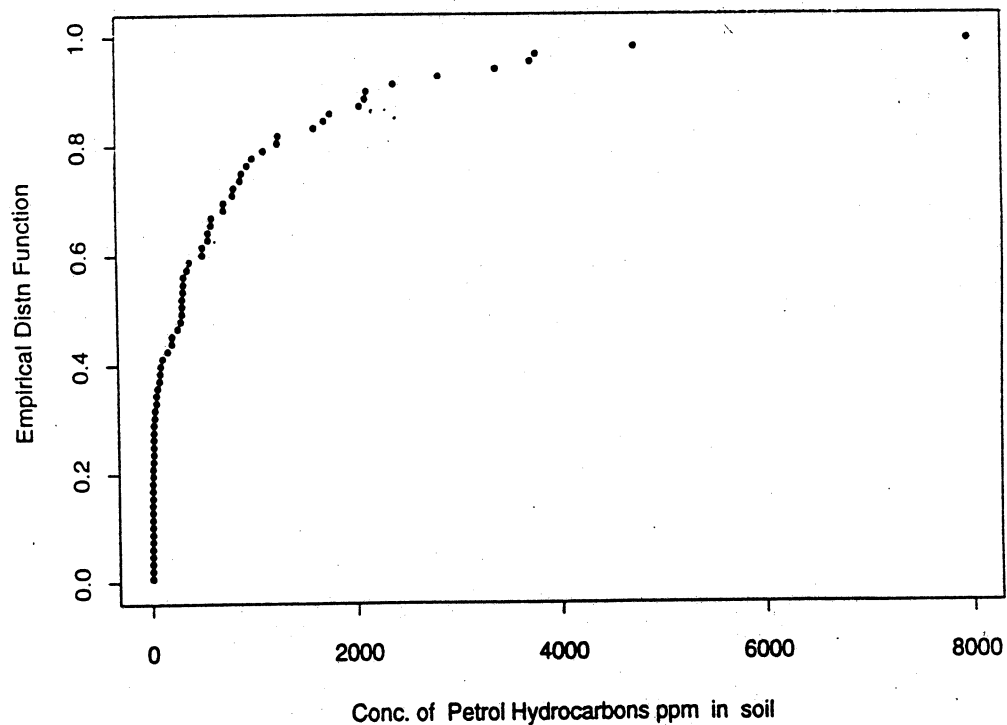
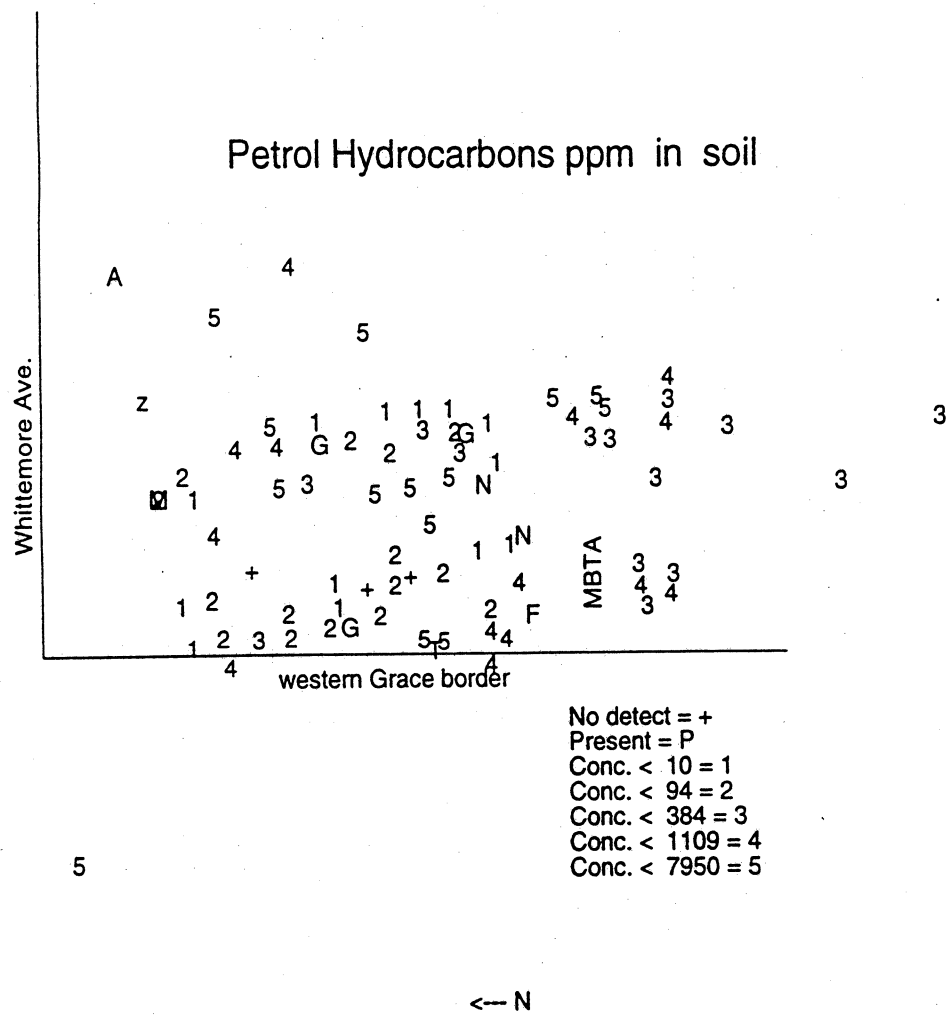




← N

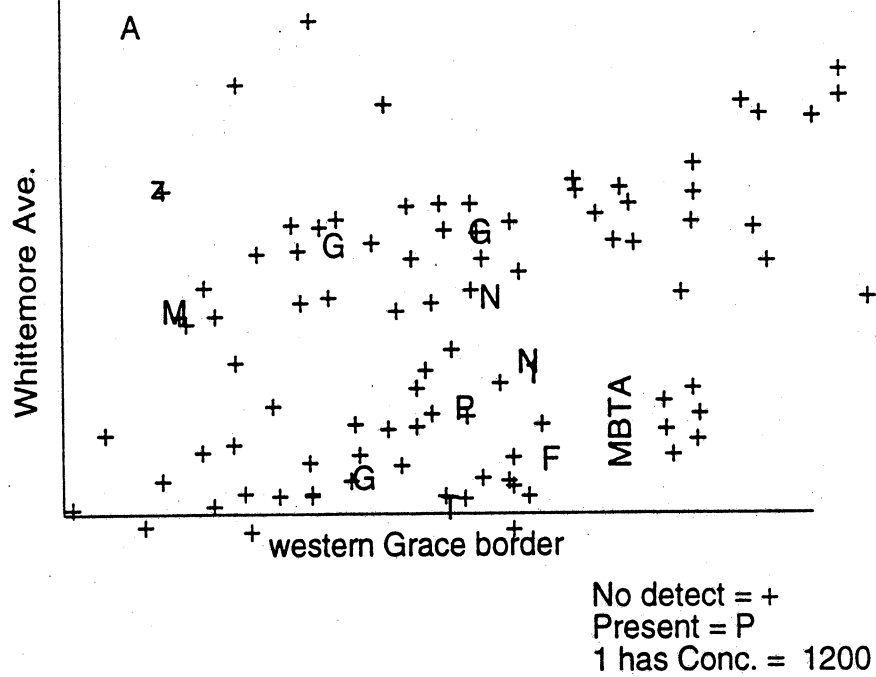


No DEP S-1 Standards. Not used in risk assessment

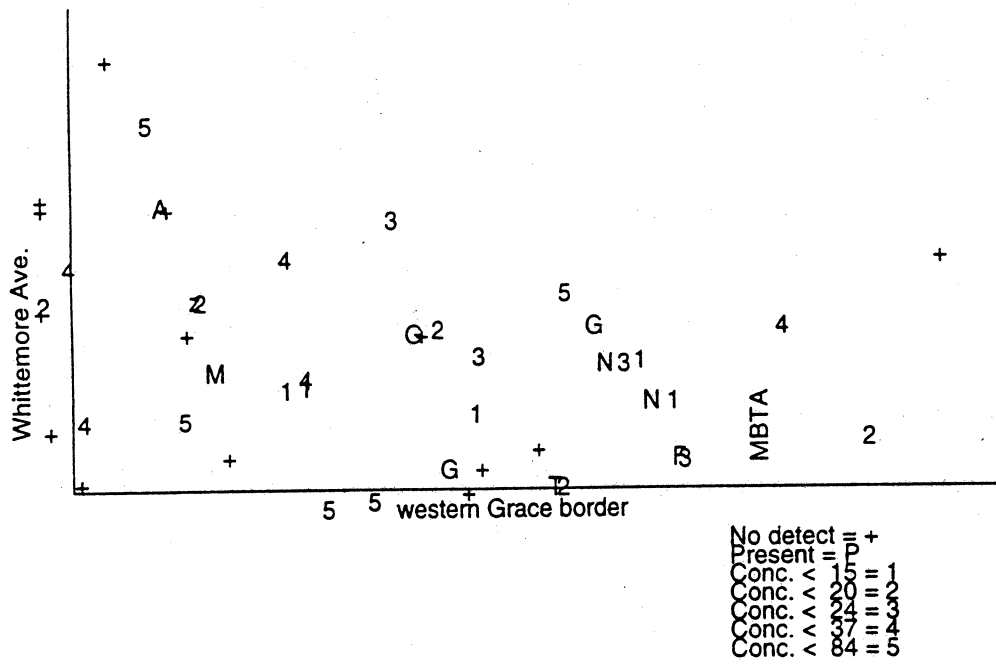


No DEP S-1 Standards. Not used in risk assessment

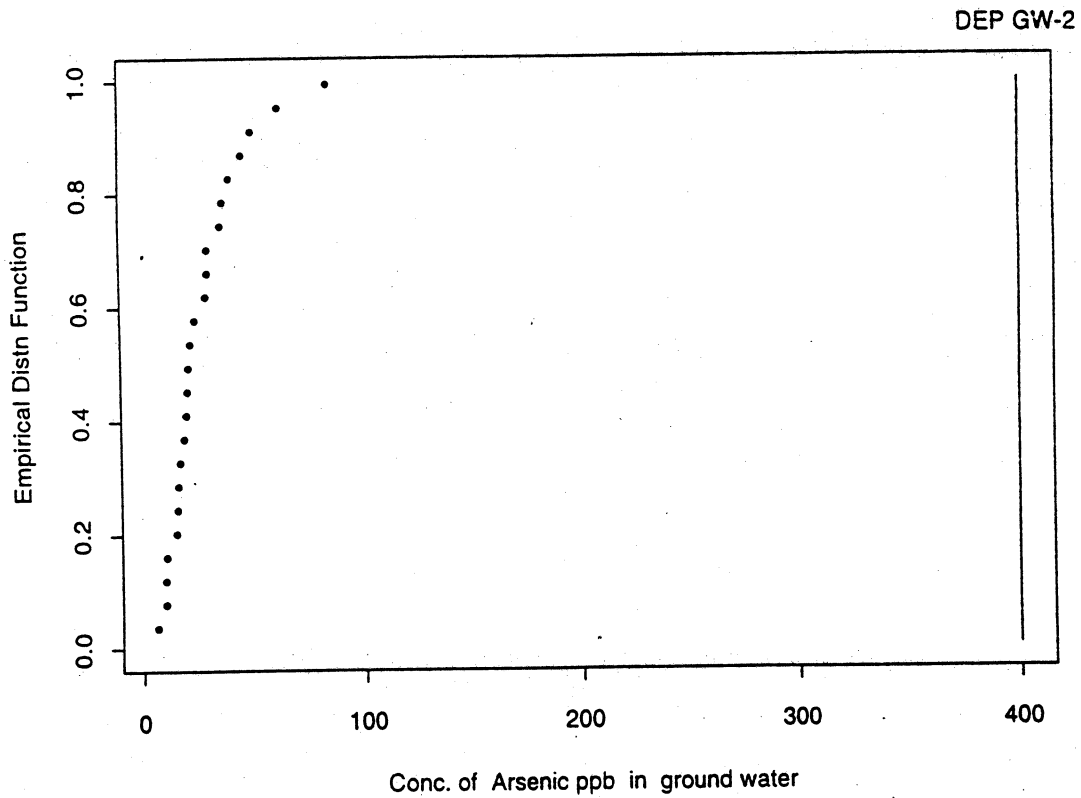
Trichloroethene ppb in soil



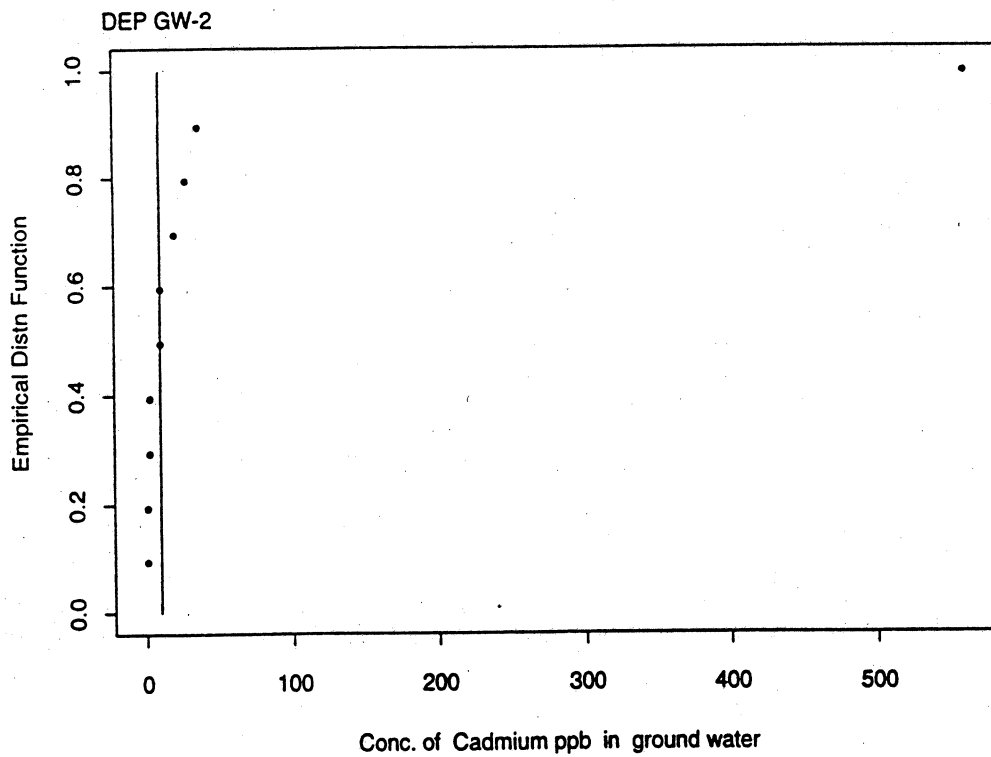
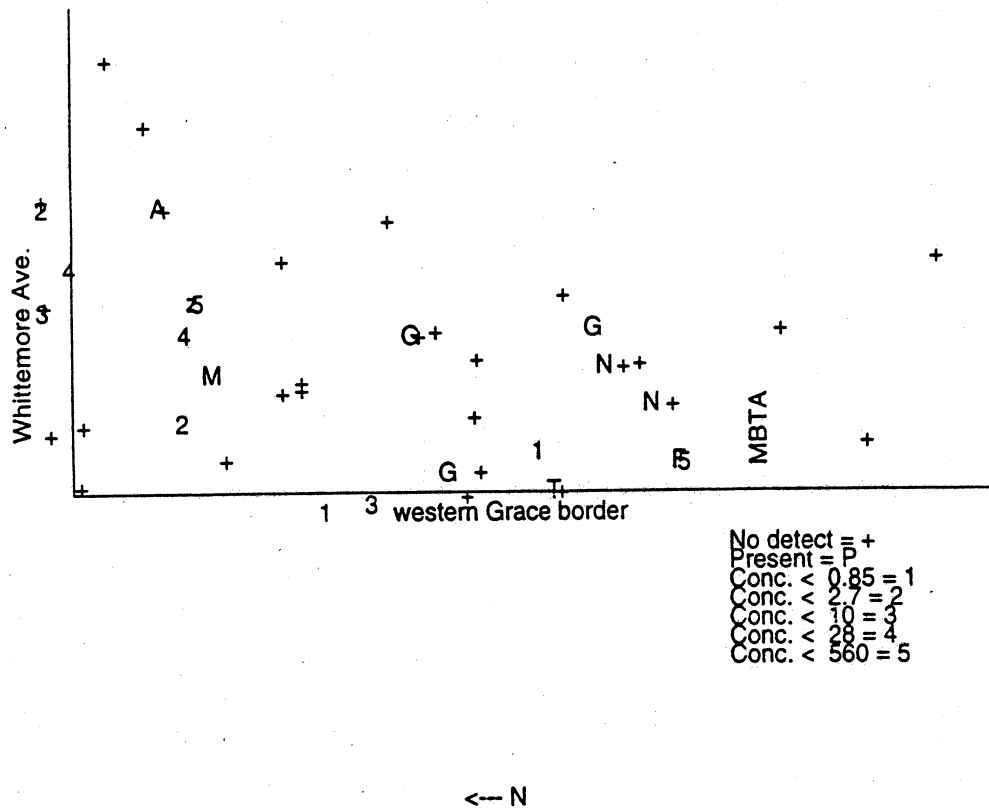
Arsenic ppb in ground water



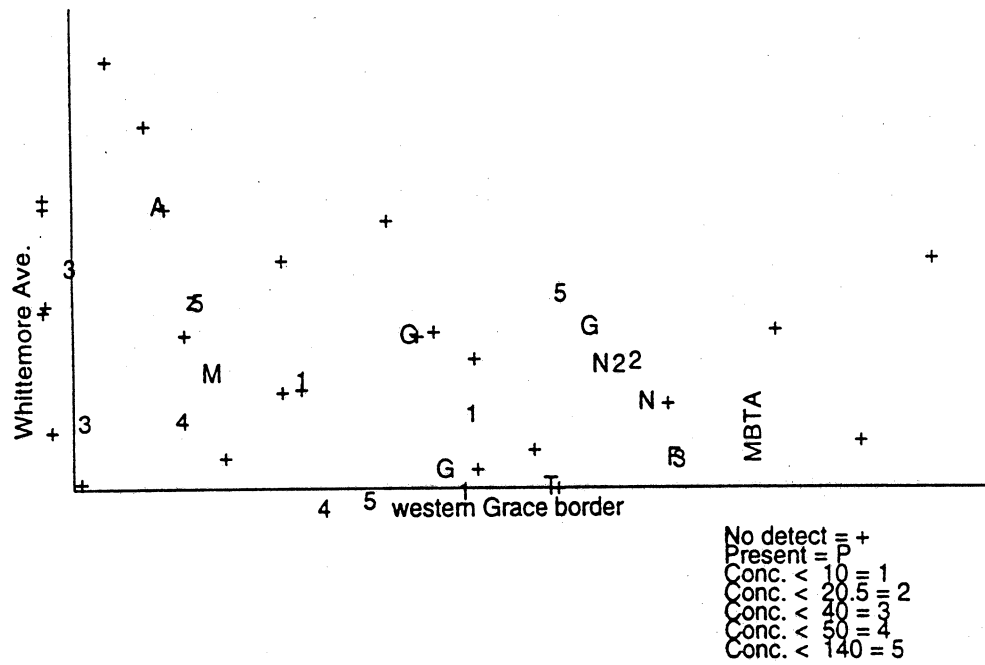
<-- N



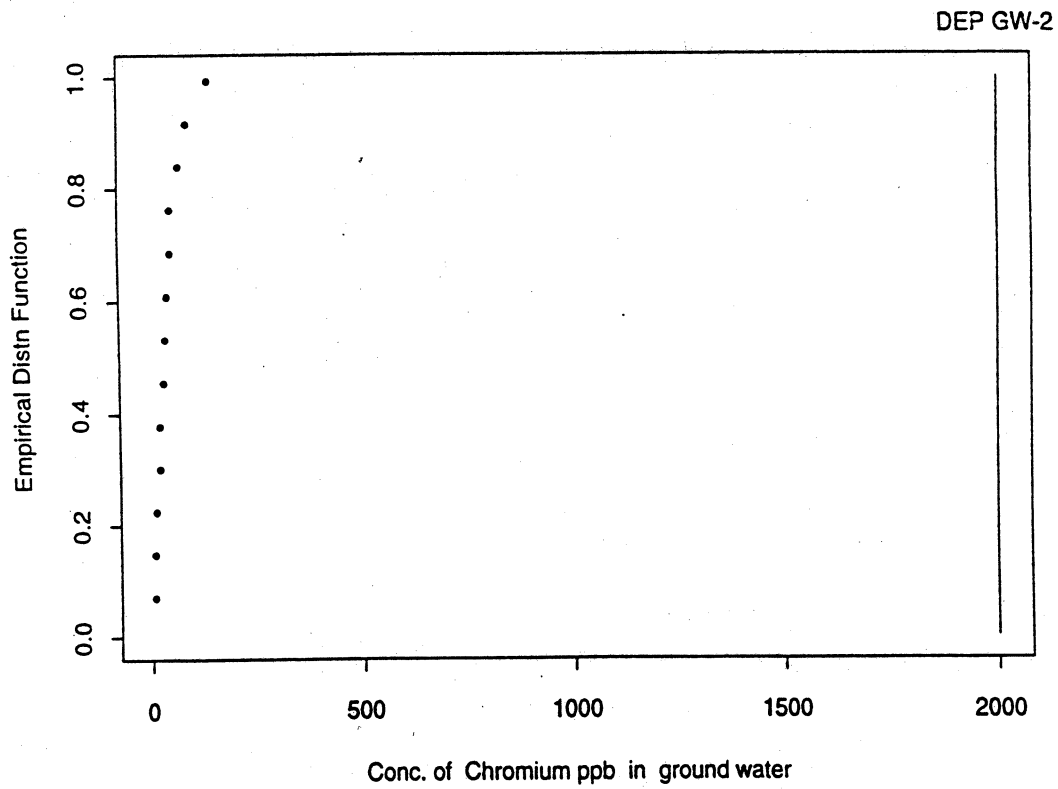
Cadmium ppb in ground water



Chromium ppb in ground water



← N



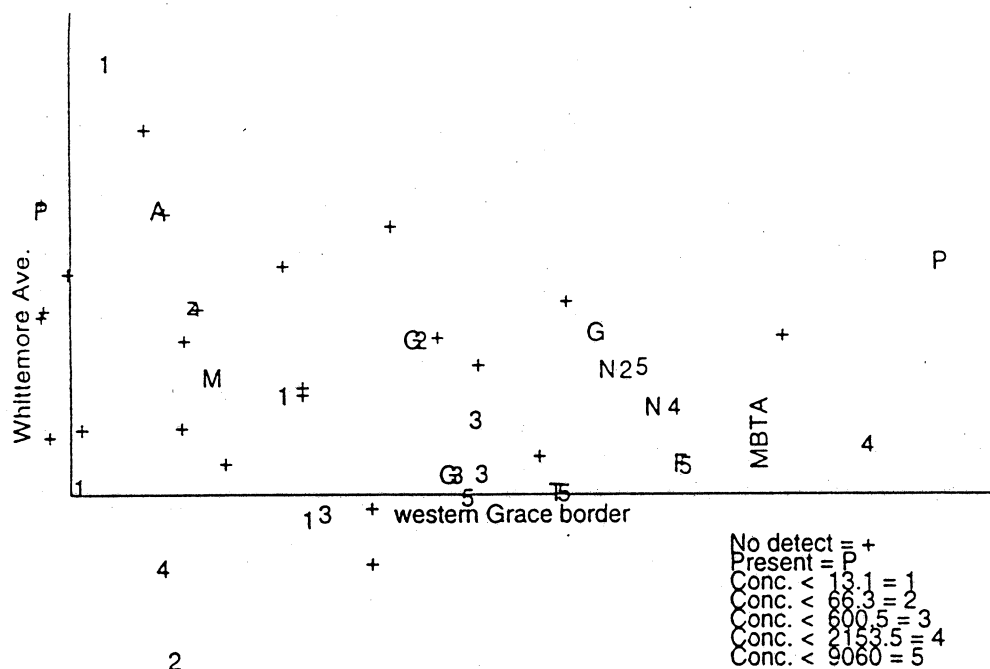
Whittemore Ave.

western Grace border

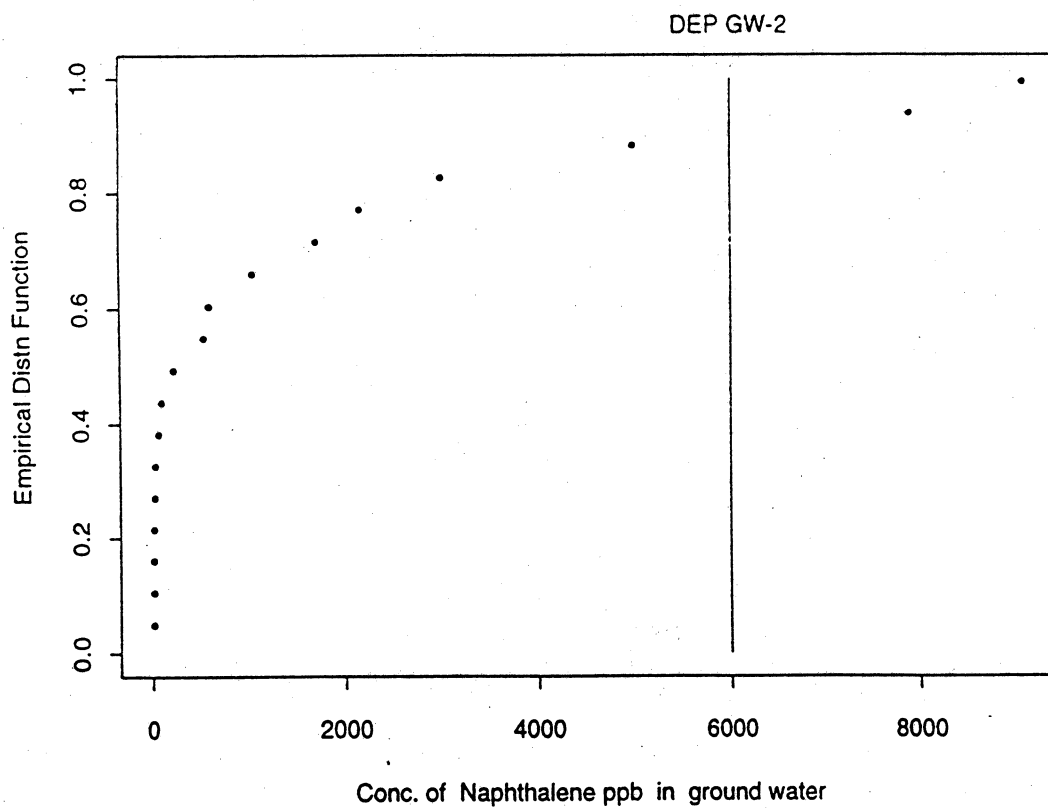
Legend:

- No detect = +
- present = p
- Conc. < 10 = 1
- Conc. < 20 = 2
- Conc. < 30 = 3
- Conc. < 40 = 4
- Conc. < 180 = 5

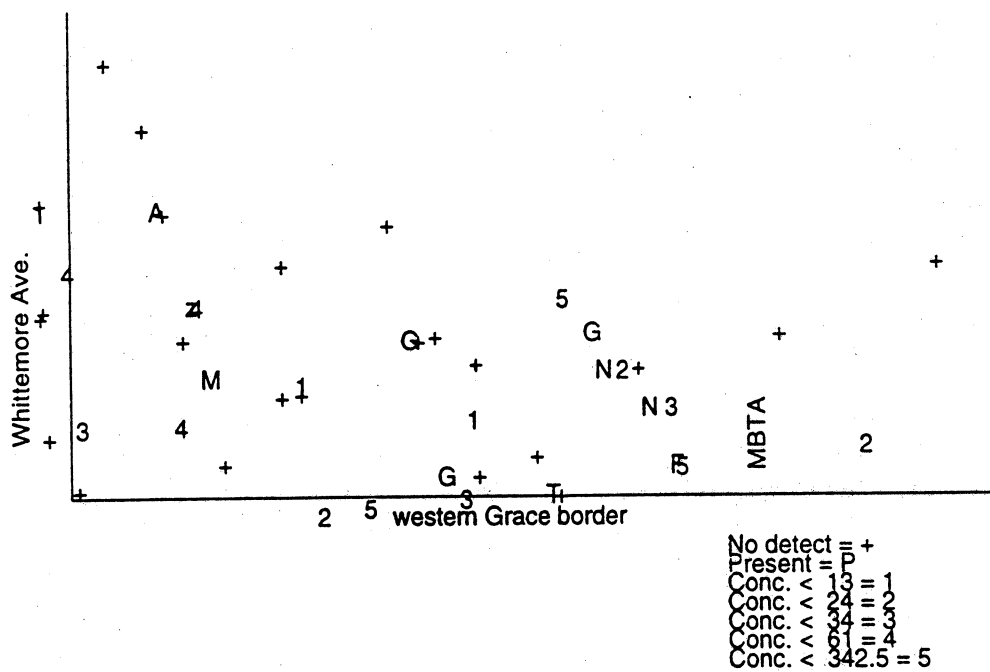
Naphthalene ppb in ground water



← N

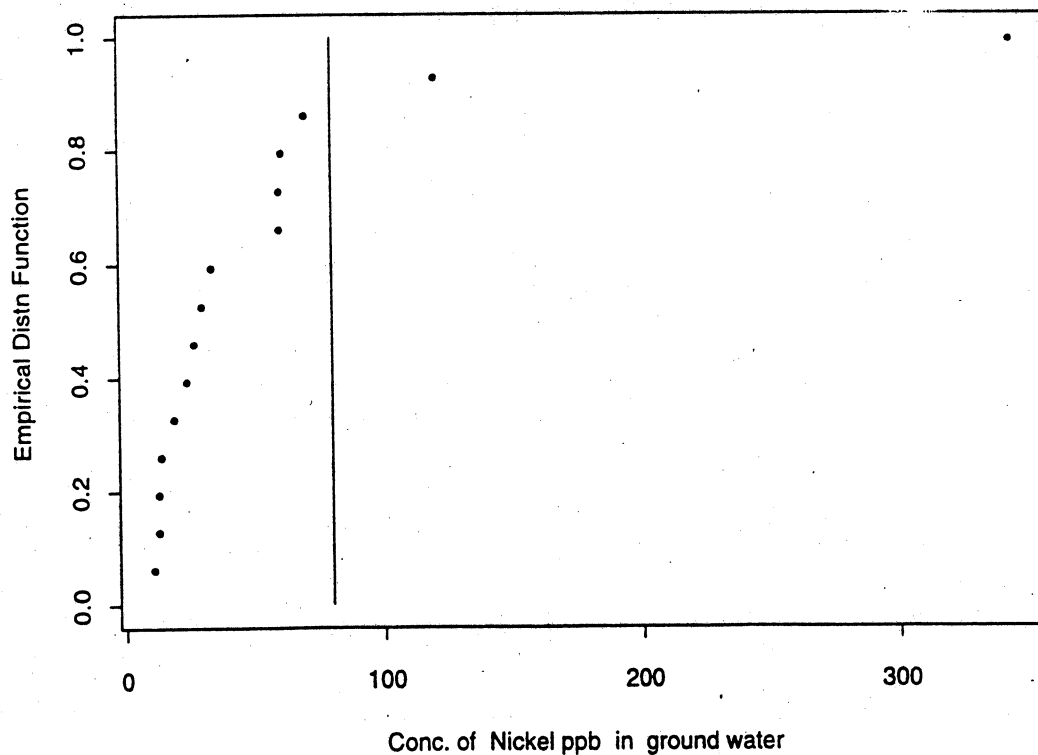


Nickel ppb in ground water

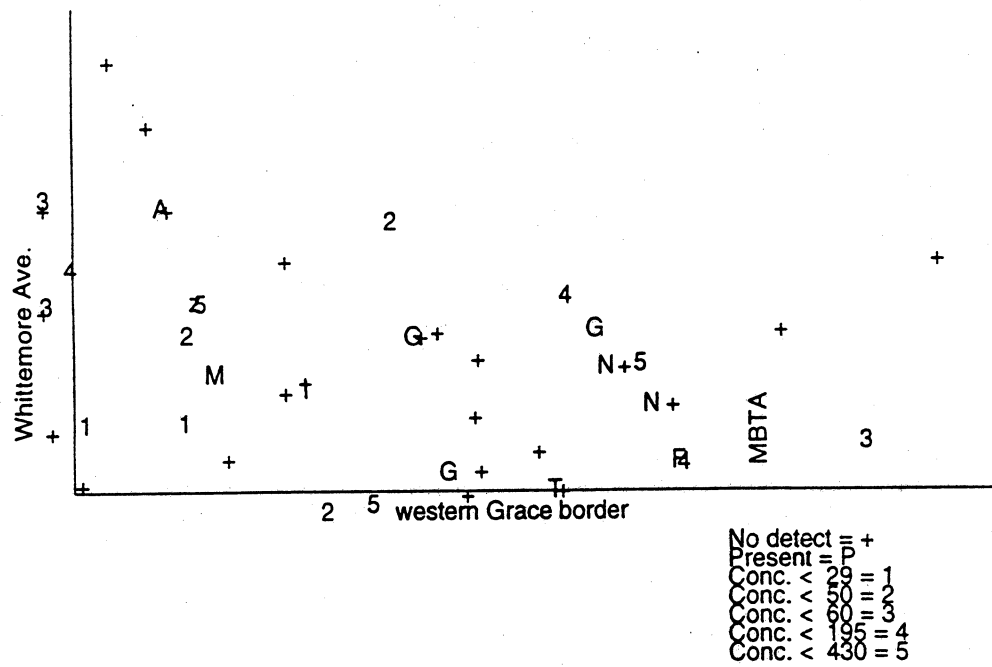


<-- N

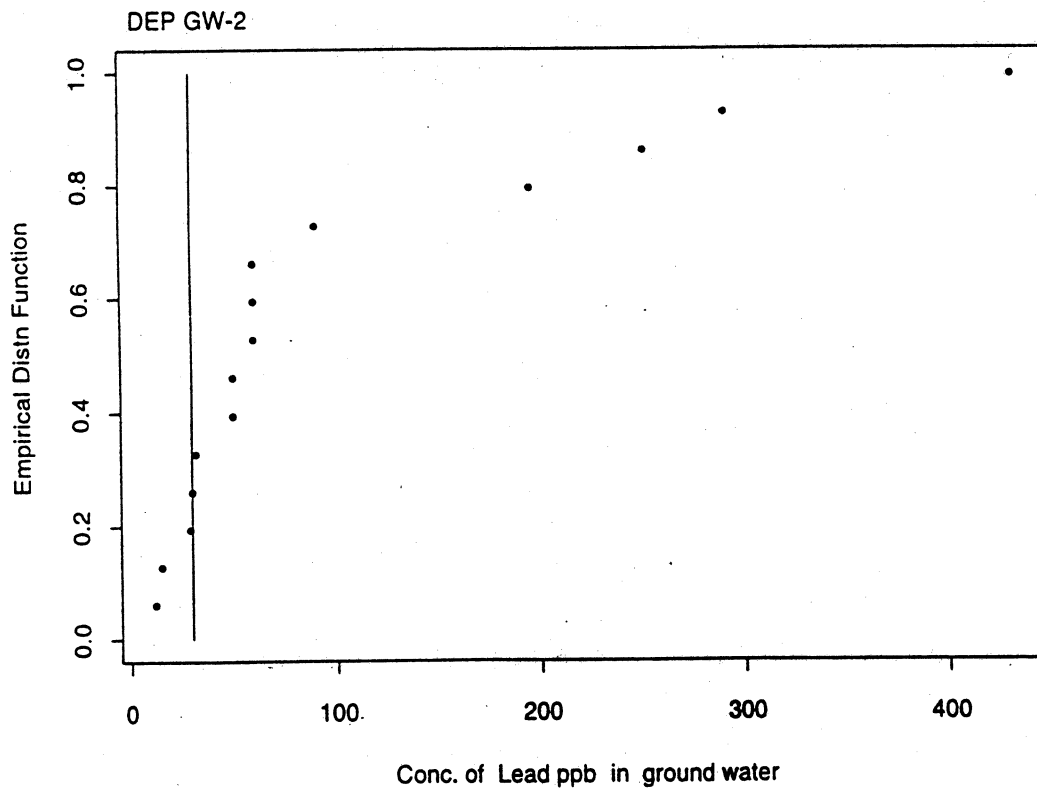
DEP GW-2



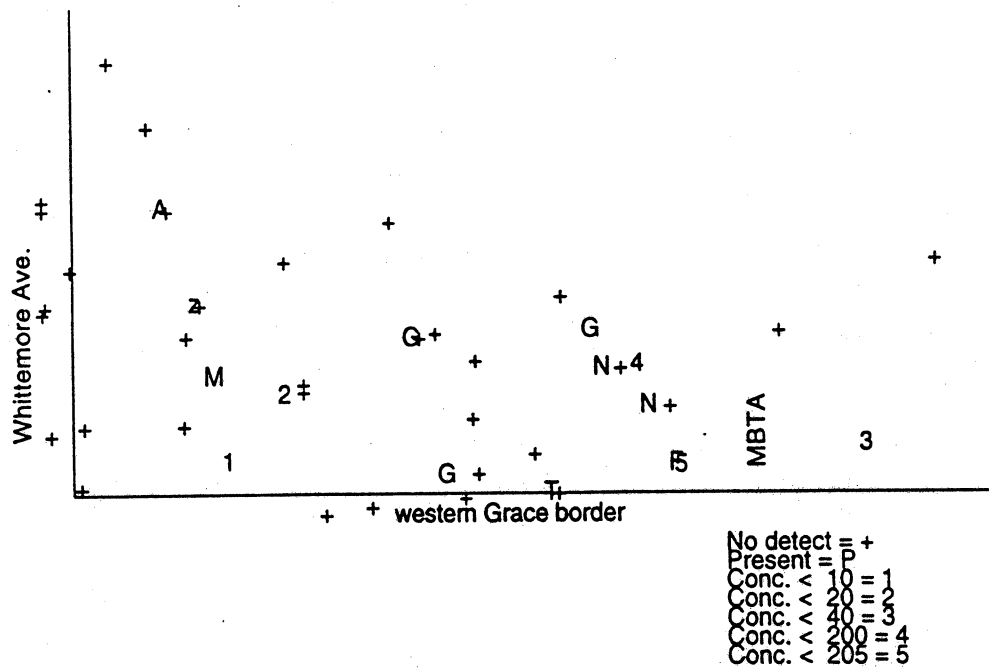
Lead ppb in ground water



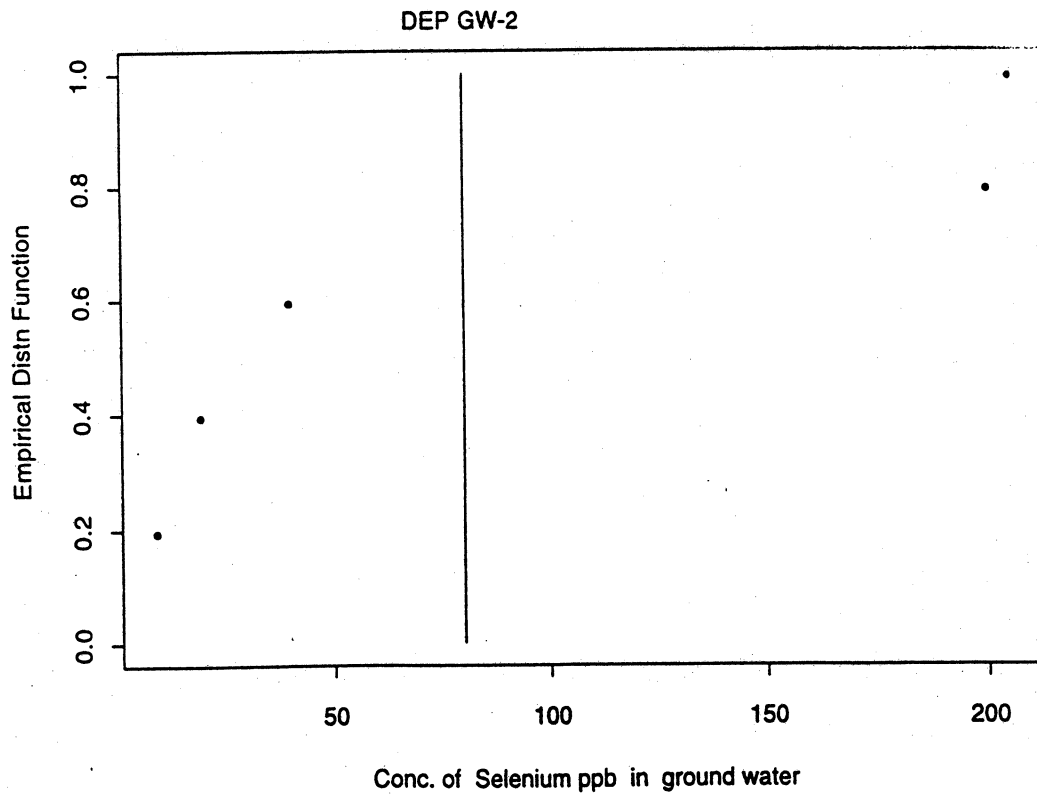
← N



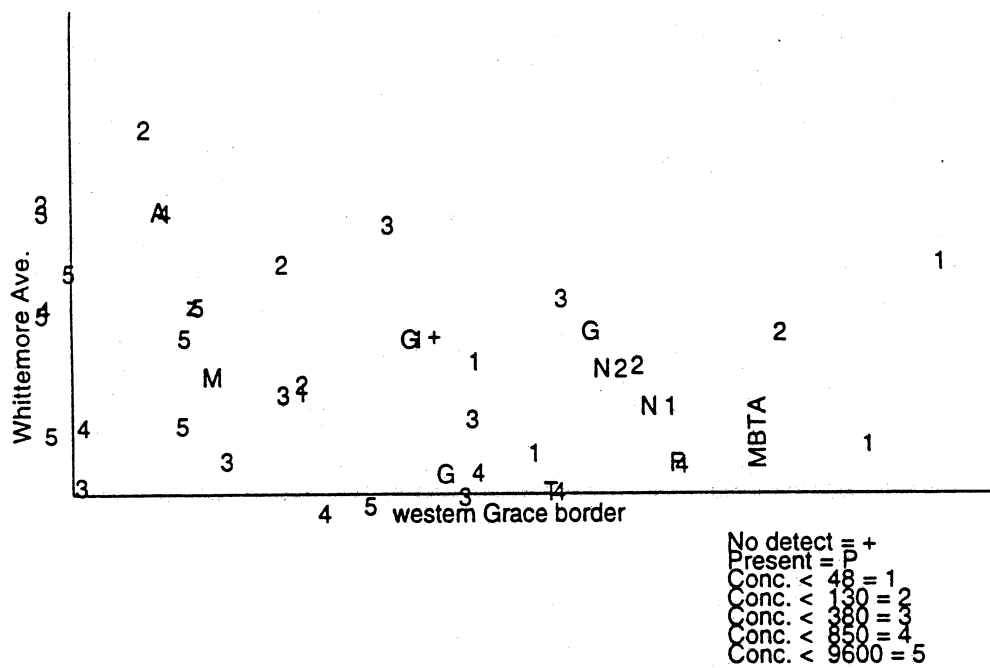
Selenium ppb in ground water



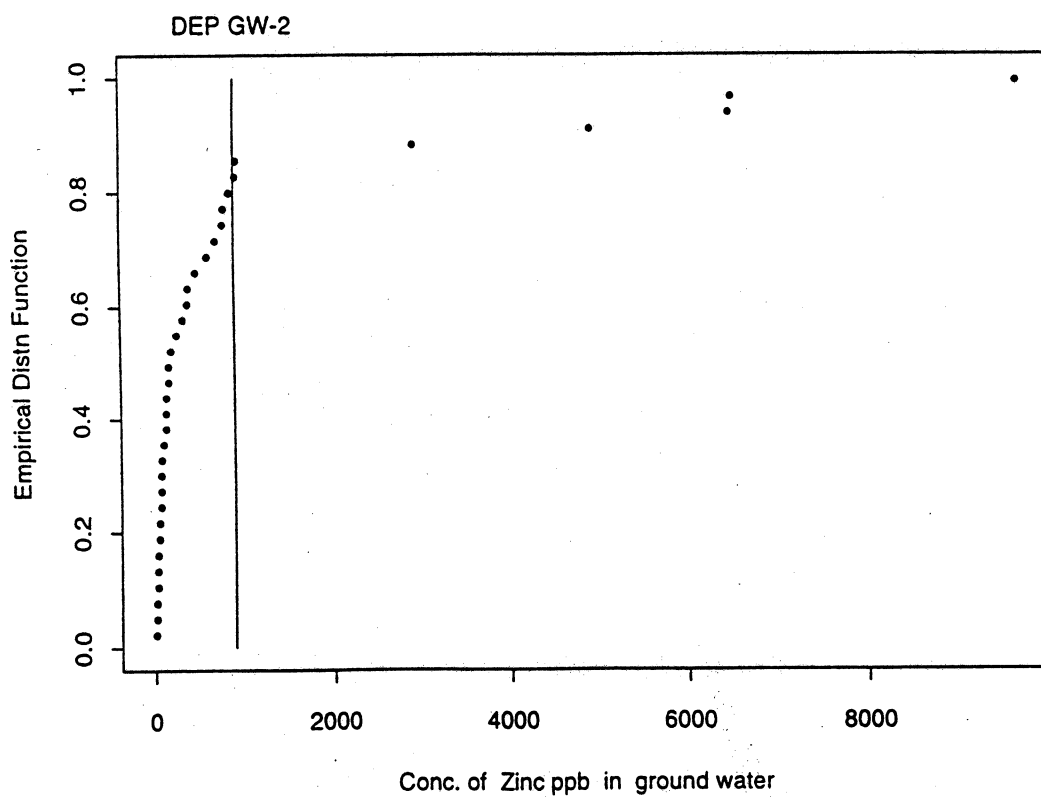
← N



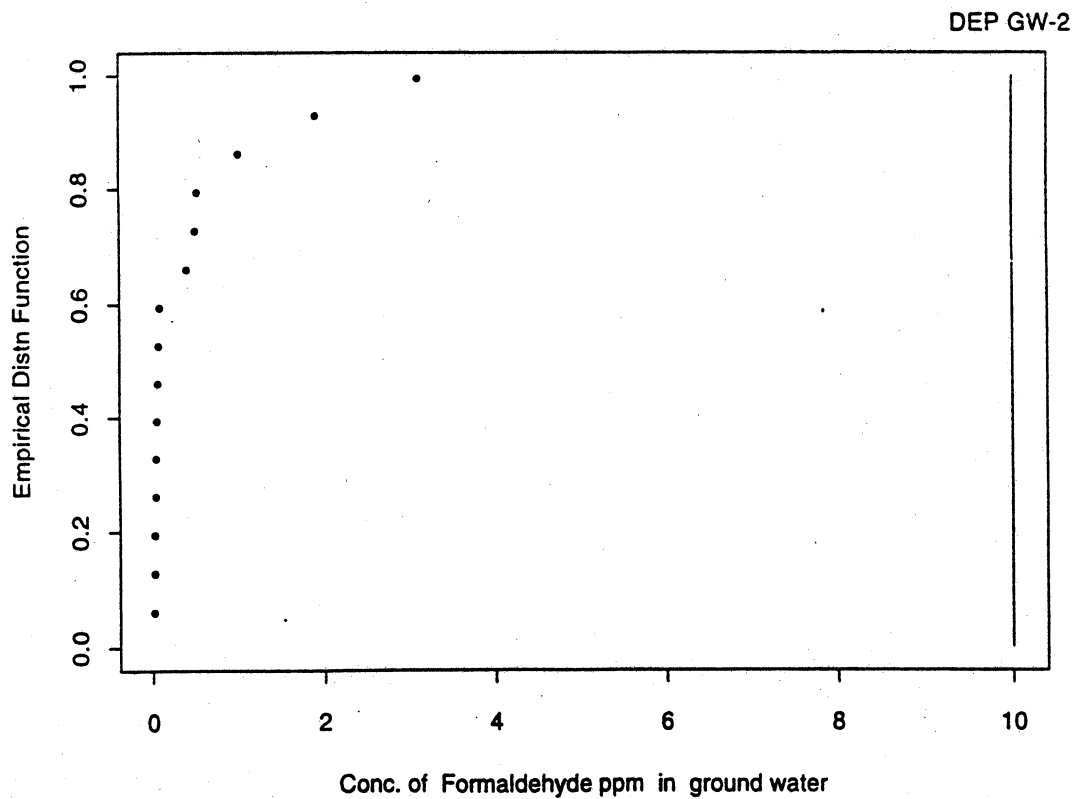
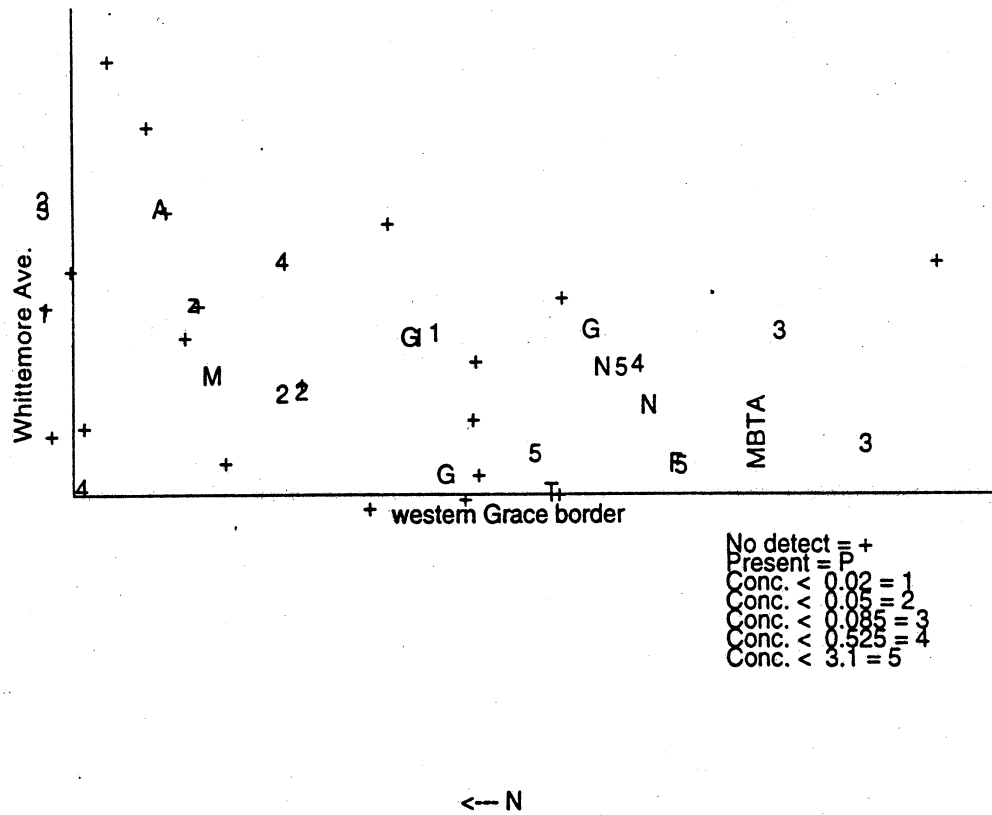
Zinc ppb in ground water



←---N



Formaldehyde ppm in ground water



Whittemore Ave.

Western Grace border

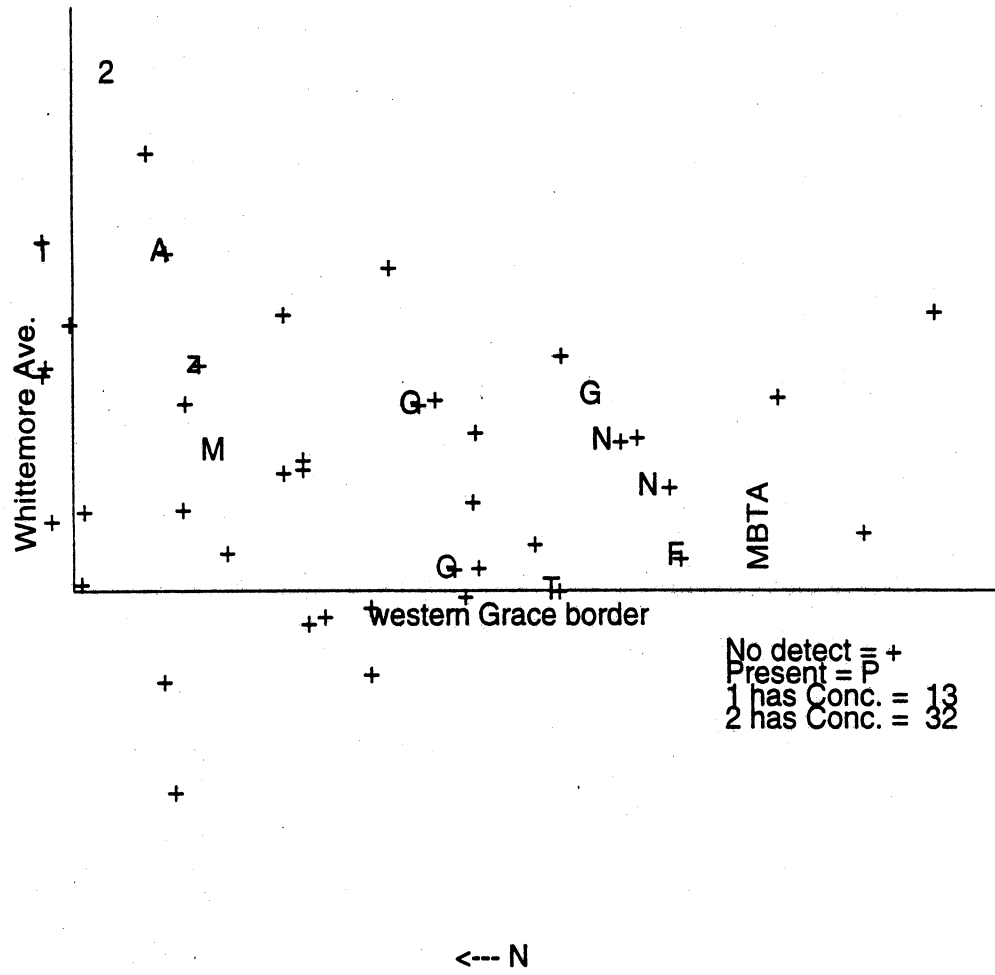
Legend:

- No detect = +
- Present = P
- 1 has Conc. = 1.8
- 2 has Conc. = 5
- 3 has Conc. = 9.6

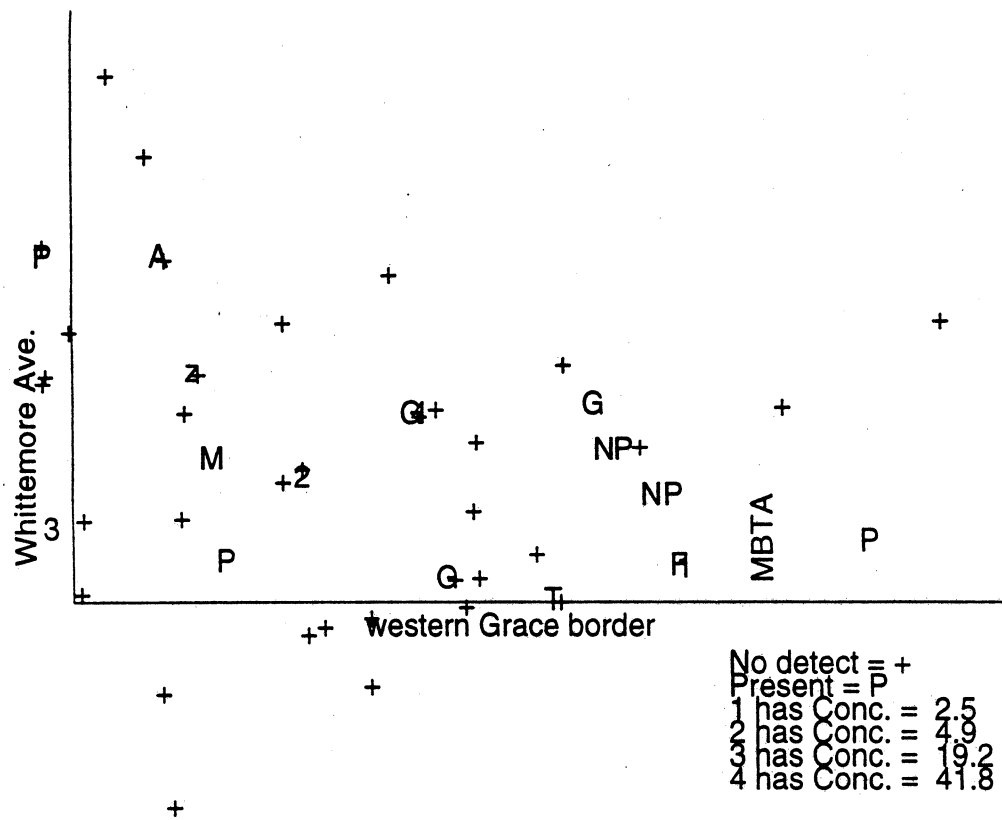
North Arrow: <--- N

←--- N

Carbon Tetrachloride ppb in ground water

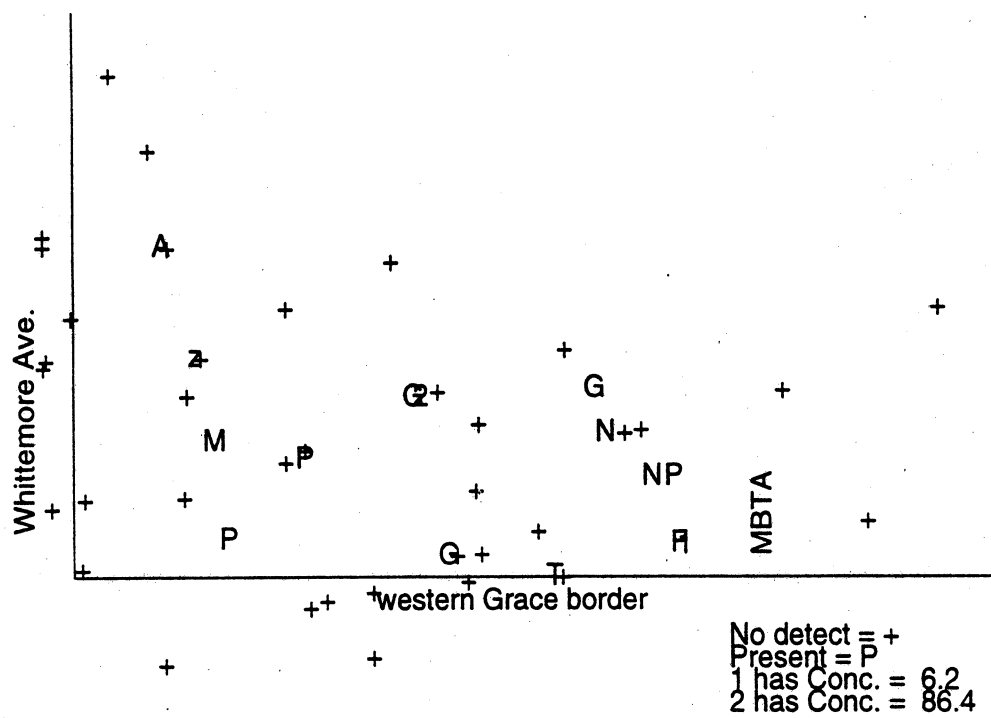


Benzo (a) pyrene ppb in ground water

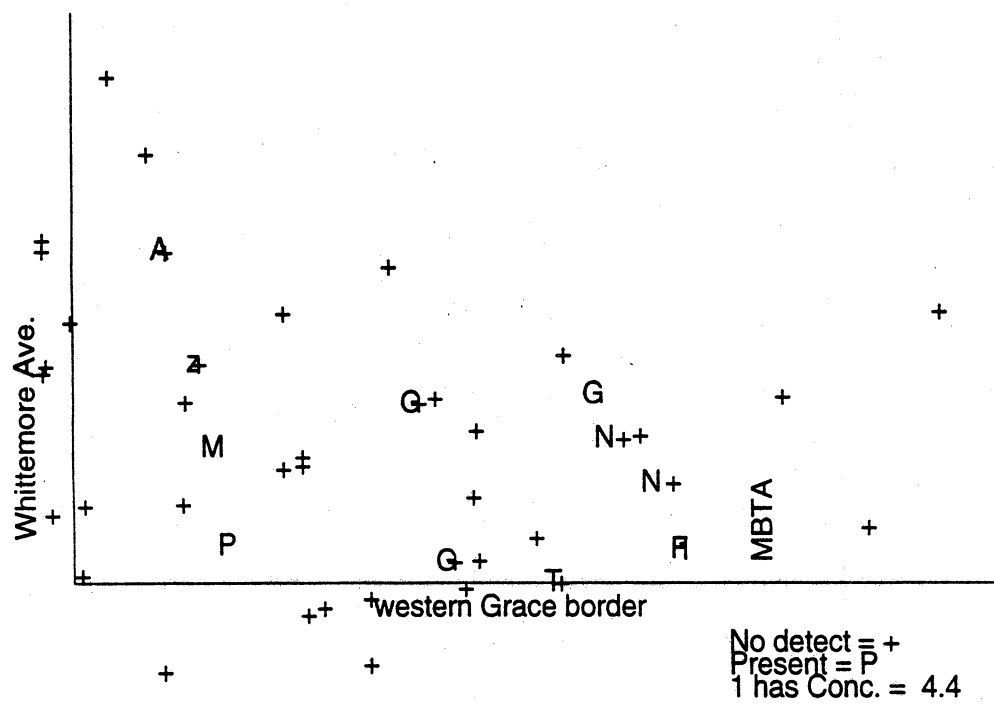


<--- N

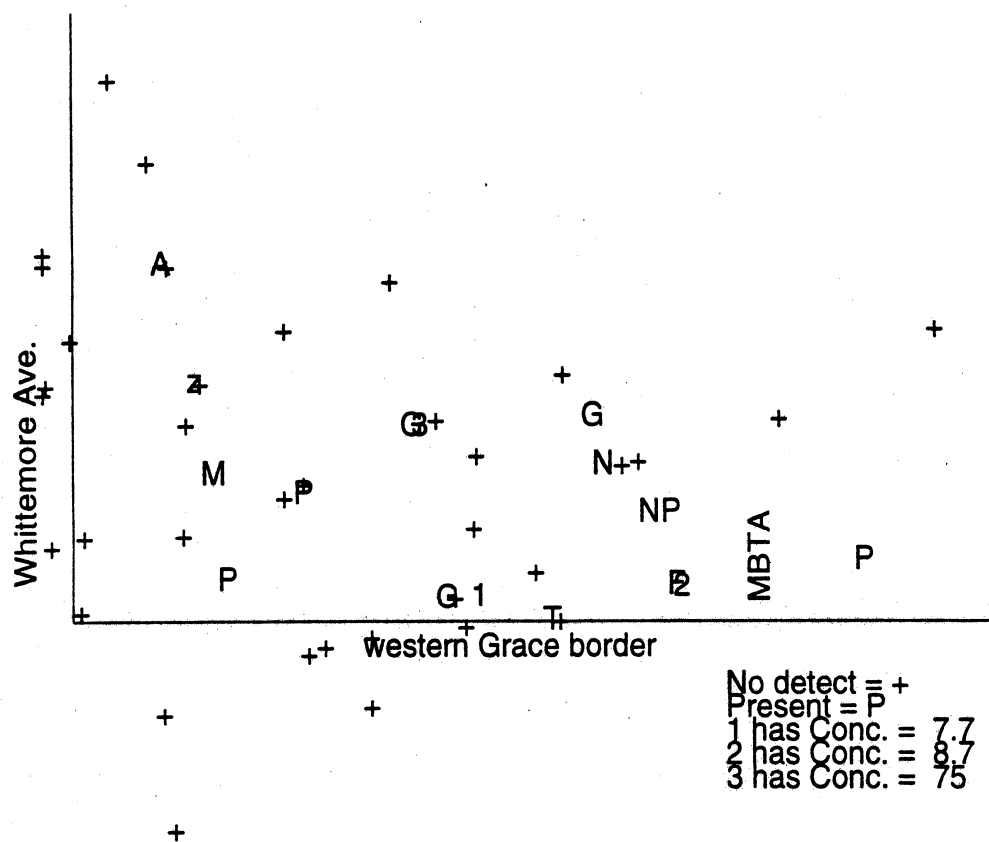
Benzo (ghi) perylene ppb in ground water



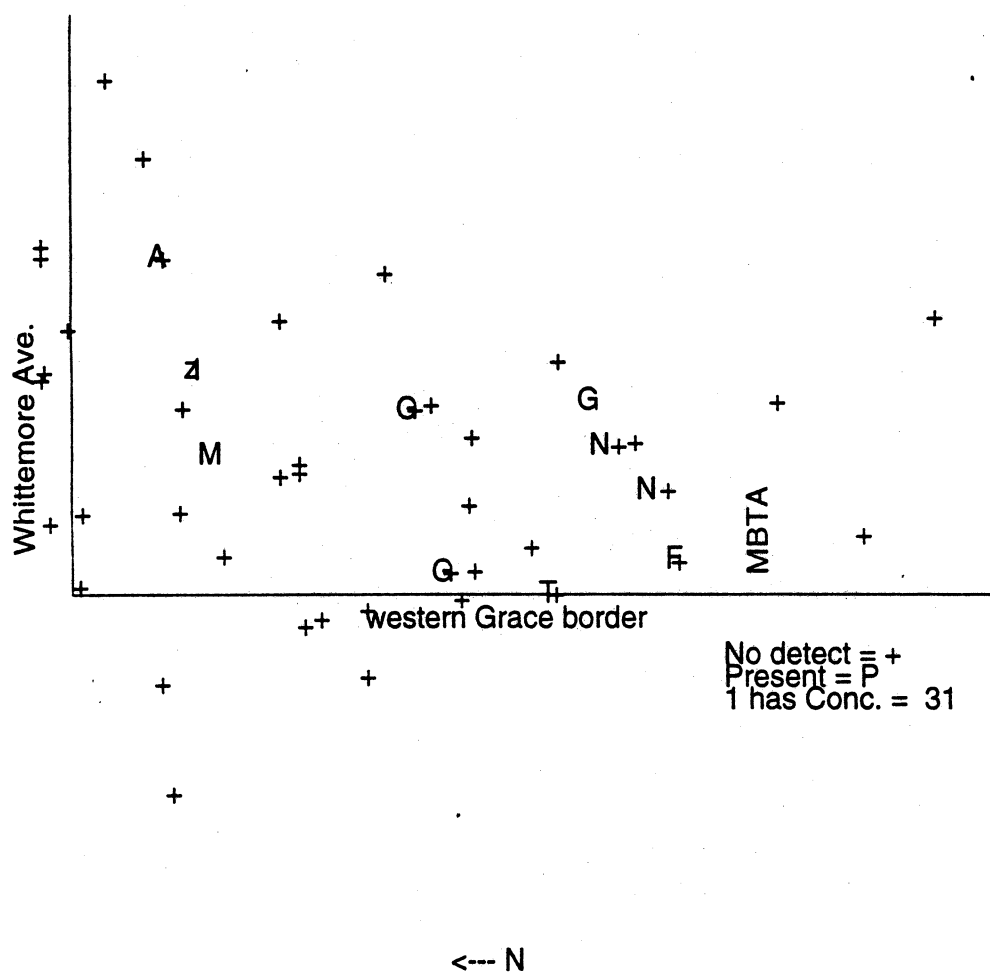
Dibenzo (a,h) anthracene ppb in ground water



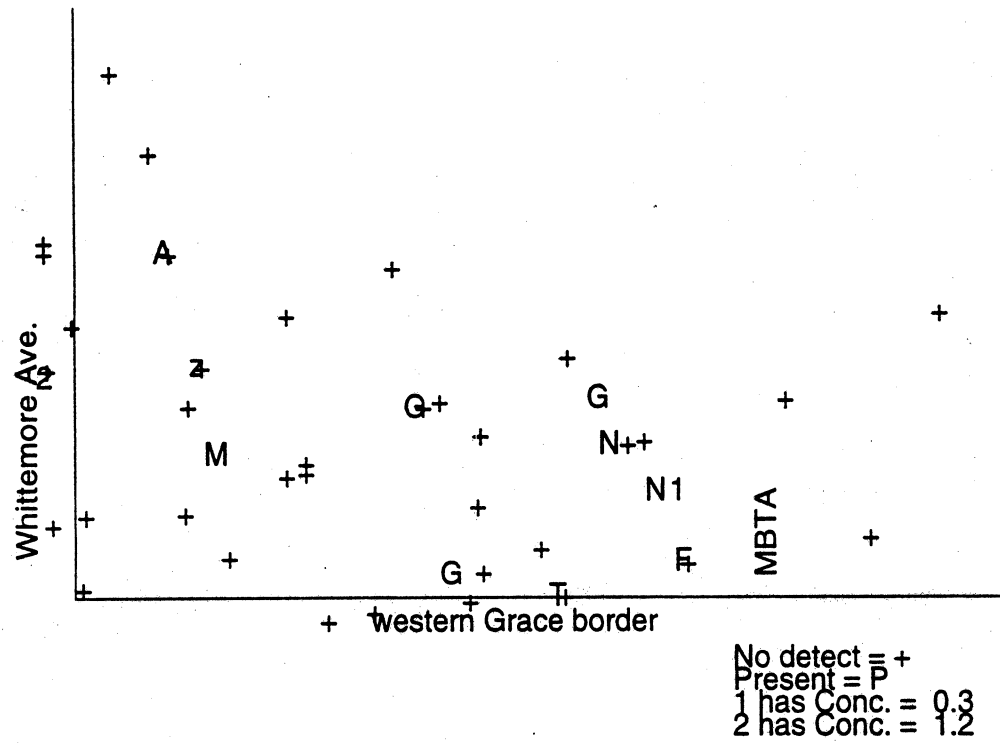
Indeno (1,2,3-cd) pyrene ppb in ground water



Diethyl phthalate ppb in ground water

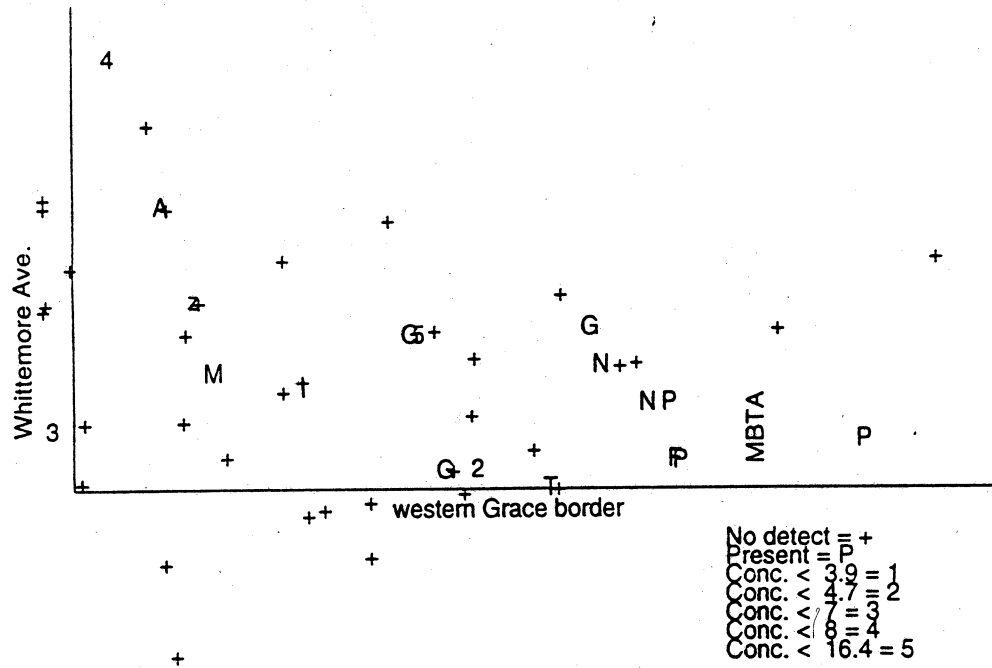


Mercury ppb in ground water

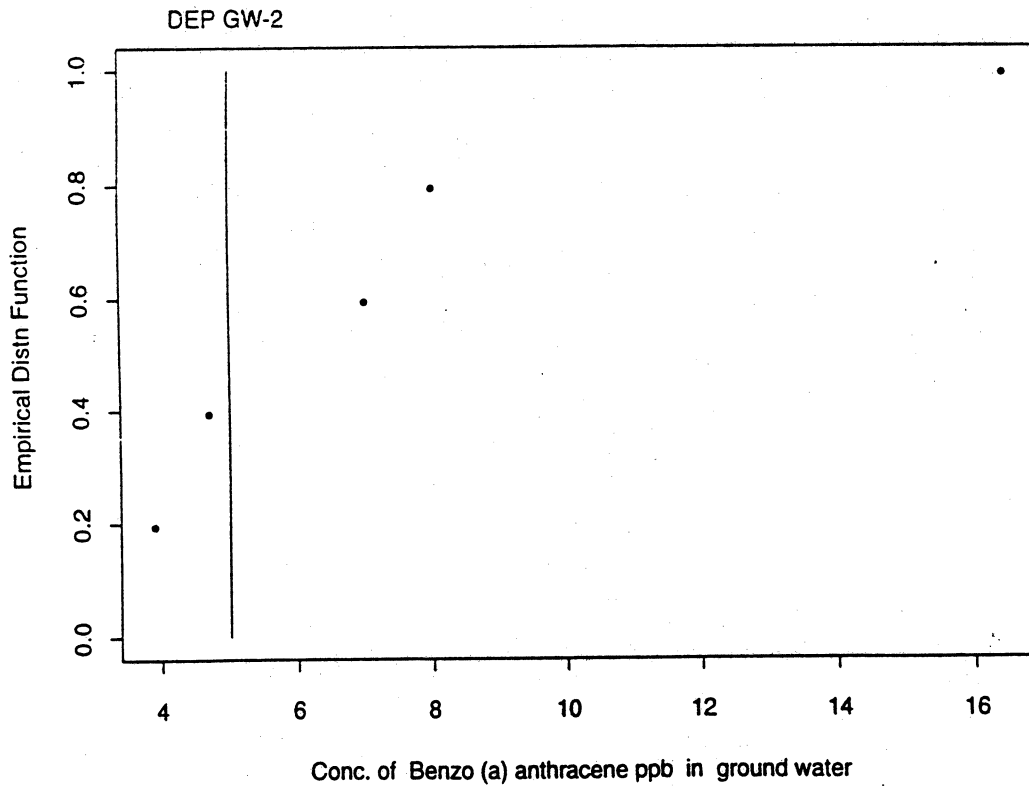


<--- N

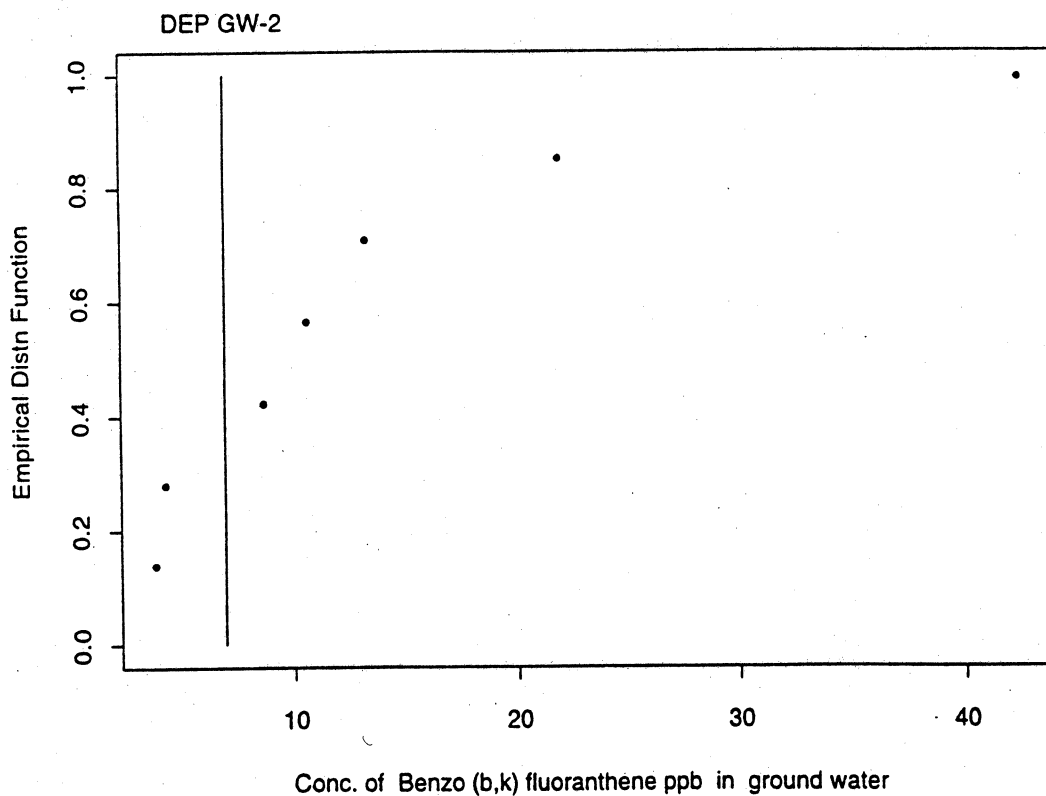
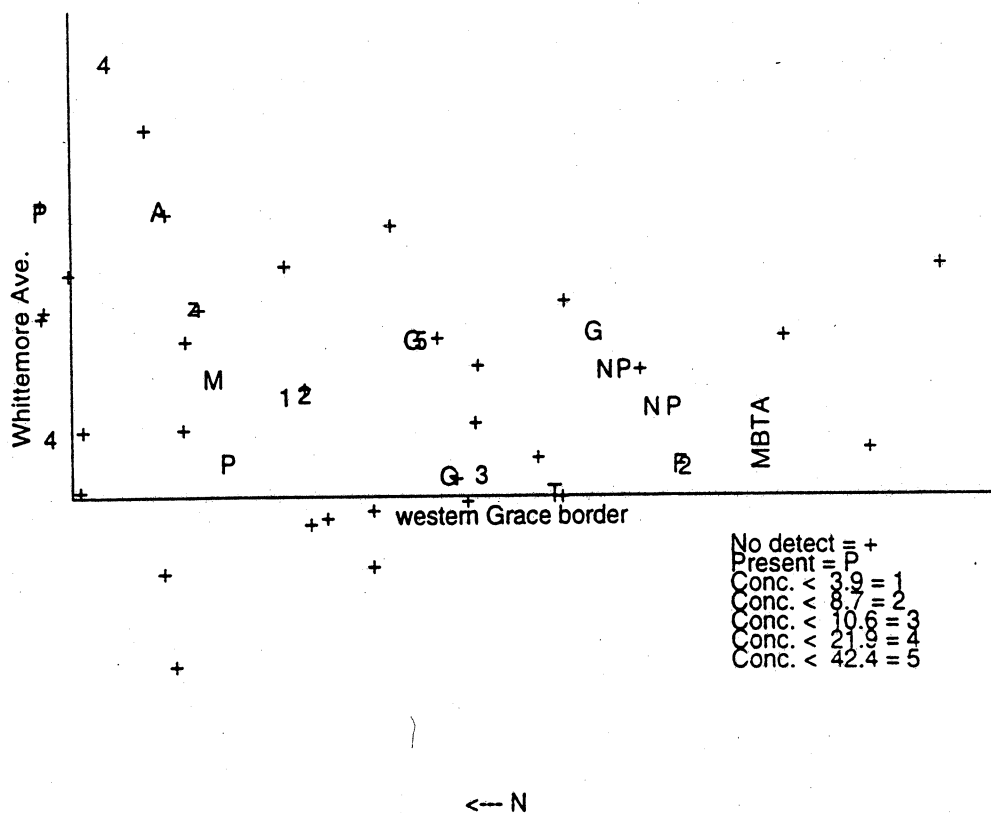
Benzo (a) anthracene ppb in ground water



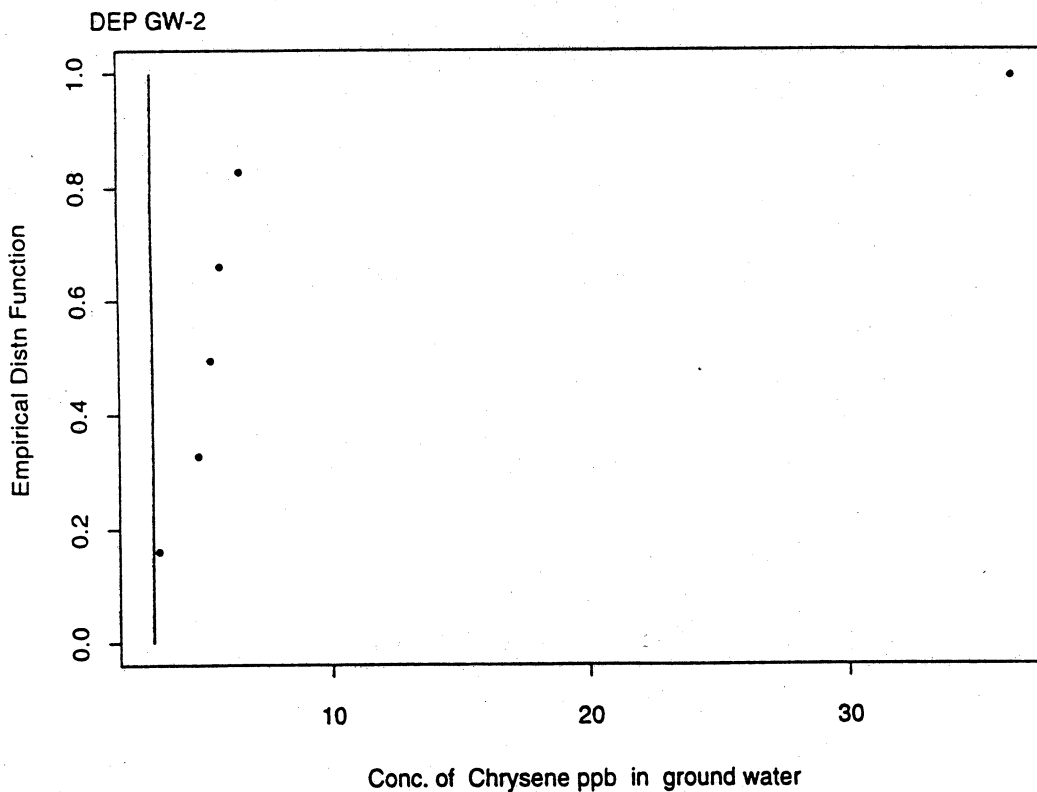
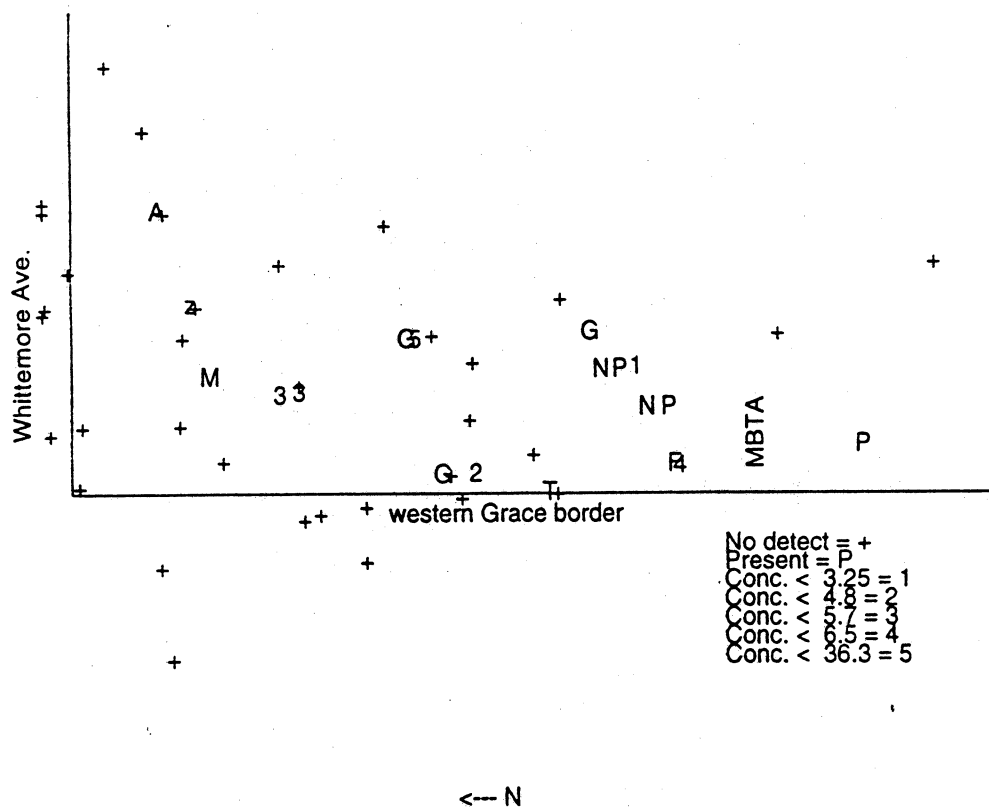
← N

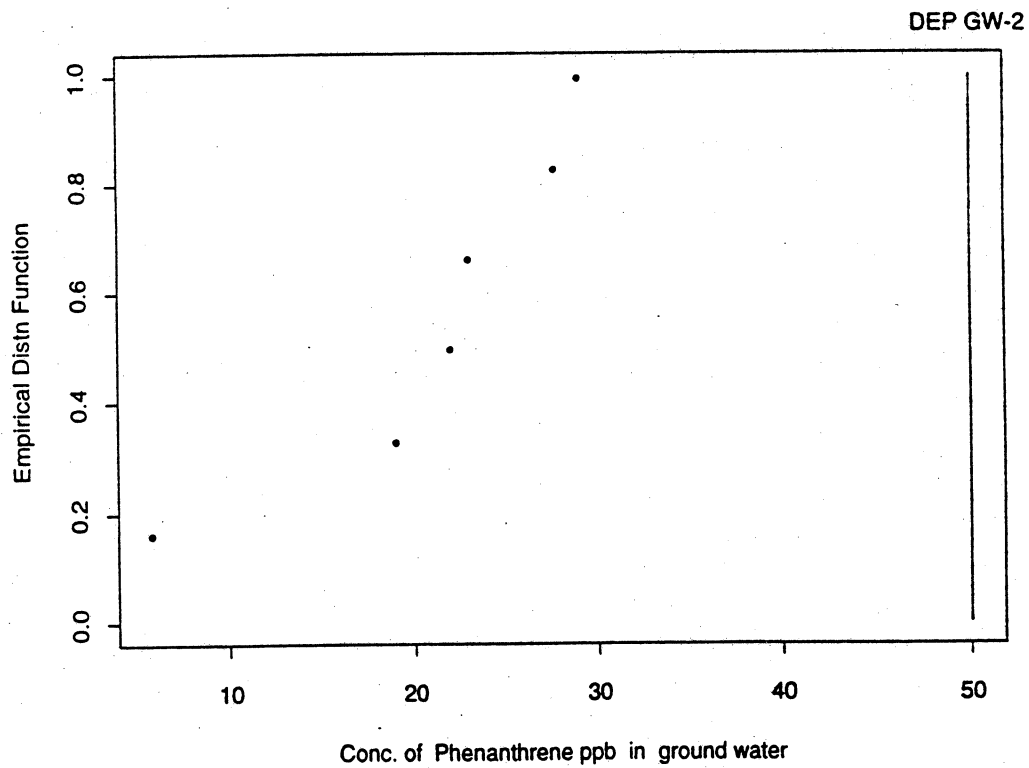


Benzo (b,k) fluoranthene ppb in ground water

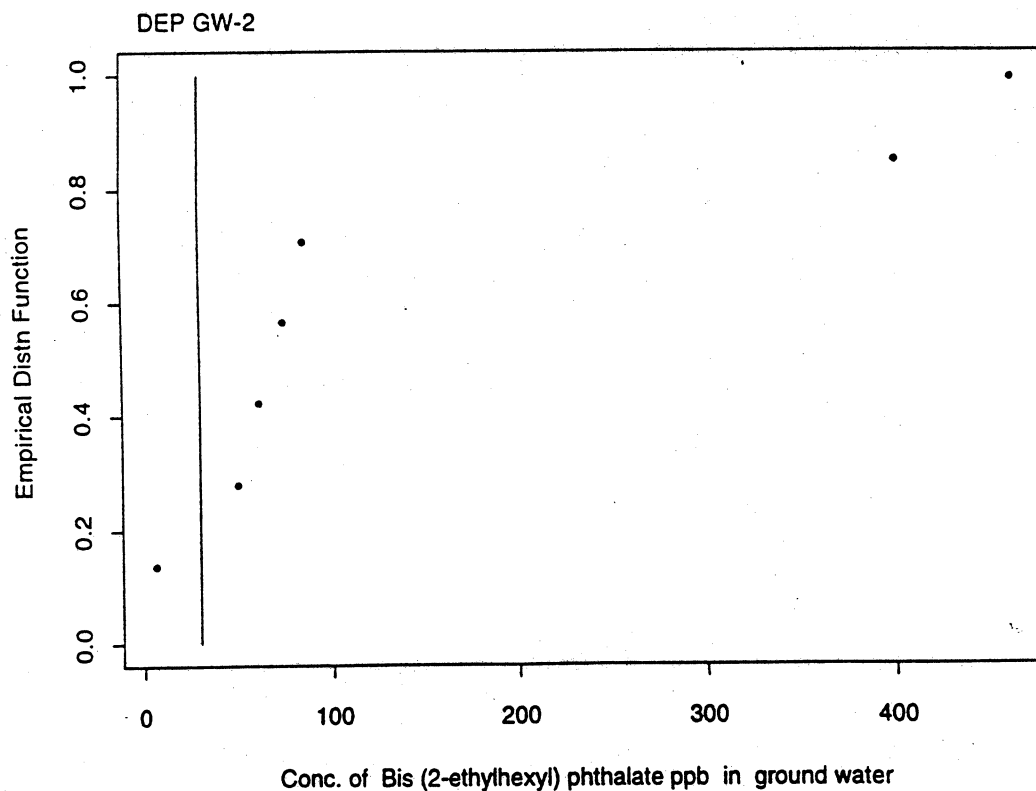
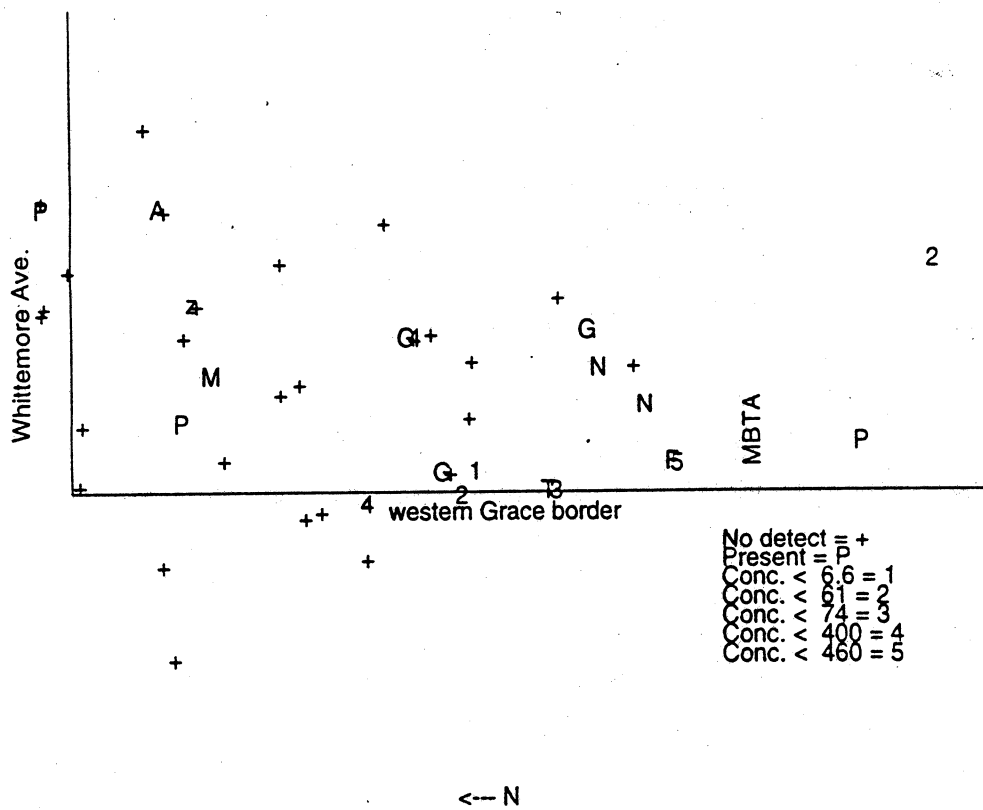


Chrysene ppb in ground water





Bis (2-ethylhexyl) phthalate ppb in ground water



APPENDIX C

LIMITATIONS

LIMITATIONS

1. Environmental Health & Engineering, Inc.'s (EH&E) assessment described in the attached report number 95.415, *Public Health Risk Evaluation for W.R. Grace Site in Cambridge, Massachusetts*, (hereafter "the Report"), was performed in accordance with generally accepted practices employed by other consultants undertaking similar studies at the same time and in the same geographical area; and EH&E observed that degree of care and skill generally exercised by such other consultants under similar circumstances and conditions. The observations described in the Report were made under the conditions stated therein. The conclusions presented in the Report were based solely upon the services described therein, and not on scientific tasks or procedures beyond the scope of described services, nor beyond the time and budgetary constraints imposed by the client.
2. Observations were made of the site as indicated within the Report. Where access to portions of the site was unavailable or limited, EH&E renders no opinion as to the presence of chemical residues, or to the presence of indirect evidence relating to chemical residues in that portion of the site.
3. The observations and recommendations contained in the Report are based on limited environmental sampling and visual observation, and were arrived at in accordance with generally-accepted standards of industrial hygiene practice. The sampling and observations conducted at the site were limited in scope, and therefore cannot be considered representative of areas not sampled or observed.
4. Where sample analyses were conducted by an outside laboratory, EH&E has relied upon the data provided, and has not conducted an independent evaluation of the reliability of these data.
5. The purpose of the Report was to assess the characteristics of the subject site as stated within the Report. No specific attempt was made to verify compliance by any party with all federal, state, or local laws and regulations.

S-244

Final Draft of Public Health
Risk Evaluation for W. R. Grace
site in Cambridge, Massachusetts
the Massachusetts Department of
Environmental Protection.

In City Council May 1, 1996