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Volume 3

Document/Contents	Date	Addressed to:
Letter and document: USGS, "Background Geochemistry of Some Rocks, Soils, Plants, and Vegetables in the Conterminous United States," 1975.	03/14/89	Karen Vendl, Remedial Project Manager, USEPA
Memorandum: Response to March 17, 1989 Conference Call questions.	03/17/89	Karen Vendl, Remedial Project Manager, USEPA, Al Sloan, CH2MHill, and John Buck, IDEM
Letter: Time required for surface water to migrate through the unsaturated zone to a monitoring well.	03/21/89	Karen Vendl, Remedial Project Manager, USEPA
Document (hand-delivered): Exhibit A - Environmental Conservation and Chemical Corporation (ECC) Site.	04/03/89	Karen Vendl, Remedial Project Manager, USEPA, and John Buck, IDEM
Letter: Proposed changes to the "ECC Monitoring Plan," method for statistical evaluation of the soil samples results, calculation of the time for diffusion in the soil of volatilized compounds, and references for organic carbon content of soils.	04/11/89	John Buck, IDEM and Karen Vendl, Remedial Project Manager, USEPA
Memorandum: Procedure to establish background water quality at the ECC site.	05/10/89	Karen Vendl, Remedial Project Manager, USEPA
Memorandum: Outstanding Technical Issues.	06/09/89	Karen Vendl, Remedial Project Manager, USEPA, John Buck and Prabhakar Kasarabada, IDEM, and Al Sloan, CH2MHill

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(continued)

Document/Contents	Date	Addressed to:
Memorandum: Additional information on remaining technical issues.	06/15/89	Karen Vendl, Remedial Project Manager, USEPA, John Buck and Prabhakar Kasarabada, IDEM
Letter and document: Exhibit A - Environmental Conservation and Chemical Corporation (ECC) Site.	07/21/89	Karen Vendl, Remedial Project Manager, USEPA
Memorandum: Technical issues for Exhibit A (filtered subsurface water samples and "J" and "B" qualified data).	08/31/89	Al Sloan, CH2MHill (faxed by Al Sloan to Charles McKinley, Office of General Counsel, USEPA)
Memorandum: ECC Exhibit A (filtered subsurface water samples and "J" and "B" qualified data).	08/31/89	Al Sloan, CH2MHill (faxed by Al Sloan to Charles McKinley, Office of General Counsel, USEPA)

ERM-North Central, Inc.
Environmental Resources Management

102 Wilmot Road • Suite 300 • Deerfield, Illinois 60015 ☎ (312) 940-7200

March 14, 1989

Karen A. Vendl
Remedial Project Manager
U.S. Environmental Protection Agency
Region 5 (5HS-11)
230 South Dearborn Street
Chicago, IL 60604

RE: Enviro-Chem ("ECC") Site

Dear Ms. Vendl:

Enclosed please find two (2) copies of the USGS document entitled "Background Geochemistry of Some Rocks, Soils, Plants, and Vegetables in the Counterminous United States," 1975.

Very truly yours

ERM-NORTH CENTRAL, INC.

Elsie F. Millano, Ph. D., P.E.
Senior Project Engineer

jls

Enclosures

cc: A. Sloan
J. Buck
T. Conway
J. Kyle
J. Amber
D. Smith
T. Harker

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Background Geochemistry of Some Rocks, Soils, Plants, and Vegetables in the Conterminous United States

By JON J. CONNOR *and* HANSFORD T. SHACKLETTE

With sections on FIELD STUDIES

By RICHARD J. EBENS, JAMES A. ERDMAN, A. T. MIESCH, RONALD R. TIDBALL, *and* HARRY A. TOURTELOT

STATISTICAL STUDIES IN FIELD GEOCHEMISTRY

GEOLOGICAL SURVEY PROFESSIONAL PAPER 574-F

Geochemical summaries for 147 landscape units sampled in 25 field studies

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BACKGROUND GEOCHEMISTRY OF SOME ROCKS, SOILS, PLANTS, AND VEGETABLES IN THE CONTERMINOUS UNITED STATES

By Jon J. Connor, Hansford T. Shacklette, and others

ABSTRACT

Geochemical summary statistics for 48 elements in natural materials from 147 landscape units have been compiled based on field and laboratory studies since 1958. Each landscape unit is briefly identified as to kind and location, and the expected concentration for one or more elements is given together with factors indicating the degree of observed variation in the study and the degree of laboratory or "analytical" variation. Also listed are the observed range and the total number of element analyses made in each study. The data on which these summaries are based have three attributes in common: They represent "large-scale" or regional geochemical studies; they represent background or "ordinary" natural geochemical variation; and they were collected according to objective sampling designs. The summaries clearly demonstrate the wide diversity to be expected in elemental properties of landscape units and suggest that published element abundances for broad categories like "soil" or "carbonate rock" may be misleading.

INTRODUCTION

Increased public concern about real or suspected chemical deterioration of the environment, together with a growing awareness of the role of trace elements in health and nutrition, underscores the need for realistic data on the chemistry, particularly the trace element chemistry, of the natural environment. A moderately voluminous literature exists in which geochemical abundances of many trace elements are summarized, but it deals largely with rocks; less seems to be known (or at least less has been published) about the distribution of trace elements in soil, plants, and waters. Some of the standard references on trace element abundances in these materials are Goldschmidt (1954), Rankama and Sahama (1955), Mason (1958), and Turekian and Wedepohl (1961). More recent summaries include Wedepohl (1967–1973), Shacklette, Hamilton, Boerngen, and Bowles (1971) and Durum, Hem, and Heidel (1971). In addition to these, the U.S. Geological Survey is currently revising Clarke's (1924) Data of Geochemistry. The revision is being published as separate chapters of U.S. Geological Survey Professional Paper 440. Nearly a third of the projected chapters have been published to date, including chapters summarizing the composition of rocks (Parker, 1967) and waters (White, Hem, and Waring, 1963; Livingstone, 1963). Because of its well-known toxicity, mercury in the environment has received as much or more attention than any other trace metal. Three general references to mercury in the environment are U.S. Geological Survey (1970), Shacklette, Boerngen, and Turner (1971), and Jenne (1972). General summaries of trace elements in soils and in plant tissue are rare, although Shacklette, Sauer, and Miesch (1970) gave trace element averages for a variety of both, including foodstuffs, in Georgia.

Much of the extant information describing the "natural condition" of the geochemical environment is of unknown reliability. Generally, many of the data (particularly the older data) on which the published summaries are based were not collected to serve as guides to background geochemistry. Rather, they may have been collected to study such things as specific geochemical processes, or to delineate mineralized areas, or perhaps to estimate the degree of chemical pollution; in short, samples of natural materials tend to be collected for a variety of scientific reasons but only rarely for the purpose of describing the ordinary properties of the natural chemical environment.

One long-term U.S. Geological Survey effort, however, has for its goal precisely this purpose. For more than a decade now, personnel of the U.S. Geological Survey have been engaged in several field projects in regional geochemistry, the primary purpose of which has been to describe the geochemical variation of broad natural units in the United States. Fundamental to all these studies has been the conscious attempt to measure the geochemical variation *as it occurs in nature*. Some of this work has been published, but most of it has not. Many studies are currently underway, and we anticipate that such studies will continue.

One such study merits special mention. The U.S. Geological Survey has recently completed a geochemical survey of the State of Missouri, many aspects of which are unique to environmental geochemistry. It not only is a survey of a broad, geologically diverse area, but it was undertaken partly in support of active, trace-element related epidemiologic studies sponsored by the University of Missouri. Moreover, we think it is the first study of its kind in which an attempt has been made to characterize rocks, waters, soils, and plants chemically by a unified team approach using (and in part testing) efficient and objective sampling designs. Connor and others (1972) described this work in a preliminary way. Details of the study are available in a series of limited-distribution progress reports (U.S. Geological Survey, 1972a–f, 1973).

The data tabulated in the present report represent the work of many people. Principal investigators are listed with a short description of each study, and authorship is cited for all published data. All unpublished data are preliminary. The reader is cautioned that some of the data summaries given here may be subject to minor revision. The sampling designs, data analyses, and geochemical summaries on which this report is based are statistical in nature; extended discussions of these subjects can be found in Miesch (1967a, b, 1972), Connor and others (1972), and Connor and Myers (1973).

A proper list of acknowledgments for this report would comprise more than 100 people including computer programmers, specialists in data handling, and assistants in the field, laboratory, and office. Unquestionably, the most important contributors are the chemists, spectrographers, and other laboratory personnel who catalogued, prepared, and measured the concentrations of up to 69 elements in more than 8,000 samples of rocks, soils, and plant material over a period of more than 10 years. They are: Lowell Artis, Phillip Aruscavage, J.W. Baker, A.J. Bartel, S.D. Botts, L.A. Bradley, Floyd Brown, Mike Brown, J.W. Budinsky, G.T. Burrow, C.L. Burton, Alice Caemmerer, J.P. Cahill, E.Y. Campbell, G.W. Chloe, Don Cole, E.F. Cooley, N.M. Conklin, W.B. Crandell, Maurice DeValliere, J.I. Dinnin, P.L.D. Elmore, E.J. Fennelly, W.H. Ficklin, J.L. Finley, F.J. Flanagan, L.D. Forshey, I.C. Frost, Johnnie Gardner, J.L. Glenn, W.D. Goss, Frank Grimaldi, J.C. Hamilton, T.F. Harms, J.L. Harris, A.G. Haubert, R.G. Havens, R.H. Heidel, A.W. Helz, M.B. Hinkle, Claude Huffman, Jr., R.L. James, L.B. Jenkins, James Kelsey, Herbert Kirschenbaum, B.W. Lanthorn, L.M. Lee, K.W. Leong, H.H. Lipp, Irving May, B.A. McCall, R.E. McGregor, J.B. McHugh, J.D. Mensik, V.M. Merritt, Leung Mei, H.T. Millard, Jr., D.E. Moore, Roosevelt Moore, John Moreland, Wayne Mountjoy, A.T. Myers, H.M. Nakagawa, H.G. Neiman, W.W. Niles, D.R. Norton, Utcana Oda, C.S.E. Papp, L.F. Rader, R.L. Rahill, L.B. Riley, E.J. Rowe, J.J. Rowe, V.E. Shaw, G.D. Shipley, Leonard Shapiro, F.O. Simon, H. Smith, M.W. Solt, A.L. Sutton, Jr., D. Taylor, J.A. Thomas, Barbara Tobin, J.E. Troxel, J.H. Turner, R.L. Turner, R.E. Van Loenen, G.H. VanSickle, J.S. Wahlberg, F.N. Ward, E.P. Welsch, Roberta Wilkie, T.L. Yager, R.J. Young, and R.A. Zielinski.

METHODS OF STUDY

OBJECTIVES

The summary data listed herein have three common characteristics and only data consistent with these attributes have been included in the tables:

1. The data represent large-scale studies, in which an assessment of regional geochemical effects is one of the objects of study. The definition of large-scale or regional is somewhat arbitrary, but all studies listed herein involved a conceptual natural unit whose geographic extension in at least one direction is of the order of 80 km or more.

2. The data represent background concentrations. Data known or suspected to reflect epigenetic mineralization, or pollution and other man-induced effects have been intentionally excluded. Because of intimate contact with the atmosphere, plants may be more susceptible to the effects of low-level, broad-scale chemical pollution than are soils and rocks. The geochemistry of cultivated soils may, of course, reflect agricultural practices. Nevertheless, only data believed to be essentially free of unusual geochemical effects have been summarized in these tables.

3. The data were collected according to objective experimental designs in an attempt to insure that unbiased estimates of the "natural" variation were obtained. The suit of samples underlying each summary statistic includes varietal samples in approximately the same proportion that these varieties occur in nature. Commonly, such objectivity has been approached through introduction of randomization procedures into selection of the sampling sites. Nearly all of the sample suites were analyzed in a randomized sequence to circumvent any potential effects of systematic laboratory error.

COLLECTION PROCEDURES

The samples on which these tabulations are based were collected according to two general kinds of sampling design. The more conventional design is one in which a single sample of the material of interest was collected at each of numerous sites spread rather evenly over the area of study. A large number of studies, however, were based on a second, more complicated sample design, one in which an effort was made to quantify the effects of "regional" variation and the factors underlying such variation. Sample collection in these latter studies was based on hierarchical designs in which samples were "nested" at various geographic scales in order to assess the proportion of geochemical variation exhibited at each scale.

Krumbein and Slack (1956) discussed such designs and the requisite mathematics in detail. The particular sample design used for each field study is given under the description of that study in the following section.

Collection procedures in the field tended to be consistent from study to study. All rock samples were taken from outcrop as single samples of a few kilograms weight. They were collected from atrificial exposures as well as from natural outcrop. These samples were trimmed in the field or laboratory in an attempt to exclude all visible weathering rinds or surface effects. Admittedly, not all weathering effects are necessarily excluded thereby.

For the most part, soils were collected at or near the surface as single samples weighing about 1 kg. They were commonly taken from shallow holes dug with spade, geologic pick, or other metal tools. Special collection procedures were used in Studies 16, 18, and 19. Soils collected from deeper parts of the soil horizon were commonly taken from sides of large pits dug specifically for sampling. Attempts were made to take soil that had not been in contact with metal collecting tools. In studies 16, 18, and 19 the samples of soil material were sieved to remove rock particles larger than 2 mm in diameter before the samples were pulverized. In the other soil studies the rocks were removed from the samples by hand sorting; therefore rock particles somewhat larger than 2 mm in diameter may have been pulverized with the soil material of some samples.

Samples of native plants were commonly collected from the terminal parts of branches over as much of the plant as practical. In deciduous woody plants, stems of the previous few years' growth were always collected; leaves were rarely collected. For conifers, leaves (needles) and stems were collected together. No attempt was made to wash or otherwise clean the collected materials prior to analysis. Elemental analysis of the cultivated plant samples was performed on the edible parts of the plant prepared as for eating but uncooked.

DESCRIPTIONS OF FIELD STUDIES

The locations of the individual field studies on which the data in this report are based are shown in figures 1 and 2 and briefly described below by the principal investigators who provided the data given in tables 5–53.

STUDY NO. 1

[Granitic rocks of Precambrian age in the St. Francois Mountains, Missouri]

By Richard J. Ebens

Samples weighing a few kilograms each were collected from outcrops of granite and rhyolite of Precambrian age in the St. Francois Mountains of southeastern Missouri in the fall of 1970. Two samples were collected from each of 15 randomly selected sampling localities in the granites of the area, and a similar suite of samples was collected from the rhyolites of the area. Ten randomly selected samples were split into 2 parts and the entire suite of 70 was placed in a random sequence prior to analysis. Preliminary results of this study are given in U.S. Geological Survey (1972e, p. 13). Study conducted by Richard J. Ebens.

STUDY NO. 2

[Arkose of the Fountain Formation of Permian and Pennsylvanian age in central Colorado]

By A. T. Miesch

Samples weighing a few kilograms each were collected during the summer of 1966 from outcrops of arkose of the Fountain Formation of Pennsylvanian and Permian age east of the Front Range in central Colorado. Ten randomly located samples were collected from each of 8 stratigraphic sections of the Fountain Formation. The length of the outcrop belt was divided into four approximately equal parts and two sections were randomly located in each part. Twenty samples were split and the total suite of 100 was placed in a random sequence prior to analysis. Study conducted by A. T. Miesch, Jon J. Connor, and Terry Quinlan.

STUDY NO. 3

[Sandstone, shale, and carbonate rocks of the Sauk sequence of Precambrian, Cambrian, and Ordovician age on the cratonic part of the Western United States]

By A. T. Miesch

Samples weighing a few kilograms each were collected from outcrops of the Sauk sequence of Sloss (1963) in the Western United States during 1962–66. The stratigraphic sequence consists largely of rocks of Cambrian and Early Ordovician age although along the western edge of the study area some rocks of late Precambrian age are included. Throughout the study area the interval typically comprises a basal transgressive sandstone that is typified by the Prospect Mountain Quartzite, Tapeats Sandstone, and Flathead Sandstone, a thin overlying shale typified by the Bright Angel and Pioche Shales, and a thick upper carbonate interval typified by the Pogonip Group. Each of the three lithic parts of this sequence exhibits a variety of formational names in different places, and each lithology was treated as a separate problem although the same sampling design was used for each part. Ten major sampling localities approximately 400 km from each other were distributed over the study area. In each locality, eight stratigraphic sections were located in the following manner. Two sections were located approximately 3 km apart, another pair of two sections (also 3 km apart) was located about 15 km from the first pair; another group of four sections was located in a similar manner 80 km away. Where possible within each section, 2 samples were randomly located in the basal sandstone, 2 more in the shale interval, and 2 in the overlying carbonate rocks for a maximum of 6 samples per section and 48 per sampling locality. In addition to the 10 major sampling localities, 10 minor localities were dispersed over the study area in an attempt to occupy wide gaps between the major sampling

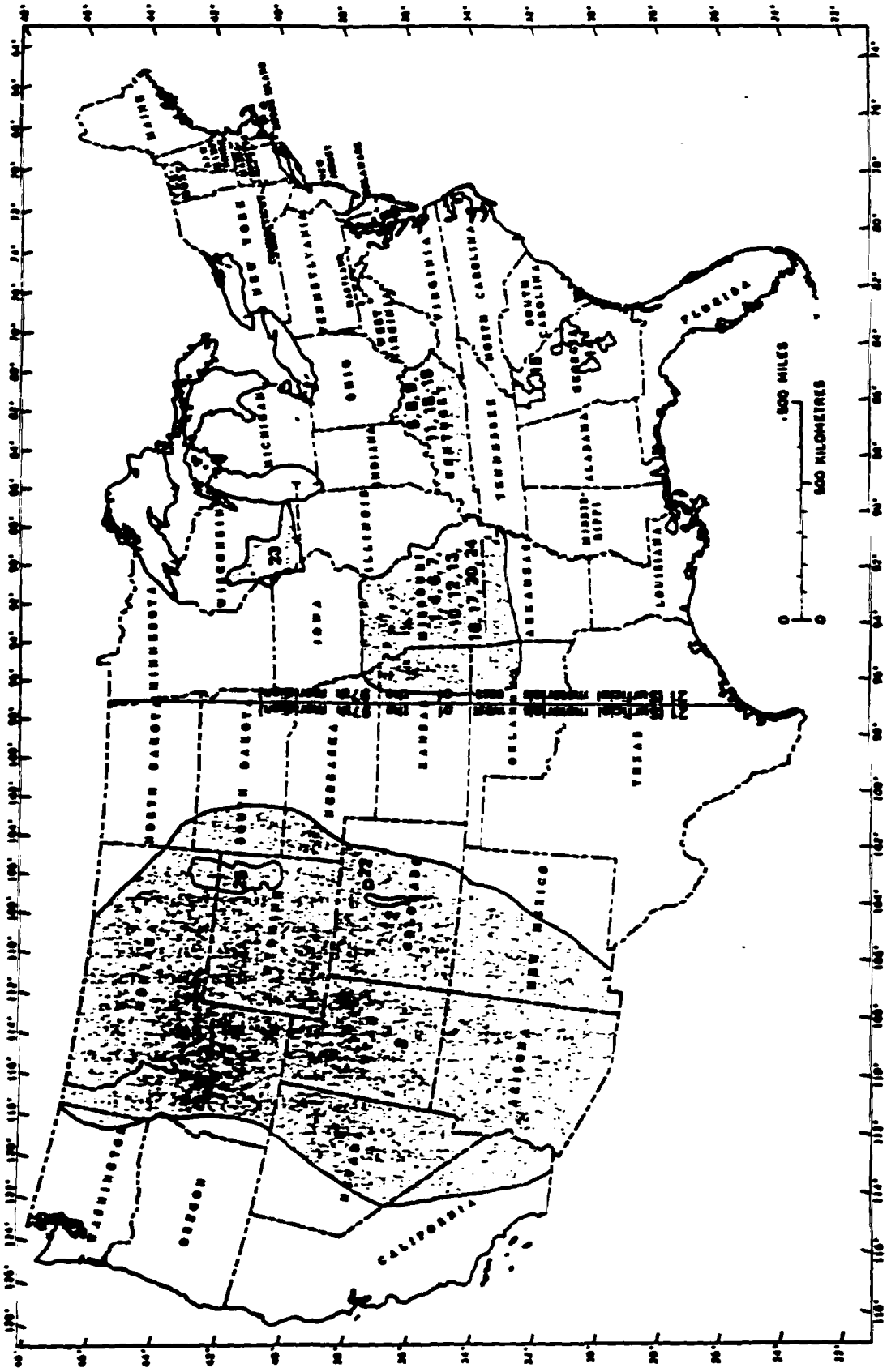

FIGURE 1.—Location of study areas where data were obtained. Numbers on the map refer to studies that are described in the text. (Sampling in area 3 was limited to rocks of the Sauk sequence.)

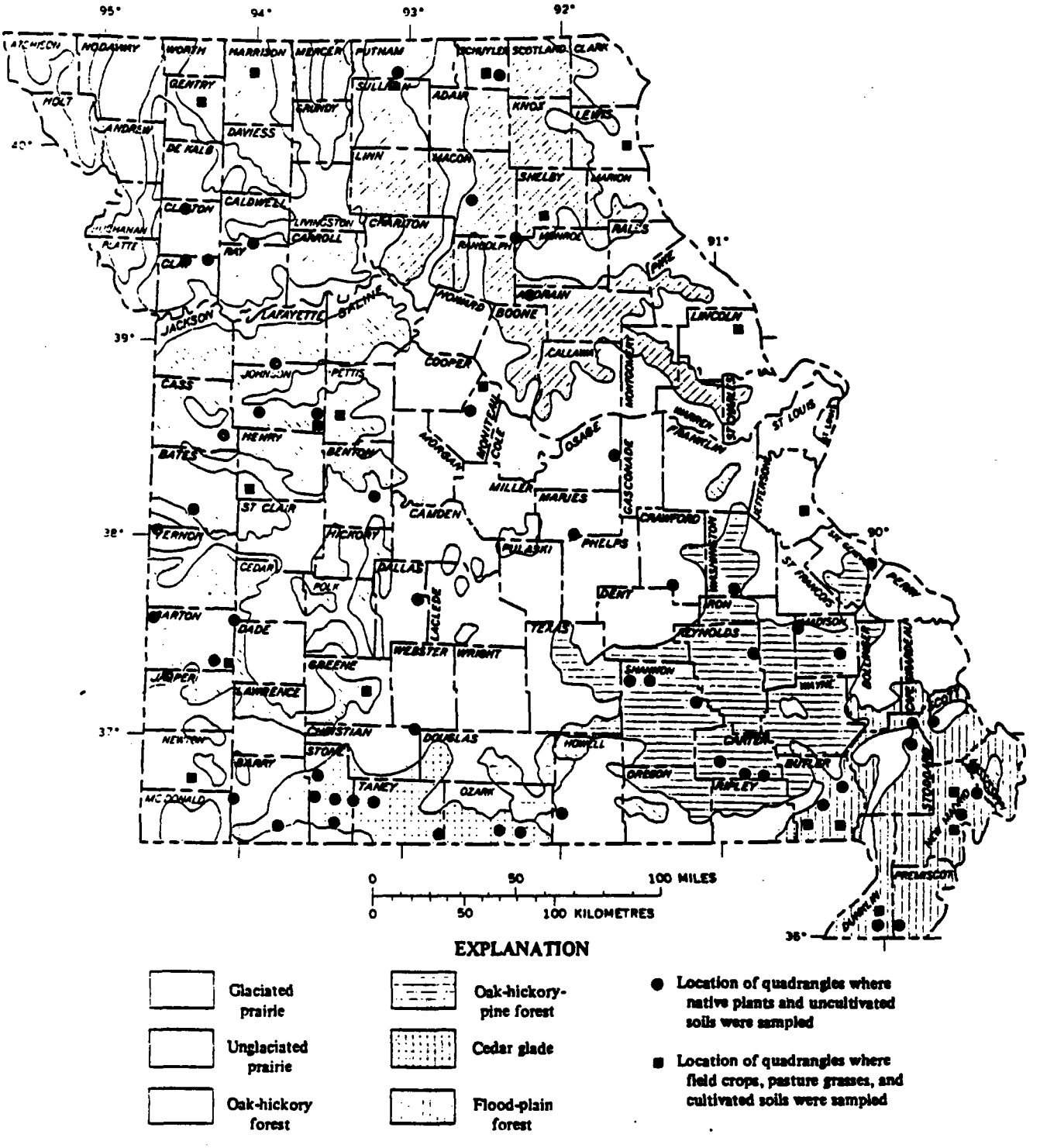

FIGURE 2.—Vegetation-type areas in Missouri, and location of quadrangles where plants and soils were sampled for Studies 17, 20, and 24. Map modified from Küchler (1964).

localities. Each minor locality consisted of only two stratigraphic sections spaced about 3 km apart. In all, 200 samples of sandstone, 168 samples of shale, and 196 samples of carbonate rock were collected. The samples of each lithic type were split into two parts and the entire suite of each placed in a random sequence prior to analysis. Study conducted by A. T. Miesch and Jon J. Connor.

STUDY NO. 4

[Sandstone and carbonate rocks of the Sauk sequence of Cambrian and Ordovician age in Missouri and northern Arkansas]

By Jon J. Connor

Samples weighing a few kilograms each were collected from outcrops of the Sauk sequence of Sloss (1963) in Missouri and Arkansas in the fall of 1970. The stratigraphic sequence consists largely of dolomitic rocks of Cambrian and Early Ordovician age and involves numerous named formations (Howe and Koenig, 1961) of which the Bonneterre and Jefferson City Dolomites are typical. Samples of carbonate rock were collected from six composite stratigraphic sections radiating outward from the St. Francois Mountains region. Each section was subdivided into 10 parts of approximately equal thickness, and 2 of these were randomly selected for similar subdivision into 10 parts. Two of these latter parts (about 5 to 10 m in thickness) were randomly selected for sampling, and 2 samples were randomly collected from each, for a total of 8 samples per section or 48 samples in all. A second study based on the same stratigraphic sections consisted of collecting 2 randomly located samples of sandstone from the Roubidoux Formation from each section, for a total of 12 samples. The carbonate rock samples were analyzed along with other carbonate rocks from Missouri (Study Nos. 6, 7, and 10). Fifteen samples of the total were split and the entire batch randomized prior to analysis. The sandstone samples were analyzed along with other sandstones and chert from Missouri (Study Nos. 6 and 7). Fifteen samples of the total were split and the entire suite of samples randomized prior to analysis. Preliminary results of these two studies are given in U.S. Geological Survey (1972e, p. 13–17). Study conducted by Jon J. Connor and Richard J. Ebens.

STUDY NO. 5

[Sandstone, shale, and carbonate rocks of Paleozoic age in Kentucky]

By Jon J. Connor

Samples weighing a few kilograms each were collected from outcrops of the following eight rock units in Kentucky in 1964–65: Limestone of Late Ordovician age; limestone of Early Mississippian age; shale, limestone, and sandstone of Late Mississippian age; and shale, limestone, and sandstone of Pennsylvanian age. These strata include a large number of named formations, particularly those of Mississippian age in western Kentucky where Chesterian rocks are well developed. Each unit was sampled according to the following design: The State was subdivided along latitude and longitude lines so that each part of the State underlain by rocks of Paleozoic age was assigned to the appropriate 1-degree "cell" (or part of a cell). In each cell, two 7½-minute quadrangles were randomly selected from all those in the cell which had been geologically mapped since 1960 and which are underlain in part by the particular unit to be sampled. Two localities of a size about 300 by 450 m were randomly selected from those parts of the 7½-minute quadrangles containing outcrops of the unit of interest and two samples were collected from randomly located sites in each locality. In all, 227 samples of carbonate rocks, 147 of shale, and 136 of sandstone were collected. Each sample was split into two parts for estimation of analytical error. Not all samples were submitted for analysis at the same time, but the samples in each submittal were placed in a random sequence prior to analysis. Because of their sideritic nature, 15 of the carbonate rock samples collected in this study have been placed in a separate lithic category in this compilation (Study No. 11). Published work based on parts of this study includes Connor (1969), Connor and Trace (1970), and Connor and Ebens (1972). Study conducted by Jon J. Connor.

STUDY NO. 6

[Sandstone, shale, and limestone of Pennsylvanian age in Missouri, Kansas, and Oklahoma]

By Jon J. Connor

Samples weighing a few kilograms each were collected of sandstone, shale, and limestone of Pennsylvanian age in Missouri, Kansas, and northwestern Oklahoma in the fall of 1970. Samples of each lithic type were collected from four composite stratigraphic sections; two are located about 80 km apart in northwestern Missouri and northeastern Kansas and the other two are located in northeastern Oklahoma about 80 km apart. Each section was subdivided into 10 parts of approximately equal thickness. Two of these parts which contained the lithology to be sampled were selected randomly and themselves similarly subdivided into 10 parts, of which 2 were randomly selected. In each of these latter parts, which were 2–10 m thick, 2 samples of the requisite lithic type were taken, making a total of 32 samples each of limestone, sandstone, and shale. The samples of limestone, sandstone, and shale were analyzed along with other suites of carbonate rocks (Study Nos. 4, 7, and 10), sandstone, chert (Study Nos. 4 and 7), and shale (Study No. 7). Fifteen samples of each suite were split into 2 parts and each lithic suite was placed in a random sequence prior to analysis. Preliminary results of this study are in U.S. Geological Survey (1972e, p. 22–24), and Connor and Ebens (1972). Study conducted by Jon J. Connor and Richard J. Ebens.

STUDY NO. 7

[Carbonate rocks, shale, and chert of Mississippian age in Missouri, Oklahoma, and Arkansas]

By Jon J. Connor

Samples weighing a few kilograms each were collected from outcrops of carbonate rocks of Mississippian age in Missouri, northeastern Oklahoma, and northern Arkansas in the fall of 1970. The outcrop belt was divided into five approximately equal segments and two stratigraphic sections about 80 km apart were located in each segemnt. Each section was subdivided into 10 approximately equal stratigraphic parts and 2 randomly located samples of carbonate rock were taken from each of 2 randomly chosen stratigraphic parts in each section, for a total of 40 samples. These samples were analyzed along with other carbonate rocks from the same general area (Study Nos. 4, 6, and 10) and all were submitted for analysis in a randomized sequence. Fifteen samples of the entire suite were split prior to analysis to estimate analytical error. A geochemical study of chert and shale interbedded with these rocks was also undertaken. For chert, a sample weighing a few kilograms was collected from the same outcrop and approximately the same beds from which each pair of carbonate rock samples was collected, resulting in a total of 20 chert samples. For shale, 2 samples each weighing a few kilograms were randomly collected from 9 of the 10 stratigraphic sections, resulting in a total of 18 samples. The samples of chert were analyzed along with other siliceous rocks (Study Nos. 4 and 6) and samples of shale were pooled with other aluminous rocks (Study No. 6), and all samples in each lithic type were submitted for analysis in a randomized sequence. Also, 15 samples in each lithic suite were split into 2 parts for estimation of analytical error. Preliminary results of this study are in U.S. Geological Survey (1972e). Study conducted by Jon J. Connor and Richard J. Ebens.

STUDY NO. 8

[Shale of Early Mississippian age in Kentucky]

By Jon J. Connor

Samples weighing a few kilograms each were collected from outcrops of shale of Early Mississippian age in Kentucky in the fall of 1965. As in Study No. 5, the State was divided into cells, each consisting of a 1-degree quadrangle. In each quadrangle, two 7½-minute quadrangles were randomly selected from all those in the cell which had been geologically mapped since 1960 and which are underlain in part by shale of Early Mississippian age. Two stratigraphic sections were randomly located in each 7½-minute quadrangle and 2 randomly located samples were collected from each section for a total of 38 samples. Each was split into 2 parts and the resulting 76 samples were submitted to the laboratory in a randomized sequence. Study conducted by Jon J. Connor.

STUDY NO. 9

[Black shale of Devonian and Mississippian age in Kentucky]

By Jon J. Connor

Samples weighing a few kilograms each were collected in Kentucky from outcrops of the Ohio, Sunbury, New Albany, and Chattanooga Shales, of Devonian and Mississippian age, in the fall of 1966. Eight randomly located samples were collected in each of 11 sampling localities distributed about 55 km apart around the outcrop belt in Kentucky. Each locality consisted of an area approximately the size of a 7½-minute quadrangle. Twenty-two of the 88 samples were split into 2 parts, and the entire suite of 110 samples was placed in a randomized sequence prior to analysis. Study conducted by Jon J. Connor and Harry A. Tourtelot.

STUDY NO. 10

[Limestone of the Tippecanoe sequence of Ordovician, Silurian, and Devonian ages in Missouri]

By Jon J. Connor

Trimmed samples weighing a few kilograms each were collected from outcrops of the Tippecanoe sequence (Sloss, 1963) in eastern Missouri in the fall of 1970. The sequence in Missouri is composed predominantly of limestone and consists of a variety of named formations of Ordovician, Silurian, and Devonian ages (Howe and Koenig, 1961). The three sampled sections are located near Hannibal, Festus, and Cape Girardeau. Each section was subdivided into 10 parts of approximately equal thickness and 2 randomly chosen parts in each section were sampled in duplicate for a total of 12 samples. These samples were analyzed along with other carbonate rocks from Missouri (Study Nos. 4, 6, and 7) and all had been submitted for analysis in a randomized sequence. Fifteen samples in the suite were split prior to analysis to estimate analytical error. Preliminary results of this study are contained in U.S. Geological Survey (1972e). Study conducted by Jon J. Connor and Richard J. Ebens.

STUDY NO. 11

[Sideritic rocks of Mississippian and Pennsylvanian age in Kentucky]

By Jon J. Connor

The collection of carbonate rocks of Late Mississippian and Pennsylvanian ages in outcrops from eastern Kentucky (Study No. 5) provided a small suite of siderite or sideritic rocks. The rocks occur as lenses or nodules in shales near or above the Mississippian-Pennsylvanian boundary as mapped. They are probably diagenetic in origin and their chemical contrast to the more common carbonate rocks of the Paleozoic section in Kentucky requires that they be treated separately. Fifteen samples were collected, and were analyzed as part of the carbonate rock collection from Kentucky (Study No. 5). Study conducted by Jon J. Connor.

STUDY NO. 12

[Residuum on carbonate rocks of Cambrian, Ordovician, and Mississippian ages in southern Missouri and northern Arkansas]

By Richard J. Ebens

Samples weighing about 2 kg each of cherty residuum (terra rossa) developed on carbonate rock units were collected in southern Missouri and northern Arkansas in the spring of 1972. The seven areas sampled are underlain by dolomites of the (1) Bonneterre, (2) Eminence or Potosi, (3) Gasconade, (4) Roubidoux, and (5) Jefferson City, Cotter, or Powell Formations, and by limestones of (6) Osagean and (7) Meramecian ages. Two samples were collected in each of 2 randomly selected sites in each of 6 randomly selected sampling localities in each of these 7 areas for a total of 168 samples. Twenty-five of the samples were split into 2 parts and then all 193 samples were arranged in a randomized sequence prior to analysis. Preliminary results of this work were published in Ebens (1973) and U.S. Geological Survey (1972e, 1973).

Residuum overlying the Bonneterre, Eminence, and Potosi Formations tends to be elevated in barium, lead, and zinc, and locally contains visible barite; therefore it was excluded from this compilation. Study conducted by Richard J. Ebens.

STUDY NO. 13

[Quaternary loess in Missouri]

By Jon J. Connor

Samples weighing about 2 kg each were collected from thick deposits of Quaternary loess in bluffs adjacent to the Mississippi and Missouri Rivers in Missouri in the fall of 1970. The 2 river courses were divided into 6 segments, each about 150 km in length; 2 localities were randomly selected in each segment and 2 samples were randomly collected from a single vertical section in each locality for a total of 24 samples. Preliminary results of this work were published in Ebens (1973) and U.S. Geological Survey (1972e). Study conducted by Jon J. Connor and Richard J. Ebens.

STUDY NO. 14

[Garden soils, vegetables, native plants, and uncultivated soils in central and south-central Georgia]

By Hansford T. Shacklette

This study and the following one were done in June and July 1965 and constitute a geochemical survey of two areas in Georgia that exhibit contrasting rates of cardiovascular mortality in humans. The counties sampled in this study were Bacon, Bleckley, Burke, Dodge, Emanuel, Jeff Davis, Jefferson, Jenkins, and Warren, all having high mortality rates. Vegetables and garden soils were sampled in 30 sites. Stems (terminal parts of branches 20–30 cm long) and leaves of native plants (trees and shrubs) and 3 soil horizons were also sampled at 30 sites. Selection of sampling sites, sampling methods, laboratory preparation and analysis of samples, and statistical treatment of the chemical data were discussed by Shacklette, Sauer, and Miesch (1970) and Shacklette, Erdman, and Keith (1973). Study conducted by Hansford T. Shacklette, Herbert I. Sauer, and A. T. Miesch.

STUDY NO. 15

[Garden soils, vegetables, native plants, and uncultivated soils in southern Georgia]

By Hansford T. Shacklette

This study was conducted as the corollary of Study No. 14. The counties sampled were Cherokee, Fannin, Forsyth, Gilmer, Hall, Murray, Pickens, Towns, and Union, all having extremely low mortality rates. The sampling plan, sampling media, sample preparation, and analysis were the same as described for Study No. 14. Study conducted by Hansford T. Shacklette, Herbert I. Sauer, and A. T. Miesch.

STUDY NO. 16

[Agricultural soils in Missouri]

By Ronald R. Tidball

The study was conducted with the cooperation of the Missouri Agricultural Extension Service in collecting samples. The surface horizon (0–15 cm depth) of cultivated agricultural soils at 10 sites in each of the 114 counties of the State was sampled during 1970. Each sample is a composite taken over a single field prior to planting. Analysis was made of air-dried soil material less than 2 mm in diameter, pulverized to –100-mesh particle size in a ceramic mill. Sixty of the 1,140 samples were split for estimation of analytical error and the entire suite of 1,200 was submitted to the laboratory in a randomized sequence. Sampling plan, analytical results, and plotted maps of the distribution of element concentrations were reported by U.S. Geological Survey (1972b–f, 1973) and Tidball (1973). Study conducted by Ronald R. Tidball.

STUDY NO. 17

[Crop plants and associated soils in Missouri]

By Hansford T. Shacklette

Mature corn grains and soybean seeds, and composite samples of the plow zone (0–15 cm) of cultivated soils, were collected in Missouri in September 1970. Insofar as possible, samples were taken at two randomly selected sites within each of five randomly selected 7½-minute quadrangles in each of the Floodplain Forest, Glaciated Prairie, Unglaciated Prairie, and Oak-hickory Forest vegetation-type areas in Missouri (fig. 2). Samples, including replicates (splits), were analyzed in a sequence random with respect to geographical origin. Sampling plan, results of chemical analyses, and statistical studies of the data were reported by U.S. Geological Survey (1972e, 1973) and Shacklette, Erdman, and Keith (1973). Study conducted by Hansford T. Shacklette, John R. Keith, and James A. Erdman.

STUDY NO. 18

[Soils and plants in Kentucky — I]

By RONALD R. TIDBALL

A reconnaissance study of the chemistry of soils and plants in Kentucky was made in the spring of 1965. Channel samples of the A, B, and C soil horizons were collected from profiles of Red-Yellow Podzolic soils. Randomly selected profile sites were located according to a hierarchical design, as follows: Two sites within a 2½-minute quadrangle, two 2½-minute quadrangles within a 7½-minute quadrangle within a 15-minute quadrangle, and two 15-minute quadrangles within a physiographic province. Samples were collected from 6 of the 12 physiographic provinces (Nos. 4, 5, 6, 7, 11, and 12) as defined by Bailey and Winsor (1964). Samples of mature stems (terminal parts of branches, about 30 cm in length) were also collected from both oak and hickory trees at each of the sites from which soil samples were collected. Fifty of the 288 soil samples and 30 of the 192 plant samples were split into 2 parts and the entire sample suite of each material was submitted to the laboratory in a randomized sequence. Study conducted by Ronald R. Tidball.

STUDY NO. 19

[Soils and plants in Kentucky — II]

By RONALD R. TIDBALL

This study used a sampling design based on the results of Study No. 18. Sampling was performed in the spring of 1967. Channel samples of the A horizon of representative profiles of Red-Yellow Podzolic soils were collected in Kentucky according to the following design. Eighteen 30-minute quadrangles were selected for sampling across southern Kentucky from long 84° to 88° W., and from lat 36° to 37° N. A random selection of sites was made as follows: Six 7½-minute quadrangles selected within each 30-minute quadrangle, one 2½-minute quadrangle within each 7½-minute quadrangle, and one site sampled within each 2½-minute quadrangle. Samples of mature stems (terminal parts of branches about 30 cm in length) were also collected from both oak and hickory trees at each site where soil was sampled. Thirty samples each of soil and plant material were split into 2 parts and the resulting sample suites of 138 soils and 276 plants were submitted to the laboratory in randomized sequence. Study conducted by Ronald R. Tidball.

STUDY NO. 20

[Native vegetation and uncultivated soils in Missouri]

By JAMES A. ERDMAN

This study was made in September and October 1970. The sampling plan was based on a hierarchical design in which the conceptual units at the top level were potential vegetation types as defined by Küchler (1964), with modifications (U.S. Geological Survey, 1972a, p. 18). The stratified sampling plan required the selection of 5 sites in each of 10 randomly selected 7½-minute quadrangles within each of the 6 vegetation-type areas in Missouri (fig. 2). Plant sampling was based on (a) ubiquitous (smooth sumac) or widespread (buckbrush) species in all vegetation-type areas, and (b) species characteristic of each vegetation type. Stems (terminal parts of branches) 10–30 cm in length of these species were collected at as many sites as possible, were dried and pulverized, and part of each sample was burned to ash for chemical analysis. The B horizon of uncultivated soil was sampled at each site, dried, pulverized, and analyzed. Fifty of the 950 plant samples and 50 of the 500 soil samples were split into 2 parts, and the resulting sample suites of 1,000 plants and 550 soils were analyzed in a sequence random with respect to geographic origin. Descriptions of the sampling plan, results of chemical analyses, plotted maps of the distribution of element concentrations, and statistical studies of the data were reported by U.S. Geological Survey (1972a–f, 1973), Erdman and Shacklette (1973), and Ebens and others (1973). Study conducted by James A. Erdman, Hansford T. Shacklette, and John R. Keith.

STUDY NO. 21

[Surficial materials in the conterminous United States]

By HANSFORD T. SHACKLETTE

As many as 1,000 samples of soils or other surficial materials, taken at a depth of approximately 20 cm from locations about 80 km apart on routes of travel across the United States were analyzed for 43 elements. Samples were collected during 1958–70 by personnel of the U.S. Geological Survey. The sampling program was designed to give estimates of the range of element abundance in surficial materials that were unaltered or very little altered from their natural condition. Even though most samples were collected in the vicinity of roads, the data for lead in this study are included in this report, because an independent study by Connor, Erdman, Sims, and Ebens (1970) had suggested that lead accumulation in subsurface soil 20 to 30 m laterally from the road surface could not be demonstrated by the analytical methods used. Results of this study were reported by Shacklette, Hamilton, Boerngen, and Bowles (1971), Shacklette, Boerngen, and Turner (1971), Shacklette, Boerngen, Cahill, and Rahill (1973), and Shacklette, Boerngen, and Keith (1974). Study conducted by Hansford T. Shacklette and Josephine G. Boerngen.

STUDY NO. 22

[Surficial materials, Longmont, Colorado, area]

By HARRY A. TOURTELOT

As a pilot study preparatory to investigating the geochemistry of the Front Range Urban Corridor (extending from Fort Collins south to Fountain, Colorado), 168 samples of surficial materials, 4 in each of 42 localities arranged in a grid pattern over twelve 7½-minute quad-

rangles, were collected and analyzed. These quadrangles were centered on Longmont and spanned the Corridor, from within the mountains eastward onto the plains. The surficial materials were collected during November 1971 through February 1972 and were sampled to a depth of 15 cm. They ranged from well-developed agricultural soils to unconsolidated sediments and rock disintegration products. Samples, including 60 replicates (splits), were analyzed in a sequence random with respect to geographical origin. Preliminary results of this study were reported by Tourtelot (1973). Study conducted by Harry A. Tourtelot.

STUDY NO. 23

[Garden vegetables and field corn in Wisconsin, Minnesota, and Iowa]

By Hansford T. Shacklette

A variety of vegetables and field corn was collected in September 1961, from up to 27 sampling sites in home and institutional gardens and commercial plantings, principally in Wisconsin. One home garden in Iowa and a cornfield in Minnesota, both near the Wisconsin boundary, were also sampled. For brevity, these collections are listed in the summary tables as being from Wisconsin only. The selection of gardens to sample was based on availability of the desired kinds of vegetables in a garden, the facility of obtaining permission to sample, and the time available. Large gardens at the county hospitals of Dane, Grant, Iowa, and Richland Counties, and a commercial truck farm in Racine County, were sampled; other sites were family gardens. Corn was sampled in fields in which the grains were mature at the time of the study. The vegetable samples were prepared as for table use (but without cooking), and the mature grains of corn were removed from the cob. The samples were dried, pulverized, and burned to ash, and the ash was analyzed by semiquantitative spectrographic and other methods. See also Shacklette, Erdman, and Keith (1973). Study conducted by Hansford T. Shacklette.

STUDY NO. 24

[Cedar in Missouri]

By James A. Erdman

Red cedar was sampled in August and September of 1969 at two randomly selected sites within each of five randomly selected 7½-minute quadrangles within each vegetation-type area of Missouri (fig. 2). The terminal 20–30 cm part of branches, including both stems and leaves, was collected and the samples were analyzed by spectrographic and other methods, as reported by U.S. Geological Survey (1972b), in a random sequence unknown to the analyst. Application of these data to a contamination study was reported by Ebens, Erdman, Feder, Case, and Selby (1973). Study conducted by James A. Erdman, Hansford T. Shacklette, and John R. Keith.

STUDY NO. 25

[Sagebrush and sagebrush, Wyoming and Montana]

By Jon J. Connor

Forty-eight samples of soil and sagebrush were collected in May 1973 from the Powder River Basin according to a hierarchical design. The basin was divided into 12 parts, each approximately 70 km on a side. Two townships were selected randomly from each part; a total of three sections were selected randomly in the two townships, and a total of four sampling sites were selected in the three sections. At each site a sample of the top 2 cm of undisturbed soil and a sample of the terminal stems and leaves of a living sagebrush were collected. Selected samples of each material were split into two parts and the samples in each resulting suite were analyzed in a randomized sequence. A few preliminary results of this study were given by Anderson, Keith, and Connor (1974). Study conducted by Jon J. Connor, John R. Keith, and Barbara M. Anderson.

METHODS OF ANALYSIS

A wide variety of analytical methods was used to generate the data underlying the tabulations in this report. In the earlier studies, the common metals in rocks and soils were generally determined by rapid spectrophotometric techniques (Shapiro and Brannock, 1962), or atomic absorption spectrophotometric methods (Shapiro, 1967). More recently, and particularly for studies in Missouri, many of these metals were analyzed by rapid X-ray fluorescence techniques. Trace-metal analysis in all work has relied heavily on both a semiquantitative emission spectrographic procedure slightly modified from that described by Myers, Havens, and Dunton, and a direct-reading emission spectrographic technique (Havens and Myers, 1973). Elements in plant ash not measured spectrographically were measured by atomic absorption, colorimetric, selective-ion electrode, or other special methods as listed in table 1. All analytical work was performed in laboratories of the U.S. Geological Survey. The analytical technique used for each entry in the summary tables 5–53 is identified by the appropriate number listed in table 1.

Forty-eight elements are listed in the summary tables. Of these, about 10 were detected in only a relatively few samples of only a few studies. Approximate limits of determination for a variety of elements commonly looked for in spectrographic work but seldom or never detected are listed in table 2.

For various reasons, 24 of the 92 naturally occurring elements were never analyzed for in any of these studies. They are the six noble gases (helium, neon, argon, krypton, xenon, and radon), nitrogen, oxygen, sulfur, chlorine, bromine, technetium, ruthenium, rhodium, cesium, promethium, osmium, iridium, polonium, astatine, francium, radium, actinium, and protactinium.

TABLE 1.—*Analytical methods used*

[Number in the first column identifies the method used for determining chemical data reported in tables 5-55. Leaders (...) indicate no data available]

No.	Name of method	Materials analyzed, and elements commonly reported	Principal references	Remarks
1	Six-step emission spectrographic.	Geologic materials, soils, and plant ash: Ag, B, Ba, Be, Ce, Co, Cr, Cu, Ga, Fe, La, Mn, Mo, Nd, Ni, Pb, Sc, Sn, Sr, Ti, V, Y, Yb, and Zr. Geologic materials and soils only: Nb. Geologic materials and plant ash only: Ca. Soils only: Bi and Sb. Soils and plant ash only: Al and W. Plant ash only: Mg.	Myers, Havens, and Dunton, 1961	Concentrations reported as midpoints of six geometric classes per order of magnitude.
2	Direct-reading emission spectrographic.	Geologic materials, soils, and plant ash: B, Ba, Be, Cr, Cu, La, Mn, Mo, Pb, and Y. Geologic materials only: Fe and Zn. Geologic materials and soils only: Co, Ga, Nb, Ni, Sc, Sr, V, and Zr. Geologic materials and plant ash only: Ti. Plant ash only: Ag.	Havens and Myers, 1973	Concentrations reported as actual values, rather than as classes of values.
3	Atomic absorption, flame	Geologic materials, soils, and plant ash: Cd, Li, Mg, Na, and Zn. Geologic materials only: Ag. Plant ash only: Ca, Co, Fe, K, and Rb.	Ward, Nakagawa, Harms, and Van Sickle, 1969; Shacklette, Boerngen, Cahill, and Rahill, 1973.	Second reference describes methods for Cd and Li only.
4	Atomic absorption, flameless.	Geologic materials, soils, and dry plants: Hg	Vaughn and McCarthy, 1964.	Unpublished modification used for dry plants.
5	X-ray fluorescence	Geologic materials and soils only: Al, Ca, Fe, K, P, Se, and Si	Liebhofsky, Pfeiffer, Winslow, and Zemany, 1960.	
6	Colorimetric	Geologic materials, soils, and dry plants: As. Soils and plant ash only: Cu, P, Pb, and Zn. Plant ash only: Si.	Ward, Lakin, Canney, and others, 1963.	Use for Pb, Cu, and Zn discontinued in 1967.
7	Catalytic	Dry plants only: I	Cuthbert and Ward, 1964.	Oxygen combustion-ceric sulfate method.
8	Neutron activation	Geologic materials only: Au. Geologic materials and soils only: I. Soils only: Th and U.	Rowe and Simon, 1968	Used in conjunction with fire assay for Au.
9	Selective-ion electrode	Geologic materials, soils, and dry plants: F	Ingram, 1970	
10	Gasometric	Geologic materials and soils only: Carbonate C	Scott, 1950	
11	Calculated	Geologic materials and soils only: Organic C	.....	Total C minus carbonate C.
12	Flame emission (photometric).	Soils only: Na. Soils and plant ash only: K	Shapiro and Brannock, 1962.	Use discontinued in 1967.
13	EDTA titration	Soils and plant ash only: Ca and Mg	..... do	Use discontinued in 1967.
14	2-3 diaminonaphthalene	Dry plants only: Se	.....	Unpublished method.
15	Gravimetric	Dry plants only: Ash	Ward, Lakin, Canney, and others, 1963.	Aliquots of dry plants weighed, burned to ash, and the ash weighed and calculated as percentage of dry weight.
16	"Rapid rock"	Geologic materials only: Carbonate C and Mn. Geologic materials and soils only: Al, Ca, Fe, K, Mg, Na, P, Si, and Tri.	Shapiro, 1967; Shapiro and Brannock, 1962.	All elements determined in aliquots of a single solution of the sample.

TABLE 2.—*Elements commonly looked for, but rarely or never detected, by multi-element spectrographic analysis, and their approximate lower limits of determination in parts per million*

[Values apply to analyses by the semiquantitative spectrographic method, except values in parentheses, which apply to analyses by the quantitative (direct-reading) spectrographic method. Leaders (—) in a figure column indicate that the element is commonly detected in the sample material listed in the column heading]

Element	Material analyzed: Rocks and soils	Material analyzed: Plant ash
Antimony	150 (300)	300
Arsenic	1,000	2,000
Bismuth	10 (10)	20
Cadmium	20 (70)	50
Cerium	150	300
Dysprosium	[1]50	[1]100
Erbium	50	100
Europium[2]	100	200
Gadolinium	[1]50	[1]100
Gallium	—	5
Germanium	10 (50)	20
Gold	20	50
Hafnium	100	200
Holmium	[1]20	[1]50
Indium	10 (10)	20
Lithium	50	100
Lutecium	[1]50	[1]70
Neodymium	[1]70	[1]70
Niobium	10	20
Palladium	1 (5)	2
Platinum	30	70
Praseodymium	[1]100	[1]200
Rhenium	30 (70)	70
Samarium	[1]100	[1]200
Silver	.5 (2)	.5
Scandium	—	5
Tantalum	200	500
Tellurium	2,000	5,000
Terbium	[1]300	[1]700
Thallium	50 (50)	500
Thorium	200	500
Thulium	[1]20	[1]50
Tin	10 (20)	15
Tungsten	100 (300)	500
Uranium	500	1,000
Zinc	200 (300)	—

[1]Looked for if yttrium is greater than 50 ppm.
[2]Looked for if lanthanum or samarium is found.

The total elemental variation observed in a specific study always includes variation due to laboratory ("analytical") procedures as well as variation due to natural effects. The inclusion of hidden and randomly sequenced sample splits in many of the laboratory submittals provided data for the estimation of total laboratory variance from the equation:

$$S_e^2 = \frac{\sum_{i=1}^{n}(X_{1i} - X_{2i})^2}{2n} \qquad (1)$$

where S_e^2 represents the error variance, X_{1i} and X_{2i} represent the concentrations (or their logarithms) of an element in the two splits of the ith sample and n is the number of samples split. Where an error was not formally defined, it resides in the estimate of total variability and remains unknowable.

GEOCHEMICAL SUMMARIES

ORGANIZATION AND USE OF DATA

The geochemical summaries tabulated herein are alphabetically arranged by the English spelling of each element. Summaries for each element are presented, as appropriate, for each of four broad environmental categories—rocks, unconsolidated geologic deposits, soils, and plants. Listed within each category are the summary results for one or more individual studies. Studies on rocks and unconsolidated geologic deposits are grouped by gross lithologic character. Soils are subdivided into those under active cultivation and those not under active cultivation when sampled; within each group, soil studies are listed by horizon or depth. In Studies 10 and 22, soils from both cultivated and uncultivated sites were included without differentiation. Plants are grouped as cultivated or native species and are listed within either group by their common names; scientific names and plant parts sampled are given in tables 3 and 4. For cultivated plants, entries in the summary tables are given for analysis of the plant as commonly prepared for eating but prior to cooking. All entries in the summary tables are given a general location, commonly the State.

Each entry in each table is identified by a study number, with which the user may find a brief description of the work in the section entitled "Descriptions of Field Studies," and a number identifying the analytical method used (from table 1). Also given are the following: a ratio, which indicates the number of samples in which the element was determined in relation to the total number analyzed; the mean, which estimates the most probable concentration to be expected in the analyzed material; the deviation, a factor which indicates the degree of variability observed; the error, a factor which indicates the reproducibility of the analytical method; and finally, the range of concentrations observed in the study.

Geometric and arithmetic means, standard deviations, standard errors, and observed ranges are given in units of percent, parts per million (ppm), or parts per billion (ppb). A part per million is 10^{-4} percent and a part per billion is 10^{-7} percent. Geometric deviations and geometric errors are factors.

The mean for each entry in the summary tables is commonly give to two significant figures. It is conventional in geochemical summaries to give an arithmetic average for the mean, and a few such entries

TABLE 3.—*Percentage of ash obtained by burning dry material of cultivated plants*

[Explanation of column headings: Study No. refers to study described in text. Plant parts designated as S, stems; L, leaves; F, fruits; SD, seeds; G, grains; R, roots; T, tubers; and B, bulbs. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (—) in figure column indicate no data available]

Common and scientific name, and collection locality	Study No.	Plant part	Mean (percent)	Deviation	Error	Observed range (percent)
Asparagus (*Asparagus officinalis* L.);						
Wisconsin	23	S	8.2	1.17	—	6.3–10
Bean, lima (*Phaseolus limensis* Macfad.);						
Georgia	14	SD	5.5	1.13	—	4.4– 7.2
	15	SD	6.7	1.18	—	5.4–10
Bean, snap (*Phaseolus vulgaris* L.); Georgia	14	F	8.4	1.34	—	4.8–15
	15	F	6.8	1.14	—	5.3– 8.9
Beet, red (*Beta vulgaris* L.); Wisconsin	23	R	9.5	1.64	—	5.5–14
Blackeyed pea (*Vigna sinensis* Endl.);						
Georgia	14	SD	5.9	1.26	—	4.2–12
	15	SD	5.2	1.09	—	4.7– 5.8
Cabbage (*Brassica oleracea* L.);						
Georgia	14	L	19	1.41	—	9.6–35
	15	L	21	1.16	—	15 –29
Wisconsin	23	L	9.4	1.19	—	7.0–13
Carrot (*Daucus carota* var. *sativa* DC.);						
Wisconsin	23	R	9.8	1.38	—	5.3–15
Corn (*Zea mays* L.);						
Georgia	14	G	4.4	1.47	—	2.3– 9.0
	15	G	3.7	1.55	—	2.0– 7.8
Missouri						
Floodplain Forest	17	G	1.8	1.17	1.09	1.4– 2.2
Glaciated Prairie	17	G	1.6	1.23	1.09	1.0– 2.1
Unglaciated Prairie	17	G	1.5	1.19	1.09	1.3– 2.1
Oak-hickory Forest	17	G	1.6	1.19	1.09	1.2– 2.0
Wisconsin	23	G	1.8	1.14	—	1.3– 6.3
Cucumber (*Cucumis sativus* L.); Wisconsin	23	F	11	1.25	—	8.3–14
Onion (*Allium cepa* L.); Wisconsin	23	B	4.8	1.11	—	4.3– 5.5
Pepper, sweet (*Capsicum frutescens* var. *grossum* Bailey); Wisconsin	23	F	7.0	1.08	—	6.5– 7.8
Potato (*Solanum tuberosum* L.); Wisconsin	23	T	5.0	1.31	—	3.8– 8.5
Tomato (*Lycopersicum esculentum* Mill.);						
Georgia	14	F	11	1.40	—	4.6–20
	15	F	9.8	1.20	—	4.9–13
Soybean (*Glycine max* Merr.); Missouri						
Floodplain Forest	17	SD	5.1	1.10	1.09	4.3– 5.8
Glaciated Prairie	17	SD	5.5	1.06	1.09	4.9– 6.0
Unglaciated Prairie	17	SD	5.3	1.06	1.09	4.8– 5.8
Oak-hickory Forest	17	SD	5.2	1.07	1.09	4.6– 5.8

here do so; an example is aluminum in cultivated surface horizon soils of Missouri (table 5, Study No. 16). However, the tendency for elements in natural materials, particularly trace elements, to exhibit positively skewed frequency distributions, suggests that the geometric mean is the more proper measure of central tendency. The geometric mean is the antilog of the arithmetic mean of the logarithmic values and, for lognormal distributions, the geometric mean is the mode.

A common problem in trace-element summaries is the necessity to summarize data which contain non-numeric concentration values such as "trace" or "less than" some specified limit. Such data are said to be censored, and, under such circumstances, the mean has been computed using special procedures described by Cohen (1959) and applied to geochemical problems by Miesch (1967b). These procedures involve an adjustment of the summary statistics computed for the non-censored part of the data. For some entries, censoring is so severe that such adjustment is unreliable or even impossible. Under these circumstances, the median of the distribution is given as the mean, or the mean is simply listed as "less than" some limiting lower value.

The use of special procedures to quantify estimates of the central tendency where part of the data is censored sometimes leads to estimates of the mean at levels below the limit of detection. For example, aluminum in dolomite of the Sauk sequence in Missouri and Arkansas (table 5, Study No. 4) is estimated to have a mean of 0.30 percent although the lowest measured concentration in 48 samples was 0.53 percent. This feature of the data analysis obviously permits a greater utilization of data which may be initially viewed as rather limited because of analytical constraints.

For those rare entries where the arithmetic average is given for the mean, it is also thought to reflect an unbiased estimate of elemental abundance. Where the geometric mean is given, the abundance may be estimated from the

TABLE 4.—*Percentage of ash obtained by burning dry material of native plant species*

[Explanation of column headings: Study No. refers to study described in text. Plant part designated as S, stems; L, leaves; and SL, stems and leaves combined. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error combined in laboratory procedures. Leaders (—) in figure columns indicate no data available]

Common and scientific name, and collection locality	Study No.	Plant part	Mean (percent)	Deviation	Error	Observed range (percent)
Black cherry (*Prunus serotina* Ehrh.);						
Georgia	14	S	2.0	1.71	—	0.19– 5.2
	15	S	2.3	1.30	—	1.3 – 5.1
	14	L	5.4	1.22	—	2.9 – 7.6
	15	L	6.5	1.21	—	4.8 – 9.6
Blackgum (*Nyssa sylvatica* Marsh.);						
Georgia	14	S	2.4	1.26	—	1.5 – 4.4
	15	S	2.8	1.21	—	2.0 – 4.1
	14	L	4.3	1.25	—	2.5 – 6.6
	15	L	5.9	1.18	—	4.8 – 9.1
Buckbush (*Symphoricarpos orbiculatus* Moench); Missouri						
Glaciated Prairie	20	S	6.0	1.16	1.10	4.6 – 8.5
Unglaciated Prairie	20	S	5.9	1.27	1.10	3.8 – 8.8
Cedar Glade	20	S	5.1	1.15	1.10	4.5 – 6.8
Oak-hickory Forest	20	S	6.3	1.17	1.10	5.5 – 8.0
Oak-hickory-pine Forest	20	S	5.6	1.14	1.10	4.5 – 6.3
Cedar (*Juniperus virginiana* L.); Missouri						
Cedar Glade	20	SL	6.0	1.16	—	4.6 – 8.5
Glaciated Prairie	24	SL	5.9	1.27	1.10	3.8 – 8.8
Unglaciated Prairie	24	SL	5.1	1.15	1.10	4.5 – 6.8
Cedar Glade	24	SL	5.9	1.09	1.10	5.3 – 6.8
Oak-hickory Forest	24	SL	6.3	1.17	1.10	5.5 – 8.0
Oak-hickory-pine Forest	24	SL	5.6	1.14	1.10	4.5 – 6.3
Hickory, pignut (*Carya glabra* (Mill.) Sweet); Kentucky	18	S	4.5	1.33	1.10	2.0 – 7.3
	19	S	5.3	1.28	1.05	2.8 –11
Hickory, shagbark (*Carya ovata* (Mill.) Koch); Kentucky	18	S	4.2	1.32	1.10	2.5 – 7.5
	19	S	5.0	1.30	1.05	2.9 – 8.0
Missouri						
Oak-hickory Forest	20	S	5.3	1.29	1.10	3.6 – 9.0
Oak-hickory-pine Forest	20	S	5.1	1.77	1.10	4.1 – 6.1
Oak, black (*Quercus velutina* Lam.); Kentucky	18	S	3.6	1.25	1.05	2.4 – 6.2
	19	S	3.9	1.20	1.05	2.5 – 5.8
Oak, post (*Quercus stellata* Wang.); Missouri	20	S	4.2	1.31	1.10	2.5 – 8.4
Oak, red (*Quercus rubra* L.); Kentucky	18	S	3.6	1.28	1.05	2.0 – 4.9
	19	S	3.7	1.32	1.05	2.5 – 6.6
Oak, white (*Quercus alba* L.)						
Kentucky	18	S	3.3	1.24	1.05	2.0 – 4.5
	19	S	3.5	1.20	1.05	2.2 – 5.5
Missouri						
Oak-hickory Forest	20	S	3.6	1.28	1.10	2.4 – 7.6
Oak-hickory-pine Forest	20	S	3.4	1.14	1.10	2.4 – 4.7
Oak, willow (*Quercus phellos* L.); Missouri						
Floodplain Forest	20	S	2.4	1.29	1.10	1.4 – 4.2
Persimmon (*Diospyros virginiana* L.);						
Georgia	14	S	3.1	1.23	—	2.2 – 5.4
	15	S	3.0	1.18	—	2.2 – 4.3
	14	L	6.0	1.27	—	3.4 – 9.5
	15	L	7.3	1.27	—	5.2 –13
Pine, shortleaf (*Pinus echinata* Mill.); Missouri	20	SL	2.7	1.23	1.10	1.7 – 4.2
Sagebrush (*Artemisia tridentata* Nutt.); Powder River Basin, Wyoming and Montana	25	SL	5.8	1.19	—	3.3 – 8.8
Sassafras (*Sassafras albidum* (Nutt.) Nees);						
Georgia	14	S	1.9	1.31	—	1.2 – 3.7
	15	S	1.9	1.26	—	1.1 – 3.6
	14	L	4.7	1.21	—	3.3 – 5.9
	14	L	5.7	1.13	—	4.6 – 6.8
Sumac, smooth (*Rhus glabra* L.); Missouri						
Floodplain Forest	20	S	3.5	1.19	1.10	2.7 – 5.2
Glaciated Prairie	20	S	4.2	1.19	1.10	2.8 – 6.7
Unglaciated Prairie	20	S	3.8	1.18	1.10	2.1 – 5.4
Cedar Glade	20	S	3.6	1.18	1.10	2.5 – 4.8
Oak-hickory Forest	20	S	3.6	1.18	1.10	2.7 – 4.9
Oak-hickory-pine Forest	20	S	3.4	1.18	1.10	2.1 – 5.6

TABLE 4.—*Percentage of ash obtained by burning dry material of native plant species*—Continued

Common and scientific name, and collection locality	Study No.	Plant part	Mean (percent)	Deviation	Error	Observed range (percent)
Sumac, winged (*Rhus copallina* L.): Georgia	14	S	3.6	1.22	—	2.5 - 5.4
	15	S	3.8	1.24	—	2.5 - 6.1
	14	L	4.6	1.20	—	2.8 - 6.2
	15	L	4.8	1.32	—	2.7 - 9.6
Sweetgum (*Liquidambar styraciflua* L.):						
Georgia	14	S	4.8	1.32	—	3.1 - 7.7
	15	S	4.1	1.37	—	2.6 - 9.0
	14	L	5.6	1.15	—	4.0 - 7.2
	15	L	5.6	1.21	—	4.3 - 8.2
Missouri						
Floodplain Forest	20	S	4.6	1.43	1.10	2.0 -12

following relation:

$$t = \tau M, \qquad (2)$$

where t estimates the abundance (as Sichel's t, see Miesch, 1967b), M is the geometric mean, and τ is an adjustment factor and is read from figure 3. For example, aluminum in the sandstones of the Sauk sequence, Western United States (table 5, Study No. 3), is estimated to have a geometric mean of 0.77 percent and a geometric deviation of 2.49. These statistics are based on 400 analyses.[1] Reading from figure 3, where D=2.49 and n=400, τ is estimated to be 1.5 and t (abundance) from equation (2) is estimated as 1.16 percent aluminum.

Finally, most of the element concentrations in plant tissue were summarized on an ash weight basis. The user who wishes to convert the mean element concentration in ash to a dry weight basis may apply the following formula:

$$M_D = (M_A \times M_P) / 100, \qquad (3)$$

where M_D approximates the mean in dry weight, M_A is the mean in ash weight, and M_P is the mean of the percent ash measured in that study (from tables 3 or 4). For example, asparagus stems collected in Wisconsin (table 5, Study No. 23) exhibit a mean aluminum concentration in ash of 0.40 percent, and a mean ash content (from table 3) of 8.2 percent. Based on equation (3) the approximate expected concentration of aluminum in dry weight is 0.033 percent.

Equally as important as the mean in background geochemical studies, however, is the magnitude of the scatter to be expected about the mean. A useful measure of this scatter in lognormal distributions is the geometric deviation, a factor which may be used to estimate the range of variation expected for any element in any unit. The geometric deviation is the antilog of the standard deviation of the logarithmic values. About 68 percent of the samples in a randomly selected suite should fall within

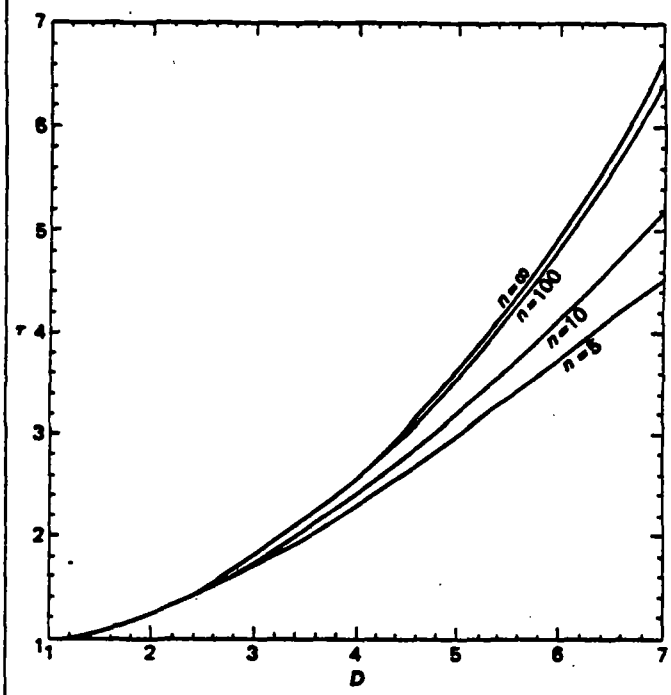

FIGURE 3.—Graphs of τ as a function of number of analyses, n, and the geometric deviation, D (from Miesch, 1967b).

the limits, M/D and $M \cdot D$, where M stands for the geometric mean and D stands for geometric deviation. About 95 percent should fall between M/D^2 and $M \cdot D^2$, and about 99.7 percent between M/D^3 and $M \cdot D^3$. For example, aluminum in granites of Precambrian age in Missouri (table 5, Study No. 1) has a geometric mean of 6.7 percent and a geometric deviation of 1.06. Thus, the most likely concentration for aluminum in a suite of randomly selected granite samples collected in outcrop in the St. Francois Mountains of southeastern Missouri is 6.7 percent; in addition, about 68 percent of the collected samples, if analyzed by emission spectrographic techniques in the U. S. Geological Survey laboratories, should range from about 6.3 (M/D) to about 7.1 ($M \cdot D$) percent aluminum. About 95 percent will fall between 6.0 (M/D^2)

[1] In this particular study, the 400 analyses are of only 200 samples and, therefore, are not independent. However, the curves on figure 3 show that use of n=400 or n=200 gives essentially the same value of τ.

and 7.5 $(M \cdot D^2)$ percent aluminum, and more than 99 percent between 5.6 (M/D^2) and 8.0 $(M \cdot D^2)$.

The deviation in censored data has been computed using procedures described by Cohen (1959) and Miesch (1967b). A number of entries in the tables of this report give no estimate of variability because of insufficient data. Nevertheless, for some of these entries, a rough estimate of the upper limit of the 68 and 95 percent ranges may be obtained. About 16 percent of the samples in a randomly collected suite are expected to fall above the 68-percent range, and about 2.5 percent should fall above the 95-percent range. Thus, where element concentrations are censored on the low side and no geometric deviation is listed, detection ratios of 0.16 and 0.025 indicate that the limit of determination approximates the upper end of the 68- and 95-percent concentration ranges, respectively, for that element in that material. For example, aluminum in chert of Mississippian age in Missouri, Oklahoma, and Arkansas (table 5, Study No. 7) was detected at a concentration of 0.53 percent in only 5 percent (1 of 20) of the samples analyzed. This suggests that the limit of analytical determination (0.53 percent) lies somewhere between the upper end of the 68-percent range and the upper end of the 95-percent range, and probably very close to the latter.

As already stated, the deviation listed for each study includes variation arising from laboratory procedures as well as variation arising from nature. Where the sampling design so permits, an estimate of that part of the total observed variation due solely to laboratory effects is given as the error, and an estimate of the variation attributed solely to natural effects may be computed from:

$$D_n = \text{antilog} \sqrt{(\log D)^2 - (\log E)^2}, \qquad (4)$$

where D_n estimates the geometric deviation corrected for laboratory effects, and D and E are the geometric deviation and geometric error, respectively, taken from the summary tables. For entries consisting of the arithmetic mean, the standard deviation and the standard error, variation due to natural effects is estimated as:

$$D_n = \sqrt{(D)^2 - (E)^2}, \qquad (5)$$

where D_n estimates the standard deviation corrected for laboratory effects, and D and E are the standard deviation and the standard error, respectively.

For example, D_n for aluminum in the Missouri granites (table 5, Study No. 1) is estimated from equation (4) to be 1.04, and the expected approximate 68, 95, and 99.7 percent ranges corrected for analytical variation are 6.4–7.0, 6.2–7.2, and 6.0–7.5 percent aluminum, respectively. D_n for aluminum in surface horizons of cultivated soils of Missouri (table 5, Study No. 16) is estimated from equation (5) as 1.14, and the expected approximate 68, 95, and 99.7 percent ranges corrected for analytical variation are 3.0–5.2, 1.8–6.4, and 0.7–7.5 percent aluminum, respectively.

For some entries, the listed error is larger than the listed deviation and D_n cannot be calculated. This occurs because the deviation and the error are themselves only estimates and are each subject to errors inherent in estimation. Where variation due to laboratory procedures forms a large part of the total observed variation, the estimate of the error may exceed the estimate of the total variability. In these circumstances, the only conclusion to be drawn is that the material under study is relatively uniform in composition and further attempts to examine its natural variability must be based on laboratory procedures more precise than those used here.

All entries lacking an estimate of the error must be used judiciously. Little can be said about the natural variation of these materials without some assumptions as to the magnitude of the laboratory effects that might be present.

CONCLUDING REMARKS

The summary statistics in this report are not those conventionally used and an attempt has been made to permit the user to estimate a "reasonable range" of concentrations, using the estimated deviation. The data given in the summary tables (tables 5–53) are meant to provide a realistic guide to expected elemental concentrations in a variety of common environmental materials under "ordinary" or natural conditions.

The reader contemplating use of these data should bear in mind several points. Because the data were analyzed by a variety of analytical methods over a long period of time, there may well be analytical bias from entry to entry, but no work has been done to measure any such potential bias. Also, although the summary data for each entry are meant to reflect something of the natural geochemical character of that entry, a collection of entries in any given category must not be viewed as representative of that category as a whole. The entries are heavily weighted to specific areas of the country. For this reason, comparisons among major categories should be made cautiously. In addition, all data in these tables are based on total element content, regardless of the forms in which the element may occur in nature.

However, one comparison in these data that is of great interest to environmental geochemistry is the marked difference in average concentration for a host of elements measured in both vegetables and native plant material. Expected concentrations of barium, calcium, lead, manganese, sodium, strontium, titanium, and yttrium are clearly higher in native trees and shrubs than in garden foodstuffs prepared for eating. These differences undoubtedly reflect the contrast in plant parts (terminal stems versus roots, leaves, and seeds), but some of the

difference may well reflect a tendency for perennial plants to "build up" concentrations over the years (Shacklette, Sauer, and Miesch, 1970, p. 25).

Another aspect to keep in mind when using these summaries is that the long agricultural and industrial history of this country may well have altered the "natural" background for some elements in some materials. The widespread atmospheric effects attendant upon combustion of leaded gasoline, for example, conceivably may alter the element content of plant tissue collected far from any pollution sources. Likewise, agricultural practices may affect trace elements in vegetables, but there seems to be no alternative to collecting vegetables as they are grown and terming their element burdens "background." The summary data on lead are probably most suspect in this sense.

Finally, the use of the summary statistics assumes some specific features about expected frequency distributions of elements in mature. To the extent that such assumptions are not valid, predictions of the expected concentration and expected range will be in error. In particular, entries exhibiting large deviations (near 5.0 or greater) may reflect unusual distributions. The most commonly encountered problem is probably that of the presence of multiple modes in the distribution.

Perhaps the greatest use of these data will be to point up the large compositional diversity to be expected routinely in ordinary materials. Even though a large part of the studies used in this compilation was undertaken in only four States (Georgia, Kentucky, Missouri, and Wisconsin), the data on sedimentary rocks, soils, native plants, and vegetables clearly illustrate this diversity. The following summary tabulates the ratio of the highest mean to the lowest mean for six elements in the seven common materials reported on in this paper:

Material	Element ratios					
	Ba	Cu	Fe	Mn	K	Sr
Rocks, sandstone	4.5	7.0	21	10	8.0	7.3
shale	2.3	10	2.5	6.5	2.5	2.2
carbonate	29	14	240	20	5.3	9.9
Soils, uncultivated	13	3.9	2.0	7.5	41	42
cultivated	8.6	3.8	9.1	18	36	28
Plant ash, vegetable	30	11	5.1	8.4	2.3	63
native species	41	5.4	11	30	7.9	17

The greatest contrast in the above summary is reflected in a ratio of 240 for the element iron in carbonate rocks. This extreme reflects the difference between iron-rich siderite (Study No. 11) and iron-poor limestone and dolomite, but other trace elements, like copper and manganese, are still seen to be highly variable within each of the three common sedimentary rock types. Expected differences within the two soil categories and the two kinds of vegetation also can be extreme, as for potassium or strontium in soils and barium or strontium in plant ash. The differences reflected in the above ratios include the effects of laboratory procedures, but the pitfalls of assigning some single average concentration to an entire category of material (such as "carbonate rocks" or "soil"), as tends to be common in published tables of element abundances, are quite apparent.

REFERENCES CITED

Anderson, B. M., Keith, J. R., and Connor, J. J., 1974, Geochemical variability of soils in the Powder River Basin: Geol. Soc. America Abs. with Programs, v. 6, no. 5, p. 422–423.

Bailey, H. H., and Winsor, J. H., 1964, Kentucky soils: Kentucky Univ. Agric. Exp. Station, Misc. Bull. 308, 174 p.

Clarke, F. W., 1924, The data of geochemistry: U.S. Geol. Survey Bull. 770,841 p.

Cohen, A. C., Jr., 1959, Simplified estimators for the normal distribution when samples are singly censored or truncated: Technometrics, v. 1, no. 3, p. 217–237.

Connor, J. J., 1969, A geochemical discriminant for sandstones of Mississippian and Pennsylvanian age in Kentucky: Colorado School Mines Quart., v. 64, no. 3, p. 17–34.

Connor, J. J., and Ebens, R. J., 1972, Geochemical variation in Pennsylvanian shale: Geol. Soc. America Abs. with Programs, v. 4, no. 6, p. 314–315.

Connor, J. J., Erdman, J. A., Sims, J. D., and Ebens, R. J., 1970, Roadside effects on trace element content of some rocks, soils, and plants of Missouri, *in* Hemphill, D. D., ed., Trace substances in environmental health–IV: Univ. Missouri, p. 26–34.

Connor, J. J., Feder, G. L., Erdman, J. A., and Tidball, R. R., 1972, Environmental geochemistry in Missouri — A multidisciplinary approach, *in* Earth sciences and the quality of life, Symposium 1: Internat. Geol. Cong., 24th, Montreal, Canada, 1972, p. 7–14.

Connor, J. J., and Myers, A. T., 1973, How to sample a mountain: Am. Soc. for Testing and Materials Spec. Tech. Pub. 540, p. 30–36.

Connor, J. J., and Trace, R. D., 1970, Outlier of Caseyville Sandstone near Princeton, Kentucky may be Bethel Sandstone, *in* Geological Survey research 1970: U.S. Geol. Survey Prof. Paper 700-D, p. D33–D35.

Cuthbert, Margaret, and Ward, F. N., 1964, Determination of iodine in vegetation, *in* Geological Survey research 1964: U.S. Geol. Survey Prof. Paper 501-C, p. C154–C156.

Durum, W. H., Hem, J. D., and Heidel, S. G., 1971, Reconnaissance of selected minor elements in surface waters of the United States, October 1970: U.S. Geol. Survey Circ. 643, 49 p.

Ebens, R. J., 1973, Geochemistry of loess and carbonate residuum in Missouri: Geol. Soc. America Abs. with Programs, v. 5, no. 4, p. 312.

Ebens, R. J., Erdman, J. A., Feder, G. L., Case, A. A., and Selby, L. A., 1973, Geochemical anomalies of a claypit area, Callaway County, Missouri, and related metabolic imbalance in beef cattle: U.S. Geol. Survey Prof. Paper 807, 24 p.

Erdman, J. A., and Shacklette, H. T., 1973, Concentrations of elements in native plants and associated soils of Missouri: Geol. Soc. America Abs. with Programs, v. 5, no. 4, p. 313.

Goldschmidt, V. M., 1954, Geochemistry: Oxford, Clarendon Press, 730 p.

Havens, R. G., and Myers, A. T., 1973, Direct-reader spectrometric analysis, *in* Vine, J. D., and Tourtelot, E. B., Geochemistry of lower Eocene sandstones in the Rocky Mountain region: U.S. Geol. Survey Prof. Paper 789, 36 p.

Howe, W. B., and Koenig, J. W., eds. 1961, The stratigraphic succession in Missouri: Rolla, Missouri Geol. Survey and Water Resources Div., v. 40, 2d ser., 185 p.

Ingram, B. L., 1970, Determination of fluoride in silicate rocks without separation of aluminum, using a specific ion electrode: Anal. Chem., v. 42, no. 14, p. 1825–1827.

Jenne, E. A., 1972, Mercury in waters of the United States, 1970–71: U.S. Geol. Survey open-file rept., 14 p.

Krumbein, W. C., and Slack, H. A., 1956, Statistical analysis of low-level radioactivity of Pennsylvania black fissile shale in Illinois: Geol. Soc. America Bull., v. 67, no. 6, p. 739–761.

Küchler, A. W., 1964, Potential natural vegetation of the conterminous United States: Am. Geog. Soc. Spec. Pub. 36, plus map.

Lishofsky, H. A., Pfeiffer, H. G., Winslow, E. H., and Zemany, P. D., 1960, X-ray absorption and emission in analytical chemistry: New York and London, John Wiley & Sons, Inc., 357 p.

Livingstone, D. A., 1963, Chemical composition of rivers and lakes, chap. G *of* Fleischer, Michael, ed., Data of geochemistry [6th ed.]: U.S. Geol. Survey Prof. Paper 440-G, 64 p.

Mason, Brian, 1958, Principles of geochemistry [2d ed.]: New York, John Wiley & Sons, Inc., 310 p.

Minch, A. T., 1967a, Theory of error in geochemical data: U.S. Geol. Survey Prof. Paper 574-A, 17 p.

———1967b, Methods of computation for estimating geochemical abundances: U.S. Geol. Survey Prof. Paper 574-B, 15 p.

———1972, Sampling problems in trace element investigations of rocks: New York Acad. Sci. Annals, v. 199, p. 95–104.

Myers, A. T., Havens, R. G., and Dunson, P. J., 1961, A spectrochemical method for the semiquantitative analysis of rocks, minerals, and ores: U.S. Geol. Survey Bull. 1084-I, p. 1207–1229.

Parker, R. L., 1967, Composition of the earth's crust, chap. D *of* Fleischer, Michael, ed., Data of geochemistry, [6th ed.]: U.S. Geol. Survey Prof. Paper 440-D, 19 p.

Rankama, Kalervo, and Sahama, T. G., 1955, Geochemistry: Chicago, Chicago Univ. Press, 912 p.

Rowe, J. J., and Simon, F. O., 1968, The determination of gold in geologic materials by neutron-activation analysis using fire assay for radio-chemical separations: U.S. Geol. Survey Circ. 599, 4 p.

Scott, W. W., 1958, Standard methods of chemical analysis, volume 1 [5th ed.]: New York, D. Van Nostrand Co., Inc., 1234 p.

Shacklette, H. T., Boerngen, J. G., Cahill, J. P., and Rahill, R. L., 1973, Lithium in surficial materials of the conterminous United States and partial data on cadmium: U.S. Geol. Survey Circ. 673, 8 p.

Shacklette, H. T., Boerngen, J. G., and Keith, J. R., 1974, Selenium, fluorine, and arsenic in surficial materials of the conterminous United States: U.S. Geol. Survey Circ. 682, 14 p.

Shacklette, H. T., Boerngen, J. G., and Turner, R. L., 1971, Mercury in the environment—Surficial materials of the conterminous United States: U.S. Geol. Survey Circ. 644, 5 p.

Shacklette, H. T., Erdman, J. A., and Keith, J. R., 1973, Trace elements in unprocessed plant foodstuffs, *in* Savage, E. P., ed., 2d Conf. on Environmental Chemicals—human and animal health, Aug. 1973 Proc.: Fort Collins, Colorado State Univ., 232 p.

Shacklette, H. T., Hamilton, J. C., Boerngen, J. G., and Bowles, J. M., 1971, Elemental composition of surficial materials in the conterminous United States: U.S. Geol. Survey Prof. Paper 574-D, 71 p.

Shacklette, H. T., Sauer, H. I., and Minch, A. T., 1970, Geochemical environments and cardiovascular mortality rates in Georgia: U.S. Geol. Survey Prof. Paper 574-C, 30 p.

Shapiro, Leonard, 1967, Rapid analysis of rocks and minerals by a single-solution method, *in* Geological Survey research 1967: U.S. Geol. Survey Prof. Paper 575-B, p. B187–B191.

Shapiro, Leonard, and Brannock, W. W., 1962, Rapid analysis of silicate, carbonate, and phosphate rocks: U.S. Geol. Survey Bull. 1144-A, 56 p.

Sloss, L. L., 1963, Sequences in the cratonic interior of North America: Geol. Soc. America Bull., v. 74, p. 93–114.

Swann, D. H., and Willman, H. B., 1961, Megagroups in Illinois: Am. Assoc. Petroleum Geologists Bull., v. 45, p. 471–483.

Tidball, R. R., 1973, Distribution of elements in agricultural soils of Missouri: Geol. Soc. America Abs. with Programs, v. 5, no. 4, p. 358–359.

Tourtelot, H. A., 1973, Regional geochemical investigations, Front Range Urban Corridor, Colorado: Geol. Soc. America Abs. with Programs, v. 5, no. 6, p. 520–521.

Turekian, K. K., and Wedepohl, K. H., 1961, Distribution of the elements in some major units of the earth's crust: Geol. Soc. America Bull., v. 72, p. 175–192.

U.S. Geological Survey, 1970, Mercury in the environment: U.S. Geol. Survey Prof. Paper 713, 67 p.

———1972a, Geochemical survey of Missouri, plans and progress for first six-month period (July–December, 1969): U.S. Geol. Survey open-file rept., 49 p.

———1972b, Geochemical survey of Missouri, plans and progress for second six-month period (January–June, 1970): U.S. Geol. Survey open-file rept., 60 p.

———1972c, Geochemical survey of Missouri, plans and progress for third six-month period (July–December, 1970): U.S. Geol. Survey open-file rept., 55 p.

———1972d, Geochemical survey of Missouri, plans and progress for fourth six-month period (January–June, 1971): U.S. Geol. Survey open-file rept., 68 p.

———1972e, Geochemical survey of Missouri, plans and progress for fifth six-month period (July–December, 1971): U.S. Geol. Survey open-file rept., 145 p.

———1972f, Geochemical survey of Missouri, plans and progress for sixth six-month period (January–June, 1972): U.S. Geol. Survey open-file rept., 86 p.

———1973, Geochemical survey of Missouri, plans and progress for seventh six-month period (June–December, 1972): U.S. Geol. Survey open-file rept., 50 p.

Vaughn, W. W., and McCarthy, J. H., Jr., 1964, An instrumental technique for the determination of submicrogram concentrations of mercury in soils, rocks, and gas, *in* Geological Survey research 1964: U.S. Geol. Survey Prof. Paper 501-D, p. D123–D127 [1965].

Ward, F. N., Lakin, H. W., Canney, F. C., and others, 1963, Analytical methods used in geochemical exploration by the U.S. Geological Survey: U.S. Geol. Survey Bull. 1152, 100 p.

Ward, F. N., Nakagawa, H. M., Harms, T. F., and VanSickle, G. H., 1969, Atomic-absorption methods of analysis useful in geochemical exploration: U.S. Geol. Survey Bull. 1289, 45 p.

Wedepohl, K. H., ed., 1969–1973, Handbook of geochemistry: Berlin, Heidelberg, New York, Springer-Verlag, 1969, v. 1, no. 1; 1969–73, v. 2, nos. 1–3.

White, D. E., Hem, J. D., and Waring, G. A., 1963, Chemical composition of subsurface waters, chap. F *in* Fleischer, Michael, ed., Data of geochemistry [6th ed.]: U.S. Geol. Survey Prof. Paper 440-F, p. F1–F67.

TABLES 5–53

Tables giving concentration of elements in rocks, unconsolidated geologic deposits, soils, and plants

TABLE 5.—*Aluminum in rocks, unconsolidated geologic deposits, soils, and plant ash*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean except that values preceded by asterisk are arithmetic mean. Deviation, geometric deviation except that values preceded by asterisk are standard deviation. Error, geometric error attributed to laboratory procedures except that values preceded by asterisk are standard error. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
ROCKS						
Granite						
Precambrian; Missouri	1 (5)	30:30	6.7	1.06	1.04	6.3 - 7.9
Rhyolite						
Precambrian; Missouri	1 (5)	30:30	6.6	1.10	1.04	5.3 - 7.9
Sandstone						
Sauk sequence; Western United States	3 (16)	400:400	.77	2.49	1.29	.058 - 8.2
Roubidoux Formation; Missouri	4 (5)	6:12	.43	1.75	1.14	<.53 - 1.1
Pope Megagroup;[1] Kentucky	5 (16)	120:120	1.6	1.78	1.34	.24 - 5.6
Pennsylvanian; Kentucky	5 (16)	152:152	2.5	2.12	1.33	.53 - 8.3
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (5)	32:32	3.0	2.30	1.14	.53 - 6.9
Chert						
Mississippian; Missouri, Oklahoma, and Arkansas	7 (5)	1:20	<.53	--	--	<.53 - .53
Shale						
Sauk sequence; Western United States	3 (16)	336:336	7.7	1.61	1.17	1.32 - 15.2
Lower Mississippian; Kentucky	8 (16)	76:76	5.4	1.49	--	2.0 - 9.2
Upper Mississippian; Kentucky	5 (16)	142:142	7.9	1.29	--	3.3 - 13
Mississippian; Missouri, Oklahoma, and Arkansas	7 (5)	18:18	4.4	1.64	1.05	1.6 - 10
Pennsylvanian; Kentucky	5 (16)	152:152	9.2	1.40	1.12	2.4 - 17
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (5)	32:32	8.5	1.24	1.05	5.3 - 11
Limestone and dolomite						
Sauk sequence; Western United States	3 (16)	386:392	.45	3.62	1.59	<.021 - 7.2
Sauk sequence; Missouri and Arkansas	4 (5)	16:48	.30	2.19	1.22	<.53 - 2.1
Upper Ordovician; Kentucky	5 (16)	80:80	.84	2.08	1.24	.13 - 3.8
Tippecanoe sequence; Missouri	10 (5)	3:12	<.53	--	--	<.53 - 1.6
Lower Mississippian; Kentucky	5 (16)	111:112	.62	3.10	1.76	<.0053 - 3.0
Upper Mississippian; Kentucky	5 (16)	139:152	.23	5.39	2.72	<.0053 - 5.1
Mississippian; Missouri, Oklahoma, and Arkansas	7 (5)	9:40	.17	3.52	1.22	<.53 - 2.1
Pennsylvanian; Kentucky	5 (16)	80:80	2.0	2.56	1.22	.079 - 4.8
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (5)	16:32	.44	2.50	1.22	<.53 - 3.2
Siderite						
Upper Paleozoic; Kentucky	11 (16)	30:30	2.8	1.83	--	.44 - 6.1

[1] Of Swann and Willman (1961).

TABLE 5.—*Aluminum in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
UNCONSOLIDATED GEOLOGIC DEPOSITS						
Carbonate residuum (terra rossa)						
On Gasconade Formation; Missouri	12 (5)	24:24	7.9	1.33	1.03	4.5 - 14
On Roubidoux Formation; Missouri	12 (5)	24:24	6.6	1.56	1.03	2.1 - 11
On Jefferson City, Cotter, and Powell Formations; Missouri	12 (5)	24:24	8.0	1.24	1.03	5.0 - 13
On Ozarkian rocks; Missouri	12 (5)	24:24	9.9	1.20	1.03	7.6 - 15
On Marmacian rocks; Missouri	12 (5)	24:24	10	1.27	1.03	5.1 - 13
Loess						
Missouri	13 (5)	24:24	5.2	1.10	--	4.2 - 5.8
SOILS						
Cultivated						
Plow zone, garden; Georgia	14 (1)	30:30	0.9	1.88	--	0.2 - 5
	15 (1)	30:30	4.6	1.70	--	1.5 - 7
Plow zone, corn field; Missouri						
Floodplain Forest	17 (5)	8:8	4.0	1.21	1.03	3.1 - 5.2
Glaciated Prairie	17 (5)	10:10	4.8	1.16	1.03	3.7 - 6.1
Unglaciated Prairie	17 (5)	10:10	3.4	1.32	1.03	2.0 - 4.8
Oak-hickory Forest	17 (5)	10:10	3.9	1.30	1.03	2.2 - 5.0
Plow zone, soybean field; Missouri						
Floodplain Forest	17 (5)	10:10	4.0	1.25	1.03	2.9 - 5.6
Glaciated Prairie	17 (5)	10:10	5.2	1.08	1.03	4.7 - 5.8
Unglaciated Prairie	17 (5)	8:8	3.8	1.29	1.03	2.4 - 4.9
Oak-hickory Forest	17 (5)	9:9	3.8	1.23	1.03	2.6 - 5.0
Plow zone, pasture field; Missouri						
Floodplain Forest	17 (5)	10:10	4.2	1.25	1.03	3.0 - 6.9
Glaciated Prairie	17 (5)	10:10	4.7	1.11	1.03	3.8 - 5.7
Unglaciated Prairie	17 (5)	10:10	3.8	1.24	1.03	2.8 - 5.5
Oak-hickory Forest	17 (5)	10:10	3.9	1.33	1.03	2.2 - 5.7
Surface horizon; Missouri	16 (5)	1,140:1,140	*4.1	*1.19	*.34	1.1 - 7.9
Uncultivated						
Surface horizon; Powder River Basin, Wyoming and Montana	25 (5)	48:48	6.3	1.39	1.25	2 - 10
A horizon; Georgia	14 (1)	29:30	1.1	2.00	--	.3 - >10
	15 (1)	30:30	4.4	1.97	--	.7 - 7
A horizon; Kentucky	18 (16)	96:96	3.8	1.27	1.02	2.0 - 6.5
	19 (16)	108:108	3.2	1.28	1.03	1.6 - 14
B horizon; Georgia	14 (1)	30:30	1.1	1.86	--	.3 - 5
	15 (1)	30:30	5.7	2.00	--	.7 - 7
B horizon; Kentucky	18 (16)	96:96	5.9	1.30	1.02	2.8 - 11
B horizon; Missouri						
Floodplain Forest	20 (5)	50:50	4.5	1.29	1.13	2.6 - 7.9

TABLE 5.—*Aluminum in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
SOILS--Continued						
Uncultivated--Continued						
B horizon; Missouri--Continued						
Glaciated Prairie	20 (5)	50:50	6.5	1.21	1.13	5.7 - 9.0
Unglaciated Prairie	20 (5)	50:50	4.7	1.34	1.13	2.1 - 9.0
Cedar Glade	20 (5)	50:50	3.2	1.42	1.13	1.6 - 5.8
Oak-hickory Forest	20 (5)	50:50	2.7	1.47	1.13	1.1 - 5.3
Oak-hickory-pine Forest	20 (5)	50:50	2.1	1.63	1.13	.5 - 5.8
C horizon; Georgia	14 (1)	30:30	1.7	2.61	--	.3 - 7
C horizon; Kentucky	18 (16)	96:96	6.1	1.39	1.02	2.5 - 12
Cultivated and uncultivated						
Surface horizon; Colorado	22 (5)	168:168	5.7	1.29	1.03	1.3 - 7.6
B horizon; Eastern United States	21 (1)	285:307	3.3	2.70	--	.7 - >10
B horizon; Western United States	21 (1)	399:484	5.4	2.02	--	.5 - >10
PLANT ASH						
Cultivated plants						
Asparagus; Wisconsin	23 (1)	5:5	0.40	1.55	--	0.3 - 0.7
Bean, lima; Georgia	14 (1)	30:30	.03	2.43	--	.01 - .2
	15 (1)	15:15	.14	3.11	--	.03 - 3
Bean, snap; Georgia	14 (1)	30:30	.09	2.18	--	.015 - .5
	15 (1)	30:30	.15	2.28	--	.02 - .7
Beet, red; Wisconsin	23 (1)	3:3	.15	2.07	--	.07 - .3
Blackeyed pea; Georgia	14 (1)	29:29	.06	2.03	--	.015 - .2
	15 (1)	4:4	.05	1.64	--	.03 - .7
Cabbage; Georgia	15 (1)	30:30	.4	2.45	--	.05 - 1.5
Cabbage; Wisconsin	23 (1)	11:11	.11	2.22	--	.03 - .7
Carrot; Wisconsin	23 (1)	8:8	.15	2.04	--	.07 - .7
Corn; Georgia	14 (1)	29:29	.07	2.03	--	.015 - .2
	15 (1)	30:30	.07	1.99	--	.015 - .3
Corn; Missouri						
Glaciated Prairie	17 (1)	10:10	.02	1.99	1.75	.005 - .05
Unglaciated Prairie	17 (1)	10:10	.02	1.99	1.75	.005 - .05
Oak-hickory Forest	17 (1)	10:10	.02	1.98	1.75	.005 - .07
Corn; Wisconsin	23 (1)	27:27	.1	1.57	--	.03 - .15
Cucumber; Wisconsin	23 (1)	4:4	.17	3.16	--	.03 - .3
Onion; Wisconsin	23 (1)	7:7	.15	2.40	--	.07 - .7
Potato; Wisconsin	23 (1)	10:10	.1	1.69	--	.07 - .3
Soybean; Missouri						
Floodplain Forest	17 (1)	10:10	.04	2.20	1.75	.005 - .07
Glaciated Prairie	17 (1)	10:10	.05	1.29	1.75	.03 - .07
Unglaciated Prairie	17 (1)	8:8	.04	1.51	1.75	.02 - .07
Oak-hickory Forest	17 (1)	9:9	.06	2.00	1.75	.01 - .1

TABLE 5.—*Aluminum in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
PLANT ASH--Continued						
Cultivated plants--Continued						
Tomato; Georgia	14 (1)	30:30	0.07	2.96	--	0.015 - 0.2
	15 (1)	30:30	.04	2.60	--	.007 - .15
Native species						
Black cherry, stems; Georgia	14 (1)	30:30	.15	2.64	--	.01 - 1
	15 (1)	30:30	.24	2.26	--	.02 - .7
Black cherry, leaves; Georgia	14 (1)	30:30	.23	1.90	--	.1 - 1.5
	15 (1)	30:30	.29	1.94	--	.05 - 1
Blackgum, stems; Georgia	14 (1)	30:30	.52	1.69	--	.15 - 1
	15 (1)	30:30	.63	1.41	--	.3 - 1.5
Blackgum, leaves; Georgia	14 (1)	30:30	.91	2.12	--	.1 - 2
	15 (1)	30:30	1.1	1.58	--	.5 - 3
Buckbush; Missouri						
Glaciated Prairie	20 (1)	47:47	1.3	1.35	1.61	.7 - 2
Unglaciated Prairie	20 (1)	48:48	1.4	1.44	1.61	.5 - 5
Cedar Glade	20 (1)	50:50	1.0	1.46	1.61	.5 - 2
Oak-hickory Forest	20 (1)	49:49	1.2	1.33	1.61	.7 - 2
Oak-hickory-pine Forest	20 (1)	41:41	1.0	1.40	1.61	.5 - 2
Cedar; Missouri						
Cedar Glade	20 (1)	50:50	.41	2.07	1.61	.15 - 10
Glaciated Prairie	24 (1)	9:9	.75	1.75	--	.2 - 1.5
Unglaciated Prairie	24 (1)	10:10	.71	1.46	--	.5 - 1.5
Cedar Glade	24 (1)	10:10	.35	1.60	--	.2 - .7
Oak-hickory Forest	24 (1)	10:10	.47	1.61	--	.2 - 1
Oak-hickory-pine Forest	24 (1)	6:6	.32	1.89	--	.15 - .7
Hickory, pignut; Kentucky	18 (1)	64:64	.72	1.70	1.18	.2 - 7
Hickory, shagbark; Kentucky	18 (1)	40:40	.73	1.58	1.18	.2 - 2
Hickory, shagbark; Missouri						
Oak-hickory Forest	20 (1)	19:19	.29	2.27	1.61	.07 - .5
Oak-hickory-pine Forest	20 (1)	7:7	.36	1.76	1.61	.1 - 1
Maple, red, stems; Georgia	14 (1)	30:30	.14	1.67	--	.07 - .7
	15 (1)	30:30	.17	1.63	--	.07 - .5
Maple, red, leaves; Georgia	14 (1)	30:30	.19	2.44	--	.01 - 1.5
	15 (1)	30:30	.37	1.92	--	.07 - 1
Oak, black; Kentucky	18 (1)	25:25	.24	1.55	1.34	.1 - .7
Oak, post; Cedar Glade, Missouri	20 (1)	50:50	.26	1.87	1.61	.07 - 1
Oak, red; Kentucky	18 (1)	28:28	.27	1.74	1.34	.15 - 1.0
Oak, white; Kentucky	18 (1)	49:49	.27	1.50	1.34	.10 - 1.4
Oak, white; Missouri						
Oak-hickory Forest	20 (1)	50:50	.19	1.62	1.61	.07 - .5
Oak-hickory-pine Forest	20 (1)	49:49	.19	1.57	1.61	.1 - 1
Oak, willow; Floodplain Forest, Missouri	20 (1)	46:46	.24	1.90	1.61	.07 - 1.5
Persimmon, stems; Georgia	14 (1)	30:30	.17	2.07	--	.02 - .7
	15 (1)	30:30	.24	1.93	--	.05 - .7

TABLE 5.—*Aluminum in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
PLANT ASH--Continued						
Native species--Continued						
Pine, shortleaf; Oak-hickory-pine Forest, Missouri	20 (1)	49:49	3.9	1.65	1.61	1.5 - 10
Sassafras, stems; Georgia	14 (1)	17:17	.39	2.42	--	.05 - 2
	15 (1)	27:27	.37	2.67	--	.05 - 2
Sassafras, leaves; Georgia	14 (1)	17:17	.43	2.26	--	.15 - 2
	15 (1)	27:27	.63	2.04	--	.15 - 2
Sumac, winged, stems; Georgia	14 (1)	30:30	.19	1.73	--	.07 - .7
	15 (1)	30:30	.23	1.90	--	.07 - 1
Sumac, winged, leaves; Georgia	14 (1)	30:30	.26	1.86	--	.1 - 1.5
	15 (1)	30:30	.51	2.12	--	.15 - 2
Sumac, smooth; Missouri						
Floodplain Forest	20 (1)	48:48	.11	2.55	1.61	.02 - 1
Glaciated Prairie	20 (1)	50:50	.13	2.09	1.61	.01 - .5
Unglaciated Prairie	20 (1)	49:49	.11	2.29	1.61	.02 - 1.5
Cedar Glade	20 (1)	49:49	.10	1.92	1.61	.02 - .5
Oak-hickory Forest	20 (1)	50:50	.12	2.11	1.61	.02 - .7
Oak-hickory-pine Forest	20 (1)	49:49	.13	1.99	1.61	.02 - .7
Sweetgum, stems; Georgia	14 (1)	28:28	.20	1.48	--	.1 - .5
	15 (1)	27:27	.37	1.77	--	.15 - 1.5
Sweetgum, leaves; Georgia	14 (1)	28:28	.62	1.54	--	.2 - 1.5
	15 (1)	27:27	.85	1.77	--	.1 - 2
Sweetgum; Floodplain Forest, Missouri	20 (1)	47:47	.18	1.85	1.61	.05 - .5

TABLE 6.—*Antimony in soils*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
Cultivated and uncultivated B horizon; Eastern United States	21 (1)	1:362	<150	--	--	<150 - 500

TABLE 7.—*Arsenic in rocks, unconsolidated geologic deposits, soils, and dry plants*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Granite						
Precambrian; Missouri	1 (6)	29:30	2.9	2.11	1.12	<1 - 19
Rhyolite						
Precambrian; Missouri	1 (6)	28:30	4.7	4.01	1.12	<1 - 300
Sandstone						
Roubidoux Formation; Missouri	4 (6)	7:12	1.1	1.57	1.62	<1 - 2.7
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (6)	29:32	4.3	2.51	1.62	<1 - 25
Chert						
Mississippian; Missouri, Oklahoma, and Arkansas	7 (6)	7:20	<1	--	--	<1 - 4.3
Shale						
Mississippian; Missouri, Oklahoma, and Arkansas	7 (6)	18:18	6.4	2.22	1.21	1.7 - 18
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (6)	32:32	9.0	2.11	1.21	1.4 - 27
Limestone and dolomite						
Ozark sequence; Missouri and Arkansas	4 (6)	28:48	1.2	2.62	1.26	<1 - 17
Tippecanoe sequence; Missouri	10 (6)	3:12	.74	1.53	1.26	<1 - 1.5
Mississippian; Missouri, Oklahoma, and Arkansas	7 (6)	17:40	.83	2.58	1.26	<1 - 6.3
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (6)	27:32	2.5	2.95	1.26	<1 - 39
UNCONSOLIDATED GEOLOGIC DEPOSITS						
Carbonate residuum (terra rossa)						
On Gasconade Formation; Missouri	12 (6)	24:24	18	1.36	1.19	11 - 31
On Roubidoux Formation; Missouri	12 (6)	24:24	15	1.88	1.19	3.7 - 42
On Jefferson City, Cotter, and Powell Formations; Missouri and Arkansas	12 (6)	24:24	19	1.74	1.19	7.9 - 61
On Ozarkian rocks; Missouri	12 (6)	24:24	21	1.38	1.19	12 - 33
On Mesozoic rocks; Missouri	12 (6)	24:24	21	1.37	1.19	8.7 - 34
Loess						
Missouri	13 (6)	24:24	8.3	1.38	--	3 - 13

TABLE 7.—*Arsenic in rocks, unconsolidated geologic deposits, soils, and dry plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
SOILS						
Cultivated						
Plow zone, corn field; Missouri						
Floodplain Forest	17 (6)	8:8	5.5	1.68	1.10	1.8 - 9.1
Glaciated Prairie	17 (6)	10:10	10	1.32	1.10	7.0 - 14
Unglaciated Prairie	17 (6)	10:10	10	1.47	1.10	4.8 - 15
Oak-hickory Forest	17 (6)	10:10	8.8	1.23	1.10	6.1 - 14
Plow zone, soybean field; Missouri						
Floodplain Forest	17 (6)	10:10	5.9	1.70	1.10	2.7 - 15
Glaciated Prairie	17 (6)	10:10	12	1.31	1.10	7.6 - 17
Unglaciated Prairie	17 (6)	8:8	11	1.52	1.10	5.5 - 24
Oak-hickory Forest	17 (6)	9:9	7.1	1.38	1.10	4.1 - 12
Plow zone, pasture field; Missouri						
Floodplain Forest	17 (6)	10:10	6.4	2.25	1.10	1.6 - 36
Glaciated Prairie	17 (6)	10:10	12	1.63	1.10	7.1 - 27
Unglaciated Prairie	17 (6)	10:10	9.3	1.41	1.10	5.1 - 14
Oak-hickory Forest	17 (6)	10:10	8.5	1.22	1.10	6.4 - 13
Surface horizon; Missouri	16 (6)	1,140:1,140	8.7	1.46	1.16	2.5 - 72
Uncultivated						
B horizon; Missouri						
Floodplain Forest	20 (6)	50:50	7.5	2.03	1.21	2.4 - 170
Glaciated Prairie	20 (6)	50:50	13	1.27	1.21	7.2 - 20
Unglaciated Prairie	20 (6)	50:50	12	1.55	1.21	3.4 - 38
Cedar Glade	20 (6)	50:50	8.4	1.73	1.21	2.6 - 22
Oak-hickory Forest	20 (6)	50:50	8.0	1.83	1.21	2.4 - 28
Oak-hickory-pine Forest	20 (6)	50:50	6.7	1.67	1.21	2.7 - 44
Cultivated and uncultivated						
Surface horizon; Colorado	22 (6)	168:168	5.4	2.20	1.36	1.2 - 24
B horizon; Eastern United States	21 (6)	413:420	5.4	2.24	--	<.2 - 73
B horizon; Western United States	21 (6)	489:490	6.1	1.82	--	<.2 - 97
DRY PLANTS						
Native species						
Buckbush; Oak-hickory Forest, Missouri	20 (6)	1:14	<0.25	--	--	<0.25 - 0.25
Sumac, smooth; Glaciated Prairie, Missouri	20 (6)	1:9	<.25	--	--	<.25 - 1.5

TABLE 8.—*Barium in rocks, unconsolidated geologic deposits, soils, and plant ash*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Granite						
Precambrian; Missouri	1 (1)	30:30	550	2.57	1.07	50 - 2,000
Rhyolite						
Precambrian; Missouri	1 (1)	30:30	640	1.98	1.07	200 - 2,000
Arkose						
Fountain Formation; Colorado	2 (2)	80:80	540	2.10	1.17	90 - 6,700
Sandstone						
Sauk sequence; Western United States	3 (2)	397:399	100	2.97	1.25	<10 - 7,500
Roubidoux Formation; Missouri	4 (1)	12:12	38	1.92	1.24	10 - 100
Pope Megagroup;[1] Kentucky	5 (2)	120:120	100	1.87	1.26	10 - 340
Pennsylvanian; Kentucky	5 (2)	152:152	140	2.13	1.20	30 - 1,700
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	32:32	170	2.17	1.24	50 - 700
Chert						
Mississippian; Missouri, Oklahoma, and Arkansas	7 (1)	20:20	23	1.52	1.24	10 - 50
Shale						
Sauk sequence; Western United States	3 (2)	336:336	510	1.86	1.12	60 - 3,900
Lower Mississippian; Kentucky	8 (2)	76:76	300	1.68	--	80 - 1,000
Upper Mississippian; Kentucky	5 (2)	142:142	250	1.46	--	110 - 1,500
Mississippian; Missouri, Oklahoma, and Arkansas	7 (1)	18:18	220	2.15	1.26	70 - 700
Pennsylvanian; Kentucky	5 (2)	152:152	410	1.53	1.11	90 - 970
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	32:32	430	1.48	1.26	200 - 700
Black shale						
Devonian and Mississippian; Kentucky	9 (2)	88:88	510	1.79	1.14	150 - 4,200
Limestone and dolomite						
Sauk sequence; Western United States	3 (2)	198:392	26	7.40	1.24	<30 - 1,400
Sauk sequence; Missouri and Arkansas	4 (1)	48:48	9.2	3.48	1.30	1 - 100
Upper Ordovician; Kentucky	5 (1)	80:80	65	3.12	1.71	10 - 3,000
Tippecanoe sequence; Missouri	10 (1)	10:12	5.6	5.04	1.30	<1 - 70
Lower Mississippian; Kentucky	5 (1)	112:112	54	2.59	1.24	10 - 300
Upper Mississippian; Kentucky	5 (1)	152:152	29	2.32	1.34	5 - 300
Pennsylvanian; Kentucky	5 (1)	80:80	160	1.99	1.24	30 - 500
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	32:32	44	3.01	1.30	10 - 500

[1] Of Swann and Williams (1961).

TABLE 8.—*Barium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS--Continued						
Siderite						
Upper Paleozoic; Kentucky	11 (1)	30:30	160	1.50	--	70 - 300
UNCONSOLIDATED GEOLOGIC DEPOSITS						
Carbonate residuum (terra rossa)						
On Gasconade Formation; Missouri	12 (1)	24:24	140	1.30	1.19	70 - 200
On Roubidoux Formation; Missouri	12 (1)	24:24	170	1.38	1.19	70 - 300
On Jefferson City, Cotter, and Powell Formations; Missouri and Arkansas	12 (1)	24:24	190	1.37	1.19	100 - 500
On Osagean rocks; Missouri	12 (1)	24:24	150	1.39	1.19	100 - 300
On Meramecian rocks; Missouri	12 (1)	24:24	170	1.24	1.19	100 - 300
Loess						
Missouri	13 (1)	24:24	840	1.30	--	500 - 1,000
SOILS						
Cultivated						
Plow zone, garden; Georgia	14 (1)	30:30	63	1.42	--	30 - 150
	15 (1)	30:30	250	1.52	--	100 - 500
Plow zone, corn field; Missouri						
Floodplain Forest	17 (1)	8:8	800	1.20	1.14	700 - 1,000
Glaciated Prairie	17 (1)	10:10	810	1.28	1.14	500 - 1,000
Unglaciated Prairie	17 (1)	10:10	600	1.39	1.14	300 - 1,000
Oak-hickory Forest	17 (1)	10:10	700	1.26	1.14	500 - 1,000
Plow zone, soybean field; Missouri						
Floodplain Forest	17 (1)	10:10	630	1.26	1.14	500 - 1,000
Glaciated Prairie	17 (1)	10:10	700	1.26	1.14	500 - 1,000
Unglaciated Prairie	17 (1)	8:8	650	1.28	1.14	500 - 1,000
Oak-hickory Forest	17 (1)	9:9	640	1.51	1.14	300 - 1,000
Plow zone, pasture field; Missouri						
Floodplain Forest	17 (1)	10:10	700	1.18	1.14	500 - 1,000
Glaciated Prairie	17 (1)	10:10	780	1.33	1.14	500 - 1,000
Unglaciated Prairie	17 (1)	10:10	670	1.46	1.14	300 - 1,000
Oak-hickory Forest	17 (1)	10:10	590	1.58	1.14	300 - 1,000
Surface horizon; Missouri	16 (1)	1,140:1,140	580	1.46	1.28	100 - 1,500
Uncultivated						
Surface horizon; Powder River Basin, Wyoming and Montana	25 (1)	48:48	740	1.36	1.29	500 - 3,000
A horizon; Georgia	14 (1)	30:30	100	1.73	--	50 - 500
	15 (1)	30:30	290	1.85	--	70 - 1,500
A horizon; Kentucky	18 (2)	96:96	296	1.46	1.09	90 - 520
	19 (2)	108:108	350	1.47	1.04	110 - 740

TABLE 8.—*Barium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
SOILS—Continued						
Uncultivated—Continued						
B horizon; Georgia	14 (1)	30:30	86	1.68	--	50 - 300
	15 (1)	30:30	270	2.00	--	30 - 700
B horizon; Kentucky	18 (2)	96:96	300	1.41	1.09	110 - 690
B horizon; Missouri						
Floodplain Forest	20 (1)	50:50	660	1.43	1.30	300 - 5,000
Glaciated Prairie	20 (1)	50:50	560	1.46	1.30	200 - 1,000
Unglaciated Prairie	20 (1)	50:50	490	1.58	1.30	200 - 1,000
Cedar Glade	20 (1)	50:50	250	1.61	1.30	100 - 700
Oak-hickory Forest	20 (1)	50:50	390	1.78	1.30	100 - 1,000
Oak-hickory-pine Forest	20 (1)	50:50	340	1.96	1.30	70 - 1,500
C horizon; Georgia	14 (1)	30:30	94	1.83	--	50 - 500
	15 (1)	30:30	290	1.77	--	70 - 700
C horizon; Kentucky	18 (2)	96:96	250	1.54	1.09	80 - 640
Cultivated and uncultivated						
Surface horizon; Colorado	22 (1)	168:168	550	1.71	1.26	150 - 1,500
B horizon; Eastern United States	21 (1)	371:371	300	2.19	--	15 - 1,000
B horizon; Western United States	21 (1)	492:492	560	1.80	--	70 - 5,000
PLANT ASH						
Cultivated plants						
Asparagus; Wisconsin	23 (1)	5:5	290	1.86	--	100 - 700
Bean, lima; Georgia	14 (1)	30:30	100	2.14	--	50 - 300
	15 (1)	15:15	190	2.67	--	20 - 200
Bean, snap; Georgia	14 (1)	30:30	170	2.73	--	70 - 300
Beet, red; Wisconsin	23 (1)	4:4	360	1.34	--	300 - 500
Blackeyed pea; Georgia	14 (1)	29:29	130	2.06	--	70 - 500
Cabbage; Georgia	14 (1)	28:28	320	2.95	--	30 - 500
	15 (1)	30:30	450	1.67	--	200 - 1,500
Cabbage; Wisconsin	23 (1)	11:11	160	1.69	--	50 - 300
Carrot; Wisconsin	23 (1)	8:8	320	2.56	--	50 - 1,000
Corn; Georgia	14 (1)	29:29	54	2.37	--	10 - 300
	15 (1)	30:30	47	2.12	--	10 - 200
Corn; Missouri						
Floodplain Forest	17 (1)	8:8	21	2.55	1.26	5 - 100
Glaciated Prairie	17 (1)	10:10	15	1.88	1.26	7 - 50
Unglaciated Prairie	17 (1)	10:10	16	1.92	1.26	5 - 50
Oak-hickory Forest	17 (1)	10:10	21	2.82	1.26	5 - 70
Corn; Wisconsin	23 (1)	27:27	32	2.10	--	10 - 150
Cucumber; Wisconsin	23 (1)	4:4	140	2.00	--	50 - 200
Onion; Wisconsin	23 (1)	7:7	200	1.62	--	100 - 500
Pepper, sweet; Wisconsin	23 (1)	4:4	62	1.67	--	30 - 100
Potato; Wisconsin	23 (1)	10:10	120	2.79	--	30 - 700

TABLE 8.—*Barium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS--Continued						
Siderite						
Upper Paleozoic; Kentucky	11 (1)	30:30	160	1.50	--	70 - 300
UNCONSOLIDATED GEOLOGIC DEPOSITS						
Carbonate residuum (terra rossa)						
On Gasconade Formation; Missouri	12 (1)	24:24	140	1.30	1.19	70 - 200
On Roubidoux Formation; Missouri	12 (1)	24:24	170	1.38	1.19	70 - 300
On Jefferson City, Cotter, and Powell Formations; Missouri and Arkansas	12 (1)	24:24	190	1.37	1.19	100 - 500
On Osagean rocks; Missouri	12 (1)	24:24	150	1.39	1.19	100 - 300
On Meramecian rocks; Missouri	12 (1)	24:24	170	1.24	1.19	100 - 300
Loess						
Missouri	13 (1)	24:24	840	1.30	--	500 - 1,000
SOILS						
Cultivated						
Plow zone, garden; Georgia	14 (1)	30:30	63	1.42	--	30 - 150
	15 (1)	30:30	250	1.52	--	100 - 500
Plow zone, corn field; Missouri						
Floodplain Forest	17 (1)	8:8	800	1.20	1.14	700 - 1,000
Glaciated Prairie	17 (1)	10:10	810	1.28	1.14	500 - 1,000
Unglaciated Prairie	17 (1)	10:10	600	1.39	1.14	300 - 1,000
Oak-hickory Forest	17 (1)	10:10	700	1.26	1.14	500 - 1,000
Plow zone, soybean field; Missouri						
Floodplain Forest	17 (1)	10:10	630	1.26	1.14	500 - 1,000
Glaciated Prairie	17 (1)	10:10	700	1.26	1.14	500 - 1,000
Unglaciated Prairie	17 (1)	8:8	650	1.28	1.14	500 - 1,000
Oak-hickory Forest	17 (1)	9:9	640	1.51	1.14	300 - 1,000
Plow zone, pasture field; Missouri						
Floodplain Forest	17 (1)	10:10	700	1.18	1.14	500 - 1,000
Glaciated Prairie	17 (1)	10:10	780	1.33	1.14	500 - 1,000
Unglaciated Prairie	17 (1)	10:10	670	1.46	1.14	300 - 1,000
Oak-hickory Forest	17 (1)	10:10	590	1.58	1.14	300 - 1,000
Surface horizon; Missouri	16 (1)	1,140:1,140	580	1.46	1.28	100 - 1,500
Uncultivated						
Surface horizon; Powder River Basin, Wyoming and Montana	25 (1)	48:48	740	1.36	1.29	500 - 3,000
A horizon; Georgia	14 (1)	30:30	100	1.73	--	50 - 500
	15 (1)	30:30	290	1.85	--	70 - 1,500
A horizon; Kentucky	18 (2)	96:96	296	1.46	1.09	90 - 520
	19 (2)	108:108	350	1.47	1.04	110 - 740

TABLE 8.—*Barium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
SOILS--Continued						
Uncultivated--Continued						
B horizon; Georgia	14 (1)	30:30	86	1.68	--	50 - 300
	15 (1)	30:30	270	2.00	--	30 - 700
B horizon; Kentucky	18 (2)	96:96	300	1.41	1.09	110 - 690
B horizon; Missouri						
Floodplain Forest	20 (1)	50:50	660	1.43	1.30	300 - 5,000
Glaciated Prairie	20 (1)	50:50	560	1.46	1.30	200 - 1,000
Unglaciated Prairie	20 (1)	50:50	490	1.58	1.30	200 - 1,000
Cedar Glade	20 (1)	50:50	250	1.61	1.30	100 - 700
Oak-hickory Forest	20 (1)	50:50	390	1.78	1.30	100 - 1,000
Oak-hickory-pine Forest	20 (1)	50:50	340	1.96	1.30	70 - 1,500
C horizon; Georgia	14 (1)	30:30	94	1.83	--	50 - 500
	15 (1)	30:30	290	1.77	--	70 - 700
C horizon; Kentucky	18 (2)	96:96	250	1.54	1.09	80 - 640
Cultivated and uncultivated						
Surface horizon; Colorado	22 (1)	168:168	550	1.71	1.26	150 - 1,500
B horizon; Eastern United States	21 (1)	371:371	300	2.19	--	15 - 1,000
B horizon; Western United States	21 (1)	492:492	560	1.80	--	70 - 5,000
PLANT ASH						
Cultivated plants						
Asparagus; Wisconsin	23 (1)	5:5	290	1.86	--	100 - 700
Bean, lima; Georgia	14 (1)	30:30	100	2.14	--	50 - 300
	15 (1)	15:15	190	2.67	--	20 - 200
Bean, snap; Georgia	14 (1)	30:30	170	2.73	--	70 - 300
Beet, red; Wisconsin	23 (1)	4:4	360	1.34	--	300 - 500
Blackeyed pea; Georgia	14 (1)	29:29	130	2.06	--	70 - 500
Cabbage; Georgia	14 (1)	28:28	320	2.95	--	30 - 500
	15 (1)	30:30	450	1.67	--	200 - 1,500
Cabbage; Wisconsin	23 (1)	11:11	160	1.69	--	50 - 300
Carrot; Wisconsin	23 (1)	8:8	320	2.56	--	50 - 1,000
Corn; Georgia	14 (1)	29:29	54	2.37	--	10 - 300
	15 (1)	30:30	47	2.12	--	10 - 200
Corn; Missouri						
Floodplain Forest	17 (1)	8:8	21	2.55	1.26	5 - 100
Glaciated Prairie	17 (1)	10:10	15	1.88	1.26	7 - 50
Unglaciated Prairie	17 (1)	10:10	16	1.92	1.26	5 - 50
Oak-hickory Forest	17 (1)	10:10	21	2.82	1.26	5 - 70
Corn; Wisconsin	23 (1)	27:27	32	2.10	--	10 - 150
Cucumber; Wisconsin	23 (1)	4:4	140	2.00	--	50 - 200
Onion; Wisconsin	23 (1)	7:7	200	1.62	--	100 - 500
Pepper, sweet; Wisconsin	23 (1)	4:4	62	1.67	--	30 - 100
Potato; Wisconsin	23 (1)	10:10	120	2.79	--	30 - 700

TABLE 8.—*Barium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
PLANT ASH--Continued						
Cultivated plants--Continued						
Soybean; Missouri						
Floodplain Forest	17 (1)	10:10	440	2.33	1.26	100 - 1,500
Glaciated Prairie	17 (1)	10:10	220	2.43	1.26	30 - 500
Unglaciated Prairie	17 (1)	8:8	290	2.18	1.26	70 - 700
Oak-hickory Forest	17 (1)	9:9	230	1.82	1.26	150 - 1,000
Tomato; Georgia	14 (1)	30:30	60	2.43	--	7 - 300
	15 (1)	30:30	38	1.80	--	15 - 150
Native species						
Black cherry, stems; Georgia	14 (1)	30:30	3,600	2.93	--	300 - 10,000
	15 (1)	30:30	3,000	3.12	--	300 - 15,000
Black cherry, leaves; Georgia	14 (1)	30:30	2,400	2.50	--	50 7,000
	15 (1)	30:30	2,100	2.80	--	200 - 10,000
Blackgum, stems; Georgia	14 (1)	30:30	7,200	2.18	--	200 - 15,000
	15 (1)	30:30	9,800	1.67	--	1,500 - 20,000
Blackgum, leaves; Georgia	14 (1)	30:30	2,800	2.54	--	50 - 7,000
	15 (1)	30:30	4,100	1.73	--	1,000 - 10,000
Buckbush; Missouri						
Glaciated Prairie	20 (1)	47:47	2,700	1.52	1.49	1,000 - 5,000
Unglaciated Prairie	20 (1)	48:48	2,500	1.48	1.49	1,000 - 7,000
Cedar Glade	20 (1)	50:50	1,200	1.84	1.49	300 - 7,000
Oak-hickory Forest	20 (1)	49:49	3,800	1.63	1.49	1,500 - 10,000
Oak-hickory-pine Forest	20 (1)	41:41	4,500	1.87	1.49	2,000 - 30,000
Cedar; Missouri						
Cedar Glade	20 (1)	49:49	320	2.50	1.49	100 - 7,000
Glaciated Prairie	24 (1)	9:9	2,000	1.63	--	1,000 - 5,000
Unglaciated Prairie	24 (1)	10:10	2,900	2.09	--	700 - 7,000
Cedar Glade	24 (1)	10:10	370	2.50	--	200 - 3,000
Oak-hickory Forest	24 (1)	10:10	3,800	2.04	--	1,500 - 10,000
Oak-hickory-pine Forest	24 (1)	6:6	4,100	1.44	--	3,000 - 7,000
Hickory, pignut; Kentucky	18 (1)	64:64	11,000	1.40	1.14	7,000 - 20,000
Hickory, shagbark; Kentucky	18 (1)	40:40	9,300	1.65	1.14	2,000 - 20,000
Hickory, shagbark; Missouri						
Oak-hickory Forest	20 (1)	19:19	7,700	2.38	1.49	500 - 20,000
Maple, red, stems; Georgia	14 (1)	30:30	3,500	2.82	--	50 - 15,000
	15 (1)	30:30	3,600	2.17	--	300 - 10,000
Maple, red, leaves; Georgia	14 (1)	30:30	1,400	2.73	--	70 - 5,000
	15 (1)	30:30	1,300	2.02	--	300 - 7,000
Oak, black; Kentucky	18 (1)	25:25	3,500	1.56	1.21	1,500 - 7,000
	19 (2)	21:22	4,300	2.03	1.06	840 - >10,000
Oak, post; Cedar Glade, Missouri	20 (1)	50:50	660	2.31	1.49	100 - 5,000
Oak, red; Kentucky	18 (1)	28:28	4,700	1.70	1.21	500 - 10,000
	19 (2)	8:8	5,300	1.75	1.06	1,700 - 10,000
Oak, white; Kentucky	18 (1)	49:49	5,500	1.43	1.21	2,000 - 15,000
	19 (2)	73:75	5,500	1.63	1.06	890 - >10,000

TABLE 8.—Barium in rocks, unconsolidated geologic deposits, soils, and plant ash—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
PLANT ASH—Continued						
Native species—Continued						
Oak, white; Missouri						
Oak-hickory Forest	20 (1)	50:50	4,200	1.58	1.49	1,000 - 10,000
Oak-hickory-pine Forest	20 (1)	49:49	5,000	1.44	1.49	3,000 - 15,000
Oak, willow; Floodplain Forest, Missouri	20 (1)	46:46	2,700	1.57	1.49	1,000 - 5,000
Persimmon, stems; Georgia	14 (1)	30:30	2,500	2.29	--	150 - 10,000
	15 (1)	30:30	1,900	2.40	--	500 - 20,000
Persimmon, leaves; Georgia	14 (1)	30:30	970	2.09	--	70 - 3,000
	15 (1)	30:30	710	2.57	--	30 - 7,000
Pine, shortleaf; Oak-hickory-pine Forest, Missouri	20 (1)	49:49	1,100	1.79	1.49	300 - 5,000
Sassafras, stems; Georgia	14 (1)	17:17	3,000	2.26	--	700 - 10,000
	15 (1)	27:27	2,600	2.37	--	500 - 10,000
Sassafras, leaves; Georgia	14 (1)	17:17	800	1.99	--	300 - 3,000
	15 (1)	27:27	710	1.76	--	300 - 2,000
Sumac, winged, stems; Georgia	14 (1)	30:30	4,500	1.97	--	700 - 15,000
	15 (1)	30:30	3,200	2.60	--	300 - 10,000
Sumac, winged, leaves; Georgia	14 (1)	30:30	1,900	1.84	--	700 - 7,000
	15 (1)	30:30	1,300	2.42	--	300 - 7,000
Sumac, smooth; Missouri						
Floodplain Forest	20 (1)	48:48	3,500	1.84	1.49	1,500 - 10,000
Glaciated Prairie	20 (1)	50:50	2,600	1.60	1.49	700 - 7,000
Unglaciated Prairie	20 (1)	49:49	2,600	1.78	1.49	700 - 10,000
Cedar Glade	20 (1)	49:49	270	2.35	1.49	70 - 3,000
Oak-hickory Forest	20 (1)	50:50	3,400	2.33	1.49	200 - 10,000
Oak-hickory-pine Forest	20 (1)	49:49	4,500	2.00	1.49	1,000 - 50,000
Sweetgum, stems; Georgia	14 (1)	28:28	2,500	1.99	--	700 - 7,000
	15 (1)	27:27	2,800	2.03	--	1,000 - 10,000
Sweetgum, leaves; Georgia	14 (1)	28:28	1,400	1.99	--	300 - 5,000
	15 (1)	27:27	1,300	2.39	--	300 - 7,000
Sweetgum, Floodplain Forest, Missouri	20 (1)	47:47	2,000	1.61	1.49	500 - 5,000

TABLE 9.—*Beryllium in rocks, unconsolidated geologic deposits, soils, and plant ash*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Granite						
Precambrian; Missouri	1 (1)	29:30	2.0	1.48	1.20	<1 - 3
Rhyolite						
Precambrian; Missouri	1 (1)	25:30	1.5	1.54	1.20	<1 - 3
Sandstone						
Sauk sequence; Western United States	3 (2)	38:400	<1	--	--	<1 - 12
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	14:32	.80	1.77	--	<1 - 1.5
Shale						
Upper Mississippian; Kentucky	5 (2)	1:142	<5	--	--	<5 - 5
Mississippian; Missouri, Oklahoma, and Arkansas	7 (1)	12:18	1.1	1.64	1.27	<1 - 3
Pennsylvanian; Kentucky	5 (2)	2:152	<5	--	--	<5 - 5
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	31:32	1.7	1.44	1.27	<1 - 3
Limestone and dolomite						
Upper Ordovician; Kentucky	5 (1)	1:80	<5	--	--	<5 - 5
Upper Mississippian; Kentucky	5 (1)	1:152	<2	--	--	<2 - 2
Pennsylvanian; Kentucky	5 (1)	4:80	<2	--	--	<2 - 10
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	1:32	<1	--	--	<1 - 1
Siderite						
Upper Paleozoic; Kentucky	11 (1)	13:30	1.7	1.29	--	<2 - 3
UNCONSOLIDATED GEOLOGIC DEPOSITS						
Carbonate residuum (terra rossa)						
On Gasconade Formation; Missouri	12 (1)	15:24	<1	--	--	<1 - 5
On Roubidoux Formation; Missouri	12 (1)	12:24	<1	--	--	<1 - 2
On Jefferson City, Cotter, and Powell Formations; Missouri and Arkansas	12 (1)	19:24	1.0	1.19	1.16	<1 - 2
On Osagean rocks; Missouri	12 (1)	15:24	1.1	1.30	1.16	<1 - 3
On Meramecian rocks; Missouri	12 (1)	22:24	1.7	1.23	1.16	<1 - 3
Loess						
Missouri	13 (1)	18:24	.95	1.22	--	<1 - 1.5

TABLE 9.—*Beryllium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
SOILS						
Cultivated						
Plow zone, garden; Georgia	15 (1)	2:30	<1.5	--	--	<1.5 - 5
Plow zone, corn field; Missouri						
Glaciated Prairie	17 (1)	4:10	1.2	1.26	--	<1.5 - 1.5
Unglaciated Prairie	17 (1)	3:10	1.1	1.31	--	<1.5 - 1.5
Oak-hickory Forest	17 (1)	2:10	<1.5	--	--	<1.5 - 1.5
Plow zone, soybean field; Missouri						
Floodplain Forest	17 (1)	1:10	<1.5	--	--	<1.5 - 1.5
Glaciated Prairie	17 (1)	4:10	1.2	1.26	--	<1.5 - 1.5
Unglaciated Prairie	17 (1)	2:8	1.0	1.34	--	<1.5 - 1.5
Oak-hickory Forest	17 (1)	1:9	<1.5	--	--	<1.5 - 1.5
Plow zone, pasture field; Missouri						
Glaciated Prairie	17 (1)	3:10	1.1	1.31	--	<1.5 - 1.5
Unglaciated Prairie	17 (1)	1:10	<1.5	--	--	<1.5 - 1.5
Oak-hickory Forest	17 (1)	1:10	<1.5	--	--	<1.5 - 1.5
Surface horizon; Missouri	16 (1)	520:1,140	.8	1.43	1.16	<1 - 2
Uncultivated						
A horizon; Georgia	14 (1)	1:30	<1	--	--	<1 - 1.5
	15 (1)	1:30	<1	--	--	<1 - 1.5
A horizon; Kentucky	18 (2)	10:96	<2	--	--	<2 - 2
B horizon; Kentucky	18 (2)	13:96	<2	--	--	<2 - 3
B horizon; Missouri						
Floodplain Forest	20 (1)	33:50	.99	1.46	--	<1 - 2
Glaciated Prairie	20 (1)	46:50	1.2	1.29	--	<1 - 2
Unglaciated Prairie	20 (1)	47:50	1.3	1.27	--	<1 - 2
Cedar Glade	20 (1)	27:50	.88	1.47	--	<1 - 1.5
Oak-hickory Forest	20 (1)	20:50	.76	1.42	--	<1 - 1.5
Oak-hickory-pine Forest	20 (1)	21:50	.77	1.47	--	<1 - 1.5
C horizon; Georgia	14 (1)	1:30	<1	--	--	<1 - 1.5
	15 (1)	1:30	<1	--	--	<1 - 1.5
C horizon; Kentucky	18 (2)	18:96	<2	--	--	<2 - 3
Cultivated and uncultivated						
Surface horizon; Colorado	22 (1)	115:168	1.4	1.52	1.16	<1.5 - 7
B horizon; Eastern United States	21 (1)	121:371	.6	2.53	--	<1 - 7
B horizon; Western United States	21 (1)	166:492	.6	2.47	--	<1 - 7
PLANT ASH						
Native species						
Hickory, pignut; Kentucky	19 (2)	11:88	<4	--	--	<4 - 6
Hickory, shagbark; Kentucky	18 (1)	11:40	.64	4.47	--	<2 - 7
	19 (2)	2:20	<4	--	--	<4 - 6
Hickory, shagbark; Missouri						
Oak-hickory Forest	20 (1)	3:19	<2	--	--	<2 - 2
Oak-hickory-pine Forest	20 (1)	4:7	2.0	2.18	--	<2 - 7

TABLE 9.—*Beryllium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
PLANT ASH--Continued						
Native species--Continued						
Oak, black; Kentucky	19 (2)	2:22	<4	--	--	<4 - 5
Oak, red; Kentucky	18 (1)	1:27	<2	--	--	<2 - 2
Oak, white; Kentucky	19 (2)	9:73	<4	--	--	<4 - 5

TABLE 10.—*Bismuth in soils*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
Cultivated and uncultivated						
B horizon; Western United States	21 (1)	2:492	<10	--	--	<10 - 15

TABLE 11.—*Boron in rocks, unconsolidated geologic deposits, soils, and plant ash*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Granite						
Precambrian; Missouri	1 (1)	5:30	<20	--	--	<20 - 20
Rhyolite						
Precambrian; Missouri	1 (1)	6:30	<20	--	--	<20 - 30
Arkose						
Fountain Formation; Colorado	2 (2)	22:80	3.2	3.46	--	<7 - 68

TABLE 11.—*Boron in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS--Continued						
Sandstone						
Roubidoux Formation; Missouri	4 (1)	6:12	18	1.78	1.40	<20 - 50
Pope Megagroup;[1] Kentucky	5 (2)	57:120	18	1.70	1.42	<20 - 54
Pennsylvanian; Kentucky	5 (2)	86:152	20	1.72	1.54	<20 - 90
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	26:32	36	2.00	1.40	<20 - 70
Chert						
Mississippian; Missouri, Oklahoma, and Arkansas	7 (1)	18:20	39	1.80	1.40	<20 - 70
Shale						
Sauk sequence; Western United States	3 (2)	216:336	43	2.41	1.15	<30 - 220
Lower Mississippian; Kentucky	8 (2)	60:76	66	2.06	--	<33 - 150
Upper Mississippian; Kentucky	5 (2)	130:142	68	1.61	--	<30 - 170
Mississippian; Missouri, Oklahoma, and Arkansas	7 (1)	18:18	64	1.73	1.73	20 - 150
Pennsylvanian; Kentucky	5 (2)	149:152	56	1.39	1.20	<30 - 160
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	32:32	72	1.34	1.73	50 - 150
Black shale						
Devonian and Mississippian; Kentucky	9 (2)	87:88	110	1.28	1.09	<30 - 190
Limestone and dolomite						
Sauk sequence; Western United States	3 (2)	16:392	<46	--	--	<46 - 130
Upper Ordovician; Kentucky	5 (1)	25:80	31	1.58	--	<50 - 100
Tippecanoe sequence; Missouri	10 (1)	1:12	<20	--	--	<20 - 20
Lower Mississippian; Kentucky	5 (1)	32:112	29	1.66	--	<50 - 100
Upper Mississippian; Kentucky	5 (1)	15:152	<50	--	--	<50 - 100
Mississippian; Missouri, Oklahoma, and Arkansas	7 (1)	2:40	<20	--	--	<20 - 300
Pennsylvanian; Kentucky	5 (1)	18:80	<50	--	--	<50 - 100
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	1:32	<20	--	--	<20 - 20
Siderite						
Upper Paleozoic; Kentucky	11 (1)	3:30	<50	--	--	<50 - 50
UNCONSOLIDATED GEOLOGIC DEPOSITS						
Carbonate residuum (terra rossa)						
On Gasconade Formation; Missouri	12 (1)	8:24	22	1.09	1.05	<20 - 20
On Roubidoux Formation; Missouri	12 (1)	8:24	22	1.09	1.05	<20 - 20
On Jefferson City, Cotter, and Powell Formations; Missouri and Arkansas	12 (1)	16:24	21	1.05	1.05	<20 - 20
On Ozarkian rocks; Missouri	12 (1)	2:24	<20	--	--	<20 - 20
On Marmaecian rocks; Missouri	12 (1)	5:24	<20	--	--	<20 - 30

[1] Of Swann and Williams (1961).

TABLE 11.—*Boron in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
UNCONSOLIDATED GEOLOGIC DEPOSITS--Continued						
Loess						
Missouri	13 (1)	24:24	35	1.46	--	30 - 70
SOILS						
Cultivated						
Plow zone, garden; Georgia	14 (1)	15:30	25	1.91	--	<30 - 100
	15 (1)	17:30	31	2.47	--	<30 - 150
Plow zone, corn field; Missouri						
Glaciated Prairie	17 (1)	9:10	25	1.53	1.51	<20 - 50
Unglaciated Prairie	17 (1)	10:10	29	1.52	1.51	20 - 50
Oak-hickory Forest	17 (1)	10:10	41	1.39	1.51	20 - 50
Plow zone, soybean field; Missouri						
Floodplain Forest	17 (1)	8:10	21	1.46	1.51	<20 - 50
Glaciated Prairie	17 (1)	10:10	29	1.52	1.51	20 - 50
Unglaciated Prairie	17 (1)	8:8	31	1.53	1.51	20 - 50
Oak-hickory Forest	17 (1)	8:9	27	1.54	1.51	<20 - 50
Plow zone, pasture field; Missouri						
Floodplain Forest	17 (1)	7:10	21	1.56	1.51	<20 - 50
Glaciated Prairie	17 (1)	9:10	28	1.60	1.51	<20 - 50
Unglaciated Prairie	17 (1)	10:10	36	1.47	1.51	20 - 50
Oak-hickory Forest	17 (1)	10:10	26	1.46	1.51	20 - 50
Surface horizon; Missouri	16 (1)	1,113:1,140	31	1.34	1.46	<20 - 700
Uncultivated						
Surface horizon; Powder River Basin, Wyoming and Montana	25 (1)	44:48	29	1.54	1.23	<20 - 70
A horizon; Georgia	14 (1)	10:30	18	2.55	--	<30 - 100
	15 (1)	13:30	22	3.08	--	<30 - 150
A horizon; Kentucky	18 (2)	87:96	45	1.46	--	<20 - 78
	19 (2)	107:108	63	1.26	1.16	<30 - 90
B horizon; Georgia	14 (1)	10:30	20	1.85	--	<30 - 50
	15 (1)	14:30	25	2.87	--	<30 - 150
B horizon; Kentucky	18 (2)	89:96	39	1.49	--	<20 - 130
B horizon; Missouri						
Floodplain Forest	20 (1)	46:50	29	1.44	1.31	<20 - 50
Glaciated Prairie	20 (1)	49:50	33	1.38	1.31	<20 - 70
Unglaciated Prairie	20 (1)	50:50	35	1.40	1.31	20 - 70
Cedar Glade	20 (1)	43:50	27	1.48	1.31	<20 - 50
Oak-hickory Forest	20 (1)	49:50	39	1.41	1.31	<20 - 70
Oak-hickory-pine Forest	20 (1)	49:50	32	1.43	1.31	<20 - 50
C horizon; Georgia	14 (1)	9:30	18	2.03	--	<30 - 70
	15 (1)	12:30	20	2.94	--	<30 - 200
C horizon; Kentucky	18 (2)	79:96	34	1.72	--	<20 - 140

TABLE 11.—*Boron in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
SOILS—Continued						
Cultivated and uncultivated						
Surface horizon; Colorado	22 (1)	70:168	<20	--	--	<20 - 70
B horizon; Eastern United States	21 (1)	295:371	32	1.92	--	<10 - 150
B horizon; Western United States	21 (1)	303:492	22	2.09	--	<10 - 300
PLANT ASH						
Cultivated plants						
Asparagus; Wisconsin	23 (1)	5:5	540	1.73	--	200 - 1,000
Bean, lima; Georgia	14 (1)	30:30	94	1.54	--	50 - 300
	15 (1)	15:15	70	1.75	--	20 - 200
Bean, snap; Georgia	14 (1)	30:30	160	1.53	--	70 - 300
	15 (1)	30:30	140	1.30	--	70 - 200
Beet, red; Wisconsin	23 (1)	1:3	44	1.96	--	<30 - 70
Blackeyed pea; Georgia	14 (1)	29:29	220	1.54	--	70 - 500
	15 (1)	4:4	140	1.22	--	100 - 150
Cabbage; Georgia	14 (1)	27:28	83	1.72	--	<30 - 300
	15 (1)	25:30	53	2.29	--	<30 - 300
Cabbage; Wisconsin	23 (1)	11:11	110	1.29	--	70 - 150
Carrot; Wisconsin	23 (1)	7:8	62	1.80	--	<30 - 100
Corn; Georgia	14 (1)	26:29	56	1.78	--	<30 - 150
	15 (1)	22:30	37	2.25	--	<30 - 150
Corn; Missouri						
Floodplain Forest	17 (1)	8:8	62	1.29	1.32	50 - 100
Glaciated Prairie	17 (1)	10:10	68	1.29	1.32	50 - 100
Unglaciated Prairie	17 (1)	10:10	59	1.19	1.32	50 - 70
Oak-hickory Forest	17 (1)	10:10	68	1.35	1.32	50 - 100
Corn; Wisconsin	23 (1)	19:27	37	1.76	--	<30 - 100
Onion; Wisconsin	23 (1)	7:7	120	1.51	--	70 - 200
Pepper, sweet; Wisconsin	23 (1)	4:4	64	1.18	--	50 - 70
Potato; Wisconsin	23 (1)	6:10	37	2.27	--	<30 - 100
Soybean; Missouri						
Floodplain Forest	17 (1)	10:10	170	1.34	1.32	100 - 200
Glaciated Prairie	17 (1)	10:10	220	1.26	1.32	150 - 300
Unglaciated Prairie	17 (1)	8:8	210	1.44	1.32	100 - 300
Oak-hickory Forest	17 (1)	9:9	240	1.36	1.32	150 - 300
Tomato; Georgia	14 (1)	27:30	56	1.73	--	<20 - 150
	15 (1)	24:30	38	1.88	--	<20 - 70
Native species						
Black cherry, stems; Georgia	14 (1)	30:30	360	1.75	--	50 - 1,000
	15 (1)	30:30	340	1.48	--	150 - 700
Black cherry, leaves; Georgia	14 (1)	30:30	290	1.43	--	70 - 500
	15 (1)	30:30	230	1.27	--	150 - 300

TABLE 11.—*Boron in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
PLANT ASH--Continued						
Native species--Continued						
Blackgum, stems; Georgia	14 (1)	30:30	430	1.57	--	100 - 700
	15 (1)	30:30	360	1.40	--	150 - 700
Blackgum, leaves; Georgia	14 (1)	30:30	600	1.75	--	70 - 1,500
	15 (1)	30:30	410	1.50	--	200 - 700
Buckbush; Missouri						
Glaciated Prairie	20 (1)	47:47	180	1.37	1.31	100 - 300
Unglaciated Prairie	20 (1)	48:48	170	1.29	1.31	100 - 300
Cedar Glade	20 (1)	50:50	180	1.35	1.31	70 - 300
Oak-hickory Forest	20 (1)	49:49	170	1.35	1.31	100 - 300
Oak-hickory-pine Forest	20 (1)	41:41	180	1.29	1.31	100 - 300
Cedar; Missouri						
Cedar Glade	20 (1)	50:50	160	1.33	1.31	100 - 300
Glaciated Prairie	24 (1)	9:9	210	1.53	--	100 - 500
Unglaciated Prairie	24 (1)	10:10	220	1.26	--	150 - 300
Cedar Glade	24 (1)	10:10	210	1.14	--	200 - 300
Oak-hickory Forest	24 (1)	10:10	210	1.30	--	150 - 300
Oak-hickory-pine Forest	24 (1)	6:6	220	1.31	--	150 - 300
Hickory, pignut; Kentucky	18 (1)	64:64	370	1.72	1.81	15 - 700
	19 (2)	88:88	160	1.26	1.24	97 - 290
Hickory, shagbark; Kentucky	18 (1)	40:40	410	1.47	1.81	200 - 700
	19 (2)	20:20	170	1.27	1.24	100 - 270
Hickory, shagbark; Missouri						
Oak-hickory Forest	20 (1)	19:19	190	1.48	1.31	100 - 500
Oak-hickory-pine Forest	20 (1)	7:7	190	1.11	1.31	150 - 200
Maple, red, stems; Georgia	14 (1)	30:30	370	1.36	--	300 - 700
	15 (1)	30:30	350	1.34	--	200 - 500
Maple, red, leaves; Georgia	14 (1)	30:30	420	1.73	--	50 - 700
	15 (1)	30:30	360	1.67	--	100 - 1,000
Oak, black; Kentucky	18 (1)	25:25	410	1.33	1.26	200 - 500
	19 (2)	22:22	140	1.29	1.24	75 - 190
Oak, post; Cedar Glade, Missouri	20 (1)	50:50	180	1.41	1.31	70 - 300
Oak, red; Kentucky	18 (1)	28:28	500	1.34	1.26	300 - 1,000
	19 (2)	8:8	180	1.34	1.24	140 - 330
Oak, white; Kentucky	18 (1)	49:49	420	1.41	1.26	200 - 700
	19 (2)	75:75	140	1.37	1.24	90 - 500
Oak, white; Missouri						
Oak-hickory Forest	20 (1)	50:50	190	1.47	1.31	100 - 500
Oak-hickory-pine Forest	20 (1)	49:49	190	1.26	1.31	100 - 300
Oak, willow; Floodplain Forest, Missouri	20 (1)	46:46	220	1.34	1.31	100 - 500
Persimmon, stems; Georgia	14 (1)	30:30	320	1.53	--	150 - 700
	15 (1)	30:30	220	1.71	--	50 - 700
Persimmon, leaves; Georgia	14 (1)	30:30	450	1.66	--	70 - 1,000
	15 (1)	30:30	360	1.80	--	70 - 700
Pine, shortleaf; Oak-hickory-pine Forest, Missouri	20 (1)	49:49	230	1.34	1.31	100 - 500

TABLE 11.—*Boron in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
PLANT ASH--Continued						
Native species--Continued						
Sassafras, stems; Georgia	14 (1)	17:17	320	1.70	--	70 - 700
	15 (1)	27:27	250	1.64	--	70 - 500
Sassafras, leaves; Georgia	14 (1)	17:17	300	1.51	--	150 - 700
	15 (1)	27:27	150	1.46	--	70 - 300
Sumac, winged, stems; Georgia	14 (1)	30:30	300	1.48	--	150 - 500
	15 (1)	30:30	230	1.67	--	50 - 500
Sumac, winged, leaves; Georgia	14 (1)	30:30	320	1.54	--	150 - 700
	15 (1)	30:30	250	1.84	--	100 - 700
Sumac, smooth; Missouri						
Floodplain Forest	20 (1)	48:48	230	1.31	1.31	150 - 500
Glaciated Prairie	20 (1)	50:50	230	1.44	1.31	150 - 500
Unglaciated Prairie	20 (1)	49:49	230	1.33	1.31	150 - 500
Cedar Glade	20 (1)	49:49	220	1.37	1.31	100 - 500
Oak-hickory Forest	20 (1)	50:50	200	1.26	1.31	100 - 300
Oak-hickory-pine Forest	20 (1)	49:49	210	1.38	1.31	100 - 500
Sweetgum, stems; Georgia	14 (1)	28:28	260	1.38	--	150 - 500
	15 (1)	27:27	190	1.39	--	100 - 300
Sweetgum, leaves; Georgia	14 (1)	28:28	400	1.51	--	200 - 700
	15 (1)	27:27	280	1.48	--	150 - 500
Sweetgum; Floodplain Forest, Missouri	20 (1)	47:47	160	1.47	1.31	50 - 300

TABLE 12.—*Cadmium in rocks, unconsolidated geologic deposits, soils, and plant ash*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Shale						
Mississippian; Missouri, Oklahoma, and Arkansas	7 (3)	2:18	<1	--	--	<1 - 5
Limestone and dolomite						
Mississippian; Missouri, Oklahoma, and Arkansas	7 (3)	1:40	<1	--	--	<1 - 1

BORON, CADMIUM

TABLE 12.—*Cadmium in rocks, unconsolidated grologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS--Continued						
Limestone and dolomite--Continued						
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (3)	2:32	<1	--	--	<1 - 12
UNCONSOLIDATED GEOLOGIC DEPOSITS						
Carbonate residuum (terra rossa)						
On Gasconade Formation; Missouri	12 (3)	2:24	<1	--	--	<1 - 4
On Roubidoux Formation; Missouri	12 (3)	2:24	<1	--	--	<1 - 1.5
On Jefferson City, Cotter, and Powell Formations; Missouri and Arkansas	12 (3)	1:24	<1	--	--	<1 - 1
On Osageen rocks; Missouri	12 (3)	4:24	<1	--	--	<1 - 3
On Meramecian rocks; Missouri	12 (3)	6:24	.42	3.40	--	<1 - 6
SOILS						
Cultivated						
Plow zone, corn field; Oak-hickory Forest, Missouri	17 (3)	1:10	<1	--	--	<1 - 1.5
Plow zone, soybean field; Missouri						
Glaciated Prairie	17 (3)	1:10	<1	--	--	<1 - 1.0
Unglaciated Prairie	17 (3)	1:8	<1	--	--	<1 - 2.5
Plow zone, pasture field; Missouri						
Floodplain Forest	17 (3)	1:10	<1	--	--	<1 - 1.0
Glaciated Prairie	17 (3)	1:10	<1	--	--	<1 - 4.5
Oak-hickory Forest	17 (3)	1:10	<1	--	--	<1 - 2.5
Surface horizon; Missouri	16 (3)	12:1,140	<1	--	--	<1 - 11
Cultivated and uncultivated						
Surface horizon; Colorado	22 (3)	10:168	<1	--	--	<1 - 4
B horizon; Eastern United States	21 (3)	2:420	<1	--	--	<1 - 1
B horizon; Western United States	21 (3)	9:492	<1	--	--	<1 - 10
PLANT ASH						
Cultivated plants						
Corn; Missouri						
Floodplain Forest	17 (3)	6:8	0.37	1.72	1.42	<0.2 - 4.4
Glaciated Prairie	17 (3)	9:10	.62	2.34	1.42	<.2 - 8.2
Unglaciated Prairie	17 (3)	9:10	.40	1.49	1.42	<.2 - 4.0
Oak-hickory Forest	17 (3)	9:10	.64	3.56	1.42	<.2 - 5.2
Soybean; Missouri						
Floodplain Forest	17 (3)	10:10	2.3	2.33	1.42	.7 - 7.0
Glaciated Prairie	17 (3)	10:10	.60	2.04	1.42	.3 - 1.6
Unglaciated Prairie	17 (3)	8:8	.80	1.53	1.42	.4 - 1.2
Oak-hickory Forest	17 (3)	9:9	.68	1.93	1.42	.2 - 1.7

TABLE 12.—*Cadmium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
PLANT ASH--Continued						
Native species						
Buckbush; Missouri						
Glaciated Prairie	20 (3)	47:47	12	1.91	1.21	2.8 - 50
Unglaciated Prairie	20 (3)	48:48	14	2.08	1.21	3.2 - 60
Cedar Glade	20 (3)	50:50	6.2	1.43	1.21	3.6 - 15
Oak-hickory Forest	20 (3)	49:49	12	1.69	1.21	3.4 - 36
Oak-hickory-pine Forest	20 (3)	41:41	10	1.86	1.21	2.8 - 40
Cedar; Missouri						
Cedar Glade	20 (3)	50:50	1.5	1.52	1.21	.050 - 3.4
Glaciated Prairie	24 (3)	9:9	3.2	1.92	--	1.5 - 9.8
Unglaciated Prairie	24 (3)	10:10	5.0	1.70	--	1.4 - 8.4
Cedar Glade	24 (3)	10:10	.95	1.60	--	.5 - 2.6
Oak-hickory Forest	24 (3)	10:10	2.6	2.64	--	.6 - 12
Oak-hickory-pine Forest	24 (3)	4:4	1.4	1.36	--	1.0 - 2.0
Hickory, shagbark; Missouri						
Oak-hickory Forest	20 (3)	19:19	18	1.80	1.21	3.2 - 40
Oak-hickory-pine Forest	20 (3)	7:7	20	1.60	1.21	9.4 - 33
Oak, post; Cedar Glade, Missouri	20 (3)	50:50	2.3	1.51	1.21	1.2 - 10
Oak, white; Missouri						
Oak-hickory Forest	20 (3)	50:50	4.1	1.39	1.21	2.0 - 7.6
Oak-hickory-pine Forest	20 (3)	49:49	3.9	1.44	1.21	1.6 - 10
Oak, willow; Floodplain Forest, Missouri	20 (3)	46:46	8.3	1.85	1.21	2.7 - 60
Pine, shortleaf; Oak-hickory-pine Forest, Missouri	20 (3)	49:49	14	1.61	1.21	4 - 38
Sagebrush; Powder River Basin, Wyoming and Montana	25 (3)	48:48	5.2	1.92	--	1.3 - 30
Sumac, smooth; Missouri						
Floodplain Forest	20 (3)	48:48	4.4	2.09	1.21	1.2 - 28
Glaciated Prairie	20 (3)	50:50	3.1	1.88	1.21	1.2 - 60
Unglaciated Prairie	20 (3)	49:49	4.2	1.83	1.21	1.2 - 12
Cedar Glade	20 (3)	49:49	1.7	1.48	1.21	.8 - 5.6
Oak-hickory Forest	20 (3)	50:50	2.8	1.63	1.21	1.0 - 11
Oak-hickory-pine Forest	20 (3)	49:49	2.2	1.60	1.21	.8 - 7.8
Sweetgum; Floodplain Forest, Missouri	20 (3)	47:47	6.0	2.00	1.21	1.4 - 21

TABLE 13.—*Calcium in rocks, unconsolidated geologic deposits, soils, and plant ash*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
ROCKS						
Granite						
Precambrian; Missouri	1 (5)	30:30	0.41	2.25	1.02	0.07 - 1.2
Rhyolite						
Precambrian; Missouri	1 (5)	23:30	.22	3.33	1.02	<.07 - 1.3
Sandstone						
Sauk sequence; Western United States	3 (16)	392:400	.22	5.70	1.90	<.014 - 14
Pope Megagroup;[1] Kentucky	5 (16)	112:120	.13	7.59	2.69	<.0072 - 15
Pennsylvanian; Kentucky	5 (16)	146:152	.094	4.45	2.09	<.0072 - 12
Chert						
Mississippian; Missouri, Oklahoma, and Arkansas	7 (5)	15:20	.42	8.55	1.32	<.07 - 9.3
Shale						
Sauk sequence; Western United States	3 (16)	332:336	.97	4.34	1.89	<.014 - 29
Lower Mississippian; Kentucky	8 (16)	74:76	.80	6.83	--	<.0072 - 14
Upper Mississippian; Kentucky	5 (16)	133:142	.49	6.98	--	<.0072 - 16
Pennsylvanian; Kentucky	5 (16)	139:152	.13	3.71	3.20	<.0072 - 4.0
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (5)	32:32	1.1	4.15	1.05	.14 - 13
Siderite						
Upper Paleozoic; Kentucky	11 (16)	30:30	4.1	2.23	--	1.4 - 30
UNCONSOLIDATED GEOLOGIC DEPOSITS						
Carbonate residuum (terra rossa)						
On Gasconade Formation; Missouri	12 (1)	23:24	0.059	4.11	1.07	<0.002 - 5
On Roubidoux Formation; Missouri	12 (1)	24:24	.041	3.36	1.07	.005 - 3
On Jefferson City, Cotter, and Powell Formations; Missouri and Arkansas	12 (1)	24:24	.086	2.15	1.07	.015 - 1.5
On Ozagean rocks; Missouri	12 (1)	24:24	.031	4.76	1.07	.002 - 1.5
On Meramecian rocks; Missouri	12 (1)	24:24	.11	2.75	1.07	.015 - 1.5
Loess						
Missouri	13 (5)	24:24	.88	2.22	--	.29 - 4.2

[1] Of Swann and Willman (1961).

TABLE 13.—Calcium in rocks, unconsolidated geologic deposits, soils, and plant ash—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
SOILS						
Cultivated						
Plow zone, garden; Georgia	14 (13)	30:30	0.08	2.16	--	0.02 - 0.5
	15 (13)	30:30	.17	2.19	--	.03 - 1
Plow zone, corn field; Missouri						
Floodplain Forest	17 (5)	8:8	.48	1.38	1.03	.35 - .83
Glaciated Prairie	17 (5)	10:10	.57	1.30	1.03	.40 - .89
Unglaciated Prairie	17 (5)	10:10	.39	2.43	1.03	.14 - 3.1
Oak-hickory Forest	17 (5)	10:10	.44	2.30	1.03	.16 - 2.0
Plow zone, soybean field; Missouri						
Floodplain Forest	17 (5)	10:10	.47	1.49	1.03	.22 - .81
Glaciated Prairie	17 (5)	10:10	.58	1.33	1.03	.42 - .97
Unglaciated Prairie	17 (5)	8:8	.38	1.76	1.03	.17 - 1.0
Oak-hickory Forest	17 (5)	9:9	.51	2.18	1.03	.31 - 3.9
Plow zone, pasture field; Missouri						
Floodplain Forest	17 (5)	10:10	.48	1.46	1.03	.21 - .89
Glaciated Prairie	17 (5)	10:10	.66	1.38	1.03	.48 - 1.2
Unglaciated Prairie	17 (5)	10:10	.47	2.34	1.03	.14 - 4.1
Oak-hickory Forest	17 (5)	10:10	.44	1.55	1.03	.21 - .86
Surface horizon; Missouri	16 (5)	1,114:1,140	.33	2.03	1.12	<.07 - 5.6
Uncultivated						
Surface horizon; Powder River Basin, Wyoming and Montana	25 (5)	48:48	.62	3.18	1.20	.05 - 7
A horizon; Georgia	14 (13)	23:30	.12	1.80	--	<.01 - .4
	15 (13)	29:30	.31	1.44	--	<.01 - .65
A horizon; Kentucky	18 (16)	91:96	.14	3.23	1.56	<.01 - 3.4
	19 (16)	105:108	.26	2.60	1.83	<.035 - 1.1
B horizon; Georgia	14 (13)	21:30	.10	1.51	--	<.01 - .25
	15 (13)	30:30	.33	1.37	--	.2 - .6
B horizon; Kentucky	18 (16)	91:96	.12	3.02	1.56	<.01 - 1.2
B horizon; Missouri						
Floodplain Forest	20 (5)	50:50	.42	1.76	1.36	.07 - 1.5
Glaciated Prairie	20 (5)	50:50	.38	1.36	1.36	.21 - .86
Unglaciated Prairie	20 (5)	49:50	.24	1.79	1.36	<.07 - .57
Cedar Glade	20 (5)	49:50	1.7	4.52	1.36	<.07 - 30
Oak-hickory Forest	20 (5)	46:50	.15	2.80	1.36	<.07 - 8.6
Oak-hickory-pine Forest	20 (5)	28:50	.065	2.44	1.36	<.07 - .57
C horizon; Georgia	14 (13)	23:30	.12	1.81	--	<.01 - .35
	15 (13)	30:30	.35	1.28	--	.2 - .5
Cultivated and uncultivated						
Surface horizon; Colorado	22 (5)	167:168	.9	2.37	1.04	<.01 - 25
B horizon; Eastern United States	21 (13)	363:370	.32	2.87	--	<.01 - 16
B horizon; Western United States	21 (13)	491:491	1.8	2.93	--	.01 - 40

TABLE 13.—*Calcium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
PLANT ASH						
Cultivated plants						
Bean, lima; Georgia	14 (13)	30:30	3	1.32	--	2.1 - 8.3
	15 (13)	15:15	3.7	1.63	--	1.9 - 8.6
Bean, snap; Georgia	14 (13)	30:30	5.3	1.39	--	2.4 - 12
	15 (13)	30:30	6.5	1.31	--	3.8 - 10
Beet, red; Wisconsin	23 (1)	3:3	1.8	1.74	--	1.0 - 3.0
Blackeyed pea; Georgia	14 (13)	29:29	6.6	1.31	--	3.6 - 12
	15 (13)	4:4	4.7	1.29	--	3.7 - 6.7
Cabbage; Georgia	14 (13)	28:28	16	1.38	--	5.5 - 23
	15 (13)	30:30	20	1.19	--	13 - 26
Cabbage; Wisconsin	23 (1)	3:11	>10	--	--	5 - >10
Corn; Georgia	14 (13)	29:29	1.8	1.44	--	.8 - 3.6
	15 (13)	30:30	1.7	1.51	--	.8 - 3.4
Corn; Missouri						
Floodplain Forest	17 (3)	8:8	.30	1.33	1.09	.2 - .44
Glaciated Prairie	17 (3)	10:10	.31	1.27	1.09	.18 - .42
Unglaciated Prairie	17 (3)	10:10	.29	1.29	1.09	.20 - .42
Oak-hickory Forest	17 (3)	10:10	.32	1.22	1.09	.24 - .42
Corn; Wisconsin	23 (1)	27:27	.70	1.99	--	.3 - 5
Onion; Wisconsin	23 (1)	5:7	6.6	2.11	--	3 - >10
Pepper, sweet; Wisconsin	23 (1)	4:4	2.7	2.19	--	1 - 5
Potato; Wisconsin	23 (1)	10:10	.81	1.63	--	.5 - 3
Soybean; Missouri						
Floodplain Forest	17 (3)	10:10	5.0	1.14	1.09	4.2 - 6.4
Glaciated Prairie	17 (3)	10:10	5.0	1.16	1.09	3.4 - 5.8
Unglaciated Prairie	17 (3)	8:8	6.2	1.12	1.09	5.0 - 7.4
Oak-hickory Forest	17 (3)	9:9	5.6	1.11	1.09	4.6 - 6.4
Tomato; Georgia	14 (13)	30:30	1.7	1.44	--	.8 - 4.6
	15 (13)	30:30	1.5	1.27	--	.8 - 2.1
Native species						
Black cherry, stems; Georgia	14 (13)	30:30	26	1.17	--	17 - 33
	15 (13)	30:30	25	1.23	--	17 - 34
Black cherry, leaves; Georgia	14 (13)	30:30	23	1.16	--	16 - 34
	15 (13)	30:30	21	1.20	--	14 - 28
Blackgum, stems; Georgia	14 (13)	30:30	25	1.14	--	20 - 32
	15 (13)	30:30	26	1.14	--	19 - 33
Blackgum, leaves; Georgia	14 (13)	30:30	17	1.21	--	11 - 24
	15 (13)	30:30	16	1.26	--	7.8 - 25
Buckbush; Missouri						
Glaciated Prairie	20 (3)	47:47	15	1.11	1.10	12 - 19
Unglaciated Prairie	20 (3)	48:48	15	1.12	1.10	12 - 20
Cedar Glade	20 (3)	50:50	18	1.15	1.10	13 - 26
Oak-hickory Forest	20 (3)	49:49	15	1.22	1.10	9.2 - 24
Oak-hickory-pine Forest	20 (3)	41:41	15	1.27	1.10	6.8 - 23

TABLE 13.—*Calcium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
PLANT ASH—Continued						
Native species—Continued						
Cedar; Missouri						
Cedar Glade	20 (3)	50:50	31	1.09	1.10	24 - 36
Glaciated Prairie	24 (3)	9:9	25	1.08	--	23 - 29
Unglaciated Prairie	24 (3)	10:10	25	1.10	--	21 - 30
Cedar Glade	24 (3)	10:10	31	1.04	--	29 - 33
Oak-hickory Forest	24 (3)	10:10	26	1.13	--	23 - 33
Oak-hickory-pine Forest	24 (3)	6:6	28	1.11	--	23 - 30
Hickory, pignut; Kentucky	18 (3)	60:60	30	1.11	1.04	19 - 34
	19 (3)	88:88	31	1.08	1.05	24 - 37
Hickory, shagbark; Kentucky	18 (3)	40:40	28	1.12	1.04	21 - 34
	19 (3)	20:20	31	1.11	1.05	21 - 37
Hickory, shagbark; Missouri						
Oak-hickory Forest	20 (3)	19:19	34	1.07	1.10	30 - 40
Oak-hickory-pine Forest	20 (3)	7:7	35	1.04	1.10	34 - 37
Maple, red, stems; Georgia	14 (13)	30:30	24	1.19	--	16 - 31
	15 (13)	30:30	25	1.20	--	13 - 32
Maple, red, leaves; Georgia	14 (13)	30:30	17	1.21	--	11 - 24
	15 (13)	30:30	16	1.26	--	9 - 24
Oak, black; Kentucky	18 (3)	25:25	29	1.09	1.06	21 - 37
	19 (3)	22:22	30	1.06	1.05	27 - 34
Oak, post; Cedar Glade, Missouri	20 (3)	50:50	32	1.11	1.10	23 - 38
Oak, red; Kentucky	18 (3)	27:27	30	1.09	1.06	26 - 36
	19 (3)	9:9	29	1.10	1.05	25 - 33
Oak, white; Kentucky	18 (3)	48:48	28	1.12	1.06	19 - 33
	19 (3)	76:76	28	1.08	1.05	23 - 36
Oak, white; Missouri						
Oak-hickory Forest	20 (3)	50:50	33	1.08	1.10	26 - 38
Oak-hickory-pine Forest	20 (3)	49:49	34	1.06	1.10	30 - 37
Oak, willow; Floodplain Forest, Missouri	20 (3)	46:46	28	1.12	1.10	21 - 35
Persimmon, stems; Georgia	14 (13)	30:30	23	1.24	--	13 - 33
	15 (13)	30:30	20	1.28	--	12 - 28
Persimmon, leaves; Georgia	14 (13)	30:30	15	1.55	--	2.3 - 25
	15 (13)	30:30	16	1.30	--	9.7 - 25
Pine, shortleaf; Oak-hickory-pine Forest, Missouri	20 (3)	49:49	13	1.31	1.10	6.4 - 23
Sassafras, stems; Georgia	14 (13)	17:17	21	1.35	--	8.3 - 28
	15 (13)	27:27	19	1.37	--	9.1 - 26
Sassafras, leaves; Georgia	14 (13)	17:17	19	1.25	--	11 - 26
	15 (13)	27:27	15	1.27	--	7.9 - 25
Sumac, winged, stems; Georgia	14 (13)	30:30	25	1.27	--	12 - 34
	15 (13)	30:30	24	1.27	--	9.8 - 35
Sumac, winged, leaves; Georgia	14 (13)	30:30	19	1.21	--	12 - 26
	15 (13)	30:30	18	1.22	--	13 - 26

TABLE 13.—*Calcium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
		PLANT ASH--Continued				
Native species--Continued						
Sumac, smooth; Missouri						
Floodplain Forest	20 (3)	48:48	24	1.20	1.10	15 - 34
Glaciated Prairie	20 (3)	50:50	26	1.14	1.10	19 - 31
Unglaciated Prairie	20 (3)	49:49	26	1.14	1.10	17 - 33
Cedar Glade	20 (3)	49:49	29	1.12	1.10	21 - 37
Oak-hickory Forest	20 (3)	50:50	24	1.20	1.10	12 - 31
Oak-hickory-pine Forest	20 (3)	49:49	27	1.11	1.10	19 - 32
Sweetgum, stems; Georgia	14 (13)	28:28	26	1.17	--	16 - 32
	15 (13)	27:27	23	1.31	--	12 - 35
Sweetgum, leaves; Georgia	14 (13)	28:28	19	1.16	--	11 - 23
	15 (13)	27:27	16	1.23	--	9.3 - 23
Sweetgum; Floodplain Forest, Missouri	20 (3)	47:47	27	1.14	1.10	20 - 36

TABLE 14.—*Carbon (carbonate) in rocks, unconsolidated geologic deposits, and soils*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean except that values preceded by asterisk are arithmetic mean. Deviation, geometric deviation except that values preceded by asterisk are standard deviation. Error, geometric error attributed to laboratory procedures except that values preceded by asterisk are standard error. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
		ROCKS				
Sandstone						
Pope Megagroup;[1] Kentucky	5 (16)	22:120	<0.014	--	--	<0.014 - 4.9
Pennsylvanian; Kentucky	5 (16)	12:152	<.014	--	--	<.014 - 3.6
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (10)	24:32	.01	--	--	<.01 - 9.4
Shale						
Pennsylvanian; Kentucky	5 (16)	41:152	<.014	--	--	<.014 - .44
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (10)	31:32	.16	5.07	1.41	<.01 - 4.3
Black shale						
Devonian and Mississippian; Kentucky	9 (10)	28:28	.060	4.16	--	.005 - 5.1

[1] Of Swann and Willman (1961).

TABLE 14.—*Carbon (carbonate) in rocks, unconsolidated geologic deposits, and soils*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
ROCKS—Continued						
Siderite						
Upper Paleozoic; Kentucky	11 (16)	30:30	*7.1	*1.96	--	2.8 - 11
UNCONSOLIDATED GEOLOGIC DEPOSITS						
Loess						
Missouri	13 (10)	22:24	0.088	5.80	--	<0.01 - 2.3
SOILS						
Cultivated						
Plow zone, corn field; Missouri						
Floodplain Forest	17 (10)	2:8	<0.01	--	--	<0.01 - .14
Glaciated Prairie	17 (10)	4:10	.0075	4.28	--	<.01 - .06
Unglaciated Prairie	17 (10)	4:10	<.01	--	--	<.01 - .75
Oak-hickory Forest	17 (10)	4:10	<.01	--	--	<.01 - .50
Plow zone, soybean field; Missouri						
Floodplain Forest	17 (10)	2:10	<.01	--	--	<.01 - .06
Glaciated Prairie	17 (10)	2:10	<.01	--	--	<.01 - .05
Unglaciated Prairie	17 (10)	3:8	<.01	--	--	<.01 - .15
Oak-hickory Forest	17 (10)	4:9	<.01	--	--	<.01 - .93
Plow zone, pasture field; Missouri						
Glaciated Prairie	17 (10)	4:10	<.01	--	--	<.01 - .18
Unglaciated Prairie	17 (10)	3:10	<.01	--	--	<.01 - .05
Oak-hickory Forest	17 (10)	3:10	<.01	--	--	<.01 - .06
Surface horizon; Missouri	16 (10)	946:1,140	.028	2.85	2.31	<.01 - 2.9
Uncultivated						
B horizon; Missouri						
Floodplain Forest	20 (10)	45:50	.046	3.06	2.73	<.01 - .51
Glaciated Prairie	20 (10)	44:50	.055	2.95	2.73	<.01 - .29
Unglaciated Prairie	20 (10)	42:50	.046	3.34	2.73	<.01 - .25
Oak-hickory Forest	20 (10)	44:50	.054	4.14	2.73	<.01 - 4.7
Oak-hickory-pine Forest	20 (10)	45:50	.055	3.11	2.73	<.01 - .34
Cultivated and uncultivated						
Surface horizon; Colorado	22 (10)	90:168	.01	8.90	1.71	<.01 - 6.4

TABLE 15.—*Carbon (organic) in rocks, unconsolidated geologic deposits, and soils*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
ROCKS						
Sandstone						
Roubidoux Formation; Missouri	4 (11)	11:12	0.30	3.13	1.93	<0.1 - 4.5
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (11)	32:32	.35	2.07	1.93	.1 - 1.4
Chert						
Mississippian; Missouri, Oklahoma, and Arkansas	7 (11)	20:20	.44	2.26	1.93	.2 - 1.4
Shale						
Mississippian; Missouri, Oklahoma, and Arkansas	7 (11)	16:18	.27	3.89	1.71	<.1 - 7.2
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (11)	27:32	.32	2.57	1.71	<.1 - 1
Black shale						
Devonian and Mississippian; Kentucky	9 (11)	88:88	10	1.58	1.15	1.7 - 21
Limestone and dolomite						
Sauk sequence; Missouri and Arkansas	4 (11)	24:48	.11	2.58	2.38	<.1 - .60
Tippecanoe sequence; Missouri	10 (11)	12:12	.28	2.55	2.38	.1 - 1.6
Mississippian; Missouri, Oklahoma, and Arkansas	7 (11)	34:40	.22	2.31	2.38	<.1 - 1
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (11)	19:32	.10	2.77	2.38	<.1 - .11
UNCONSOLIDATED GEOLOGIC DEPOSITS						
Loess						
Missouri	13 (11)	24:24	0.13	1.62	--	0.1 - 0.3
SOILS						
Cultivated						
Plow zone, corn field; Missouri						
Floodplain Forest	17 (11)	8:8	0.91	1.32	1.32	0.6 - 1.3
Glaciated Prairie	17 (11)	10:10	1.7	1.26	1.32	1.1 - 2.2
Unglaciated Prairie	17 (11)	10:10	1.4	1.33	1.32	1.0 - 2.0
Oak-hickory Forest	17 (11)	10:10	1.4	1.56	1.32	.8 - 2.8
Plow zone, soybean field; Missouri						
Floodplain Forest	17 (11)	10:10	.93	1.57	1.32	.4 - 1.7
Glaciated Prairie	17 (11)	10:10	1.6	1.32	1.32	.9 - 2.2
Unglaciated Prairie	17 (11)	8:8	1.6	1.48	1.32	1.0 - 3.1
Oak-hickory Forest	17 (11)	9:9	1.1	1.60	1.32	.4 - 1.8

TABLE 15.—*Carbon (organic) in rocks, unconsolidated geologic deposits, and soils*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
SOILS--Continued						
Cultivated--Continued						
Plow zone, pasture field; Missouri						
Floodplain Forest	17 (11)	10:10	1.1	1.69	1.32	0.5 - 3.1
Glaciated Prairie	17 (11)	10:10	2.2	1.22	1.32	1.6 - 3.0
Unglaciated Prairie	17 (11)	10:10	1.7	1.29	1.32	1.1 - 2.7
Oak-hickory Forest	17 (11)	10:10	1.5	1.60	1.32	.7 - 3.2
Surface horizon; Missouri	16 (11)	1,140:1,140	1.3	1.53	1.11	.08 - 5.2
Uncultivated						
B horizon; Missouri						
Floodplain Forest	20 (11)	50:50	.89	2.09	1.34	.1 - 4.0
Glaciated Prairie	20 (11)	50:50	.83	1.69	1.34	.2 - 2.4
Unglaciated Prairie	20 (11)	50:50	.98	1.48	1.34	.5 - 1.9
Cedar Glade	20 (11)	50:50	2.8	1.64	1.34	.7 - 5.9
Oak-hickory Forest	20 (11)	50:50	.96	1.69	1.34	.4 - 3.8
Oak-hickory-pine Forest	20 (11)	50:50	.70	1.81	1.34	.2 - 2.9
Cultivated and uncultivated						
Surface horizon; Colorado	22 (11)	168:168	1.1	2.43	1.02	.4 - 1.5

TABLE 16.—*Cerium in rocks, unconsolidated geologic deposits, soils, and plant ash*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Granite						
Precambrian; Missouri	1 (1)	20:30	150	--	--	<150 - 150
Rhyolite						
Precambrian; Missouri	1 (1)	23:30	150	--	--	<150 - 150
Sandstone						
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	10:32	<150	--	--	<150 - 300

TABLE 16.—*Cerium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS--Continued						
Shale						
Mississippian; Missouri, Oklahoma, and Arkansas	7 (1)	2:18	<100	--	--	<100 - 100
Pennsylvanian; Kentucky	5 (1)	6:35	<150	--	--	<150 - 150
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	9:32	<100	--	--	<100 - 150
Limestone and dolomite						
Pennsylvanian; Kentucky	5 (1)	1:80	<500	--	--	<500 - 500
UNCONSOLIDATED GEOLOGIC DEPOSITS						
Carbonate residuum (terra rossa)						
On Gasconade Formation; Missouri	12 (1)	1:24	<150	--	--	<150 - 200
On Jefferson City, Cotter, and Powell Formations; Missouri and Arkansas	12 (1)	1:24	<150	--	--	<150 - 200
On Osagean rocks; Missouri	12 (1)	5:24	<150	--	--	<150 - 300
On Meramecian rocks; Missouri	12 (1)	1:24	<150	--	--	<150 - 200
Loess						
Missouri	13 (1)	2:24	<100	--	--	<100 - 100
SOILS						
Cultivated						
Plow zone, garden; Georgia	14 (1)	5:30	<150	--	--	<150 - 500
Surface horizon; Missouri	16 (1)	435:1,140	120	1.27	--	<150 - 300
Uncultivated						
A horizon; Georgia	14 (1)	6:30	<150	--	--	<150 - 500
	15 (1)	5:30	79	1.58	--	<150 - 200
B horizon; Georgia	14 (1)	4:30	50	2.19	--	<150 - 300
	15 (1)	6:30	58	2.43	--	<150 - 500
B horizon; Missouri						
Glaciated Prairie	20 (1)	11:50	97	1.36	--	<150 - 150
Unglaciated Prairie	20 (1)	16:50	110	1.34	--	<150 - 200
Cedar Glade	20 (1)	5:50	<150	--	--	<150 - 200
Oak-hickory Forest	20 (1)	6:50	78	1.45	--	<150 - 150
Oak-hickory-pine Forest	20 (1)	2:50	<150	--	--	<150 - 150
C horizon; Georgia	14 (1)	6:30	76	1.76	--	<150 - 200
	15 (1)	3:30	58	1.81	--	<150 - 200
Cultivated and uncultivated						
Surface horizon; Colorado	22 (1)	15:168	<200	--	--	<200 - 700
B horizon; Eastern United States	21 (1)	65:322	78	1.70	--	<150 - 300
B horizon; Western United States	21 (1)	76:485	74	1.64	--	<150 - 300

TABLE 16.—*Cerium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
PLANT ASH						
Cultivated plants						
Tomato; Georgia	14 (1)	1:30	<150	--	--	<150 - 300
Native species						
Hickory, shagbark; Oak-hickory-pine Forest, Missouri	20 (1)	4:6	350	1.69	--	<150 - 700

TABLE 17.—*Chromium in rocks, unconsolidated geologic deposits, soils, and plant ash*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Granite						
Precambrian; Missouri	1 (1)	12:30	<1	--	--	<1 - 7
Rhyolite						
Precambrian; Missouri	1 (1)	14:30	.83	3.86	--	<1 - 15
Arkose						
Fountain Formation; Colorado	2 (2)	80:80	15	1.82	1.17	1 - 87
Sandstone						
Sauk sequence; Western United States	3 (2)	398:400	6.5	2.09	1.33	<1 - 130
Roubidoux Formation; Missouri	4 (1)	10:12	2.0	2.47	1.33	<1 - 7
Pope Megagroup;[1] Kentucky	5 (2)	120:120	39	2.00	1.75	3 - 210
Pennsylvanian; Kentucky	5 (2)	152:152	26	2.06	1.36	3 - 210
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	32:32	7.4	2.25	1.33	5 - 100
Shale						
Sauk sequence; Western United States	3 (2)	336:336	75	1.76	1.11	15 - 260
Lower Mississippian; Kentucky	8 (2)	76:76	62	1.43	--	26 - 130
Upper Mississippian; Kentucky	5 (2)	142:142	96	1.30	--	34 - 160
Mississippian; Missouri, Oklahoma, and Arkansas	7 (1)	18:18	130	2.28	1.18	50 - 700
Pennsylvanian; Kentucky	5 (2)	152:152	88	1.35	1.10	35 - 230

[1] Of Swann and Willman (1961).

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TABLE 25.—*Lanthanum in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS--Continued						
Rhyolite						
Precambrian; Missouri	1 (1)	29:30	59	1.55	1.18	<30 - 150
Arkose						
Fountain Formation; Colorado	2 (2)	67:80	21	1.92	1.46	<10 - 100
Sandstone						
Sauk sequence; Western United States	3 (2)	127:400	6	3.16	1.24	<10 - 140
Pope Megagroup;[1] Kentucky	5 (2)	1:120	<50	--	--	<50 - 54
Pennsylvanian; Kentucky	5 (2)	9:152	<50	--	--	<50 - 60
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	26:32	36	1.88	1.14	<30 - 100
Chert						
Mississippian; Missouri, Oklahoma, and Arkansas	7 (1)	1:20	<30	--	--	<30 - 30
Shale						
Sauk sequence; Western United States	3 (2)	153:336	67	1.33	1.14	<10 - 150
Lower Mississippian; Kentucky	8 (2)	4:76	<70	--	--	<70 - 90
Upper Mississippian; Kentucky	5 (2)	21:142	29	1.85	--	<70 - 110
Mississippian; Missouri, Oklahoma, and Arkansas	7 (1)	14:18	30	--	--	<30 - 150
Pennsylvanian; Kentucky	5 (2)	40:152	41	1.67	--	<70 - 140
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	32:32	49	1.37	1.19	30 - 70
Black shale						
Devonian and Mississippian; Kentucky	9 (2)	3:88	<70	--	--	<70 - 98
Limestone and dolomite						
Sauk sequence; Western United States	3 (2)	12:392	<60	--	--	<60 - 66
Lower Mississippian; Kentucky	5 (1)	5:112	<70	--	--	<70 - 300
Mississippian; Missouri, Oklahoma, and Arkansas	7 (1)	11:40	<30	--	--	<30 - 30
Pennsylvanian; Kentucky	5 (1)	6:80	<70	--	--	<70 - 150
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	5:32	24	1.20	--	<30 - 70
Siderite						
Upper Paleozoic; Kentucky	11 (1)	3:30	<70	--	--	<70 - 70
UNCONSOLIDATED GEOLOGIC DEPOSITS						
Carbonate residuum (terra rossa)						
On Gasconade Formation; Missouri	12 (1)	3:24	<30	--	--	<30 - 100
On Roubidoux Formation; Missouri	12 (1)	2:24	<30	--	--	<30 - 50
On Jefferson City, Cotter, and Powell Formations; Missouri and Arkansas	12 (1)	2:24	<30	--	--	<30 - 70

[1] Of Swann and Willman (1961).

TABLE 25.—*Lanthanum in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
UNCONSOLIDATED GEOLOGIC DEPOSITS—Continued						
Carbonate residuum (terra rossa)—Continued						
On Ozarkian rocks; Missouri	12 (1)	17:24	63	2.45	--	<30 - 1,000
On Mesozoic rocks; Missouri	12 (1)	18:24	50	--	--	<30 - 500
Loess						
Missouri	13 (1)	24:24	42	1.33	--	30 - 70
SOILS						
Cultivated						
Plow zone, garden; Georgia	14 (1)	11:30	18	2.86	--	<30 - 150
	15 (1)	18:30	33	2.14	--	<30 - 200
Plow zone, corn field; Missouri						
Glaciated Prairie	17 (1)	9:10	49	1.09	1.18	<50 - 50
Unglaciated Prairie	17 (1)	7:10	45	1.18	1.18	<50 - 50
Oak-hickory Forest	17 (1)	7:10	45	1.18	1.18	<50 - 50
Plow zone, soybean field; Missouri						
Floodplain Forest	17 (1)	3:10	33	1.39	1.18	<50 - 50
Glaciated Prairie	17 (1)	5:10	40	1.28	1.18	<50 - 50
Oak-hickory Forest	17 (1)	6:9	44	1.20	1.18	<50 - 50
Plow zone, pasture field; Missouri						
Floodplain Forest	17 (1)	2:10	28	1.48	1.18	<50 - 50
Glaciated Prairie	17 (1)	6:10	43	1.23	1.18	<50 - 50
Unglaciated Prairie	17 (1)	8:10	47	1.14	1.18	<50 - 50
Oak-hickory Forest	17 (1)	5:10	40	1.42	1.18	<50 - 70
Surface horizon; Missouri	16 (1)	1,136:1,140	41	1.39	1.26	<30 - 150
Uncultivated						
Surface horizon; Powder River Basin, Wyoming and Montana	25 (1)	38:48	30	--	--	<30 - 70
A horizon; Georgia	14 (1)	16:30	26	2.40	--	<30 - 200
	15 (1)	20:30	34	1.73	--	<30 - 100
A horizon; Kentucky	18 (2)	85:96	39	1.26	--	<30 - 81
	19 (2)	35:108	43	1.51	1.05	<50 - 75
B horizon; Georgia	14 (1)	14:30	26	2.40	--	<30 - 100
	15 (1)	22:30	34	1.73	--	<30 - 200
B horizon; Kentucky	18 (2)	84:96	39	1.29	--	<30 - 84
B horizon; Missouri						
Floodplain Forest	20 (1)	45:50	32	1.23	1.22	<30 - 50
Glaciated Prairie	20 (1)	50:50	39	1.35	1.22	30 - 50
Unglaciated Prairie	20 (1)	50:50	45	1.37	1.22	30 - 70
Cedar Glade	20 (1)	45:50	33	1.36	1.22	<30 - 70
Oak-hickory Forest	20 (1)	46:50	35	1.37	1.22	<30 - 70
Oak-hickory-pine Forest	20 (1)	40:50	30	1.31	1.22	<30 - 70
C horizon; Georgia	14 (1)	17:30	30	2.03	--	<30 - 100
	15 (1)	20:30	32	1.64	--	<30 - 100

TABLE 25.—*Lanthanum in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
SOILS--Continued						
Uncultivated--Continued						
C horizon; Kentucky	18 (2)	81:96	41	1.35	--	<30 - 80
Cultivated and uncultivated						
Surface horizon; Colorado	22 (1)	86:168	40	1.59	1.41	<50 - 200
B horizon; Eastern United States	21 (1)	226:370	33	1.90	--	<30 - 200
B horizon; Western United States	21 (1)	345:492	35	1.81	--	<30 - 200
PLANT ASH						
Native species						
Black cherry, stems; Georgia	15 (1)	10:30	14	5.14	--	<30 - 300
Black cherry, leaves; Georgia	14 (1)	4:30	<30	--	--	<30 - 200
	15 (1)	11:30	17	4.73	--	<30 - 200
Buckbush; Missouri						
Oak-hickory Forest	20 (1)	5:49	34	1.48	--	<70 - 70
Oak-hickory-pine Forest	20 (1)	8:41	43	1.39	--	<70 - 70
Hickory, pignut; Kentucky	18 (1)	59:64	200	3.82	1.25	<70 - 2,000
	19 (2)	85:88	270	1.82	1.03	<100 - 1,000
Hickory, shagbark; Kentucky	18 (2)	37:40	180	3.62	1.25	<70 - 1,000
	19 (2)	17:20	190	1.66	1.03	<120 - 420
Hickory, shagbark; Missouri						
Oak-hickory Forest	20 (1)	16:19	110	1.70	--	<70 - 300
Oak-hickory-pine	20 (1)	7:7	270	2.20	--	100 - 700
Oak, black; Kentucky	18 (1)	1:25	<30	--	--	<30 - 100
	19 (2)	1:22	<100	--	--	<100 - 240
Oak, red; Kentucky	18 (1)	1:28	<30	--	--	<30 - 300
Oak, white; Kentucky	19 (2)	2:73	<130	--	--	<130 - 310
Persimmon, stems; Georgia	14 (1)	4:30	<30	--	--	<30 - 300
	15 (1)	5:30	<30	--	--	<30 - 150
Persimmon, leaves; Georgia	14 (1)	5:30	<30	--	--	<30 - 300
	15 (1)	12:30	22	3.03	--	<30 - 100
Sumac, winged, stems; Georgia	15 (1)	9:30	<30	--	--	<30 - 150
Sumac, winged, leaves; Georgia	14 (1)	5:30	<30	--	--	<30 - 300
	15 (1)	13:30	24	4.59	--	<30 - 200
Sweetgum, stems; Georgia	14 (1)	4:28	<30	--	--	<30 - 150
	15 (1)	11:27	22	3.04	--	<30 - 150
Sweetgum, leaves; Georgia	15 (1)	11:27	22	3.23	--	<30 - 100

TABLE 26.—*Lead in rocks, unconsolidated geologic deposits, soils, and plant ash*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean except that values preceded by asterisk are arithmetic mean. Deviation, geometric deviation except that values preceded by asterisk are standard deviation. Error, geometric error attributed to laboratory procedures except that values preceded by asterisk are standard error. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Granite						
Precambrian; Missouri	1 (1)	30:30	21	1.50	1.50	10 - 70
Rhyolite						
Precambrian; Missouri	1 (1)	30:30	18	1.50	1.50	10 - 70
Arkose						
Fountain Formation; Colorado	2 (2)	72:80	10	2.12	1.58	<3 - 35
Sandstone						
Sauk sequence; Western United States	3 (2)	321:400	5	2.54	1.60	<3 - 680
Pope Megagroup;[1] Kentucky	5 (2)	27:120	<7	--	--	<7 - 190
Pennsylvanian; Kentucky	5 (2)	78:152	6	1.87	1.50	<7 - 25
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	29:32	17	2.01	1.22	<10 - 150
Chert						
Mississippian; Missouri, Oklahoma, and Arkansas	7 (1)	2:20	<10	--	--	<10 - 10
Shale						
Sauk sequence; Western United States	3 (2)	107:336	<3	--	--	<3 - 1,300
Lower Mississippian; Kentucky	8 (2)	30:76	16	1.50	--	<20 - 42
Upper Mississippian; Kentucky	5 (2)	89:142	21	1.76	--	<20 - 150
Mississippian; Missouri, Oklahoma, and Arkansas	7 (1)	13:18	11	1.58	1.34	<10 - 30
Pennsylvanian; Kentucky	5 (2)	119:152	24	1.37	1.37	<20 - 53
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	30:32	17	1.92	1.34	<10 - 100
Black shale						
Devonian and Mississippian; Kentucky	9 (2)	63:88	23	1.67	1.37	<20 - 110
Limestone and dolomite						
Sauk sequence; Western United States	3 (2)	49:392	<20	--	--	<20 - 540
Sauk sequence; Missouri and Arkansas	4 (1)	8:48	<10	--	--	<10 - 150
Upper Ordovician; Kentucky	5 (1)	41:80	18	1.14	1.14	<20 - 30
Tippecanoe sequence; Missouri	10 (1)	2:12	4.0	2.06	1.35	<10 - 15
Lower Mississippian; Kentucky	5 (1)	34:112	<20	--	--	<20 - 50
Upper Mississippian; Kentucky	5 (1)	27:152	14	1.26	--	<20 - 30
Mississippian; Missouri, Oklahoma, and Arkansas	7 (1)	5:40	<10	--	--	<10 - 7,000

[1] Of Swann and Willman (1961).

Metal Concentrations in ppm

	USGS Prof Paper 1270 Shacklette & Boerngen, 1984		USGS Prof Paper 574-F Connor & Shacklette, 1975		BYRON BACKGROUND STATION 55-23 WEST OF GERMAN CHURCH RD	
	AVG	RANGE	MEAN	RANGE	SURFACE	2' DEPTH
-b	.66	<1 -8.8				
4s	7.2	<0.1-97	[1-50]		1.9	1.3
D	.92	<1-15	[0.1-40]			
k	not listed	[0.01-0.7]	<1	<1-4.5	0.23	0.09
	54	1-2,000	1-2000		5.0	8.4
	25	<1-700	2-100			
D'	19	<10-700	2-200		6.6	6.6
3	.09	<0.01-4.6	0.01-0.3		.09	0.37
	19	<5-700	5-500		9.7	14.0
	.39	<0.1-4.3	0.1-2			
Ag	not listed	0.1-5	<.5	<.5-3		
T	not listed					
Zn	60	<5-2,900	10-300		18.9	23.9

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TABLE 26.—*Lead in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS--Continued						
Limestone and dolomite--Continued						
Pennsylvanian; Kentucky	5 (1)	58:80	<20	--	--	<20 - 200
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	9:32	4.2	3.13	1.35	<10 - 70
Siderite						
Upper Paleozoic; Kentucky	11 (1)	19:30	19	1.24	--	<20 - 30
UNCONSOLIDATED GEOLOGIC DEPOSITS						
Carbonate residuum (terra rossa)						
On Gasconade Formation; Missouri	12 (1)	24:24	29	1.89	1.23	15 - 150
On Roubidoux Formation; Missouri	12 (1)	23:24	22	2.05	1.23	<10 - 150
On Jefferson City, Cotter, and Powell Formations; Missouri and Arkansas	12 (1)	24:24	22	1.59	1.23	15 - 50
On Osagean rocks; Missouri	12 (1)	24:24	24	1.59	1.23	15 - 100
On Meramecian rocks; Missouri	12 (1)	24:24	26	1.49	1.23	15 - 70
Loess						
Missouri	13 (1)	24:24	15	1.30	1.23	10 - 20
SOILS						
Cultivated						
Plow zone, garden; Georgia	14 (6)	4:30	2.6	2.77	--	<10 - 15
	15 (6)	28:30	26	2.31	--	<10 - 300
Plow zone, corn field; Missouri						
Floodplain Forest	17 (1)	8:8	18	1.16	1.25	15 - 20
Glaciated Prairie	17 (1)	10:10	20	1.29	1.25	15 - 30
Unglaciated Prairie	17 (1)	10:10	23	1.28	1.25	15 - 30
Oak-hickory Forest	17 (1)	10:10	27	1.91	1.25	15 - 150
Plow zone, soybean field; Missouri						
Floodplain Forest	17 (1)	10:10	18	1.15	1.25	15 - 20
Glaciated Prairie	17 (1)	10:10	25	1.41	1.25	15 - 30
Unglaciated Prairie	17 (1)	8:8	31	1.82	1.25	15 - 100
Oak-hickory Forest	17 (1)	9:9	25	1.48	1.25	15 - 50
Plow zone, pasture field; Missouri						
Floodplain Forest	17 (1)	10:10	18	1.16	1.25	15 - 20
Glaciated Prairie	17 (1)	10:10	25	1.63	1.25	15 - 30
Unglaciated Prairie	17 (1)	10:10	22	1.33	1.25	15 - 30
Oak-hickory Forest	17 (1)	10:10	25	1.41	1.25	15 - 50
Surface horizon; Missouri	16 (1)	1,130:1,130	20	1.38	1.22	10 - 70
Uncultivated						
Surface horizon; Powder River Basin, Wyoming and Montana	25 (1)	48:48	17	1.24	1.22	10 - 30

TABLE 26.—*Lead in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
SOILS--Continued						
Uncultivated--Continued						
A horizon; Georgia	14 (6)	7:30	2.8	4.24	--	<10 - 70
	15 (6)	27:30	21	1.83	--	<10 - 70
A horizon; Kentucky	18 (2)	93:96	14	1.51	1.21	<7 - 96
	19 (2)	102:108	17	1.33	1.20	<10 - 30
B horizon; Georgia	14 (6)	3:30	<10	--	--	<10 - 15
	15 (6)	25:30	17	1.68	--	<10 - 50
B horizon; Kentucky	18 (2)	88:96	12	1.60	1.21	<7 - 33
B horizon; Missouri						
Floodplain Forest	20 (1)	49:50	19	1.56	1.23	<10 - 100
Glaciated Prairie	20 (1)	50:50	19	1.31	1.23	15 - 50
Unglaciated Prairie	20 (1)	50:50	24	1.50	1.23	15 - 70
Cedar Glade	20 (1)	50:50	25	1.52	1.23	10 - 70
Oak-hickory Forest	20 (1)	50:50	23	1.50	1.23	15 - 100
Oak-hickory-pine Forest	20 (1)	49:50	18	1.64	1.23	<10 - 200
C horizon; Georgia	14 (6)	6:30	2.6	4.12	--	<10 - 30
	15 (6)	26:30	17	1.58	--	<10 - 30
C horizon; Kentucky	18 (2)	85:96	*15	*6.1	*1.21	<7 - 37
Cultivated and uncultivated						
Surface horizon; Colorado	22 (1)	168:168	28	1.62	1.25	15 - 150
B horizon; Eastern United States	21 (1)	291:371	14	1.96	--	<7 - 300
B horizon; Western United States	21 (1)	440:492	18	1.93	--	<7 - 700
PLANT ASH						
Cultivated plants						
Asparagus; Wisconsin	23 (6)	5:5	87	2.79	--	25 - 300
Bean, lima; Georgia	14 (6)	1:30	<10	--	--	<10 - 50
	15 (6)	1:15	<10	--	--	<10 - 50
Bean, snap; Georgia	14 (6)	2:30	<10	--	--	<10 - 70
	15 (6)	2:30	<10	--	--	<10 - 30
Beet, red; Wisconsin	23 (6)	2:3	<10	--	--	<10 - 25
Blackeyed pea; Georgia	14 (6)	4:29	<10	--	--	<10 - 70
Cabbage; Georgia	14 (6)	1:28	<10	--	--	<10 - 20
	15 (6)	1:30	<10	--	--	<10 - 20
Carrot; Wisconsin	23 (6)	3:8	<10	--	--	<10 - 25
Corn; Georgia	14 (6)	6:29	7.1	3.11	--	<10 - 70
	15 (6)	1:30	<10	--	--	<10 - 70
Corn; Missouri						
Floodplain Forest	17 (1)	1:8	<20	--	--	<20 - 50
Glaciated Prairie	17 (1)	1:10	<20	--	--	<20 - 30
Corn; Wisconsin	23 (6)	10:27	<10	--	--	<10 - 150
Onion; Wisconsin	23 (6)	2:7	<10	--	--	<10 - 25
Potato; Wisconsin	23 (6)	7:10	<10	--	--	<10 - 50
Tomato; Georgia	14 (6)	8:30	<10	--	--	<10 - 300

TABLE 26.—*Lead in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
PLANT ASH--Continued						
Native species						
Black cherry, stems; Georgia	14 (6)	30:30	210	2.71	--	30 - 1,000
	15 (6)	29:30	270	4.64	--	<10 - 2,000
Black cherry, leaves; Georgia	14 (6)	23:30	33	4.65	--	<10 - 700
	15 (6)	29:30	58	2.40	--	<10 - 500
Blackgum, stems; Georgia	14 (6)	29:30	250	2.88	--	<10 - 1,000
	15 (6)	30:30	480	2.34	--	70 - 3,000
Blackgum, leaves; Georgia	14 (6)	29:30	57	2.01	--	<10 - 2,000
	15 (6)	30:30	96	2.56	--	10 - 1,000
Buckbush; Missouri						
Glaciated Prairie	20 (1)	47:47	200	1.76	1.59	50 - 500
Unglaciated Prairie	20 (1)	48:48	210	1.91	1.59	70 - 1,000
Cedar Glade	20 (1)	50:50	300	1.85	1.59	100 - 2,000
Oak-hickory Forest	20 (1)	49:49	260	1.88	1.59	70 - 1,000
Oak-hickory-pine Forest	20 (1)	41:41	420	1.84	1.59	150 - 1,500
Cedar; Missouri						
Cedar Glade	20 (1)	50:50	100	2.06	1.59	30 - 1,500
Glaciated Prairie	24 (1)	9:9	86	1.54	--	50 - 200
Unglaciated Prairie	24 (1)	10:10	91	1.42	--	70 - 150
Cedar Glade	24 (1)	10:10	70	1.26	--	50 - 100
Oak-hickory Forest	24 (1)	10:10	120	3.25	--	50 - 1,500
Oak-hickory-pine Forest	24 (1)	6:6	64	2.16	--	20 - 200
Hickory, pignut; Kentucky	18 (1)	64:64	210	1.61	1.19	100 - 700
	19 (2)	88:88	260	1.51	1.32	120 - 940
Hickory, shagbark; Kentucky	18 (1)	40:40	170	1.57	1.19	70 - 500
	19 (2)	20:20	220	1.65	1.32	88 - 510
Hickory, shagbark; Missouri						
Oak-hickory Forest	20 (1)	19:19	100	1.66	1.59	30 - 200
Oak-hickory-pine Forest	20 (1)	7:7	190	1.65	1.59	100 - 300
Maple, red, stems; Georgia	14 (6)	29:30	120	2.59	--	<10 - 700
	15 (6)	30:30	230	3.13	--	30 - 2,000
Maple, red, leaves; Georgia	14 (6)	26:30	41	2.92	--	<10 - 300
	15 (6)	30:30	100	2.21	--	30 - 700
Oak, black; Kentucky	18 (1)	25:25	150	1.63	1.12	70 - 500
	19 (2)	22:22	140	1.46	1.32	63 - 240
Oak, post; Cedar Glade, Missouri	20 (1)	50:50	80	1.87	1.59	30 - 700
Oak, red; Kentucky	18 (1)	28:28	120	1.34	1.12	70 - 200
	19 (2)	8:8	150	1.52	1.32	90 - 260
Oak, white; Kentucky	18 (1)	49:49	150	1.92	1.12	10 - 700
	19 (2)	75:75	180	1.49	1.32	50 - 440
Oak, white; Missouri						
Oak-hickory Forest	20 (1)	50:50	100	1.85	1.59	30 - 500
Oak-hickory-pine Forest	20 (1)	49:49	140	1.72	1.59	50 - 1,000
Oak, willow; Floodplain Forest, Missouri	20 (1)	46:46	120	1.85	1.59	30 - 500

TABLE 26.—*Lead in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
		PLANT ASH--Continued				
Native species--Continued						
Persimmon, stems; Georgia	14 (6)	29:30	110	2.90	--	<10 - 700
	15 (6)	29:30	150	3.85	--	<10 - 1,500
Persimmon, leaves; Georgia	14 (6)	22:30	24	4.13	--	<10 - 700
	15 (6)	29:30	68	2.59	--	<10 - 500
Pine, shortleaf; Oak-hickory-pine Forest, Missouri	20 (1)	49:49	250	1.70	1.59	100 - 1,500
Sassafras, stems; Georgia	14 (6)	17:17	210	2.37	--	30 - 700
	15 (6)	25:27	140	4.91	--	<10 - 1,000
Sassafras, leaves; Georgia	14 (6)	17:17	83	1.66	--	30 - 200
	15 (6)	27:27	95	2.28	--	30 - 500
Sumac, winged, stems; Georgia	14 (6)	27:30	110	3.91	--	<10 - 1,500
	15 (6)	29:30	110	3.09	--	<10 - 700
Sumac, winged, leaves; Georgia	14 (6)	29:30	67	2.29	--	<10 - 500
	15 (6)	30:30	120	2.25	--	30 - 700
Sumac, smooth; Missouri						
Floodplain Forest	20 (1)	34:48	26	2.28	1.59	<20 - 200
Glaciated Prairie	20 (1)	42:50	32	1.82	1.59	<20 - 100
Unglaciated Prairie	20 (1)	38:49	28	2.11	1.59	<20 - 150
Cedar Glade	20 (1)	43:49	42	2.17	1.59	<20 - 300
Oak-hickory Forest	20 (1)	37:50	30	2.36	1.59	<20 - 150
Oak-hickory-pine Forest	20 (1)	46:49	61	2.23	1.59	<20 - 300
Sweetgum, stems; Georgia	14 (6)	27:28	120	2.86	--	<10 - 700
	15 (6)	26:27	110	3.31	--	<10 - 700
Sweetgum, leaves; Georgia	14 (6)	25:28	45	2.47	--	<10 - 200
	15 (6)	27:27	91	2.07	--	20 - 300
Sweetgum; Floodplain Forest, Missouri	20 (1)	45:47	65	2.09	1.59	<20 - 300

TABLE 27.—*Lithium in rocks, unconsolidated geologic deposits, soils, and plant ash*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Granite						
Precambrian; Missouri	1 (3)	13:30	<5	--	--	<5 - 31
Rhyolite						
Precambrian; Missouri	1 (3)	16:30	5.2	2.19	--	<5 - 14
Sandstone						
Roubidoux Formation; Missouri	4 (3)	3:12	2.1	2.47	1.26	<5 - 9
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (3)	31:32	17	2.30	1.26	<5 - 53
Chert						
Mississippian; Missouri, Oklahoma, and Arkansas	7 (3)	6:20	2.8	2.01	1.26	<5 - 7
Shale						
Mississippian; Missouri, Oklahoma, and Arkansas	7 (3)	18:18	25	1.84	1.13	11 - 110
Pennsylvanian; Kansas, Missouri, and Oklahoma	6 (3)	32:32	79	1.48	1.03	36 - 120
Limestone and dolomite						
Sauk sequence; Missouri and Arkansas	4 (3)	5:48	1.1	2.67	--	<5 - 9
Tippecanoe sequence; Missouri	10 (3)	3:12	<5	--	--	<5 - 18
Mississippian; Missouri, Oklahoma, and Arkansas	7 (3)	5:40	.78	3.87	--	<5 - 18
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (3)	11:32	2.6	2.93	--	<5 - 21
UNCONSOLIDATED GEOLOGIC DEPOSITS						
Carbonate residuum (terra rossa)						
On Gasconade Formation; Missouri	12 (3)	24:24	44	1.35	1.06	24 - 76
On Roubidoux Formation; Missouri	12 (3)	24:24	34	1.71	1.06	9 - 62
On Jefferson City, Cotter, and Powell Formations; Missouri and Arkansas	12 (3)	24:24	46	1.40	1.06	24 - 71
On Osagean rocks; Missouri	12 (3)	24:24	38	1.49	1.06	18 - 68
On Meramecian rocks; Missouri	12 (3)	24:24	44	1.46	1.06	19 - 70
Loess						
Missouri	13 (3)	24:24	23	1.24	--	17 - 34

TABLE 27.—*Lithium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
SOILS						
Cultivated						
Plow zone, corn field; Missouri						
Floodplain Forest	17 (3)	8:8	15	1.32	1.03	9 - 22
Glaciated Prairie	17 (3)	10:10	22	1.22	1.03	18 - 34
Unglaciated Prairie	17 (3)	10:10	18	1.22	1.03	12 - 25
Oak-hickory Forest	17 (3)	10:10	19	1.17	1.03	16 - 26
Plow zone, soybean field; Missouri						
Floodplain Forest	17 (3)	10:10	15	1.42	1.03	8 - 24
Glaciated Prairie	17 (3)	10:10	24	1.12	1.03	20 - 30
Unglaciated Prairie	17 (3)	8:8	20	1.20	1.03	16 - 27
Oak-hickory Forest	17 (3)	9:9	18	1.17	1.03	13 - 22
Plow zone, pasture field; Missouri						
Floodplain Forest	17 (3)	10:10	16	1.49	1.03	8 - 39
Glaciated Prairie	17 (3)	10:10	21	1.12	1.03	18 - 26
Unglaciated Prairie	17 (3)	10:10	20	1.16	1.03	16 - 24
Oak-hickory Forest	17 (3)	10:10	20	1.21	1.03	16 - 28
Surface horizon; Missouri	16 (3)	1,140:1,140	22	1.28	1.05	7 - 47
Uncultivated						
B horizon; Missouri						
Floodplain Forest	20 (3)	50:50	20	1.63	1.06	7 - 49
Glaciated Prairie	20 (3)	50:50	32	1.21	1.06	21 - 58
Unglaciated Prairie	20 (3)	50:50	29	1.33	1.06	16 - 66
Cedar Glade	20 (3)	50:50	23	1.55	1.06	7 - 120
Oak-hickory Forest	20 (3)	50:50	18	1.33	1.06	10 - 31
Oak-hickory-pine Forest	20 (3)	50:50	15	1.41	1.06	6 - 31
Cultivated and uncultivated						
Surface horizon; Colorado	22 (3)	168:168	22	1.87	1.06	7 - 88
B horizon; Eastern United States	21 (3)	336:360	17	2.10	--	<5 - 136
B horizon; Western United States	21 (3)	447:447	23	1.62	--	6 - 130
PLANT ASH						
Native species						
Buckbush; Missouri						
Glaciated Prairie	20 (3)	42:47	5.3	1.37	--	<4 - 12
Unglaciated Prairie	20 (3)	41:46	5.2	1.38	--	<4 - 10
Cedar Glade	20 (3)	31:47	4.0	--	--	<4 - 8
Oak-hickory Forest	20 (3)	34:46	4.5	1.43	--	<4 - 10
Oak-hickory-pine Forest	20 (3)	26:39	4.0	--	--	<4 - 12
Cedar; Missouri						
Cedar Glade	20 (3)	5:49	<4	--	--	<4 - 4

TABLE 27.—*Lithium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
PLANT ASH--Continued						
Native species--Continued						
Hickory, pignut; Kentucky	18 (3)	61:64	11	1.95	1.84	<4.6 - 60
	19 (3)	68:88	6.4	2.06	1.68	<4.6 - 42
Hickory, shagbark; Kentucky	18 (3)	39:40	14	2.30	1.84	<4.6 - 130
	19 (3)	15:20	6.1	1.68	1.54	<4.6 - 14
Hickory, shagbark; Missouri						
Oak-hickory Forest	20 (3)	10:19	4.0	--	--	<4 - 12
Oak-hickory-pine Forest	20 (3)	4:7	4.6	1.52	--	<4 - 8
Oak, black; Kentucky	18 (3)	23:25	15	2.63	1.71	<4.6 - 84
	19 (3)	19:22	8.4	2.07	1.68	<4.6 - 37
Oak, red; Kentucky	18 (3)	27:28	12	2.00	1.71	<4.6 - 60
	19 (3)	8:9	8.3	2.11	1.68	<4.6 - 23
Oak, white; Kentucky	18 (3)	48:49	15	1.86	1.71	<4.6 - 65
	19 (3)	72:76	14	1.82	1.68	<4.6 - 46
Pine, shortleaf; Oak-hickory-pine Forest, Missouri	20 (3)	19:48	<4	--	--	<4 - 10
Sagebrush; Powder River Basin, Wyoming and Montana	25 (3)	48:48	9.4	1.82	--	2.0 - 48

TABLE 28.—*Magnesium in rocks, unconsolidated geologic deposits, soils, and plant ash*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
ROCKS						
Granite						
Precambrian; Missouri	1 (3)	30:30	0.092	2.65	1.07	0.012 - .45
Rhyolite						
Precambrian; Missouri	1 (3)	30:30	.059	2.85	1.07	.0060 - .48
Sandstone						
Sauk sequence; Western United States	3 (16)	367:400	.17	3.17	2.36	<.03 - 4.3
Pope Megagroup;[1] Kentucky	5 (16)	119:120	.13	3.69	1.58	<.0060 - 1.7

[1] Of Swann and Willman (1961).

TABLE 28.—*Magnesium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
ROCKS--Continued						
Sandstone--Continued						
Pennsylvanian; Kentucky	5 (16)	147:152	0.091	3.62	1.69	<0.0060 - 0.84
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (3)	32:32	.21	4.29	1.54	.024 - 3.8
Shale						
Sauk sequence; Western United States	3 (16)	336:336	1.0	2.25	1.27	.024 - 9.8
Lower Mississippian; Kentucky	8 (16)	76:76	1.1	1.90	--	.30 - 4.2
Upper Mississippian; Kentucky	5 (16)	142:142	1.0	1.61	--	.42 - 4.6
Mississippian; Missouri, Oklahoma, and Arkansas	7 (3)	18:18	1.6	2.62	1.22	.43 - 6.8
Pennsylvanian; Kentucky	5 (16)	152:152	.61	1.83	1.16	.090 - 1.4
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (3)	32:32	.95	1.45	1.22	.28 - 1.8
Siderite						
Upper Paleozoic; Kentucky	11 (16)	30:30	1.6	1.46	--	.66 - 3.3
UNCONSOLIDATED GEOLOGIC DEPOSITS						
Carbonate residuum (terra rossa)						
On Gasconade Formation; Missouri	12 (3)	24:24	0.50	1.92	1.04	0.19 - 5.5
On Roubideaux Formation; Missouri	12 (3)	24:24	.43	2.13	1.04	.11 - 4.0
On Jefferson City, Cotter, and Powell Formations; Missouri and Arkansas	12 (3)	24:24	.60	1.47	1.04	.28 - 1.7
On Ozarkan rocks; Missouri	12 (3)	24:24	.40	1.41	1.04	.23 - .75
On Meramecian rocks; Missouri	12 (3)	24:24	.43	1.30	1.04	.24 - .59
Loess						
Missouri	12 (3)	24:24	.63	1.83	--	.31 - 2.1
SOILS						
Cultivated						
Plow zone, garden; Georgia	14 (13)	30:30	0.027	1.84	--	0.01 - 0.1
	15 (13)	30:30	.24	1.95	--	.07 - 1
Plow zone, corn field; Missouri						
Floodplain Forest	17 (3)	8:8	.27	1.82	1.09	.10 - .65
Glaciated Prairie	17 (3)	10:10	.36	1.36	1.09	.25 - .59
Unglaciated Prairie	17 (3)	10:10	.21	1.38	1.09	.13 - .34
Oak-hickory Forest	17 (3)	10:10	.26	1.56	1.09	.11 - .52
Plow zone, soybean field; Missouri						
Floodplain Forest	17 (3)	10:10	.26	1.81	1.09	.11 - .74
Glaciated Prairie	17 (3)	10:10	.38	1.18	1.09	.31 - .51
Unglaciated Prairie	17 (3)	8:8	.22	1.37	1.09	.14 - .36
Oak-hickory Forest	17 (3)	9:9	.23	1.47	1.09	.11 - .31
Plow zone, pasture field; Missouri						
Floodplain Forest	17 (3)	10:10	.25	1.91	1.09	.08 - .81
Glaciated Prairie	17 (3)	10:10	.35	1.36	1.09	.26 - .71

TABLE 28.—*Magnesium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
SOILS--Continued						
Cultivated--Continued						
Plow zone, pasture field; Missouri--Continued						
Unglaciated Prairie	17 (3)	10:10	0.25	1.43	1.09	0.14 - 0.42
Oak-hickory Forest	17 (3)	10:10	.27	1.60	1.09	.11 - .51
Surface horizon; Missouri	16 (3)	1,140:1,140	.26	1.65	1.10	.05 - 2.8
Uncultivated						
Surface horizon; Powder River Basin, Wyoming and Montana	25 (3)	48:48	.50	1.71	1.17	.15 - 2
A horizon; Georgia	14 (13)	30:30	.026	2.48	--	.01 - .3
	15 (13)	30:30	.25	2.19	--	.03 - .7
A horizon; Kentucky	18 (16)	96:96	.19	1.57	1.08	.05 - .6
	19 (16)	108:108	.18	1.37	1.22	.08 - .73
B horizon; Georgia	14 (13)	30:30	.025	2.17	--	.01 - .2
	15 (13)	30:30	.29	2.16	--	.03 - .7
B horizon; Kentucky	18 (16)	96:96	.35	1.49	1.08	.07 - .9
B horizon; Missouri						
Floodplain Forest	20 (3)	50:50	.31	1.80	1.19	.14 - 1.1
Glaciated Prairie	20 (3)	50:50	.54	1.38	1.19	.23 - 1.0
Unglaciated Prairie	20 (3)	50:50	.35	1.57	1.19	.14 - .78
Cedar Glade	20 (3)	50:50	.84	3.06	1.19	.07 - 7.5
Oak-hickory Forest	20 (3)	50:50	.18	2.25	1.19	.04 - 4.8
Oak-hickory-pine Forest	20 (3)	50:50	.11	1.67	1.19	.04 - .58
C horizon; Georgia	14 (13)	30:30	.041	3.05	--	.005 - .5
	15 (13)	30:30	.37	2.09	--	.1 - 2
C horizon; Kentucky	18 (16)	96:96	.34	1.89	1.08	.01 - 2
Cultivated and uncultivated						
Surface horizon; Colorado	22 (3)	168:168	.4	2.21	1.22	.1 - 1.9
B horizon; Eastern United States	21 (13)	358:358	.23	3.39	--	.005 - 5
B horizon; Western United States	21 (13)	491:492	.78	2.21	--	.5 - >10
PLANT ASH						
Cultivated plants						
Asparagus; Wisconsin	23 (13)	5:5	5.7	1.41	--	3 - 7
Bean, lima; Georgia	14 (13)	30:30	3.4	1.53	--	1.5 - 7
	15 (13)	15:15	2.8	1.15	--	2 - 3
Bean, snap; Georgia	14 (13)	30:30	3.6	1.42	--	1.5 - 7
	15 (13)	30:30	4.3	1.49	--	2 - 12
Beet, red; Wisconsin	23 (13)	3:3	2.6	1.26	--	2 - 3
Blackeyed pea; Georgia	14 (13)	29:29	5.0	1.62	--	2 - 12
	15 (13)	4:4	5.2	1.49	--	3 - 7
Cabbage; Georgia	14 (13)	28:28	2.7	1.90	--	.5 - 7
	15 (13)	30:30	2.2	1.68	--	.7 - 7

TABLE 28.—*Magnesium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
		PLANT ASH--Continued				
Cultivated plants--Continued						
Cabbage; Wisconsin	23 (13)	11:11	2.3	1.27	--	1.5 - 3
Carrot; Wisconsin	23 (13)	8:8	2.1	1.80	--	1 - 5
Corn; Georgia	14 (13)	29:29	3.7	1.66	--	1 - 12
	15 (13)	30:30	4.0	1.41	--	2 - 7
Corn; Missouri						
Floodplain Forest	17 (1)	8:8	6.2	1.19	1.20	5 - 7
Glaciated Prairie	17 (1)	10:10	6.3	1.18	1.20	5 - 7
Unglaciated Prairie	17 (1)	10:10	6.5	1.15	1.20	5 - 7
Oak-hickory Forest	17 (1)	10:10	5.9	1.19	1.20	5 - 7
Corn; Wisconsin	23 (13)	12:27	13	2.20	--	3 - >10
Cucumber; Wisconsin	23 (13)	4:4	2.7	1.22	--	2 - 3
Onion; Wisconsin	23 (13)	7:7	2.7	1.40	--	2 - 5
Pepper, sweet; Wisconsin	23 (13)	4:4	2.5	1.26	--	2 - 3
Potato; Wisconsin	23 (13)	10:10	2.2	1.56	--	1 - 5
Soybean; Missouri						
Floodplain Forest	17 (1)	10:10	2.5	1.43	1.20	1 - 3
Glaciated Prairie	17 (1)	10:10	3.0	1.24	1.20	2 - 5
Unglaciated Prairie	17 (1)	8:8	3.2	1.35	1.20	2 - 5
Oak-hickory Forest	17 (1)	9:9	3.6	1.40	1.20	2 - 5
Tomato; Georgia	14 (13)	30:30	1.7	1.41	--	.7 - 3
	15 (13)	30:30	1.5	1.38	--	.7 - 3
Native species						
Black cherry, stems; Georgia	14 (13)	26:30	4.8	1.73	--	1.5 - >10
	15 (13)	30:30	4.0	1.49	--	1.5 - 7
Black cherry, leaves; Georgia	14 (13)	21:30	6.8	1.73	--	1.5 - >10
	15 (13)	24:30	6.7	1.26	--	5 - >10
Blackgum, stems; Georgia	14 (13)	29:30	5.7	1.45	--	2 - >10
	15 (13)	27:30	5.9	1.33	--	3 - >10
Blackgum, leaves; Georgia	14 (13)	6:30	>10	--	--	2 - >10
	15 (13)	12:30	8.9	1.27	--	5 - >10
Buckbush; Missouri						
Glaciated Prairie	20 (1)	47:47	3.5	1.56	1.34	1.5 - 7
Unglaciated Prairie	20 (1)	48:48	3.8	1.51	1.34	2 - 7
Cedar Glade	20 (1)	50:50	4.7	1.55	1.34	2 - 10
Oak-hickory Forest	20 (1)	49:49	3.6	1.65	1.34	1 - 7
Oak-hickory-pine Forest	20 (1)	41:41	3.4	1.59	1.34	1.5 - 7
Cedar; Missouri						
Cedar Glade	20 (1)	50:50	3.0	1.81	1.34	.7 - 7
Glaciated Prairie	24 (1)	9:9	4.7	1.51	--	3 - 10
Unglaciated Prairie	24 (1)	10:10	4.6	1.46	--	2 - 7
Cedar Glade	24 (1)	10:10	6.1	1.19	--	5 - 7
Oak-hickory Forest	24 (1)	10:10	4.7	1.42	--	3 - 7
Oak-hickory-pine Forest	24 (1)	6:6	3.9	1.70	--	2 - 7

TABLE 28.—*Magnesium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
		PLANT ASH--Continued				
Native species--Continued						
Hickory, pignut; Kentucky	18 (3)	60:60	2.7	2.15	1.37	0.72 - 22
	19 (3)	88:88	1.8	1.50	1.05	.4 - 3.5
Hickory, shagbark; Kentucky	18 (3)	40:40	3.0	1.77	1.37	1.1 - 24
	19 (3)	20:20	1.6	1.45	1.05	.66 - 3.4
Hickory, shagbark; Missouri						
Oak-hickory Forest	20 (1)	19:19	2.5	2.11	1.34	.5 - 10
Oak-hickory-pine Forest	20 (1)	7:7	2.2	1.63	1.34	1 - 5
Maple, red, stems; Georgia	14 (13)	30:30	2.5	1.50	--	1 - 6
	15 (13)	30:30	2.3	1.50	--	1 - 7
Maple, red, leaves; Georgia	14 (13)	30:30	5.1	1.56	--	2 - 10
	15 (13)	30:30	4.9	1.45	--	2 - 7
Oak, black; Kentucky	18 (3)	25:25	2.4	2.00	1.96	1.1 - 11
	19 (3)	22:22	1.7	1.34	1.05	.98 - 2.9
Oak, post; Cedar Glade, Missouri	20 (1)	50:50	3.1	2.02	1.34	.7 - 7
Oak, red; Kentucky	18 (3)	27:27	2.2	1.78	1.96	1.1 - 13
	19 (3)	9:9	1.7	1.37	1.05	1.0 - 2.4
Oak, white; Kentucky	18 (3)	47:47	2.0	1.90	1.96	.84 - 12
	19 (3)	76:76	1.6	1.27	1.05	.92 - 2.6
Oak, white; Missouri						
Oak-hickory Forest	20 (1)	50:50	1.8	1.86	1.34	.5 - 7
Oak-hickory-pine Forest	20 (1)	49:49	1.6	1.50	1.34	.7 - 7
Oak, willow; Floodplain Forest, Missouri	20 (1)	46:46	3.4	1.54	1.34	1.5 - 7
Persimmon, stems; Georgia	14 (13)	27:29	5.3	1.43	--	3 - >10
	15 (13)	30:30	4.4	1.37	--	3 - 10
Persimmon, leaves; Georgia	14 (13)	18:30	7.3	1.67	--	3 - >10
	15 (13	28:30	5.5	1.43	--	3 - >10
Pine, shortleaf; Oak-hickory-pine Forest, Missouri	20 (1)	49:49	3.5	1.40	1.34	1.5 - 5
Sassafras, stems; Georgia	14 (13)	17:17	3.2	1.69	--	.7 - 7
	15 (13)	27:27	3.0	1.61	--	1 - 7
Sassafras, leaves; Georgia	14 (13)	25:27	4.7	1.46	--	3 - >10
	15 (13)	25:27	4.7	1.46	--	3 - >10
Sumac, winged, stems; Georgia	14 (13)	30:30	2.9	1.53	--	1.5 - 7
	15 (13)	30:30	2.3	1.41	--	1.5 - 7
Sumac, winged, leaves; Georgia	14 (13)	27:30	5.2	1.55	--	2 - >10
	15 (13)	30:30	3.6	1.49	--	1.5 - 7
Sumac, smooth; Missouri						
Floodplain Forest	20 (1)	48:48	2.9	1.48	1.34	1.5 - 7
Glaciated Prairie	20 (1)	50:50	2.2	1.54	1.34	1.0 - 7
Unglaciated Prairie	20 (1)	49:49	2.3	1.40	1.34	1.5 - 5
Cedar Glade	20 (1)	49:49	2.2	1.69	1.34	.7 - 7
Oak-hickory Forest	20 (1)	50:50	2.0	1.43	1.34	.7 - 5
Oak-hickory-pine Forest	20 (1)	49:49	2.0	1.50	1.34	1.0 - 5

TABLE 28.—*Magnesium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
PLANT ASH—Continued						
Native species--Continued						
Sweetgum, stems; Georgia	14 (13)	28:28	2.6	1.46	--	1.5 - 7
	15 (13)	27:27	3.1	1.63	--	1 - 7
Sweetgum; Floodplain Forest, Missouri	20 (1)	47:47	2.7	1.85	1.34	.7 - 7

TABLE 29.—*Manganese in rocks, unconsolidated geologic deposits, soils, and plant ash*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Granite						
Precambrian; Missouri	1 (1)	30:30	290	2.18	1.23	70 - 1,500
Rhyolite						
Precambrian; Missouri	1 (1)	30:30	320	2.46	1.23	70 - 1,500
Arkose						
Fountain Formation; Colorado	2 (2)	80:80	210	2.92	1.54	18 - 1,700
Sandstone						
Sauk sequence; Western United States	3 (16)	265:400	120	3.52	1.79	<77 - 10,000
Roubidoux Formation; Missouri	4 (1)	12:12	29	3.42	2.25	2 - 150
Pope Megagroup;[1] Kentucky	5 (2)	120:120	87	4.41	1.11	9 - 2,300
Pennsylvanian; Kentucky	5 (2)	152:152	89	4.26	1.22	5 - 1,700
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	32:32	300	4.60	2.25	7 - 3,000
Chert						
Mississippian; Missouri, Oklahoma, and Arkansas	7 (1)	20:20	49	4.38	2.25	.5 - 200
Shale						
Sauk sequence; Western United States	3 (16)	303:336	420	2.19	2.35	<155 - 6,600
Lower Mississippian; Kentucky	8 (2)	76:76	190	1.79	--	77 - 1,600

[1] Of Swann and Willman (1961).

TABLE 29.—*Manganese in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS--Continued						
Shale--Continued						
Upper Mississippian; Kentucky	5 (2)	142:142	130	2.50	--	19 - 4,600
Mississippian; Missouri, Oklahoma, and Arkansas	7 (1)	18:18	140	2.05	1.18	20 - 300
Pennsylvanian; Kentucky	5 (2)	152:152	180	3.11	1.48	12 - 1,000
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	32:32	170	1.97	1.18	30 - 500
Black shale						
Devonian and Mississippian; Kentucky	9 (2)	88:88	65	2.02	1.09	27 - 780
Limestone and dolomite						
Sauk sequence; Western United States	3 (2)	392:392	320	3.20	1.27	11 - 4,500
Sauk sequence; Missouri and Arkansas	4 (1)	48:48	83	3.04	1.29	15 - 2,000
Upper Ordovician; Kentucky	5 (1)	80:80	520	1.80	1.55	50 - 1,500
Tippecanoe sequence; Missouri	10 (1)	12:12	110	2.62	1.29	30 - 300
Lower Mississippian; Kentucky	5 (1)	112:112	160	2.75	1.50	10 - 1,500
Upper Mississippian; Kentucky	5 (1)	152:152	140	2.41	1.34	15 - 1,000
Mississippian; Missouri, Oklahoma, and Arkansas	7 (1)	40:40	160	2.05	1.29	15 - 700
Pennsylvanian; Kentucky	5 (1)	80:80	910	1.63	1.41	200 - 3,000
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	32:32	830	2.37	1.29	200 - 7,000
Siderite						
Upper Paleozoic; Kentucky	11 (1)	30:30	1,700	1.69	--	500 - 3,000
UNCONSOLIDATED GEOLOGIC DEPOSITS						
Carbonate residuum (terra rossa)						
On Gasconade Formation; Missouri	12 (1)	24:24	95	2.23	1.23	30 - 1,500
On Roubidoux Formation; Missouri	12 (1)	24:24	79	1.96	1.23	30 - 500
On Jefferson City, Cotter, and Powell Formations; Missouri and Arkansas	12 (1)	24:24	91	2.30	1.23	30 - 500
On Osagean rocks; Missouri	12 (1)	24:24	110	2.34	1.23	20 - 700
On Meramecian rocks; Missouri	12 (1)	24:24	150	2.47	1.23	30 - 1,000
Loess						
Missouri	13 (1)	24:24	510	1.69	--	150 - 1,000
SOILS						
Cultivated						
Plow zone, garden; Georgia	14 (1)	30:30	99	2.14	--	20 - 700
	15 (1)	30:30	410	1.84	--	150 - 2,000
Plow zone, corn field; Missouri						
Floodplain Forest	17 (1)	8:8	460	2.32	1.28	100 - 1,000
Glaciated Prairie	17 (1)	10:10	590	1.73	1.28	200 - 1,500

TABLE 28.—*Manganese in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
SOILS--Continued						
Cultivated--Continued						
Plow zone, corn field; Missouri--Continued						
Unglaciated Prairie	17 (1)	10:10	530	1.94	1.28	150 - 1,500
Oak-hickory Forest	17 (1)	10:10	530	1.41	1.28	300 - 700
Plow zone, soybean field; Missouri						
Floodplain Forest	17 (1)	10:10	350	2.31	1.28	70 - 1,500
Glaciated Prairie	17 (1)	10:10	500	2.20	1.28	150 - 1,500
Unglaciated Prairie	17 (1)	8:8	590	1.89	1.28	300 - 1,500
Oak-hickory Forest	17 (1)	9:9	650	2.09	1.28	200 - 1,500
Plow zone, pasture field; Missouri						
Floodplain Forest	17 (1)	10:10	350	2.02	1.28	100 - 1,500
Glaciated Prairie	17 (1)	10:10	580	1.89	1.28	200 - 1,500
Unglaciated Prairie	17 (1)	10:10	600	1.33	1.28	300 - 700
Oak-hickory Forest	17 (1)	10:10	490	1.50	1.28	300 - 1,000
Surface horizon; Missouri	16 (1)	1,140:1,140	740	1.83	1.30	15 - 3,000
Uncultivated						
Surface horizon; Powder River Basin, Wyoming and Montana	25 (1)	48:48	250	1.63	--	70 - 1,000
A horizon; Georgia	14 (1)	30:30	130	1.86	--	50 - 700
	15 (1)	30:30	320	1.64	--	100 - 700
A horizon; Kentucky	18 (2)	96:96	400	2.17	1.06	46 - 1,800
	19 (2)	103:108	600	1.90	1.45	<150 - 2,200
B horizon; Georgia	14 (1)	30:30	85	2.03	--	20 - 700
	15 (1)	30:30	280	1.95	--	100 - 1,500
B horizon; Kentucky	18 (2)	96:96	170	1.91	1.06	39 - 620
B horizon; Missouri						
Floodplain Forest	20 (1)	49:50	710	2.72	1.41	100 - >20,000
Glaciated Prairie	20 (1)	50:50	430	2.25	1.41	70 - 2,000
Unglaciated Prairie	20 (1)	50:50	780	2.29	1.41	150 - 7,000
Cedar Glade	20 (1)	50:50	1,100	1.57	1.41	500 - 5,000
Oak-hickory Forest	20 (1)	50:50	730	2.16	1.41	70 - 3,000
Oak-hickory-pine Forest	20 (1)	50:50	660	2.09	1.41	150 - 2,000
C horizon; Georgia	14 (1)	30:30	61	1.87	--	20 - 300
	15 (1)	30:30	220	1.76	--	50 - 700
C horizon; Kentucky	18 (2)	96:96	140	2.47	1.06	19 - 2,000
Cultivated and uncultivated						
Surface horizon; Colorado	22 (1)	168:168	210	1.59	1.21	100 - 700
B horizon; Eastern United States	21 (1)	369:370	290	3.65	--	<2 - 7,000
B horizon; Western United States	21 (1)	491:491	390	1.94	--	30 - 5,000

TABLE 29.—*Manganese in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
		PLANT ASH				
Cultivated plants						
Asparagus; Wisconsin	23 (1)	5:5	470	1.78	--	200 - 1,000
Bean, lima; Georgia	14 (1)	30:30	320	1.68	--	150 - 1,000
	15 (1)	15:15	350	1.61	--	200 - 1,000
Bean, snap; Georgia	14 (1)	30:30	370	1.88	--	150 - 1,000
	15 (1)	30:30	340	1.70	--	150 - 1,000
Beet, red; Wisconsin	23 (1)	3:3	250	1.88	--	150 - 500
Blackeyed pea; Georgia	14 (1)	29:29	810	1.64	--	300 - 2,000
	15 (1)	4:4	480	1.42	--	300 - 700
Cabbage; Georgia	14 (1)	28:28	450	2.40	--	70 - 2,000
	15 (1)	30:30	400	2.26	--	100 - 1,500
Cabbage; Wisconsin	23 (1)	11:11	220	1.71	--	150 - 700
Carrot; Wisconsin	23 (1)	8:8	96	2.00	--	20 - 150
Corn; Georgia	14 (1)	29:29	350	1.64	--	15 - 1,000
	15 (1)	30:30	230	1.87	--	100 - 700
Corn; Missouri						
Glaciated Prairie	17 (1)	10:10	260	1.40	1.16	200 - 500
Unglaciated Prairie	17 (1)	10:10	320	1.31	1.16	200 - 500
Oak-hickory Forest	17 (1)	10:10	290	1.14	1.16	200 - 300
Corn; Wisconsin	23 (1)	27:27	290	1.48	--	150 - 700
Cucumber; Wisconsin	23 (1)	4:4	110	1.55	--	70 - 200
Onion; Wisconsin	23 (1)	7:7	220	2.05	--	100 - 700
Pepper, sweet; Wisconsin	23 (1)	4:4	200	1.98	--	100 - 500
Potato; Wisconsin	23 (1)	10:10	110	1.55	--	50 - 150
Soybean; Missouri						
Floodplain Forest	17 (1)	10:10	400	1.57	1.16	200 - 1,000
Glaciated Prairie	17 (1)	10:10	320	1.31	1.16	200 - 500
Unglaciated Prairie	17 (1)	8:8	310	1.42	1.16	200 - 500
Oak-hickory Forest	17 (1)	9:9	360	1.29	1.16	300 - 500
Tomato; Georgia	14 (1)	30:30	170	1.94	--	70 - 500
	15 (1)	30:30	100	1.49	--	50 - 300
Native species						
Black cherry, stems; Georgia	14 (1)	30:30	5,700	2.46	--	300 - 20,000
	15 (1)	30:30	5,600	2.27	--	1,000 - 30,000
Black cherry, leaves; Georgia	14 (1)	30:30	5,700	2.44	--	150 - 15,000
	15 (1)	30:30	3,700	2.07	--	500 - 15,000
Blackgum, stems; Georgia	14 (1)	30:30	8,400	2.69	--	150 - 30,000
	15 (1)	30:30	9,500	1.86	--	500 - 20,000
Blackgum, leaves; Georgia	14 (1)	30:30	9,300	2.53	--	500 - 20,000
	15 (1)	30:30	9,600	2.11	--	1,000 - 30,000
Buckbush; Missouri						
Glaciated Prairie	20 (1)	47:47	4,900	2.03	1.38	500 - 15,000
Unglaciated Prairie	20 (1)	48:48	5,100	1.88	1.38	1,000 - 15,000
Cedar Glade	20 (1)	50:50	6,300	1.61	1.38	2,000 - 20,000

TABLE 28.—*Manganese in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
PLANT ASH--Continued						
Native species--Continued						
Buckbush; Missouri--Continued						
Oak-hickory Forest	20 (1)	49:49	10,000	1.62	1.38	3,000 - 20,000
Oak-hickory-pine Forest	20 (1)	41:41	10,000	1.55	1.38	5,000 - 30,000
Cedar; Missouri						
Cedar Glade	20 (1)	50:50	1,700	2.21	1.38	300 - 30,000
Glaciated Prairie	24 (1)	9:9	4,800	2.21	--	1,500 - 15,000
Unglaciated Prairie	24 (1)	10:10	5,300	2.40	--	700 - 15,000
Cedar Glade	24 (1)	10:10	1,600	1.85	--	700 - 7,000
Oak-hickory Forest	24 (1)	10:10	5,700	1.92	--	2,000 - 15,000
Oak-hickory-pine Forest	24 (1)	6:6	6,700	1.53	--	5,000 - 15,000
Hickory, pignut; Kentucky	18 (1)	64:64	8,800	1.61	1.21	2,000 - 30,000
	19 (2)	88:88	7,300	1.86	1.11	1,900 - 27,000
Hickory, shagbark; Kentucky	18 (1)	40:40	10,000	1.85	1.21	1,500 - 30,000
	19 (2)	20:20	7,500	1.95	1.11	2,300 - 25,000
Hickory, shagbark; Missouri						
Oak-hickory Forest	20 (1)	19:19	8,300	1.89	1.38	2,000 - 20,000
Oak-hickory-pine Forest	20 (1)	7:7	12,000	1.42	1.38	7,000 - 20,000
Maple, red, stems; Georgia	14 (1)	30:30	6,800	1.80	--	1,000 - 15,000
	15 (1)	30:30	6,800	1.92	--	1,500 - 20,000
Maple, red, leaves; Georgia	14 (1)	30:30	8,200	2.63	--	150 - 20,000
	15 (1)	30:30	6,700	2.37	--	500 - 20,000
Oak, black; Kentucky	18 (1)	25:25	13,000	2.05	1.21	1,000 - 30,000
	19 (2)	22:22	9,000	2.08	1.11	1,500 - 32,000
Oak, post; Cedar Glade, Missouri	20 (1)	50:50	3,200	2.36	1.38	500 - 20,000
Oak, red; Kentucky	18 (1)	28:28	13,000	1.71	1.21	5,000 - 50,000
	19 (2)	8:8	8,900	2.54	1.11	3,500 - 37,000
Oak, white; Kentucky	18 (1)	49:49	13,000	1.60	1.21	5,000 - 50,000
	19 (2)	75:75	11,000	1.75	1.11	3,700 - 38,000
Oak, white; Missouri						
Oak-hickory Forest	20 (1)	50:50	12,000	1.74	1.38	1,000 - 30,000
Oak-hickory-pine Forest	20 (1)	49:49	13,000	1.57	1.38	5,000 - 30,000
Persimmon, stems; Georgia	14 (1)	30:30	7,200	1.99	--	1,000 - 20,000
	15 (1)	30:30	6,200	1.86	--	1,500 - 20,000
Persimmon, leaves; Georgia	14 (1)	30:30	8,900	2.35	--	500 - 30,000
	15 (1)	30:30	8,000	1.97	--	1,500 - 20,000
Pine, shortleaf; Oak-hickory-pine Forest, Missouri	20 (1)	49:49	14,000	1.59	1.38	3,000 - 30,000
Sassafras, stems; Georgia	14 (1)	17:17	2,100	2.07	--	500 - 7,000
	15 (1)	27:27	3,300	2.14	--	700 - 10,000
Sassafras, leaves; Georgia	14 (1)	17:17	2,700	2.19	--	700 - 15,000
	15 (1)	27:27	4,300	1.89	--	1,500 - 10,000
Sumac, winged, stems; Georgia	14 (1)	30:30	2,800	2.14	--	700 - 15,000
	15 (1)	30:30	2,000	2.26	--	300 - 10,000

TABLE 29.—*Manganese in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
PLANT ASH--Continued						
Native species--Continued						
Sumac, winged, leaves; Georgia	14 (1)	30:30	1,400	1.62	--	500 - 5,000
	15 (1)	30:30	970	1.85	--	300 - 5,000
Sumac, smooth; Missouri						
Floodplain Forest	20 (1)	48:48	760	1.74	1.38	300 - 2,000
Glaciated Prairie	20 (1)	50:50	550	1.68	1.38	200 - 1,500
Unglaciated Prairie	20 (1)	49:49	640	1.62	1.38	300 - 2,000
Cedar Glade	20 (1)	49:49	470	1.62	1.38	200 - 1,500
Oak-hickory Forest	20 (1)	50:50	690	1.60	1.38	150 - 2,000
Oak-hickory-pine Forest	20 (1)	49:49	770	1.58	1.38	200 - 2,000
Sweetgum, stems; Georgia	14 (1)	28:28	4,100	1.99	--	700 - 15,000
	15 (1)	27:27	6,800	1.74	--	1,500 - 20,000
Sweetgum, leaves; Georgia	14 (1)	28:28	9,600	1.90	--	1,500 - 30,000
	15 (1)	27:27	13,000	1.67	--	5,000 - 30,000
Sweetgum; Floodplain Forest, Missouri	20 (1)	47:47	6,300	2.11	1.38	1,000 - 30,000

TABLE 30.—*Mercury in rocks, unconsolidated geologic deposits, soils, and dry plants*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppb)	Deviation	Error	Observed range (ppb)
ROCKS						
Granite						
Precambrian; Missouri	1 (4)	26:30	14	1.71	1.47	<10 - 700
Rhyolite						
Precambrian; Missouri	1 (4)	23:30	15	1.82	1.47	<10 - 740
Sandstone						
Roubidoux Formation; Missouri	4 (4)	6:12	7.9	2.82	1.35	<10 - 50
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (4)	24:32	16	2.40	1.35	<10 - 150
Chert						
Mississippian; Missouri, Oklahoma, and Arkansas	7 (4)	18:20	17	2.28	1.35	<10 - 60

TABLE 30.—*Mercury in rocks, unconsolidated geologic deposits, soils, and dry plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppb)	Deviation	Error	Observed range (ppb)
ROCKS--Continued						
Shale						
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (4)	30:32	45	2.60	1.44	<10 - 190
Black shale						
Devonian and Mississippian; Kentucky	9 (4)	84:88	340	3.37	2.18	<40 - 1,500
Limestone and dolomite						
Sauk sequence; Missouri and Arkansas	4 (4)	47:48	28	2.05	1.34	<10 - 110
Tippecanoe sequence; Missouri	10 (4)	11:12	22	2.57	1.34	<10 - 100
Mississippian; Missouri, Oklahoma, and Arkansas	7 (4)	38:40	30	2.37	1.34	<10 - 130
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (4)	30:32	30	2.96	1.34	<10 - 170
UNCONSOLIDATED GEOLOGIC DEPOSITS						
Carbonate residuum (terra rossa)						
On Gasconade Formation; Missouri	12 (4)	24:24	68	1.63	1.30	20 - 170
On Roubidoux Formation; Missouri	12 (4)	20:24	35	2.85	1.30	<10 - 290
On Jefferson City, Cotter, and Powell Formations; Missouri and Arkansas	12 (4)	24:24	40	1.79	1.30	20 - 120
On Ozarkian rocks; Missouri	12 (4)	24:24	53	1.94	1.30	10 - 150
On Mississippian rocks; Missouri	12 (4)	24:24	48	2.13	1.39	10 - 140
Loess						
Missouri	13 (4)	23:24	35	1.79	--	<10 - 80
SOILS						
Cultivated						
Plow zone, corn field; Missouri						
Floodplain Forest	17 (4)	8:8	37	1.93	1.41	10 - 90
Glaciated Prairie	17 (4)	10:10	51	1.81	1.41	30 - 210
Unglaciated Prairie	17 (4)	10:10	42	1.70	1.41	20 - 140
Oak-hickory Forest	17 (4)	10:10	38	1.56	1.41	20 - 70
Plow zone, soybean field; Missouri						
Floodplain Forest	17 (4)	10:10	42	2.00	1.41	10 - 100
Glaciated Prairie	17 (4)	10:10	51	1.89	1.41	10 - 110
Unglaciated Prairie	17 (4)	8:8	46	1.72	1.41	20 - 130
Oak-hickory Forest	17 (4)	9:9	30	2.29	1.41	10 - 70
Plow zone, pasture field; Missouri						
Floodplain Forest	17 (4)	10:10	53	2.16	1.41	20 - 260
Glaciated Prairie	17 (4)	10:10	69	1.51	1.41	40 - 120
Unglaciated Prairie	17 (4)	10:10	38	1.21	1.41	30 - 50
Oak-hickory Forest	17 (4)	10:10	57	1.68	1.41	30 - 140
Surface horizon; Missouri	16 (4)	1,124:1,140	39	1.80	1.53	<10 - 800

TABLE 30.—*Mercury in rocks, unconsolidated geologic deposits, soils, and dry plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppb)	Deviation	Error	Observed range (ppb)
SOILS-Continued						
Uncultivated						
B horizon; Missouri						
Floodplain Forest	20 (4)	50:50	57	2.07	1.82	20 - 500
Glaciated Prairie	20 (4)	50:50	68	1.70	1.82	30 - 260
Unglaciated Prairie	20 (4)	50:50	46	1.76	1.82	10 - 310
Cedar Glade	20 (4)	50:50	160	2.39	1.82	30 - 1,500
Oak-hickory Forest	20 (4)	50:50	55	1.91	1.82	10 - 260
Oak-hickory-pine Forest	20 (4)	50:50	45	2.05	1.82	10 - 500
Cultivated and uncultivated						
Surface horizon; Colorado	22 (4)	153:168	35	3.84	1.66	<10 - 420
B horizon; Eastern United States	21 (4)	420:420	96	2.53	--	10 - 3,400
B horizon; Western United States	21 (4)	491:492	55	2.46	--	<10 - 4,600
DRY PLANTS						
Native species						
Buckbush; Missouri						
Glaciated Prairie	20 (4)	1:23	<25	--	--	<25 - 50
Oak-hickory Forest	20 (4)	2:29	<25	--	--	<25 - 50
Cedar; Cedar Glade, Missouri	20 (4)	2:28	<25	--	--	<25 - 25
Oak, post; Cedar Glade, Missouri	20 (4)	1:25	<25	--	--	<25 - 25
Pine, shortleaf; Oak-hickory-pine Forest, Missouri	20 (4)	3:25	<25	--	--	<25 - 25

TABLE 31.—*Molybdenum in rocks, unconsolidated geologic deposits, soils, and plant ash*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Granite						
Precambrian; Missouri	1 (1)	12:30	<3	--	--	<3 - 15
Rhyolite						
Precambrian; Missouri	1 (1)	5:30	<3	--	--	<3 - 3

TABLE 31.—*Molybdenum in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS—Continued						
Sandstone						
Sauk sequence; Western United States-	3 (2)	49:400	<4	--	--	<4 - 30
Pennsylvanian; Missouri, Kansas, and Oklahoma----------	6 (1)	4:32	<3	--	--	<3 - 30
Shale						
Mississippian; Missouri, Oklahoma, and Arkansas----------	7 (1)	6:18	<3	--	--	<3 - 10
Black shale						
Devonian and Mississippian; Kentucky-	9 (2)	82:88	72	2.16	1.12	<22 - 290
Limestone and dolomite						
Sauk sequence; Missouri and Arkansas-	4 (1)	7:48	.79	2.98	--	<3 - 7
Upper Ordovician; Kentucky----------	5 (1)	2:80	<7	--	--	<7 - 15
Lower Mississippian; Kentucky--------	5 (1)	2:112	<7	--	--	<7 - 30
Upper Mississippian; Kentucky--------	5 (1)	12:152	<7	--	--	<7 - 20
Mississippian; Missouri, Oklahoma, and Arkansas----------	7 (1)	3:40	<3	--	--	<3 - 7
Pennsylvanian; Kentucky----------	5 (1)	6:80	<7	--	--	<7 - 20
Pennsylvanian; Missouri, Kansas, and Oklahoma----------	6 (1)	3:32	<3	--	--	<3 - 3
Siderite						
Upper Paleozoic; Kentucky----------	11 (1)	19:30	7.2	1.68	--	<7 - 20
UNCONSOLIDATED GEOLOGIC DEPOSITS						
Carbonate residuum (terra rossa)						
On Gasconade Formation; Missouri-----	12 (1)	1:24	<3	--	--	<3 - 3
On Roubidoux Formation; Missouri-----	12 (1)	1:24	<3	--	--	<3 - 3
On Jefferson City, Cotter, and Powell Formations; Missouri and Arkansas--	12 (1)	6:24	<3	--	--	<3 - 3
On Ozarkian rocks; Missouri----------	12 (1)	2:24	<3	--	--	<3 - 3
On Mesozoic rocks; Missouri--------	12 (1)	2:24	<3	--	--	<3 - 7
SOILS						
Cultivated						
Surface horizon; Missouri----------	16 (1)	16:1,140	<3	--	--	<3 - 15
Uncultivated						
Surface horizon; Powder River Basin, Wyoming and Montana----------	25 (1)	3:48	<3	--	--	<3 - 20
A horizon; Kentucky----------	18 (2)	2:96	<8	--	--	<8 - 86
B horizon; Kentucky----------	18 (2)	3:96	<8	--	--	<8 - 170

TABLE 31.—*Molybdenum in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
SOILS--Continued						
Uncultivated--Continued						
B horizon; Missouri						
Floodplain Forest	20 (1)	1:50	<3	--	--	<3 - 10
Glaciated Prairie	20 (1)	4:50	<3	--	--	<3 - 7
Cedar Glade	20 (1)	3:50	<3	--	--	<3 - 5
Oak-hickory Forest	20 (1)	2:50	<3	--	--	<3 - 30
Oak-hickory-pine Forest	20 (1)	1:50	<3	--	--	<3 - 7
C horizon; Kentucky	18 (2)	4:96	<8	--	--	<8 - 170
Cultivated and uncultivated						
Surface horizon; Colorado	22 (1)	7:168	<3	--	--	<3 - 7
B horizon; Eastern United States	21 (1)	32:371	<3	--	--	<3 - 7
B horizon; Western United States	21 (1)	48:492	<3	--	--	<3 - 7
PLANT ASH						
Cultivated plants						
Asparagus; Wisconsin	23 (1)	4:6	9.9	1.45	--	<3 - 15
Bean, lima; Georgia	14 (1)	20:30	9.5	4.88	--	<3 - 150
	15 (1)	8:15	5.1	3.29	--	<3 - 20
Bean, snap; Georgia	14 (1)	15:30	4.7	5.29	--	<3 - 50
	15 (1)	11:30	<3	--	--	<3 - 30
Blackeyed pea; Georgia	14 (1)	8:29	<3	--	--	<3 - 70
Cabbage; Georgia	14 (1)	7:28	<3	--	--	<3 - 30
	15 (1)	6:30	<3	--	--	<3 - 20
Cabbage; Wisconsin	23 (1)	10:11	15	1.51	--	<3 - 30
Corn; Georgia	14 (1)	10:29	2.5	3.69	--	<3 - 15
	15 (1)	1:30	<3	--	--	<3 - 20
Corn; Missouri						
Floodplain Forest	17 (1)	8:8	18	1.66	1.35	7 - 30
Glaciated Prairie	17 (1)	9:10	11	1.83	1.35	<3 - 20
Unglaciated Prairie	17 (1)	7:10	7.9	2.72	1.35	<3 - 30
Oak-hickory Forest	17 (1)	8:10	11	2.19	1.35	<3 - 30
Corn; Wisconsin	23 (1)	22:27	16	1.94	--	<3 - 70
Onion; Wisconsin	23 (1)	4:7	10	1.88	--	<3 - 20
Pepper, sweet; Wisconsin	23 (1)	3:4	10	1.37	--	<3 - 15
Potato; Wisconsin	23 (1)	2:10	6.6	1.32	--	<3 - 10
Soybean; Missouri						
Floodplain Forest	17 (1)	7:10	10	3.77	1.35	<3 - 70
Glaciated Prairie	17 (1)	8:10	17	3.95	1.35	<3 - 70
Unglaciated Prairie	17 (1)	6:8	9.4	3.16	1.35	<3 - 50
Oak-hickory Forest	17 (1)	9:9	20	2.04	1.35	5 - 70
Tomato; Georgia	14 (1)	3:30	<3	--	--	<3 - 30

TABLE 31.—*Molybdenum in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
		PLANT ASH--Continued				
Native species						
Black cherry, stems; Georgia	14 (1)	1:30	<5	--	--	<5 - 10
Black cherry, leaves; Georgia	14 (1)	1:30	<5	--	--	<5 - 20
Blackgum, stems; Georgia	14 (1)	1:30	<5	--	--	<5 - 10
Blackgum, leaves; Georgia	14 (1)	1:30	<5	--	--	<5 - 15
Buckbush; Missouri						
Glaciated Prairie	20 (1)	11:47	2.0	2.48	--	<5 - 20
Cedar Glade	20 (1)	34:50	6.5	2.68	--	<5 - 30
Oak-hickory Forest	20 (1)	7:49	1.4	2.49	--	<5 - 10
Oak-hickory-pine Forest	20 (1)	9:41	1.6	3.12	--	<5 - 15
Cedar; Missouri						
Cedar Glade	20 (1)	22:50	3.4	2.43	--	<5 - 30
Glaciated Prairie	24 (1)	4:9	2.2	4.59	--	<3 - 15
Unglaciated Prairie	24 (1)	4:10	2.0	3.45	--	<3 - 15
Cedar Glade	24 (1)	8:10	7.6	2.39	--	<3 - 30
Oak-hickory Forest	24 (1)	3:10	1.3	4.35	--	<3 - 10
Oak-hickory-pine Forest	24 (1)	4:6	5.3	2.68	--	<3 - 15
Hickory, pignut; Kentucky	18 (1)	5:64	<10	--	--	<10 - 300
	19 (2)	1:88	<30	--	--	<30 - 39
Hickory, shagbark; Kentucky	18 (1)	4:40	<5	--	--	<5 - 200
Maple, red, stems; Georgia	14 (1)	1:30	<5	--	--	<5 - 10
	15 (1)	1:30	<5	--	--	<5 - 7
Maple, red, leaves; Georgia	14 (1)	1:30	<5	--	--	<5 - 20
Oak, black; Kentucky	18 (1)	6:25	.76	1.82	--	<3 - 100
	19 (2)	1:22	<30	--	--	<30 - 90
Oak, red; Kentucky	18 (1)	2:28	<5	--	--	<3 - 70
Oak, white; Kentucky	18 (1)	3:49	<5	--	--	<3 - 20
	19 (2)	1:72	<30	--	--	<30 - 120
Persimmon, stems; Georgia	14 (1)	2:30	<5	--	--	<5 - 20
	15 (1)	2:30	<5	--	--	<5 - 15
Persimmon, leaves; Georgia	14 (1)	1:30	<5	--	--	<5 - 20
Sassafras, stems; Georgia	14 (1)	3:17	1.6	3.87	--	<5 - 20
	15 (1)	6:27	<5	--	--	<5 - 50
Sassafras, leaves; Georgia	15 (1)	1:27	<5	--	--	<5 - 7
Sumac, winged, stems; Georgia	14 (1)	1:30	<5	--	--	<5 - 20
	15 (1)	1:30	<5	--	--	<5 - 7
Sumac, winged, leaves; Georgia	14 (1)	2:30	<5	--	--	<5 - 15
	15 (1)	1:30	<5	--	--	<5 - 15
Sumac, smooth; Missouri						
Floodplain Forest	20 (1)	6:48	.91	3.38	--	<5 - 15
Glaciated Prairie	20 (1)	7:50	.76	4.27	--	<5 - 20
Unglaciated Prairie	20 (1)	3:49	<5	--	--	<5 - 5
Cedar Glade	20 (1)	21:49	3.3	2.80	--	<5 - 30
Oak-hickory Forest	20 (1)	3:50	<5	--	--	<5 - 20
Oak-hickory-pine Forest	20 (1)	4:49	<5	--	--	<5 - 70

TABLE 32.—*Neodymium in rocks, unconsolidated geologic deposits, soils, and plant ash*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Granite						
Precambrian; Missouri	1 (1)	25:30	75	1.33	1.17	<70 - 150
Rhyolite						
Precambrian; Missouri	1 (1)	28:30	77	1.31	1.17	<70 - 150
UNCONSOLIDATED GEOLOGIC DEPOSITS						
Loess						
Missouri	13 (1)	5:24	<50	--	--	<50 - 70
SOILS						
Cultivated						
Plow zone, garden; Georgia	14 (1)	3:30	<70	--	--	<70 - 150
	15 (1)	2:30	<70	--	--	<70 - 300
Plow zone, pasture field; Missouri						
Floodplain Forest	17 (1)	1:10	<70	--	--	<70 - 70
Oak-hickory Forest	17 (1)	1:10	<70	--	--	<70 - 70
Surface horizon; Missouri	16 (1)	739:1,140	63	1.17	--	<70 - 150
Uncultivated						
A horizon; Georgia	14 (1)	4:30	9.2	4.85	--	<70 - 300
	15 (1)	2:30	<70	--	--	<70 - 150
B horizon; Georgia	14 (1)	2:30	<70	--	--	<70 - 150
	15 (1)	6:30	28	2.33	--	<70 - 150
B horizon; Missouri						
Glaciated Prairie	20 (1)	27:50	60	1.21	--	<70 - 70
Unglaciated Prairie	20 (1)	30:50	61	1.18	--	<70 - 70
Cultivated and uncultivated						
Surface horizon; Colorado	22 (1)	65:168	47	1.73	--	<70 - 300
PLANT ASH						
Cultivated plants						
Tomato; Georgia	14 (1)	1:30	<70	--	--	<70 - 150

TABLE 32.—*Neodymium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
PLANT ASH—Continued						
Native species						
Black cherry, leaves, Georgia	14 (1)	1:30	<70	--	--	<70 - 150
	15 (1)	1:30	<70	--	--	<70 - 200
Hickory, shagbark; Oak-hickory-pine Forest, Missouri	28 (1)	3:7	<150	--	--	<150 - 150
Maple, red, stems; Georgia	14 (1)	1:30	<70	--	--	<70 - 150
Persimmon, stems; Georgia	14 (1)	1:30	<70	--	--	<70 - 700
Persimmon, leaves; Georgia	14 (1)	2:30	<70	--	--	<70 - 300
Sumac, winged, stems; Georgia	14 (1)	1:30	<70	--	--	<70 - 300
Sumac, winged, leaves; Georgia	14 (1)	2:30	<70	--	--	<70 - 300
	15 (1)	3:30	<70	--	--	<70 - 300
Sweetgum, stems; Georgia	14 (1)	3:28	<70	--	--	<70 - 200
Sweetgum, leaves; Georgia	14 (1)	1:28	<70	--	--	<70 - 150
	15 (1)	3:27	<70	--	--	<70 - 200

TABLE 33.—*Nickel in rocks, unconsolidated geologic deposits, soils, and plant ash*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1: Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Granite						
Precambrian; Missouri	1 (1)	1:30	<5	--	--	<5 - 7
Rhyolite						
Precambrian; Missouri	1 (1)	1:30	<5	--	--	<5 - 5
Arkose						
Fountain Formation; Colorado	2 (2)	30:80	1.2	5.46	--	<2 - 24
Sandstone						
Sauk sequence; Western United States	3 (2)	258:400	3.0	2.64	1.45	<2 - 48

TABLE 33.—*Nickel in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS--Continued						
Sandstone--Continued						
Roubidoux Formation; Missouri--------	4 (1)	1:12	<5	--	--	<5 - 5
Pope Megagroup;[1] Kentucky----------	5 (2)	116:120	11	1.96	1.30	<5 - 39
Pennsylvanian; Kentucky----------	5 (2)	147:152	9.4	1.93	1.31	<5 - 31
Pennsylvanian; Missouri, Kansas, and Oklahoma----------	6 (1)	29:32	18	1.62	1.44	<5 - 150
Chert						
Mississippian; Missouri, Oklahoma, and Arkansas----------	7 (1)	1:20	<5	--	--	<5 - 7
Shale						
Sauk sequence; Western United States-	3 (2)	330:336	26	1.70	1.07	<7 - 74
Lower Mississippian; Kentucky--------	8 (2)	76:76	43	1.81	--	17 - 270
Upper Mississippian; Kentucky--------	5 (2)	142:142	39	1.45	--	13 - 85
Mississippian; Missouri, Oklahoma, and Arkansas----------	7 (1)	18:18	21	2.34	1.22	10 - 100
Pennsylvanian; Kentucky----------	5 (2)	149:152	30	1.71	1.15	<10 - 83
Pennsylvanian; Missouri, Kansas, and Oklahoma----------	6 (1)	32:32	38	1.50	1.22	10 - 70
Black shale						
Devonian and Mississippian; Kentucky-	9 (2)	88:88	110	2.04	1.09	13 - 420
Limestone and dolomite						
Sauk sequence; Western United States-	3 (2)	236:392	6.4	1.99	1.23	<7 - 41
Sauk sequence; Missouri and Arkansas-	4 (1)	2:48	<5	--	--	<5 - 7
Upper Ordovician; Kentucky----------	5 (1)	38:80	7.6	1.67	1.32	<10 - 20
Tippecanoe sequence; Missouri--------	10 (1)	1:12	<5	--	--	<5 - 5
Lower Mississippian; Kentucky--------	5 (1)	76:112	11	2.03	1.37	<10 - 70
Upper Mississippian; Kentucky--------	5 (1)	52:152	6.4	1.95	1.30	<10 - 50
Mississippian; Missouri, Oklahoma, and Arkansas----------	7 (1)	11:40	2.3	2.43	1.09	<5 - 15
Pennsylvanian; Kentucky----------	5 (1)	72:80	16	1.90	1.31	<10 - 100
Pennsylvanian; Missouri, Kansas, and Oklahoma----------	6 (1)	17:32	4.3	2.24	1.09	<5 - 15
Siderite						
Upper Paleozoic; Kentucky----------	11 (1)	26:30	13	1.69	--	<10 - 50
UNCONSOLIDATED GEOLOGIC DEPOSITS						
Carbonate residuum (terra rossa)						
On Gasconade Formation; Missouri-----	12 (1)	24:24	24	1.72	1.32	15 - 150
On Roubidoux Formation; Missouri-----	12 (1)	24:24	17	1.87	1.32	10 - 150
On Jefferson City, Cotter, and Powell Formations; Missouri and Arkansas--	12 (1)	24:24	20	1.47	1.32	15 - 50
On Osagean rocks; Missouri----------	12 (1)	24:24	23	1.46	1.32	10 - 50
On Meramecian rocks; Missouri--------	12 (1)	24:24	29	1.73	1.32	15 - 100

[1] Of Swenn and Willman (1961).

TABLE 38.—*Nickel in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
UNCONSOLIDATED GEOLOGIC DEPOSITS--Continued						
Loess						
Missouri	13 (1)	24:24	22	1.03	--	15 - 30
SOILS						
Cultivated						
Plow zone, garden; Georgia	14 (1)	11:30	1.8	4.02	--	<3 - 20
	15 (1)	30:30	18	1.70	--	5 - 50
Plow zone, corn field; Missouri						
Floodplain Forest	17 (1)	6:8	8.4	2.36	1.23	<5 - 20
Glaciated Prairie	17 (1)	10:10	14	1.51	1.23	7 - 30
Unglaciated Prairie	17 (1)	9:10	10	1.96	1.23	<5 - 20
Oak-hickory Forest	17 (1)	9:10	11	2.16	1.23	<5 - 30
Plow zone, soybean field; Missouri						
Floodplain Forest	17 (1)	9:10	9.8	1.67	1.23	<5 - 15
Glaciated Prairie	17 (1)	10:10	16	1.40	1.23	10 - 30
Unglaciated Prairie	17 (1)	6:8	8.4	2.44	1.23	<5 - 20
Oak-hickory Forest	17 (1)	9:9	11	1.80	1.23	5 - 30
Plow zone, pasture field; Missouri						
Floodplain Forest	17 (1)	10:10	10	1.53	1.23	5 - 15
Glaciated Prairie	17 (1)	10:10	14	1.23	1.23	10 - 20
Unglaciated Prairie	17 (1)	9:10	9.7	1.77	1.23	<5 - 20
Oak-hickory Forest	17 (1)	9:10	13	2.01	1.23	<5 - 30
Surface horizon; Missouri	16 (1)	1,131:1,140	14	1.59	1.24	<5 - 70
Uncultivated						
Surface horizon; Powder River Basin, Wyoming and Montana	25 (1)	46:48	13	1.60	1.23	<5 - 30
A horizon; Georgia	14 (1)	8:30	<3	--	--	<3 - 50
	15 (1)	29:30	14	2.10	--	<3 - 70
A horizon; Kentucky	18 (2)	96:96	13	1.34	1.03	6 - 31
	19 (2)	108:108	13	1.49	1.09	5 - 40
B horizon; Georgia	15 (1)	29:30	17	1.95	--	<3 - 50
B horizon; Kentucky	18 (2)	96:96	20	1.42	1.03	9 - 47
B horizon; Missouri						
Floodplain Forest	20 (1)	50:50	18	1.65	1.26	7 - 50
Glaciated Prairie	20 (1)	50:50	23	1.49	1.26	15 - 70
Unglaciated Prairie	20 (1)	49:50	20	1.88	1.26	<5 - 70
Cedar Glade	20 (1)	49:50	23	2.31	1.26	<5 - 300
Oak-hickory Forest	20 (1)	47:50	12	1.82	1.26	<5 - 50
Oak-hickory-pine Forest	20 (1)	47:50	8.8	1.75	1.26	<5 - 30
C horizon; Georgia	14 (1)	18:30	4.4	3.30	--	<3 - 20
	15 (1)	30:30	21	1.65	--	3 - 50
C horizon; Kentucky	18 (2)	96:96	20	1.66	1.03	6 - 110

TABLE 33.—*Nickel in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
SOILS--Continued						
Cultivated and uncultivated						
Surface horizon; Colorado	22 (1)	126:168	7.9	2.32	1.28	<5 - 30
B horizon; Eastern United States	21 (1)	317:371	13	2.60	--	<5 - 700
B horizon; Western United States	21 (1)	482:492	16	2.03	--	<5 - 700
PLANT ASH						
Cultivated plants						
Asparagus; Wisconsin	23 (1)	3:6	5.8	2.00	--	<5 - 15
Bean, lima; Georgia	14 (1)	30:30	19	1.93	--	7 - 70
	15 (1)	15:15	21	2.17	--	7 - 70
Bean, snap; Georgia	14 (1)	28:30	15	2.27	--	<5 - 100
	15 (1)	28:30	17	2.37	--	<5 - 70
Beet, red; Wisconsin	23 (1)	2:3	10	2.22	--	<5 - 20
Blackeyed pea; Georgia	14 (1)	29:29	18	1.60	--	7 - 50
	15 (1)	3:4	17	2.74	--	<5 - 30
Cabbage; Georgia	15 (1)	5:30	3	1.87	--	<5 - 30
Cabbage; Wisconsin	23 (1)	9:11	12	2.04	--	<5 - 30
Carrot; Wisconsin	23 (1)	5:8	6.5	1.64	--	<5 - 15
Corn; Georgia	14 (1)	14:29	2.7	3.22	--	<5 - 30
	15 (1)	16:30	5.8	1.51	--	<5 - 15
Corn; Missouri						
Floodplain Forest	17 (1)	7:8	12	1.95	1.52	<5 - 30
Glaciated Prairie	17 (1)	10:10	23	2.04	1.52	5 - 70
Unglaciated Prairie	17 (1)	10:10	32	1.73	1.52	20 - 70
Oak-hickory Forest	17 (1)	10:10	28	2.03	1.52	7 - 50
Corn; Wisconsin	23 (1)	24:27	14	1.94	--	<5 - 50
Cucumber; Wisconsin	23 (1)	3:4	16	2.88	--	<5 - 50
Onion; Wisconsin	23 (1)	4:7	6.2	1.77	--	<5 - 15
Pepper, sweet; Wisconsin	23 (1)	4:4	29	2.76	--	5 - 70
Potato; Wisconsin	23 (1)	8:10	12	1.92	--	<5 - 30
Soybean; Missouri						
Floodplain Forest	17 (1)	10:10	130	2.62	1.52	30 - 500
Glaciated Prairie	17 (1)	10:10	94	1.50	1.52	50 - 200
Unglaciated Prairie	17 (1)	8:8	110	1.50	1.52	70 - 200
Oak-hickory Forest	17 (1)	9:9	87	1.71	1.52	50 - 200
Native species						
Black cherry, stems; Georgia	14 (1)	22:30	6.2	2.94	--	<5 - 50
	15 (1)	21:30	5.8	3.02	--	<5 - 50
Black cherry, leaves; Georgia	14 (1)	30:30	14	1.65	--	7 - 30
	15 (1)	29:30	16	2.24	--	<5 - 70
Blackgum, stems; Georgia	14 (1)	29:30	31	2.24	--	<5 - 150
	15 (1)	29:30	60	2.91	--	<5 - 500

TABLE 33.—*Nickel in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
PLANT ASH--Continued						
Native species--Continued						
Blackgum, leaves; Georgia	14 (1)	29:30	62	3.31	--	<5 - 1,300
	15 (1)	29:30	120	3.20	--	<5 - 700
Buckbush; Missouri						
Glaciated Prairie	20 (1)	47:47	12	1.51	1.36	7 - 30
Unglaciated Prairie	20 (1)	48:48	12	1.49	1.36	5 - 20
Cedar Glade	20 (1)	49:49	7.5	1.45	1.36	5 - 30
Oak-hickory Forest	20 (1)	49:49	11	1.49	1.36	5 - 30
Oak-hickory-pine Forest	20 (1)	41:41	12	1.62	1.36	5 - 50
Cedar; Missouri						
Cedar Glade	20 (1)	41:50	5.6	2.89	1.36	<2 - 70
Glaciated Prairie	24 (1)	9:9	62	1.47	--	30 - 100
Unglaciated Prairie	24 (1)	10:10	82	1.65	--	50 - 200
Cedar Glade	24 (1)	9:10	7	--	--	<7 - 50
Oak-hickory Forest	24 (1)	10:10	37	2.03	--	10 - 100
Oak-hickory-pine Forest	24 (1)	6:6	33	1.23	--	30 - 50
Hickory, pignut; Kentucky	18 (1)	64:64	100	1.91	1.36	30 - 500
	19 (2)	88:88	92	1.92	1.16	20 - 380
Hickory, shagbark; Kentucky	18 (1)	40:40	95	1.89	1.36	30 - 300
	19 (2)	20:20	78	1.94	1.16	30 - 260
Hickory, shagbark; Missouri						
Oak-hickory Forest	20 (1)	19:19	60	2.42	1.36	10 - 200
Oak-hickory-pine Forest	20 (1)	7:7	70	2.13	1.36	15 - 150
Maple, red, stems; Georgia	14 (1)	25:30	7.5	2.26	--	<5 - 30
	15 (1)	27:30	8.6	2.22	--	<5 - 50
Maple, red, leaves; Georgia	14 (1)	18:30	4.0	3.15	--	<5 - 30
	15 (1)	20:30	5.0	3.13	--	<5 - 50
Oak, black; Kentucky	18 (1)	25:25	33	1.86	1.22	7 - 70
	19 (2)	22:22	25	2.04	1.16	12 - 200
Oak, post; Cedar Glade, Missouri	20 (1)	49:50	8.6	1.71	1.36	<2 - 30
Oak, red; Kentucky	18 (1)	28:28	28	1.86	1.22	10 - 150
	19 (2)	8:8	19	1.91	1.16	8 - 62
Oak, white; Kentucky	18 (1)	49:49	28	1.85	1.22	10 - 200
	19 (2)	75:75	24	1.55	1.16	10 - 87
Oak, white; Missouri						
Oak-hickory Forest	20 (1)	50:50	21	1.80	1.36	5 - 70
Oak-hickory-pine Forest	20 (1)	49:49	20	1.63	1.36	7 - 70
Oak, willow; Floodplain Forest, Missouri	20 (1)	46:46	130	1.77	1.36	30 - 300
Persimmon, stems; Georgia	14 (1)	30:30	27	1.88	--	5 - 100
	15 (1)	30:30	43	2.20	--	10 - 150
Persimmon, leaves; Georgia	14 (1)	30:30	18	2.25	--	7 - 300
	15 (1)	30:30	19	1.87	--	7 - 70
Pine, shortleaf; Oak-hickory-pine Forest, Missouri	20 (1)	49:49	50	1.82	1.36	15 - 200

TABLE 17.—*Chromium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS--Continued						
Shale--Continued						
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	32:32	95	1.26	1.18	70 - 150
Black shale						
Devonian and Mississippian; Kentucky	9 (2)	88:88	84	1.38	1.06	46 - 190
Limestone and dolomite						
Sauk sequence; Western United States	3 (2)	308:392	11	2.87	1.16	<5 - 150
Sauk sequence; Missouri and Arkansas	4 (1)	48:48	3.6	2.09	1.29	1 - 20
Upper Ordovician; Kentucky	5 (1)	80:80	11	1.82	1.39	2 - 30
Tippecanoe sequence; Missouri	10 (1)	11:12	2.7	2.60	1.29	<1 - 15
Lower Mississippian; Kentucky	5 (1)	112:112	19	2.33	1.33	5 - 150
Upper Mississippian; Kentucky	5 (1)	152:152	17	1.82	1.37	2 - 70
Mississippian; Missouri, Oklahoma, and Arkansas	7 (1)	38:40	9.4	3.27	1.29	<1 - 70
Pennsylvanian; Kentucky	5 (1)	80:80	29	1.78	1.33	10 - 70
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	32:32	16	2.09	1.29	7 - 70
Siderite						
Upper Paleozoic; Kentucky	11 (1)	30:30	21	1.76	--	10 - 70
UNCONSOLIDATED GEOLOGIC DEPOSITS						
Carbonate residuum (terra rossa)						
On Gasconade Formation; Missouri	12 (1)	24:24	57	1.39	1.18	30 - 100
On Roubidoux Formation; Missouri	12 (1)	24:24	54	1.54	1.18	20 - 100
On Jefferson City, Cotter and Powell Formations; Missouri and Arkansas	12 (1)	24:24	70	1.26	1.18	50 - 100
On Meramecian rocks; Missouri	12 (1)	24:24	95	1.27	1.18	70 - 150
Loess						
Missouri	13 (1)	24:24	70	1.16	--	50 - 100
SOILS						
Cultivated						
Plow zone, garden; Georgia	14 (1)	30:30	15	2.00	--	7 - 150
	14 (1)	30:30	48	1.62	--	15 - 150
Plow zone, corn field; Missouri						
Floodplain Forest	17 (1)	8:8	43	1.56	1.13	20 - 70
Glaciated Prairie	17 (1)	10:10	70	1.18	1.13	50 - 100
Unglaciated Prairie	17 (1)	10:10	63	1.18	1.13	50 - 70
Oak-hickory Forest	17 (1)	10:10	66	1.24	1.13	50 - 100

TABLE 17.—*Chromium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
SOILS—Continued						
Cultivated—Continued						
Plow zone, soybean field; Missouri						
Floodplain Forest	17 (1)	10:10	40	1.77	1.13	15 - 100
Glaciated Prairie	17 (1)	10:10	63	1.18	1.13	50 - 70
Unglaciated Prairie	17 (1)	8:8	67	1.13	1.13	50 - 70
Oak-hickory Forest	17 (1)	9:9	65	1.16	1.13	50 - 70
Plow zone, pasture field; Missouri						
Floodplain Forest	17 (1)	10:10	39	1.54	1.13	20 - 70
Glaciated Prairie	17 (1)	10:10	63	1.18	1.13	50 - 70
Unglaciated Prairie	17 (1)	10:10	59	1.19	1.13	50 - 70
Oak-hickory Forest	17 (1)	10:10	70	1.26	1.13	50 - 100
Surface horizon; Missouri	16 (1)	1,140:1,140	54	1.44	1.27	10 - 150
Uncultivated						
Surface horizon; Powder River Basin, Wyoming and Montana	25 (1)	48:48	45	1.49	1.28	20 - 100
A horizon; Georgia	14 (1)	30:30	11	1.99	--	3 - 100
	15 (1)	30:30	41	1.79	--	30 - 100
A horizon; Kentucky	18 (2)	96:96	60	1.31	1.07	26 - 140
	19 (2)	108:108	60	1.29	1.15	29 - 140
B horizon; Georgia	14 (1)	30:30	11	1.81	--	3 - 50
	15 (1)	30:30	44	1.63	--	15 - 150
B horizon; Kentucky	18 (2)	96:96	76	1.30	1.07	37 - 170
B horizon; Missouri						
Floodplain Forest	20 (1)	50:50	38	1.80	1.24	7 - 70
Glaciated Prairie	20 (1)	50:50	66	1.15	1.24	50 - 100
Unglaciated Prairie	20 (1)	50:50	65	1.23	1.24	30 - 100
Cedar Glade	20 (1)	50:50	42	1.51	1.24	20 - 70
Oak-hickory Forest	20 (1)	50:50	43	1.45	1.24	20 - 100
Oak-hickory-pine Forest	20 (1)	50:50	30	1.67	1.24	10 - 70
C horizon; Georgia	14 (1)	30:30	16	2.08	--	3 - 50
	15 (1)	30:30	47	1.56	--	10 - 100
C horizon; Kentucky	18 (2)	96:96	78	1.45	1.07	20 - 170
Cultivated and uncultivated						
Surface horizon; Colorado	22 (1)	168:168	31	2.07	1.26	7 - 84
B horizon; Eastern United States	21 (1)	371:371	36	2.52	--	1 - 100
B horizon; Western United States	21 (1)	492:492	38	2.16	--	3 - 1,500
PLANT ASH						
Cultivated plants						
Asparagus; Wisconsin	23 (1)	5:5	6.6	1.15	--	5 - 7
Bean, lima; Georgia	14 (1)	4:30	.42	3.53	--	<2 - 7
	15 (1)	6:15	<2	--	--	<2 - 50

TABLE 17.—*Chromium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
		PLANT ASH--Continued				
Cultivated plants--Continued						
Blackeyed pea; Georgia	14 (1)	12:29	<2	--	--	<2 - 30
	15 (1)	1:4	<2	--	--	<2 - 2
Cabbage; Georgia	14 (1)	20:28	2.2	1.66	--	<2 - 7
	15 (1)	26:30	5.7	2.61	--	<2 30
Cabbage; Wisconsin	23 (1)	3:11	<2	--	--	<2 - 15
Carrot; Wisconsin	23 (1)	2:8	<2	--	--	<2 - 10
Corn; Georgia	14 (1)	9:29	<2	--	--	<2 - 5
	15 (1)	10:30	1.4	1.83	--	<2 - 5
Corn; Floodplain Forest	17 (1)	2:8	<2	--	--	<2 - 5
Corn; Wisconsin	23 (1)	11:27	1.5	2.24	--	<2 - 7
Cucumber; Wisconsin	23 (1)	2:4	1.8	1.11	--	<2 - 2
Onion; Wisconsin	23 (1)	3:7	1.6	2.20	--	<2 - 5
Pepper, sweet; Wisconsin	23 (1)	4:4	4.2	1.52	--	3 - 7
Potato; Wisconsin	23 (1)	5:10	1.7	3.73	--	<2 - 10
Tomato; Georgia	14 (1)	19:30	2.4	2.54	--	<2 - 15
	15 (1)	5:30	<2	--	--	<2 - 5
Native species						
Black cherry, stems; Georgia	14 (1)	29:30	5.0	1.69	--	<2 - 15
	15 (1)	28:30	6.1	1.99	--	<2 - 15
Black cherry, leaves; Georgia	14 (1)	28:30	3.7	1.83	--	<2 - 30
	15 (1)	28:30	5.1	1.92	--	<2 - 15
Blackgum, stems; Georgia	14 (1)	30:30	7.8	2.37	--	2 - 100
	15 (1)	30:30	7.9	1.70	--	3 - 15
Blackgum, leaves; Georgia	14 (1)	29:30	6.4	2.13	--	<2 - 70
	15 (1)	30:30	10	2.00	--	3 - 50
Buckbush; Missouri						
Glaciated Prairie	20 (1)	47:47	20	1.52	1.51	7 - 50
Unglaciated Prairie	20 (1)	48:48	22	1.49	1.51	10 - 50
Cedar Glade	20 (1)	49:49	14	1.38	1.51	7 - 30
Oak-hickory Forest	20 (1)	49:49	21	1.57	1.51	10 - 70
Oak-hickory-pine Forest	20 (1)	41:41	19	1.72	1.51	7 - 50
Cedar, Missouri						
Cedar Glade	20 (1)	50:50	7.5	1.76	1.51	3 - 30
Glaciated Prairie	24 (1)	9:9	15	1.62	--	5 - 30
Unglaciated Prairie	24 (1)	10:10	12	1.73	--	5 - 30
Cedar Glade	24 (1)	10:10	5.9	1.93	--	3 - 15
Oak-hickory Forest	24 (1)	10:10	9.8	1.81	--	5 - 20
Oak-hickory-pine Forest	24 (1)	6:6	6.3	2.36	--	2 - 20
Hickory, pignut; Kentucky	18 (1)	64:64	7.0	1.86	1.52	2 - 50
Hickory, shagbark; Kentucky	18 (1)	40:40	8.1	1.72	1.52	2 - 30
	19 (2)	15:20	11	1.32	1.26	<10 - 21
Hickory, shagbark; Missouri						
Oak-hickory Forest	20 (1)	17:19	2.9	1.83	1.51	<2 - 10
Oak-hickory-pine Forest	20 (1)	6:7	2.9	1.92	1.51	<2 - 7

TABLE 17.—*Chromium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
		PLANT ASH--Continued				
Native species--Continued						
Maple, red, stems; Georgia	14 (1)	27:30	3.9	2.15	--	<2 - 70
	15 (1)	29:30	4.6	1.77	--	<2 - 10
Maple, red, leaves; Georgia	14 (1)	28:30	4.1	1.67	--	<2 - 15
	15 (1)	30:30	6.0	1.80	--	<2 - 20
Oak, black; Kentucky	18 (1)	25:25	7.9	1.51	1.66	5 - 20
	19 (2)	4:22	<10	--	--	<10 - 28
Oak, post; Cedar Glade, Missouri	20 (1)	49:50	4.9	1.97	1.51	<2 - 20
Oak, red; Kentucky	18 (1)	28:28	7.6	1.95	1.66	3 - 50
	19 (2)	2:8	<11	--	--	<11 - 11
Oak, white; Kentucky	18 (1)	49:49	9.6	2.00	1.66	3 - 70
	19 (2)	24:75	<7	--	--	<7 - 60
Oak, white; Missouri						
Oak-hickory Forest	20 (1)	46:50	3.5	1.85	1.51	<2 - 15
Oak-hickory-pine Forest	20 (1)	47:49	3.6	2.00	1.51	<2 - 70
Oak, willow; Floodplain Forest, Missouri	20 (1)	46:46	6.0	1.90	1.51	2 - 20
Persimmon, stems; Georgia	14 (1)	28:30	4.0	1.81	--	<2 - 15
	15 (1)	27:30	5.1	2.57	--	<2 - 50
Persimmon, leaves; Georgia	14 (1)	27:30	3.4	1.79	--	<2 - 10
	15 (1)	29:30	5.0	2.02	--	<2 - 20
Pine, shortleaf; Oak-hickory-pine Forest, Missouri	20 (1)	49:49	13	1.60	1.51	5 - 30
Sassafras, stems; Georgia	14 (1)	16:17	10	1.99	--	<2 - 30
	15 (1)	27:27	10	2.47	--	2 - 70
Sassafras, leaves; Georgia	14 (1)	17:17	7.6	1.78	--	3 - 30
	15 (1)	27:27	13	1.90	--	3 - 30
Sumac, winged, stems; Georgia	14 (1)	30:30	5.2	1.67	--	2 - 20
Sumac, winged, leaves; Georgia	14 (1)	30:30	5.2	1.67	--	2 - 15
	15 (1)	27:30	4.0	2.07	--	<2 - 20
Sumac, smooth; Missouri						
Floodplain Forest	20 (1)	37:48	4.7	2.86	1.51	<2 - 150
Glaciated Prairie	20 (1)	40:50	3.2	1.83	1.51	<2 - 20
Unglaciated Prairie	20 (1)	36:49	3.3	1.98	1.51	<2 - 30
Cedar Glade	20 (1)	31:49	2.2	2.05	1.51	<2 - 15
Oak-hickory Forest	20 (1)	40:50	2.7	1.95	1.51	<2 - 15
Oak-hickory-pine Forest	20 (1)	43:49	3.1	1.87	1.51	<2 - 20
Sweetgum, stems; Georgia	14 (1)	28:28	4.5	1.60	--	2 - 15
	15 (1)	27:27	5.9	1.73	--	3 - 30
Sweetgum, leaves; Georgia	14 (1)	28:28	5.6	1.62	--	2 - 20
	15 (1)	27:27	9.1	2.19	--	2 - 100
Sweetgum; Floodplain Forest, Missouri	20 (1)	47:47	3.9	1.84	1.51	2 - 15

TABLE 18.—*Cobalt in rocks, unconsolidated geologic deposits, soils, and plant ash*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Granite						
Precambrian; Missouri	1 (1)	8:30	<3	--	--	<3 - 7
Rhyolite						
Precambrian; Missouri	1 (1)	5:30	<3	--	--	<3 - 5
Arkose						
Fountain Formation; Colorado	2 (2)	6:80	<1	--	--	<1 - 9
Sandstone						
Sauk sequence; Western United States	3 (2)	281:400	1.6	2.76	1.59	<1 - 20
Roubidoux Formation; Missouri	4 (1)	1:12	<3	--	--	<3 - 3
Pope Megagroup;[1] Kentucky	5 (2)	43:120	1.9	2.87	1.34	<3 - 14
Pennsylvanian; Kentucky	5 (2)	85:152	2.4	2.98	1.33	<2 - 15
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	29:32	7.4	2.71	1.27	<3 - 15
Shale						
Sauk sequence; Western United States	3 (2)	275:336	13	1.69	1.17	<8 - 65
Lower Mississippian; Kentucky	8 (2)	60:76	9.5	1.67	--	<8 - 30
Upper Mississippian; Kentucky	5 (2)	112:142	11	1.83	--	<8 - 51
Mississippian; Missouri, Oklahoma, and Arkansas	7 (1)	18:18	4.8	1.91	1.26	2 - 15
Pennsylvanian; Kentucky	5 (2)	100:152	9.0	2.17	1.31	<8 - 71
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	32:32	12	1.67	1.26	2 - 20
Black shale						
Devonian and Mississippian; Kentucky	9 (2)	52:88	8.1	3.31	1.20	<8 - 57
Limestone and dolomite						
Sauk sequence; Western United States	3 (2)	4:392	<20	--	--	<20 - 23
Sauk sequence; Missouri and Arkansas	4 (1)	4:48	<3	--	--	<3 - 5
Upper Ordovician; Kentucky	5 (1)	12:80	3.3	1.63	--	<7 - 10
Tippecanoe sequence; Missouri	10 (1)	1:12	<3	--	--	<3 - 3
Lower Mississippian; Kentucky	5 (1)	19:112	3.6	1.59	--	<7 - 10
Upper Mississippian; Kentucky	5 (1)	8:152	<7	--	--	<7 - 10
Mississippian; Missouri, Oklahoma, and Arkansas	7 (1)	2:40	<3	--	--	<3 - 5
Pennsylvanian; Kentucky	5 (1)	54:80	7.1	1.61	1.20	<7 - 30
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	12:32	1.3	3.34	--	<3 - 7
Siderite						
Upper Paleozoic; Kentucky	11 (1)	14:30	5.5	1.90	--	<7 - 15

[1] Of Swann and Willman (1961).

TABLE 18.—*Cobalt in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
UNCONSOLIDATED GEOLOGIC DEPOSITS						
Carbonate residuum (terra rossa)						
On Gasconade Formation; Missouri	12 (1)	19:24	7.7	2.14	1.17	<3 - 50
On Roubidoux Formation; Missouri	12 (1)	17:24	5.9	1.52	1.17	<3 - 15
On Jefferson City, Cotter, and Powell Formations; Missouri and Arkansas	12 (1)	20:24	6.3	1.70	1.17	<3 - 20
On Gasconade rocks; Missouri	12 (1)	14:24	5.6	2.10	1.17	<3 - 20
On Maquoketa rocks; Missouri	12 (1)	21:24	6.7	1.87	1.17	<3 - 30
Loess						
Missouri	13 (1)	24:24	9.8	1.29	--	7 - 15
SOILS						
Cultivated						
Plow zone, garden; Georgia	14 (1)	4:30	1.3	2.68	--	<3 - 10
	15 (1)	28:30	9.9	1.68	--	<3 - 30
Plow zone, corn field; Missouri						
Floodplain Forest	17 (1)	6:8	5.2	1.51	1.20	<3 - 10
Glaciated Prairie	17 (1)	10:10	8.1	1.28	1.20	5 - 10
Unglaciated Prairie	17 (1)	10:10	9.7	1.81	1.20	5 - 30
Oak-hickory Forest	17 (1)	10:10	8.7	1.41	1.20	5 - 15
Plow zone, soybean field; Missouri						
Floodplain Forest	17 (1)	8:10	5.6	1.44	1.20	<3 - 10
Glaciated Prairie	17 (1)	10:10	10	1.42	1.20	5 - 15
Unglaciated Prairie	17 (1)	7:8	10	2.31	1.20	<3 - 50
Oak-hickory Forest	17 (1)	9:9	7.7	1.42	1.20	5 - 15
Plow zone, pasture field; Missouri						
Floodplain Forest	17 (1)	10:10	6.0	1.42	1.20	5 - 15
Glaciated Prairie	17 (1)	10:10	8.7	1.46	1.20	5 - 20
Unglaciated Prairie	17 (1)	10:10	8.5	1.53	1.20	5 - 15
Oak-hickory Forest	17 (1)	10:10	8.8	1.48	1.20	5 - 15
Surface horizon; Missouri	16 (1)	1,139:1,140	10	1.50	1.27	<3 - 30
Uncultivated						
Surface horizon; Powder River Basin, Wyoming and Montana	25 (1)	46:48	6.2	1.36	1.09	<3 - 10
A horizon; Georgia	14 (1)	6:30	1.5	3.08	--	<3 - 10
	15 (1)	28:30	9.8	1.74	--	<3 - 30
A horizon; Kentucky	18 (2)	96:96	10	1.45	1.09	4 - 27
	19 (2)	104:108	10	1.73	1.18	<3 - 33
B horizon; Georgia	14 (1)	4:30	1.0	3.19	--	<3 - 10
	15 (1)	29:30	10	1.81	--	<3 - 30
B horizon; Kentucky	18 (2)	96:96	8.4	1.39	1.09	2 - 17

TABLE 18.—*Cobalt in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
SOILS--Continued						
Uncultivated--Continued						
B horizon; Missouri						
Floodplain Forest	20 (1)	50:50	8.3	1.72	1.29	3 - 30
Glaciated Prairie	20 (1)	50:50	11	1.55	1.29	3 - 30
Unglaciated Prairie	20 (1)	50:50	14	1.83	1.29	3 50
Cedar Glade	20 (1)	50:50	9.5	1.48	1.29	5 - 30
Oak-hickory Forest	20 (1)	49:50	10	1.71	1.29	<3 - 30
Oak-hickory-pine Forest	20 (1)	50:50	9.5	1.89	1.29	3 - 50
C horizon; Georgia	14 (1)	7:30	1.9	2.60	--	<3 - 10
	15 (1)	11:30	11	1.64	--	<3 - 30
C horizon; Kentucky	18 (2)	95:96	7.6	1.61	1.09	<2 - 37
Cultivated and uncultivated						
Surface horizon; Colorado	22 (1)	109:168	5	1.66	1.15	<3 - 10
B horizon; Eastern United States	21 (1)	286:371	7	2.55	--	<3 - 70
B horizon; Western United States	21 (1)	445:492	8	2.01	--	<3 - 50
PLANT ASH						
Cultivated plants						
Bean, lima; Georgia	14 (1)	1:29	<7	--	--	<7 - 10
	15 (1)	5:15	4.6	1.63	--	<7 - 10
Bean, snap; Georgia	14 (1)	6:30	2.4	2.79	--	<7 - 15
	15 (1)	15:30	6.2	3.31	--	<7 - 70
Blackeyed pea; Georgia	14 (1)	1:29	<7	--	--	<7 - 10
Cabbage; Georgia	15 (1)	1:30	<7	--	--	<7 - 10
Corn; Missouri						
Floodplain Forest	17 (3)	3:8	<1	--	--	<1 - 1
Glaciated Prairie	17 (3)	5:10	1.0	--	--	<1 - 9
Unglaciated Prairie	17 (3)	3:7	.50	4.06	1.24	<1 - 5
Oak-hickory Forest	17 (3)	2:10	<1	--	--	<1 - 2
Soybean; Missouri						
Floodplain Forest	17 (3)	7:10	1.0	--	--	<1 - 6
Glaciated Prairie	17 (3)	8:10	2.0	2.97	1.24	<1 - 8
Unglaciated Prairie	17 (3)	6:8	2.1	3.75	1.24	<1 - 13
Oak-hickory Forest	17 (3)	8:9	2.1	2.39	1.24	<1 - 12
Tomato; Georgia	15 (1)	1:30	<7	--	--	<7 - 7
Native species						
Black cherry, stems; Georgia	14 (1)	5:30	<7	--	--	<7 - 100
	15 (1)	9:30	3.7	2.39	--	<7 - 20
Blackgum, stems; Georgia	14 (1)	28:30	120	3.54	--	<7 - 1,500
	15 (1)	27:30	190	6.14	--	<7 - 1,500
Blackgum, leaves; Georgia	14 (1)	27:30	290	5.83	--	<7 - 5,000
	15 (1)	27:30	400	7.67	--	<7 - 10,000

TABLE 18.—*Cobalt in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
		PLANT ASH--Continued				
Native species--Continued						
Buckbush; Missouri						
Glaciated Prairie	20 (3)	47:47	4.0	1.43	1.41	2 - 8
Unglaciated Prairie	20 (3)	47:48	4.8	1.76	1.41	<1 - 18
Cedar Glade	20 (3)	50:50	4.4	1.42	1.41	2 - 12
Oak-hickory Forest	20 (3)	49:49	4.7	1.68	1.41	2 - 20
Oak-hickory-pine Forest	20 (3)	41:41	5.4	1.91	1.41	2 - 30
Cedar; Missouri						
Cedar Glade	20 (3)	45:50	1.2	1.48	--	<1 - 4
Glaciated Prairie	24 (1)	7:9	6.5	1.90	--	<5 - 15
Unglaciated Prairie	24 (1)	3:10	2.1	3.68	--	<5 - 15
Oak-hickory Forest	24 (1)	2:10	1.9	2.43	--	<5 - 7
Oak-hickory-pine Forest	24 (1)	1:6	<5	--	--	<5 - 10
Hickory, pignut; Kentucky	18 (1)	58:64	18	2.47	1.24	<7 - 150
	19 (2)	72:88	23	1.70	1.09	<15 - 110
Hickory, shagbark; Kentucky	18 (1)	38:40	21	2.55	1.24	<7 - 150
	19 (2)	14:20	21	2.08	1.09	<15 - 100
Hickory, shagbark; Missouri						
Oak-hickory Forest	20 (3)	18:19	5.9	2.07	1.41	<1 - 16
Oak-hickory-pine Forest	20 (3)	7:7	7.4	1.93	1.41	2 - 16
Maple, red, stems; Georgia	14 (1)	1:30	<7	--	--	<7 - 10
Oak, black; Kentucky	18 (1)	19:25	8.1	1.71	1.20	<7 - 20
	19 (2)	7:22	11	2.07	1.09	<15 - 37
Oak, post; Cedar Glade, Missouri	20 (3)	30:50	.95	1.97	1.41	<1 - 4
Oak, red; Kentucky	18 (1)	18:28	7.7	2.20	1.20	<7 - 50
	19 (2)	2:8	<15	--	--	<15 - 15
Oak, white; Kentucky	18 (1)	22:49	5.7	2.02	1.20	<7 - 70
	19 (2)	11:75	<7	--	--	<7 - 37
Oak, white; Missouri						
Oak-hickory Forest	20 (3)	45:50	2.0	2.09	1.41	<1 - 9
Oak-hickory-pine Forest	20 (3)	47:49	2.7	2.20	1.41	<1 - 12
Oak, willow; Floodplain Forest, Missouri	20 (3)	44:46	.95	1.97	1.41	<1 - 12
Persimmon, stems; Georgia	14 (1)	5:30	<7	--	--	<7 - 1,000
	15 (1)	7:30	2.2	3.63	--	<7 - 30
Persimmon, leaves; Georgia	14 (1)	3:30	<7	--	--	<7 - 2,000
Pine, shortleaf; Oak-hickory-pine Forest, Missouri	20 (3)	49:49	9.7	1.75	1.41	2 - 30
Sagebrush; Powder River Basin; Wyoming and Montana	25 (3)	43:43	2.0	1.74	--	1 - 6
Sassafras stems; Georgia	15 (1)	1:27	<7	--	--	<7 - 15
Sumac, smooth; Missouri						
Floodplain Forest	20 (3)	23:48	.75	2.80	1.41	<1 - 7
Glaciated Prairie	20 (3)	18:50	.65	1.88	1.41	<1 - 3
Unglaciated Prairie	20 (3)	23:49	.78	2.10	1.41	<1 - 4
Cedar Glade	20 (3)	16:49	.71	1.42	1.41	<1 - 2
Oak-hickory Forest	20 (3)	35:50	1.1	1.75	1.41	<1 - 3
Oak-hickory-pine Forest	20 (3)	30:49	.97	2.17	1.41	<1 - 7

TABLE 18.—*Cobalt in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
PLANT ASH--Continued						
Native species--Continued						
Sweetgum, stems; Georgia	14 (1)	6:28	2.0	3.72	--	<7 - 30
	15 (1)	3:27	2.5	1.92	--	<7 - 10
Sweetgum, leaves; Georgia	14 (1)	2:28	<7	--	--	<7 - 7
Sweetgum; Floodplain Forest, Missouri	20 (3)	37:47	1.5	2.36	1.41	<1 - 11

TABLE 19.—*Copper in rocks, unconsolidated geologic deposits, soils, and plant ash*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Granite						
Precambrian; Missouri	1 (1)	28:30	2.2	1.98	1.18	<1 - 10
Rhyolite						
Precambrian; Missouri	1 (1)	20:30	1.6	2.18	1.18	<1 - 7
Arkose						
Fountain Formation; Colorado	2 (2)	80:80	8.1	1.70	1.36	2 - 26
Sandstone						
Sauk sequence; Western United States	3 (2)	380:400	5.0	2.76	1.79	<1 - 210
Roubidoux Formation; Missouri	4 (1)	8:12	1.2	2.14	1.23	<1 - 5
Pope Megagroup;[1] Kentucky	5 (2)	120:120	8.0	1.75	1.30	3 - 47
Pennsylvanian; Kentucky	5 (2)	152:152	7.7	1.59	1.27	1 - 27
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	32:32	8.4	2.52	1.23	1.5 - 30
Chert						
Mississippian; Missouri, Oklahoma, and Arkansas	7 (1)	12:20	1.1	2.02	1.23	<1 - 5
Shale						
Sauk sequence; Western United States	3 (2)	305:336	14	2.75	1.12	<3 - 98
Lower Mississippian; Kentucky	8 (2)	73:76	14	2.04	--	<3 - 55
Upper Mississippian; Kentucky	5 (2)	137:142	16	1.94	--	<4 - 60
Mississippian; Missouri, Oklahoma, and Arkansas	6 (1)	18:18	13	2.83	1.23	5 - 100

[1] Of Swann and Willman (1961).

TABLE 19.—*Copper in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS—Continued						
Black shale						
Devonian and Mississippian; Kentucky	9 (2)	88:88	130	1.62	1.06	25 - 400
Limestone and dolomite						
Sauk sequence; Western United States	3 (2)	302:392	2.3	4.33	1.60	<1 - 94
Sauk sequence; Missouri and Arkansas	4 (1)	39:48	2.0	2.53	1.30	<1 - 20
Upper Ordovician; Kentucky	5 (1)	78:80	5.3	1.78	1.36	<2 - 20
Tippecanoe sequence; Missouri	10 (1)	6:12	.84	3.51	1.30	<1 - 5
Lower Mississippian; Kentucky	5 (1)	108:112	4.0	2.09	1.56	<2 - 70
Upper Mississippian; Kentucky	5 (1)	120:152	2.6	1.90	1.47	<2 - 15
Mississippian; Missouri, Oklahoma, and Arkansas	7 (1)	20:40	.85	2.04	1.30	<1 - 7
Pennsylvanian; Kentucky	5 (1)	80:80	12	1.77	1.26	2 - 50
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	32:32	3.5	2.14	1.30	1.5 - 15
Siderite						
Upper Paleozoic; Kentucky	11 (1)	30:30	12	1.92	--	2 - 50
UNCONSOLIDATED GEOLOGIC DEPOSITS						
Carbonate residuum (terra rossa)						
On Gasconade Formation; Missouri	12 (1)	24:24	36	1.81	1.18	15 - 100
On Roubidoux Formation; Missouri	12 (1)	24:24	21	2.04	1.18	7 - 150
On Jefferson City, Cotter, and Powell Formations; Missouri	12 (1)	24:24	22	1.48	1.18	10 - 50
On Ozarkan rocks; Missouri	12 (1)	24:24	18	1.30	1.18	15 - 30
On Mesozoic rocks; Missouri	12 (1)	24:24	17	1.36	1.18	10 - 30
Loess						
Missouri	13 (1)	24:24	18	1.31	--	10 - 30
SOILS						
Cultivated						
Plow zone, garden; Georgia	14 (6)	30:30	9.9	1.85	--	2 - 50
	15 (6)	30:30	39	2.01	--	15 - 700
Plow zone, corn field; Missouri						
Floodplain Forest	17 (1)	8:8	11	1.82	1.14	3 - 20
Glaciated Prairie	17 (1)	10:10	18	1.41	1.14	10 - 30
Unglaciated Prairie	17 (1)	10:10	14	1.33	1.14	10 - 20
Oak-hickory Forest	17 (1)	10:10	19	1.51	1.14	10 - 50
Plow zone, soybean field; Missouri						
Floodplain Forest	17 (1)	10:10	12	1.53	1.14	5 - 20
Glaciated Prairie	17 (1)	10:10	19	1.13	1.14	15 - 20
Unglaciated Prairie	17 (1)	8:8	14	1.34	1.14	10 - 20
Oak-hickory Forest	17 (1)	9:9	16	1.33	1.14	10 - 20

TABLE 19.—*Copper in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
SOILS--Continued						
Cultivated--Continued						
Plow zone, pasture field; Missouri						
Floodplain Forest	17 (1)	10:10	12	1.54	1.14	7 - 30
Glaciated Prairie	17 (1)	10:10	18	1.16	1.14	15 - 20
Unglaciated Prairie	17 (1)	10:10	16	1.23	1.14	10 - 20
Oak-hickory Forest	17 (1)	10:10	16	1.25	1.14	10 - 20
Surface horizon; Missouri	16 (1)	1,140:1,140	13	1.55	1.28	5 - 150
Uncultivated						
Surface horizon; Powder River Basin, Wyoming and Montana	25 (1)	48:48	14	1.63	1.15	3 - 30
A horizon; Georgia	14 (6)	30:30	8.7	1.77	--	3 - 50
	15 (6)	30:30	26	1.72	--	15 - 100
A horizon; Kentucky	18 (2)	96:96	13	1.40	1.05	7 - 42
	19 (2)	108:108	12	1.32	1.10	6 - 26
B horizon; Georgia	14 (6)	30:30	8.8	1.77	--	3 - 50
	15 (6)	30:30	29	1.80	--	15 - 100
B horizon; Kentucky	18 (2)	96:96	20	1.51	1.05	8 - 100
B horizon; Missouri						
Floodplain Forest	20 (1)	50:50	15	1.99	1.54	3 - 100
Glaciated Prairie	20 (1)	50:50	23	1.66	1.54	10 - 70
Unglaciated Prairie	20 (1)	50:50	18	1.63	1.54	7 - 50
Cedar Glade	20 (1)	50:50	17	1.94	1.54	7 - 100
Oak-hickory Forest	20 (1)	50:50	13	1.99	1.54	3 - 70
Oak-hickory-pine Forest	20 (1)	50:50	12	1.88	1.54	5 - 70
C horizon; Georgia	14 (6)	30:30	11	2.04	--	3 - 50
	15 (6)	30:30	33	1.88	--	10 - 100
C horizon; Kentucky	18 (2)	96:96	19	1.63	1.05	5 - 300
Cultivated and uncultivated						
Surface horizon; Colorado	22 (1)	168:168	13	2.17	1.31	3 - 100
B horizon; Eastern United States	21 (6)	361:371	14	2.54	--	<1 - 150
B horizon; Western United States	21 (6)	492:492	21	2.00	--	2 - 300
PLANT ASH						
Cultivated plants						
Asparagus; Wisconsin	23 (6)	5:5	93	1.34	--	70 - 150
Bean, lima; Georgia	14 (6)	30:30	93	1.29	--	70 - 150
	15 (6)	15:15	94	1.34	--	70 - 150
Bean, snap; Georgia	14 (6)	30:30	85	1.47	--	30 - 200
	15 (6)	30:30	110	1.40	--	70 - 300
Beet, red; Wisconsin	23 (6)	3:3	73	1.74	--	40 - 120
Blackeyed pea; Georgia	14 (6)	29:29	96	1.37	--	70 - 150

TABLE 18.—*Copper in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
PLANT ASH—Continued						
Cultivated plants—Continued						
Cabbage; Georgia	14 (6)	28:28	22	1.57	--	10 - 70
	15 (6)	30:30	21	2.04	--	10 - 300
Cabbage; Wisconsin	23 (6)	11:11	29	2.03	--	20 - 150
Carrot; Wisconsin	23 (6)	8:8	110	1.43	--	20 - 120
Corn; Georgia	14 (6)	29:29	100	1.35	--	70 - 150
	15 (6)	30:30	94	1.37	--	50 - 150
Corn; Missouri						
Floodplain Forest	17 (1)	8:8	70	1.30	1.25	50 - 100
Glaciated Prairie	17 (1)	10:10	69	1.49	1.25	30 - 100
Unglaciated Prairie	17 (1)	10:10	94	1.35	1.25	70 - 150
Oak-hickory Forest	17 (1)	10:10	81	1.42	1.25	50 - 150
Corn; Wisconsin	23 (6)	27:27	150	1.37	--	60 - 220
Cucumber; Wisconsin	23 (6)	4:4	77	1.38	--	60 - 120
Onion; Wisconsin	23 (6)	7:7	96	1.62	--	40 - 150
Pepper, sweet; Wisconsin	23 (6)	4:4	98	1.26	--	80 - 120
Potato; Wisconsin	23 (6)	10:10	94	1.57	--	40 - 150
Soybean; Missouri						
Floodplain Forest	17 (1)	10:10	170	1.26	1.25	100 - 200
Glaciated Prairie	17 (1)	10:10	180	1.26	1.25	100 - 200
Unglaciated Prairie	17 (1)	8:8	210	1.30	1.25	150 - 300
Oak-hickory Forest	17 (1)	9:9	230	1.30	1.25	150 - 300
Tomato; Georgia	14 (6)	30:30	79	1.48	--	30 - 150
	15 (6)	30:30	86	1.71	--	50 - 500
Native species						
Black cherry, stems; Georgia	14 (6)	30:30	170	1.60	--	70 - 500
	15 (6)	30:30	180	1.52	--	100 - 7,000
Black cherry, leaves; Georgia	14 (6)	30:30	77	1.50	--	30 - 300
	15 (6)	30:30	69	1.39	--	30 - 150
Blackgum, stems; Georgia	14 (6)	30:30	240	1.88	--	20 - 700
	15 (6)	30:30	270	1.80	--	70 - 700
Blackgum, leaves; Georgia	14 (6)	30:30	130	1.90	--	70 - 2,000
	15 (6)	30:30	100	1.37	--	50 - 200
Buckbush; Missouri						
Glaciated Prairie	20 (1)	47:47	190	1.61	1.36	100 - 1,500
Unglaciated Prairie	20 (1)	48:48	200	1.46	1.36	100 - 700
Cedar Glade	20 (1)	49:49	160	1.32	1.36	100 - 300
Oak-hickory Forest	20 (1)	49:49	180	1.45	1.36	100 - 700
Oak-hickory-pine Forest	20 (1)	41:41	160	1.40	1.36	100 - 500
Cedar; Missouri						
Cedar Glade	20 (1)	50:50	50	1.63	1.36	20 - 200
Glaciated Prairie	24 (1)	9:9	110	1.35	--	70 - 150
Unglaciated Prairie	24 (1)	10:10	97	1.32	--	70 - 150
Cedar Glade	24 (1)	10:10	59	1.27	--	50 - 100
Oak-hickory Forest	24 (1)	10:10	66	1.71	--	30 - 150
Oak-hickory-pine Forest	24 (1)	6:6	79	1.33	--	50 - 100

TABLE 19.—*Copper in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
	PLANT ASH--Continued					
Native species--Continued						
Hickory, pignut; Kentucky	18 (1)	64:64	110	1.54	1.17	50 - 500
	19 (2)	88:88	98	1.49	1.10	46 - 500
Hickory, shagbark; Kentucky	18 (1)	40:40	130	1.52	1.17	50 - 500
	19 (2)	20:20	96	1.33	1.10	55 - 160
Hickory, shagbark; Missouri						
Oak-hickory Forest	20 (1)	19:19	90	1.53	1.36	50 - 200
Oak-hickory-pine Forest	20 (1)	7:7	100	1.25	1.36	70 - 150
Maple, red, stems; Georgia	14 (6)	30:30	150	1.27	--	100 - 300
	15 (6)	30:30	150	1.51	--	70 - 500
Maple, red, leaves; Georgia	14 (6)	30:30	140	1.86	--	20 - 300
	15 (6)	30:30	150	1.45	--	70 - 300
Oak, black; Kentucky	18 (1)	25:25	120	1.68	1.23	70 - 500
	19 (2)	22:22	99	1.21	1.10	61 - 150
Oak, post; Cedar Glade, Missouri	20 (1)	50:50	130	1.49	1.36	50 - 500
Oak, red; Kentucky	18 (1)	28:28	120	1.33	1.23	70 - 200
	19 (2)	8:8	95	1.31	1.10	60 - 120
Oak, white; Kentucky	18 (1)	49:49	130	1.31	1.23	70 - 200
	19 (2)	75:75	120	1.20	1.10	60 - 180
Oak, white; Missouri						
Oak-hickory Forest	20 (1)	50:50	130	1.57	1.36	50 - 300
Oak-hickory-pine Forest	20 (1)	49:49	140	1.34	1.36	70 - 200
Oak, willow; Floodplain Forest, Missouri	20 (1)	46:46	200	1.61	1.36	70 - 700
Persimmon, stems; Georgia	14 (6)	29:30	230	2.00	--	<10 - 2,000
	15 (6)	30:30	250	1.59	--	100 - 700
Persimmon, leaves; Georgia	14 (6)	30:30	70	1.52	--	20 - 150
	15 (6)	30:30	64	1.49	--	20 - 100
Pine, shortleaf; Oak-hickory-pine Forest, Missouri	20 (1)	49:49	160	1.44	1.36	50 - 500
Sassafras, stems; Georgia	14 (6)	17:17	160	2.63	--	20 - 1,500
	15 (6)	27:27	170	1.34	--	100 - 300
Sassafras, leaves; Georgia	14 (6)	17:17	140	2.21	--	50 - 1,500
	15 (6)	27:27	120	1.34	--	70 - 200
Sumac, winged, stems; Georgia	14 (6)	30:30	160	1.56	--	70 - 500
	15 (6)	30:30	160	1.49	--	70 - 300
Sumac, winged, leaves; Georgia	14 (6)	30:30	86	1.47	--	30 - 150
	15 (6)	30:30	84	1.44	--	50 - 200
Sumac, smooth; Missouri						
Floodplain Forest	20 (1)	48:48	110	1.40	1.36	50 - 200
Glaciated Prairie	20 (1)	50:50	110	1.41	1.36	50 - 200
Unglaciated Prairie	20 (1)	49:49	100	1.46	1.36	30 - 150
Cedar Glade	20 (1)	49:49	86	1.58	1.36	30 - 300
Oak-hickory Forest	20 (1)	50:50	89	1.43	1.36	50 - 200
Oak-hickory-pine Forest	20 (1)	49:49	97	1.51	1.36	50 - 300

TABLE 19.—*Copper in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
		PLANT ASH--Continued				
Native species--Continued						
Sweetgum, stems; Georgia	14 (6)	28:28	130	2.20	--	30 - 3,000
	15 (6)	27:27	150	1.46	--	50 - 300
Sweetgum, leaves; Georgia	14 (6)	28:28	130	1.92	--	70 - 2,000
	15 (6)	27:27	130	1.42	--	70 - 200
Sweetgum; Floodplain Forest, Missouri	20 (1)	47:47	130	1.90	1.36	20 - 700

TABLE 20.—*Fluorine in rocks, unconsolidated geologic deposits, soils, and dry plants*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
		ROCKS				
Granite						
Precambrian; Missouri	1 (9)	28:30	390	3.59	3.48	<10 - 1,400
Rhyolite						
Precambrian; Missouri	1 (9)	29:30	350	2.87	3.48	<10 - 1,400
Sandstone						
Roubidoux Formation; Missouri	4 (9)	6:12	9.8	4.83	1.34	<10 - 90
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (9)	29:32	120	4.07	1.34	<10 - 920
Chert						
Mississippian; Missouri, Oklahoma, and Arkansas	7 (9)	6:20	<10	--	--	<10 - 50
Shale						
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (9)	32:32	700	1.66	2.28	300 - 1,400
Limestone and dolomite						
Sauk sequence; Missouri and Arkansas	4 (9)	45:48	89	3.03	1.63	<10 - 340
Tippecanoe sequence; Missouri	10 (9)	10:12	67	5.77	1.63	<10 - 620
Mississippian; Missouri, Oklahoma, and Arkansas	7 (9)	27:40	38	6.01	1.63	<10 - 830
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (9)	29:32	100	3.46	1.63	<10 - 450

TABLE 20.—*Fluorine in rocks, unconsolidated geologic deposits, soils, and dry plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
UNCONSOLIDATED GEOLOGIC DEPOSITS						
Carbonate residuum (terra rossa)						
On Gasconade Formation; Missouri	12 (9)	24:24	820	1.82	1.26	330 - 5,900
On Roubidoux Formation; Missouri	12 (9)	24:24	770	2.09	1.26	100 - 2,800
On Jefferson City, Cotter, and Powell Formations; Missouri and Arkansas	12 (9)	24:24	1,000	1.40	1.26	500 - 1,800
On Osagean rocks; Missouri	12 (9)	24:24	700	1.48	1.26	360 - 1,900
On Meramecian rocks; Missouri	12 (9)	24:24	770	1.42	1.26	390 - 1,800
Loess						
Missouri	13 (9)	24:24	290	1.47	--	150 - 460
SOILS						
Cultivated						
Plow zone, corn field; Missouri						
Floodplain Forest	17 (9)	8:8	210	1.82	1.86	110 - 590
Glaciated Prairie	17 (9)	10:10	440	1.95	1.86	240 - 2,020
Unglaciated Prairie	17 (9)	10:10	220	1.57	1.86	120 - 520
Oak-hickory Forest	17 (9)	10:10	200	1.56	1.86	70 - 330
Plow zone, soybean field; Missouri						
Floodplain Forest	17 (9)	10:10	160	1.89	1.86	70 - 420
Glaciated Prairie	17 (9)	10:10	360	1.43	1.86	220 - 890
Unglaciated Prairie	17 (9)	8:8	220	1.63	1.86	100 - 540
Oak-hickory Forest	17 (9)	9:9	250	1.76	1.86	110 - 640
Plow zone, pasture field; Missouri						
Floodplain Forest	17 (9)	10:10	170	1.93	1.86	60 - 580
Glaciated Prairie	17 (9)	10:10	290	1.60	1.86	140 - 780
Unglaciated Prairie	17 (9)	10:10	290	2.32	1.86	140 - 2,310
Oak-hickory Forest	17 (9)	10:10	240	1.73	1.86	100 - 530
Surface horizon; Missouri	16 (9)	1,140:1,140	270	2.22	1.86	10 - 6,400
Uncultivated						
B horizon; Missouri						
Floodplain Forest	20 (9)	50:50	250	2.21	2.43	30 - 1,900
Glaciated Prairie	20 (9)	50:50	480	1.54	2.43	190 - 1,100
Unglaciated Prairie	20 (9)	50:50	360	1.71	2.43	110 - 950
Cedar Glade	20 (9)	50:50	410	2.18	2.43	40 - 480
Oak-hickory Forest	20 (9)	50:50	190	2.40	2.43	50 - 1,800
Oak-hickory-pine Forest	20 (9)	50:50	160	2.66	2.43	10 - 1,000
Cultivated and uncultivated						
Surface horizon; Colorado	22 (9)	168:168	420	2.21	1.33	40 - 2,840
B horizon; Eastern United States	21 (9)	374:420	120	4.38	--	<10 - 3,680
B horizon; Western United States	21 (9)	479:491	250	2.66	--	<10 - 1,900

TABLE 28.—*Fluorine in rocks, unconsolidated geologic deposits, soils, and dry plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
		DRY PLANTS				
Cultivated plants						
Corn; Missouri						
Floodplain Forest	17 (9)	1:8	<0.5	--	--	<0.5 - 0.5
Glaciated Prairie	17 (9)	1:10	<.5	--	--	<.5 - .5
Unglaciated Prairie	17 (9)	1:10	<.5	--	--	<.5 - .5
Oak-hickory Forest	17 (9)	2:10	.43	1.12	--	<.5 - .5
Soybean; Missouri						
Floodplain Forest	17 (9)	5:10	.46	1.86	--	<.5 - 1
Glaciated Prairie	17 (9)	5:10	.47	1.07	--	<.5 - .5
Unglaciated Prairie	17 (9)	6:8	.49	1.04	--	<.5 - .5
Oak-hickory Forest	17 (9)	3:9	<.5	--	--	<.5 - 1
Native species						
Buckbush; Missouri						
Glaciated Prairie	20 (9)	11:11	1.6	1.49	--	1 - 3
Unglaciated Prairie	20 (9)	3:3	1.4	2.56	--	.5 - 3
Cedar Glade	20 (9)	5:5	1.1	1.79	--	.5 - 2
Oak-hickory Forest	20 (9)	13:13	1.4	1.64	--	.5 - 3
Oak-hickory-pine Forest	20 (9)	7:7	1.3	1.45	--	1 - 2
Cedar; Cedar Glade, Missouri	20 (9)	11:11	1.6	1.58	--	1 - 3
Hickory, shagbark; Oak-hickory Forest, Missouri	20 (9)	3:4	.78	1.54	--	<.5 - 1
Oak, post; Cedar Glade, Missouri	20 (9)	6:6	1.1	1.69	--	.5 - 2
Oak, white; Missouri						
Oak-hickory Forest	20 (9)	10:12	.5	--	--	<.5 - 1
Oak-hickory-pine Forest	20 (9)	10:11	.71	1.49	--	<.5 - 1
Oak, willow; Floodplain Forest, Missouri	20 (9)	9:11	.77	1.72	--	<.5 - 2
Pine, shortleaf; Oak-hickory-pine Forest, Missouri	20 (9)	4:4	.84	1.41	--	.5 - 1
Sumac, smooth; Missouri						
Floodplain Forest	20 (9)	7:9	.5	--	--	<.5 - 1
Glaciated Prairie	20 (9)	5:8	.5	--	--	<.5 - 1
Unglaciated Prairie	20 (9)	9:11	.5	--	--	<.5 - 1
Cedar Glade	20 (9)	10:11	.76	1.67	--	<.5 - 2
Oak-hickory Forest	20 (9)	5:9	.5	--	--	<.5 - 1
Oak-hickory-pine Forest	20 (9)	5:8	.5	--	--	<.5 - 1
Sweetgum; Floodplain Forest, Missouri	20 (9)	11:14	.66	1.58	--	<.5 - 1

TABLE 21.—*Gallium in rocks, unconsolidated geologic deposits, soils, and plant ash*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Granite						
Precambrian; Missouri	1 (1)	30:30	29	1.11	1.14	20 - 30
Rhyolite						
Precambrian; Missouri	1 (1)	30:30	28	1.20	1.14	15 - 30
Arkose						
Fountain Formation; Colorado	2 (2)	69:80	7.6	1.87	1.33	<3 - 23
Sandstone						
Sauk sequence; Western United States	3 (2)	108:400	<2	--	--	<2 - 25
Pope Megagroup;[1] Kentucky	5 (2)	13:120	1.5	2.91	1.08	<8 - 13
Pennsylvanian; Kentucky	5 (2)	70:152	3.8	2.86	1.22	<3 - 21
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	29:32	10	2.06	1.05	<3 - 30
Shale						
Sauk sequence; Western United States	3 (2)	306:336	24	1.65	1.13	<10 - 48
Lower Mississippian; Kentucky	8 (2)	62:76	15	1.66	--	<10 - 30
Upper Mississippian; Kentucky	5 (2)	138:142	22	1.38	--	<10 - 36
Mississippian; Missouri, Oklahoma, and Arkansas	7 (1)	18:18	16	1.81	1.14	7 - 50
Pennsylvanian; Kentucky	5 (2)	144:152	26	1.54	1.11	<11 - 60
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	32:32	30	1.45	1.14	15 - 50
Black shale						
Devonian and Mississippian; Kentucky	9 (2)	87:88	22	1.25	1.11	<15 - 33
Limestone and dolomite						
Sauk sequence; Western United States	3 (2)	35:392	<10	--	--	<10 - 20
Sauk sequence; Missouri and Arkansas	4 (1)	2:48	<3	--	--	<3 - 7
Upper Ordovician; Kentucky	5 (1)	12:80	5.4	1.49	--	<10 - 15
Tippecanoe sequence; Missouri	10 (1)	1:12	<3	--	--	<3 - 7
Lower Mississippian; Kentucky	5 (1)	19:112	5.6	1.50	--	<10 - 15
Upper Mississippian; Kentucky	5 (1)	11:152	<10	--	--	<10 - 20
Mississippian; Missouri, Oklahoma, and Arkansas	7 (1)	2:40	<3	--	--	<3 - 7
Pennsylvanian; Kentucky	5 (1)	52:80	10	1.71	1.34	<10 - 20
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	8:32	2.2	2.34	--	<3 - 10
Siderite						
Upper Paleozoic; Kentucky	11 (1)	28:30	13	1.66	--	<10 - 50

[1] Of Swann and Willman (1961).

TABLE 21.—*Gallium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
UNCONSOLIDATED GEOLOGIC DEPOSITS						
Carbonate residuum (terra rossa)						
On Gasconade Formation; Missouri	12 (1)	24:24	20	1.49	1.19	10 - 50
On Roubidoux Formation; Missouri	12 (1)	23:24	16	1.67	1.19	<5 - 30
On Jefferson City, Cotter, and Powell Formations; Missouri and Arkansas	12 (1)	24:24	21	1.39	1.19	10 - 50
On Ozarkian rocks; Missouri	12 (1)	24:24	26	1.33	1.19	20 - 50
On Ozarkian rocks; Missouri	12 (1)	24:24	26	1.39	1.19	15 - 50
Loess						
Missouri	13 (1)	24:24	16	1.15	--	15 - 20
SOILS						
Cultivated						
Plow zone, garden; Georgia	14 (1)	8:30	<1.5	--	--	<1.5 - 10
	15 (1)	30:30	20	1.78	--	3 - 50
Plow zone, corn field; Missouri						
Floodplain Forest	17 (1)	8:8	12	1.23	1.19	10 - 15
Glaciated Prairie	17 (1)	10:10	15	1.21	1.19	10 - 20
Unglaciated Prairie	17 (1)	10:10	11	1.35	1.19	7 - 15
Oak-hickory Forest	17 (1)	10:10	12	1.37	1.19	7 - 20
Plow zone, soybean field; Missouri						
Floodplain Forest	17 (1)	10:10	12	1.36	1.19	7 - 20
Glaciated Prairie	17 (1)	10:10	16	1.15	1.19	15 - 20
Unglaciated Prairie	17 (1)	8:8	11	1.28	1.19	7 - 15
Oak-hickory Forest	17 (1)	9:9	11	1.22	1.19	10 - 15
Plow zone, pasture field; Missouri						
Floodplain Forest	17 (1)	10:10	12	1.23	1.19	10 - 15
Glaciated Prairie	17 (1)	10:10	15	1.18	1.19	10 - 20
Unglaciated Prairie	17 (1)	10:10	11	1.28	1.19	7 - 15
Oak-hickory Forest	17 (1)	10:10	12	1.24	1.19	10 - 15
Surface horizon; Missouri	16 (1)	1,111:1,140	11	1.49	1.22	<5 - 30
Uncultivated						
Surface horizon; Powder River Basin, Wyoming and Montana	25 (1)	48:48	12	1.31	1.13	7 - 20
A horizon; Georgia	14 (1)	10:30	15	3.57	--	<1.5 - 30
	15 (1)	29:30	17	2.32	--	<1.5 - 50
A horizon; Kentucky	18 (2)	83:96	7.5	1.53	1.10	<5 - 21
	19 (2)	68:108	11	1.31	1.15	<10 - 23
B horizon; Georgia	14 (1)	10:30	1.9	2.31	--	<1.5 - 7
	15 (1)	30:30	21	1.96	--	3 - 50
B horizon; Kentucky	18 (2)	94:96	15	1.57	1.10	<5 - 42
B horizon; Missouri						
Floodplain Forest	20 (1)	50:50	12	1.53	1.29	5 - 30
Glaciated Prairie	20 (1)	50:50	19	1.40	1.29	7 - 30
Unglaciated Prairie	20 (1)	50:50	14	1.51	1.29	5 - 30

TABLE 21.—*Gallium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
SOILS--Continued						
Uncultivated--Continued						
B horizon; Missouri--Continued						
Cedar Glade	20 (1)	47:50	11	1.64	1.29	<5 - 20
Oak-hickory Forest	20 (1)	48:50	8.4	1.54	1.29	<5 - 20
Oak-hickory-pine Forest	20 (1)	37:50	5.9	1.92	1.29	<5 - 20
C horizon; Georgia	14 (1)	19:30	3.7	2.21	--	<1.5 - 15
	15 (1)	30:30	29	1.85	--	5 - 70
C horizon; Kentucky	18 (2)	93:96	15	1.67	1.10	<5 - 46
Cultivated and uncultivated						
Surface horizon; Colorado	22 (1)	168:168	17	1.52	1.17	5 - 30
B horizon; Eastern United States	21 (1)	301:370	10	2.53	--	<5 - 70
B horizon; Western United States	21 (1)	483:492	18	1.71	--	<5 - 70
PLANT ASH						
Native species						
Blackgum, stems; Georgia	15 (1)	2:30	<5	--	--	<5 - 100
Blackgum, leaves; Georgia	15 (1)	2:30	<5	--	--	<5 - 200
Buckbush; Missouri						
Glaciated Prairie	20 (1)	11:47	2.8	1.54	--	<5 - 7
Unglaciated Prairie	20 (1)	9:48	2.4	1.73	--	<5 - 7
Oak-hickory Forest	20 (1)	9:49	2.7	1.51	--	<5 - 7
Oak-hickory-pine Forest	20 (1)	5:41	1.5	2.24	--	<5 - 10
Persimmon, leaves; Georgia	15 (1)	1:30	<5	--	--	<5 - 5
Sassafras, leaves; Georgia	15 (1)	1:27	<5	--	--	<5 - 5
Sumac, winged, leaves; Georgia	15 (1)	1:30	<5	--	--	<5 - 5

TABLE 22.—*Gold in rocks*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppb)	Deviation	Error	Observed range (ppb)
Arkose						
Fountain Formation; Colorado	2 (8)	80:80	0.26	2.14	2.11	0.06 - 1.6

TABLE 23.—*Iodine in unconsolidated geologic deposits, soils, and dry plants*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean except that values preceded by asterisk are arithmetic mean. Deviation, geometric deviation except that values preceded by asterisk are standard deviation. Error, geometric error attributed to laboratory procedures except that values preceded by asterisk are standard error. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
UNCONSOLIDATED GEOLOGIC DEPOSITS						
Loess						
Missouri	13 (8)	24:24	1.2	1.83	1.09	0.20 - 4.7
SOILS						
Cultivated						
Surface horizon; Missouri	16 (8)	114:114	*4.3	*1.65	*0.46	1.2 - 11
DRY PLANTS						
Cultivated plants						
Corn; Missouri						
Floodplain Forest	17 (7)	8:8	5.4	1.16	1.12	4 - 6
Glaciated Prairie	17 (7)	10:10	5.7	1.17	1.12	5 - 7
Unglaciated Prairie	17 (7)	10:10	5.3	1.22	1.12	4 - 7
Oak-hickory Forest	17 (7)	10:10	4.6	1.24	1.12	3 - 6
Soybean; Missouri						
Floodplain Forest	17 (7)	10:10	13	1.14	1.12	10 - 16
Glaciated Prairie	17 (7)	10:10	13	1.14	1.12	10 - 16
Unglaciated Prairie	17 (7)	8:8	12	1.15	1.12	10 - 14
Oak-hickory Forest	17 (7)	9:9	13	1.15	1.12	10 - 16
Native species						
Buckbush; Missouri						
Glaciated Prairie	20 (7)	11:11	4.7	1.11	--	4 - 5
Unglaciated Prairie	20 (7)	7:7	5.4	1.10	--	5 - 6
Cedar Glade	20 (7)	8:8	4.7	1.16	--	4 - 6
Oak-hickory Forest	20 (7)	16:16	5.1	1.13	--	4 - 6
Oak-hickory-pine Forest	20 (7)	10:10	4.6	1.16	--	4 - 5
Cedar; Missouri						
Cedar Glade	20 (7)	11:11	5.0	1.18	--	4 - 6
Glaciated Prairie	24 (7)	9:9	5.4	1.29	--	4 - 10
Unglaciated Prairie	24 (7)	10:10	4.4	1.12	--	4 - 5
Cedar Glade	24 (7)	10:10	4.5	1.12	--	4 - 5
Oak-hickory Forest	24 (7)	10:10	4.4	1.12	--	4 - 5
Oak-hickory-pine Forest	24 (7)	6:6	4.3	1.23	--	3 - 5
Hickory, pignut; Kentucky	18 (7)	64:64	3.2	1.29	1.31	2 - 5
Hickory, shagbark; Kentucky	18 (7)	40:40	3.2	1.28	1.31	2 - 5
Hickory, shagbark; Oak-hickory Forest, Missouri	20 (7)	4:4	4.2	1.12	--	4 - 5

TABLE 23.—*Iodine in unconsolidated geologic deposits, soils, and dry plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
	DRY PLANTS--Continued					
Native species--Continued						
Oak, black; Kentucky	18 (7)	25:25	2.8	1.39	1.29	2 - 5
Oak, post; Cedar Glade, Missouri	20 (7)	8:8	4.2	1.19	--	3 - 5
Oak, red; Kentucky	18 (7)	28:28	3.1	1.26	1.29	2 - 5
Oak, white; Kentucky	18 (7)	49:49	3.3	1.33	1.29	2 - 5
Oak, white; Missouri						
Oak-hickory Forest	20 (7)	12:12	4.6	1.22	--	3 - 6
Oak-hickory-pine Forest	20 (7)	11:11	4.6	1.12	--	4 - 5
Oak, willow; Floodplain Forest, Missouri	20 (7)	12:12	4.6	1.15	--	4 - 6
Pine, shortleaf; Oak-hickory-pine Forest, Missouri	20 (7)	4:4	4.9	1.18	--	4 - 6
Sumac, smooth; Missouri						
Floodplain Forest	20 (7)	9:9	4.8	1.10	--	4 - 5
Glaciated Prairie	20 (7)	9:9	4.6	1.16	--	4 - 6
Unglaciated Prairie	20 (7)	11:11	4.6	1.18	--	3 - 5
Cedar Glade	20 (7)	11:11	4.3	1.18	--	3 - 5
Oak-hickory Forest	20 (7)	9:9	4.6	1.12	--	4 - 5
Oak-hickory-pine Forest	20 (7)	8:8	4.0	1.24	--	3 - 5
Sweetgum; Floodplain Forest, Missouri	20 (7)	14:14	4.1	1.20	--	3 - 6

TABLE 24.—*Iron in rocks, unconsolidated geologic deposits, soils, and plant ash*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean except that values preceded by asterisk are arithmetic mean. Deviation, geometric deviation except that values preceded by asterisk are standard deviation. Error, geometric error attributed to laboratory procedures except that values preceded by asterisk are standard error. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
	ROCKS					
Granite						
Precambrian; Missouri	1 (5)	30:30	1.7	1.60	1.03	0.84 - 3.5
Rhyolite						
Precambrian; Missouri	1 (5)	30:30	1.9	1.27	1.03	1.2 - 3.1

TABLE 24.—*Iron in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
ROCKS--Continued						
Arkose						
Fountain Formation; Colorado	2 (2)	80:80	0.63	2.50	1.12	0.03 - 4.3
Sandstone						
Rembidoux Formation; Missouri	4 (5)	7:12	.090	3.26	1.15	<.070 - .42
Pope Megagroup;[1] Kentucky	5 (2)	120:120	.96	2.43	1.09	.090 - 5.5
Pennsylvanian; Kentucky	5 (2)	152:152	1.0	3.20	1.14	.080 - 9.9
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (5)	32:32	1.9	2.06	1.15	.56 - 7.7
Chert						
Mississippian; Missouri, Oklahoma, and Arkansas	7 (5)	10:20	.081	1.96	1.15	<.070 - .21
Shale						
Lower Mississippian; Kentucky	8 (2)	76:76	3.5	1.95	--	.75 - 8.6
Upper Mississippian; Kentucky	5 (2)	142:142	4.2	1.72	--	.80 - 10
Mississippian; Missouri, Oklahoma, and Arkansas	7 (5)	18:18	1.8	1.58	1.03	.77 - 3.4
Pennsylvanian; Kentucky	5 (2)	152:152	4.5	1.93	1.28	.45 - 10
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (5)	32:32	3.8	1.50	1.03	.91 - 8.4
Black shale						
Devonian and Mississippian; Kentucky	9 (2)	88:88	3.3	1.74	1.36	.83 - 10
Limestone and dolomite						
Sauk sequence; Western United States	3 (2)	387:392	.63	2.77	1.81	<.05 - 5.6
Sauk sequence; Missouri and Arkansas	4 (5)	46:48	.17	2.44	1.04	<.070 - .27
Upper Ordovician; Kentucky	5 (1)	78:80	.90	1.95	--	.2 - >10
Tippecanoe sequence; Missouri	10 (5)	10:12	.11	2.79	1.04	<.070 - .56
Lower Mississippian; Kentucky	5 (1)	112:112	.54	2.38	--	.05 - 3
Upper Mississippian; Kentucky	5 (1)	152:152	.37	2.56	--	.05 - 3
Mississippian; Missouri, Oklahoma, and Arkansas	7 (5)	30:40	.15	3.71	1.04	<.070 - 1.4
Pennsylvanian; Kentucky	5 (1)	80:80	2.1	1.84	--	.5 - 10
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (5)	32:32	.96	2.49	1.04	.21 - 3.7
Siderite						
Upper Paleozoic; Kentucky	11 (16)	30:30	*26	*9.36	--	8.0 - 39
UNCONSOLIDATED GEOLOGIC DEPOSITS						
Carbonate residuum (terra rossa)						
On Gasconade Formation; Missouri	12 (5)	24:24	4.3	1.30	1.02	2.5 - 7.0
On Rembidoux Formation; Missouri	12 (5)	24:24	3.5	1.60	1.02	1.1 - 5.9
On Jefferson City, Cotter, and Powell Formations; Missouri and Arkansas	12 (5)	24:24	3.9	1.25	1.02	2.1 - 5.7

[1] Of Swann and Willman (1961).

TABLE 24.—*Iron in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
UNCONSOLIDATED GEOLOGIC DEPOSITS--Continued						
Carbonate residuum (terra rossa)--Continued						
On Osageam rocks; Missouri	12 (5)	24:24	5.3	1.30	1.02	3.3 - 8.0
On Maramecian rocks; Missouri	12 (5)	24:24	5.7	1.34	1.02	2.7 - 11
Loess						
Missouri	13 (5)	24:24	2.4	1.11	--	2.1 - 3.1
SOILS						
Cultivated						
Plow zone, garden; Georgia	15 (1)	30:30	2.0	1.54	--	1 - 5
Plow zone, corn field; Missouri						
Floodplain Forest	17 (5)	8:8	1.4	1.80	1.03	.4 - 3.1
Glaciated Prairie	17 (5)	10:10	2.4	1.28	1.03	1.6 - 3.3
Unglaciated Prairie	17 (5)	10:10	2.3	1.32	1.03	1.6 - 3.8
Oak-hickory Forest	17 (5)	10:10	2.1	1.14	1.03	1.7 - 2.6
Plow zone, soybean field; Missouri						
Floodplain Forest	17 (5)	10:10	1.4	1.96	1.03	.3 - 4.6
Glaciated Prairie	17 (5)	10:10	2.8	1.13	1.03	2.2 - 3.1
Unglaciated Prairie	17 (5)	8:8	2.5	1.42	1.03	1.7 - 5.1
Oak-hickory Forest	17 (5)	9:9	1.9	1.12	1.03	1.6 - 2.3
Plow zone, pasture field; Missouri						
Floodplain Forest	17 (5)	10:10	1.6	1.96	1.03	.4 - 4.6
Glaciated Prairie	17 (5)	10:10	2.3	1.20	1.03	2.0 - 3.4
Unglaciated Prairie	17 (5)	10:10	2.0	1.28	1.03	1.3 - 2.8
Oak-hickory Forest	17 (5)	10:10	2.2	1.23	1.03	1.5 - 2.9
Surface horizon; Missouri	16 (5)	1,140:1,140	*2.1	*.64	*.12	.49 - 5.4
Uncultivated						
Surface horizon; Powder River Basin, Wyoming and Montana	25 (1)	48:48	1.9	1.58	1.26	.7 - 10
A horizon; Georgia	14 (1)	30:30	.47	2.27	--	.1 - 3
	15 (1)	30:30	2.1	1.68	--	.5 - 5
A horizon; Kentucky	18 (16)	96:96	2.1	1.62	1.06	.47 - 6
	19 (16)	108:108	2.1	1.54	1.27	.77 - 13
B horizon; Georgia	14 (1)	30:30	.48	2.04	--	.15 - 2
	15 (1)	30:30	2.6	1.74	--	.7 - 7
B horizon; Kentucky	18 (16)	96:96	4.2	1.55	1.06	.62 - 9.7
B horizon; Missouri						
Floodplain Forest	20 (5)	50:50	2.1	1.69	1.10	.7 - 9.4
Glaciated Prairie	20 (5)	50:50	3.5	1.26	1.10	1.8 - 5.1
Unglaciated Prairie	20 (5)	50:50	3.5	1.53	1.10	1.4 - 12.3
Cedar Glade	20 (5)	50:50	1.9	1.43	1.10	.8 - 3.8
Oak-hickory Forest	20 (5)	50:50	1.9	1.43	1.10	.8 - 5.3
Oak-hickory-pine Forest	20 (5)	50:50	1.5	1.51	1.10	.7 - 3.9

TABLE 24.—*Iron in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
SOILS--Continued						
Uncultivated--Continued						
C horizon; Georgia	15 (1)	30:30	3.0	1.59	--	1 - 5
C horizon; Kentucky	18 (16)	96:96	4.3	1.63	1.06	.60 - 11
Cultivated and uncultivated						
Surface horizon; Colorado	22 (5)	168:168	2.0	1.61	1.04	.6 - 5
B horizon; Eastern United States	21 (1)	369:370	1.5	2.76	--	.01 - >10
B horizon; Western United States	21 (1)	490:491	2.0	1.90	--	.15 - >10
PLANT ASH						
Cultivated plants						
Asparagus; Wisconsin	23 (1)	5:5	0.27	1.60	--	0.15 - 0.5
Bean, lima; Georgia	14 (1)	30:30	.11	1.27	--	.07 - .15
	15 (1)	15:15	.16	2.15	--	.07 - 1
Bean, snap; Georgia	14 (1)	30:30	.099	1.36	--	.07 - .2
	15 (1)	30:30	.14	1.96	--	.03 - .7
Beet, red; Wisconsin	23 (1)	4:4	.063	1.21	--	.05 - .07
Blackeyed pea; Georgia	14 (1)	29:29	.11	1.43	--	.03 - .15
	15 (1)	4:4	.11	1.55	--	.07 - .2
Cabbage; Georgia	14 (1)	28:28	.071	1.46	--	.03 - .3
	15 (1)	30:30	.19	2.13	--	.03 - .7
Cabbage; Wisconsin	23 (1)	11:11	.076	2.16	--	.03 - .3
Carrot; Wisconsin	23 (1)	8:8	.060	2.15	--	.02 - .2
Corn; Georgia	14 (1)	29:29	.086	1.57	--	.05 - .5
	15 (1)	30:30	.099	1.65	--	.03 - .3
Corn; Missouri						
Floodplain Forest	17 (1)	8:8	.17	1.67	1.23	.1 - .5
Glaciated Prairie	17 (1)	10:10	.13	1.28	1.23	.1 - .2
Unglaciated Prairie	17 (1)	10:10	.16	1.13	1.23	.15 - .2
Oak-hickory Forest	17 (1)	10:10	.13	1.30	1.23	.1 - .2
Corn; Wisconsin	23 (1)	27:27	.13	1.45	--	.05 - .3
Cucumber; Wisconsin	23 (1)	4:4	.077	1.20	--	.07 - .1
Onion; Wisconsin	23 (1)	7:7	.094	1.83	--	.03 - .2
Pepper, sweet; Wisconsin	23 (1)	4:4	.16	1.15	--	.15 - .2
Potato; Wisconsin	23 (1)	10:10	.063	1.56	--	.03 - .15
Soybean; Missouri						
Floodplain Forest	17 (1)	10:10	.10	1.14	1.23	.1 - .15
Glaciated Prairie	17 (1)	10:10	.12	1.24	1.23	.1 - .15
Unglaciated Prairie	17 (1)	8:8	.13	1.23	1.23	.1 - .15
Oak-hickory Forest	17 (1)	9:9	.13	1.28	1.23	.1 - .2
Tomato; Georgia	14 (1)	30:30	.078	2.21	--	.02 - 1.5
	15 (1)	30:30	.053	1.56	--	.02 - .2

TABLE 24.—*Iron in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
		PLANT ASH--Continued				
Native species						
Black cherry, stems; Georgia	14 (1)	30:30	0.15	1.81	--	0.07 - 0.7
	15 (1)	30:30	.19	2.52	--	.01 - 1.5
Black cherry, leaves; Georgia	14 (1)	30:30	.14	1.75	--	.07 - 1.5
	15 (1)	30:30	.21	1.63	--	.1 - .7
Blackgum, stems; Georgia	14 (1)	30:30	.14	1.69	--	.07 - .5
	15 (1)	30:30	.19	2.33	--	.015 - 1.0
Blackgum, leaves; Georgia	14 (1)	30:30	.18	1.84	--	.07 - 1.5
	15 (1)	30:30	.26	2.47	--	.03 - 2.0
Buckbush; Missouri						
Glaciated Prairie	20 (1)	47:47	.76	1.74	1.45	.05 - 2
Unglaciated Prairie	20 (1)	48:48	.93	1.64	1.45	.3 - 5
Cedar Glade	20 (1)	50:50	.56	1.44	1.45	.3 - 1
Oak-hickory Forest	20 (1)	49:49	.69	1.58	1.45	.3 - 2
Oak-hickory-pine Forest	20 (1)	41:41	.56	1.96	1.45	.05 - 1.5
Cedar; Missouri						
Cedar Glade	20 (1)	50:50	.28	1.66	1.45	.1 - 1
Glaciated Prairie	24 (1)	9:9	.72	1.58	--	.03 - 1.5
Unglaciated Prairie	24 (1)	10:10	.59	1.77	--	.3 - 1.5
Cedar Glade	24 (1)	10:10	.28	1.43	--	.2 - .5
Oak-hickory Forest	24 (1)	10:10	.35	1.71	--	.2 - .7
Oak-hickory-pine Forest	24 (1)	6:6	.24	1.60	--	.15 - .5
Hickory, pignut; Kentucky	18 (3)	60:60	.12	1.46	1.23	.06 - .39
	19 (3)	88:88	.12	1.44	1.07	.05 - .31
Hickory, shagbark; Kentucky	18 (3)	40:40	.12	1.54	1.23	.06 - .27
	19 (3)	20:20	.15	1.44	1.07	.09 - .34
Hickory, shagbark; Missouri						
Oak-hickory Forest	20 (1)	19:19	.13	1.67	1.45	.05 - .3
Oak-hickory-pine Forest	20 (1)	7:7	.16	1.57	1.45	.1 - .3
Maple, red, stems; Georgia	14 (1)	30:30	.094	1.47	--	.05 - .3
	15 (1)	30:30	.14	1.59	--	.07 - .3
Maple, red, leaves; Georgia	14 (1)	30:30	.17	1.96	--	.1 - 1.5
	15 (1)	30:30	.28	1.89	--	.1 - 1.0
Oak, black; Kentucky	18 (3)	25:25	.13	1.66	1.24	.06 - .38
	19 (3)	22:22	.10	1.32	1.07	.06 - .16
Oak, post; Cedar Glade, Missouri	20 (1)	50:50	.19	1.57	1.45	.07 - .5
Oak, red; Kentucky	18 (3)	27:27	.12	1.50	1.24	.08 - .52
	19 (3)	9:9	.09	1.33	1.07	.06 - .13
Oak, white; Kentucky	18 (3)	47:47	.14	1.47	1.24	.06 - .35
	19 (3)	76:76	.12	1.41	1.07	.06 - .34
Oak, white; Missouri						
Oak-hickory Forest	20 (1)	50:50	.14	1.88	1.45	.01 - .3
Oak-hickory-pine Forest	20 (1)	49:49	.16	1.43	1.45	.07 - .5
Oak, willow; Floodplain Forest, Missouri	20 (1)	46:46	.25	1.59	1.45	.1 - .7

TABLE 24.—*Iron in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
PLANT ASH—Continued						
Native species—Continued						
Persimmon, stems; Georgia	14 (1)	30:30	0.10	1.46	--	0.07 - 3
	15 (1)	30:30	.15	2.34	--	.015 - 2
Persimmon, leaves; Georgia	14 (1)	30:30	.13	1.56	--	.07 - .3
	15 (1)	30:30	.19	2.18	--	.03 - 1
Pine, shortleaf; Oak-hickory-pine Forest, Missouri	20 (1)	49:49	.52	1.59	1.45	.2 - 1.5
Sassafras, stems; Georgia	14 (1)	17:17	.19	2.27	--	.05 - 1.5
	15 (1)	27:27	.25	3.21	--	.03 - 2
Sassafras, leaves; Georgia	14 (1)	17:17	.22	2.35	--	.1 - 1.5
	15 (1)	27:27	.35	2.24	--	.1 - 1.5
Sumac, winged, stems; Georgia	14 (1)	30:30	.12	1.66	--	.07 - .7
	15 (1)	30:30	.16	1.92	--	.07 - 1
Sumac, winged, leaves; Georgia	14 (1)	30:30	.15	1.91	--	.07 - 1.5
	15 (1)	30:30	.29	2.25	--	.07 - 1.5
Sumac, smooth; Missouri						
Floodplain Forest	20 (1)	48:48	.11	1.98	1.45	.005 - .5
Glaciated Prairie	20 (1)	50:50	.13	1.52	1.45	.05 - .5
Unglaciated Prairie	20 (1)	49:49	.13	1.74	1.45	.05 - .5
Cedar Glade	20 (1)	49:49	.10	1.68	1.45	.05 - .5
Oak-hickory Forest	20 (1)	50:50	.11	1.89	1.45	.005 - .3
Oak-hickory-pine Forest	20 (1)	49:49	.12	1.66	1.45	.05 - .5
Sweetgum, stems; Georgia	14 (1)	28:28	.081	1.48	--	.03 - .2
	15 (1)	27:27	.11	2.00	--	.03 - .7
Sweetgum, leaves; Georgia	14 (1)	28:28	.15	2.06	--	.07 - 2
	15 (1)	27:27	.19	1.89	--	.07 - 1.5
Sweetgum; Floodplain Forest, Missouri	20 (1)	47:47	.13	1.68	1.45	.02 - .3

TABLE 25.—*Lanthanum in rocks, unconsolidated geologic deposits, soils, and plant ash*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Granite						
Precambrian; Missouri	1 (1)	29:30	54	1.49	1.18	<30 - 100

TABLE 33.—*Nickel in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
PLANT ASH--Continued						
Native species--Continued						
Sassafras, stems; Georgia	14 (1)	17:17	12	1.55	--	7 - 30
	15 (1)	27:27	14	1.72	--	7 - 50
Sassafras, leaves; Georgia	14 (1)	17:17	14	1.70	--	7 - 50
	15 (1)	27:27	18	1.80	--	7 - 50
Sumac, winged, stems; Georgia	14 (1)	25:30	7.4	2.36	--	<5 - 30
	15 (1)	23:30	7.9	3.23	--	<5 - 100
Sumac, winged, leaves; Georgia	14 (1)	19:30	4.2	3.15	--	<5 - 70
	15 (1)	21:30	5.5	3.06	--	<5 - 50
Sumac, smooth; Missouri						
Floodplain Forest	20 (1)	46:48	17	2.51	1.36	<2 - 100
Glaciated Prairie	20 (1)	48:50	11	2.15	1.36	<2 - 50
Unglaciated Prairie	20 (1)	47:49	11	1.93	1.36	<2 - 30
Cedar Glade	20 (1)	13:49	.81	3.56	1.36	<2 - 10
Oak-hickory Forest	20 (1)	36:50	4.0	2.82	1.36	<2 - 30
Oak-hickory-pine Forest	20 (1)	35:49	3.9	2.68	1.36	<2 - 30
Sweetgum, stems; Georgia	14 (1)	27:28	12	1.93	--	<5 - 30
	15 (1)	27:27	30	2.34	--	7 - 150
Sweetgum, leaves; Georgia	14 (1)	28:28	29	2.07	--	7 - 150
	15 (1)	27:27	63	2.11	--	15 - 300
Sweetgum; Floodplain Forest, Missouri	20 (1)	47:47	50	1.93	1.36	10 - 150

TABLE 34.—*Niobium in rocks, unconsolidated geologic deposits, and soils*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Granite						
Precambrian; Missouri	1 (1)	26:30	11	1.31	1.15	<10 - 20
Rhyolite						
Precambrian; Missouri	1 (1)	28:30	12	1.29	1.15	<10 - 20

TABLE 34.—*Niobium in rocks, unconsolidated geologic deposits, and soils*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS—Continued						
Sandstone						
Sauk sequence; Western United States-	3 (2)	21:400	<20	--	--	<20 - 62
Pope Megagroup;[1] Kentucky----------	5 (2)	4:120	<20	--	--	<20 - 40
Pennsylvanian; Kentucky----------	5 (2)	16:152	<20	--	--	<20 - 28
Pennsylvanian; Missouri, Kansas, and Oklahoma----------	6 (1)	18:32	8.8	1.35	1.26	<10 - 15
Shale						
Sauk sequence; Western United States-	3 (2)	16:336	<30	--	--	<30 - 42
Upper Mississippian; Kentucky--------	5 (2)	1:142	<30	--	--	<30 - 30
Mississippian; Missouri, Oklahoma, and Arkansas----------	7 (1)	3:18	<10	--	--	<10 - 10
Pennsylvanian; Kentucky----------	5 (2)	4:152	<30	--	--	<30 - 43
Pennsylvanian; Missouri, Kansas, and Oklahoma----------	6 (1)	11:32	7.7	1.25	--	<10 - 10
UNCONSOLIDATED GEOLOGIC DEPOSITS						
Carbonate residuum (terra rossa)						
On Roubidoux Formation; Missouri-----	12 (1)	1:24	<10	--	--	<10 - 10
On Ozarkian rocks; Missouri----------	12 (1)	1:24	<10	--	--	<10 - 10
Loess						
Missouri----------	13 (1)	4:24	<10	--	--	<10 - 10
SOILS						
Cultivated						
Plow zone, garden; Georgia----------	14 (1)	20:25	13	1.34	--	<10 - 20
	15 (1)	20:25	16	1.52	--	<10 - 30
Plow zone, corn field; Missouri						
Floodplain Forest----------	17 (1)	3:8	7.9	1.24	1.18	<10 - 10
Glaciated Prairie----------	17 (1)	4:10	8.0	1.23	1.18	<10 - 10
Unglaciated Prairie----------	17 (1)	8:10	9.5	1.10	1.18	<10 - 10
Plow zone, soybean field; Missouri						
Floodplain Forest----------	17 (1)	2:10	6.6	1.33	1.18	<10 - 10
Glaciated Prairie----------	17 (1)	3:10	7.4	1.27	1.18	<10 - 10
Unglaciated Prairie----------	17 (1)	6:8	9.4	1.11	1.18	<10 - 10
Oak-hickory Forest----------	17 (1)	8:9	9.8	1.07	1.18	<10 - 10
Plow zone, pasture field; Missouri						
Floodplain Forest----------	17 (1)	4:10	8.0	1.23	1.18	<10 - 10
Glaciated Prairie----------	17 (1)	5:10	8.5	1.19	1.18	<10 - 10
Unglaciated Prairie----------	17 (1)	8:10	9.5	1.10	1.18	<10 - 10
Oak-hickory Forest----------	17 (1)	6:10	8.9	1.16	1.18	<10 - 10
Surface horizon; Missouri----------	16 (1)	375:1,140	7.2	1.38	1.11	<10 - 15

[1] Of Swann and Willman (1961).

TABLE 34.—*Niobium in rocks, unconsolidated geologic deposits, and soils*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
		SOILS--Continued				
Uncultivated						
Surface horizon; Powder River Basin, Wyoming and Montana	25 (1)	26:48	8.7	1.18	--	<10 - 10
A horizon; Georgia	14 (1)	26:30	12	1.33	--	<10 - 20
	15 (1)	25:30	16	1.43	--	<10 - 30
A horizon; Kentucky	18 (2)	77:96	12	1.33	--	<10 - 28
B horizon; Georgia	14 (1)	27:30	13	1.34	--	<10 - 20
	15 (1)	28:30	18	1.43	--	<10 - 30
B horizon; Kentucky	18 (2)	78:96	12	1.27	--	<10 - 21
B horizon; Missouri						
Floodplain Forest	20 (1)	7:50	5.8	1.38	--	<10 - 10
Glaciated Prairie	20 (1)	19:50	7.9	1.24	--	<10 - 10
Unglaciated Prairie	20 (1)	22:50	8.1	1.26	--	<10 - 15
Cedar Glade	20 (1)	1:50	<10	--	--	<10 - 10
Oak-hickory Forest	20 (1)	22:50	8.0	1.38	--	<10 - 15
Oak-hickory-pine Forest	20 (1)	21:50	7.9	1.36	--	<10 - 15
C horizon; Georgia	14 (1)	24:30	13	1.51	--	<10 - 30
	15 (1)	29:30	19	1.40	--	<10 - 50
C horizon; Kentucky	18 (2)	56:96	10	1.31	--	<10 - 22
Cultivated and uncultivated						
Surface horizon; Colorado	22 (1)	57:168	6.7	1.48	--	<10 - 20
B horizon; Eastern United States	21 (1)	264:328	13	1.54	--	<7 - 20
B horizon; Western United States	21 (1)	339:492	11	1.74	--	<7 - 100

TABLE 35.—*Phosphorus in rocks, unconsolidated geologic deposits, soils, and plant ash*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
		ROCKS				
Granite						
Precambrian; Missouri	1 (5)	19:30	0.030	2.75	1.55	<0.017 - 0.17

TABLE 35.—*Phosphorus in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
ROCKS—Continued						
Rhyolite						
Precambrian; Missouri	1 (5)	22:30	0.024	2.77	1.55	<0.017 - 0.17
Sandstone						
Sauk sequence; Western United States	3 (16)	393:400	.096	2.49	2.15	<.0087 - .96
Roubidoux Formation; Missouri	4 (5)	5:12	.010	2.22	1.47	<.013 - .035
Pope Megagroup;[1] Kentucky	5 (16	106:120	.017	2.96	1.24	<.0044 - .14
Pennsylvanian; Kentucky	5 (16)	145:152	.024	2.58	1.90	<.0044 - .13
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (5)	30:32	.057	2.24	1.47	<.013 - .17
Shale						
Sauk sequence; Western United States	3 (16)	335:336	.069	2.24	1.50	<.013 - 4.5
Lower Mississippian; Kentucky	8 (16)	74:76	.027	2.15	--	<.0044 - .24
Upper Mississippian; Kentucky	5 (16)	140:142	.035	2.02	--	<.0044 - .25
Mississippian; Missouri, Oklahoma, and Arkansas	7 (5)	13:18	.030	2.95	1.47	<.013 - 1.6
Pennsylvanian; Kentucky	5 (16)	152:152	.048	1.97	1.47	.0087 - .18
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (5)	32:32	.061	1.89	1.22	.017 - .17
Limestone and dolomite						
Sauk sequence; Western United States	3 (16)	310:392	.015	5.55	1.73	<.0044 - .70
Sauk sequence; Missouri and Arkansas	4 (5)	12:48	.0044	4.21	2.03	<.013 - .044
Upper Ordovician; Kentucky	5 (16)	76:80	.064	2.98	1.90	<.0044 - .29
Tippecanoe sequence; Missouri	10 (5)	4:12	<.013	--	--	<.013 - .22
Lower Mississippian; Kentucky	5 (16)	75:112	.0090	4.47	2.65	<.0044 - .79
Upper Mississippian; Kentucky	5 (16)	92:152	.0061	3.45	2.50	<.0044 - .087
Mississippian; Missouri, Oklahoma, and Arkansas	7 (5)	17:40	.0092	6.35	2.03	<.013 - .30
Pennsylvanian; Kentucky	5 (16)	74:80	.045	3.53	2.13	<.0044 - 1.4
Pennsylvanian; Missouri, Kansas, and and Oklahoma	6 (5)	24:32	.034	3.69	2.03	<.013 - .31
Siderite						
Upper Paleozoic; Kentucky	11 (16)	29:30	.18	2.94	--	<.0044 - .70
UNCONSOLIDATED GEOLOGIC DEPOSITS						
Carbonate residuum (terra rossa)						
On Gasconade Formation; Missouri	12 (5)	9:24	0.019	1.35	--	<0.022 - 0.033
On Roubidoux Formation; Missouri	12 (5)	7:24	.017	1.42	--	<.022 - .031
On Jefferson City, Cotter, and Powell Formations; Missouri and Arkansas	12 (5)	4:24	.011	1.78	--	<.022 - .036
On Osagean rocks; Missouri	12 (5)	16:24	.027	1.79	--	<.022 - .075
On Meramecian rocks; Missouri	12 (5)	13:24	.024	2.67	--	<.022 - .13
Loess						
Missouri	13 (5)	24:24	.061	1.55	--	.030 - .13

[1] Of Swann and Willman (1961).

TABLE 35.—*Phosphorus in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
SOILS						
Cultivated						
Plow zone, garden; Georgia	14 (6)	30:30	0.017	2.10	--	0.004 - 0.09
	15 (6)	30:30	.043	1.73	--	.012 - .09
Plow zone, corn field; Missouri						
Floodplain Forest	17 (5)	8:8	.074	1.64	1.63	.038 - .15
Glaciated Prairie	17 (5)	9:10	.063	1.66	1.63	<.022 - .11
Unglaciated Prairie	17 (5)	8:10	.041	2.04	1.63	<.022 - .15
Oak-hickory Forest	17 (5)	10:10	.059	1.87	1.63	.023 - .12
Plow zone, soybean field; Missouri						
Floodplain Forest	17 (5)	10:10	.078	1.57	1.63	.041 - .17
Glaciated Prairie	17 (5)	10:10	.066	1.60	1.63	.024 - .14
Unglaciated Prairie	17 (5)	7:8	.048	1.59	1.63	<.022 - .092
Oak-hickory Forest	17 (5)	7:9	.041	1.80	1.63	<.022 - .083
Plow zone, pasture field; Missouri						
Floodplain Forest	17 (5)	10:10	.067	1.52	1.63	.031 - .14
Glaciated Prairie	17 (5)	10:10	.067	1.53	1.63	.038 - .14
Unglaciated Prairie	17 (5)	9:10	.038	1.52	1.63	<.022 - .074
Oak-hickory Forest	17 (5)	8:10	.050	1.98	1.63	<.022 - .10
Surface horizon; Missouri	16 (5)	1,130:1,140	.059	1.61	1.30	<.01 - .61
Uncultivated						
A horizon; Georgia	14 (6)	30:30	.0065	1.86	--	.002 - .03
	15 (6)	30:30	.020	2.09	--	.002 - .09
A horizon; Kentucky	18 (16)	96:96	.03	1.47	1.12	.013 - .13
	19 (16)	108:108	.025	1.40	1.16	.009 - .061
B horizon; Georgia	14 (6)	27:30	.0038	1.90	--	<.002 - .012
	15 (6)	30:30	.014	2.08	--	.002 - .044
B horizon; Kentucky	18 (16)	96:96	.03	1.53	1.12	.009 - .140
B horizon; Missouri						
Floodplain Forest	20 (5)	49:50	.068	1.86	1.48	<.017 - .44
Glaciated Prairie	20 (5)	44:50	.033	1.58	1.48	<.017 - .065
Unglaciated Prairie	20 (5)	47:50	.038	1.56	1.48	<.017 - .079
Cedar Glade	20 (5)	50:50	.083	1.73	1.48	.022 - .22
Oak-hickory Forest	20 (5)	40:50	.033	1.88	1.48	<.017 - .12
Oak-hickory-pine Forest	20 (5)	42:50	.030	1.67	1.48	<.017 - .096
C horizon; Georgia	14 (6)	26:30	.0035	2.28	--	<.002 - .030
	15 (6)	30:30	.014	2.14	--	.002 - .060
C horizon; Kentucky	18 (16)	96:96	.02	1.69	1.12	.009 - .205
Cultivated and uncultivated						
Surface horizon; Colorado	22 (5)	166:168	.10	1.87	1.17	<.020 - .50
B horizon; Eastern United States	21 (6)	367:371	.018	3.03	--	<.002 - .60
B horizon; Western United States	21 (6)	489:491	.032	2.33	--	<.002 - .45

TABLE 35.—*Phosphorus in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
PLANT ASH						
Cultivated plants						
Asparagus; Wisconsin	23 (6)	6:6	1.7	1.33	--	1.0 - 2.0
Bean, lima; Georgia	14 (6)	30:30	6.7	1.25	--	4.8 - 9.0
	15 (6)	15:15	4.7	1.28	--	3.6 - 6.0
Bean, snap; Georgia	14 (6)	30:30	4.9	1.30	--	1.8 - 9.0
	15 (6)	30:30	5.2	1.25	--	3.6 - 7.5
Blackeyed pea; Georgia	14 (6)	29:29	7.0	1.30	--	3.6 - 9.0
	15 (6)	4:4	7.8	1.21	--	6.0 - 9.0
Cabbage; Georgia	14 (6)	28:28	2.1	1.63	--	.90 - 6.0
	15 (6)	30:30	1.2	1.38	--	.60 - 2.4
Cabbage; Wisconsin	23 (6)	11:11	2.2	1.42	--	1.5 - 5.0
Carrot; Wisconsin	23 (6)	8:8	2.4	1.46	--	1.5 - 5.0
Corn; Georgia	14 (6)	29:29	11	1.19	--	9.0 - 18
	15 (6)	30:30	10	1.26	--	6.0 - 15
Corn; Missouri						
Floodplain Forest	17 (6)	8:8	22	1.16	1.12	18 - 24
Glaciated Prairie	17 (6)	10:10	21	1.16	1.12	18 - 24
Unglaciated Prairie	17 (6)	10:10	20	1.16	1.12	18 - 24
Oak-hickory Forest	17 (6)	10:10	21	1.16	1.12	18 - 24
Cucumber; Wisconsin	23 (6)	4:4	2.2	1.22	--	2.0 - 3.0
Onion; Wisconsin	23 (6)	7:7	3.7	1.31	--	3.0 - 5.0
Pepper, sweet; Wisconsin	23 (6)	4:4	1.9	1.15	--	1.5 - 2.0
Potato; Wisconsin	23 (6)	10:10	2.2	1.26	--	1.5 - 3.0
Soybean; Missouri						
Glaciated Prairie	17 (6)	10:10	9.1	1.43	1.12	6.0 - 12
Unglaciated Prairie	17 (6)	8:8	10	1.38	1.12	6.0 - 12
Tomato; Georgia	14 (6)	30:30	4.9	1.30	--	2.4 - 6.0
	15 (6)	30:30	5.2	1.25	--	1.8 - 3.6
Native species						
Black cherry, stems; Georgia	14 (6)	30:30	2.1	1.60	--	.60 - 3.6
	15 (6)	30:30	2.3	1.48	--	1.2 - 4.8
Black cherry, leaves; Georgia	14 (6)	30:30	2.0	1.48	--	.90 - 4.8
	15 (6)	30:30	1.9	1.36	--	1.2 - 3.6
Blackgum, stems; Georgia	14 (6)	30:30	1.3	1.37	--	.60 - 2.4
	15 (6)	30:30	1.2	1.21	--	.60 - 1.8
Blackgum, leaves; Georgia	14 (6)	30:30	1.7	1.33	--	1.2 - 2.4
	15 (6)	30:30	1.6	1.28	--	1.2 - 2.4
Buckbush; Missouri						
Glaciated Prairie	20 (6)	47:47	2.6	1.30	1.18	1.8 - 4.8
Unglaciated Prairie	20 (6)	48:48	2.4	1.40	1.18	.60 - 4.8
Cedar Glade	20 (6)	50:50	1.7	1.28	1.18	1.2 - 3.6
Oak-hickory Forest	20 (6)	49:49	2.1	1.27	1.18	1.2 - 3.6
Oak-hickory-pine Forest	20 (6)	41:41	1.8	1.32	1.18	1.2 - 3.6
Cedar; Missouri						
Cedar Glade	20 (6)	50:50	1.3	1.25	1.18	.6 - 1.8
Glaciated Prairie	24 (6)	9:9	2.3	1.33	--	1.7 - 3.6

TABLE 35.—*Phosphorus in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
PLANT ASH--Continued						
Native species--Continued						
Cedar; Missouri--Continued						
Unglaciated Prairie	24 (6)	10:10	2.3	1.29	--	1.8 - 3.6
Cedar Glade	24 (6)	10:10	1.4	1.30	--	.80 - 2.0
Oak-hickory Forest	24 (6)	10:10	1.9	1.31	--	1.2 - 2.4
Oak-hickory-pine Forest	24 (6)	6:6	1.9	1.28	--	1.6 - 3.2
Hickory, pignut; Kentucky	18 (6)	64:64	.76	1.43	1.17	.04 - 1.8
	19 (6)	88:88	1.2	1.34	1.09	.47 - 2.4
Hickory, shagbark; Kentucky	18 (6)	40:40	.84	1.44	1.17	.44 - 1.8
	19 (6)	20:20	1.2	1.21	1.09	.76 - 1.6
Hickory, shagbark; Missouri						
Oak-hickory Forest	20 (6)	19:19	.83	1.43	1.18	.60 - 1.2
Oak-hickory-pine Forest	20 (6)	7:7	.98	1.45	1.18	.60 - 1.2
Maple, red, stems; Georgia	14 (6)	30:30	1.4	1.51	--	.60 - 3.6
	15 (6)	30:30	1.6	1.44	--	.90 - 3.0
Maple, red, leaves; Georgia	14 (6)	30:30	1.8	1.30	--	1.2 - 3.0
	15 (6)	30:30	2.1	1.26	--	1.5 - 3.6
Oak, black; Kentucky	18 (6)	25:25	.88	1.41	1.16	.44 - 1.8
	19 (6)	22:22	1.1	1.33	1.09	.51 - 2.5
Oak, post; Cedar Glade, Missouri	20 (6)	50:50	.94	1.44	1.18	.60 - 1.8
Oak, red; Kentucky	18 (6)	28:28	.85	1.47	1.16	.60 - 1.8
	19 (6)	9:9	.89	1.48	1.09	.56 - 1.9
Oak, white; Kentucky	18 (6)	49:49	1.2	1.41	1.16	.60 - 2.4
	19 (6)	77:77	1.2	1.30	1.09	.62 - 2.7
Oak, white; Missouri						
Oak-hickory Forest	20 (6)	50:50	1.3	1.42	1.18	.60 - 3.2
Oak-hickory-pine Forest	20 (6)	49:49	1.1	1.35	1.18	.60 - 1.8
Oak, willow; Floodplain Forest, Missouri	20 (6)	46:46	2.1	1.32	1.18	1.2 - 3.6
Persimmon, stems; Georgia	14 (6)	30:30	1.5	1.60	--	.60 - 4.8
	15 (6)	30:30	2.0	1.51	--	1.2 - 4.8
Persimmon, leaves; Georgia	14 (6)	30:30	1.4	1.28	--	.90 - 2.4
	15 (6)	30:30	1.6	1.36	--	.90 - 3.0
Pine, shortleaf; Oak-hickory-pine Forest, Missouri	20 (6)	49:49	2.3	1.24	1.18	1.8 - 3.6
Sagebrush; Powder River Basin, Wyoming and Montana	25 (6)	48:48	3.1	1.34	--	.8 - 4.8
Sassafras, stems; Georgia	14 (6)	17:17	2.0	1.31	--	1.2 - 3.6
	15 (6)	27:27	2.5	1.36	--	1.2 - 4.8
Sassafras, leaves; Georgia	14 (6)	17:17	2.3	1.30	--	1.8 - 4.8
	15 (6)	27:27	2.2	1.28	--	1.2 - 3.6
Sumac, winged, stems; Georgia	14 (6)	28:28	.71	1.76	--	.30 - 2.4
	15 (6)	27:27	1.2	1.66	--	.48 - 2.4
Sumac, winged, leaves; Georgia	14 (6)	28:28	1.4	1.42	--	.90 - 3.6
	15 (6)	27:27	1.9	1.33	--	1.2 - 3.0

TABLE 35.—*Phosphorus in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
PLANT ASH--Continued						
Native species--Continued						
Sumac, smooth; Missouri						
Floodplain Forest	20 (6)	48:48	2.3	1.27	1.18	1.2 - 3.6
Glaciated Prairie	20 (6)	50:50	1.2	1.20	1.18	1.2 - 3.6
Unglaciated Prairie	20 (6)	49:49	1.7	1.24	1.18	1.2 - 3.6
Cedar Glade	20 (6)	49:49	1.2	1.45	1.18	.60 - 2.4
Oak-hickory Forest	20 (6)	50:50	1.8	1.30	1.18	1.2 - 3.6
Oak-hickory-pine Forest	20 (6)	49:49	1.4	1.34	1.18	.6 - 2.4
Sweetgum, stems; Georgia	14 (6)	28:28	.71	1.76	--	.30 - 2.4
	15 (6)	27:27	1.2	1.66	--	.48 - 2.4
Sweetgum, leaves; Georgia	14 (6)	28:28	1.4	1.42	--	.90 - 3.6
	15 (6)	27:27	1.9	1.33	--	1.2 - 3.0
Sweetgum; Floodplain Forest, Missouri	20 (6)	47:47	.96	1.63	1.18	.30 - 2.6

TABLE 36.—*Potassium in rocks, unconsolidated geologic deposits, soils, and plant ash*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean except that values preceded by asterisk are arithmetic mean. Deviation, geometric deviation except that values preceded by asterisk are standard deviation. Error, geometric error attributed to laboratory procedures except that values preceded by asterisk are standard error. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
ROCKS						
Granite						
Precambrian; Missouri	1 (5)	30:30	4.3	1.11	1.01	3.2 - 5.1
Rhyolite						
Precambrian; Missouri	1 (5)	30:30	4.8	1.35	1.01	2.2 - 8.1
Sandstone						
Sauk sequence; Western United States	3 (16)	385:400	.32	4.67	1.86	<.0083 - 4.5
Roubideux Formation; Missouri	4 (5)	7:12	.083	2.99	1.01	<.083 - .42
Pope Megagroup;[1] Kentucky	5 (16)	117:120	.30	3.02	1.79	<.0083 - 1.2
Pennsylvanian; Kentucky	5 (16)	148:152	.51	3.55	2.16	<.0083 - 2.4
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (5)	31:32	.66	2.81	1.01	<.083 - 2.0

[1] Of Swann and Willman (1961).

TABLE 36.—*Potassium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
ROCKS--Continued						
Chert						
Mississippian; Missouri, Oklahoma, and Arkansas	7 (5)	2:20	<0.083	--	--	<0.083 - 0.17
Shale						
Sauk sequence; Western United States	3 (16)	336:336	5.4	1.54	1.23	.91 - 11
Lower Mississippian; Kentucky	8 (16)	76:76	1.8	1.59	--	.42 - 3.5
Upper Mississippian; Kentucky	5 (16)	142:142	2.3	1.40	--	1.0 - 5.1
Mississippian; Missouri, Oklahoma, and Arkansas	7 (5)	18:18	2.2	1.56	1.03	.91 - 3.5
Pennsylvanian; Kentucky	5 (16)	152:152	2.3	1.59	1.13	.33 - 4.0
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (5)	32:32	2.7	1.29	1.03	1.5 - 3.7
Limestone and dolomite						
Sauk sequence; Western United States	3 (16)	383:392	.32	3.69	1.66	<.017 - 4.2
Sauk sequence; Missouri and Arkansas	4 (5)	39:48	.20	3.57	1.11	<.083 - 1.6
Upper Ordovician; Kentucky	5 (16)	80:80	.40	2.05	1.28	.083 - 1.7
Tippecanoe sequence; Missouri	10 (5)	8:12	.12	3.41	1.11	<.083 - 1.4
Lower Mississippian; Kentucky	5 (16)	109:112	.30	3.02	2.34	<.0083 - 1.4
Upper Mississippian; Kentucky	5 (16)	145:152	.17	3.21	2.78	<.0083 - 2.1
Pennsylvanian; Kentucky	5 (16)	80:80	.56	2.49	1.32	.025 - 1.6
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (5)	28:32	.16	2.52	1.11	<.083 - 1.0
Siderite						
Upper Paleozoic; Kentucky	11 (16)	30:30	.64	1.69	--	.22 - 1.4
UNCONSOLIDATED GEOLOGIC DEPOSITS						
Carbonate residuum (terra rossa)						
On Gasconade Formation; Missouri	12 (5)	24:24	1.0	1.47	1.03	0.46 - 1.8
On Roubidoux Formation; Missouri	12 (5)	24:24	1.1	2.10	1.03	.19 - 3.0
On Jefferson City, Cotter, and Powell Formations; Missouri and Arkansas	12 (5)	24:24	1.7	1.57	1.03	.65 - 4.7
On Ozagean rocks; Missouri	12 (5)	24:24	.91	1.57	1.03	.37 - 1.8
On Meramecian rocks; Missouri	12 (5)	24:24	1.1	1.36	1.03	.53 - 2.2
Loess						
Missouri	13 (5)	24:24	1.9	1.13	--	1.2 - 2.2
SOILS						
Cultivated						
Plow zone, garden; Georgia	14 (12)	30:30	0.041	2.30	--	0.01 - 0.4
	15 (12)	30:30	.92	1.91	--	.16 - 2.6
Plow zone, corn field; Missouri						
Floodplain Forest	17 (5)	8:8	1.7	1.15	1.01	1.4 - 2.1
Glaciated Prairie	17 (5)	10:10	1.7	1.12	1.01	1.4 - 2.0
Unglaciated Prairie	17 (5)	10:10	1.2	1.41	1.01	.60 - 1.7

TABLE 56.—*Potassium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
SOILS--Continued						
Cultivated--Continued						
Flow zone, corn field; Missouri--Continued						
Oak-hickory Forest	17 (5)	10:10	1.5	1.43	1.01	0.86 - 2.2
Flow zone, soybean field; Missouri						
Floodplain Forest	17 (5)	10:10	1.7	1.09	1.01	1.4 - 1.8
Glaciated Prairie	17 (5)	10:10	1.6	1.08	1.01	1.5 - 1.7
Unglaciated Prairie	17 (5)	8:8	1.2	1.41	1.01	.68 - 1.7
Oak-hickory Forest	17 (5)	9:9	1.5	1.30	1.01	1.1 - 2.2
Flow zone, pasture field; Missouri						
Floodplain Forest	17 (5)	10:10	1.7	1.10	1.01	1.4 - 1.8
Glaciated Prairie	17 (5)	10:10	1.6	1.13	1.01	1.5 - 2.0
Unglaciated Prairie	17 (5)	10:10	1.3	1.34	1.01	.66 - 1.7
Oak-hickory Forest	17 (5)	10:10	1.5	1.40	1.01	.83 - 2.1
Surface horizon; Missouri	16 (5)	1,140:1,140	*1.4	*.40	*.07	.33 - 3.7
Uncultivated						
Surface horizon; Powder River Basin, Wyoming and Montana	25 (5)	48:48	2.6	1.25	1.16	2 - 5
A horizon; Georgia	14 (12)	30:30	.073	2.85	--	.02 - 1.0
	15 (12)	30:30	1.2	1.98	--	.17 - 3.7
A horizon; Kentucky	18 (16)	96:96	1.0	1.55	1.14	.20 - 2.1
	19 (16)	108:108	1.0	1.42	1.14	.39 - 2.0
B horizon; Georgia	14 (12)	30:30	.079	2.84	--	.02 - 1.4
	15 (12)	30:30	1.1	1.99	--	.18 - 2.5
B horizon; Kentucky	18 (16)	96:96	1.2	1.70	1.14	.07 - 3.2
B horizon; Missouri						
Floodplain Forest	20 (5)	50:50	1.8	1.14	1.25	1.2 - 2.2
Glaciated Prairie	20 (5)	50:50	1.5	1.28	1.25	.75 - 2.5
Unglaciated Prairie	20 (5)	50:50	1.3	1.45	1.25	.58 - 3.1
Cedar Glade	20 (5)	50:50	1.7	1.50	1.25	.50 - 3.5
Oak-hickory Forest	20 (5)	50:50	1.1	1.61	1.25	.42 - 2.1
Oak-hickory-pine Forest	20 (5)	50:50	.86	1.96	1.25	.17 - 4.4
C horizon; Georgia	14 (12)	30:30	.089	2.83	--	.02 - 1.6
	15 (12)	30:30	1.2	1.97	--	.18 - 2.8
C horizon; Kentucky	18 (16)	96:96	1.1	1.68	1.14	.080 - 4.3
Cultivated and uncultivated						
Surface horizon; Colorado	22 (5)	168:168	2.9	1.40	1.01	.5 - 4.9
B horizon; Eastern United States	21 (12)	370:370	.74	3.56	--	.005 - 3.7
B horizon; Western United States	21 (12)	491:491	1.7	1.60	--	.19 - 6.3

TABLE 36.—*Potassium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
PLANT ASH						
Cultivated plants						
Bean, lima; Georgia	14 (12)	30:30	35	1.05	--	30 - 39
	15 (12)	15:15	34	1.08	--	28 - 38
Bean, snap; Georgia	14 (12)	30:30	33	1.10	--	23 - 37
	15 (12)	30:30	33	1.08	--	28 - 39
Blackeyed pea; Georgia	14 (12)	29:29	31	1.09	--	27 - 36
	15 (12)	4:4	33	1.05	--	31 - 34
Cabbage; Georgia	14 (12)	28:28	21	1.33	--	9.2 - 33
	15 (12)	30:30	18	1.24	--	12 - 27
Corn; Georgia	14 (12)	29:29	35	1.09	--	26 - 39
	15 (12)	30:30	36	1.07	--	31 - 40
Corn; Missouri						
Floodplain Forest	17 (3)	8:8	29	1.09	1.05	24 - 32
Glaciated Prairie	17 (3)	10:10	30	1.07	1.05	26 - 33
Unglaciated Prairie	17 (3)	10:10	31	1.05	1.05	30 - 35
Oak-hickory Forest	17 (3)	10:10	31	1.06	1.05	30 - 35
Soybean; Missouri						
Floodplain Forest	17 (3)	10:10	41	1.06	1.05	38 - 45
Glaciated Prairie	17 (3)	10:10	40	1.06	1.05	37 - 46
Unglaciated Prairie	17 (3)	8:8	39	1.03	1.05	38 - 40
Oak-hickory Forest	17 (3)	9:9	41	1.06	1.05	38 - 45
Tomato; Georgia	14 (12)	30:30	38	1.07	--	30 - 42
	15 (12)	30:30	40	1.08	--	34 - 51
Native species						
Black cherry, stems; Georgia	14 (12)	30:30	12	1.45	--	6.0 - 28
	15 (12)	30:30	14	1.51	--	4.2 - 26
Black cherry, leaves; Georgia	14 (12)	30:30	14	1.37	--	5.6 - 27
	15 (12)	30:30	17	1.27	--	11 - 28
Blackgum, stems; Georgia	14 (12)	30:30	11	1.30	--	6.2 - 16
	15 (12)	30:30	11	1.31	--	5.8 - 21
Blackgum, leaves; Georgia	14 (12)	30:30	16	1.23	--	11 - 23
	15 (12)	30:30	19	1.25	--	10 - 28
Buckbush; Missouri						
Glaciated Prairie	20 (3)	47:47	16	1.15	1.16	12 - 20
Unglaciated Prairie	20 (3)	48:48	16	1.16	1.16	11 - 20
Cedar Glade	20 (3)	50:50	15	1.16	1.16	9.6 - 18
Oak-hickory Forest	20 (3)	49:49	15	1.21	1.16	9.2 - 22
Oak-hickory-pine Forest	20 (3)	41:41	15	1.24	1.16	8.6 - 22
Cedar; Missouri						
Cedar Glade	20 (3)	50:50	6.3	1.26	1.16	3.6 - 10
Glaciated Prairie	24 (3)	9:9	8.9	1.31	--	5.0 - 14
Unglaciated Prairie	24 (3)	10:10	11	1.39	--	6.0 - 15
Cedar Glade	24 (3)	10:10	6.8	1.20	--	5.0 - 8.0
Oak-hickory Forest	24 (3)	10:10	9.8	1.32	--	6.0 - 14
Oak-hickory-pine Forest	24 (3)	6:6	9.1	1.37	--	6.4 - 16

TABLE 36.—*Potassium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)	
PLANT ASH--Continued							
Native species--Continued							
Hickory, pignut; Kentucky	18 (3)	64:64	5.9	1.44	1.07	3.3	- 17
	19 (3)	88:88	6.0	1.34	1.13	2.7	- 12
Hickory, shagbark; Kentucky	18 (3)	40:40	6.7	1.45	1.07	3.0	- 16
	19 (3)	20:20	6.3	1.35	1.13	4.2	- 16
Hickory, shagbark; Missouri							
Oak-hickory Forest	20 (3)	19:19	3.4	1.31	1.16	2.4	- 5.4
Oak-hickory-pine Forest	20 (3)	7:7	2.9	1.21	1.16	2.2	- 4.0
Maple, red, stems; Georgia	14 (12)	30:30	11	1.51	--	5.6	- 26
	15 (12)	30:30	12	1.44	--	5.8	- 32
Maple, red, leaves; Georgia	14 (12)	30:30	12	1.26	--	5.6	- 17
	15 (12)	30:30	15	1.31	--	8.6	- 24
Oak, black; Kentucky	18 (3)	25:25	7.5	1.28	1.08	4.1	- 13
	19 (3)	22:22	7.9	1.23	1.13	5.5	- 12
Oak, post; Cedar Glade, Missouri	20 (3)	50:50	4.4	1.38	1.16	2.0	- 11
Oak, red; Kentucky	18 (3)	28:28	6.7	1.27	1.08	4.5	- 11
	19 (3)	9:9	7.3	1.60	1.13	3.0	- 14
Oak, white; Kentucky	18 (3)	49:49	8.4	1.32	1.08	4.9	- 15
	19 (3)	76:76	9.1	1.27	1.13	4.4	- 15
Oak, white; Missouri							
Oak-hickory Forest	20 (3)	50:50	5.1	1.29	1.16	3.0	- 9.6
Oak-hickory-pine Forest	20 (3)	49:49	4.9	1.22	1.16	3.0	- 6.9
Oak, willow; Floodplain Forest, Missouri	20 (3)	46:46	7.8	1.37	1.16	4.4	- 14
Persimmon, stems; Georgia	14 (12)	30:30	16	1.31	--	7.8	- 30
	15 (12)	30:30	19	1.25	--	15	- 29
Persimmon, leaves; Georgia	14 (12)	30:30	21	1.24	--	14	- 31
	15 (12)	30:30	23	1.19	--	15	- 32
Pine, shortleaf; Oak-hickory-pine Forest, Missouri	20 (3)	49:49	11	1.35	1.16	5.6	- 20
Sassafras, stems; Georgia	14 (12)	17:17	19	1.28	--	13	- 32
	15 (12)	27:27	20	1.33	--	13	- 34
Sassafras, leaves; Georgia	14 (12)	17:17	19	1.27	--	12	- 29
	15 (12)	27:27	23	1.22	--	14	- 32
Sumac, winged, stems; Georgia	14 (12)	30:30	14	1.53	--	5.2	- 30
	15 (12)	30:30	16	1.41	--	7.6	- 34
Sumac, winged, leaves; Georgia	14 (12)	30:30	19	1.29	--	10	- 29
	15 (12)	30:30	21	1.25	--	12	- 31
Sumac, smooth; Missouri							
Floodplain Forest	20 (3)	48:48	13	1.34	1.16	5.6	- 22
Glaciated Prairie	20 (3)	50:50	13	1.26	1.16	8.0	- 20
Unglaciated Prairie	20 (3)	49:49	13	1.24	1.16	8.6	- 22
Cedar Glade	20 (3)	49:49	10	1.32	1.16	3.8	- 16
Oak-hickory Forest	20 (3)	50:50	13	1.20	1.16	9.2	- 19
Oak-hickory-pine Forest	20 (3)	49:49	12	1.22	1.16	7.4	- 19

TABLE 36.—*Potassium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
PLANT ASH--Continued						
Native species--Continued						
Sweetgum, stems; Georgia	14 (12)	28:28	6.1	1.89	--	2.4 - 26
	15 (12)	27:27	11	2.10	--	1.3 - 28
Sweetgum, leaves; Georgia	14 (12)	28:28	10	1.31	--	7.0 - 23
	15 (12)	27:27	14	1.28	--	9.6 - 21
Sweetgum; Floodplain Forest, Missouri	20 (3)	47:47	4.1	1.59	1.16	1.2 - 12

TABLE 37.—*Rubidium in plant ash*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
Native species						
Hickory, pignut; Kentucky	18 (3)	64:64	56	1.61	1.17	18 - 155
	19 (3)	88:88	56	1.62	1.11	18 - 170
Hickory, shagbark; Kentucky	18 (3)	40:40	51	1.68	1.17	18 - 192
	19 (3)	20:20	55	1.70	1.11	18 - 110
Oak, black; Kentucky	18 (3)	25:25	72	1.72	1.42	37 - 210
	19 (3)	22:22	94	1.39	1.11	55 - 190
Oak, red; Kentucky	18 (3)	28:28	74	1.62	1.42	37 - 260
	19 (3)	9:9	87	1.42	1.11	64 - 160
Oak, white; Kentucky	18 (3)	49:49	93	1.55	1.42	37 - 230
	19 (3)	76:76	110	1.65	1.11	37 - 400

TABLE 38.—*Scandium in rocks, unconsolidated geologic deposits, soils, and plant ash*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Granite						
Precambrian; Missouri	1 (1)	18:30	5.3	2.39	1.28	<5 - 15
Rhyolite						
Precambrian; Missouri	1 (1)	24:30	6.5	1.99	1.28	<5 - 15
Arkose						
Fountain Formation; Colorado	2 (2)	16:80	1.7	1.95	--	<3 - 9
Sandstone						
Sauk sequence; Western United States	3 (2)	237:400	3.2	1.76	1.24	<3 - 25
Pope Megagroup;[1] Kentucky	5 (2)	19:120	2.1	2.68	1.16	<8 - 14
Pennsylvanian; Kentucky	5 (2)	93:152	5.0	1.92	1.29	<5 - 16
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	26:32	7.2	2.12	--	<5 - 15
Shale						
Sauk sequence; Western United States	3 (2)	331:336	18	1.26	1.07	<10 - 28
Lower Mississippian; Kentucky	8 (2)	74:76	15	1.26	--	<10 - 22
Upper Mississippian; Kentucky	5 (2)	141:142	17	1.19	--	<10 - 22
Mississippian; Missouri, Oklahoma, and Arkansas	7 (1)	17:18	8.2	1.60	1.21	<10 - 20
Pennsylvanian; Kentucky	5 (2)	152:152	18	1.21	1.09	10 - 26
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	32:32	15	1.26	1.21	10 - 20
Black shale						
Devonian and Mississippian; Kentucky	9 (2)	88:88	15	1.15	1.08	10 - 21
Limestone and dolomite						
Upper Ordovician; Kentucky	5 (1)	3:80	<10	--	--	<10 - 10
Lower Mississippian; Kentucky	5 (1)	22:112	6.1	1.45	--	<10 - 15
Upper Mississippian; Kentucky	5 (1)	5:152	<10	--	--	<10 - 15
Mississippian; Missouri, Oklahoma, and Arkansas	7 (1)	3:40	<5	--	--	<5 - 7
Pennsylvanian; Kentucky	5 (1)	49:80	9.0	1.45	1.14	<10 - 30
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	4:32	<5	--	--	<5 - 7
Siderite						
Upper Paleozoic; Kentucky	11 (1)	15:30	8.4	1.80	--	<10 - 20

[1] Of Swann and Willman (1961).

SCANDIUM

TABLE 38.—*Scandium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
UNCONSOLIDATED GEOLOGIC DEPOSITS						
Carbonate residuum (terra rossa)						
On Gasconade Formation; Missouri	12 (1)	24:24	9.1	1.32	1.12	5 - 15
On Roubidoux Formation; Missouri	12 (1)	22:24	7.8	1.44	1.12	<5 - 15
On Jefferson City, Cotter, and Powell Formations; Missouri and Arkansas	12 (1)	24:24	9.2	1.34	1.12	5 - 15
On Osagean rocks; Missouri	12 (1)	24:24	15	1.29	1.12	7 - 20
On Meramecian rocks; Missouri	12 (1)	24:24	12	1.40	1.12	7 - 20
Loess						
Missouri	13 (1)	24:24	9.0	1.18	--	7 - 10
SOILS						
Cultivated						
Plow zone, garden; Georgia	14 (1)	8:30	2.8	1.65	--	<5 - 7
	15 (1)	30:30	9.0	1.35	--	5 - 15
Plow zone, corn field; Missouri						
Floodplain Forest	17 (1)	7:8	5.2	1.24	1.09	<5 - 7
Glaciated Prairie	17 (1)	10:10	8.1	1.20	1.09	7 - 10
Unglaciated Prairie	17 (1)	9:10	6.3	1.25	1.09	<5 - 7
Oak-hickory Forest	17 (1)	9:10	6.3	1.33	1.09	<5 - 10
Plow zone, soybean field; Missouri						
Floodplain Forest	17 (1)	8:10	5.1	1.31	1.09	<5 - 7
Glaciated Prairie	17 (1)	10:10	8.4	1.21	1.09	7 - 10
Unglaciated Prairie	17 (1)	8:8	6.7	1.25	1.09	5 - 10
Oak-hickory Forest	17 (1)	9:9	6.5	1.16	1.09	5 - 7
Plow zone, pasture field; Missouri						
Floodplain Forest	17 (1)	8:10	5.1	1.31	1.09	<5 - 7
Glaciated Prairie	17 (1)	10:10	7.3	1.12	1.09	7 - 10
Unglaciated Prairie	17 (1)	10:10	6.3	1.18	1.09	5 - 7
Oak-hickory Forest	17 (1)	10:10	6.3	1.26	1.09	5 - 10
Surface horizon; Missouri	16 (1)	1,092:1,140	7.6	1.34	1.16	<5 - 15
Uncultivated						
Surface horizon; Powder River Basin, Wyoming and Montana	25 (1)	44:48	7.3	1.43	1.16	<5 - 15
A horizon; Georgia	14 (1)	8:30	2.1	2.64	--	<5 - 15
	15 (1)	29:30	8.6	1.47	--	<5 - 15
A horizon; Kentucky	18 (2)	96:96	10	1.21	1.06	7 - 17
	19 (2)	47:108	4.9	2.22	1.05	<5 - 15
B horizon; Georgia	14 (1)	9:30	2.6	2.06	--	<5 - 15
B horizon; Kentucky	18 (2)	96:96	13	1.24	1.06	7 - 22
B horizon; Missouri						
Floodplain Forest	20 (1)	42:50	7.1	1.58	1.23	<5 - 15
Glaciated Prairie	20 (1)	50:50	12	1.34	1.23	7 - 15

TABLE 38.—*Scandium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
SOILS--Continued						
Uncultivated--Continued						
B horizon; Missouri--Continued						
Unglaciated Prairie	20 (1)	50:50	10	1.33	1.23	7 - 20
Cedar Glade	20 (1)	43:50	6.8	1.59	1.23	<5 - 20
Oak-hickory Forest	20 (1)	37:50	5.4	1.49	1.23	<5 - 10
Oak-hickory-pine Forest	20 (1)	30:50	4.7	1.78	1.23	<5 - 15
C horizon; Georgia	14 (1)	20:30	5.0	1.67	--	<5 - 15
	15 (1)	30:30	11	1.43	--	5 - 20
C horizon; Kentucky	18 (2)	96:96	13	1.30	1.06	7 - 20
Cultivated and uncultivated						
Surface horizon; Colorado	22 (1)	123:168	5.9	1.79	1.3	<5 - 15
B horizon; Eastern United States	21 (1)	282:371	7.0	1.85	--	<5 - 30
B horizon; Western United States	21 (1)	437:492	9.0	1.74	--	<5 - 50
PLANT ASH						
Native species						
Blackgum, leaves; Georgia	15 (1)	1:30	<5	--	--	<5 - 10
Sassafras, stems; Georgia	15 (1)	1:27	<5	--	--	<5 - 10
Sassafras, leaves; Georgia	14 (1)	1:17	<5	--	--	<5 - 10
Sumac, winged, leaves; Georgia	14 (1)	1:30	<5	--	--	<5 - 10

TABLE 39.—*Selenium in rocks, unconsolidated geologic deposits, soils, and dry plants*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Granite						
Precambrian; Missouri	1 (5)	18:30	0.12	1.64	1.73	<0.1 - 0.4
Rhyolite						
Precambrian; Missouri	1 (5)	15:30	.11	1.76	1.73	<.1 - .4

TABLE 39.—*Selenium in rocks, unconsolidated geologic deposits, soils, and dry plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS--Continued						
Sandstone						
Roubidoux Formation; Missouri	4 (5)	6:12	0.086	2.06	1.67	<0.1 - 0.2
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (5)	19:32	.11	2.80	1.67	<.1 - 1.7
Chert						
Mississippian; Missouri, Oklahoma, and Arkansas	7 (5)	12:20	.11	1.76	1.67	<.1 - .3
Shale						
Mississippian; Missouri, Oklahoma, and Arkansas	7 (5)	18:18	.64	3.47	1.73	.2 - 9
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (5)	29:32	.46	3.63	1.73	<.1 - 12
Limestone and dolomite						
Sauk sequence; Missouri and Arkansas	4 (5)	35:48	.18	2.21	1.96	<.1 - .8
Tippecanoe sequence; Missouri	10 (5)	9:12	.16	1.97	1.96	<.1 - .3
Mississippian; Missouri, Oklahoma, and Arkansas	7 (5)	32:40	.19	2.28	1.96	<.1 - 1
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (5)	29:32	.31	2.69	1.96	<.1 - 7.4
UNCONSOLIDATED GEOLOGIC DEPOSITS						
Carbonate residuum (terra rossa)						
On Gasconade Formation; Missouri	12 (5)	23:24	0.29	1.69	1.72	<0.1 - 0.7
On Roubidoux Formation; Missouri	12 (5)	20:24	.22	2.12	1.72	<.1 - .8
On Jefferson City, Cotter, and Powell Formations; Missouri and Arkansas	12 (5)	20:24	.25	2.00	1.72	<.1 - .5
On Osagean rocks; Missouri	12 (5)	21:24	.40	2.43	1.72	<.1 - 1.9
On Meramecian rocks; Missouri	12 (5)	24:24	.38	1.74	1.72	.2 - 1.4
Loess						
Missouri	13 (5)	19:24	.17	2.02	--	<.1 - .4
SOILS						
Cultivated						
Plow zone, corn field; Missouri						
Floodplain Forest	17 (5)	8:8	.31	1.51	1.25	.2 - 0.6
Glaciated Prairie	17 (5)	10:10	.67	1.67	1.25	.3 - 1.5
Unglaciated Prairie	17 (5)	10:10	.52	1.48	1.25	.3 - 1.1
Oak-hickory Forest	17 (5)	10:10	.31	1.43	1.25	.2 - .6
Plow zone, soybean field; Missouri						
Floodplain Forest	17 (5)	10:10	.33	1.67	1.25	.1 - .6
Glaciated Prairie	17 (5)	10:10	.74	1.71	1.25	.4 - 1.4
Unglaciated Prairie	17 (5)	8:8	.67	1.56	1.25	.3 - 1.2
Oak-hickory Forest	17 (5)	9:9	.31	1.31	1.25	.2 - .4

TABLE 38.—*Selenium in rocks, unconsolidated geologic deposits, soils, and dry plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
SOILS--Continued						
Cultivated--Continued						
Flow zone, pasture field; Missouri						
Floodplain Forest	17 (5)	10:10	0.28	1.65	1.25	0.1 - 0.7
Glaciated Prairie	17 (5)	10:10	.62	1.68	1.25	.3 - 1.5
Unglaciated Prairie	17 (5)	10:10	.47	1.39	1.25	.3 - .8
Oak-hickory Forest	17 (5)	10:10	.38	1.43	1.25	.2 - .6
Surface horizon; Missouri	16 (5)	925:1,140	.28	2.54	1.67	<.1 - 2.7
Uncultivated						
B horizon; Missouri						
Floodplain Forest	20 (5)	42:50	.31	2.78	1.52	<.1 - 2.4
Glaciated Prairie	20 (5)	49:50	.73	2.11	1.52	<.1 - 3.4
Unglaciated Prairie	20 (5)	50:50	.67	1.64	1.52	.2 - 3.1
Cedar Glade	20 (5)	46:50	.31	2.10	1.52	<.1 - 1.4
Oak-hickory Forest	20 (5)	48:50	.31	1.90	1.52	<.1 - 1.0
Oak-hickory-pine Forest	20 (5)	46:50	.27	2.01	1.52	<.1 - 1.0
Cultivated and uncultivated						
Surface horizon; Colorado	22 (5)	143:168	.23	2.88	1.60	<.1 - 1.4
B horizon; Eastern United States	21 (5)	390:420	.39	2.17	--	<.1 - 1.4
B horizon; Western United States	21 (5)	413:492	.25	2.53	--	<.1 - 4.3
DRY PLANTS						
Cultivated plants						
Corn; Missouri						
Floodplain Forest	17 (14)	8:8	0.062	2.41	1.09	0.01 - 0.2
Glaciated Prairie	17 (14)	10:10	.072	2.61	1.09	.02 - .4
Unglaciated Prairie	17 (14)	10:10	.047	1.88	1.09	.02 - .15
Oak-hickory Forest	17 (14)	10:10	.040	2.96	1.09	.02 - .50
Soybean; Missouri						
Floodplain Forest	17 (14)	10:10	.17	2.68	1.09	.06 - 1.25
Glaciated Prairie	17 (14)	10:10	.098	1.83	1.09	.04 - .25
Unglaciated Prairie	17 (14)	8:8	.097	2.28	1.09	.04 - .35
Oak-hickory Forest	17 (14)	9:9	.077	1.94	1.09	.04 - .40
Native species						
Buckbush; Missouri						
Glaciated Prairie	20 (14)	47:47	.043	1.45	1.22	.02 - .08
Unglaciated Prairie	20 (14)	46:46	.038	1.49	1.22	.02 - .08
Cedar Glade	20 (14)	49:49	.023	1.33	1.22	.02 - .04
Oak-hickory Forest	20 (14)	46:46	.032	1.47	1.22	.02 - .08
Oak-hickory-pine Forest	20 (14)	39:39	.031	1.47	1.22	.02 - .06
Cedar; Cedar Glade, Missouri	20 (14)	50:50	.021	1.36	1.22	.01 - .04
Hickory, shagbark; Missouri						
Oak-hickory Forest	20 (14)	19:19	.022	1.52	1.22	.02 - .04
Oak-hickory-pine Forest	20 (14)	7:7	.027	1.45	1.22	.02 - .04

TABLE 39.—*Selenium in rocks, unconsolidated geologic deposits, soils, and dry plants*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
DRY PLANTS--Continued						
Native species--Continued						
Oak, post; Cedar Glade, Missouri	20 (14)	46:49	0.020	1.56	1.22	<0.01 - 0.04
Oak, white; Missouri						
Oak-hickory Forest	20 (14)	48:50	.018	1.43	1.22	<.01 - .04
Oak-hickory-pine Forest	20 (14)	48:49	.019	1.43	1.22	<.01 - .04
Oak, willow; Floodplain Forest, Missouri	20 (14)	45:45	.032	2.02	1.22	.01 - .3
Pine, shortleaf; Oak-hickory-pine Forest, Missouri	20 (14)	49:49	.062	1.71	1.22	.02 - .2
Sagebrush; Powder River Basin, Wyoming and Montana	25 (14)	48:48	.42	2.47	--	.08 - 4.8
Sumac, smooth; Missouri						
Floodplain Forest	20 (14)	47:48	.027	1.98	1.22	<.01 - .25
Glaciated Prairie	20 (14)	49:50	.022	1.83	1.22	<.01 - .10
Unglaciated Prairie	20 (14)	39:49	.013	1.67	1.22	<.01 - .04
Sweetgum; Floodplain Forest, Missouri	20 (14)	47:47	.065	2.36	1.22	.01 - .4

TABLE 40.—*Silicon in rocks, unconsolidated geologic deposits, soils, and plant ash*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean except that values preceded by asterisk are arithmetic mean. Deviation, geometric deviation except that values preceded by asterisk are standard deviation. Error, geometric error attributed to laboratory procedures except that values preceded by asterisk are standard error. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
ROCKS						
Granite						
Precambrian; Missouri	1 (5)	30:30	*35	*1.22	*1.08	33 - 37
Rhyolite						
Precambrian; Missouri	1 (5)	30:30	*35	*1.37	*1.08	33 - 37
Shale						
Sauk sequence; Western United States	3 (16)	336:336	*27	*5.89	*1.29	5.3 - 39
Lower Mississippian; Kentucky	8 (16)	76:76	*31	*4.27	--	20 - 39
Upper Mississippian; Kentucky	5 (16)	142:142	*29	*4.54	--	17 - 39
Mississippian; Missouri, Oklahoma, and Arkansas	7 (5)	18:18	23	1.40	1.02	13 - 37

TABLE 48.—*Silicon in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
ROCKS--Continued						
Shale--Continued						
Pennsylvanian; Kentucky	5 (16)	152:152	*30	*4.30	*0.51	23 - 42
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (5)	32:32	27	1.15	1.02	19 - 37
Limestone and dolomite						
Sauk sequence; Western United States	3 (16)	388:392	2.3	4.24	1.47	<.056 - 24
Sauk sequence; Missouri and Arkansas	4 (5)	40:48	1.6	3.44	1.07	<.47 - 31
Upper Ordovician; Kentucky	5 (16)	80:80	3.4	2.56	1.09	.56 - 15
Tippecanoe sequence; Missouri	10 (5)	9:12	1.0	4.53	1.07	<.47 - 12
Lower Mississippian; Kentucky	5 (16)	112:112	8.0	2.35	1.04	1.2 - 30
Upper Mississippian; Kentucky	5 (16)	152:152	2.7	2.58	1.11	.45 - 26
Mississippian; Missouri, Oklahoma, and Arkansas	7 (5)	28:40	1.1	4.53	1.07	<.47 - 24
Pennsylvanian; Kentucky	5 (16)	80:80	7.2	2.41	1.08	.70 - 21
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (5)	32:32	2.9	2.98	1.07	.47 - 17
Siderite						
Upper Paleozoic; Kentucky	11 (16)	30:30	6.8	1.95	--	1.6 - 26
UNCONSOLIDATED GEOLOGIC DEPOSITS						
Carbonate residuum (terra rossa)						
On Gasconade Formation; Missouri	12 (5)	24:24	29	1.21	1.03	15 - 36
On Roubidoux Formation; Missouri	12 (5)	24:24	31	1.21	1.03	18 - 43
On Jefferson City, Cotter, and Powell Formations; Missouri and Arkansas	12 (5)	24:24	30	1.09	1.03	24 - 36
On Osagean rocks; Missouri	12 (5)	24:24	26	1.17	1.03	21 - 34
On Meramecian rocks; Missouri	12 (5)	24:24	25	1.19	1.03	19 - 36
Loess						
Missouri	13 (5)	24:24	34	1.05	--	30 - 36
SOILS						
Cultivated						
Plow zone, corn field; Missouri						
Floodplain Forest	17 (5)	8:8	*38	*3.09	--	31 - 42
Glaciated Prairie	17 (5)	10:10	*35	*1.64	--	32 - 37
Unglaciated Prairie	17 (5)	10:10	*37	*2.35	--	35 - 42
Oak-hickory Forest	17 (5)	10:10	*38	*2.23	--	35 - 41
Plow zone, soybean field; Missouri						
Floodplain Forest	17 (5)	10:10	*37	*2.94	--	33 - 42
Glaciated Prairie	17 (5)	10:10	*35	*.83	--	33 - 36
Unglaciated Prairie	17 (5)	8:8	*37	*2.29	--	36 - 41
Oak-hickory Forest	17 (5)	9:9	*38	*2.39	--	33 - 41

TABLE 40.—*Silicon in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
SOILS--Continued						
Cultivated--Continued						
Surface horizon; Missouri	16 (5)	1,140:1,140	*35	*2.77	*1.32	23 - 43
Uncultivated						
A horizon; Kentucky	18 (16)	96:96	*38	*2.24	*.40	28 - 41
	19 (16)	108:108	39	1.04	1.01	31 - 42
B horizon; Kentucky	18 (16)	96:96	*35	*2.93	*.40	26 - 41
B horizon; Missouri						
Floodplain Forest	20 (5)	50:50	*36	*3.60	--	27 - 42
Glaciated Prairie	20 (5)	50:50	*32	*2.36	--	27 - 37
Unglaciated Prairie	20 (5)	50:50	*34	*3.18	--	26 - 40
Cedar Glade	20 (5)	50:50	*29	*8.14	--	7 - 43
Oak-hickory Forest	20 (5)	50:50	*39	*3.47	--	22 - 43
Oak-hickory-pine Forest	20 (5)	50:50	*41	*2.65	--	33 - 44
C horizon; Kentucky	18 (16)	96:96	*34	*3.87	*.40	25 - 42
Cultivated and uncultivated						
Surface horizon; Colorado	22 (5)	168:168	33	1.16	1.02	10 - 42
PLANT ASH						
Native species						
Hickory, pignut; Kentucky	19 (6)	88:88	1.3	1.48	1.81	0.50 - 3.8
Hickory, shagbark; Kentucky	18 (6)	2:2	.83	1.25	--	.71 - .98
	19 (6)	20:20	1.3	1.38	1.81	.69 - 2.5
Oak, red; Kentucky	19 (6)	8:9	.29	2.74	1.81	<.34 - 3.7

TABLE 41.—*Silver in rocks, soils, and plant ash*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Shale						
Mississippian; Missouri, Oklahoma, and Arkansas	7 (1)	3:18	<0.5	--	--	<0.5 - 3

TABLE 41.—*Silver in rocks, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS--Continued						
Black shale						
Devonian and Mississippian; Kentucky-	9 (3)	43:88	0.18	2.22	1.66	<0.2 - 0.90
Limestone and dolomite						
Lower Mississippian; Kentucky--------	5 (1)	1:112	<10	--	--	<10 - 10
SOILS						
Cultivated						
Surface horizon; Missouri----------	16 (1)	4:1,140	<0.5	--	--	<0.5 - 3
Uncultivated						
B horizon; Oak-hickory Forest, Missouri----------	20 (1)	1:50	<.5	--	--	<.5 - 3
Cultivated and uncultivated						
Surface horizon; Colorado----------	22 (1)	3:168	<.5	--	--	<.5 - 1.5
B horizon; Western United States-----	21 (1)	4:477	<.5	--	--	<.5 - 5
PLANT ASH						
Cultivated plants						
Bean, snap; Georgia----------	14 (1)	1:30	<0.5	--	--	<0.5 - 2
Cabbage; Georgia----------	14 (1)	1:28	<.5	--	--	<.5 - 2
Tomato; Georgia----------	14 (1)	3:30	<.5	--	--	<.5 - 7
Native species						
Black cherry, stems; Georgia---------	14 (1)	1:30	< 5	--	--	<.5 - 2
Black cherry, leaves; Georgia--------	14 (1)	1:30	<.5	--	--	<.5 - 5
Blackgum, stems; Georgia----------	14 (1)	4:30	<.5	--	--	<.5 - 5
Blackgum, leaves; Georgia----------	14 (1)	2:30	<.5	--	--	<.5 - 2
Cedar; Missouri						
Oak-hickory Forest----------	20 (1)	2:10	<1	--	--	<1 - 5
Oak-hickory-pine Forest----------	20 (1)	1:10	<1	--	--	<1 - 1.5
Hickory, pignut; Kentucky----------	18 (2)	1:64	<.4	--	--	<.4 - 7
Maple, red, stems; Georgia----------	14 (1)	1:30	<.5	--	--	<.5 - 3
Oak, red; Kentucky----------	18 (2)	2:28	<.4	--	--	<.4 - 20
Oak, white; Kentucky----------	18 (2)	3:49	<.4	--	--	<.4 - 3
Pine, shortleaf; Oak-hickory-pine Forest, Missouri----------	20 (1)	14:49	.5	2.53	--	<1 - 3
Sassafras, leaves; Georgia----------	14 (1)	1:17	<.5	--	--	<.5 - 3
Sweetgum, stems; Georgia----------	15 (1)	1:27	<.5	--	--	<.5 - 2

TABLE 42.—*Sodium in rocks, unconsolidated geologic deposits, soils, and plant ash*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean except that values preceded by asterisk are arithmetic mean. Deviation, geometric deviation except that values preceded by asterisk are standard deviation. Error, geometric error attributed to laboratory procedures except that values preceded by asterisk are standard error. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
ROCKS						
Granite						
Precambrian; Missouri	1 (3)	30:30	2.8	1.38	1.03	2.1 - 3.5
Sandstone						
Roubidoux Formation; Missouri	4 (3)	12:12	.013	2.53	1.45	.0074 - .059
Pope Megagroup;[1] Kentucky	5 (16)	108:120	.098	5.03	3.53	<.0074 - 2.2
Pennsylvanian; Kentucky	5 (16)	143:152	.19	4.93	3.01	<.0074 - 1.6
Chert						
Mississippian; Missouri, Oklahoma, and Arkansas	7 (3)	19:20	.013	1.71	1.45	<.0074 - .022
Shale						
Sauk sequence; Western United States	3 (16	326:336	.17	3.15	2.21	<.015 - 2.8
Lower Mississippian; Kentucky	8 (16)	76:76	.39	1.86	--	.074 - 1.0
Upper Mississippian; Kentucky	5 (16)	134:142	.15	2.93	--	<.0074 - .89
Mississippian; Missouri, Oklahoma, and Arkansas	7 (3)	18:18	.088	2.16	1.54	.03 - .41
Pennsylvanian; Kentucky	5 (16)	150:152	.27	2.40	1.91	<.0074 - 1.4
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (3)	32:32	.50	1.67	1.54	.30 - 1.1
Limestone and dolomite						
Sauk sequence; Missouri and Arkansas	4 (3)	48:48	.027	1.48	1.44	.015 - .58
Upper Ordovician; Kentucky	5 (16)	69:80	.077	4.10	3.09	<.0074 - .51
Tippecanoe sequence; Missouri	10 (3)	12:12	.013	2.33	1.44	.0074 - .55
Lower Mississippian; Kentucky	5 (16)	79:112	.028	6.45	3.62	<.0074 - .44
Upper Mississippian; Kentucky	5 (16)	103:152	.020	6.10	3.84	<.0074 - .59
Mississippian; Missouri, Oklahoma, and Arkansas	7 (3)	38:40	.017	2.63	1.44	<.0074 - .096
Pennsylvanian; Kentucky	5 (16)	75:80	.17	3.82	2.29	<.0074 - .74
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (3)	32:32	.045	2.43	1.44	.015 - .27
UNCONSOLIDATED GEOLOGIC DEPOSITS						
Carbonate residuum (terra rossa)						
On Gasconade Formation; Missouri	12 (3)	24:24	0.032	1.58	1.14	0.015 - 0.18
On Roubidoux Formation; Missouri	12 (3)	24:24	.035	1.57	1.14	.015 - .13

[1] Of Swann and Willman (1961).

TABLE 42.—*Sodium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
UNCONSOLIDATED GEOLOGIC DEPOSITS--Continued						
Carbonate residuum (terra rossa)--Continued						
On Jefferson City, Cotter, and Powell Formations; Missouri and Arkansas--	12 (3)	24:24	0.038	1.25	1.14 0.022	- 0.074
On Osagean rocks; Missouri----------	12 (3)	24:24	.036	1.51	1.14 .015	- .074
On Meramecian rocks; Missouri--------	12 (3)	24:24	.045	1.42	1.14 .022	- .16
Loess						
Missouri----------	13 (3)	24:24	.95	1.21	-- .53	- 1.2
SOILS						
Cultivated						
Flow zone, corn field; Missouri						
Floodplain Forest----------	17 (3)	8:8	0.79	1.11	1.02 0.68	- 0.93
Glaciated Prairie----------	17 (3)	10:10	.69	1.13	1.02 .54	- .78
Unglaciated Prairie----------	17 (3)	10:10	.45	1.84	1.02 .16	- .85
Oak-hickory Forest----------	17 (3)	10:10	.55	1.68	1.02 .23	- .91
Flow zone, soybean field; Missouri						
Floodplain Forest----------	17 (3)	10:10	.76	1.15	1.02 .60	- .96
Glaciated Prairie----------	17 (3)	10:10	.68	1.09	1.02 .58	- .76
Unglaciated Prairie----------	17 (3)	8:8	.56	1.50	1.02 .30	- .89
Oak-hickory Forest----------	17 (3)	9:9	.53	1.49	1.02 .22	- .76
Flow zone, pasture field; Missouri						
Floodplain Forest----------	17 (3)	10:10	.74	1.22	1.02 .49	- .94
Glaciated Prairie----------	17 (3)	10:10	.70	1.11	1.02 .57	- .82
Unglaciated Prairie----------	17 (3)	10:10	.50	1.50	1.02 .26	- .76
Oak-hickory Forest----------	17 (3)	10:10	.51	1.67	1.02 .21	- .94
Surface horizon; Missouri----------	16 (3)	1,140:1,140	*.53	*.23	*.03 .07	- 1.2
Uncultivated						
A horizon; Georgia----------	14 (12)	6:30	<.02	--	-- <.02	- .15
	15 (12)	29:30	.21	2.82	-- <.02	- .7
A horizon; Kentucky----------	18 (16)	92:96	.25	3.07	1.35 <.02	- 1.3
B horizon; Georgia----------	14 (12)	3:30	<.02	--	-- <.02	- .7
	15 (12)	29:30	.20	2.86	-- <.02	- 1.0
B horizon; Kentucky----------	18 (16)	89:96	.24	3.25	1.35 <.02	- 1.1
B horizon; Missouri						
Floodplain Forest----------	20 (3)	50:50	.62	1.65	1.42 .04	- 1.0
Glaciated Prairie----------	20 (3)	50:50	.50	1.45	1.42 .13	- .81
Unglaciated Prairie----------	20 (3)	50:50	.38	1.62	1.42 .10	- .81
Cedar Glade----------	20 (3)	50:50	.13	1.70	1.42 .06	- .74
Oak-hickory Forest----------	20 (3)	50:50	.27	2.01	1.42 .04	- .78
Oak-hickory-pine Forest----------	20 (3)	50:50	.19	1.86	1.42 .06	- .89
C horizon; Georgia----------	14 (12)	3:30	<.05	--	-- <.05	- .1
	15 (12)	30:30	.20	2.35	-- .03	- .7
C horizon; Kentucky----------	18 (16)	86:96	.16	4.64	1.35 <.01	- 1.4

TABLE 42.—*Sodium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
SOILS--Continued						
Cultivated and uncultivated						
Surface horizon; Colorado	22 (3)	168:168	0.98	1.70	1.05 0.12	- 2.2
B horizon; Eastern United States	21 (12)	245:304	.26	4.11	-- <.02	- 1.5
B horizon; Western United States	21 (12)	484:484	1.0	1.98	-- .05	- 10
PLANT ASH						
Cultivated plants						
Corn; Missouri						
Floodplain Forest	17 (3)	8:8	0.0039	1.67	1.23 0.0025	- 0.010
Glaciated Prairie	17 (3)	10:10	.0032	1.51	1.23 .0025	- .0075
Unglaciated Prairie	17 (3)	7:10	.0025	--	-- <.0025	- .0050
Oak-hickory Forest	17 (3)	8:10	.0025	--	-- <.0025	- .0050
Soybean; Missouri						
Floodplain Forest	17 (3)	10:10	.0033	1.43	1.23 .0025	- .0050
Glaciated Prairie	17 (3)	8:10	.0025	--	-- <.0025	- .0050
Unglaciated Prairie	17 (3)	8:8	.0037	1.56	1.23 .0025	- .0075
Oak-hickory Forest	17 (3)	8:9	.0033	1.77	1.23 <.0025	- .0075
Native species						
Buckbush; Missouri						
Glaciated Prairie	20 (3)	47:47	.097	1.40	1.36 .03	- .20
Unglaciated Prairie	20 (3)	46:46	.096	1.28	1.36 .05	- .15
Cedar Glade	20 (3)	47:47	.064	1.27	1.36 .04	- .10
Oak-hickory Forest	20 (3)	44:44	.082	1.36	1.36 .05	- .17
Oak-hickory-pine Forest	20 (3)	39:39	.077	1.27	1.36 .05	- .16
Cedar; Missouri						
Cedar Glade	20 (3)	49:49	.022	1.46	1.36 .01	- .05
Glaciated Prairie	24 (3)	9:9	.28	1.36	-- .16	- .40
Unglaciated Prairie	24 (3)	10:10	.31	1.33	-- .20	- .42
Cedar Glade	24 (3)	10:10	.20	1.25	-- .12	- .26
Oak-hickory Forest	24 (3)	10:10	.27	1.65	-- .14	- .48
Oak-hickory-pine Forest	24 (3)	6:6	.27	1.34	-- .20	- .42
Hickory, pignut; Kentucky	18 (3)	64:64	.11	1.45	1.47 .06	- .26
	19 (3)	88:88	.10	1.31	1.36 .06	- .27
Hickory, shagbark; Kentucky	18 (3)	40:40	.11	1.52	1.47 .05	- .30
	19 (3)	20:20	.10	1.27	1.36 .06	- .14
Hickory, shagbark; Missouri						
Oak-hickory Forest	20 (3)	19:19	.028	1.55	1.36 .02	- .05
Oak-hickory-pine Forest	20 (3)	7:7	.032	1.33	1.36 .02	- .05
Oak, black; Kentucky	18 (3)	25:25	.13	1.52	1.47 .06	- .39
	19 (3)	22:22	.12	1.36	1.36 .08	- .87
Oak, post; Cedar Glade, Missouri	20 (3)	49:49	.042	1.46	1.36 .02	- .16
Oak, red; Kentucky	18 (3)	28:28	.14	1.59	1.47 .06	- .60
	19 (3)	9:9	.13	1.37	1.36 .09	- .24
Oak, white; Kentucky	18 (3)	49:49	.16	1.58	1.47 .08	- .50
	19 (3)	76:76	.15	1.43	1.36 .05	- .34

TABLE 42.—*Sodium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (percent)	Deviation	Error	Observed range (percent)
PLANT ASH--Continued						
Native species--Continued						
Oak, white; Missouri						
Oak-hickory Forest	20 (3)	50:50	0.038	1.33	1.36	0.02 - 0.07
Oak-hickory-pine Forest	20 (3)	49:49	.034	1.30	1.36	.02 - .06
Oak, willow; Floodplain Forest, Missouri	20 (3)	46:46	.084	1.54	1.36	.03 - .26
Pine, shortleaf; Oak-hickory-pine Forest, Missouri	20 (3)	48:48	.058	1.45	1.36	.02 - .15
Sumac, smooth; Missouri						
Floodplain Forest	20 (3)	48:48	.031	1.64	1.36	.01 - .10
Glaciated Prairie	20 (3)	50:50	.025	1.60	1.36	.01 - .12
Unglaciated Prairie	20 (3)	49:49	.022	1.88	1.36	.01 - .14
Cedar Glade	20 (3)	48:48	.023	1.60	1.36	.01 - .16
Oak-hickory Forest	20 (3)	50:50	.023	1.46	1.36	.01 - .04
Oak-hickory-pine Forest	20 (3)	49:49	.028	1.57	1.36	.01 - .07
Sweetgum; Floodplain Forest, Missouri	20 (3)	47:47	.067	1.57	1.36	.03 - .22

TABLE 43.—*Strontium in rocks, unconsolidated geologic deposits, soils, and plant ash*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Granite						
Precambrian; Missouri	1 (1)	30:30	81	2.12	1.16	15 - 300
Rhyolite						
Precambrian; Missouri	1 (1)	30:30	64	2.18	1.16	20 - 300
Arkose						
Fountain Formation; Colorado	2 (2)	79:80	99	2.12	1.22	<10 - 440
Sandstone						
Sauk sequence; Western United States	3 (2)	329:400	31	3.37	1.31	<10 - 2,200
Roubidoux Formation; Missouri	4 (1)	12:12	13	2.23	1.25	5 - 50

TABLE 43.—*Strontium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS--Continued						
Sandstone--Continued						
Pope Megagroup;[1] Kentucky	5 (2)	94:120	34	2.53	1.45	<20 - 300
Pennsylvanian; Kentucky	5 (2)	145:152	43	2.51	1.49	<10 - 380
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	32:32	95	4.19	1.25	7 - 700
Chert						
Mississippian; Missouri, Oklahoma, and Arkansas	7 (1)	16:20	8.1	2.55	1.25	<5 - 70
Shale						
Sauk sequence; Western United States	3 (2)	327:336	150	2.08	1.13	<30 - 4,000
Lower Mississippian; Kentucky	8 (2)	73:76	92	1.60	--	<30 - 260
Upper Mississippian; Kentucky	5 (2)	139:142	110	1.80	--	<30 - 960
Mississippian; Missouri, Oklahoma, and Arkansas	7 (1)	18:18	150	1.87	1.17	70 - 700
Pennsylvanian; Kentucky	5 (2)	149:152	120	1.62	1.22	<30 - 260
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	32:32	200	1.65	1.17	100 - 1,000
Black shale						
Devonian and Mississippian; Kentucky	9 (2)	88:88	90	1.39	1.14	30 - 220
Limestone and dolomite						
Sauk sequence; Missouri and Arkansas	4 (1)	48:48	100	1.56	1.23	30 - 200
Upper Ordovician; Kentucky	5 (1)	80:80	450	2.23	1.49	100 - 2,000
Tippecanoe sequence; Missouri	10 (1)	12:12	360	2.27	1.23	150 - 1,500
Lower Mississippian; Kentucky	5 (1)	112:112	360	2.04	1.25	70 - 1,500
Upper Mississippian; Kentucky	5 (1)	152:152	540	1.85	1.45	100 - 5,000
Mississippian; Missouri, Oklahoma, and Arkansas	7 (1)	40:40	270	3.62	1.23	70 - 10,000
Pennsylvanian; Kentucky	5 (1)	80:80	480	1.89	1.29	200 - 5,000
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	32:32	990	3.86	1.23	70 - 5,000
Siderite						
Upper Paleozoic; Kentucky	11 (1)	30:30	190	1.48	--	100 - 500
UNCONSOLIDATED GEOLOGIC DEPOSITS						
Carbonate residuum (terra rossa)						
On Gasconade Formation; Missouri	12 (1)	24:24	40	1.52	1.25	20 - 100
On Roubidoux Formation; Missouri	12 (1)	24:24	50	1.52	1.25	10 - 300
On Jefferson City, Cotter, and Powell Formations; Missouri and Arkansas	12 (1)	24:24	44	1.40	1.25	30 - 70
On Osagean rocks; Missouri	12 (1)	24:24	62	1.52	1.25	30 - 150
On Meramecian rocks; Missouri	12 (1)	24:24	51	1.57	1.25	30 - 150
Loess						
Missouri	13 (1)	24:24	220	1.28	--	150 - 300

[1] Of Swann and Willman (1961).

TABLE 43.—*Strontium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
SOILS						
Cultivated						
Flow zone, garden; Georgia	14 (1)	5:30	3.6	2.35	--	<5 - 15
	15 (1)	29:30	33	2.21	--	<5 - 200
Flow zone, corn field; Missouri						
Floodplain Forest	17 (1)	8:8	150	1.21	1.14	100 - 200
Glaciated Prairie	17 (1)	10:10	150	1.21	1.14	100 - 200
Unglaciated Prairie	17 (1)	10:10	110	1.64	1.14	50 - 200
Oak-hickory Forest	17 (1)	10:10	120	1.53	1.14	50 - 200
Flow zone, soybean field; Missouri						
Floodplain Forest	17 (1)	10:10	140	1.19	1.14	100 - 150
Glaciated Prairie	17 (1)	10:10	140	1.14	1.14	100 - 150
Unglaciated Prairie	17 (1)	8:8	120	1.55	1.14	50 - 150
Oak-hickory Forest	17 (1)	9:9	110	1.48	1.14	50 - 150
Flow zone, pasture field; Missouri						
Floodplain Forest	17 (1)	10:10	140	1.14	1.14	100 - 150
Glaciated Prairie	17 (1)	10:10	150	1.21	1.14	100 - 200
Unglaciated Prairie	17 (1)	10:10	110	1.58	1.14	50 - 200
Oak-hickory Forest	17 (1)	10:10	120	1.57	1.14	50 - 200
Surface horizon; Missouri	16 (1)	1,140:1,140	110	1.60	1.25	20 - 500
Uncultivated						
Surface horizon; Powder River Basin, Wyoming and Montana	25 (1)	48:48	160	1.53	1.23	50 - 500
A horizon; Georgia	14 (1)	11:30	5.7	2.73	--	<5 - 50
	15 (1)	29:30	30	2.22	--	<5 - 150
A horizon; Kentucky	18 (2)	95:96	82	1.72	1.10	<5 - 350
	19 (2)	99:108	67	1.81	1.16	<5 - 170
B horizon; Georgia	14 (1)	9:30	6.5	1.61	--	<5 - 15
	15 (1)	29:30	27	1.98	--	<5 - 100
B horizon; Kentucky	18 (2)	96:96	95	1.53	1.10	20 - 240
B horizon; Missouri						
Floodplain Forest	20 (1)	50:50	120	1.32	1.33	70 - 200
Glaciated Prairie	20 (1)	50:50	120	1.35	1.33	70 - 200
Unglaciated Prairie	20 (1)	50:50	95	1.51	1.33	30 - 200
Cedar Glade	20 (1)	50:50	72	1.51	1.33	20 - 150
Oak-hickory Forest	20 (1)	50:50	66	1.66	1.33	30 - 150
Oak-hickory-pine Forest	20 (1)	50:50	42	1.90	1.33	10 - 150
C horizon; Georgia	14 (1)	17:30	9.0	1.86	--	<5 - 50
	15 (1)	30:30	29	1.82	--	10 - 70
C horizon; Kentucky	18 (2)	95:96	88	1.89	1.10	<5 - 330
Cultivated and uncultivated						
Surface horizon; Colorado	22 (1)	168:168	160	1.70	1.29	50 - 500
B horizon; Eastern United States	21 (1)	343:371	51	3.56	--	<5 - 700
B horizon; Western United States	21 (1)	492:492	210	2.12	--	10 - 3,000

TABLE 43.—*Strontium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
		PLANT ASH				
Cultivated plants						
Asparagus; Wisconsin	23 (1)	5:5	590	2.38	--	300 - 2,000
Bean, lima; Georgia	14 (1)	30:30	88	1.63	--	30 - 300
	15 (1)	15:15	140	2.28	--	50 - 1,000
Bean, snap; Georgia	14 (1)	30:30	210	1.80	--	50 - 700
	15 (1)	30:30	290	1.75	--	100 - 700
Beet, red; Wisconsin	23 (1)	3:3	420	1.34	--	300 - 500
Blackeyed pea; Georgia	14 (1)	29:29	180	1.81	--	50 - 500
	15 (1)	4:4	130	1.40	--	100 - 200
Cabbage; Georgia	14 (1)	28:28	620	2.34	--	100 - 3,000
	15 (1)	30:30	880	1.89	--	200 - 3,000
Cabbage; Wisconsin	23 (1)	11:11	410	3.10	--	30 - 1,500
Carrot; Wisconsin	23 (1)	8:8	300	2.68	--	30 - 700
Corn; Georgia	14 (1)	24:29	52	1.75	--	<7 - 150
	15 (1)	30:30	50	1.95	--	15 - 150
Corn; Missouri						
Floodplain Forest	17 (1)	6:8	14	2.73	1.22	<7 - 50
Glaciated Prairie	17 (1)	9:10	17	1.72	1.22	<7 - 30
Unglaciated Prairie	17 (1)	10:10	15	1.55	1.22	7 - 30
Oak-hickory Forest	17 (1)	9:10	17	2.04	1.22	<7 - 50
Corn; Wisconsin	23 (1)	21:21	21	2.02	--	7 - 70
Cucumber; Wisconsin	23 (1)	4:4	340	1.29	--	300 - 500
Onion; Wisconsin	23 (1)	7:7	370	1.72	--	200 - 700
Pepper, sweet; Wisconsin	23 (1)	4:4	93	1.58	--	50 - 150
Potato; Wisconsin	23 (1)	10:10	75	2.53	--	30 - 700
Soybean; Missouri						
Floodplain Forest	17 (1)	10:10	330	1.72	1.22	150 - 700
Glaciated Prairie	17 (1)	10:10	290	1.63	1.22	200 - 500
Unglaciated Prairie	17 (1)	8:8	430	1.38	1.22	300 - 700
Oak-hickory Forest	17 (1)	9:9	170	1.83	1.22	70 - 500
Tomato; Georgia	14 (1)	29:30	71	1.96	--	<7 - 300
	15 (1)	30:30	69	2.00	--	15 - 700
Native species						
Black cherry, stems; Georgia	14 (1)	30:30	1,900	1.68	--	700 - 7,000
	15 (1)	30:30	2,400	2.29	--	300 - 7,000
Black cherry, leaves; Georgia	14 (1)	30:30	1,200	1.74	--	500 - 5,000
	15 (1)	30:30	1,600	2.11	--	300 - 5,000
Blackgum, stems; Georgia	14 (1)	30:30	1,900	1.93	--	700 - 7,000
	15 (1)	30:30	3,500	2.14	--	1,000 - 20,000
Blackgum, leaves; Georgia	14 (1)	30:30	930	1.72	--	300 - 3,000
	15 (1)	30:30	1,900	1.94	--	700 - 10,000
Buckbush; Missouri						
Glaciated Prairie	20 (1)	47:47	1,800	1.43	1.31	700 - 5,000
Unglaciated Prairie	20 (1)	48:48	1,700	1.46	1.31	700 - 5,000

TABLE 43.—*Strontium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
PLANT ASH--Continued						
Native species--Continued						
Buckbush; Missouri--Continued						
Cedar Glade	20 (1)	50:50	340	1.52	1.31	200 - 1,500
Oak-hickory Forest	20 (1)	49:49	1,500	1.96	1.31	300 - 5,000
Oak-hickory-pine Forest	20 (1)	41:41	1,500	1.72	1.31	500 - 3,000
Cedar; Missouri						
Cedar Glade	20 (1)	50:50	340	1.63	1.31	200 - 1,000
Glaciated Prairie	24 (1)	9:9	2,200	1.55	--	1,000 - 5,000
Unglaciated Prairie	24 (1)	10:10	2,600	1.50	--	1,500 - 5,000
Cedar Glade	24 (1)	10:10	410	1.55	--	300 - 1,000
Oak-hickory Forest	24 (1)	10:10	2,300	2.01	--	700 - 5,000
Oak-hickory-pine Forest	24 (1)	6:6	2,500	1.72	--	1,000 - 5,000
Hickory, pignut; Kentucky	18 (1)	64:64	5,300	1.54	1.23	1,000 - 10,000
Hickory, shagbark; Kentucky	18 (1)	40:40	4,600	1.70	1.23	1,000 - 10,000
Hickory, shagbark; Missouri						
Oak-hickory Forest	20 (1)	19:19	3,200	2.03	1.31	500 - 7,000
Oak-hickory-pine Forest	20 (1)	7:7	5,100	1.56	1.31	2,000 - 7,000
Maple, red, stems; Georgia	14 (1)	30:30	1,500	1.87	--	700 - 7,000
	15 (1)	30:30	1,800	1.91	--	500 - 10,000
Maple, red, leaves; Georgia	14 (1)	30:30	680	1.97	--	300 - 3,000
	15 (1)	30:30	770	2.04	--	150 - 5,000
Oak, black; Kentucky	18 (1)	25:25	1,900	1.45	1.15	700 - 3,000
Oak, post; Cedar Glade, Missouri	20 (1)	50:50	320	1.53	1.31	200 - 1,500
Oak, red; Kentucky	18 (1)	28:28	1,800	1.55	1.15	1,000 - 5,000
Oak, white; Kentucky	18 (1)	49:49	2,000	1.70	1.15	700 - 7,000
Oak, white; Missouri						
Oak-hickory Forest	20 (1)	50:50	1,800	1.59	1.31	500 - 5,000
Oak-hickory-pine Forest	20 (1)	49:49	2,300	1.88	1.31	500 - 7,000
Oak, willow; Floodplain Forest, Missouri	20 (1)	46:46	1,800	1.36	1.31	1,000 - 3,000
Persimmon, stems; Georgia	14 (1)	30:30	1,100	1.91	--	500 - 5,000
	15 (1)	30:30	1,100	1.96	--	300 - 7,000
Persimmon, leaves; Georgia	14 (1)	30:30	540	2.03	--	150 - 20,000
	15 (1)	30:30	620	1.98	--	200 - 5,000
Pine, shortleaf; Oak-hickory-pine Forest, Missouri	20 (1)	49:49	570	1.85	1.31	200 - 2,000
Sassafras, stems; Georgia	14 (1)	17:17	1,800	2.30	--	300 - 10,000
	15 (1)	27:27	1,700	1.85	--	500 - 7,000
Sassafras, leaves; Georgia	14 (1)	17:17	1,100	2.33	--	300 - 10,000
	15 (1)	27:27	930	1.91	--	200 - 3,000
Sumac, winged, stems; Georgia	14 (1)	30:30	2,200	1.71	--	700 - 7,000
	15 (1)	30:30	2,300	2.22	--	500 - 7,000
Sumac, winged, leaves; Georgia	14 (1)	30:30	1,100	1.59	--	500 - 3,000
	15 (1)	30:30	1,100	1.59	--	500 - 3,000
Sumac, smooth; Missouri						
Floodplain Forest	20 (1)	48:48	3,400	1.62	1.31	1,000 - 10,000
Glaciated Prairie	20 (1)	50:50	3,500	1.49	1.31	2,000 - 7,000

TABLE 43.—*Strontium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
PLANT ASH--Continued						
Native species--Continued						
Sumac, smooth; Missouri--Continued						
Unglaciated Prairie	20 (1)	49:49	3,700	1.46	1.31	1,500 - 5,000
Cedar Glade	20 (1)	49:49	400	1.72	1.31	200 - 3,000
Oak-hickory Forest	20 (1)	50:50	2,700	2.19	1.31	300 - 10,000
Oak-hickory-pine Forest	20 (1)	49:49	3,100	1.79	1.31	700 - 7,000
Sweetgum, stems; Georgia	14 (1)	18:28	1,200	1.87	--	500 - 7,000
	15 (1)	27:27	1,500	2.03	--	300 - 7,000
Sweetgum, leaves; Georgia	14 (1)	28:28	620	1.80	--	200 - 2,000
	15 (1)	27:27	750	1.98	--	200 - 3,000
Sweetgum; Floodplain Forest, Missouri	20 (1)	47:47	2,000	1.51	1.31	1,000 - 7,000

TABLE 44.—*Thorium in soils*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
Uncultivated						
Surface horizon; Powder River Basin, Wyoming and Montana	25 (8)	48:48	9.4	1.26	--	5.3 - 15

TABLE 45.—*Tin in rocks, soils, and plant ash*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Rhyolite:						
Precambrian; Missouri	1 (1)	1:30	<10	--	--	<10 - 20
SOILS						
Cultivated						
Plow zone, garden; Georgia	14 (1)	2:30	<10	--	--	<10 - 20
	15 (1)	3:30	<10	--	--	<10 - 20
Plow zone, corn field; Missouri						
Glaciated Prairie	17 (1)	1:10	<10	--	--	<10 - 10
Oak-hickory Forest	17 (1)	1:10	<10	--	--	<10 - 100
Plow zone, soybean field; Missouri						
Glaciated Prairie	17 (1)	1:10	<10	--	--	<10 - 10
Unglaciated Prairie	17 (1)	1:8	<10	--	--	<10 - 70
Plow zone, pasture field; Glaciated Prairie, Missouri	17 (1)	1:10	<10	--	--	<10 - 30
Surface horizon; Missouri	16 (1)	9:1,140	<10	--	--	<10 - 50
Cultivated and uncultivated						
Surface horizon; Colorado	22 (1)	4:168	<10	--	--	<10 - 30
B horizon; Eastern United States	21 (1)	2:371	<10	--	--	<10 - 15
B horizon; Western United States	21 (1)	7:492	<10	--	--	<10 - 20
PLANT ASH						
Cultivated plants						
Carrot; Wisconsin	23 (1)	1:8	<15	--	--	<15 - 20
Corn; Wisconsin	23 (1)	1:27	<15	--	--	<15 - 30
Beet, red; Wisconsin	23 (1)	1:3	<15	--	--	<15 - 20
Native species						
Buckbush; Missouri						
Glaciated Prairie	20 (1)	1:47	<15	--	--	<15 - 30
Unglaciated Prairie	20 (1)	1:48	<15	--	--	<15 - 20

TABLE 46.—*Titanium in rocks, unconsolidated geologic deposits, soils, and plant ash*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Granite						
Precambrian; Missouri	1 (1)	30:30	1,200	1.83	1.10	500 - 5,000
Rhyolite						
Precambrian; Missouri	1 (1)	30:30	1,400	1.47	1.10	700 - 3,000
Arkose						
Fountain Formation; Colorado	2 (2)	80:80	600	1.79	1.26	180 - 2,900
Sandstone						
Sauk sequence; Western United States	3 (16)	373:400	570	4.21	1.76	<60 - 17,000
Roubidoux Formation; Missouri	4 (1)	12:12	83	5.63	1.29	20 - 5,000
Pope Megagroup;[1] Kentucky	5 (16)	120:120	1,800	1.75	2.45	480 - 5,900
Pennsylvanian; Kentucky	5 (16)	152:152	2,200	2.15	1.39	120 - 6,600
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	32:32	2,200	2.79	1.29	70 - 7,000
Chert						
Mississippian; Missouri, Oklahoma, and Arkansas	7 (1)	20:20	20	5.15	1.29	2 - 200
Shale						
Sauk sequence; Western United States	3 (16)	336:336	3,900	1.66	1.23	600 - 17,000
Lower Mississippian; Kentucky	8 (16)	76:76	3,600	1.55	--	1,000 - 6,600
Upper Mississippian; Kentucky	5 (16)	142:142	4,700	1.23	--	2,200 - 7,200
Mississippian; Missouri, Oklahoma, and Arkansas	7 (1)	18:18	2,300	1.76	1.17	700 - 5,000
Pennsylvanian; Kentucky	5 (16)	152:152	5,700	1.21	1.05	2,400 - 13,000
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	32:32	4,200	1.41	1.17	2,000 - 5,000
Black shale						
Devonian and Mississippian; Kentucky	9 (2)	88:88	3,900	1.30	1.15	1,300 - 7,400
Limestone and dolomite						
Sauk sequence; Western United States	3 (2)	375:392	170	3.49	1.22	<20 - 2,800
Sauk sequence; Missouri and Arkansas	4 (1)	47:48	34	4.96	1.38	<2 - 200
Upper Ordovician; Kentucky	5 (1)	80:80	390	2.47	1.48	50 - 2,000
Tippecanoe sequence; Missouri	10 (1)	10:12	31	8.60	1.38	<2 - 500
Lower Mississippian; Kentucky	5 (1)	112:112	280	2.99	1.37	50 - 3,000
Upper Mississippian; Kentucky	5 (1)	152:152	140	2.90	1.50	10 - 2,000
Pennsylvanian; Kentucky	5 (1)	80:80	810	2.74	1.31	100 - 3,000
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	32:32	180	3.16	1.38	30 - 1,000

[1] Of Swann and Willman (1961).

TABLE 46.—*Titanium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS--Continued						
Siderite						
Upper Paleozoic; Kentucky	11 (1)	30:30	750	2.08	--	150 - 3,000
UNCONSOLIDATED GEOLOGIC DEPOSITS						
Carbonate residuum (terra rossa)						
On Gasconade Formation; Missouri	12 (1)	24:24	1,400	1.26	1.11	700 - 2,000
On Roubidoux Formation; Missouri	12 (1)	24:24	1,400	1.30	1.11	1,000 - 3,000
On Jefferson City, Cotter, and Powell Formations; Missouri and Arkansas	12 (1)	24:24	1,500	1.17	1.11	1,000 - 2,000
On Ozagean rocks; Missouri	12 (1)	24:24	1,500	1.14	1.11	1,000 - 2,000
On Meramecian rocks; Missouri	12 (1)	24:24	1,500	1.17	1.11	1,000 - 2,000
Loess						
Missouri	13 (1)	24:24	3,800	1.37	--	2,000 - 7,000
SOILS						
Cultivated						
Plow zone, garden; Georgia	14 (1)	30:30	1,900	1.36	--	1,000 - 3,000
	15 (1)	30:30	3,200	1.41	--	2,000 - 7,000
Plow zone, corn field; Missouri						
Floodplain Forest	17 (1)	8:8	2,200	1.49	1.36	1,500 - 5,000
Glaciated Prairie	17 (1)	10:10	2,700	1.35	1.36	2,000 - 5,000
Unglaciated Prairie	17 (1)	10:10	3,100	1.49	1.36	1,500 - 5,000
Oak-hickory Forest	17 (1)	10:10	3,400	1.35	1.36	2,000 - 5,000
Plow zone, soybean field; Missouri						
Floodplain Forest	17 (1)	10:10	1,800	1.34	1.36	1,000 - 3,000
Glaciated Prairie	17 (1)	10:10	2,600	1.36	1.36	2,000 - 5,000
Unglaciated Prairie	17 (1)	8:8	3,100	1.42	1.36	2,000 - 5,000
Oak-hickory Forest	17 (1)	9:9	4,000	1.31	1.36	3,000 - 5,000
Plow zone, pasture field; Missouri						
Floodplain Forest	17 (1)	10:10	1,700	1.34	1.36	1,000 - 3,000
Glaciated Prairie	17 (1)	10:10	2,700	1.39	1.36	1,500 - 3,000
Unglaciated Prairie	17 (1)	10:10	3,700	1.30	1.36	3,000 - 5,000
Oak-hickory Forest	17 (1)	10:10	2,900	1.29	1.36	2,000 - 5,000
Surface horizon; Missouri	16 (1)	1,140:1,140	3,300	1.31	1.20	1,500 - 7,000
Uncultivated						
Surface horizon; Powder River Basin, Wyoming and Montana	25 (1)	48:48	1,900	1.21	1.12	1,500 - 3,000
A horizon; Georgia	14 (1)	30:30	1,700	1.94	--	700 - 7,000
	15 (1)	30:30	2,900	1.50	--	700 - 5,000
A horizon; Kentucky	18 (16)	96:96	6,600	1.31	1.04	2,700 - 12,000
	19 (16)	108:108	5,600	1.13	1.07	3,700 - 7,800

TABLE 46.—*Titanium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
SOILS--Continued						
Uncultivated--Continued						
B horizon; Georgia	14 (1)	30:30	1,800	1.64	--	700 - 7,000
	15 (1)	30:30	3,600	1.55	--	1,000 - 7,000
B horizon; Kentucky	18 (16)	96:96	6,100	1.33	1.04	2,600 - 11,000
B horizon; Missouri						
Floodplain Forest	20 (1)	50:50	2,600	1.51	1.19	1,000 - 5,000
Glaciated Prairie	20 (1)	50:50	3,700	1.30	1.19	3,000 - 7,000
Unglaciated Prairie	20 (1)	50:50	3,900	1.34	1.19	3,000 - 7,000
Cedar Glade	20 (1)	50:50	1,900	1.43	1.19	700 - 3,000
Oak-hickory Forest	20 (1)	50:50	3,500	1.44	1.19	1,500 - 7,000
Oak-hickory-pine Forest	20 (1)	50:50	3,300	1.61	1.19	1,000 - 7,000
C horizon; Georgia	14 (1)	30:30	2,100	1.65	--	700 - 10,000
	15 (1)	30:30	3,600	1.47	--	1,500 - 7,000
C horizon; Kentucky	18 (16)	96:96	5,200	1.40	1.04	1,600 - 10,000
Cultivated and uncultivated						
Surface horizon; Colorado	22 (1)	168:168	1,600	1.58	1.22	500 - 3,000
B horizon; Western United States	21 (1)	491:491	2,100	1.82	--	500 - 10,000
PLANT ASH						
Cultivated plants						
Asparagus; Wisconsin	23 (1)	5:5	180	1.16	--	150 - 200
Bean, lima; Georgia	14 (1)	26:30	8.3	3.93	--	<2 - 200
Bean, snap; Georgia	14 (1)	30:30	73	2.69	--	3 - 500
	15 (1)	30:30	70	2.59	--	5 - 700
Beet, red; Wisconsin	23 (1)	3:3	27	2.65	--	10 - 70
Blackeyed pea; Georgia	14 (1)	29:29	37	2.53	--	5 - 200
	15 (1)	4:4	18	2.96	--	5 - 700
Cabbage; Georgia	14 (1)	28:28	85	2.37	--	15 - 700
	15 (1)	30:30	250	2.82	--	15 - 1,500
Cabbage; Wisconsin	23 (1)	11:11	25	3.77	--	7 - 700
Carrot; Wisconsin	23 (1)	8:8	28	2.67	--	10 - 200
Corn; Georgia	14 (1)	26:29	20	5.00	--	<2 - 500
	15 (1)	29:30	21	3.79	--	<2 - 300
Corn; Missouri						
Floodplain Forest	17 (1)	3:8	<5	--	--	<5 - 700
Glaciated Prairie	17 (1)	2:10	<5	--	--	<5 - 10
Unglaciated Prairie	17 (1)	3:10	<5	--	--	<5 - 200
Corn; Wisconsin	23 (1)	26:27	20	2.11	--	<2 - 150
Cucumber; Wisconsin	23 (1)	4:4	19	1.72	--	10 - 30
Onion; Wisconsin	23 (1)	7:7	41	2.92	--	10 - 200
Pepper, sweet; Wisconsin	23 (1)	4:4	110	1.82	--	50 - 200
Potato; Wisconsin	23 (1)	10:10	18	2.87	--	7 - 200

TABLE 46.—*Titanium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
PLANT ASH--Continued						
Cultivated plants--Continued						
Soybean; Missouri						
Floodplain Forest	17 (1)	2:10	<5	--	--	<5 - 20
Glaciated Prairie	17 (1)	6:10	5	--	--	<5 - 200
Unglaciated Prairie	17 (1)	5:8	4.7	2.33	--	<5 - 20
Oak-hickory Forest	17 (1)	8:9	11	3.67	--	<5 - 100
Tomato; Georgia	14 (1)	29:30	32	4.31	--	<2 - 700
	15 (1)	24:30	5.6	4.25	--	<2 - 70
Native species						
Black cherry, stems; Georgia	14 (1)	30:30	130	1.82	--	50 - 700
	15 (1)	30:30	110	2.37	--	10 - 700
Black cherry, leaves; Georgia	14 (1)	30:30	170	1.92	--	70 - 1,500
	15 (1)	30:30	140	1.95	--	20 - 500
Blackgum, stems; Georgia	14 (1)	30:30	150	1.81	--	70 - 700
	15 (1)	30:30	140	1.81	--	50 - 500
Blackgum, leaves; Georgia	14 (1)	30:30	200	2.22	--	20 - 1,500
	15 (1)	30:30	240	2.23	--	70 - 2,000
Buckbush; Missouri						
Glaciated Prairie	20 (1)	47:47	980	1.57	1.49	500 - 3,000
Unglaciated Prairie	20 (1)	48:48	1,200	1.76	1.49	150 - 3,000
Cedar Glade	20 (1)	50:50	710	1.51	1.49	300 - 2,000
Oak-hickory Forest	20 (1)	49:49	1,200	1.73	1.49	500 - 3,000
Oak-hickory-pine Forest	20 (1)	41:41	1,000	1.91	1.49	300 - 3,000
Cedar; Missouri						
Cedar Glade	20 (1)	50:50	330	1.67	1.49	150 - 1,500
Glaciated Prairie	24 (1)	9:9	630	1.73	--	300 - 1,500
Unglaciated Prairie	24 (1)	10:10	620	1.79	--	300 - 1,500
Cedar Glade	24 (1)	10:10	250	1.30	--	150 - 300
Oak-hickory Forest	24 (1)	10:10	300	2.04	--	70 - 700
Oak-hickory-pine Forest	24 (1)	6:6	280	2.32	--	100 - 1,000
Hickory, pignut; Kentucky	18 (1)	64:64	120	1.91	1.37	20 - 1,000
	19 (2)	88:88	91	1.43	1.10	30 - 220
Hickory, shagbark; Kentucky	18 (1)	40:40	130	1.60	1.37	50 - 500
	19 (2)	20:20	110	1.45	1.10	60 - 250
Hickory, shagbark; Missouri						
Oak-hickory Forest	20 (1)	19:19	110	1.92	1.49	30 - 200
Oak-hickory-pine Forest	20 (1)	7:7	120	1.57	1.49	70 - 200
Maple, red, stems; Georgia	14 (1)	30:30	86	1.81	--	20 - 300
	15 (1)	30:30	93	1.85	--	5 - 700
Maple, red, leaves; Georgia	14 (1)	30:30	140	2.33	--	30 - 700
	15 (1)	30:30	210	1.84	--	70 - 1,000
Oak, black; Kentucky	18 (1)	25:25	110	1.53	1.36	50 - 200
	19 (2)	22:22	80	1.23	1.10	50 - 110
Oak, post; Cedar Glade, Missouri	20 (1)	50:50	220	1.75	1.49	50 - 500

TABLE 46.—*Titanium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
PLANT ASH--Continued						
Native species--Continued						
Oak, red; Kentucky	18 (1)	28:28	81	1.99	1.36	10 - 300
	19 (2)	8:8	78	1.25	1.10	50 - 100
Oak, white; Kentucky	18 (1)	49:49	120	1.87	1.36	10 - 1,000
	19 (2)	75:75	89	1.31	1.10	50 - 200
Oak, white; Missouri						
Oak-hickory Forest	20 (1)	50:50	160	1.68	1.49	50 - 700
Oak-hickory-pine Forest	20 (1)	49:49	150	1.68	1.49	70 - 1,000
Oak, willow; Floodplain Forest, Missouri	20 (1)	46:46	190	1.72	1.49	70 - 1,000
Persimmon, stems; Georgia	14 (1)	29:29	96	2.09	--	<2 - 3,000
	15 (1)	30:30	100	2.18	--	20 - 300
Persimmon, leaves; Georgia	14 (1)	30:30	130	2.27	--	5 - 700
	15 (1)	30:30	150	1.99	--	50 - 1,000
Pine, shortleaf; Oak-hickory-pine Forest, Missouri	20 (1)	49:49	630	2.07	1.49	200 - 2,000
Sassafras, stems; Georgia	14 (1)	17:17	320	2.09	--	70 - 1,500
	15 (1)	27:27	200	3.64	--	15 - 2,000
Sassafras, leaves; Georgia	14 (1)	17:17	300	2.17	--	70 - 1,500
	15 (1)	27:27	280	2.42	--	30 - 1,500
Sumac, winged, stems; Georgia	14 (1)	30:30	150	2.27	--	20 - 700
	15 (1)	30:30	110	2.09	--	30 - 700
Sumac, winged, leaves; Georgia	14 (1)	30:30	200	2.01	--	70 - 1,500
	15 (1)	30:30	250	2.47	--	20 - 1,000
Sumac, smooth; Missouri						
Floodplain Forest	20 (1)	48:48	98	2.54	1.49	10 - 700
Glaciated Prairie	20 (1)	50:50	120	1.65	1.49	20 - 300
Unglaciated Prairie	20 (1)	49:49	120	1.99	1.49	20 - 1,000
Cedar Glade	20 (1)	49:49	94	1.77	1.49	30 - 300
Oak-hickory Forest	20 (1)	50:50	130	2.15	1.49	30 - 700
Oak-hickory-pine Forest	20 (1)	49:49	170	1.89	1.49	50 - 1,500
Sweetgum, stems; Georgia	14 (1)	28:28	77	1.84	--	30 - 200
	15 (1)	27:27	69	2.40	--	7 - 300
Sweetgum, leaves; Georgia	14 (1)	28:28	120	1.94	--	30 - 700
	15 (1)	27:27	140	2.09	--	30 - 700
Sweetgum; Floodplain Forest, Missouri	20 (1)	47:47	120	2.02	1.49	30 - 700

TABLE 47.—*Tungsten in soils and plant ash*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
SOILS						
Cultivated and uncultivated						
B horizon; Western United States-----	21 (1)	1:492	<100	--	--	<100 - 1,000
PLANT ASH						
Native species						
Sassafras, leaves; Georgia----------	14 (1)	1:17	<30	--	--	<30 - 50
Sweetgum, stems; Georgia----------	14 (1)	1:28	<30	--	--	<30 - 30
Sweetgum, leaves; Georgia----------	14 (1)	1:28	<30	--	--	<30 - 70

TABLE 48.—*Uranium in soils*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
Uncultivated						
Surface horizon; Powder River Basin, Wyoming and Montana----------	25 (8)	48:48	3.0	1.28	--	1.7 - 7.0

TABLE 49.—*Vanadium in rocks, unconsolidated geologic deposits, soils, and plant ash*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Granite						
Precambrian; Missouri	1 (1)	10:30	<7	--	--	<7 - 30
Rhyolite						
Precambrian; Missouri	1 (1)	14:30	<7	--	--	<7 - 70
Arkose						
Fountain Formation; Colorado	2 (2)	80:80	24	1.75	1.16	8 - 96
Sandstone						
Sauk sequence; Western United States	3 (2)	387:400	11	2.40	1.44	<2 - 270
Roubidoux Formation; Missouri	4 (1)	5:12	5.3	1.43	1.06	<7 - 10
Pope Megagroup;[1] Kentucky	5 (2)	109:120	16	2.22	1.43	<6 - 290
Pennsylvanian; Kentucky	5 (2)	149:152	20	2.18	1.20	<5 - 78
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	32:32	38	2.24	1.06	7 - 150
Shale						
Sauk sequence; Western United States	3 (2)	336:336	74	1.68	1.13	15 - 310
Lower Mississippian; Kentucky	8 (2)	76:76	110	1.61	--	40 - 390
Upper Mississippian; Kentucky	5 (2)	142:142	100	1.40	--	34 - 230
Mississippian; Missouri, Oklahoma, and Arkansas	7 (1)	18:18	120	1.87	1.14	50 - 500
Pennsylvanian; Kentucky	5 (2)	152:152	110	1.52	1.11	25 - 250
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	32:32	140	1.36	1.14	70 - 200
Black shale						
Devonian and Mississippian; Kentucky	9 (2)	76:88	400	2.34	1.10	120 - >1,100
Limestone and dolomite						
Sauk sequence; Western United States	3 (2)	285:392	14	2.39	1.20	<10 - 150
Sauk sequence; Missouri and Arkansas	4 (1)	29:48	6.5	1.70	1.22	<7 - 50
Upper Ordovician; Kentucky	5 (1)	58:80	16	1.70	1.25	<15 - 50
Tippecanoe sequence; Missouri	10 (1)	4:12	3.9	2.42	1.22	<7 - 15
Lower Mississippian; Kentucky	5 (1)	101:112	26	2.26	1.29	<15 - 150
Upper Mississippian; Kentucky	5 (1)	134:152	24	2.15	1.26	<15 - 200
Mississippian; Missouri, Oklahoma, and Arkansas	7 (1)	25:40	7.5	2.11	1.22	<7 - 70
Pennsylvanian; Kentucky	5 (1)	77:80	40	1.87	1.36	<15 - 100
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	29:32	15	2.29	1.22	<7 - 50
Siderite						
Upper Paleozoic; Kentucky	11 (1)	29:30	35	2.16	--	<15 - 150

[1] Of Swann and Willman (1961).

TABLE 48.—*Vanadium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
UNCONSOLIDATED GEOLOGIC DEPOSITS						
Carbonate residuum (terra rossa)						
On Gasconade Formation; Missouri	12 (1)	24:24	110	1.42	1.18	70 - 200
On Roubidoux Formation; Missouri	12 (1)	24:24	86	1.66	1.18	30 - 150
On Jefferson City, Cotter, and Powell Formations; Missouri and Arkansas	12 (1)	24:24	99	1.27	1.18	70 - 150
On Ozarkian rocks; Missouri	12 (1)	24:24	130	1.32	1.18	70 - 200
On Mesozoic rocks; Missouri	12 (1)	24:24	130	1.33	1.18	70 - 200
Loess						
Missouri	13 (1)	24:24	93	1.22	--	70 - 150
SOILS						
Cultivated						
Plow zone, garden; Georgia	14 (1)	30:30	20	1.92	--	10 - 100
	15 (1)	30:30	65	1.38	--	30 - 100
Plow zone, corn field; Missouri						
Floodplain Forest	17 (1)	8:8	52	1.74	1.16	20 - 100
Glaciated Prairie	17 (1)	10:10	84	1.21	1.16	70 - 100
Unglaciated Prairie	17 (1)	10:10	63	1.26	1.16	50 - 100
Oak-hickory Forest	17 (1)	10:10	78	1.35	1.16	50 - 100
Plow zone, soybean field; Missouri						
Floodplain Forest	17 (1)	10:10	42	1.65	1.16	15 - 70
Glaciated Prairie	17 (1)	10:10	93	1.16	1.16	70 - 100
Unglaciated Prairie	17 (1)	8:8	71	1.47	1.16	50 - 150
Oak-hickory Forest	17 (1)	9:9	60	1.19	1.16	50 - 70
Plow zone, pasture field; Missouri						
Floodplain Forest	17 (1)	10:10	48	1.49	1.16	20 - 70
Glaciated Prairie	17 (1)	10:10	78	1.33	1.16	50 - 100
Unglaciated Prairie	17 (1)	10:10	68	1.29	1.16	50 - 100
Oak-hickory Forest	17 (1)	10:10	63	1.18	1.16	50 - 70
Surface horizon; Missouri	16 (1)	1,140:1,140	69	1.50	1.25	15 - 150
Uncultivated						
Surface horizon; Powder River Basin, Wyoming and Montana	25 (1)	48:48	77	1.36	1.21	30 - 150
A horizon; Georgia	14 (1)	26:30	15	2.14	--	<5 - 150
	15 (1)	30:30	57	1.58	--	15 - 100
A horizon; Kentucky	18 (2)	96:96	42	1.52	1.04	15 - 120
	19 (2)	108:108	48	1.37	1.08	21 - 130
B horizon; Georgia	14 (1)	26:30	16	1.90	--	<5 - 70
	15 (1)	30:30	66	1.40	--	30 - 100
B horizon; Kentucky	18 (2)	96:96	83	1.54	1.04	22 - 260
B horizon; Missouri						
Floodplain Forest	20 (1)	50:50	64	1.87	1.18	15 - 150
Glaciated Prairie	20 (1)	50:50	110	1.34	1.18	70 - 150

TABLE 49.—*Vanadium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
SOILS--Continued						
Uncultivated--Continued						
B horizon; Missouri--Continued						
Unglaciated Prairie	20 (1)	50:50	92	1.39	1.18	50 - 150
Cedar Glade	20 (1)	50:50	59	1.58	1.18	20 - 150
Oak-hickory Forest	20 (1)	50:50	53	1.48	1.18	20 - 100
Oak-hickory-pine Forest	20 (1)	50:50	37	1.70	1.18	15 - 100
C horizon; Georgia	14 (1)	26:30	25	2.43	--	<5 - 70
	15 (1)	30:30	77	1.36	--	10 - 50
C horizon; Kentucky	18 (2)	96:96	84	1.70	1.04	19 - 320
Cultivated and uncultivated						
Surface horizon; Colorado	22 (1)	168:168	54	1.88	1.21	15 - 200
B horizon; Eastern United States	21 (1)	356:371	46	2.41	--	<5 - 300
B horizon; Western United States	21 (1)	492:492	66	1.91	--	7 - 500
PLANT ASH						
Cultivated plants						
Asparagus; Wisconsin	23 (1)	2:6	<5	--	--	<5 - 20
Bean, lima; Georgia	15 (1)	1:30	<5	--	--	<5 - 30
Bean, snap; Georgia	14 (1)	1:30	<5	--	--	<5 - 700
	15 (1)	1:30	<5	--	--	<5 - 200
Blackeyed pea; Georgia	14 (1)	1:29	<5	--	--	<5 - 20
Cabbage; Georgia	14 (1)	3:30	<5	--	--	<5 - 20
	15 (1)	5:30	<5	--	--	<5 - 50
Corn; Floodplain Forest, Missouri	17 (1)	1:8	<5	--	--	<5 - 15
Tomato; Georgia	14 (1)	3:30	<5	--	--	<5 - 30
Native species						
Black cherry, stems; Georgia	14 (1)	4:30	3	3.45	--	<5 - 30
	15 (1)	4:30	6.7	1.68	--	<5 - 20
Black cherry, leaves; Georgia	14 (1)	2:30	<5	--	--	<5 - 50
Blackgum, stems; Georgia	14 (1)	7:30	6.9	2.24	--	<5 - 30
	15 (1)	6:30	7.0	1.98	--	<5 - 20
Blackgum, leaves; Georgia	14 (1)	2:30	<5	--	--	<5 - 50
	15 (1)	7:30	5.8	2.80	--	<5 - 50
Buckbush; Missouri						
Glaciated Prairie	20 (1)	47:47	22	1.48	--	10 - 50
Unglaciated Prairie	20 (1)	48:48	23	1.55	--	10 - 50
Cedar Glade	20 (1)	50:50	14	1.52	--	5 - 30
Oak-hickory Forest	20 (1)	49:49	19	1.50	--	10 - 50
Oak-hickory-pine Forest	20 (1)	41:41	18	1.63	--	7 - 50
Cedar; Missouri						
Cedar Glade	20 (1)	17:50	2.6	3.08	--	<5 - 20
Glaciated Prairie	24 (1)	7:9	14	1.81	--	<5 - 30

TABLE 48.—*Vanadium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
		PLANT ASH--Continued				
Native species--Continued						
Cedar; Missouri--Continued						
Unglaciated Prairie	24 (1)	5:10	8.6	2.23	--	<5 - 30
Oak-hickory Forest	24 (1)	5:10	8.6	1.60	--	<5 - 15
Oak-hickory-pine Forest	24 (1)	1:6	<5	--	--	<5 - 10
Hickory, shagbark; Kentucky	18 (1)	1:40	<5	--	--	<5 - 10
Maple, red, stems; Georgia	14 (1)	4:30	4.6	2.35	--	<5 - 20
	15 (1)	1:30	<5	--	--	<5 - 20
Maple, red, leaves; Georgia	14 (1)	2:30	<5	--	--	<5 - 30
	15 (1)	2:30	<5	--	--	<5 - 30
Oak, black; Kentucky	18 (1)	1:25	<5	--	--	<5 - 15
Oak, red; Kentucky	18 (1)	1:27	<5	--	--	<5 - 20
Oak, white; Kentucky	18 (1)	3:49	<5	--	--	<5 - 20
Persimmon, stems; Georgia	14 (1)	4:29	4.6	2.35	--	<5 - 20
	15 (1)	5:30	6.0	2.07	--	<5 - 20
Persimmon, leaves; Georgia	14 (1)	1:30	<5	--	--	<5 - 30
	15 (1)	4:30	4.0	2.65	--	<5 - 30
Pine, shortleaf; Oak-hickory-pine Forest, Missouri	20 (1)	41:49	10	2.12	--	<5 - 30
Sassafras, stems; Georgia	14 (1)	10:17	15	1.83	--	<5 - 50
	15 (1)	9:27	7.4	3.13	--	<5 - 70
Sassafras, leaves; Georgia	14 (1)	5:17	7.0	2.95	--	<5 - 50
Sumac, winged, stems; Georgia	14 (1)	3:30	<5	--	--	<5 - 30
	15 (1)	2:30	<5	--	--	<5 - 30
Sumac, winged, leaves; Georgia	14 (1)	3:30	<5	--	--	<5 - 50
	15 (1)	7:17	6.2	2.59	--	<5 - 30
Sweetgum, stems; Georgia	14 (1)	3:28	4.0	2.45	--	<5 - 20
Sweetgum, leaves; Georgia	14 (1)	1:28	<5	--	--	<5 - 20
	15 (1)	2:27	<5	--	--	<5 - 30

TABLE 50.—*Ytterbium in rocks, unconsolidated geologic deposits, soils, and plant ash*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Granite						
Precambrian; Missouri	1 (1)	30:30	6.9	1.24	1.18	3 - 10
Rhyolite						
Precambrian; Missouri	1 (1)	30:30	7.7	1.31	1.18	3 - 15
Sandstone						
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	29:32	1.9	1.98	1.14	<1 - 7
Shale						
Mississippian; Missouri, Oklahoma, and Arkansas	7 (1)	18:18	2.3	1.93	1.31	1 - 10
Pennsylvanian; Kentucky	5 (1)	35:35	3.8	1.32	--	2 - 5
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	32:32	3.4	1.49	1.31	2 - 7
Limestone and dolomite						
Upper Ordovician; Kentucky	5 (1)	14:80	<2	--	--	<2 - 2
Lower Mississippian; Kentucky	8 (1)	21:112	<2	--	--	<2 - 7
Upper Mississippian; Kentucky	5 (1)	8:152	<2	--	--	<2 - 2
Mississippian; Missouri, Oklahoma, and Arkansas	7 (1)	18:40	<1	--	--	<1 - 3
Pennsylvanian; Kentucky	5 (1)	51:80	<2	--	--	<2 - 10
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	9:32	<1	--	--	<1 - 2
Siderite						
Upper Paleozoic; Kentucky	11 (1)	28:30	3.4	1.80	--	<2 - 7
UNCONSOLIDATED GEOLOGIC DEPOSITS						
Carbonate residuum (terra rossa)						
On Gasconade Formation; Missouri	12 (1)	22:24	1.5	1.64	1.18	<1 - 7
On Roubidoux Formation; Missouri	12 (1)	18:24	1.3	1.60	1.18	<1 - 3
On Jefferson City, Cotter, and Powell Formations; Missouri and Arkansas	12 (1)	18:24	1.3	1.61	1.18	<1 - 3
On Osagean rocks; Missouri	12 (1)	24:24	2.6	1.98	1.18	1 - 20
On Meramecian rocks; Missouri	12 (1)	24:24	2.5	1.93	1.18	1 - 10
Loess						
Missouri	13 (1)	24:24	3.5	2.75	--	2 - 7

TABLE 58.—*Ytterbium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
SOILS						
Cultivated						
Plow zone, garden; Georgia	14 (1)	30:30	2.7	1.76	--	1 - 20
	15 (1)	30:30	2.8	1.45	--	1.5 - 7
Plow zone, corn field; Missouri						
Floodplain Forest	17 (1)	8:8	2.0	1.56	1.23	1 - 5
Glaciated Prairie	17 (1)	10:10	2.7	1.22	1.23	2 - 3
Unglaciated Prairie	17 (1)	10:10	3.0	1.24	1.23	2 - 5
Plow zone, soybean field; Missouri						
Floodplain Forest	17 (1)	10:10	1.5	1.48	1.23	1 - 3
Glaciated Prairie	17 (1)	10:10	2.9	1.14	1.23	2 - 3
Unglaciated Prairie	17 (1)	8:8	3.6	1.30	1.23	3 - 5
Oak-hickory Forest	17 (1)	9:9	3.8	1.31	1.23	3 - 5
Plow zone, pasture field; Missouri						
Floodplain Forest	17 (1)	10:10	1.7	1.47	1.23	1 - 3
Glaciated Prairie	17 (1)	10:10	2.7	1.35	1.23	2 - 5
Unglaciated Prairie	17 (1)	10:10	3.7	1.30	1.23	3 - 5
Oak-hickory Forest	17 (1)	10:10	3.0	1.24	1.23	2 - 5
Surface horizon; Missouri	16 (1)	1,138:1,140	3.2	1.31	1.25	<1 - 7
Uncultivated						
Surface horizon; Powder River Basin, Wyoming and Montana	25 (1)	47:47	1.8	1.31	1.29	1 - 5
A horizon; Georgia	14 (1)	30:30	2.5	1.95	--	1 - 15
	15 (1)	30:30	3.5	2.01	--	1 - 30
B horizon; Georgia	14 (1)	30:30	2.5	1.66	--	1 - 10
	15 (1)	30:30	3.4	1.97	--	1.5 - 50
B horizon; Missouri						
Floodplain Forest	20 (1)	48:50	2.1	1.56	1.24	<1 - 5
Glaciated Prairie	20 (1)	50:50	3.0	1.27	1.24	2 - 5
Unglaciated Prairie	20 (1)	50:50	3.4	1.42	1.24	1.5 - 7
Cedar Glade	20 (1)	49:50	2.0	1.66	1.24	<1 - 7
Oak-hickory Forest	20 (1)	50:50	2.8	1.44	1.24	1 - 5
Oak-hickory-pine Forest	20 (1)	50:50	2.4	1.69	1.24	1 - 7
C horizon; Georgia	15 (1)	30:30	28	1.62	--	1 - 70
Cultivated and uncultivated						
Surface horizon; Colorado	22 (1)	164:168	2.4	1.73	1.31	<1 - 7
B horizon; Eastern United States	21 (1)	299:317	3.0	2.03	--	<1 - 50
B horizon; Western United States	21 (1)	469:478	3.0	1.67	--	<1 - 20

TABLE 50.—*Ytterbium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
		PLANT ASH				
Cultivated plants						
Cabbage; Georgia	14 (1)	2:28	<2	--	--	<2 - 30
	15 (1)	2:30	<2	--	--	<2 - 5
Corn; Georgia	14 (1)	1:29	<2	--	--	<2 - 500
Native species						
Black cherry, stems; Georgia	14 (1)	3:30	<2	--	--	<2 - 5
	15 (1)	3:30	<2	--	--	<2 - 3
Black cherry, leaves; Georgia	14 (1)	6:30	<2	--	--	<2 - 7
	15 (1)	4:30	<2	--	--	<2 - 3
Blackgum, stems; Georgia	14 (1)	4:30	<2	--	--	<2 - 7
	15 (1)	3:30	<2	--	--	<2 - 5
Blackgum, leaves; Georgia	14 (1)	5:30	<2	--	--	<2 - 3
	15 (1)	3:30	<2	--	--	<2 3
Buckbush; Missouri						
Glaciated Prairie	20 (1)	11:47	1.6	1.18	--	<2 - 2
Unglaciated Prairie	20 (1)	18:48	1.7	1.21	--	<2 - 3
Oak-hickory Forest	20 (1)	13:49	1.4	1.42	--	<2 - 3
Oak-hickory-pine Forest	20 (1)	13:41	1.5	1.51	--	<2 - 3
Hickory, pignut; Kentucky	18 (1)	32:64	1.8	1.98	1.09	<2 - 7
Hickory, shagbark; Kentucky	18 (1)	19:40	1.7	2.41	1.09	<2 - 10
Hickory, shagbark; Missouri						
Oak-hickory Forest	20 (1)	4:19	1.6	1.19	--	<2 - 2
Oak-hickory-pine Forest	20 (1)	4:7	<2	--	--	<2 - 7
Persimmon, stems; Georgia	14 (1)	5:30	<2	--	--	<2 - 7
	15 (1)	1:30	<2	--	--	<2 - 3
Persimmon, leaves; Georgia	14 (1)	7:30	<2	--	--	<2 - 20
	15 (1)	3:30	<2	--	--	<2 - 2
Pine, shortleaf; Oak-hickory-pine Forest, Missouri	20 (1)	6:49	1.4	1.23	--	<2 - 3
Sumac, winged, stems; Georgia	14 (1)	3:30	<2	--	--	<2 - 300
Sumac, winged, leaves; Georgia	15 (1)	6:30	<2	--	--	<2 - 7
Sweetgum, stems; Georgia	14 (1)	6:28	<2	--	--	<2 - 7
	15 (1)	5:27	<2	--	--	<2 - 3
Sweetgum, leaves; Georgia	14 (1)	6:28	<2	--	--	<2 - 300
	15 (1)	14:27	1.1	3.51	--	<2 - 7

TABLE 51.—*Yttrium in rocks, unconsolidated geologic deposits, soils, and plant ash*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Granite						
Precambrian; Missouri	1 (1)	30:30	69	1.32	1.15	30 - 100
Rhyolite						
Precambrian; Missouri	1 (1)	30:30	67	1.42	1.15	20 - 100
Arkose						
Fountain Formation; Colorado	2 (2)	58:80	9.4	2.45	--	<5 - 57
Sandstone						
Sauk sequence; Western United States	3 (2)	297:400	9	2.79	1.54	<5 - 140
Pope Megagroup;[1] Kentucky	5 (2)	33:120	11	2.23	1.21	<20 - 60
Pennsylvanian; Kentucky	5 (2)	123:152	12	2.27	1.45	<7 - 87
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	28:32	22	2.14	1.06	<10 - 50
Chert						
Mississippian; Missouri, Oklahoma, and Arkansas	7 (1)	1:20	<10	--	--	<10 - 15
Shale						
Sauk sequence; Western United States	3 (2)	292:336	35	1.65	1.17	<20 - 200
Lower Mississippian; Kentucky	8 (2)	71:76	30	1.39	--	<20 - 81
Upper Mississippian; Kentucky	5 (2)	130:142	30	1.40	--	<20 - 94
Mississippian; Missouri, Oklahoma, and Arkansas	7 (1)	18:18	25	1.87	1.19	10 - 150
Pennsylvanian; Kentucky	5 (2)	150:152	38	1.49	1.16	<20 - 480
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	32:32	30	1.61	1.19	10 - 70
Black shale						
Devonian and Mississippian; Kentucky	9 (2)	88:88	38	1.32	1.17	20 - 80
Limestone and dolomite						
Sauk sequence; Western United States	3 (2)	29:392	<25	--	--	<25 - 60
Upper Ordovician; Kentucky	5 (1)	11:80	14	1.22	--	<20 - 20
Tippecanoe sequence; Missouri	10 (1)	1:12	<10	--	--	<10 - 15
Lower Mississippian; Kentucky	5 (1)	21:112	<20	--	--	<20 - 70
Upper Mississippian; Kentucky	5 (1)	6:152	<20	--	--	<20 - 20
Mississippian; Missouri, Oklahoma, and Arkansas	7 (1)	34:40	17	1.97	1.09	<10 - 70
Pennsylvanian; Kentucky	5 (1)	50:80	20	--	--	<20 - 500

[1] Of Swann and Willman (1961).

TABLE 51.—*Yttrium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS--Continued						
Limestone and dolomite--Continued						
Pennsylvanian; Missouri, Kansas, and Oklahoma	6 (1)	15:32	8.0	2.39	1.09	<10 - 50
Siderite						
Upper Paleozoic; Kentucky	11 (1)	25:30	37	3.09	--	<20 - 700
UNCONSOLIDATED GEOLOGIC DEPOSITS						
Carbonate residuum (terra rossa)						
On Gasconade Formation; Missouri	12 (1)	16:24	10	--	--	<10 - 70
On Roubidoux Formation; Missouri	12 (1)	14:24	10	1.58	1.15	<10 - 30
On Jefferson City, Cotter, and Powell Formations; Missouri and Arkansas	12 (1)	13:24	10	--	--	<10 - 50
On Osagean rocks; Missouri	12 (1)	24:24	27	2.62	1.15	10 - 500
On Meramecian rocks; Missouri	12 (1)	23:24	27	2.54	1.15	<10 - 50
Loess						
Missouri	13 (1)	24:24	32	1.41	--	20 - 50
SOILS						
Cultivated						
Plow zone, garden; Georgia	14 (1)	29:30	22	1.99	--	<10 - 200
	15 (1)	30:30	25	1.44	--	15 - 50
Plow zone, corn field; Missouri						
Floodplain Forest	17 (1)	8:8	16	1.46	1.26	10 - 30
Glaciated Prairie	17 (1)	10:10	22	1.26	1.26	15 - 30
Unglaciated Prairie	17 (1)	10:10	25	1.37	1.26	20 - 50
Oak-hickory Forest	17 (1)	10:10	27	1.35	1.26	20 - 50
Plow zone, soybean field; Missouri						
Floodplain Forest	17 (1)	10:10	15	1.43	1.26	10 - 30
Glaciated Prairie	17 (1)	10:10	21	1.30	1.26	15 - 30
Unglaciated Prairie	17 (1)	8:8	32	1.35	1.26	20 - 50
Oak-hickory Forest	17 (1)	9:9	27	1.37	1.26	20 - 50
Plow zone, pasture field; Missouri						
Floodplain Forest	17 (1)	10:10	15	1.43	1.26	10 - 30
Glaciated Prairie	17 (1)	10:10	22	1.58	1.26	10 - 50
Unglaciated Prairie	17 (1)	10:10	31	1.36	1.26	20 - 50
Surface horizon; Missouri	16 (1)	1,138:1,140	32	1.35	1.25	<10 - 70
Uncultivated						
Surface horizon; Powder River Basin, Wyoming and Montana	25 (1)	48:48	17	1.28	1.18	10 - 50
A horizon; Georgia	14 (1)	29:30	21	2.04	--	<10 - 200
	15 (1)	30:30	26	1.83	--	10 - 150

TABLE 51—*Yttrium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
SOILS--Continued						
Uncultivated--Continued						
A horizon; Kentucky	18 (2)	96:96	33	1.26	1.08	19 - 60
	19 (2)	108:108	39	1.25	1.09	17 - 66
B horizon; Georgia	14 (1)	30:30	20	1.77	--	10 - 100
	15 (1)	30:30	26	2.00	--	10 - 500
B horizon; Kentucky	18 (2)	96:96	28	1.29	1.08	12 - 58
B horizon; Missouri						
Floodplain Forest	20 (1)	48:50	23	1.63	1.20	<10 - 50
Glaciated Prairie	20 (1)	50:50	30	1.30	1.20	15 - 50
Unglaciated Prairie	20 (1)	50:50	37	1.35	1.20	20 - 70
Cedar Glade	20 (1)	49:50	22	1.79	1.20	<10 - 70
Oak-hickory Forest	20 (1)	50:50	27	1.50	1.20	15 - 70
Oak-hickory-pine Forest	20 (1)	49:50	22	1.69	1.20	<10 - 70
C horizon; Georgia	14 (1)	29:30	25	2.30	--	<10 - 200
	15 (1)	30:30	21	1.57	--	10 - 50
C horizon; Kentucky	18 (2)	96:96	26	1.48	1.08	9 - 100
Cultivated and uncultivated						
Surface horizon; Colorado	22 (1)	159:168	18	1.77	1.37	<10 - 50
B horizon; Eastern United States	21 (1)	342:361	23	1.93	--	<5 - 200
B horizon; Western United States	21 (1)	480:492	25	1.66	--	<10 - 150
PLANT ASH						
Cultivated plants						
Bean, snap; Georgia	14 (1)	2:30	<5	--	--	<5 - 30
Blackeyed pea; Georgia	14 (1)	1:29	<5	--	--	<5 - 20
Cabbage; Georgia	14 (1)	3:28	<5	--	--	<5 - 100
	15 (1)	4:30	<5	--	--	<5 - 30
Tomato; Georgia	14 (1)	2:30	<5	--	--	<5 - 30
Native species						
Black cherry, stems; Georgia	14 (1)	7:30	<5	--	--	<5 - 70
	15 (1)	9:30	<5	--	--	<5 - 70
Black cherry, leaves; Georgia	14 (1)	8:30	<5	--	--	<5 - 150
	15 (1)	10:30	<5	--	--	<5 - 70
Blackgum, stems; Georgia	14 (1)	6:30	<5	--	--	<5 - 70
Blackgum, leaves; Georgia	14 (1)	5:30	<5	--	--	<5 - 70
Buckbush; Missouri						
Glaciated Prairie	20 (1)	14:47	17	1.16	--	<20 - 50
Unglaciated Prairie	20 (1)	17:48	16	1.28	--	<20 - 30
Oak-hickory Forest	20 (1)	16:49	15	1.21	--	<20 - 30
Oak-hickory-pine Forest	20 (1)	17:41	17	1.39	--	<20 - 30
Hickory, pignut; Kentucky	18 (1)	56:64	45	2.90	1.23	<20 - 500
	19 (2)	84:88	47	1.74	1.02	<20 - 160

TABLE 51.—*Yttrium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
PLANT ASH--Continued						
Native species--Continued						
Hickory, shagbark; Kentucky	18 (1)	34:40	41	3.14	1.23	<20 - 300
	19 (2)	19:20	35	1.48	1.02	<21 - 78
Hickory, shagbark; Missouri						
Oak-hickory Forest	20 (1)	14:19	23	1.69	--	<20 - 70
Oak-hickory-pine Forest	20 (1)	7:7	46	2.11	--	20 - 150
Oak, black; Kentucky	18 (1)	5:25	2.1	5.40	--	<10 - 30
	19 (2)	3:22	<10	--	--	<10 - 41
Oak, red; Kentucky	18 (1)	8:27	3.2	5.89	--	<10 - 100
Oak, white; Kentucky	18 (1)	12:49	3.0	4.52	--	<10 - 50
	19 (2)	3:74	<10	--	--	<10 - 54
Persimmon, stems; Georgia	14 (1)	7:30	<5	--	--	<5 - 300
	15 (1)	4:30	<5	--	--	<5 - 50
Persimmon, leaves; Georgia	14 (1)	8:30	<5	--	--	<5 - 300
	15 (1)	10:30	5.4	3.38	--	<5 - 30
Sumac, winged, stems; Georgia	14 (1)	5:30	<5	--	--	<5 - 70
Sumac, winged, leaves; Georgia	14 (1)	9:30	<5	--	--	<5 - 150
Sweetgum, stems; Georgia	14 (1)	6:28	<5	--	--	<5 - 150
	15 (1)	7:27	<5	--	--	<5 - 50
Sweetgum, leaves; Georgia	14 (1)	7:28	<5	--	--	<5 - 300

TABLE 52.—*Zinc in rocks, unconsolidated geologic deposits, soils, and plant ash*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Granite						
Precambrian; Missouri	1 (3)	30:30	51	2.29	1.04	15 - 310
Rhyolite						
Precambrian; Missouri	1 (3)	30:30	42	2.46	1.04	10 - 120

TABLE 52.—*Zinc in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS--Continued						
Sandstone						
Sauk sequence; Western United States-	3 (2)	58:400	<50	--	--	<50 - 530
Roubidoux Formation; Missouri--------	4 (3)	2:12	5.2	1.61	1.14	<10 - 12
Pennsylvanian; Missouri, Kansas, and Oklahoma----------	6 (3)	27:32	31	2.95	1.14	<10 - 280
Chert						
Mississippian; Missouri, Oklahoma, and Arkansas----------	7 (3)	5:20	<10	--	--	<10 - 90
Shale						
Lower Mississippian; Kentucky--------	8 (2)	4:76	<500	--	--	<500 - 650
Upper Mississippian; Kentucky--------	5 (2)	7:142	<500	--	--	<500 - 1,500
Mississippian; Missouri, Oklahoma, and Arkansas----------	7 (3)	18:18	55	3.09	1.08	6 - 250
Pennsylvanian; Kentucky----------	5 (2)	4:152	<500	--	--	<500 - 780
Pennsylvanian; Missouri, Kansas, and Oklahoma----------	6 (3)	32:32	82	1.47	1.08	25 - 130
Black shale						
Devonian and Mississippian; Kentucky-	9 (2)	8:8	<500	--	--	<500 - 2,300
Limestone and dolomite						
Sauk sequence; Western United States-	3 (2)	8:392	<500	--	--	<500 - 1,300
Sauk sequence; Missouri and Arkansas-	4 (3)	17:48	6.3	2.05	1.72	<10 - 50
Tippecanoe sequence; Missouri--------	10 (3)	9:12	12	1.53	1.72	<10 - 22
Mississippian; Missouri, Oklahoma, and Arkansas----------	7 (3)	38:40	19	1.68	1.72	<10 - 100
Pennsylvanian; Missouri, Kansas, and Oklahoma----------	6 (3)	31:32	24	2.32	1.72	<10 - 140
UNCONSOLIDATED GEOLOGIC DEPOSITS						
Carbonate residuum (terra rossa)						
On Cassconade Formation; Missouri-----	12 (3)	24:24	92	1.99	1.04	32 - 370
On Roubidoux Formation; Missouri-----	12 (3)	24:24	66	2.15	1.04	20 - 250
On Jefferson City, Cotter, and Powell Formations; Missouri and Arkansas--	12 (3)	24:24	50	1.35	1.04	30 - 100
On Ozarkian rocks; Missouri----------	12 (3)	24:24	110	1.69	1.04	42 - 400
On Mesozoic rocks; Missouri--------	12 (3)	24:24	120	1.97	1.04	44 - 1,000
Loess						
Missouri----------	13 (3)	24:24	61	1.27	--	37 - 90
SOILS						
Cultivated						
Plow zone, garden; Georgia----------	14 (6)	1:30	<25	--	--	<25 - 700
	15 (6)	29:30	64	1.82	--	<25 - 1,000

TABLE 52.—*Zinc in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
SOILS--Continued						
Cultivated--Continued						
Plow zone, corn field; Missouri						
Floodplain Forest	17 (3)	8:8	37	1.69	1.07	13 - 62
Glaciated Prairie	17 (3)	10:10	55	1.29	1.07	34 - 74
Unglaciated Prairie	17 (3)	10:10	41	1.29	1.07	30 - 57
Oak-hickory Forest	17 (3)	10:10	53	1.43	1.07	31 - 100
Plow zone, soybean field; Missouri						
Floodplain Forest	17 (3)	10:10	42	1.74	1.07	16 - 74
Glaciated Prairie	17 (3)	10:10	61	1.26	1.07	45 - 92
Unglaciated Prairie	17 (3)	8:8	63	2.11	1.07	41 - 360
Oak-hickory Forest	17 (3)	9:9	41	1.41	1.07	26 - 65
Plow zone, pasture field; Missouri						
Floodplain Forest	17 (3)	10:10	45	1.70	1.07	20 - 147
Glaciated Prairie	17 (3)	10:10	68	1.74	1.07	37 - 300
Unglaciated Prairie	17 (3)	10:10	41	1.29	1.07	31 - 66
Oak-hickory Forest	17 (3)	10:10	58	1.74	1.07	27 - 235
Surface horizon; Missouri	16 (3)	1,140:1,140	49	1.55	1.08	18 - 640
Uncultivated						
A horizon; Georgia	14 (6)	7:30	<25	--	--	<25 - 50
	15 (6)	29:30	40	1.64	--	<25 - 100
A horizon; Kentucky	18 (3)	80:96	27	1.43	1.04	<20 - 75
	19 (3)	89:108	26	1.46	1.08	<20 - 135
B horizon; Georgia	14 (6)	3:30	<25	--	--	<25 - 25
	15 (6)	28:30	41	1.61	--	<25 - 75
B horizon; Kentucky	18 (3)	86:96	36	1.55	1.04	<20 - 110
B horizon; Missouri						
Floodplain Forest	20 (3)	50:50	54	1.67	1.12	18 - 153
Glaciated Prairie	20 (3)	50:50	67	1.44	1.12	31 - 194
Unglaciated Prairie	20 (3)	50:50	51	1.41	1.12	22 - 116
Cedar Glade	20 (3)	50:50	54	1.71	1.12	22 - 275
Oak-hickory Forest	20 (3)	50:50	36	1.59	1.12	12 - 190
Oak-hickory-pine Forest	20 (3)	50:50	30	1.62	1.12	10 - 138
C horizon; Georgia	14 (6)	3:30	<25	--	--	<25 - 50
	15 (6)	30:30	43	1.59	--	25 - 100
C horizon; Kentucky	18 (3)	86:96	33	1.74	1.04	<20 - 180
Cultivated and uncultivated						
Surface horizon; Colorado	22 (3)	168:168	58	1.70	1.07	16 - 300
B horizon; Eastern United States	21 (6)	314-371	36	1.89	--	<5 - 400
B horizon; Western United States	21 (6)	481:492	51	1.78	--	<10 - 2,000

TABLE 52.—*Zinc in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
PLANT ASH						
Cultivated plants						
Asparagus; Wisconsin	23 (6)	5:5	280	1.46	--	200 - 400
Bean, lima; Georgia	14 (6)	30:30	600	1.18	--	400 - 1,000
	15 (6)	15:15	390	1.47	--	200 - 700
Bean, snap; Georgia	14 (6)	30:30	530	1.36	--	200 - 1,000
	15 (6)	30:30	520	1.23	--	300 - 800
Beet, red; Wisconsin	23 (6)	3:3	390	1.29	--	300 - 500
Blackeyed pea; Georgia	14 (6)	29:29	750	1.27	--	400 - 1,200
	15 (6)	4:4	650	1.09	--	600 - 700
Cabbage; Georgia	14 (6)	28:28	340	2.57	--	100 - 5,000
	15 (6)	30:30	210	2.39	--	100 - 6,000
Cabbage; Wisconsin	23 (6)	11:11	250	1.53	--	100 - 400
Carrot; Wisconsin	23 (6)	8:8	180	1.46	--	100 - 300
Corn; Georgia	14 (6)	29:29	840	1.44	--	400 - 2,000
	15 (6)	30:30	850	1.38	--	600 - 2,000
Corn; Missouri						
Floodplain Forest	17 (3)	8:8	1,700	1.14	1.11	1,400 - 2,200
Glaciated Prairie	17 (3)	10:10	1,800	1.29	1.11	1,200 - 2,800
Unglaciated Prairie	17 (3)	10:10	1,900	1.11	1.11	1,600 - 2,300
Oak-hickory Forest	17 (3)	10:10	1,900	1.25	1.11	1,400 - 2,500
Corn; Wisconsin	23 (6)	27:27	1,000	1.30	--	500 - 1,600
Cucumber; Wisconsin	23 (6)	4:4	310	1.39	--	200 - 400
Onion; Wisconsin	23 (6)	7:7	330	1.44	--	200 - 500
Pepper, sweet; Wisconsin	23 (6)	4:4	260	1.40	--	200 - 400
Potato; Wisconsin	23 (6)	10:10	280	1.41	--	200 - 400
Soybean; Missouri						
Floodplain Forest	17 (3)	10:10	890	1.17	1.11	700 - 1,140
Glaciated Prairie	17 (3)	10:10	870	1.09	1.11	840 - 960
Unglaciated Prairie	17 (3)	8:8	1,100	1.19	1.11	1,000 - 1,500
Oak-hickory Forest	17 (3)	9:9	1,100	1.08	1.11	920 - 1,200
Tomato; Georgia	14 (6)	30:30	290	1.40	--	200 - 600
	15 (6)	30:30	210	1.39	--	100 - 400
Native species						
Black cherry, stems; Georgia	14 (6)	30:30	1,300	1.59	--	300 - 3,000
	15 (6)	30:30	1,100	1.64	--	500 - 4,000
Black cherry, leaves; Georgia	14 (6)	30:30	220	1.66	--	100 - 2,000
	15 (6)	30:30	200	1.38	--	100 - 300
Blackgum, stems; Georgia	14 (6)	30:30	910	1.65	--	400 - 3,000
	15 (6)	30:30	970	1.47	--	500 - 2,000
Blackgum, leaves; Georgia	14 (6)	30:30	260	1.39	--	100 - 500
	15 (6)	30:30	270	1.37	--	200 - 600
Buckbush; Missouri						
Glaciated Prairie	20 (3)	47:47	1,400	1.48	1.21	580 - 3,200
Unglaciated Prairie	20 (3)	48:48	1,800	1.79	1.21	640 - 7,400
Cedar Glade	20 (3)	50:50	1,200	1.40	1.21	440 - 2,800

TABLE 52.—*Zinc in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
PLANT ASH--Continued						
Native species--Continued						
Buckbush; Missouri--Continued						
Oak-hickory Forest	20 (3)	49:49	1,400	1.41	1.21	600 - 3,400
Oak-hickory-pine Forest	20 (3)	41:41	1,400	1.53	1.21	530 - 3,500
Cedar; Missouri						
Cedar Glade	20 (3)	50:50	310	1.27	1.21	200 - 520
Glaciated Prairie	24 (3)	9:9	640	2.02	--	340 - 3,600
Unglaciated Prairie	24 (3)	10:10	740	1.54	--	380 - 1,440
Cedar Glade	24 (3)	10:10	320	1.22	--	280 - 540
Oak-hickory Forest	24 (3)	10:10	480	1.67	--	300 - 1,800
Oak-hickory-pine Forest	24 (3)	6:6	380	1.26	--	280 - 560
Hickory, pignut; Kentucky	18 (3)	60:60	1,500	1.75	1.09	400 - 10,000
	19 (3)	88:88	1,000	2.05	1.15	200 - 4,700
Hickory, shagbark; Kentucky	18 (3)	40:40	1,600	1.72	1.09	400 - 3,700
	19 (3)	20:20	1,000	1.82	1.15	300 - 2,300
Hickory, shagbark; Missouri						
Oak-hickory Forest	20 (3)	19:19	1,500	1.65	1.21	440 - 3,800
Oak-hickory-pine Forest	20 (3)	7:7	1,600	1.24	1.21	1,180 - 2,200
Maple, red, stems; Georgia	14 (6)	30:30	480	1.40	--	300 - 1,200
	15 (6)	30:30	690	1.30	--	400 - 1,200
Maple, red, leaves; Georgia	14 (6)	30:30	450	1.41	--	200 - 1,200
	15 (6)	30:30	570	1.29	--	400 - 1,200
Oak, black; Kentucky	18 (3)	25:25	540	1.65	1.14	200 - 1,200
	19 (3)	22:22	430	1.60	1.15	200 - 1,500
Oak, post; Cedar Glade, Missouri	20 (3)	50:50	300	1.43	1.21	160 - 620
Oak, red; Kentucky	18 (3)	27:27	460	1.63	1.14	200 - 2,100
	19 (3)	9:9	410	1.37	1.15	200 - 600
Oak, white; Kentucky	18 (3)	48:48	430	1.67	1.14	180 - 2,100
	19 (3)	76:76	400	1.57	1.15	100 - 2,400
Oak, white; Missouri						
Oak-hickory Forest	20 (3)	50:50	320	1.31	1.21	160 - 500
Oak-hickory-pine Forest	20 (3)	49:49	350	1.39	1.21	160 - 600
Oak, willow; Floodplain Forest, Missouri	20 (3)	46:46	440	1.59	1.21	160 - 2,200
Persimmon, stems; Georgia	14 (6)	30:30	790	1.46	--	400 - 2,000
	15 (6)	30:30	1,100	1.61	--	400 - 3,000
Persimmon, leaves; Georgia	14 (6)	30:30	170	1.58	--	100 - 500
	15 (6)	30:30	200	1.32	--	100 - 300
Pine, shortleaf; Oak-hickory-pine Forest, Missouri	20 (3)	49:49	1,200	1.41	1.21	360 - 2,100
Sagebrush; Powder River Basin, Wyoming and Montana	25 (3)	48:48	421	1.30	--	200 - 800
Sassafras, stems; Georgia	14 (6)	17:17	1,600	1.94	--	600 - 6,000
	15 (6)	27:27	1,300	1.68	--	400 - 3,000
Sassafras, leaves; Georgia	14 (6)	17:17	550	1.67	--	300 - 2,000
	15 (6)	27:27	460	1.28	--	300 - 1,000

TABLE 52.—*Zinc in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
PLANT ASH--Continued						
Native species--Continued						
Sumac, winged, stems; Georgia	14 (6)	30:30	740	1.43	--	300 - 1,600
	15 (6)	30:30	780	1.64	--	300 - 2,100
Sumac, winged, leaves; Georgia	14 (6)	30:30	360	1.33	--	200 - 700
	15 (6)	30:30	370	1.44	--	200 - 1,000
Sumac, smooth; Missouri						
Floodplain Forest	20 (3)	48:48	770	1.63	1.21	300 - 3,100
Glaciated Prairie	20 (3)	50:50	860	1.44	1.21	360 - 1,800
Unglaciated Prairie	20 (3)	49:49	820	1.42	1.21	460 - 2,200
Cedar Glade	20 (3)	49:49	520	1.59	1.21	160 - 1,600
Oak-hickory Forest	20 (3)	50:50	660	1.41	1.21	360 - 1,600
Oak-hickory-pine Forest	20 (3)	49:49	500	1.56	1.21	160 - 1,400
Sweetgum, stems; Georgia	14 (6)	28:28	560	1.56	--	200 - 1,200
	15 (6)	27:27	710	1.57	--	400 - 2,000
Sweetgum, leaves; Georgia	14 (6)	28:28	560	1.41	--	300 - 1,200
	15 (6)	27:27	760	1.35	--	400 - 1,200

TABLE 53.—*Zirconium in rocks, unconsolidated geologic deposits, soils, and plant ash*

[Explanation of column headings: Study No. refers to study described in text; method of analysis (in parentheses) refers to method listed in table 1. Ratio, number of samples in which the element was found in measurable concentrations to number of samples analyzed. Mean, geometric mean. Deviation, geometric deviation. Error, geometric error attributed to laboratory procedures. Leaders (--) in figure column indicate no data available]

Sample and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS						
Granite						
Precambrian; Missouri	1 (1)	30:30	140	1.56	1.39	70 - 500
Rhyolite						
Precambrian; Missouri	1 (1)	30:30	200	1.76	1.39	20 - 500
Arkose						
Fountain Formation; Colorado	2 (2)	80:80	55	1.72	1.37	18 - 170
Sandstone						
Sauk sequence; Western United States	3 (2)	400:400	74	2.49	1.42	10 - 880

TABLE 53.—*Zirconium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
ROCKS--Continued						
Sandstone--Continued						
Roubidoux Formation; Missouri--------	4 (1)	12:12	22	1.63	1.32	10 - 30
Pope Megagroup;[1] Kentucky----------	5 (2)	120:120	130	2.04	1.34	21 - 720
Pennsylvanian; Kentucky----------	5 (2)	152:152	120	2.44	1.30	22 - 1,000
Pennsylvanian; Missouri, Kansas, and Oklahoma----------	6 (1)	32:32	170	2.28	1.32	30 - 700
Chert						
Mississippian; Missouri, Oklahoma, and Arkansas----------	7 (1)	3:20	1.1	6.90	1.32	<10 - 30
Shale						
Sauk sequence; Western United States-	3 (2)	327:336	190	1.98	1.15	<36 - 840
Lower Mississippian; Kentucky--------	8 (2)	76:76	150	1.96	--	48 - 770
Upper Mississippian; Kentucky--------	5 (2)	142:142	180	1.62	--	79 - 720
Mississippian; Missouri, Oklahoma, and Arkansas----------	7 (1)	18:18	95	2.00	1.46	30 - 300
Pennsylvanian; Kentucky----------	5 (2)	151:152	230	1.63	1.13	93 - >1,000
Pennsylvanian; Missouri, Kansas, and Oklahoma----------	6 (1)	32:32	110	1.48	1.46	70 - 300
Black shale						
Devonian and Mississippian; Kentucky-	9 (2)	88:88	140	1.25	1.10	75 - 280
Limestone and dolomite						
Sauk sequence; Western United States-	3 (2)	231:392	23	2.21	1.19	<25 - 160
Sauk sequence; Missouri and Arkansas-	4 (1)	21:48	7.2	1.98	1.15	<10 - 30
Upper Ordovician; Kentucky----------	5 (1)	55:80	32	2.28	1.52	<20 - 100
Tippecanoe sequence; Missouri--------	10 (1)	4:12	<10	--	--	<10 - 50
Lower Mississippian; Kentucky--------	5 (1)	47:112	12	6.12	1.19	<20 - 1,000
Upper Mississippian; Kentucky--------	5 (1)	34:152	6.5	3.79	--	<20 - 150
Mississippian; Missouri, Oklahoma, and Arkansas----------	7 (1)	18:40	6.7	4.79	1.15	<10 - 30
Pennsylvanian; Kentucky----------	5 (1)	58:80	42	2.77	1.33	<20 - 200
Pennsylvanian; Missouri, Kansas, and Oklahoma----------	6 (1)	25:32	14	2.28	1.15	<10 - 70
Siderite						
Upper Paleozoic; Kentucky----------	11 (1)	23:30	32	2.47	--	<20 - 150
UNCONSOLIDATED GEOLOGIC DEPOSITS						
Carbonate residuum (terra rossa)						
On Gasconade Formation; Missouri-----	12 (1)	24:24	61	1.40	1.20	30 - 150
On Roubidoux Formation; Missouri-----	12 (1)	24:24	67	1.46	1.20	30 - 150
On Jefferson City, Cotter, and Powell Formations; Missouri and Arkansas--	12 (1)	24:24	65	1.33	1.20	30 - 100
On Osagean rocks; Missouri----------	12 (1)	24:24	67	1.26	1.20	50 - 100
On Meramecian rocks; Missouri--------	12 (1)	24:24	67	1.23	1.20	50 - 100

[1] Of Swann and Willman (1961).

TABLE 58.—*Zirconium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
UNCONSOLIDATED GEOLOGIC DEPOSITS--Continued						
Loess						
Missouri	13 (1)	24:24	230	1.32	--	150 - 300
SOILS						
Cultivated						
Plow zone, garden; Georgia	14 (1)	30:30	310	1.59	--	150 - 700
	15 (1)	30:30	180	1.48	--	70 - 300
Plow zone, corn field; Missouri						
Floodplain Forest	17 (1)	8:8	190	1.77	1.32	100 - 700
Glaciated Prairie	17 (1)	10:10	180	1.16	1.32	150 - 200
Unglaciated Prairie	17 (1)	10:10	240	1.23	1.32	200 - 300
Oak-hickory Forest	17 (1)	10:10	260	1.61	1.32	100 - 500
Plow zone, soybean field; Missouri						
Floodplain Forest	17 (1)	10:10	150	1.39	1.32	70 - 200
Glaciated Prairie	17 (1)	10:10	180	1.34	1.32	100 - 300
Unglaciated Prairie	17 (1)	8:8	270	1.37	1.32	200 - 500
Oak-hickory Forest	17 (1)	9:9	360	1.40	1.32	200 - 500
Plow zone, pasture field; Missouri						
Floodplain Forest	17 (1)	10:10	140	1.36	1.32	100 - 200
Glaciated Prairie	17 (1)	10:10	190	1.30	1.32	100 - 300
Unglaciated Prairie	17 (1)	10:10	290	1.29	1.32	200 - 500
Oak-hickory Forest	17 (1)	10:10	240	1.30	1.32	150 - 300
Surface horizon; Missouri	16 (1)	1,140:1,140	310	1.53	1.35	70 - 700
Uncultivated						
Surface horizon; Powder River Basin, Wyoming and Montana	25 (1)	48:48	150	1.45	1.20	70 - 500
A horizon; Georgia	14 (1)	30:30	260	1.60	--	100 - 700
A horizon; Kentucky	18 (2)	96:96	440	1.30	--	210 - 800
	19 (2)	108:108	460	1.34	1.14	160 - 890
B horizon; Georgia	14 (1)	30:30	290	1.62	--	100 - 700
	15 (1)	30:30	210	1.51	--	70 - 500
B horizon; Kentucky	18 (2)	96:96	330	1.40	--	140 - 860
B horizon; Missouri						
Floodplain Forest	20 (1)	50:50	160	1.93	1.48	30 - 500
Glaciated Prairie	20 (1)	50:50	210	1.42	1.48	100 - 500
Unglaciated Prairie	20 (1)	50:50	300	1.52	1.48	150 - 700
Cedar Glade	20 (1)	50:50	120	1.68	1.48	50 - 500
Oak-hickory Forest	20 (1)	50:50	300	1.63	1.48	70 - 700
Oak-hickory-pine Forest	20 (1)	50:50	260	1.74	1.48	70 - 500
C horizon; Kentucky	18 (2)	96:96	280	1.56	--	100 - 660

TABLE 55.—*Zirconium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
SOILS--Continued						
Cultivated and uncultivated						
Surface horizon; Colorado	22 (1)	168:168	135	1.80	1.29	46 - 500
B horizon; Eastern United States	21 (1)	371:371	250	1.95	--	30 - 2,000
B horizon; Western United States	21 (1)	491:492	170	1.78	--	<30 - 1,500
PLANT ASH						
Cultivated plants						
Bean, lima; Georgia	14 (1)	1:30	<20	--	--	<20 - 70
	15 (1)	1:15	<20	--	--	<20 - 50
Bean, snap; Georgia	14 (1)	5:30	<20	--	--	<20 - 150
	15 (1)	1:30	<20	--	--	<20 - 30
Blackeyed pea; Georgia	14 (1)	1:29	<20	--	--	<20 - 20
Cabbage; Georgia	14 (1)	6:28	<20	--	--	<20 - 700
	15 (1)	9:30	<20	--	--	<20 - 500
Corn; Georgia	14 (1)	1:29	<20	--	--	<20 - 20
Corn; Floodplain Forest, Missouri	17 (1)	1:8	<20	--	--	<20 - 20
Tomato; Georgia	14 (1)	1:30	<20	--	--	<20 - 20
Native species						
Black cherry, stems; Georgia	14 (1)	3:30	<20	--	--	<20 - 30
Black cherry, leaves; Georgia	14 (1)	7:30	<20	--	--	<20 - 70
	15 (1)	1:30	<20	--	--	<20 - 30
Blackgum, stems; Georgia	14 (1)	7:30	<20	--	--	<20 - 50
	15 (1)	4:30	<20	--	--	<20 - 30
Blackgum, leaves; Georgia	14 (1)	15:30	9.7	4.11	--	<20 - 70
	15 (1)	11:30	<20	--	--	<20 - 150
Buckbush; Missouri						
Glaciated Prairie	20 (1)	47:47	69	1.78	--	20 - 200
Unglaciated Prairie	20 (1)	48:48	85	1.71	--	30 - 200
Cedar Glade	20 (1)	48:50	44	1.68	--	<20 - 150
Oak-hickory Forest	20 (1)	49:49	79	2.16	--	20 - 500
Oak-hickory-pine Forest	20 (1)	41:41	66	2.32	--	20 - 200
Cedar; Missouri						
Glaciated Prairie	24 (1)	8:9	44	1.86	--	<20 - 100
Unglaciated Prairie	24 (1)	10:10	44	1.72	--	20 - 70
Cedar Glade	24 (1)	5:10	18	1.52	--	<20 - 30
Oak-hickory Forest	24 (1)	8:10	29	1.89	--	<20 - 70
Oak-hickory-pine Forest	24 (1)	3:6	17	2.59	--	<20 - 70
Hickory, shagbark; Oak-hickory-pine Forest; Missouri	20 (1)	2:19	7.6	1.97	--	<20 - 30
Maple, red, stems; Georgia	14 (1)	3:30	<20	--	--	<20 - 30
	15 (1)	1:30	<20	--	--	<20 - 20

TABLE 58.—*Zirconium in rocks, unconsolidated geologic deposits, soils, and plant ash*—Continued

Sample, and collection locality	Study No. and method of analysis	Ratio	Mean (ppm)	Deviation	Error	Observed range (ppm)
		PLANT ASH--Continued				
Native species--Continued						
Maple, red, leaves; Georgia	14 (1)	12:30	6.5	4.19	--	<20 - 70
	15 (1)	3:30	<20	--	--	<20 - 150
Persimmon, stems; Georgia	14 (1)	6:30	2.4	4.61	--	<20 - 30
	15 (1)	1:30	<20	--	--	<20 - 20
Persimmon, leaves; Georgia	14 (1)	7:30	2.7	4.91	--	<20 - 30
	15 (1)	3:30	<20	--	--	<20 - 70
Pine, shortleaf; Oak-hickory-pine Forest; Missouri	20 (1)	36:49	29	2.62	--	<20 - 150
Sassafras, stems; Georgia	14 (1)	7:17	<20	--	--	<20 - 150
	15 (1)	7:27	<20	--	--	<20 - 70
Sassafras, leaves; Georgia	14 (1)	7:17	<20	--	--	<20 - 150
	15 (1)	6:27	<20	--	--	<20 - 150
Sumac, winged, stems; Georgia	14 (1)	7:30	<20	--	--	<20 - 100
	15 (1)	3:30	<20	--	--	<20 - 70
Sumac, winged, leaves; Georgia	14 (1)	12:30	6.2	5.00	--	<20 - 100
	15 (1)	7:30	<20	--	--	<20 - 150
Sumac, smooth; Missouri						
Floodplain Forest	20 (1)	6:48	4.1	3.49	--	<20 - 50
Oak-hickory Forest	20 (1)	11:50	11	1.85	--	<20 - 50
Sweetgum; Floodplain Forest, Missouri	20 (1)	6:47	6.7	2.30	--	<20 - 50

ERM-North Central, Inc.
Environmental Resources Management

102 Wilmot Road • Suite 300 • Deerfield, Illinois 60015 ☎ (312) 940-7200

MEMORANDUM

TO: Al Sloan
Karen Vendl
John Buck

FROM: Dave Schlott DAS

DATE: March 17, 1989

SUBJECT: ECC - Response to 3/17/89 Conference Call Questions

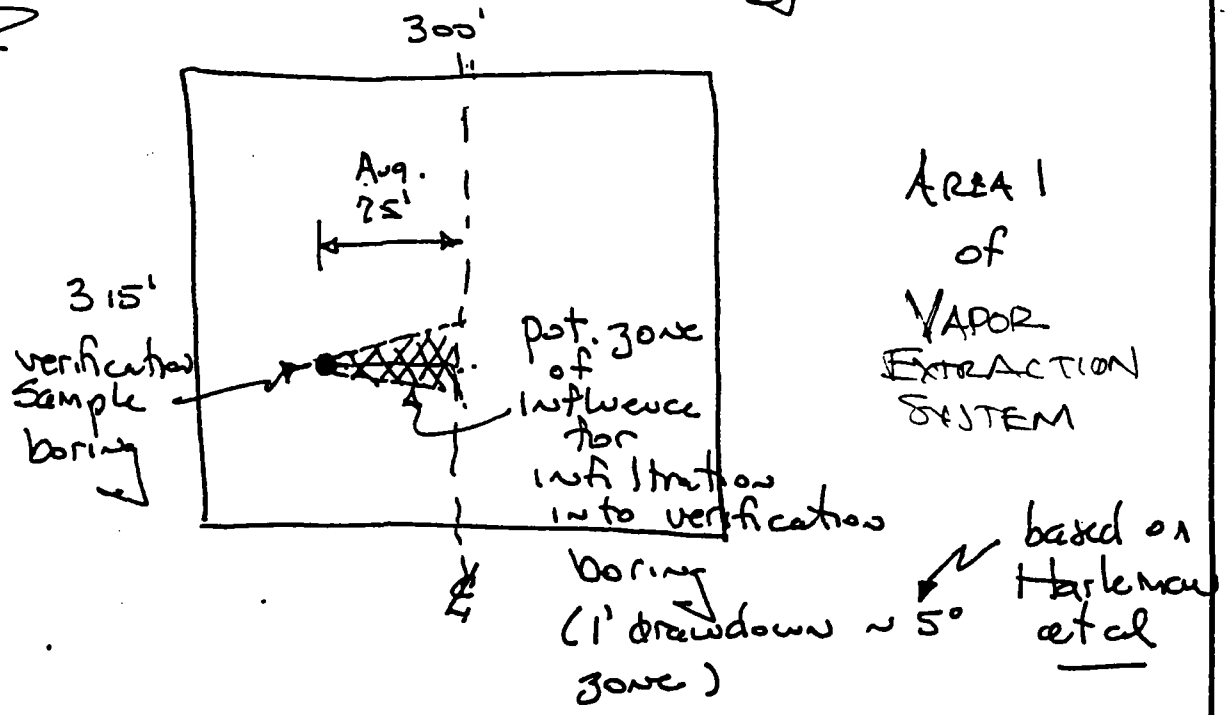
Attached please find an evaluation of the impact of locating 20 verification borings thru the final cover detail. Balance of information requested will be faxed on Monday.

cc: John Kyle
Tim Harker
Jerry Amber
Don Smith

ERM-North Central, Inc. Suite 300 • 102 Wilmot Road • Deerfield, Illinois 60015 • (312) 940-7200

Project ECC W.O. No. Sheet of
Subject Response to 3/17/89 Q. Time of travel - cont. By RGB/DAS Date 3/17/89
Chkd by Date

Plan - Effect of verification borings.



$$\text{AREA} = [75'(\sin 2\tfrac{1}{2}°)]75' \doteq 250\ ft^2$$

For 20 borings => $\frac{20(250\ ft^2)}{150{,}000} = 3.3\%$

NB - cap. performance assumed to be 99% efficient without borings.

Therefore, verification borings could increase infiltration by a factor of 3.3.

ERM-North Central, Inc.
Environmental Resources Management

102 Wilmot Road • Suite 300 • Deerfield, Illinois 60015 ☎ (312) 940-7200

March 21, 1989

Karen Vendl
Remedial Project Manager
USEPA
Region 5 (5HS-11)
230 South Dearborn Street
Chicago, IL 60604

RE: EnviroChem (ECC) Site

Dear Ms. Vendl:

Attached is the information requested during our telephone conference on 3/17/89. We look forward to the meeting John Kyle is setting up with you and the EPA's Innovative Technology group for next week to discuss technical issues.

Sincerely,

ERM-NORTH CENTRAL, INC.

David A. Schlott

jls

cc: Al Sloan
John Buck

ERM-North Central, Inc.

ATTACHMENT TO LETTER DATED 3/21/89

I. Vertical Movement of Water Through Cover System To The Saturated Till

Calculations and assumptions are shown in Figure 1 attached.

II. Other Factors

Two additional factors influence the time required for surface water to migrate through the unsaturated zone and to a monitoring well:

(1) re-establishment of field moisture capacity; and

(2) horizontal movement of water in the native till soil.

Field moisture capacity (estimated at 15%-30% for soil typical of the ECC site*) will be reestablished by water infiltrating through the cover system and the soils dehydrated by the vapor extraction process. Although the RI estimated the net infiltration rate to be 7.8 inches per year, the RCRA compliant cover system will reduce the rate of infiltration by 99%.

Regarding the horizontal movement of water in the till, the RI states that the velocity at the ECC site ranges between 1.0 and 2.6 feet per year.

* Dragun, James, The Soil Chemistry of Hazardous Materials, Hazardous Materials Control Research Institute (1988)

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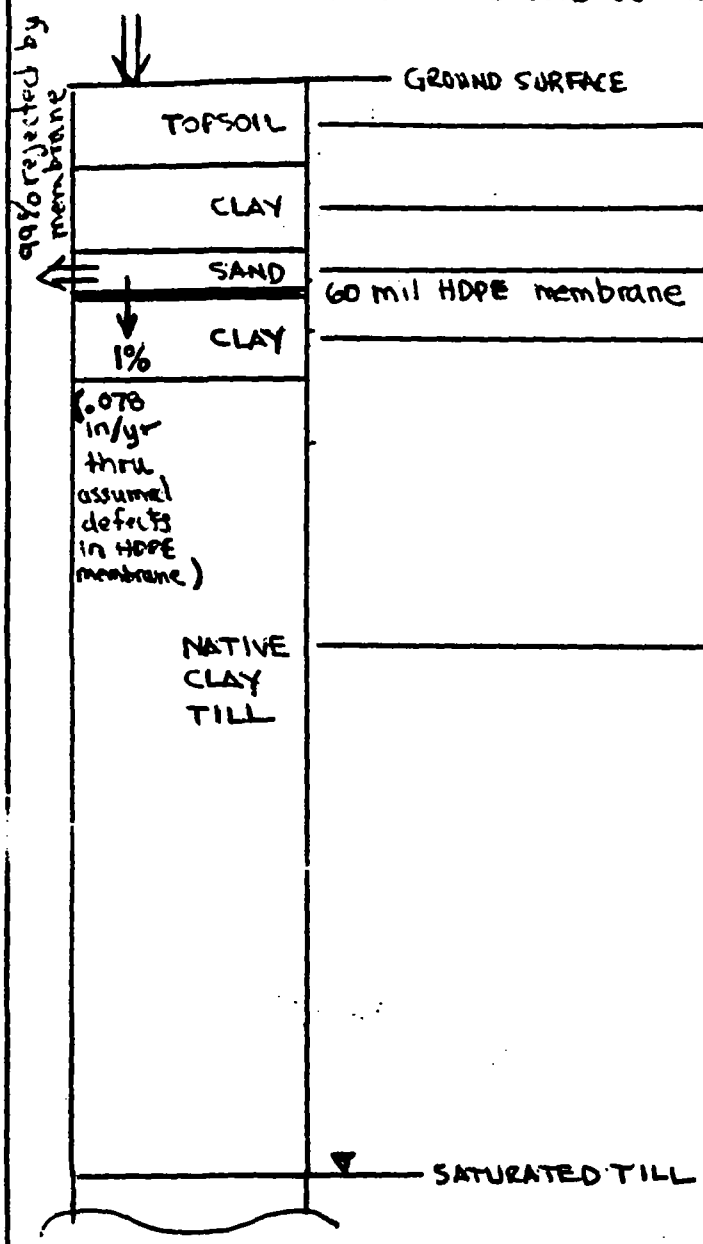
Project ECC Site W.O. No. _____ Sheet 1 of 1
Subject Figure 1 - Vertical Movement of Water Through Cover System and Till By DAS/ROB Date 3/21/89
Chkd by _____ Date _____



	DEPTH	VOIDS (%)	PERMEABILITY (cm/sec)	VELOCITY SATURATED (FT/DAY)	* TIME (YEARS)	
TOPSOIL	1'-0"	30.	10^{-4}	1	~0	
CLAY	1'-0"	10	10^{-7}	3×10^{-3}	~1	
SAND	6"	35	10^{-3}	8	~0	
CLAY	1'-0"	10	10^{-7}	3×10^{-3}	~1	**
NATIVE CLAY TILL	10'-0"	15	10^{-6}	2×10^{-2}	~1.4	**
TOTAL TIME					3.4	***

TYPICAL SOIL PROFILE

* Time to transmit water to next layer

** After upper layer and this layer reach field moisture capacity

*** Time for water to migrate from the surface to the saturated till after soil has reached field moisture capacity

Hand-delivered
on April 3, 1989
EFM

EXHIBIT A

**ENVIRONMENTAL CONSERVATION AND
CHEMICAL CORPORATION (ECC) SITE
ZIONSVILLE, INDIANA**

MARCH, 1989

PREPARED FOR:

ECC SETTLING DEFENDANTS

PREPARED BY:

**ENVIRONMENTAL RESOURCES MANAGEMENT-NORTH CENTRAL, INC.
102 WILMOT ROAD, SUITE 300
DEERFIELD, ILLINOIS 60015
PROJECT NO.: 8076**

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EXHIBIT A

1.0 INTRODUCTION

This document is a Remedial Action Plan (hereafter, "Remedial Action Plan", "Exhibit A" or the "Document") and describes the work to be performed at the Environmental Conservation and Chemical Corporation ("ECC") Superfund site as required by the 1989 ECC Consent Decree ("Consent Decree" or "Decree"). This document is attached as Exhibit A to, and is incorporated by reference into and made an enforceable part of, that Decree.

The purpose of this Exhibit A is to set forth those remedial activities to be performed at the ECC site necessary to achieve a health-based cleanup so that the site will not, once the work is performed, cause or present any risk to human health or the environment. The settling defendants under the Consent Decree ("Settling Defendants") shall arrange to have the work required hereunder performed by a Contractor or Contractors ("Contractor") in accordance with the requirements and specifications set forth herein.

2.0 REMEDIAL ACTION PLAN

This Remedial Action Plan (RAP) addresses, in a technically feasible and cost-effective manner, all environmental concerns regarding the ECC site, namely:

- Direct contact with soils containing volatile organics (VOCs), base neutral/acid organics, and heavy metals;

- Contamination of ground water by precipitation percolating through soils containing VOCs, base neutral/acid organics, and heavy metals;

- Contamination of surface waters by overland migration of water in contact with soils containing VOCs, base neutral/acid organics, and heavy metals;

- Ingestion of ground water containing VOCs, base neutral/acid organics, and heavy metals; and

- Contamination of surface waters by discharge of ground water containing VOCs, base neutral/acid organics and heavy metals.

Additionally, the RAP complies with the Superfund Amendments and Reauthorization Act (SARA) of 1986 by treating the contaminants at ECC so that they do not present any current or currently foreseeable future risk to health or the environment.

The RAP, which is described in detail in the following sections, includes the components listed below:

- Soil vapor extraction, concentration, and destruction;

- Installation of a RCRA-compliant cover;

- Establishment of access restrictions; and

- Ground water and surface water monitoring.

The intent of this RAP is to provide for the implementation of a comprehensive remedy that will remediate the site and will constitute "clean closure" by removing and destroying wastes at the site so as to preclude any risk to human health and the environment through any media (air, soil, surface water, or ground water). The soil vapor extraction system to be implemented under this Document will result in a cleanup level for constituents of concern in the site soils so as to obviate the need for ground water interception/collection systems at the site. Specifically, the soil vapor extraction system has been designed and will be operated to achieve Cleanup Standards (as specified in Table 3-1 below) in the soil as well as in the ground and surface water at the site that will protect human health and the environment.

Design of the vapor extraction system in the area beneath the concrete slab and placement of components of the RCRA-compliant cover over the site in advance of the vapor extraction process will prevent the infiltration of water beneath the concrete slab and migration through the subbase of the concrete slab.

Surface water and ground water sampling will be conducted during and after the operation of the vapor extraction system to verify the effectiveness of the RAP.

The components of the RAP as presented herein are compatible with the proposed remedy for the adjacent Northside Sanitary Landfill (NSL) site. As the remedial design is finalized for the NSL site, the respective RAPs for ECC and NSL will be reviewed to ensure compatibility of design and construction schedules for each system.

2.1 Elements of the RAP

2.1.1 Soil Vapor Extraction, Concentration and Destruction

The objective of the soil vapor extraction activity is to remove and destroy existing VOCs from the soils (as provided herein) and thereby:

- Prevent contact with contaminated soils;
- Prevent migration of contaminants from the soils to the surface water and ground water; and
- Prevent migration of contaminants from the ground water to the surface water.

Enhanced soil vapor extraction has been selected as the technology for removing the existing VOCs and certain base neutral/acid organics of potential concern from the soils at the ECC site. By systematically and uniformly moving air through the zone of contamination, volatilization and hence removal of organics are accelerated. For the ECC site, air movement through the soil will be controlled by a network of vertical trenches

installed throughout the zone of contamination. The process also involves the continuous extraction of organics-laden air from the trench system and treatment of the air by activated carbon to remove the organics. The organics so collected will then be destroyed off-site in conformance with applicable federal and state requirements.

The effectiveness of vapor extraction for organics removal from the ECC soils was demonstrated during a pilot test conducted by Terra Vac in June, 1988. The description of the pilot test, including the results obtained, was previously submitted to USEPA and the State of Indiana, and is specifically incorporated by reference herein and made a part hereof. The test showed an initial high organics extraction rate of 1.9 pounds per day per foot of trench that decreased over the course of the pilot test to a steady state rate of approximately 0.25 pounds per day per foot of trench. Although the Terra Vac pilot study provides the foundation for the system designed herein for ECC, during the conceptual and preliminary engineering phase, several engineering and operational enhancements were developed which will improve overall performance and effectiveness of the vacuum extraction system to be implemented under this RAP. These system enhancements are the result of consultations among ERM-North Central, Inc., Midwest Water Resource, Inc. (MWRI), and Terra Vac, Inc. A summary of the key improvements are:

- Virtual elimination of surface water infiltration within the zone of contamination;

- Substantial reduction in the volume of air required for effective remediation;

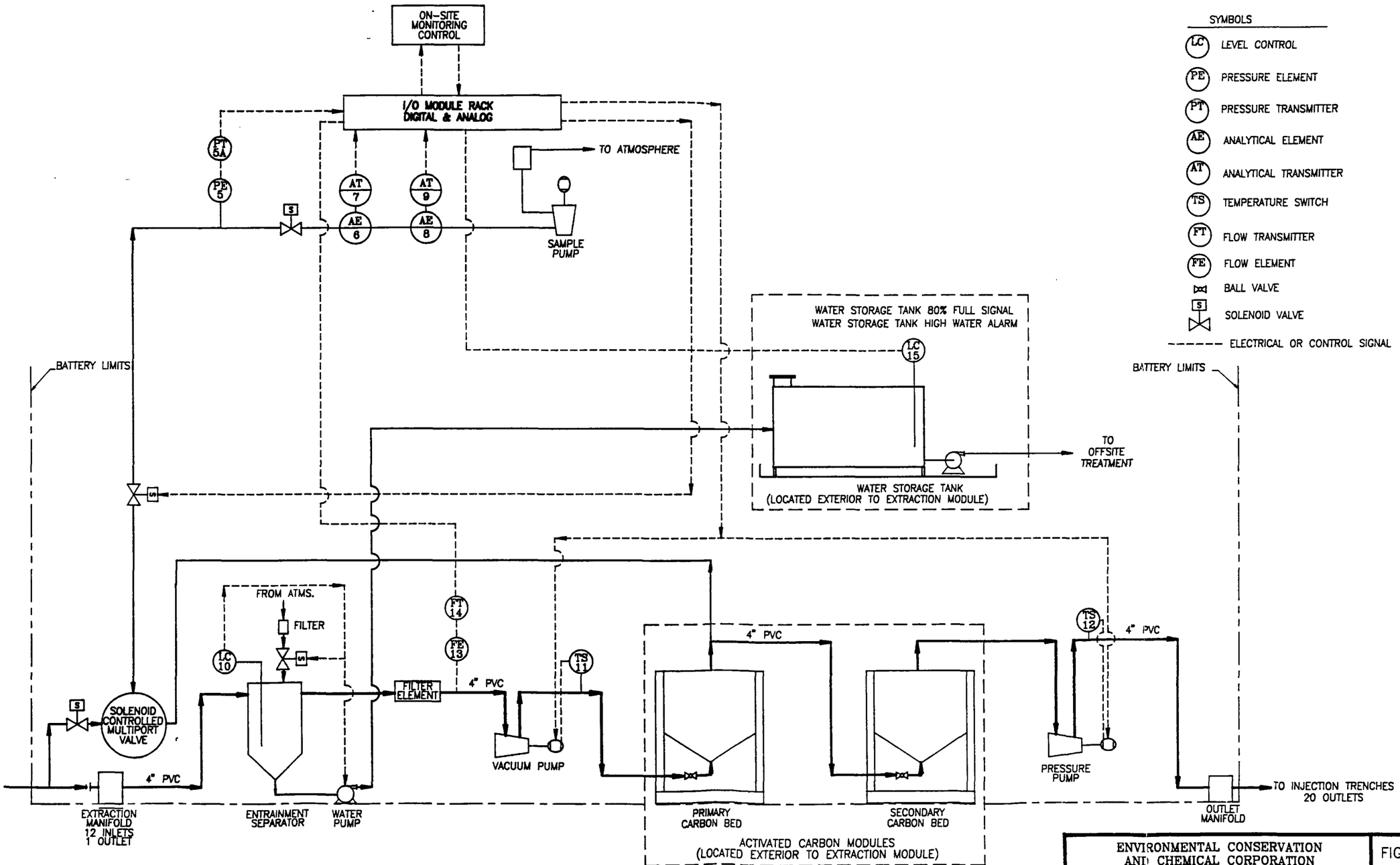
- Virtual elimination of atmospheric discharges of treated extraction air;

- Positive control (collection and removal) of any till moisture encountered in the zone of treatment; and

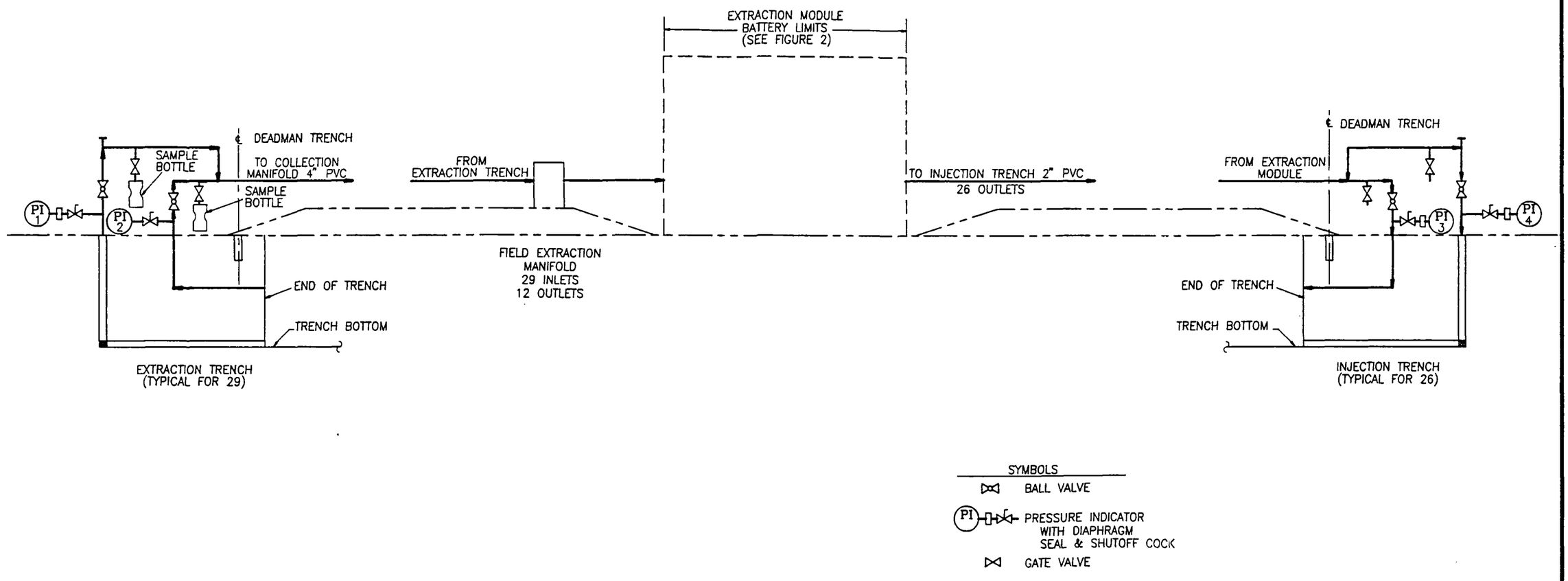
- Uniform and essentially horizontal movement of air through the zone of contamination resulting in optimal air/organics contact during operation.

The following discussion and drawings clearly illustrate the design and operation details of the soil vapor extraction system.

The soil vapor extraction process is illustrated in Figures 2-1 and 2-2. The basic operation consists of extraction of air using a single vacuum pump from a network of 29 extraction trenches located throughout the site. Free liquid entrained in the air is removed by gravity in an entrainment separator. Periodically, water which accumulates in the entrainment separator is pumped to an on-site storage tank for subsequent transport to an off-site facility for treatment as necessary, in accordance with applicable Federal, State and local regulations. From the vacuum pump, air passes through the carbon adsorption system, which consists of two upflow carbon columns connected in series. Off-gasses from the carbon adsorption system are withdrawn by a pump which boosts the pressure and reinjects air into a network of 26 injection trenches located throughout the site. Each injection trench is located between and parallel to a pair of extraction trenches. The injected air then migrates from the injection



ENVIRONMENTAL CONSERVATION AND CHEMICAL CORPORATION ZIONSVILLE, INDIANA PROCESS FLOW DIAGRAM– EXTRACTION MODULE	FIGURE NO. 2–2
ERM ERM–North Central, Inc.	2/28/89 mo



ENVIRONMENTAL CONSERVATION AND CHEMICAL CORPORATION ZIONSVILLE, INDIANA PROCESS FLOW AND INSTRUMENT DIAGRAM	FIGURE NO. 2-1
ERM ERM-North Central, Inc.	3/20/89 mo

trench through the soil towards the extraction trench. As the air migrates through the soil towards the extraction trench, the organics are vaporized into the air stream. Components of the RCRA-compliant cover will be placed over the entire trench network to prevent air and water infiltration into the system during operation.

The major system components are:

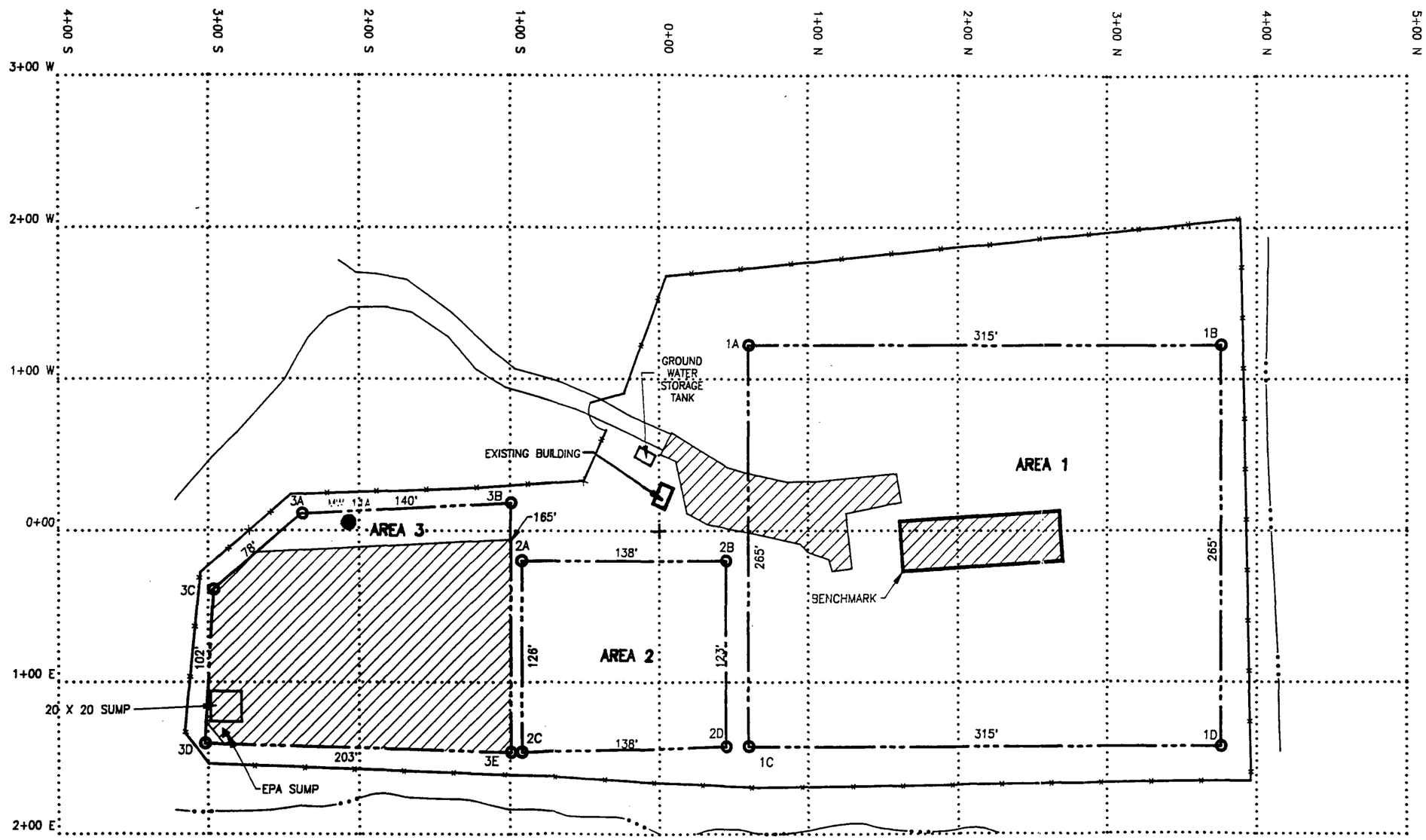
- Extraction and injection trenches;
- Soil vapor extraction system;
- Water collection system;
- Carbon adsorption system;
- Air injection system; and
- RCRA-compliant cover.

A description of the design and operational features of each of these components is presented below.

Extraction and Injection Trenches

The area where remedial activity will occur is depicted in Figure 2-3. The west boundary of Area 1 encompasses the extent of ECC activities as verified by an examination of aerial photographs and coincides with a pre-existing earthen berm which formed the western boundary of ECC's water containment system for this area.

LOCATION COORDINATES		
POINT	N/S	E/W
1A	0+60 N	1+22 W
1B	3+76 N	1+22 W
1C	0+60 N	1+42 E
1D	3+76 N	1+42 E
2A	0+92 S	0+20 E
2B	0+45 N	0+20 E
2C	0+92 S	1+46 E
2D	0+45 N	1+42 E
3A	2+38 S	0+11 W
3B	1+00 S	0+18 W
3C	2+98 S	0+39 E
3D	3+03 S	1+40 E
3E	1+00 S	1+46 E
MW 11A	2+08 S	0+06 W
EPA SUMP	2+86 S	1+34 E
BENCHMARK	1+62 N	0+27 E



APPROX. SCALE (ft)

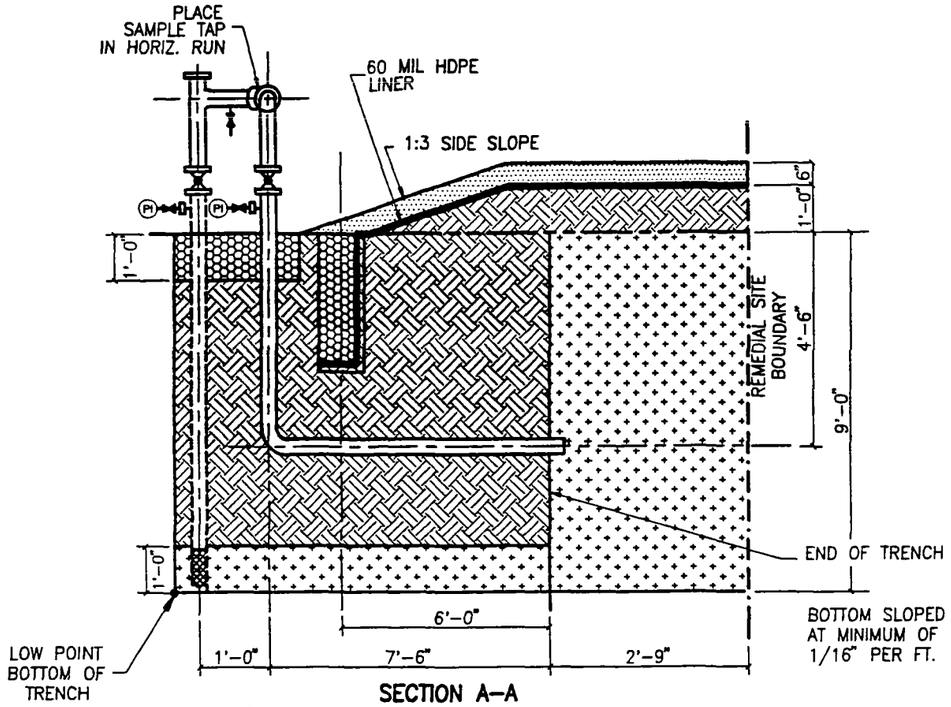
0 25 50 100

LEGEND:

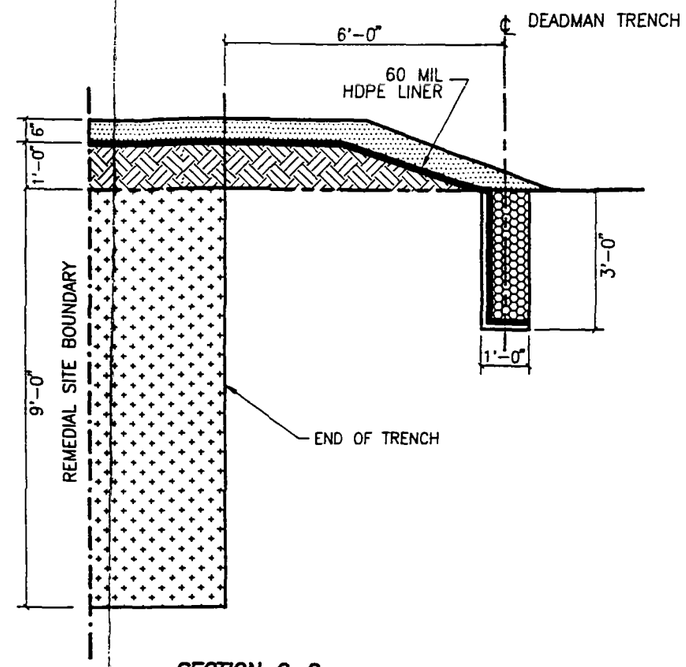
- FENCE LINE
- BUILDING LINE
- PAVEMENT EDGES
- BOUNDARY LINES
- DRAINAGE DITCH
- CONCRETE
- BOUNDARY CORNER

+ REFERENCE POINT FROM CH M-HILL TECHNICIAL DOCUMENT NO. 2 DATE 9/16/88 (921700 N; 725900 E)

ENVIRONMENTAL CONSERVATION AND CHEMICAL CORPORATION ZIONSVILLE, INDIANA REMEDIAL AREA BOUNDARIES	FIGURE NO. 2-3
ERM ERM-North Central, Inc.	3/22/89
	CS

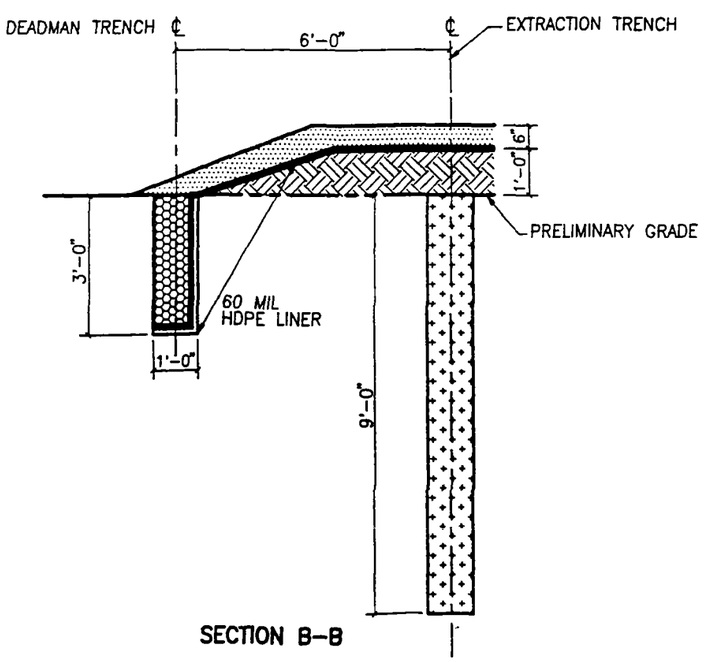


SECTION A–A
(TYPICAL OF INJECTION AND EXTRACTION TRENCHES)

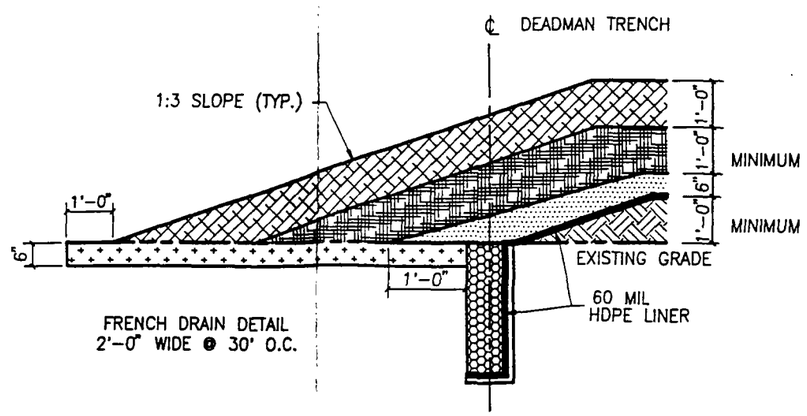


SECTION C–C

NOTE: SECTIONS REFER TO PLAN SHOWN IN FIGURE 2–4.

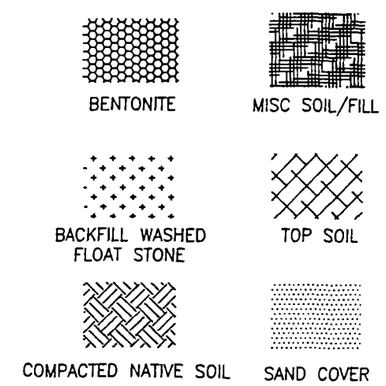


SECTION B–B



NOTE: FINAL COVER SLOPE 2% MINIMUM. SEED WITH APPROPRIATE SEED MIXTURE OF GRASSES.

FINAL RCRA–COMPLIANT COVER

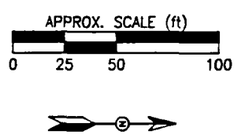


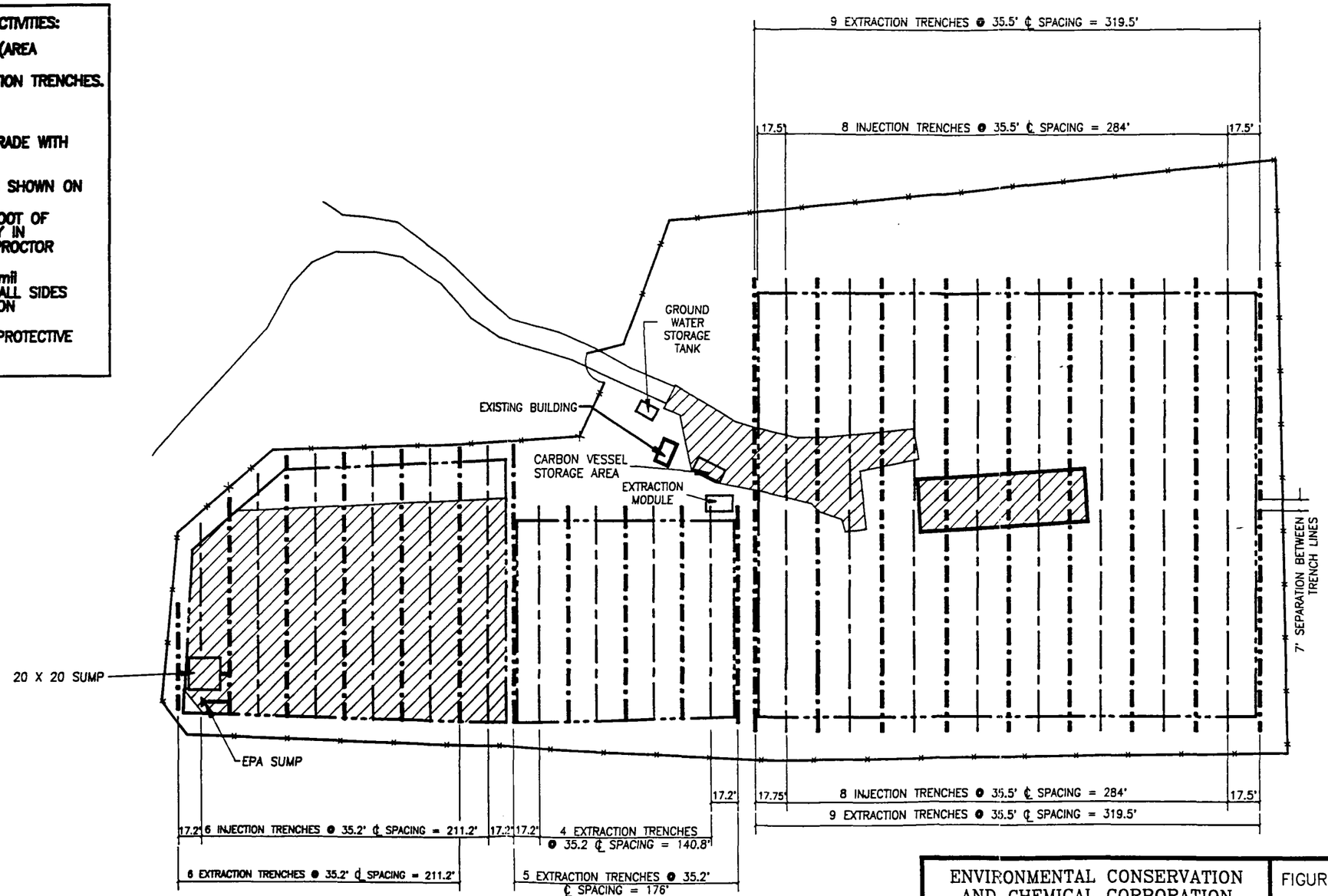
NOTE: NOT TO SCALE

ENVIRONMENTAL CONSERVATION AND CHEMICAL CORPORATION ZIONSVILLE, INDIANA VAPOR EXTRACTION–TRENCH DETAILS	FIGURE NO. 2–5
ERM ERM–North Central, Inc.	3/20/89 cs

SEQUENCE OF CONSTRUCTION ACTIVITIES:

1. GRADE EXISTING TREATMENT SITE (AREA NOS. 1,2, & 3) TO EVEN SLOPE.
2. EXCAVATE INJECTION AND EXTRACTION TRENCHES.
3. FILL INJECTION TRENCHES WITH FLOAT STONE AS SHOWN ON FIGURE 2-5.
4. FILL EXTRACTION TRENCHES TO GRADE WITH FLOAT STONE AS SHOWN ON FIGURE 2-5.
5. EXCAVATE DEADMAN TRENCHES AS SHOWN ON FIGURE 2-6.
6. COVER TREATMENT SITE WITH 1 FOOT OF NATIVE SOIL OF 10^{-7} PERMEABILITY IN 6" LAYERS COMPACTED TO 95% PROCTOR DENSITY.
7. COVER TREATMENT SITE WITH 60 mil HDPE PLASTIC LINER ANCHORING ALL SIDES IN DEADMAN TRENCH AS SHOWN ON FIGURE 2-5.
8. COVER TREATMENT SITE WITH 6" PROTECTIVE LAYER OF SAND AS SHOWN ON FIGURE 2-5.





LEGEND:

- FENCE LINE
- BUILDING LINE
- PAVEMENT EDGES
- BOUNDARY LINES
- INJECTION TRENCHES
- EXTRACTION TRENCHES
- CONCRETE

ENVIRONMENTAL CONSERVATION AND CHEMICAL CORPORATION ZIONSVILLE, INDIANA SOIL VAPOR EXTRACTION-TRENCH PLAN	FIGURE NO. 2-4
ERM ERM-North Central, Inc.	3/23/89 cs

The layout and construction details for the network of 29 extraction trenches and 26 injection trenches are presented in Figures 2-4 and 2-5. Trench spacing varies between 17 and 18 feet, and trench length varies depending on the configuration of the site. The maximum length of any trench will be 165 feet. Construction details of extraction trenches and injection trenches are identical. By implementing minor above-ground piping changes, injection trenches can and will be utilized as extraction trenches. The work required under this RAP will initially involve using the original extraction trenches for extraction; at some point in the process, the extraction trenches will be converted to injection trenches, and vice versa, to ensure complete vapor extraction of the soil.

All trenches are to be a minimum of 9-feet deep as measured from existing grade, and will be backfilled with washed "float" stone. The trench width will be 12-15 inches. The bottom elevation for both injection and extraction trenches will be sloped at a minimum of 1/16-inch per foot to a low point located at the water collection pipe as noted in Section A-A of Figure 2-5.

Soil removed from the trench excavation will be spread over the surface during construction of the cover system and covered in accordance with the final RCRA-compliant cover detail illustrated in Figure 2-5. Soil removed from the trenches constructed in the areas of the concrete pad (Area 3) will be spread over the surface in Areas 2 and 3 with trench spoils from those areas.

Each trench will be equipped at one end with a vapor extraction pipe and a water collection pipe as illustrated in Section A-A of Figure 2-5. Both pipes will be 4-inch diameter, Schedule 40 PVC. Each pipe segment will be equipped with pressure/vacuum

indicator, isolating valve and sample tap. A "T" at the top of the water collection pipe will permit the future installation of air piping to air lift water from the trench network, if necessary. Individual 4-inch, Schedule 40 PVC pipes will be routed from each extraction trench to the extraction module. The extraction module will be located adjacent to the existing concrete pad near the site entrance. Alternatively, two or three extraction trenches will be manifolded together and conveyed to the extraction module via a 4-inch, Schedule 40 PVC pipe. Injection trench piping is identical to the extraction trench piping and, as previously described, will permit it to be utilized as an extraction trench during the operation of the vapor extraction system. To minimize field piping from the extraction module to the injection trenches, 4 to 8 injection trenches will be manifolded together. Four-inch, Schedule 40 PVC pipe will be used to convey air returned from the extraction module to the injection trench.

The EPA Sump will be backfilled with the material used to backfill trenches (i.e, float stone) and a 4-inch PVC pipe will be installed between the sump and the nearest extraction trench, thereby tying the EPA Sump directly into the vapor extraction system. The existing 20 ft. x 20 ft. sump will be handled similarly, and will be dewatered prior to installing the RCRA compliant cover system.

Soil Vapor Extraction System

The vacuum pump will have a capacity of 500 standard cubic feet per minute (SCFM) and will be capable of developing a vacuum of 18 inches Hg. The normal operating vacuum will be 12 inches Hg. Based on MWRI's experience with soils characteristic of the ECC

site and on the Terra Vac pilot study results at the ECC site, the zone of influence at the operating vacuum will be at least 40 feet (20 feet either side of the trench). The selected spacing between trenches of 17 to 18 feet is well within this zone of influence. The vacuum will be applied at the trench outlet and will be uniformly distributed throughout the entire length and vertical dimension of the trench. The highly porous backfill material used will assure this uniform distribution of vacuum throughout the extraction trench. The reinjection pressure of air in each adjacent injection trench will be approximately 37.4 inches Hg (1.25 atm). Therefore, the pressure differential and driving force for air movement between injection and extraction trenches is approximately 19.4 inches Hg (0.65 atm).

The selection of the design air volume of 500 SCFM is based upon MWRI's experience and is consistent with pilot plant test results (by Terra Vac). The criteria established is to provide at least one air volume change per soil pore volume per day. Based upon an area of treatment of 150,000 square feet, a depth of contamination of 9 feet, and a soil porosity of 10%, 500 SCFM exceeds the MWRI criteria by 400%.

The vapor extraction process will operate continuously and will shut down automatically only in the event of an operating problem or malfunction. The following are conditions which will shut down normal operating sequence of the vapor extraction system:

- High vapor temperature prior to activated carbon treatment (to be established by activated carbon vendor selected);

- Low vapor temperature prior to activated carbon indicating high relative humidity (to be established by activated carbon vendor selected);

- High water level in water entrainment separator indicating operating problems with liquid transfer operation;

- High water level in ground water storage tank;

- High or low pressure conditions on vacuum or pressure pumps (to be established by vapor extraction system vendor selected); and

- Power interruptions for the site.

During normal operation, vapor extraction will be stopped to facilitate carbon vessel change out as described later in this section and during transfer of water from the entrainment separator to the on-site ground water storage tank.

The air extracted from the system will be continuously monitored by in-line instrumentation as shown on the process flow diagram (Figure 2-2) and described on Table 2-1 (Instrument Summary Sheet). The capability will exist to sample individual trench exhausts or the combined air stream. Sample taps will be provided to collect vapor samples for detailed chemical analysis. The on-line instrumentation will consist of a photoionization

ERM- NORTH CENTRAL, INC.
INSTRUMENT SUMMARY SHEET

CLIENT Environmental Conservation and Chemical Corporation
PROJECT NUMBER 8009DSECC

SHEET TABLE 2-1
SPEC NO
DATE 2/28/89

	TAG NO.	SERVICE	MOUNTING PANEL	MOUNTING FIELD	REFERENCES SPEC SHEET	REFERENCES FLOW DIA.	NOTES
	PI-1	Pressure Indicator					
	thru	with diaphragm					
	PI-4	Seal and shutoff cock		X		2-1	
	PE-5	Pressure sensing element					
	PT-5A	Pressure transmitter		X		2-2	
	AE-6	Moisture sensing element		X		2-2	
	AT-7	Moisture transmitter	X			2-2	
	AE-8	Volatile organics detector and quantifier	X			2-2	
	AT-9	Volatile organics quantitifed signal transmitter	X			2-2	
	CC-10	3-point water level control and alarm		X		2-2	
	TS-11	Gas temperature sensor with high level system					
		shutdown switch		X		2-2	
	TS-12	Gas temperature sensor with high level system					
		shutdown switch		X		2-2	
	FE-13	Gas flow measuring element		X		2-2	
	FE-14	Gas flow signal transmitter		X		2-2	
	LC-15	3-point water level control and alarm		X		2-2	

detector (PID) and moisture analyzer. The vacuum pump, controls and instrumentation are located in the extraction module building.

Water Collection System

The high vacuum vapor extraction system selected will be capable of entrainment and movement of water which accumulates in the extraction trenches. Any free liquid in the extracted vapor will be separated by gravity in an entrainment separator located in the vapor extraction module building. A level control system will be utilized to control the removal of water which accumulates in the entrainment separator as required. The separator tank is equipped with a vacuum breaker system which will open the tank to the atmosphere to permit water to be transferred by pump from the separator to an on-site water storage tank as necessary. The time required to make this transfer will depend upon the equipment supplied by the vapor extraction system vendor selected. The size of the tank will depend upon the off-site handling/treatment option selected. The tank will be equipped with level measurement and control to advise operating personnel to the status of liquid accumulation in the storage tank.

Periodically, the contents of the water storage tank will need to be removed. The removed water will either be sent to the Indianapolis POTW via the NSL pipeline or truck, or to another off-site facility for handling and treatment as necessary, in accordance with applicable Federal, State and local regulations.

Carbon Adsorption System

From the water entrainment tank, the air passes through a particulate filter preceding the vacuum pump. The exhaust from the vacuum pump will be piped directly to a two-stage carbon adsorption system (primary and secondary). This system will consist of two vessels in series each containing approximately 1,800 pounds of granular activated carbon. The organics contained in the extracted air will be adsorbed on the activated carbon. The moisture content of the air stream will be less than 50% relative humidity and temperatures will be approximately 150°F, both acceptable for efficient operation of carbon adsorption.

During the initial phases of operation, when organics concentrations in the air stream will be highest, the carbon capacity for the organics is expected to be about 25% by weight. During the latter phases of remediation as organic concentration of vapor decreases, the projected carbon capacity for organics will range between 10-15% by weight. Based upon an assumed total mass of organics of about 5,000 pounds (Appendix A), the total quantity of activated carbon required for the entire remediation program is 25,000 pounds. This equates to fourteen 1800-pound carbon vessels for the entire program.

The vapor from the primary carbon vessel will be monitored frequently (approximately once per hour) by an on-line PID analyzer. When the PID analyzer detects organic vapor in the air stream between the primary and secondary carbon vessels, the vacuum extraction system will shut down automatically to permit the removal and replacement of the "spent" primary carbon vessel. An operator will be alerted to this condition, and will

disconnect the primary carbon bed from the service. The spent carbon vessel will be removed and replaced by a carbon vessel containing fresh activated carbon. The unit previously serving as the secondary carbon bed will become the primary carbon bed and the unit just placed in operation will be the secondary carbon bed. Once this switch is complete, the soil vapor extraction system (i.e., vacuum pump and injection pump) will be restarted, and the system operation resumed. The arrangement of two activated carbon vessels in series (i.e., primary and secondary) will permit optimal utilization of the activated carbon, and efficient capture of the organics.

The spent carbon vessels will be stored on-site. The vessels will be stored on the existing concrete pad adjacent to the vapor extraction module building, inside the fenced area. An approximate location of this area is shown in Figure 2-4. The inlet and outlet connections to each vessel will be capped and sealed appropriately. Periodically when a truckload quantity of vessels has accumulated, and at the conclusion of the vacuum extraction program, the vessels containing the spent carbon will be transported in accordance with applicable federal, state and local requirements to an off-site facility where the carbon will be regenerated by high temperature incineration, and in the process, the organics adsorbed on the carbon will be destroyed.

Air Injection System

The exhaust air from the secondary carbon bed will be piped to the injection pump located in the extraction module building. The injection pump will be capable of delivering 500 SCFM at 10 psig (1.65 atm). The discharge from the injection pump will be distributed to the 26 injection wells via a system of manifolds.

Control of the injection pump will be interlocked with the vacuum extraction pump. The pipe at each injection trench will be equipped with a pressure/vacuum gauge so that injection pressure at the trench can be periodically monitored.

During the soil vapor extraction program, the injection trenches will be utilized as extraction trenches and vice versa. This can be accomplished by minor above ground manifold piping modifications. It is also planned that as the Cleanup Standards set forth in Table 3-1 below are met for individual trench "areas", the corresponding extraction and injection trenches will be isolated from the extraction and injection operation by closing the shut off valves located at each trench. This will permit the soil vapor extraction system to concentrate on any remaining areas which have not fully achieved the Cleanup Standards specified in Table 3-1, thereby accelerating cleanup of those areas.

RCRA-Compliant Cover

The operation of the vapor extraction system will be enhanced by the installation of components of the RCRA-compliant cover over the entire site. Details of the final RCRA-compliant cover are presented in Section 2.1.2. At a minimum during vapor extraction, all but the final soil cover above the sand layer covering the 60 mil high density polyethylene (HDPE) membrane will be installed. A majority of the final soil cover detail may be installed prior to and during vapor extraction.

Miscellaneous

- Each extraction trench is equipped with two sample taps, one on the vacuum pipe and one on the water collection pipe. Each of these taps can be fitted with a sample bottle for the collection of free moisture.

- Electrical service required for the site remediation work will be 3-phase 460 volt. Total electrical demand will be approximately 100 KVA. Power distribution will be to the extraction module building. Operating voltage for the extraction and injection pumps will be 460 volts. A 110 volt supply will be provided for miscellaneous site lighting, equipment, instrumentation and controls. Power distribution to any site construction and office trailers will also be provided.

- Prior to construction of the trenches, the following activities will be conducted:

    1. The existing buildings will be demolished and disposed of off-site;

    2. The existing tanks removed and properly disposed of off-site; and

3. The site will be graded to fill existing depressions and to eliminate any sharp grade changes.

- As discussed in more detail in Section 3.7 below, if the Cleanup Standards set forth in Table 3-1 are not achieved within 5 years, additional work may need to be implemented (see Section 3.7 for details).

2.1.2 RCRA-Compliant Cover

The RCRA-compliant cover installed over the site will:

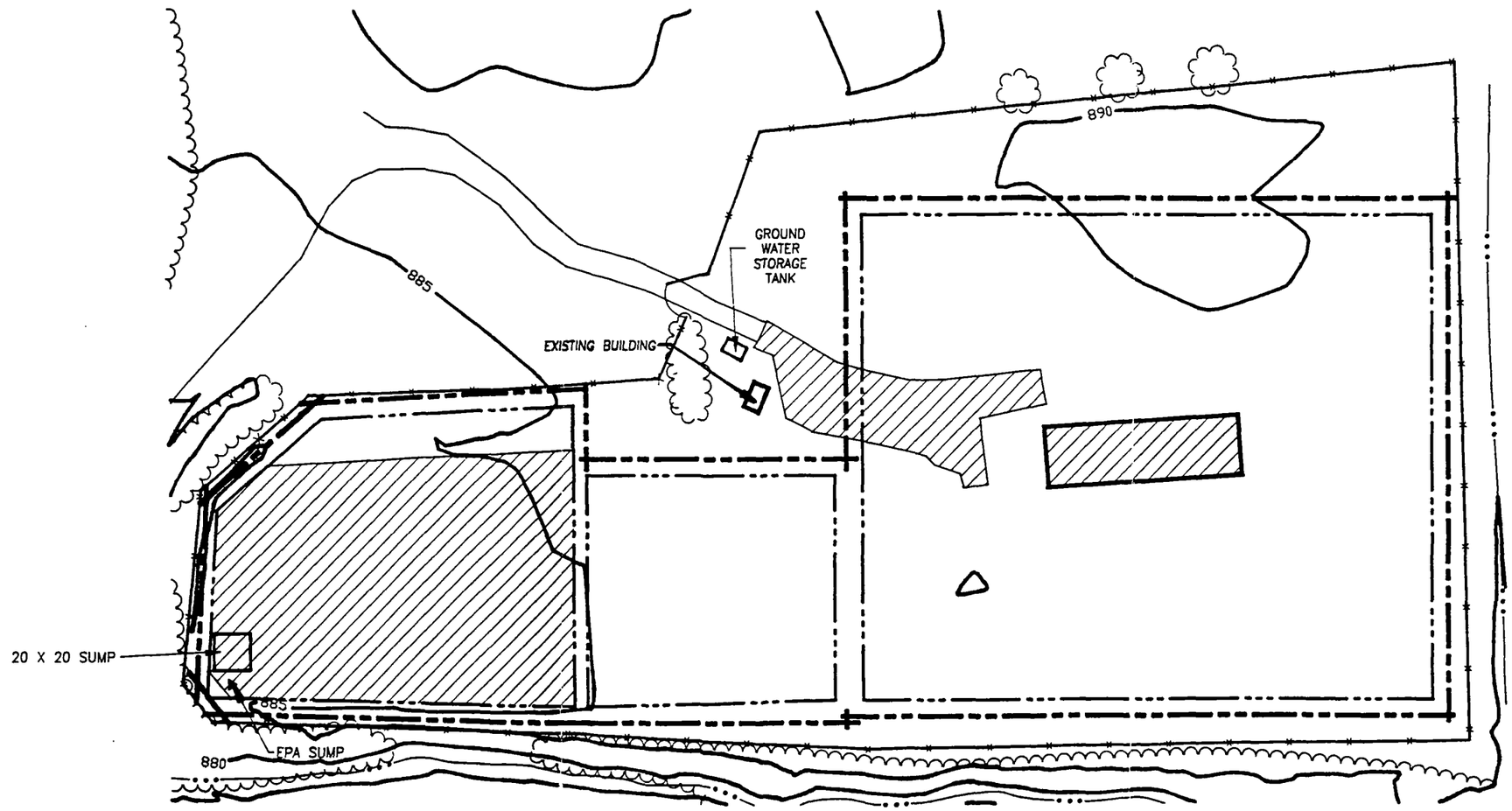
- Prevent contact with underlying soil;
- Prevent contamination of surface runoff;
- Reduce the infiltration of water through the soils thereby preventing ground water and subsequent surface water contamination;
- Enhance the efficiency of the soil vapor extraction system;
- Promote evapotranspiration;
- Promote drainage of precipitation away from the site; and
- Mitigate erosion.

The RCRA-compliant cover illustrated in Figure 2-5 will consist of a minimum of 1-foot of compacted, highly impermeable native soil, a continuous welded 60 millimeter high density polyethylene (HDPE) plastic membrane, a minimum 6-inch layer of compacted sand for drainage, 1 to 3 feet of miscellaneous soil/fill material and 1 foot of top soil to support vegetation. The final grading plan will ensure a minimum slope of 2%. The native soil used will be the silty clay till available in the area, which can and will be compacted by standard methods to 95% proctor density. If soil from the NSL borrow area is not available, material with similar performance will be obtained from another source.

To provide a perimeter seal of the HDPE membrane, a 1-foot wide, 3-foot deep "deadman trench" will be installed around the site boundary (Figure 2-6). The HDPE membrane will be draped into this trench. The trench will then be backfilled and compacted with native soil (silty clay till) to 95% proctor density. The final soil cover will extend approximately 6 feet beyond the deadman trench as noted on Figure 2-6.

As previously described, the material excavated from the trenches will be graded uniformly throughout the trench area and incorporated into the top layer of existing surface soil prior to the construction of the final cover detail.

The RCRA-compliant cover will be installed over the entire site, including the concrete pad, and some components will be installed prior to initiation of the vapor extraction process, as described in Section 2.1.1. At completion of the soil vapor extraction program all surface piping will be removed from the site in addition to any equipment, buildings or trailers. The extraction and injection trench piping will be cut off at the current grade,



APPROX. SCALE (ft)

0 25 50 100

LEGEND:

- FENCE LINE
- BUILDING LINE
- PAVEMENT EDGES
- BOUNDARY LINES
- DEADMAN TRENCH
- DRAINAGE DITCH
- CONCRETE

NOTES: (1) DEADMAN TRENCH TO BE LOCATED APPROXIMATELY 9' BEYOND REMEDIAL SITE BOUNDARIES (ALL SIDES).

(2) DEADMAN TRENCH DEFINES THE BOUNDARY OF THE HDPE LINER. SOIL COVER ABOVE LINER EXTENDS APPROXIMATELY 6' BEYOND THE DEADMAN BOUNDARY.

ENVIRONMENTAL CONSERVATION AND CHEMICAL CORPORATION ZIONSVILLE, INDIANA DEADMAN TRENCHING PLAN	FIGURE NO. 2-6
ERM ERM-North Central, Inc.	3/22/89 cs

filled with grout, and covered with a minimum of 1 foot of topsoil, which will be vegetated. Vegetation which will be established will be characterized by fibrous, shallow, laterally growing roots, such as grass (which may include red fescue and Kentucky blue grass).

2.1.3 Access Restrictions

The objectives of implementing access restrictions are to:

- Prior to implementation of the RAP, to minimize the potential for contact with any soils and water containing VOCs, base neutral/acid organics, and heavy metals; and

- Prevent any contaminant migration that might result from future excavation and development.

Access restrictions will consist of:

- Fencing around the site perimeter and posting of signs;

- Filing of appropriate restrictions with the County Recorder's Office prohibiting usage of the site for excavation and development (to be done by owner);

- Filing of appropriate restrictions with the County Recorder's Office prohibiting usage of ground water from the saturated till and the underlying sand and gravel (to be done by owner); and

- Filing of appropriate restrictions with the County Recorder's Office prohibiting installation of new water wells other than monitoring wells (to be done by owner).

Ground water use restrictions would be only temporary and will be in place until compliance with the ground water Cleanup Standards in Table 3-1 is achieved and, until such time, will extend to areas where utilization of the shallow ground water could potentially result in contamination being drawn to these locations.

2.1.4 Ground Water and Surface Water Monitoring

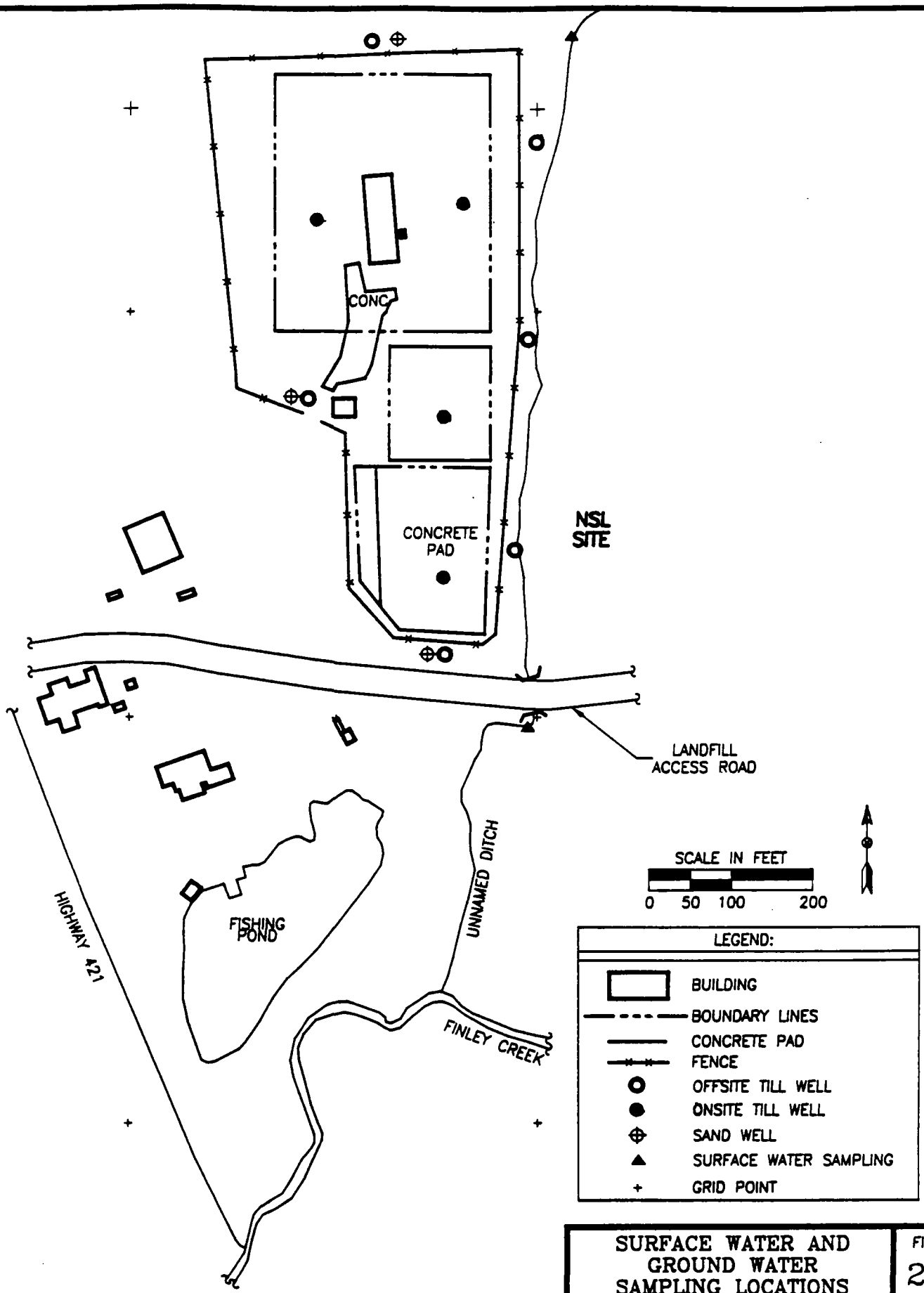
The monitoring activities will:

- Detect any VOCs migrating to the ground water and surface water during and after vapor extraction; and

- Monitor and verify the effectiveness of the remediation.

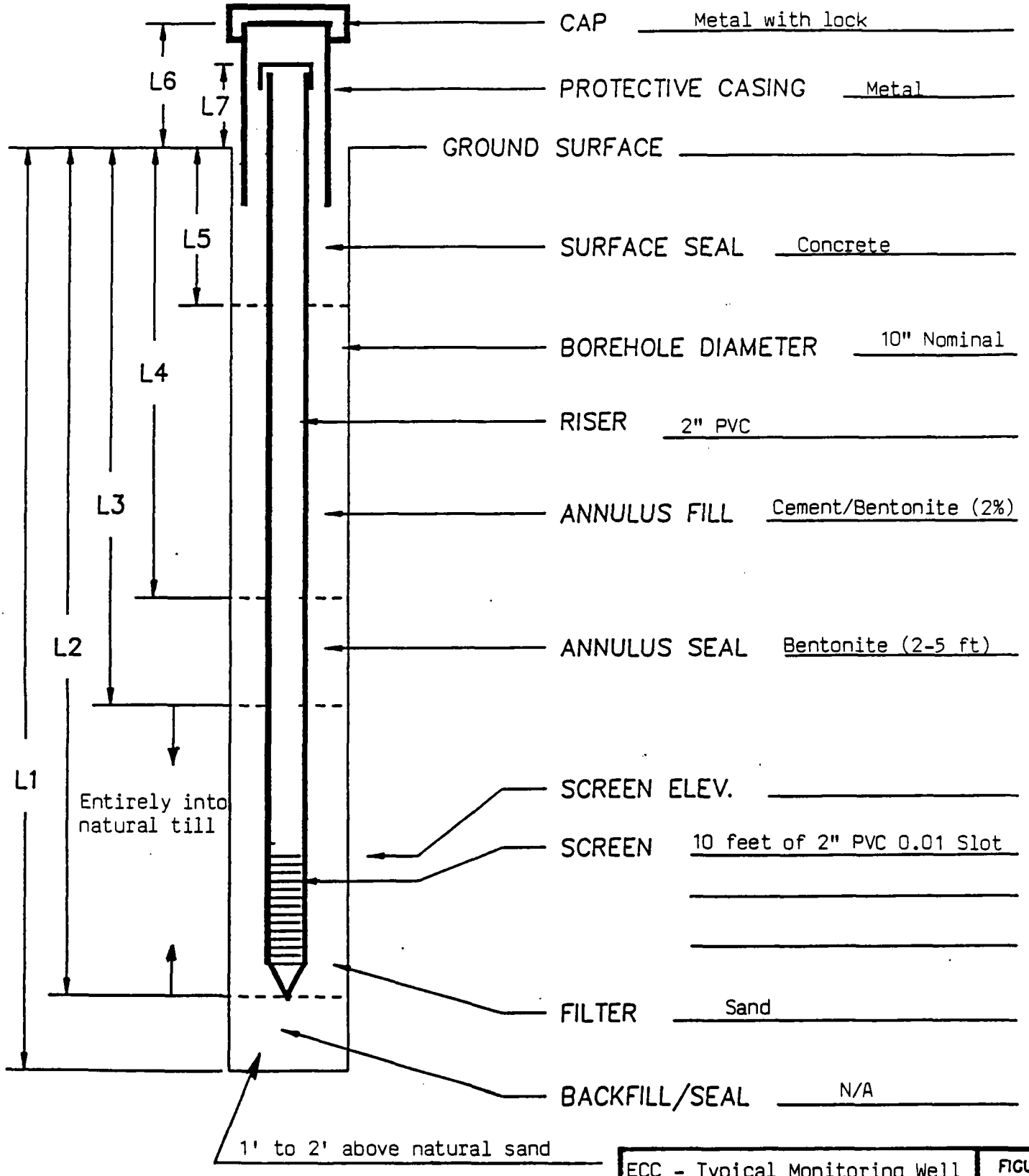
Two separate types of ground water monitoring systems will be operated under this RAP. The first is the on-site till monitoring system described in Section 4.0 below; sampling results from those wells will be compared to the ground water Cleanup Standards in Table 3-1 and will be used to calculate soil concentrations for comparison to the soil Cleanup Standards in Table 3-1.

The second type of ground water monitoring system involves off-site wells screened in the till and in the sand and gravel. Sampling results from these wells will also be used to determine compliance within the ground water Cleanup Standards in Table 3-1. This latter ground water monitoring network will consist of ten (10) wells, which will be located around the periphery of and downgradient from the ECC site (Figure 2-7). Six (6) wells will be installed in the till, completed in the saturated zone, and four (4) wells will be completed in the sand and gravel unit underlying the saturated surface till. The wells will be constructed of 2-inch PVC pipe. Screen length will vary for each well. Total depth for the wells completed in the till will be 1-2 feet less than total depth to the contact between the till and underlying sand and gravel. Wells completed in the sand and gravel will screen the total thickness of that sand and gravel unit. Figures 2-8 and 2-9 illustrate well construction details for the ground water monitoring wells in the till and in the sand and gravel, respectively. The location of the monitoring wells is based on the ground water elevation contours shown in Figure 2-10.



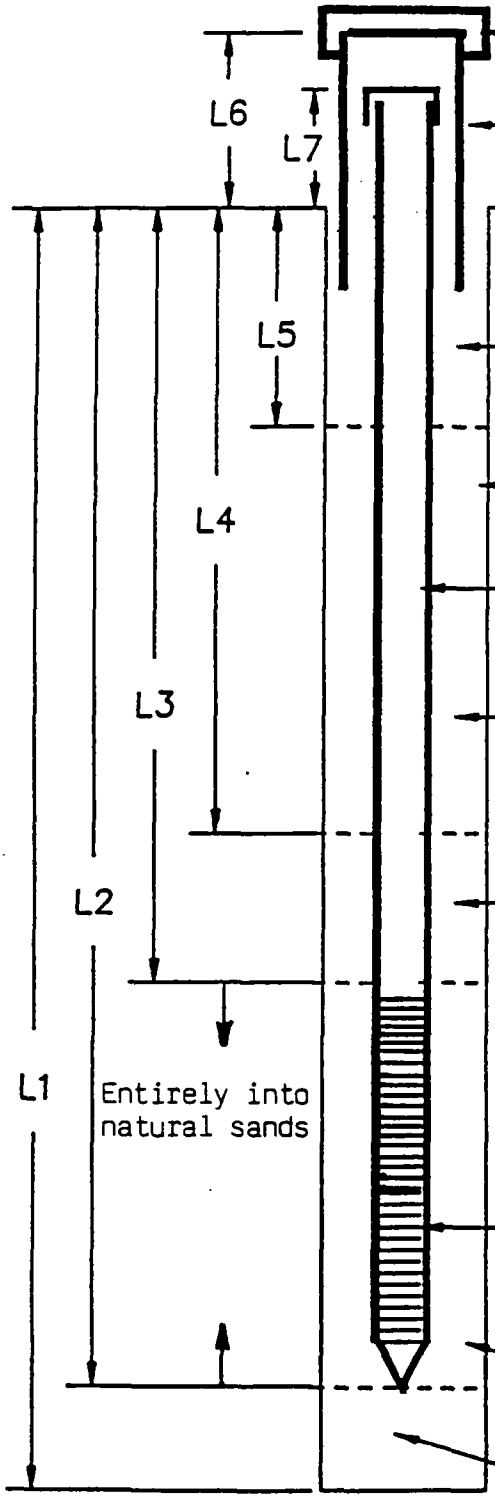
SURFACE WATER AND GROUND WATER SAMPLING LOCATIONS	FIGURE 2-7
ERM-North Central, Inc.	3/23/89 mo

MONITORING WELL CONSTRUCTION



ECC - Typical Monitoring Well Construction Detail Well in Glacial Till	FIGUR 2-8
ERM ERM-North Central, Inc.	

MONITORING WELL CONSTRUCTION



CAP — Metal with lock

PROTECTIVE CASING — Metal

GROUND SURFACE

SURFACE SEAL — Concrete

BOREHOLE DIAMETER — 10" Nominal

RISER — 2" PVC

ANNULUS FILL — Cement/Bentonite (2%)

ANNULUS SEAL — Bentonite (2-5 ft) In upper tills

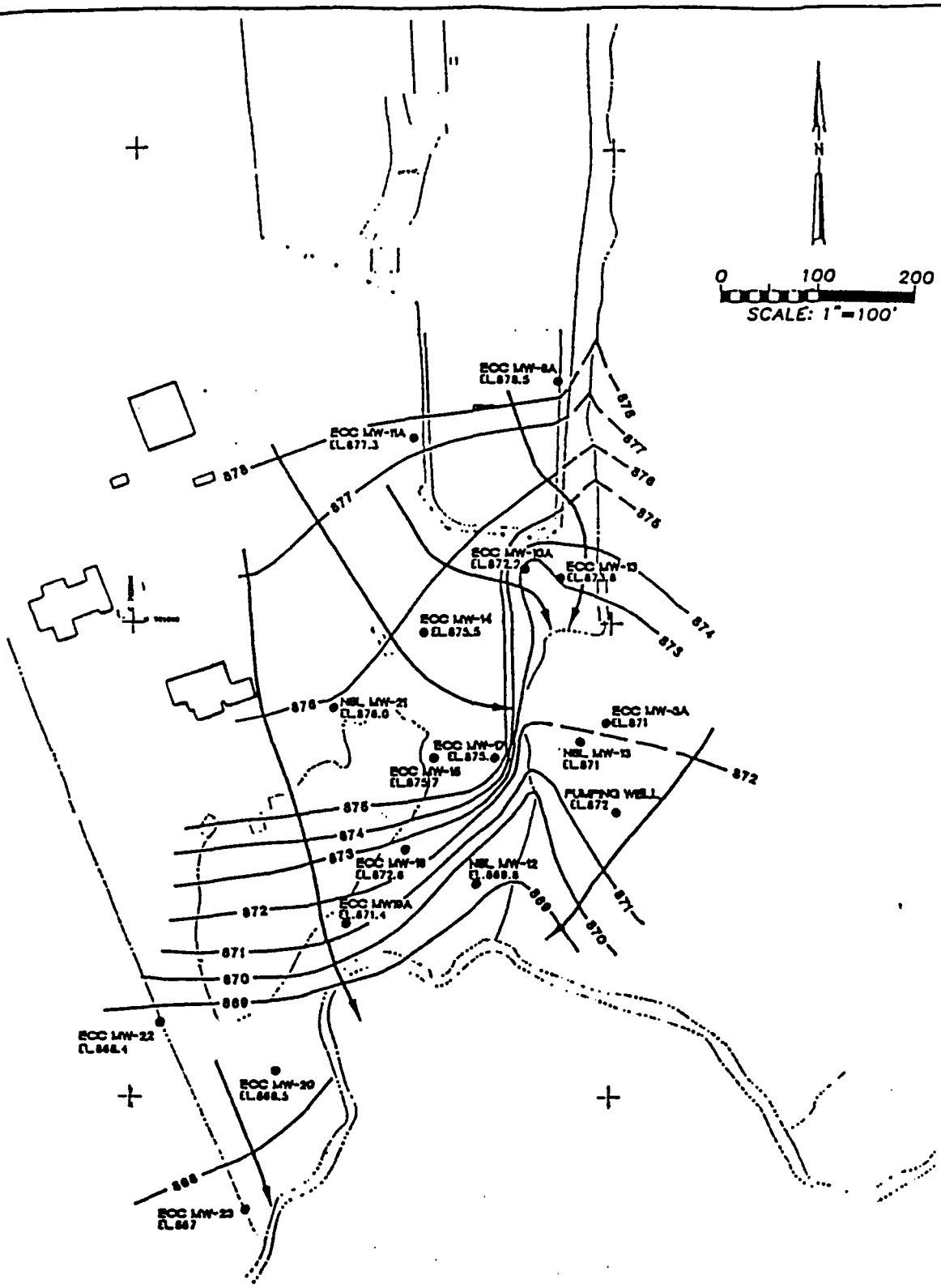
SCREEN ELEV.

SCREEN — 2" PVC 0.01 Slot (Entire depth of sand and grave

FILTER — Sand

BACKFILL/SEAL — N/A

ECC - Typical Monitoring Well Construction Detail Well in Sand & Gravel	FIGUR 2-9
ERM ERM-North Central, Inc.	



LEGEND

—869— POTENTIOMETRIC SURFACE CONTOUR FOR SAND AND GRAVEL AQUIFER. CONTOUR INTERVAL: 1 FOOT.

- - 869 - - INFERRED POTENTIOMETRIC SURFACE CONTOUR

→ DIRECTION OF GROUNDWATER MOVEMENT IN SURFICIAL AQUIFER

NOTE: Contours have been drawn to suggest that the pond is not hydraulically connected to the sand and gravel aquifer. This relationship has not been fully established.

From CH2M HILL Technical Memorandum No. 2, dated September 16, 1988.

POTENTIOMETRIC SURFACE MAP OF UPPER SAND AND GRAVEL AQUIFER	FIGURE 2-10
ERM ERM-North Central, Inc.	10/27/88 CS

Samples from the off-site wells will be collected quarterly during site soil remediation and analyzed for the parameters in Table 3-1. Monitoring will be continued on a semi-annual basis as specified below.

The surface water will be monitored by sampling the Unnamed Ditch just upgradient and just downgradient of the ECC site as depicted in Figure 2-7. Surface water will be sampled at the same frequency as ground water and analyzed for the same parameters.

The semi-annual ground and surface water monitoring called for in this Section 2.1.4 will terminate as follows: As mentioned above, this RAP calls for sampling certain on-site ground water monitoring wells screened in the till. As discussed in Section 4.0, once the laboratory analyses of samples from these on-site till wells in two consecutive, quarterly sampling events lead to the demonstration that the soil Cleanup Standards in Table 3.1 have been met, sampling of the on-site till wells will be discontinued. Once that has occurred, sampling of the off-site wells and surface water under this Section 2.1.4 will be terminated when two consecutive, semi-annual sampling events reveal that none of the Cleanup Standards in Table 3-1 have been exceeded for the appropriate media. If such standards are not achieved for the on-site till wells, off-site wells, or surface water, then additional monitoring activities under Section 3.7 may need to occur.

3.0 REMEDIAL ACTION CLEANUP STANDARDS

This section presents site-specific Cleanup Standards to be used at the ECC site to determine the end point of remediation activities and to accomplish clean closure of the site. Achieving these standards will result in the cleanup of the soil and ground water at the site so that without any further remedial action thereafter, the site will not adversely affect any environmental media, including ground water, surface water, or the atmosphere, and so that direct contact through dermal exposure, inhalation, or ingestion will not result in a threat to human health or the environment. As discussed in Section 3.7 below, if these standards are not achieved in 5 years, then alternative Additional Work as described in Section 3.7 may need to be undertaken.

Sections 3.1 through 3.6 describe the standards to be met to achieve a clean closure.

3.1 Cleanup Standards

To accomplish clean closure of the site, the following Cleanup Standards will be met:

- Soil concentrations will not exceed the soil levels shown in Table 3-1;

- Surface water concentrations from (ECC in Unnamed Ditch south of the site) above the levels shown in Table 3-1 will be prevented; and

TABLE 3-1 (Page 1 of 2)
SITE-SPECIFIC CLEANUP STANDARDS
ENVIRONMENTAL CONSERVATION AND CHEMICAL CORPORATION (ECC) SITE

Compounds	Acceptable Ground Water Concentration (1) (ug/l)		Acceptable Stream Concentration (2) (ug/l)	Acceptable Soil Concentration Value (ug/kg)	Method
VOLATILE ORGANICS (VOCs):					
Acetone	3,500	RB		490	(3)
Chlorobenzene	1,050	RB		177,000	(3)
Chloroform	100	MCL	15.7	2,300	(3)
1,1-Dichloroethane	0.38	RB		5.7	(3)
1,1-Dichloroethene	7	MCL	1.85	120	(3)
Ethylbenzene	3,500	RB	3,280	1,200,000	(3)
Methylene Chloride	4.7	RB	15.7	20	(3)
Methyl Ethyl Ketone	1,750	RB		780	(3)
Methyl Isobutyl Ketone	1,750	RB		8,900	(3)
Tetrachloroethene	0.69	RB	8.85	130	(3)
Toluene	10,500	RB	3,400	1,250,000	(3)
1,1,1-Trichloroethane	200	MCL	5,280	7,200	(3)
1,1,2-Trichloroethane	0.61	RB	41.8	22	(3)
Trichloroethene	5	MCL	80.7	240	(3)
Total Xylenes	70,000	RB		31,000,000	(3)
BASE NEUTRAL/ACID ORGANICS:					
Bis(2-ethylhexyl)phthalate	2.5	RB	50,000	50,000	(4)
Di-n-Butyl Phthalate	3,500	RB	154,000	8,500,000	(4)
Diethyl Phthalate	28,000	RB	52,100	11,300,000	(3)
Isophorone	8.5	RB		52	(3)
Naphthalene	14,000	RB	620	3,480,000	(3)
Phenol	1,400	RB	570	9,800	(3)
INORGANICS:					
Antimony	14	RB		500,000	(5)
Arsenic	50	MCL	(6)	97,000	(5)
Barium	1,000	MCL		5,000,000	(5)
Beryllium	175	RB		7,000	(5)
Cadmium	10	MCL		10,000	(5)
Chromium	50	MCL	11	1,500,000	(5)
Lead	50	MCL	10	700,000	(5)
Manganese	7,000	RB		7,000,000	(5)
Nickel	700	RB	100	700,000	(5)
Silver	50	MCL		5,000	(5)
Tin	21,000	RB		20,000	(5)
Vanadium	245	RB		500,000	(5)
Zinc	7,000	RB	47	2,000,000	(5)
Cyanide	700	RB	5.2	1,700,000	(4)
PESTICIDES/PCBs:					
PCBs				10,000	(7)

TABLE 3-1 (Page 2 of 2)

NOTES:

(1) MCL = Drinking water Maximum Contaminant Level. 40 CFR 141.
RB = risk-based standard. U.S. EPA, Draft RCRA Facility Investigation Guidance, 1987.

(2) Stream Criteria, from Table 1 of the Record of Decision for the site, September 25, 1987.

(3) Acceptable soil value is based on ingestion of ground water at the site boundary, assuming a dilution of leachate to ground water of 1:196 (Appendix B).

(4) Acceptable soil value is based on ingestion of soil, assuming an ingestion rate of 0.2 grams of soil per day by a 17 kilogram child, as per the RCRA Facility Investigation Guidance and the EPA Memorandum on Interim Final Guidance for Soil Ingestion Rates.

(5) Upper limit of background concentrations listed in U.S. Geological Survey, Background Geochemistry of Some Rocks, Soils, Plants, and Vegetables in the Conterminous United States, Professional Paper 574-F, 1975.

(6) Value in Table 1 of the ROD is below treatability and detection limits.

(7) 40 CFR Part 761.125 . Polychlorinated Biphenyls Spill Cleanup Policy Rule.

- Ground water concentrations above the levels shown in Table 3-1 in the till and sand and gravel monitoring wells will be prevented.

3.2 Calculation of Cleanup Standards

Table 3-1 lists the Cleanup Standards. The equations for calculation of the risks, supporting data and complete references are included in Appendix B.

The calculation of risk-based concentrations shown in Table 3-1 follows the procedures presented in the USEPA Draft RCRA Facility Investigation (RFI) Guidance, July, 1987, and in the USEPA Memorandum on Interim Final Guidance for Soil Ingestion Rates, January 27, 1989. The assumed ingestion rates for soil are either 0.1 grams of soil per day for a 70 kilogram person for 70 years (for compounds with potency factors) or 0.2 grams of soil per day for a 17 kilogram child for 5 years (for compounds with reference doses). The ingestion rate for ground water is 2 liters of water per day by a 70 kg person for 70 years.

Three columns of data, corresponding to ground water, surface water, and soil Cleanup Standards, are presented in Table 3-1. Ground water concentrations are based on either the drinking water Maximum Contaminant Level (MCL) or the appropriate risk-based concentration. These limits assume, as a worst case, that the ground water in the till could be utilized as a lifetime source of drinking water. However, the use of the ground water in the till as a source of drinking water was rejected as infeasible in the ECC Remedial Investigation (RI), page 6-22. As a result, the use of drinking water standards and risk-based standards based upon daily, long-term human consumption of the

till water for Cleanup Standards under this RAP represents an extremely conservative assumption when the real-life risks presented by the ECC site are considered.

Surface water concentrations are taken from the Record of Decision (ROD) for the site, dated September 25, 1987.

Soil concentrations are selected in the following order: (1) regulated cleanup level, such as for PCBs; (2) background concentrations, such as for metals; or (3) lowest of the risk-based concentrations for soil or ground water ingestion.

Table 3-2 presents the compounds detected in soils at the site at levels above the Cleanup Standards specified in Table 3-1. Table 3-3 shows the vapor pressure and solubility of these compounds.

3.3 Volatile Organics (VOCs)

The vapor extraction system to be installed at the site will reduce the current VOCs soil concentrations to the levels shown in Table 3-1. VOC concentrations in ground water in the till and sand and gravel will also be reduced to the levels specified in Table 3-1 by eliminating the source of VOCs, and by extracting ground water from the till in the zone of treatment during the vapor extraction activities.

3.4 Base Neutral/Acid Organics

With the vapor pressures shown in Table 3-3, isophorone and phenol will be reduced to acceptable levels by the vapor extraction system.

TABLE 3-2
COMPOUNDS DETECTED IN THE SOIL AT CONCENTRATIONS
ABOVE THE SITE-SPECIFIC SOIL CLEANUP STANDARDS

Compound	Soil Concentration (ug/kg) Cleanup Standard	Maximum Detected Concentration
VOLATILE ORGANICS (VOCs):		
Acetone	490	650,000
Chloroform	2,300	2,900
1,1-Dichloroethane	5.7	35,000
1,1-Dichloroethene	120	380
Ethylbenzene	1,200,000	1,500,000
Methylene Chloride	20	310,000
Methyl Ethyl Ketone	780	2,800,000
Methyl Isobutyl Ketone	8,900	190,000
Tetrachloroethene	130	650,000
Toluene	1,250,000	2,000,000
1,1,1-Trichloroethane	7,200	1,100,000
1,1,2-Trichloroethane	22	550
Trichloroethene	240	4,800,000
BASE NEUTRAL/ACID ORGANICS:		
Bis(2-ethylhexyl)phthalate	50,000	370,000
Isophorone	52	440,000
Phenol	9,800	570,000
PESTICIDES/PCBs:		
PCBs	10,000	39,000
INORGANICS:		
Cadmium	10,000	27,000

TABLE 3-3
CHEMICAL PROPERTIES OF COMPOUNDS
DETECTED IN THE SOILS ABOVE CLEANUP STANDARDS

Compound	Solubility (ug/l)	Vapor Pressure (mm Hg)
VOLATILE ORGANICS (VOCs):		
Acetone	1,000,000,000	270
Chloroform	8,200,000	151
1,1-Dichloroethane	5,500,000	182
1,1-Dichloroethene	2,250,000	600
Ethylbenzene	152,000	7
Methylene Chloride	20,000,000	362
Methyl Ethyl Ketone	268,000,000	77.5
Methyl Isobutyl Ketone	17,000,000	6
Tetrachloroethene	200,000	17.8
Toluene	535,000	28.1
1,1,1-Trichloroethane	4,400,000	123
1,1,2-Trichloroethane	4,500,000	30
Trichloroethene	1,100,000	57.9
BASE NEUTRAL/ACID ORGANICS:		
Bis(2-ethylhexyl)phthalate	1,300	0.0000002
Isophorone	12,000	0.38
Phenol	93,000,000	0.341
PESTICIDES/PCBs:		
Aroclor-1232	1,450	0.00406
Aroclor-1260	2.7	0.0000405

REFERENCES:

U.S. EPA, Superfund Public Health Evaluation Manual, 1986.

U.S. EPA, Water-Related Environmental Fate of 129 Priority Pollutants, December 1979.

Bis(2-ethylhexyl)phthalate (EHP) will not be significantly extracted by soil vapor extraction due to its low vapor pressure (see Table 3-3). However, EHP does not and will not present any risk to human health or the environment. First, EHP was only detected in 8 of 35 samples at the site. Second, EHP is easily biodegraded under aerobic conditions, with a half life of about two weeks (USEPA, Water-Related Environmental Fate of 129 Priority Pollutants, December, 1979). The vapor extraction system to be implemented by Settling Defendants will create an aerobic environment conducive to accelerated biodegradation of EHP even beyond that which may have occurred since the RI samples were taken in 1984. Third, EHP has a high affinity for organic carbon in soil. As a result, any amount of EHP that may remain in the soil is unlikely to adversely impact ground water because it will be chemically fixed to the soil and because the RCRA-compliant cover will substantially reduce (by 99%) infiltration through the soil. The RCRA compliant cover will also eliminate any potential for risk from any possible contact with or migration of EHP. Finally, the ground water and surface water Cleanup Standards that are part of this RAP will ensure that ground water and surface water are protected from adverse impacts.

As a result of the comprehensive remedy to be implemented by Settling Defendants, no route of exposure (air, ground water, surface water, or direct contact/ingestion) will create a risk to human health or the environment.

3.5 Pesticides/PCBs

Due to their low vapor pressures (Table 3-3), the PCBs will also not be removed by vacuum vapor extraction. However, PCBs also will not present any risk to human health or the environment. First, PCBs were detected above the soil Cleanup Standards at only one location (TP-9, 1-2') and only detected at any level in 6 of 35 soil samples collected at the site. It is also noteworthy that PCBs have never been detected in any ground water monitoring wells at and around the site. Second, PCBs have an extremely low solubility and a very high affinity for organic carbon in soil and are, therefore, chemically fixed to the soil and immobile at the site. As a result, any amount of PCBs remaining in the soil is unlikely to adversely impact ground water. Moreover, the RCRA-compliant cover will substantially reduce (by 99%) infiltration through the soil thereby further protecting the environment. Finally, the RCRA-compliant cover will eliminate any potential for risk from any possible contact with or migration of PCBs.

As a result of the measures to be implemented by Settling Defendants, no route of exposure for PCBs (air, ground water, surface water, or direct contact/ingestion) will create a risk to human health or the environment.

3.6 Inorganics

Cadmium was the only inorganic compound detected at the site at concentrations above the respective Cleanup Standards specified in Table 3-1. However, cadmium also does not and will not present any risk to human health or the environment. First, and like PCBs, cadmium was only detected above the cleanup standards

at one location (TP-8, 2.5-4'). Second, cadmium was only detected in 6 of 36 soil samples collected at the site for inorganics analysis. Third, cadmium is an element which occurs naturally in the environment; its presence likely results from natural weathering processes of soil in the environment. Fourth, any amount of cadmium remaining in the soil is unlikely to adversely impact ground water because the RCRA compliant cover will substantially reduce (by 99%) infiltration through the soil. Fifth, the RCRA compliant cover will eliminate any potential for risk from any possible contact with or migration of cadmium. Finally, the ground water and surface water cleanup standards that are part of this RAP will ensure that ground water and surface water are protected from adverse impacts. As a result, no route of exposure for cadmium (air, ground water, surface water, or direct contact/ingestion) will create a risk to human health or the environment.

3.7 Additional Work

If Additional Work is required under Section VII of the Consent Decree, Settling Defendants shall either perform such Additional Work as the Parties may agree or shall arrange with a Contractor to perform the following additional work at the site:

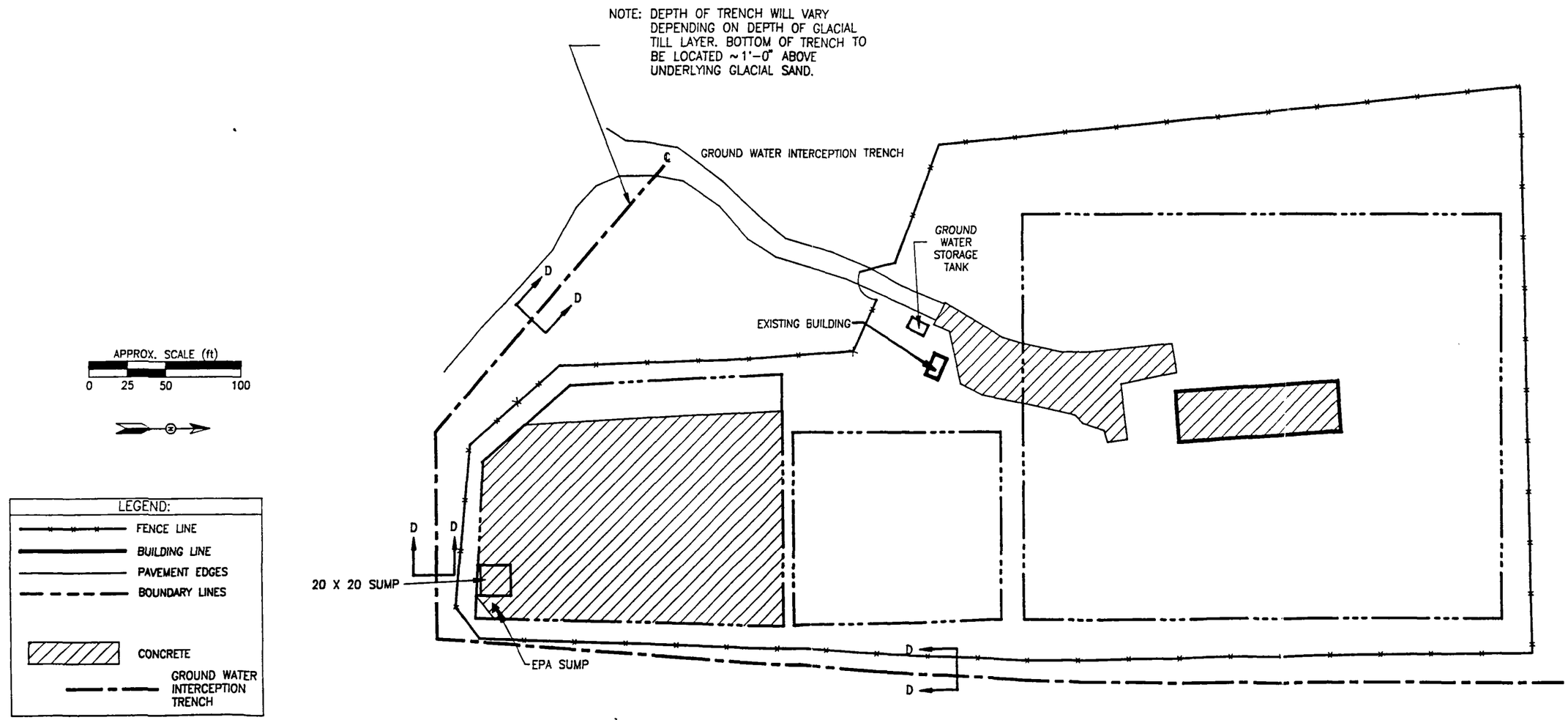
- The RCRA-compliant cover will be maintained and access and land use restrictions will remain in effect.

- If ground water beneath the site exceeds the Cleanup Standards for ground water in Table 3-1, a ground water interception trench will be constructed around the south and east sides of the ECC site as depicted in Figures 3-1 and 3-2.

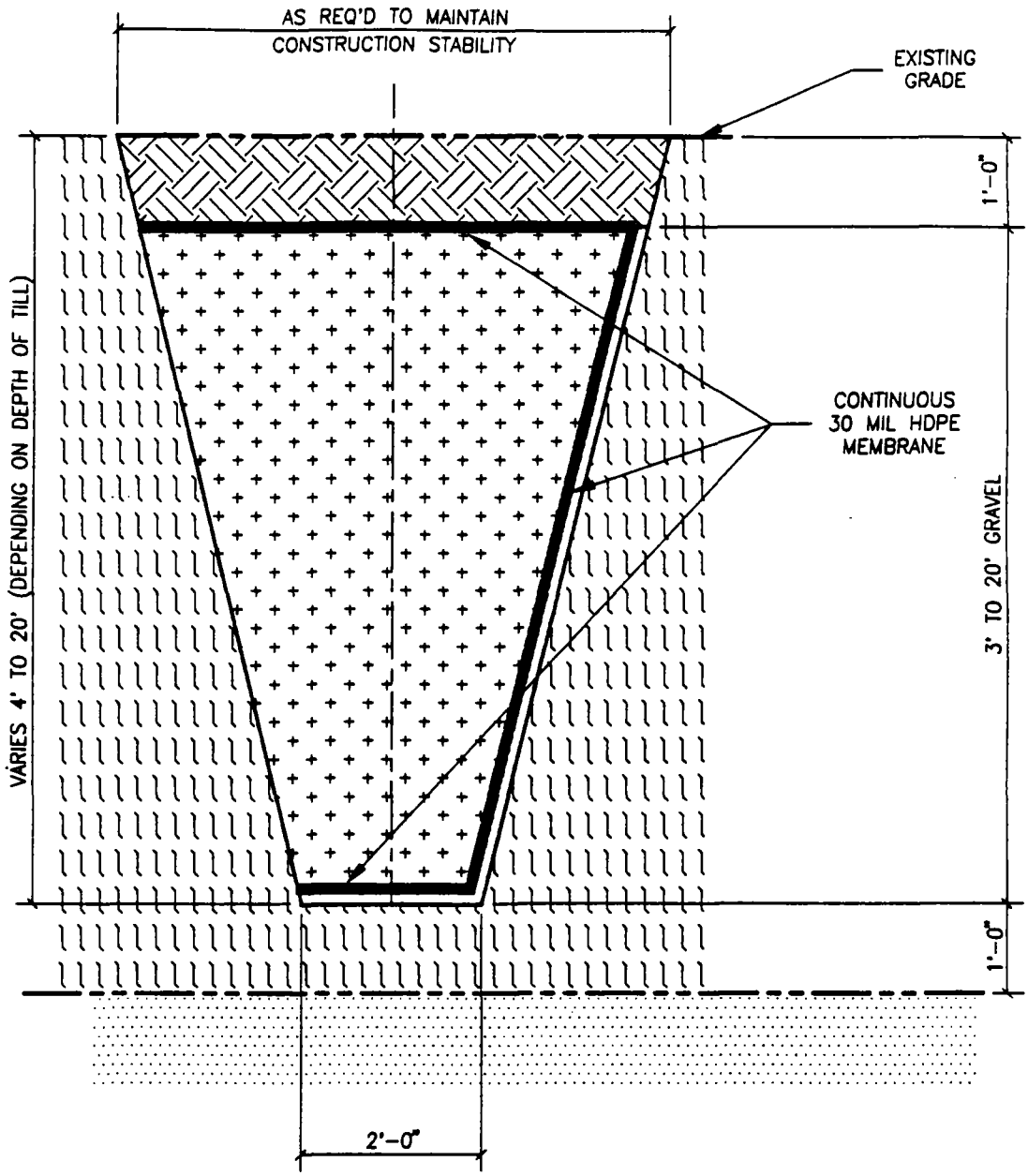
- Ground water that exceeds the Cleanup Standards for ground water in Table 3-1 will be collected in this trench, pumped out and transported to the Indianapolis POTW (via the NSL pipeline or tank truck), or to such other facility, for appropriate handling and treatment in accordance with federal, state and local requirements.

- Ground water will continue to be collected and treated in this manner until two consecutive, semi-annual ground water samples collected from the ground water interception trench show that the ground water Cleanup Standards in Table 3-1 have been met unless the Parties to the Decree otherwise agree or the Court orders that said remedial action may be terminated.

- Semi-annual ground water sampling and monitoring will continue so long as ground water continues to be collected.



ENVIRONMENTAL CONSERVATION AND CHEMICAL CORPORATION ZIONSVILLE, INDIANA GROUND WATER INTERCEPTION TRENCH	FIGURE NO. 3-1
ERM ERM-North Central, Inc.	3/22/89 CS



LEGEND:

- COMPACTED NATIVE SOIL
- WASHED FLOAT STONE
- SAND
- GLACIAL TILL
- 30 MIL HDPE COVER

SECTION D-D

GROUND WATER INTERCEPTION TRENCH CROSS-SECTION	FIGURE 3-2
ERM ERM-North Central, Inc.	3/23/89 mo

Nothing in this Section 3.7 shall prevent the Settling Defendants from undertaking additional work under this section before the expiration of the 5 year period should it become evident that the vapor extraction system will not achieve the Cleanup Standards in Table 3-1.

4.0 REMEDIAL ACTION COMPLIANCE MONITORING

Remedial action compliance monitoring within the site (i.e., attainment of soil concentrations specified in Table 3-1) is presented below.

Enhanced volatilization of compounds is designed to achieve the required removals of VOCs, phenol and isophorone as presented in Appendix C. The time required to accomplish this removal depends on the type of compound and soil, air flow rate and temperature, and on an efficient diffusion of air through the soil pores. Therefore, both estimation of the time required for treatment using vapor extraction models (Appendix C) and surrogate analyses, as shown herein, will be used to determine the duration of vapor extraction operation.

The two surrogate analyses to be used to verify that acceptable soil concentrations have been reached are extracted vapor analysis and on-site till water analysis. The only media that come into contact with the on-site soils are air and water. Sampling the extracted air and till water provides an accurate, efficient and effective method of assaying what concentrations are left in the soil. An additional benefit is that these methods can be accomplished while preserving the integrity of the RCRA-compliant cover to be placed on the site. As the only media

that come in contact with the soil will meet the Table 3-1 soil Cleanup Standards, then any concentrations that theoretically could remain in the soil: (1) are not capable of migrating; (2) cannot, by definition, result in a hazard to the air or ground water; and (3) are effectively isolated from contact and exposure by the cover.

4.1 Vapor Extraction Model

A computer model which simulates the vapor extraction system was used to estimate the time required for removal of the maximum detected soil concentrations to acceptable soil cleanup standards specified in Table 3-1. Appendix C summarizes the characteristics of the model and the data used. The air flow rate was proportionately reduced from the total flow of 500 SCFM, using the ratio of length of element to total length of trench, and conservatively assuming an efficiency ratio for the operation of 15 percent. Based on the model results, it is expected that after one year of operation, all the VOCs, as well as phenol and isophorone, will be below the soil Cleanup Standards in Table 3-1 in a "worst case" soil element which contains all the compounds at their maximum detected concentrations.

4.2 Extracted Vapor Analysis

The vapor extraction system will be capable of providing vapor samples from each individual extraction trench as well as from the combined air flow.

The combined air flow will be sampled daily during the first week of operation, weekly for the following 4 weeks, and monthly thereafter. Samples will be analyzed for the VOCs of concern (Table 3-1), phenol and isophorone. Also, air flow rate will be monitored and recorded, to provide sufficient data to calculate the mass of organics removed from the soils and the effectiveness of the system. These data will also aid in estimating the treatment time remaining, based on the organics mass rate extracted per day.

Air samples from individual extraction trenches will be collected at the beginning of the vapor extraction system operation to establish a baseline of organics removal per trench. These samples will be analyzed for the VOCs of concern (Table 3-1), phenol and isophorone. Once the mass rate extracted per day is reduced to 5 percent of the initial week's rate, additional samples of individual trenches will be collected every three months, to determine when individual extraction trenches can be shut down. The criterion for shutting down individual trenches will be that two consecutive air samples from an individual trench show vapor concentrations to be in equilibrium with the soil Cleanup Standards in Table 3-1. Table 4-1 shows the soil vapor concentrations in equilibrium with these soil Cleanup Standards.

To confirm that all the compounds have been removed to their respective soil Cleanup Standard in Table 3-1, the "restart spike" method will be used. This method consists of periodically shutting down and restarting the vapor extraction system. By shutting down the system, equilibrium conditions of organics within the soil matrix are re-established. Therefore, when the vapor extraction system is restarted, the initial organics

TABLE 4-1 (Page 1 of 2)
SOIL GAS CONCENTRATIONS IN EQUILIBRIUM
WITH SOIL CLEANUP STANDARDS

Component (1)	Molecular Weight (2) (g/gmole)	Vapor Pressure (2) (mm Hg)	Solubility (2) (ug/l)	Henry's Law Constant (3) (dimensionless)	Soil-water Partition Coefficient (4) (l/kg)	Soil Cleanup Standard (5) (ug/kg)	Soil Gas Concentration (6) (mg/m3)	Soil Gas Concentration (6) ppmv
VOLATILE ORGANICS (VOCs):								
Acetone	58.1	270	1,000,000,000	0.000889	0.00071	490	0.000309	0.000128
Chloroform	119	151	8,200,000	0.124	0.116	2,300	33.1	6.68
1,1-Dichloroethane	99	182	5,500,000	0.186	0.076	5.7	0.080	0.0196
1,1-Dichloroethene	97	600	2,250,000	1.47	0.086	120	15.1	3.81
Ethylbenzene	106	7	152,000	0.277	1.75	1,200,000	580,872	133,534
Methylene Chloride	84.9	362	20,000,000	0.0871	0.022	20	0.0383	0.0109
Methyl Ethyl Ketone	72.1	77.5	268,000,000	0.00118	0.00226	780	0.00208	0.000708
Methyl Isobutyl Ketone	100	6	17,000,000	0.00200	0.026	8,900	0.463	0.113
Tetrachloroethene	166	17.8	200,000	0.837	0.941	130	102	14.9
Toluene	92.1	28.1	535,000	0.274	0.607	1,250,000	207,975	54,302
1,1,1-Trichloroethane	133	123	4,400,000	0.211	0.183	7,200	278	50.1
1,1,2-Trichloroethane	133	30	4,500,000	0.0502	0.183	22	0.202	0.0364
Trichloroethene	132	57.9	1,100,000	0.394	0.242	240	22.9	4.19
BASE NEUTRAL/ACID ORGANICS:								
Isophorone	138	0.38	12,000	0.248	0.031	52	0.399	0.0706
Phenol	94.1	0.341	93,000,000	0.0000196	0.036	9,800	0.00690	0.00176

TABLE 4-1 (Page 2 of 2)

NOTES:
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(1) Compounds above soil cleanup standards in Table 3-1 to be removed by vapor extraction.

(2) Data from U.S. EPA, Superfund Public Health Evaluation Manual, 1986.

(3) Calculated as:

$$\text{Henry's Law Constant (nondimensional)} = \frac{\text{(Vapor Pressure, mm Hg)} * \text{(Molecular Weight, g/gmole)} * \text{(1,000,000 ug/g)} * \text{(1,000 cm3/l)}}{\text{(Solubility, ug/l)} * \text{(R, mm Hg-cm3/gmole-K)} * \text{(T, K)}}$$

where: R = gas law constant = 62,361 mm Hg-cm3/gmole-K; and T = soil temperature = 283 K.

(4) From Appendix B, Table B6.

(5) From Table 3-1.

(6) Calculated as:

$$\text{Concentration in soil gas (mg/m3)} = \frac{\text{(Concentration in soil, ug/kg)} * \text{(Henry's Law Constant, nondimensional)} * \text{(1,000 l/m3)}}{\text{(Partition coefficient, l/kg)} * \text{(1,000 ug/mg)}}$$

Concentration in soil gas (ppmv) = (Concentration in soil gas, mg/m3) / (Factor, mg/m3/ppmv)

The factors for conversion of mg/m3 to parts per million by volume (ppmv) were obtained from Vershueren, K., Handbook of Environmental Environmental Data on Organic Chemicals, 2nd Edition, 1983.

concentration in the extracted gas will be higher than under normal operation. Once "spike" concentrations are lower than the soil cleanup levels in Table 3-1, vapor extraction will be discontinued. An approach to this method, based on MWRI's experience in field systems, is attached as Appendix D (to be prepared). The actual restart spike procedure may vary somewhat, depending upon the vapor extraction system contractor selected.

4.3 Till Water Analysis

Till water within the zone of soil vapor extraction treatment will be collected from four monitoring wells completed in the till and from randomly selected injection trenches. The wells will be 2-in. PVC and will be screened from one foot above trenches bottom to 1-2 feet above the contact between the till and underlying sand and gravel. Screens will have 0.01 inch openings. The wells will have a sand pack to one foot above the top of the screen and a bentonite grout to ground surface.

Samples of the till water will be collected at the beginning of the soil vapor extraction operation, and every three months thereafter. Every time till water is to be collected, the vapor extraction system will be shut down, to allow water to stabilize within the till. Samples will be collected and analyzed for the VOCs of concern (Table 3-1), phenol and isophorone. These results will then be used to calculate soil concentrations (as presented in Appendix B, Table B6).

5.0 MISCELLANEOUS PROVISIONS AND SCHEDULING

Additional future activities will consist of preparing a document package for EPA and State review and approval that will include the project plans (as presented below) and the appropriate construction contract specifications and revised drawings to facilitate competitive bidding by potential contractors. This document package will be submitted to EPA and the State within six (6) months of the entry of the Decree and prior to the construction of the NSL pipeline.

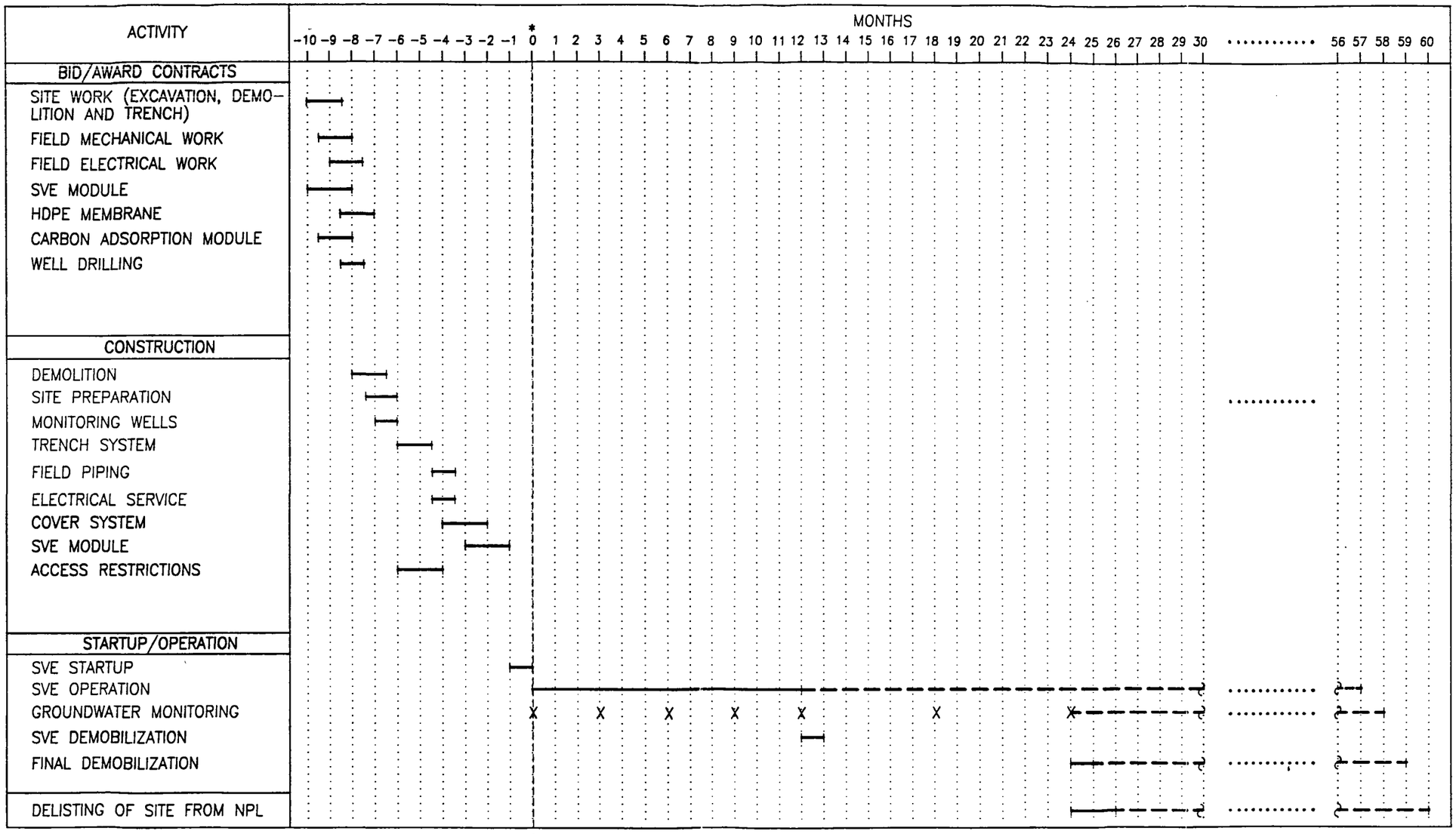
The project plans to be provided are: the Health and Safety Plan, the Quality Assurance Project Plan, and the Field Sampling Plan. Outlines of each plan are included in Appendix E.

The Health and Safety Plan will contain the procedures to be followed to protect on-site personnel and the general public during the remediation at the ECC site.

The Quality Assurance Project Plan will present the procedures for sampling, laboratory analyses, field measurement, and reporting that will provide data to a degree of quality consistent with its intended use and defensible in a court of law.

The Field Sampling Plan will define in detail the sampling and data-gathering methods to be used for the ECC remediation.

Figure 5-1 sets forth the Remedial Action Implementation Schedule for implementing the remedy required under the Consent Decree.



NOTES:

SVE ≙ SOIL VAPOR EXTRACTION

* MONTH "0" CORRESPONDS TO THE DATE THE NSL PIPELINE IS AVAILABLE FOR ECC USE

* * SVE SYSTEM OPERATION IS PLANNED FOR 12 MOS. BUT MAY BE EXTENDED IF NECESSARY TO ACHIEVE CLEANUP STANDARDS

* * * FINAL DEMOBILIZATION AND DELISTING ACTIVITIES WILL OCCUR ONCE CLEANUP STANDARDS HAVE BEEN ACHIEVED & VERIFIED.

REMEDIAL ACTION IMPLEMENTATION SCHEDULE	FIGURE NO. 5-1
ERM ERM-North Central, Inc.	3/23/89 mo

APPENDIX A

ESTIMATE OF MASS OF ORGANICS IN THE SOILS TO BE REMOVED BY VAPOR EXTRACTION

APPENDIX A
ESTIMATE OF MASS OF ORGANICS IN THE SOILS
TO BE REMOVED BY VAPOR EXTRACTION

Location	Sampling depth ft	Assumed contamination depth, ft	Total VOCs concentration ug/kg	Mass of VOCs lb
TP-1	1 - 1.5	2	1,972	0.271
TP-2	1 - 1.5	2	28	0.004
TP-3	1 - 1.5	2	108,800	14.978
TP-4	1 - 2	2.5	99,730	17.162
TP-4	2.5 - 3.5	4	4,416	1.216
TP-5	1 - 2	2	24,287	3.343
TP-5	2 - 3	1.5	291	0.030
TP-6	1 - 2	2	12,468,000	1,716.410
TP-6	2 - 3	1.5	22,690	2.343
TP-6	4 - 5	1.5	2,416	0.249
TP-7	1 - 2.5	2.5	267,000	45.946
TP-7	2.5 - 4	2	280,090	38.559
TP-8	1 - 2.5	2.5	3,687	0.634
TP-8	2.5 - 4	2	433,600	59.692
TP-9	1 - 3	3	14,604,000	3,015.694
TP-9	3 - 5	2.5	130	0.022
TP-10	1 - 3	3	958	0.198
TP-10	3 - 5	2.5	432	0.074
TP-11	1 - 3	3	130	0.027
TP-11	3 - 5	2.5	67	0.012
TP-12	1 - 3	3	35,030	7.234
TP-12	3 - 5	2.5	3,609	0.621
SB-01	2.5 - 4	3	3,303	0.682
SB-02	2.5 - 4	3	12,900	2.664
SB-03	2.5 - 4	3	70,070	14.469
SB-04	2 - 3.5	2.5	175	0.030
SB-06	2 - 3.5	2.5	222,010	38.204
SB-08	2.5 - 4	3	3,012	0.622
SB-09	2.5 - 4	3	61,490	12.698
SB-01	5.5 - 7	2	27	0.004
SB-02	5.5 - 7	2	34	0.005
SB-04	5 - 6.5	2	51	0.007
SB-08	7 - 8.5	2	188	0.026
SB-09	5.7 - 7	2	8,069	1.111
			TOTAL VOCs, lb	4,995

* The area contaminated is assumed to be a 25'x25' square around each sampling location. TP = test pit; SB = soil boring. Soil concentrations from ECC RI, Section 4.

APPENDIX B

CALCULATION OF RISK-BASED CLEANUP STANDARDS

APPENDIX B

CALCULATION OF RISK-BASED CLEANUP STANDARDS

The equations used to calculate risk-based concentrations are shown in Table B1. The ingestion rates and acceptable risks are listed in Table B2. The potency factors and references doses for compounds without any regulatory or background level are from a memorandum from the USEPA Toxics Integration Branch, OERR, Washington, D.C., dated December 19, 1988, with the Corrections to the July, 1988 Update of the Characterization Tables in the Superfund Public Health Evaluation Manual.

Table B3 presents the calculation of risk-based acceptable ground water concentrations in the till for compounds without a regulatory limit (drinking water Maximum Contaminant Level or PCBs Spill Cleanup Policy level). Table B4 shows that the resulting concentrations of compounds at Unnamed Ditch will be below the Stream Criteria presented in Table 1 of the Record of Decision (ROD) for the site, dated September 25, 1987. The dilution obtained from discharge of the ground water in the till to Unnamed Ditch is 1:1800, as presented in Appendix C of the ECC Remedial Investigation. Note that most of the calculated concentrations in the ditch are below detection limits.

Tables B5 and B6 list the acceptable risk-based soil concentrations, based on soil and ground water ingestion, respectively. The calculation of acceptable soil concentrations based on ground water ingestion follows the procedures presented in Appendix C of the ECC RI. Only those compounds without regulatory limit or background levels in soils are listed in Tables B5 and B6. Also, cyanide is not present for lack of a organic carbon/water partition coefficient. It is conservatively

TABLE B1

EQUATIONS USED TO CALCULATE RISK-BASED CONCENTRATIONS *

SOIL (concentrations in ug/kg):

$$\frac{\text{Risk} * \text{Body Weight (kg)} * 1000\ (\text{ug/mg}) * 1000\ (\text{g/kg})}{\text{Ingestion rate (g/d)} * \text{Potency Factor (mg/kg/d)}^{-1}}$$

or

$$\frac{\text{Risk} * \text{Body Weight (kg)} * \text{Reference Dose (mg/kg/d)} * 1000\ (\text{ug/mg}) * 1000\ (\text{g/kg})}{\text{Ingestion rate (g/d)}}$$

GROUND WATER (concentrations in ug/l):

$$\frac{\text{Risk} * \text{Body Weight (kg)} * 1000\ (\text{ug/mg})}{\text{Ingestion rate (l/d)} * \text{Potency Factor (mg/kg/d)}^{-1}}$$

or

$$\frac{\text{Risk} * \text{Body Weight (kg)} * \text{Reference Dose (mg/kg/d)} * 1000\ (\text{ug/mg})}{\text{Ingestion rate (l/d)}}$$

TABLE B2
INGESTION RATES AND ACCEPTABLE RISKS

INGESTION RATES * :

SOILS:

0.1 grams per day by a 70-kilogram person for 70 years

or

0.2 grams per day by a 17-kilogram child for 5 years

GROUND WATER:

2 liters of water per day by a 70-kilogram person for 70 years

ACCEPTABLE RISKS:

COMPOUNDS WITH POTENCY FACTORS:

10^{-6}

COMPOUNDS WITH REFERENCE DOSES:

1

* From U.S. EPA, RCRA Facility Investigation Guidance, 1987, and U.S. EPA, Office of Solid Waste and Emergency Response, Memorandum on Interim Final Guidance for Soil Ingestion Rates, January 27, 1989.

TABLE B3

ECC - ACCEPTABLE HEALTH-BASED GROUND WATER CONCENTRATIONS

Compound (1)	Potency Factor (2) (mg/kg/d)-1	Reference Dose (2) (mg/kg/d)	Acceptable Ground Water Concentration (3) (ug/l)
VOLATILE ORGANICS (VOCs):			
Acetone		0.1	3,500
Chlorobenzene		0.03	1,050
1,1-Dichloroethane	0.091		0.38
Ethylbenzene		0.1	3,500
Methylene Chloride	0.0075		4.7
Methyl Ethyl Ketone		0.05	1,750
Methyl Isobutyl Ketone		0.05	1,750
Tetrachloroethene	0.051		0.69
Toluene		0.3	10,500
1,1,2-Trichloroethane	0.057		0.61
Total Xylenes		2	70,000
BASE NEUTRAL/ACID ORGANICS:			
Bis(2-ethylhexyl)phthalate	0.014		2.5
Di-n-Butyl Phthalate		0.1	3,500
Diethyl Phthalate		0.8	28,000
Isophorone	0.0041		8.5
Naphthalene		0.4	14,000
Phenol		0.04	1,400
INORGANICS:			
Antimony		0.0004	14
Beryllium		0.005	175
Manganese		0.2	7,000
Nickel		0.02	700
Tin		0.6	21,000
Vanadium		0.007	245
Zinc		0.2	7,000
Cyanide		0.02	700

(1) Only compounds without a regulatory limit (drinking water Maximum Contaminant Level [40 CFR 141] or PCBs Spill Cleanup Policy Rule [40 CFR 761] level) are shown.

(2) From USEPA Toxics Integration Branch, OERR, Washington, D.C. December 1988 correction to the July 1988 Update of the Risk Characterization Tables in the Superfund Public Health Evaluation Manual.

(3) Acceptable ground water concentrations calculated using an ingestion rate of 2 liters per day by a 70 kg adult for 70 years. Acceptable risk = 1E-06 for compounds with potency and 1 for compounds with reference dose.

TABLE B4
COMPARISON OF SITE-SPECIFIC STREAM CRITERIA
WITH STREAM CONCENTRATIONS BASED ON NATURAL
DISCHARGE OF GROUND WATER FROM THE TILL

Compounds (1)	Acceptable Stream Concentration (1) (ug/l)	Concentration at Unnamed Ditch due to Discharge of Till Water at Acceptable Concentrations (2) (ug/l)
VOLATILE ORGANICS (VOCs):		
Chloroform	15.7	0.056
1,1-Dichloroethene	1.85	0.0039
Ethylbenzene	3,280	1.9
Methylene Chloride	15.7	0.0026
Tetrachloroethene	8.85	0.00038
Toluene	3,400	5.8
1,1,1-Trichloroethane	5,280	0.11
1,1,2-Trichloroethane	41.8	0.00034
Trichloroethene	80.7	0.0028
BASE NEUTRAL/ACID ORGANICS:		
Bis(2-ethylhexyl)phthalate	50,000	0.0014
Di-n-Butyl Phthalate	154,000	1.9
Diethyl Phthalate	52,100	15.6
Naphthalene	620	7.8
Phenol	570	0.78
INORGANICS:		
Arsenic	0.0175	0.028
Chromium	11	0.028
Lead	10	0.028
Nickel	100	0.39
Zinc	47	3.9
Cyanide	5.2	0.39

(1) From Table 1 of the Record of Decision (ROD) for the site, September 25, 1987. Only those compounds detected in ECC soil samples that are listed in this table are shown.

(2) Assuming a dilution of 1:1800 for natural discharge of till ground water at acceptable concentrations into Unnamed Ditch (from ECC Remedial Investigation, Appendix C).

TABLE B5

ECC - ACCEPTABLE SOIL CONCENTRATIONS BASED ON SOIL INGESTION

Compounds (1)	Potency Factor (2) (mg/kg/d)-1	Reference Dose (2) (mg/kg/d)	Acceptable Soil Concentrations (3) (ug/kg)	Range of Acceptable Soil Concentrations (4) (ug/kg)
VOLATILE ORGANICS (VOCs):				
Acetone		0.1	8,500,000	850,000-850,000,000
Chlorobenzene		0.03	2,550,000	255,000-255,000,000
Chloroform	0.0061		114,754	11,475-11,475,400
1,1-Dichloroethane	0.091		7,692	769-769,200
1,1-Dichloroethene	0.6		1,167	117-116,700
Ethylbenzene		0.1	8,500,000	850,000-850,000,000
Methylene Chloride	0.0075		93,333	9,333-9,333,300
Methyl Ethyl Ketone		0.05	4,250,000	425,000-425,000,000
Methyl Isobutyl Ketone		0.05	4,250,000	425,000-425,000,000
Tetrachloroethene	0.051		13,725	1,373-1,372,500
Toluene		0.3	25,500,000	2,550,000-2,550,000,000
1,1,1-Trichloroethane		0.09	7,650,000	765,000-765,000,000
1,1,2-Trichloroethane	0.057		12,281	1,228-1,228,100
Trichloroethene	0.011		63,636	6,364-6,363,600
Total Xylenes		2	170,000,000	17,000,000-17,000,000,000
BASE NEUTRAL/ACID ORGANICS:				
Bis(2-ethylhexyl)phthalate	0.014		50,000	5,000-5,000,000
Di-n-Butyl Phthalate		0.1	8,500,000	850,000-850,000,000
Diethyl Phthalate		0.8	68,000,000	6,800,000-6,800,000,000
Isophorone	0.0041		170,732	17,073-17,073,200
Naphthalene		0.4	34,000,000	3,400,000-3,400,000,000
Phenol		0.04	3,400,000	340,000-340,000,000
INORGANICS:				
Cyanide		0.02	1,700,000	170,000-170,000,000

(1) Compounds shown are those without a regulatory limit or background level in soils.

(2) From USEPA Toxics Integration Branch, OERR, Washington, D.C. December 19, 1988 corrections to the July 1988 Update of the Characterization Tables in the Superfund Public Health Evaluation Manual.

(3) Intake for compounds with potency: 0.1 g of soil/d by 70 kg resident adults.
Intake for compounds with reference dose: 0.2 g of soil/d by 17 kg resident children.
Acceptable risks: 1E-06 for compounds with potency; 1 for compounds with reference doses.

(4) Range shown is for risks of 10-4 to 10-7 for compounds with potency and 1 for compounds with reference doses.

TABLE B6 (Page 1 of 2)

ECC - ACCEPTABLE SOIL CONCENTRATIONS BASED ON GROUND WATER INGESTION AT THE SITE (10-6 RISK)

Compound (1)	Solubility (2) (ug/l)	Log Kow (2)	Kd (3)	Acceptable Ground Water Concentration (4) (ug/l)		Acceptable Leachate Concentration (5) (ug/l)	Acceptable Soil Concentration (6) (ug/kg)
VOLATILE ORGANICS (VOCs):							
Acetone	1,000,000,000	-0.24	0.00071	3,500	RB	686,275	490
Chlorobenzene	466,000	2.84	0.858	1,050	RB	205,882	176,620
Chloroform	8,200,000	1.97	0.116	100	MCL	19,608	2,269
1,1-Dichloroethane	5,500,000	1.79	0.076	0.38	RB	74.5	5.70
1,1-Dichloroethene	2,250,000	1.84	0.086	7	MCL	1,373	118
Ethylbenzene	152,000	3.15	1.75	3,500	RB	686,275	1,202,042
Methylene Chloride	20,000,000	1.25	0.022	4.7	RB	922	20.3
Methyl Ethyl Ketone	268,000,000	0.26	0.00226	1,750	RB	343,137	774
Methyl Isobutyl Ketone	17,000,000		0.02604	1,750	RB	343,137	8,935
Tetrachloroethene	200,000	2.88	0.941	0.69	RB	135	127
Toluene	535,000	2.69	0.607	10,500	RB	2,058,824	1,250,377
1,1,1-Trichloroethane	4,400,000	2.17	0.183	200	MCL	39,216	7,193
1,1,2-Trichloroethane	4,500,000	2.17	0.183	0.61	RB	120	21.9
Trichloroethene	1,100,000	2.29	0.242	5	MCL	980	237
Total Xylenes	198,000	3.26	2.26	70,000	RB	13,725,490	30,970,595
BASE NEUTRAL/ACID ORGANICS:							
Bis(2-ethylhexyl)phthalate	1,300	8.7	621472	2.5	RB	490	304,643,220
Di-n-Butyl Phthalate	13,000	5.2	197	3,500	RB	686,275	134,871,303
Diethyl Phthalate	4,320,000	3.22	2.06	28,000	RB	5,490,196	11,298,207
Isophorone	12,000		0.031	8.5	RB	1,667	51.7
Naphthalene	30,000	3.01	1.269	14,000	RB	2,745,098	3,483,209
Phenol	93,000,000	1.46	0.036	1,400	RB	274,510	9,817

TABLE B6 (Page 2 of 2)

(1) Compounds shown are those without a regulatory limit or a soil background level. Also, cyanide is not included because a specific Kow is not available.

(2) From ECC RI, Table 4-4, and Verschueren, 1983, Handbook of Environmental Data on Organic Chemicals.

(3) From ECC RI, Table 4-4. Calculated as 10^log Kow * OC, where OC= organic carbon content = 0.00124. For isophorone and methyl isobutyl ketone, the Kd is obtained as Kd = Koc * OC, where Koc = organic carbon-water partition coefficient, obtained from log Koc = (-0.55 * log S) + 3.64 (Exhibit A-1 of the Superfund Public Health Evaluation Manual, 1986).

(4) RB = risk-based concentration, from Table B3. MCL = Maximum Contaminant Level, from Superfund Public Health Evaluation Manual, update of November, 1987.

(5) Leachate discharge/ground water discharge = 0.0051 (Appendix C of the ECC RI; and reduction of the 7.8 in/yr recharge used in the RI under the current conditions (page 5-8) by 99 percent due to the cap).

(6) Soil concentration (ug/kg) = Kd * Concentration in leachate (ug/l).

assumed that the volume of leachate from the soils will be reduced by 99 percent from the 7.8 in/yr used in the RI, by installing the RCRA-compliant cover over the site.

A range of acceptable soil concentrations based on water ingestion using the published ranges for organic carbon content of till soils and the SARA range of risk for Superfund site cleanups, is presented in Table B7. The concentrations shown in Table B6 were used to determine the Cleanup Standards specified in Table 3-1, using a risk of 10^{-6} and a soil organic carbon content of 0.12%, as presented in the RI.

Finally, Table B8 presents the complete list of references used for the calculation of the proposed Cleanup Standards specified in Table 3-1.

TABLE B7

ECC - ACCEPTABLE SOIL CONCENTRATIONS BASED ON GROUND WATER INGESTION AT THE SITE (RANGE OF RISKS)

Compound (1)	Range of Kd (2)	Acceptable Soil Concentration (3)	
		Range for 10-4 risk	Range for 10-7 risk
VOLATILE ORGANICS (VOCs):			
Acetone	0.000058-0.0044	40-3,019	40-3,019
Chlorobenzene	0.069-5.24	14,200-1,080,000	14,200-1,080,000
Chloroform	0.0093-0.71	182-13,900	182-13,900
1,1-Dichloroethane	0.0062-0.47	46.2-3,500	0.046-3.50
1,1-Dichloroethene	0.0069-0.52	9.47-714	9.47-714
Ethylbenzene	0.14-10.7	96,800-7,340,000	96,800-7,340,000
Methylene Chloride	0.0018-0.14	166-12,900	0.166-12.9
Methyl Ethyl Ketone	0.00018-0.014	61.8-4,800	61.8-4,800
Methyl Isobutyl Ketone	0.0021-0.16	721-54,900	721-54,900
Tetrachloroethene	0.076-5.78	1,028-78,200	1.03-78.2
Toluene	0.049-3.72	101,000-7,660,000	101,000-7,660,000
1,1,1-Trichloroethane	0.015-1.14	588-44,700	588-44,700
1,1,2-Trichloroethane	0.015-1.14	179-13,600	0.179-13.6
Trichloroethene	0.020-1.52	19.6-1,490	19.6-1,490
Total Xylenes	0.18-13.7	2,470,000-188,000,000	2,470,000-188,000,000
BASE NEUTRAL/ACID ORGANICS:			
Bis(2-ethylhexyl)phthalate	50100-3810000	2,460,000,000-187,000,000,000	2,460,000-187,000,000
Di-n-Butyl Phthalate	15.8-1200	10,800,000-824,000,000	10,800,000-824,000,000
Diethyl Phthalate	0.17-12.9	933,000-70,800,000	933,000-70,800,000
Isophorone	0.0025-0.19	417-31,700	0.417-31.7
Naphthalene	0.10-7.6	275,000-20,900,000	275,000-20,900,000
Phenol	0.0029-0.22	796-60,400	796-60,400

(1) Compounds shown are those without a regulatory limit or a soil background level. Also, cyanide is not included because a specific Kow is not available.

(2) For a range of organic carbon content of 0.0001 to 0.0019 obtained from: U.S. Department of Agriculture, Soil Classification - A Comprehensive System. Soil Conservation Service, 7th Approximation, 1960. Calculated as presented in Table B6.

(3) Acceptable soil concentrations at the risk shown (for compounds with potency) for a range of organic carbon content of 0.0001 to 0.0076. Calculated as presented in Table B6.

TABLE B8

REFERENCES

CH2MHILL, Environmental Conservation and Chemical Corporation Feasibility Study, December, 1986.

CH2MHILL, Environmental Conservation and Chemical Corporation Remedial Investigation, March, 1986.

USEPA, Office of Solid Waste and Emergency Response, Memorandum on Interim Final Guidance for Soil Ingestion Rates, January 27, 1989.

USEPA, Region V, Record of Decision for Environmental Conservation and Chemical Corporation, and Northside Sanitary Landfill, Zionsville, Indiana, September 25, 1987.

USEPA, Draft RCRA Facility Investigation Guidance, July, 1987, OSWER Directive 9502.00-6C.

USEPA, National Primary Drinking Water Regulations, 40 CFR 141, last amended by 53 FR 37408, September 26, 1988.

USEPA, Polychlorinated Biphenyls Spill Cleanup Policy Rule, 40 CFR Part 761, published in the Federal Register on April 2, 1987.

USEPA, Superfund Public Health Evaluation Manual, October, 1986, PB87-183125 with updates of November 16, 1987 and July, 1988.

USEPA, Toxics Integration Branch, OERR, Washington, D.C., December, 198 Memorandum with Corrections to the July, 1988 Update of the Risk Characterization Tables in the Superfund Public Health Evaluation Manual.

USEPA, Water-Related Environmental Fate of 129 Priority Pollutants, December, 1979 PB80-204381.

US Geological Survey, Background Geochemistry of Some Rocks, Soils, Plans, and Vegetables in the Conterminous United States, Professional Paper 574-F, 1975.

Veschueren, K., Handbook of Environmental Data on Organic Chemicals, 1983.

APPENDIX C

ECC - VAPOR EXTRACTION MODEL

APPENDIX C

ECC - VAPOR EXTRACTION MODEL

This program was written in FORTRAN by Michael C. Marley and George E. Hoag and reported in "Induced Soil Venting for Recovery/Restoration of Gasoline Hydrocarbons in the Vadose Zone," Proceedings, Petroleum Hydrocarbons and Organic Chemicals in Ground Water Conference, Houston, TX, 1984.

The program is based on the concentration of each component in the vapor phase in the soil, using the partial pressure exerted by each compound, as expressed by the following equation:

$$ZT = \frac{VP * X * V * MW}{R * T}$$

where:

ZT = concentration of the component in the vapor phase, mg/l
VP = vapor pressure of compound, mm Hg
X = mole fraction = moles of component/total moles of organics in soil
V = volume of element, liters
MW = molecular weight of component
R = gas constant = 82.4 atm - cm^3/gmoles^oK
T = temperature = 294.25^oK

The program uses the finite difference method to calculate the change in number of moles of each component during a small time interval (i) and then recalculate over the next time interval (i+1), using the reduced number of moles resulting from subtracting the change in number of moles calculated for interval i from the number of moles present in the soil at the beginning of interval i.

The program runs for a finite length of time or until all the components are removed. The program was rewritten in BASIC and applied to the ECC site.

Table C-1 shows the chemical data used to run the model. The compounds to be evaluated are those shown in Table 3-2, except for EHP, PCBs, and cadmium, which are not amenable to removal by vapor extraction. The maximum detected soil concentrations were taken from Section 4 of the ECC RI, while the vapor pressure and molecular weight data are from USEPA, Superfund Public Health Evaluation Manual, 1986.

As there was significant variation of compounds concentrations between soil samples at the site, a theoretical block size was chosen. This theoretical soil block is 10 ft x 10 ft x 2 ft deep and was assumed to contain all components of interest at their maximum detected concentrations (Table C-1). Furthermore, it was conservatively assumed that the air flow through the soil would only be 15% efficient in removing the organics. In effect, this represents a worst case estimate of the time required to remove the organics from the soils. The mass of this block was estimated as 10,200 kg.

TABLE C1

ECC - CHEMICAL DATA OF COMPOUNDS

Compound (1)	Molecular Weight (2)	Vapor Pressure (2) (mm Hg)	Maximum Detected Soil Concentration (3) (ug/kg)
VOLATILE ORGANICS:			
Acetone	58.1	270	650,000
Chloroform	119	151	2,900
1,1-Dichloroethane	99	182	35,000
1,1-Dichloroethene	97	600	380
Ethylbenzene	106	7	1,500,000
Methylene Chloride	85	362	310,000
Methyl Ethyl Ketone	72.1	77.5	2,800,000
Methyl Isobutyl Ketone	100	6	190,000
Tetrachloroethene	166	17.8	650,000
Toluene	92.1	28.1	2,000,000
1,1,1-Trichloroethane	133	123	1,100,000
1,1,2-Trichloroethane	133	30	550
Trichloroethene	132	57.9	4,800,000
BASE NEUTRAL/ACID ORGANICS:			
Phenol	94.1	0.341	570,000
Isophorone	138	0.38	440,000

(1) Compounds shown are those amenable to soil vapor extraction.

(2) From U.S. EPA, Superfund Public Health Evaluation Manual, 1986.

(3) From ECC RI, March 1986.

The air flow rate was estimated as a fraction of the total air flow rate to be used at the site (500 SCFM), based on the length of injection trench influencing the assumed soil block (10 ft) as a ratio of the total length of injection trenches (3,800 ft). This represents an air flow rate of 37.26 liters per minute.

The results, summarized in Figure C1, show that essentially no VOCs will be present in the hypothetical soil element after 130 days of soil vapor extraction. To remove phenol and isophorone to the Cleanup Standards in Table 3-1, operation of the vapor extraction system for a total of approximately 360 days is necessary.

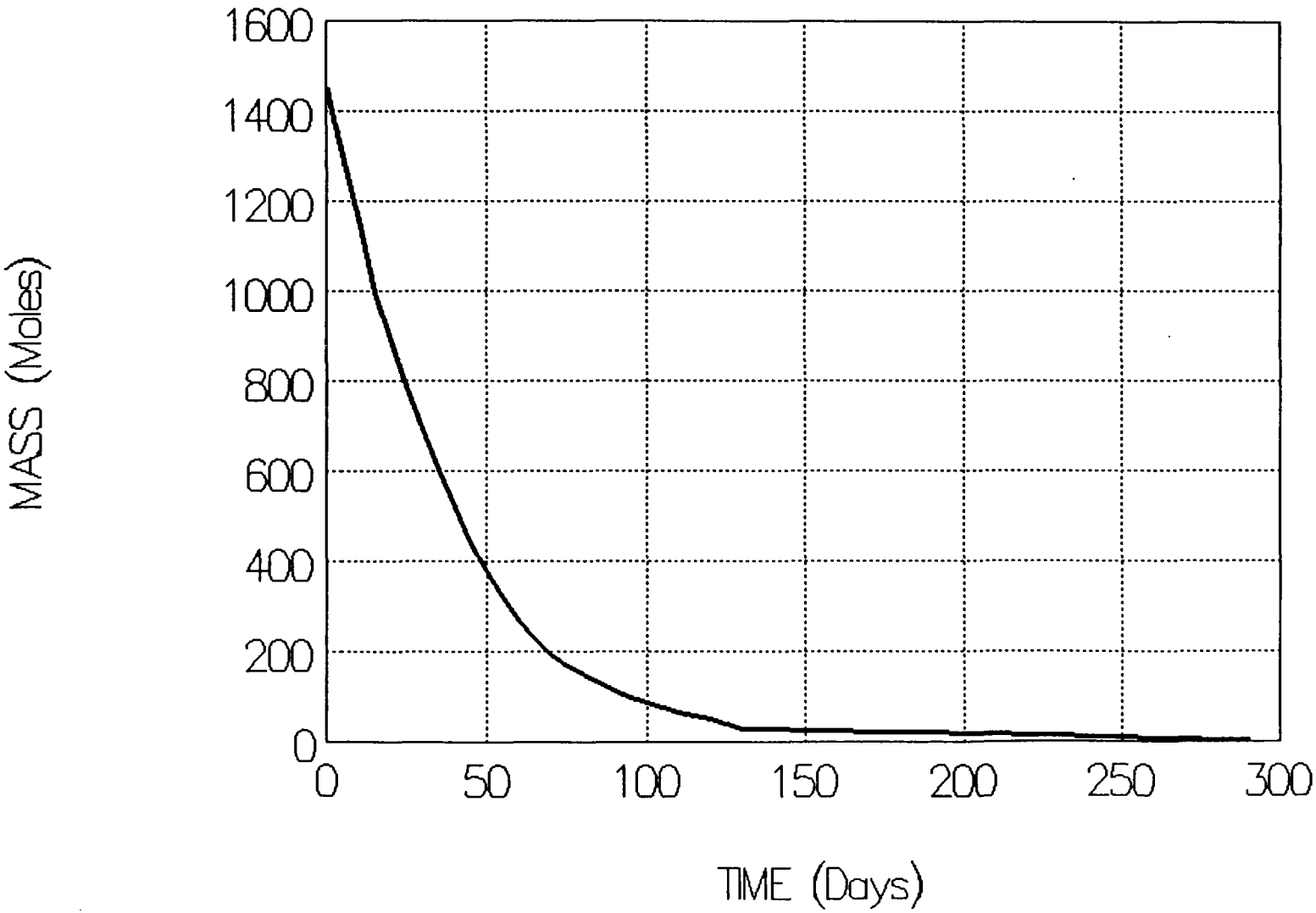
Actual large-scale soil vapor extraction systems have been operated with excellent removals of compounds such as tetrachloroethene, trichloroethene, 1,3-dichloropropene, methyl ethyl ketone, methyl isobutyl ketone, toluene, and xylenes. Some published references are:

- Lisiecki, J.B., and F.C. Payne. "Enhanced Volatilization: Possibilities, Practicalities, and Performance." Presented at the Engineering Foundation Conference, Mercersburg, PA, August 7-12, 1988.

- Regalbuto, D.P., J.A. Barrera and J.B. Lisiecki. "In-Situ Removal of VOCs by Means of Enhanced Volatilization." Proceedings of the Conference on Petroleum Hydrocarbons and Organic Chemicals in Ground Water: Prevention, Detection, and Restoration, Houston, TX, November 9-11, 1988.

Figure C1

ECC VAPOR EXTRACTION MODEL RESULTS



- Johnson, J.J., and R.J. Sterrett. "Analysis of In-Situ Soil Air Stripping Data." Proceedings of the 5th National Conference on Hazardous Wastes and Hazardous Materials, Las Vegas, Nevada, April 19-21, 1988.

A full-scale vapor extraction system (Lisiecki and Payne, 1988) was able to remove tetrachloroethene from 5,600,000 ug/kg to 17 ug/kg, as found by soil sample analysis, in 280 days. Therefore, both theoretical models and actual results show that the required removals will be accomplished by vapor extraction.

APPENDIX D

VAPOR EXTRACTION SYSTEM
RESTART SPIKE METHOD
MWRI'S APPROACH

APPENDIX E
OUTLINE OF PROJECT PLANS

ENVIRONMENTAL CONSERVATION AND CHEMICAL CORPORATION (ECC) SITE ZIONSVILLE, INDIANA

HEALTH AND SAFETY PLAN
OUTLINE

1.0 INTRODUCTION

2.0 GENERAL INFORMATION

- 2.1 Project Safety Officer
- 2.2 Emergency Agencies
- 2.3 Key Project Personnel

3.0 NATURE OF POTENTIAL HAZARDS

- 3.1 Chemical Hazards
- 3.2 Physical Hazards

4.0 GENERAL WORK PROCEDURE

- 4.1 Supervision and Audits of Safety Procedures
- 4.2 Site Control and Work Zones
- 4.3 General Work Rules for Field Activities

5.0 SAFETY TRAINING

6.0 ENVIRONMENTAL MONITORING PROGRAM

7.0 DECONTAMINATION PROCEDURES

- 7.1 Equipment Decontamination
- 7.2 Personnel Decontamination

8.0 PERSONNEL PROTECTIVE EQUIPMENT

- 8.1 Respiratory Protection
- 8.2 Dermal Protection/Protective Clothing

9.0 EMERGENCY PROCEDURES

- 9.1 Worker Injury
- 9.2 Fires
- 9.3 Spills
- 9.4 Evacuation Plan

QUALITY ASSURANCE PROJECT PLAN
OUTLINE

1.0 PROJECT DESCRIPTION

- 1.1 Introduction
- 1.2 Site Description
- 1.3 Proposed Remedial Action Plan
- 1.4 Sample Network and Rationale
- 1.5 Project Schedule

2.0 PROJECT ORGANIZATION AND RESPONSIBILITY

- 2.1 Management
- 2.2 Field Activity
- 2.3 Laboratory Analysis
- 2.4 Quality Assurance
- 2.5 Performance and System Audits

3.0 QUALITY ASSURANCE OBJECTIVES

- 3.1 Level of QC Effort
- 3.2 Accuracy, Precision, and Sensitivity of Analyses
  - 3.2.1 Data Completeness, Representativeness and Comparability
  - 3.2.2 Documentation
  - 3.2.3 Quality Control Requirements

4.0 SAMPLING PLAN

5.0 SAMPLE CUSTODY PROCEDURES

6.0 CALIBRATION PROCEDURES AND FREQUENCY

- 6.1 Field Instruments
- 6.2 Laboratory Equipment

7.0 ANALYTICAL PROCEDURES

8.0 INTERNAL QUALITY CONTROL CHECKS

- 8.1 Analytical Laboratories
- 8.2 Field Quality Control

QUALITY ASSURANCE PROJECT PLAN
OUTLINE
(continued)

9.0 DATA REDUCTION, VALIDATION AND REPORTING

- 9.1 Documentation
- 9.2 Data Validation
- 9.3 Reporting
- 9.4 Data Package/Data Deliverables

10.0 PERFORMANCE AND SYSTEM AUDITS

- 10.1 Laboratory
- 10.2 Field Activities

11.0 PREVENTATIVE MAINTENANCE

- 11.1 Laboratory Equipment
- 11.2 Field Equipment

12.0 SPECIFIC ROUTINE PROCEDURES USED TO ASSESS DATA PRECISION, ACCURACY AND COMPLETENESS

13.0 CORRECTIVE ACTION

- 13.1 Analytical Laboratories
- 13.2 Field Work

14.0 QUALITY ASSURANCE REPORT

FIELD SAMPLING PLAN
OUTLINE

1.0 INTRODUCTION

2.0 SITE BACKGROUND

- 2.1 Site Description

3.0 SAMPLING OBJECTIVES

4.0 SAMPLE LOCATION & FREQUENCY

- 4.1 Ground Water Monitoring
- 4.2 Surface Water
- 4.3 Extracted Vapor

5.0 SAMPLE DESIGNATION

6.0 SAMPLING EQUIPMENT & PROCEDURES

- 6.1 Ground Water Monitoring
  - 6.1.1 Monitoring Well Design and Installation
  - 6.1.2. Ground Water Sampling
    - 6.1.2.1 Water Level Measurement
    - 6.1.2.2 Well Depth Measurement
    - 6.1.2.3 Well Evacuation
    - 6.1.2.4 Sample Withdrawal
- 6.2 Surface Water Sampling
- 6.3 Extracted Vapor Monitoring

7.0 SAMPLE HANDLING AND ANALYSIS

8.0 FIELD QUALITY CONTROL SAMPLES

ERM-North Central, Inc.
Environmental Resources Management

102 Wilmot Road • Suite 300 • Deerfield, Illinois 60015 ☎ (312) 940-7200

April 11, 1989

John Buck
Indiana Department of Environmental Management
5500 W. Bradbury
Indianapolis, IN 46241

Karen Vendl
U.S. Environmental Protection Agency
Region V (5HS-11)
230 S. Dearborn Street
Chicago, IL 60604

REF: ECC Exhibit A

Dear John and Karen:

Enclosed please find our proposed changes to the "ECC Monitoring Plan" (Plan) which was discussed at the IDEM offices in Indianapolis on April 5, 1989. Upon receipt of your concurrence, we intend that the Plan be incorporated into Sections 2.1.4 and 4.0 of Exhibit A to the Consent Decree.

Although we continue to disagree that direct soil sampling is necessary to demonstrate attainment of the cleanup objectives, we will agree to perform post-SVES soil sampling as in the "ECC Monitoring Plan", with the provision that the sampling results are to be evaluated using a statistical procedure similar to the one used by EPA for the metal finishing effluent limitations, to be detailed in Appendix E of Exhibit A to the Consent Decree. (A copy of the proposed Appendix E is being sent to you under separate cover by the end of this week.)

The statistical procedure is presented in the Development Document for Effluent Limitations Guidelines and Standards for the Metal Finishing Point Source Category, EPA, Jun. 83, PB84-115989.

The method consists of calculating a maximum daily limit for compliance based on the use of a variability factor, which accounts for the normal fluctuations in wastewater concentrations expected in well operated treatment systems.

We propose to use the same principle, based on the variability of the site's conditions, to determine if an individual sample is above compliance.

The variability factor for the maximum daily limit is "the ratio of the [delta] log-normally estimated 99th percentile of the distribution of within-plant pollutant values to the arithmetic mean of the source values." The delta log-normal distribution has: (1) a discrete portion which models the possibility of obtaining a below detection limit value; and (2) a continuous portion which is a log-normal probability distribution modeling the distribution of all values above the detection limit. Appendix E will include the equations to be used for the statistical analysis, including the test for log-normality.

Also enclosed please find three tables:

1) Calculations of the time for diffusion of volatilized compounds to concentrations in equilibrium with soil cleanup standards.

   This table shows that the rate of establishment of soil vapor levels following SVES is very rapid.

2) Calculation of the time for diffusion of volatilized compounds to different percentages of the saturation concentration.

   This table shows that even the slowest diffusing materials (MIBK, PCE and 112-TCA) will establish 95% of their saturation vapor levels within 30 min at a distance of 1 cm. This is equivalent to 5.5 ft in 3.5 days and therefore, would be collected by the SVES restart procedure.

   Tables 1 and 2 support our position that twice/week restart spikes, as we proposed at our meeting, are appropriate.

3) Organic carbon content of soils - References.

This table provides an initial list of soil organic carbon references. We believe the table amply demonstrates the conservative nature of the organic carbon level used in Exhibit A (which was taken from RI).

We trust that the above information, together with the enclosure, will be agreeable to IDEM and EPA, thus enabling us to immediately proceed with amending Sections 2.1.4 and 4.0 of Exhibit A to the Consent Decree.

Very truly yours,

ERM-NORTH CENTRAL, INC.

Roy O.Ball, Ph.D., P.E.
Principal

lms
cc: Al Sloan
Charles McKinely,Esq.
ECC Technical Committee

INSERTS TO SECTIONS 2.1.4 AND 4.0

ECC MONITORING

The ECC remediation calls for soil vapor extraction to reduce the amount of compounds that are the most prone to migrate off-site via ground water movement. However, there are other constituents in the soil such as metals and PCBs which will not be removed by the soil vapor extraction system (SVES). Consequently, a monitoring plan which adequately determines concentrations of volatile organics, base neutral/acid extractable organics, inorganics and PCBs in the media of concern is required to verify that the site does not present a potential threat to human health and the environment both now and in the future. To accomplish this level of protection, the following scheme will be implemented to determine compliance with the Cleanup Standards in Table 3-1.

1. **Soil Vapor Extraction System Monitoring**

During the operation of the SVES the extracted vapor will be monitored as outlined in Section 4.2 of Exhibit A. The methodology used to determine soil vapor levels that are in equilibrium with acceptable soil concentrations, as well as a tabulation of those numbers, are included in Section 4 of Exhibit A. The SVES distribution system will be maintained until the remedy is complete.

The system will be restarted twice per week to determine whether restart spikes demonstrate vapor concentrations to be in equilibrium with soil concentrations below the specified soil cleanup levels.

2. Soil Samples

Once four consecutive restart spikes, as described above, indicate that the specified soil cleanup levels have been achieved, a total of sixteen soil samples from "hot" spots previously defined in the RI, plus four samples from randomly selected points elsewhere on site will be collected. All soil samples will be analyzed for the VOCs in Table 3-1, as well as for phenol and isophorone. The results of the analyses will be evaluated for compliance with the levels specified in Table 3-1 using the statistical procedure described in Appendix E.

3. On-Site Till Samples

The on-site till wells will be monitored on a quarterly basis during the operation of the SVES. After the SVES is shut down, these on-site wells will be sampled for five years on a semi-annual basis. The on-site wells will be sampled for the volatiles, base neutral/acid extractable organics, inorganics and PCBs shown on Table 3-1.

Verification of VOC Cleanup

Operation of the SVES may be discontinued as described in Exhibit A, Sections 2.1.4 and 4.2. However, verification of soil cleanup will not be established until: 1) four consecutive restart spikes are below the

calculated equilibrium point; 2) the post-SVES soil samples show compliance with the specified soil cleanup levels for volatiles, phenol and isophorone ; and 3) on site till wells show compliance with ground water cleanup levels specified in Table 3-1. If the verification sampling from any of the above components show exceedances of their corresponding soil cleanup levels specified in Table 3-1, the SVES must be restarted and continued until the above verification techniques show no exceedances of the soil cleanup levels specified in Table 3-1 or until Additional Work is implemented as outlined in Section VII of the Consent Decree and Section 3.7 of Exhibit A.

4. Compliance Monitoring

The off-site till wells, sand and gravel wells and the surface water will be sampled on a quarterly basis during the operation of the SVES. Sampling will be conducted on a semi-annual basis thereafter to coincide with the on-site till well analysis. Once it has been determined that the soil cleanup levels have been achieved by the restarts, the on-site till well analysis and the soil sampling (as described above), the off-site compliance wells and surface water sampling will be discontinued if the monitoring results have shown no exceedances of the established ground water and stream criteria specified in Table 3-1 during the five years of on-site till well monitoring. Samples from the wells and surface water will be analyzed for the VOCs, base neutral/acid extractable organics, PCBs and inorganics shown in Table 3-1.

If the off-site compliance ground water monitoring wells and surface water samples indicate off-site contamination above the corresponding levels in Table 3-1, additional remedial measures consistent with Section VII of the Consent Decree and Section 3.7 of Exhibit A may be required.

Semi-annual off-site ground water and surface water compliance monitoring will continue for a period of five years after any additional remedial measures have achieved the ground water standards and stream criteria specified in Table 3-1.

CALCULATION OF THE TIME FOR DIFFUSION OF VOLATILIZED COMPOUNDS TO CONCENTRATION IN EQUILIBRIUM WITH SOIL CLEANUP STANDARDS

Compound	Vapor Pressure (mm Hg)	Molecular Weight (g/gmole)	Mole Fraction (mole/mole)	Saturation Concentration (mg/l)	Concentration in Equilibrium with Soil Cleanup Standards (mg/l)	Diffusivity of Compound in Air (cm2/s)	Error Function erf(z)	z	Time to Move 1 cm (sec)
Acetone	270	58.1	0.01	8.59	0.00000031	0.103	1.00000	> 2.9	0.29
			0.10	85.87			1.00000	> 2.9	0.29
			0.50	429.34			1.00000	> 2.9	0.29
Chloroform	151	119	0.01	9.84	0.033	0.0887	0.99664	2.05	0.67
			0.10	98.36			0.99966	2.5	0.45
			0.50	491.80			0.99993	2.8	0.36
1,1-Dichloroethane	182	99	0.01	9.86	0.00008	0.091	0.99999	2.9	0.33
			0.10	98.63			1.00000	> 2.9	0.33
			0.50	493.14			1.00000	> 2.9	0.33
1,1-Dichloroethene	600	97	0.01	31.86	0.0151	0.0791	0.99953	2.48	0.51
			0.10	318.58			0.99995	2.8	0.40
			0.50	1592.89			0.99999	2.9	0.38
Ethylbenzene	7	106	0.01	0.41	40.62	0.0715	---		
			0.10	4.06			---		
			0.50	20.31			---		
Methylene Chloride	362	84.9	0.01	16.82	0.0000383	0.102	1.00000	> 2.9	0.29
			0.10	168.23			1.00000	> 2.9	0.29
			0.50	841.16			1.00000	> 2.9	0.29
Methyl Ethyl Ketone	77.5	72.1	0.01	3.06	0.00000208	0.0842	1.00000	> 2.9	0.35
			0.10	30.59			1.00000	> 2.9	0.35
			0.50	152.93			1.00000	> 2.9	0.35
Methyl Isobutyl Ketone	6	100	0.01	0.33	0.00046	0.0728	0.99860	2.3	0.65
			0.10	3.28			0.99986	2.65	0.49
			0.50	16.42			0.99997	2.8	0.44
Tetrachloroethene	17.8	166	0.01	1.62	0.102	0.0741	0.93694	1.31	1.97
			0.10	16.17			0.99369	1.93	0.91
			0.50	80.87			0.99874	2.3	0.64
Toluene	28.1	92.1	0.01	1.42	141.66	0.0783	---		
			0.10	14.17			---		
			0.50	70.83			---		
1,1,1-Trichloroethane	123	133	0.01	8.95	0.278	0.0797	0.96895	1.52	1.36
			0.10	89.55			0.99690	2.1	0.71
			0.50	447.73			0.99938	2.45	0.52

Compound	Vapor Pressure (mm Hg)	Molecular Weight (g/gmole)	Mole Fraction (mole/mole)	Saturation Concentration (mg/l)	Concentration in Equilibrium with Soil Cleanup Standards (mg/l)	Diffusivity of Compound in Air (cm2/s)	Error Function erf(z)	z	Time to Move 1 cm (sec)
1,1,2-Trichloroethane	30	133	0.01	2.18	0.000202	0.0797	0.99991	2.8	0.40
			0.10	21.84			0.99999	2.9	0.37
			0.50	109.20			1.00000	> 2.9	0.37
Trichloroethene	57.9	132	0.01	4.18	0.229	0.0812	0.94526	1.36	1.66
			0.10	41.84			0.99453	1.96	0.80
			0.50	209.18			0.99891	2.35	0.56
Phenol	0.341	94.1	0.01	0.018	0.0000069	0.0842	0.99961	2.5	0.48
			0.10	0.176			0.99996	2.8	0.38
			0.50	0.878			0.99999	2.9	0.35
Isophorone	0.38	138	0.01	0.029	0.000399	0.0644	0.98610	1.74	1.28
			0.10	0.287			0.99861	2.3	0.73
			0.50	1.435			0.99972	2.55	0.60

REFERENCES AND EQUATIONS:

Vapor pressure and molecular weight: From "Superfund Public Health Evaluation Manual," USEPA, October 1986, EPA 540/1-86-060.
Mole fraction: Assumed over a range of possible values.

$$\text{Saturation Concentration (mg/l)} = \frac{P \cdot MWi}{R \cdot T} = \frac{Vp\ (\text{mm Hg}) \cdot xi\ (\text{mole/mole}) \cdot MWi\ (\text{g/gmole}) \cdot 1000\ (\text{mg/g}) \cdot 1000\ (\text{cm3/l})}{82.04\ [(\text{atm.cm3})/(\text{gmole.K})] \cdot 293\ (\text{K}) \cdot 760\ (\text{mm Hg/atm})} =$$

$$= 0.0547 \cdot Vp \cdot Xi \cdot MWi$$

Where: P = partial pressure, mm Hg; MWi = molecular weight, g/gmole; R = gas law constant, 82.04 atm.cm3/gmole/K; T = temperature, 293 K; Vp = vapor pressure, mm Hg; xi = mole fraction of compound in air, mole/mole.

Diffusivity in air (at 20 C) = Di = From "Superfund Exposure Assessment Manual, Final Draft," USEPA, September 22, 1987, OSWER Directive 9285.5-1.

$$\text{Error function} = \text{erf}(z) = \text{erf}\ \frac{x}{2\ [\text{sqrt}(Di.t)]} = 1 - \frac{C}{Cs}$$

Where: x = distance traveled by compound, 1 cm; t = time to travel 1 cm, seconds; C = concentration in equilibrium with soil cleanup standards (Table 3-1), mg/l; Cs = saturation concentration, mg/l; sqrt = square root; z = x/{2[sqrt(Di.t)]}.

CALCULATION OF THE TIME FOR DIFFUSION OF VOLATILIZED COMPOUNDS TO DIFFERENT PERCENTAGES OF THE SATURATION CONCENTRATION

Compound	Vapor Pressure (mm Hg)	Molecular Weight (g/gmole)	Mole Fraction (mole/mole)	Saturation Concentration (mg/l)	50, 90 or 95 % of the Saturation Concentration (mg/l)	%	Diffusivity of Compound in Air (cm2/s)	Error Function erf(z)	z	Time to Move 1 cm (sec)	(min)
Acetone	270	58.1	0.01	8.59	4.29	50	0.103	0.50	0.48	10.53	
			0.10	85.87	42.93			0.50	0.48	10.53	
			0.50	429.34	214.67			0.50	0.48	10.53	
Chloroform	151	119	0.01	9.84	8.85	90	0.0887	0.10	0.09	347.96	5.80
			0.10	98.36	88.52			0.10			
			0.50	491.80	442.62			0.10			
1,1-Dichloroethane	182	99	0.01	9.86	8.88	90	0.091	0.10	0.09	339.17	
			0.10	98.63	88.77			0.10			
			0.50	493.14	443.83			0.10			
1,1-Dichloroethene	600	97	0.01	31.86	15.93	50	0.0791	0.50	0.5205	11.67	
			0.10	318.58	159.29			0.50			
			0.50	1592.89	796.45			0.50			
Ethylbenzene	7	106	0.01	0.41	0.20		0.0715	---			
			0.10	4.06	2.03			---			
			0.50	20.31	10.15			---			
Methylene Chloride	362	84.9	0.01	16.82	8.41	50	0.102	0.50	0.5205	9.05	
			0.10	168.23	84.12			0.50			
			0.50	841.16	420.58			0.50			
Methyl Ethyl Ketone	77.5	72.1	0.01	3.06	1.53	50	0.0842	0.50	0.5205	10.96	
			0.10	30.59	15.29			0.50			
			0.50	152.93	76.47			0.50			
Methyl Isobutyl Ketone	6	100	0.01	0.33	0.31	95	0.0728	0.05	0.045	1695.84	28.26
			0.10	3.28	3.12			0.05			
			0.50	16.42	15.60			0.05			
Tetrachloroethene	17.8	166	0.01	1.62	1.54	95	0.0741	0.05	0.045	1666.08	27.77
			0.10	16.17	15.37			0.05			
			0.50	80.87	76.83			0.05			
Toluene	28.1	92.1	0.01	1.42	0.71		0.0783	---			
			0.10	14.17	7.08			---			
			0.50	70.83	35.42			---			
1,1,1-Trichloroethane	123	133	0.01	8.95	4.48	50	0.0797	0.50	0.5205	11.50	
			0.10	89.55	44.77			0.50			
			0.50	447.73	223.87			0.50			

Compound	Vapor Pressure (mm Hg)	Molecular Weight (g/gmole)	Mole Fraction (mole/mole)	Saturation Concentration (mg/l)	50, 90 or 95 % of the Saturation Concentration (mg/l)	%	Diffusivity of Compound in Air (cm2/s)	Error Function erf(z)	z	Time to Move 1 cm (sec)	(min)
1,1,2-Trichloroethane	30	133	0.01	2.18	2.07	95	0.0797	0.05	0.045	1549.02	25.82
			0.10	21.84	20.75			0.05			
			0.50	109.20	103.74			0.05			
Trichloroethene	57.9	132	0.01	4.18	2.09	50	0.0812	0.50	0.5205	11.36	
			0.10	41.84	20.92			0.50			
			0.50	209.18	104.59			0.50			
Phenol	0.341	94.1	0.01	0.018	0.02	90	0.0842	0.10	0.09	366.56	6.11
			0.10	0.176	0.16			0.10			
			0.50	0.878	0.79			0.10			
Isophorone	0.38	138	0.01	0.029	0.01	50	0.0644	0.50	0.5205	14.33	
			0.10	0.287	0.14			0.50			
			0.50	1.435	0.72			0.50			

REFERENCES AND EQUATIONS:

Vapor pressure and molecular weight: From "Superfund Public Health Evaluation Manual," USEPA, October 1986, EPA 540/1-86-060.
Mole fraction: Assumed over a range of possible values.

$$\text{Saturation Concentration (mg/l)} = \frac{P \cdot MWi}{R \cdot T} = \frac{Vp\ (\text{mm Hg}) \cdot xi\ (\text{mole/mole}) \cdot MWi\ (\text{g/gmole}) \cdot 1000\ (\text{mg/g}) \cdot 1000\ (\text{cm3/l})}{82.04\ [(\text{atm.cm3})/(\text{gmole.K})] \cdot 293\ (\text{K}) \cdot 760\ (\text{mm Hg/atm})} =$$

$$= 0.0547 \cdot Vp \cdot Xi \cdot MWi$$

Where: P = partial pressure, mm Hg; MWi = molecular weight, g/gmole; R = gas law constant, 82.04 atm.cm3/gmole/K; T = temperature, 293 K; Vp = vapor pressure, mm Hg; xi = mole fraction of compound in air, mole/mole.

Diffusivity in air (at 20 C) = Di = From "Superfund Exposure Assessment Manual, Final Draft," USEPA, September 22, 1987, OSWER Directive 9285.5-1.

$$\text{Error function} = erf(z) = erf\ \frac{x}{2\ [sqrt(Di.t)]} = 1 - \frac{C}{Cs}$$

Where: x = distance traveled by compound, 1 cm; t = time to travel 1 cm, seconds; C = 50, 90 or 95 percent of the saturation concentration, mg/l; Cs = saturation concentration, mg/l; sqrt = square root; z = x/{2[sqrt(Di.t)]}.

ORGANIC CARBON CONTENT OF SOILS
REFERENCES

Organic Carbon Content, %	Type of Soil (depth)	Geographic Area	Reference
0.125 (avg over 1.5 acre site)	Loamy sand (4 ft)	Etiwanda, CA (arid region)	Elabd, H., and W.A. Jury. 1986. "Spatial variability of Pesticide Adsorption Parameters." Environmental Science and Technology, Vol. 20, No. 3, pp. 256-260.
0.2 (avg over 1.5 acre site)	Loamy sand (2 and 3 ft)	Ibid	Ibid
0.26 (avg over 1.5 acre site)	Loamy sand (1 ft)	Ibid	Ibid
1.9	Silt loam	Corvallis, OR	Chiou, C.T., P.E. Porter, and D.W. Schneddign. 1983. "Partition Equilibria of Nonionic Organic Compounds between Soil Organic Matter and Water." Environmental Science and Technology, Vol. 17, No. 4, pp. 227-231.
0.15	Sand close to river	Switzerland	Schwarzenbach, R.P., and J. Westall. 1981. "Transport of Nonpolar Organic Compounds from Surface Water to Groundwater. Laboratory Sorption Studies." Environmental Science and Technology, Vol. 15, No. 11, pp. 1360-1367.
2.1	Air-dried soil	Iowa	Wu, S., and P.M. Gschwend. 1986. "Sorption Kinetics of Hydrophobic Organic Compounds to Natural Sediments and Soils." Environmental Science and Technology, Vol. 20, No. 7, pp. 717-725.
0.11	Loess sample	Turin, Iowa	Karickhoff, S.W. 1984. "Organic Pollutant Sorption in Aquatic Systems." Journal of Hydraulic Engineering, Vol. 110, No. 6, pp. 707-735.
1.3	Soil	Fern Clyffe State Park, IL	Ibid
0.02	Aquifer -- water table zone 98 % sand	Borden, Canada	Abdul, A.S., T.L. Gibson, and D.N. Rai. 1986. "The Effect of Organic Carbon on the Adsorption of Fluorene by Aquifer Materials." Hazardous Waste and Hazardous Materials. Vol. 3, No. 4, pp. 429-440.
0.52	Aquifer -- water table zone 87 % sand	Flint, MI	Ibid
1.8	Aquifer -- water table zone 91 % sand	Flint, MI	Ibid

Organic Carbon Content, %	Type of Soil (depth)	Geographic Area	Reference
0.05	Fine-sand soil	Wilmington, DE	Stokman, S.K. 1987. "Estimates of Concentrations of Soluble Petroleum Hydrocarbons Migrating into Ground Water from Contaminated Soil Sources." Proceedings of the National Water Well Association/American Petroleum Institute Conference on Petroleum Hydrocarbons and Organic Chemicals in Ground Water - Prevention, Detection and Restoration. Houston, TX, pp. 541-558.
0.1	Shaly-silt soil	Philadelphia, PA	Ibid
0.05	Fine to coarse sand, 96% sand	Michigan	Chiang, C.Y., C.L. Klein, J.P. Salanitro, and H.L. Wisniewski. 1986. "Data Analyses and Computer Modelling of the Benzene Plume in an Aquifer Beneath a Gas Plant." Proceedings of the National Water Well Association/American Petroleum Institute Conference on Petroleum Hydrocarbons and Organic Chemicals in Ground Water - Prevention, Detection and Restoration. Houston, TX, pp. 157-176.
0.27	Lincoln fine sand (surface soil)	Little Sandy Creek near Ada, OK	Clark, G.L., A.T. Kan, and M.B. Tomson. 1986. "Kinetic Interaction of Neutral Trace Level Organic Compounds with Soil Organic Material." Proceedings of the National Water Well Association/American Petroleum Institute Conference on Petroleum Hydrocarbons and Organic Chemicals in Ground Water - Prevention, Detection and Restoration. Houston, TX, pp. 151-156.
0.74	Fine to medium grained sand (3 ft)	Indian River County, FL	Kemblowski, M.W., J.P. Salinatro, G.M. Deeley, and C.C. Stanley. 1987. "Fate and Transport of Residual Hydrocarbon in Groundwater - A Case Study." Proceedings of the National Water Well Association/ American Petroleum Institute Conference on Petroleum Hydrocarbons and Organic Chemicals in Ground Water - Prevention, Detection and Restoration. Houston, TX, pp. 207-231.
0.44	Fine to medium grained sand (7 ft)	Indian River County, FL	Ibid
0.12	Fine to medium grained sand (13 ft)	Indian River County, FL	Ibid
0.36	Fine to medium grained sand (3 ft)	Indian River County, FL	Ibid

Organic Carbon Content, %	Type of Soil (depth)	Geographic Area	Reference
0.15	Fine to medium grained sand (13 ft)	Indian River County, FL	Ibid
1.08	Fine to medium grained sand (2 ft)	Indian River County, FL	Ibid
0.16	Fine to medium grained sand (11 ft)	Indian River County, FL	Ibid
0.72	Fine to medium grained sand (3 ft)	Indian River County, FL	Ibid
0.26	Fine to medium grained sand (10 ft)	Indian River County, FL	Ibid
0.74	Glacial till (1-2 ft)	Sargent County, ND	"Soil Classification - A Comprehensive System." 1960. U.S. Department of Agriculture, Soil Conservation Service, 7th Approximation.
0.33	Glacial till (2-3 ft)	Sargent County, ND	Ibid
0.18	Glacial till (4.5-5 ft)	Sargent County, ND	Ibid
0.1	Till (1-2 ft)	Strafford County, New Hampshire	Ibid
0.08	Till (2-3 ft)	Strafford County, New Hampshire	Ibid
0.03	Till (4-5 ft)	Strafford County, New Hampshire	Ibid
0.01	Till (5-7 ft)	Strafford County, New Hampshire	Ibid
0.59	Calcareous, glacial till (1-2 ft)	Greenbrier County, West Virginia	Ibid
0.27	Calcareous, glacial till (2-3 ft)	Greenbrier County, West Virginia	Ibid

Organic Carbon Content, %	Type of Soil (depth)	Geographic Area	Reference
0.08	Calcareous, glacial till (4-5 ft)	Greenbrier County, West Virginia	Ibid
0.38	Calcareous, glacial till (1-2 ft)	Tonkins County, New York	Ibid
0.16	Calcareous, glacial till (2-3 ft)	Tonkins County, New York	Ibid
0.17	Calcareous, glacial till (4.5-6.5 ft)	Tonkins County, New York	Ibid
0.14	Calcareous, glacial till (6.5-7 ft)	Tonkins County, New York	Ibid
0.76	Glacial till (1-2 ft)	Waseca County, Minnesota	Ibid
0.3	Glacial till (2-3 ft)	Waseca County, Minnesota	Ibid
0.19	Glacial till (> 4 ft)	Waseca County, Minnesota	Ibid
0.51	Glacial till (1-2 ft)	Sargent County, ND	Ibid
0.18	Glacial till (2-3 ft)	Sargent County, ND	Ibid
0.16	Glacial till (3.5-5 ft)	Sargent County, ND	Ibid
0.64	Firm, glacial till (1-2 ft)	Spink County, SD	Ibid
0.36	Firm, glacial till (2-3 ft)	Spink County, SD	Ibid
0.31	Firm, glacial till (4-5 ft)	Spink County, SD	Ibid
0.46	Glacial till (1-2 ft)	Renville County, ND	Ibid

Organic Carbon Content, %	Type of Soil (depth)	Geographic Area	Reference
0.24	Glacial till (2-3 ft)	Renville County, ND	Ibid
0.13	Glacial till (4-5 ft)	Renville County, ND	Ibid
0.25	Glacial till (2-3 ft)	Adair County, Iowa	Ibid
0.08	Glacial till (> 6 ft)	Adair County, Iowa	Ibid
0.74	Calcareous, glacial till (1-2 ft)	Ward County, ND	Ibid
0.2	Calcareous, glacial till (2-3 ft)	Ward County, ND	Ibid
0.19	Calcareous, glacial till (4-5 ft)	Ward County, ND	Ibid
0.35	Glacial till (1-2 ft)	Cayuga County, NY	Ibid
0.1	Glacial till (2-3 ft)	Cayuga County, NY	Ibid
0.12	Glacial till (6-7 ft)	Cayuga County, NY	Ibid

ERM-North Central, Inc.

MEMORANDUM

TO: Karen Vendl, USEPA
Al Sloan, CH2MHill

FROM: Roy O. Ball/Elsie F. Millano EFM
ERM-North Central, Inc.

DATE: May 10, 1989

RE: ECC Exhibit A

As per our telephone conversation of today, we are enclosing our proposed procedure to establish background ground water quality at the ECC site. We plan to include this procedure in Section 4.0 - Remedial Action Compliance Monitoring of Exhibit A.

enclosures

cc: Jerry Amber, Ford Motor Company
Donald Smith, Pratt & Lambert
John Kyle, Barnes & Thornburg
Tim Harker, The Harker Firm

PROCEDURE TO ESTABLISH BACKGROUND GROUND WATER QUALITY AT THE ECC SITE

Background ground water quality will be determined using historical and cleanup-generated data for the following background wells: (1) in the sand and gravel, wells 1A, 2A and one new monitoring well located north of the site, as shown in Figure 2-7 of Exhibit A; and (2) in the till, one new monitoring well located north of the site, as shown in Figure 2-7 of Exhibit A.

Because of the probability of having values below the Required Detection Limit (RDL), the pooled background data should be analyzed using the delta log-normal distribution. The following values will be calculated for each parameter: probability of observing a value below the RQL ($\hat{d}_j$), estimated mean of the transformed data ($\bar{x}_j$), and estimated variance of the transformed data ($\hat{\sigma}^2$). Equations for each of these parameters will be included in Exhibit A, and are shown in our May 9, 1989 submittal to J. Buck and K. Vendl. Log-normality will be established using the tests specified in that document.

If a non-background value is less than the upper 95th percentile of the delta log-normal distribution of the background samples, the Cleanup Standard is concluded to be met. The upper 95th percentile is calculated as:

$$P_{95j} = \exp(\bar{x}_j + y_q, \hat{\sigma})$$

Should the non-background value be higher than the upper 95th percentile, resampling will be required.

ERM-North Central, Inc.

MEMORANDUM

DATE: June 9, 1989

TO: Karen Vendl
John Buck
Prabhakar Kasarabada
Al Sloan

FROM: Roy Ball/Dave Schlott DAS

SUBJECT: ECC Consent Decree - Outstanding Technical Issues

Per our telephone conference call last Monday (6/5/89), we identified three outstanding technical issues which need to be resolved for purposes of the Consent Decree. Attached for your consideration is a brief discussion of our suggested approach for dealing with each of the outstanding technical issues.

Should you have any questions or wish to discuss, please give us a call.

cc: ECC Steering Committee

ECC CONSENT DECREE

SUGGESTED APPROACH FOR SETTLEMENT OF OUTSTANDING TECHNICAL ISSUES

ISSUE 1: STATISTICAL PROCEDURE FOR ANALYSIS OF SOIL CONFIRMATION SAMPLING RESULTS

As we discussed by telephone on 6/5/89, the confidence levels in estimating the mean exceeds 50% if we have 3 or fewer positive values and the data are not closely distributed. To avoid unrealistic reliance on the calculated average only, compliance with the clean-up standards for soil in Table 3-1 should be based on an approach which incorporates a confidence limit for the mean.

Specifically, we propose that for each compound listed in Table 3-1 except isophorone, the numerical average of the 20 soil sample results for each compound, assigning all non-detect results a value of 1/2 the detection limit, must not exceed the prescribed clean-up standard by more than 25%. Isophorone is a special case and is the subject of discussion in Issue 3 below.

ISSUE 2: COMPARISON OF UPGRADIENT/UPSTREAM DATA WITH DOWNGRADIENT/DOWNSTREAM DATA

We propose that the test for difference between upgradient/upstream data and downgradient/downstream data be based on the range of such data.

We believe this is preferable to the RCRA students "t"-test, because of the limited amount of data and the significant variability evident in historical (RI) data for the site.

Our proposed approach is that the clean-up objective for each compound in surface water and off-site ground water shall be the greater of the appropriate criteria shown in Table 3-1 and the maximum level reported for that compound in upgradient/upstream samples.

ISSUE 3: COMPLIANCE FOR ISOPHORONE

Using CLP procedures, the required quantification limit for isophorone in soil is 330 ug/kg, however the compliance limit established in Table 3-1 is only 52 ug/kg. Obviously, an alternative approach to demonstrate compliance is required.

In lieu of analyzing soil samples directly for isophorone and employing the approved statistical procedure to demonstrate compliance, we propose using the analyses of the two surrogates: the soil vapor and the onsite till water. The levels in the soil vapor and the ground water which correspond to a value of 52 ug/kg for isophorone in soil are 76 Vppm and 8.5 mg/l respectively.

The proposed compliance procedure is to collect one vapor sample from each of the 28 extraction trenches and one water sample from each of the four onsite till wells and analyze each for isophorone. Each result will then be transformed to its soil equivalent, and the resulting 32 data points will be analyzed using the "statistical procedure" described earlier to demonstrate compliance with the isophorone limit. The detection limits for isophorone in vapor and water are 1 Vppm and 2.5 ug/l, respectively.

ERM-North Central, Inc.

MEMORANDUM

TO: Karen Vendl - EPA
Prabhakar Kasarabada - IDEM
Al Sloan - CH2M-Hill

CC: ECC Steering Committee

FROM: Dave Schlott/R. Ball DAS

DATE: June 15, 1989

SUBJECT: ECC Technical Issues

Attached is additional information requested to assist in resolution of the three remaining technical issues.

- Table 1 is an evaluation of data from a site in Kimross, Michigan. It has been included to illustrate data distribution from a site after completion of vapor extraction. The "upper bound" using a statistical evaluation has been calculated and compared to the calculated average.

- Table 2 compares the "observed maximum" to the "upper bound" using a statistical evaluation of the existing background data for ground water at the ECC site.

- Table 3 is an evaluation of various equations for calculating Koc values. Each has been applied to the calculation of the Koc value for isophorone.

Please review and I will be calling at 10:30 as scheduled to discuss. If you have any questions or wish to discuss before hand, don't hesitate to give me a call at (312) 405-0100.

Followup Note: 6/16/89

Per my conversation with Prabhakar Kasarabada this morning, the 10:30 a.m. telephone conference call for today has been cancelled and is tentatively rescheduled for 6/23/89. Prabhakar will advise as to the acceptable time and the list and phone numbers of IDEM/EPA participants for this call. ERM will initiate the call. Anyone wishing to discuss the attached information prior to this conference call, is welcomed to call either Roy or myself.

TABLE 1

SOIL CONFIRMATION DATA FROM SOIL VAPOR EXTRACTION SYSTEM - KINROSS, MICHIGAN
SOURCE: MIDWEST WATER RESOURCES, INC CHARLOTTE, MICHIGAN
16-Jun-89

	CASE I ANALYSIS USING MAXIMUM OBSERVED VALUES >MDL IN EACH BORING ONLY			CASE II ANALYSIS USING OBSERVED VALUES & 1/2 THE MDL FOR NON-DETECTS			CASE III ALL MWRI DATA FOR TOLUENE (UG/KG) USING 1/2 MDL FOR NON-DETECTS	
	MAX. OBSERVED VALUE (mg/kg)			MAX. OBSERVED VALUE (mg/kg)				
BORING NO.	TOLUENE	METHYLENE CHLORIDE	1,2 DCA **	TOLUENE	METHYLENE CHLORIDE	1,2 DCA **	NO OF SAMPLES	VALUE
1				0.005	0.005	0.005	187@	0.005
2				0.005	0.005	0.005	6@	0.01
3				0.005	0.005	0.005	2@	0.02
4	0.45			0.45	0.005	0.005	1@	0.04
5		0.03		0.005	0.03	0.005	1@	0.05
6		0.01		0.005	0.01	0.005	1@	0.45
7	0.04			0.04	0.005	0.005		
8	0.01			0.01	0.005	0.005		
9	0.05			0.05	0.005	0.005		
10				0.005	0.005	0.005		
11			0.01	0.005	0.005	0.01		
12				0.005	0.005	0.005		
13	0.01			0.01	0.005	0.005		
14				0.005	0.005	0.005		
15	0.02			0.02	0.005	0.005		
16				0.005	0.005	0.005		
17				0.005	0.005	0.005		
18				0.005	0.005	0.005		
METHOD DETECTION LIMIT(MDL)	0.010	0.010	0.010	0.010	0.010	0.010	0.010	
# >MDL	6	2	1	6	2	1	11	
CALCULATED AVERAGE	0.097	0.020	0.010	0.036	0.007	0.005	0.007955	
STD DEV	0.159	0.010	NA	0.101	0.006	0.001	0.031874	
% STD DEV OF AVG	164	50	NA	285	87	22	401	
NO. OF VALUES-N	6	2	1	18	18	18	198	
CORRESPONDING "t" STATISTIC	1.476	3.078	NA	1.333	1.333	1.333	1.282	
UPPER BOUND OF 90% C.I.*	0.192	0.042	NA	0.067	0.008	0.006	0.011	
UPPER BOUND VS CALC.AVG(%):								
FROM MWRI DATA ABOVE	199	209	NA	190	127	107	137	
ERM PROPOSAL	125	125	125	125	125	125	125	
IDEM PROPOSAL	110	110	110	110	110	110	110	

* AVERAGE + (STD DEV)/(SQRT(N))*("t" STATISTIC)

** 1,2, DICHLOROETHANE

ECC BACKGROUND MONITORING WELL DATA EVALUATION
OF MAXIMUM OBSERVED VALUE VS. "t" DISTRIBUTION

TABLE 2 (PAGE 1 of 2) - DATA

16-Jun-89		(ug/l) DETECTION LIMIT	MONITORING WELL ECCMW1A (ug/l)				MONITORING WELL ECCMW2A (ug/l)		
COMPOUND			7/19/83	11/29/83	12/13/84	4/27/88	7/19/83	11/29/83	12/13/84
ANTIMONY	*	20							
	**		10	10	10	10	10	10	10
ARSENIC	*	10							
	**		5	5	5	5	5	5	5
BARIUM	*	100	306	366	328	316	330	268	287
	**		306	366	328	316	330	268	287
BERYLLIUM	*	5							
	**		2.5	2.5	2.5	2.5	2.5	2.5	2.5
CADMIUM	*	1				3			
	**		0.5	0.5	0.5	3	0.5	0.5	0.5
CHROMIUM	*	50			11	8			11
	**		25	25	11	8	25	25	11
LEAD	*	5			7	10			
	**		2.5	2.5	7	10	2.5	2.5	2.5
MANGANESE	*	10	110	103	66	51	56	49	49
	**		110	103	66	51	56	49	49
NICKEL	*	40				6			
	**		20	20	20	6	20	20	20
SILVER	*	10		25					65
	**		5	25	5	5	5	5	65
TIN	*	20							
	**		10	10	10	10	10	10	10
VANADIUM	*	200							
	**		100	100	100	100	100	100	100
ZINC	*	10		45	69	305		11	260
	**		5	45	69	305	5	11	260
CYANIDE	*	10							
	**		5	5	5	5	5	5	5
ACETONE	*	10							
	**		5	5	5	5	5	5	5
METHYLENE CHLORIDE	*	5		9	22			11	3
	**		2.5	9	22	2.5	2.5	11	3
MEK	*	5		9					
	**		2.5	9	2.5	2.5	2.5	2.5	2.5
PCE	*	5		9				9	
	**		2.5	9	2.5	2.5	2.5	9	2.5
TCE	*	5		9				9	
	**		2.5	9	2.5	2.5	2.5	9	2.5
XYLENE	*	5					9		
	**		2.5	2.5	2.5	2.5	9	2.5	2.5
BIS-2, ETHL PTH	*	20		23					
	**		10	23	10	10	10	10	10

* - EVALUATION OF DATA USING VALUES GREATER THAN THE DETECTION LIMIT ONLY

** - EVALUATION OF DATA ASUMMING THE VALUE OF NON-DETECT SAMPLES EQUAL TO 1/2 THE DETECTION LIMIT

*** - (AVG)+(((STD DEV)/(SQRT(# OF SAMPLES)))*("t" STAT))

ECC BACKGROUND MONITORING WELL DATA EVALUATION
OF MAXIMUM OBSERVED VALUE VS. "t" DISTRIBUTION

TABLE 2 (PAGE 2 of 2) - CALCULATIONS

COMPOUND	DETECTION LIMIT	COMPUTED AVERAGE	COMPUTED STANDARD DEVIATION	# OF SAMPLES	"t" STAT FOR 95% C.I.	UPPER BOUND USING C.I.***	OBSERVED MAXIMUM
ANTIMONY	20	ERR	ERR	0	NA	ERR	ERR *
		10.00	0.00	7	1.943	10.0	10.0 **
ARSENIC	10	ERR	ERR	0	NA	ERR	ERR *
		5.00	0.00	7	1.943	5.0	5.0 **
BARIUM	100	314.43	29.44	7	1.943	336.1	366.0 *
		314.43	29.44	7	1.943	336.1	366.0 **
BERYLLIUM	5	ERR	ERR	0	NA	ERR	ERR *
		2.50	0.00	7	1.943	2.5	2.5 **
CADMIUM	1	3.00	0.00	1	NA	3.0	3.0 *
		0.86	0.87	7	1.943	1.5	3.0 **
CHROMIUM	50	10.00	1.41	3	2.920	12.4	11.0 *
		18.57	7.48	7	1.943	24.1	25.0 **
LEAD	5	8.50	1.50	2	6.134	15.0	10.0 *
		4.21	2.83	7	1.943	6.3	10.0 **
MANGANESE	10	69.14	24.32	7	1.943	87.0	110.0 *
		69.14	24.32	7	1.943	87.0	110.0 **
NICKEL	40	6.00	0.00	1	NA	6.0	6.0 *
		18.00	4.90	7	1.943	21.6	20.0 **
SILVER	10	45.00	20.00	2	6.134	131.7	65.0 *
		16.43	21.00	7	1.943	31.8	65.0 **
TIN	20	ERR	ERR	0	NA	ERR	ERR *
		10.00	0.00	7	1.943	10.0	10.0 **
VANADIUM	200	ERR	ERR	0	NA	ERR	ERR *
		100.00	0.00	7	1.943	100.0	100.0 **
ZINC	10	138.00	120.26	5	2.132	252.7	305.0 *
		100.00	118.07	7	1.943	186.7	305.0 **
CYANIDE	10	ERR	ERR	0	NA	ERR	ERR *
		5.00	0.00	7	1.943	5.0	5.0 **
ACETONE	10	ERR	ERR	0	NA	ERR	ERR *
		5.00	0.00	7	1.943	5.0	5.0 **
METHYLENE	5	11.25	6.87	4	2.353	19.3	22.0 *
		7.50	6.76	7	1.943	12.5	22.0 **
MEK	5	9.00	0.00	1	NA	9.0	9.0 *
		3.43	2.27	7	1.943	5.1	9.0 **
PCE	5	9.00	0.00	2	6.314	9.0	9.0 *
		4.36	2.94	7	1.943	6.5	9.0 **
TCE	5	9.00	0.00	2	6.314	9.0	9.0 *
		4.36	2.94	7	1.943	6.5	9.0 **
XYLENE	5	9.00	0.00	1	NA	9.0	9.0 *
		3.43	2.27	7	1.943	5.1	9.0 **
BIS-2, ET	20	23.00	0.00	1	NA	23.0	23.0 *
		11.86	4.55	7	1.943	15.2	23.0 **

* - EVALUATION OF DATA USING VALUES GREATER THAN THE DETECTION LIMIT ONLY
** - EVALUATION OF DATA ASUMMING THE VALUE OF NON-DETECT SAMPLES EQUAL TO 1/2 THE DETECTION LI
*** - (AVG)+(((STD DEV)/(SQRT(# OF SAMPLES)))*("t" STAT))

TABLE 3

EVALUATION OF EQUATIONS FOR CALCULATING Koc VALUE FOR ISOPHORONE

EQ NO	EQUATION FOR LOG Koc *	SOLUBILITY UNITS REQ'D FOR EQ	LOG Kow **	CALCULATED log Koc	Koc	Kd
1	-.55 LOG S + 3.64	12000 mg/l	NA	1.39645031	24.91439	0.030894
2	-.54 LOG S + .44	0.00139 MOLE FRACTION	NA	1.98277201	96.11076	0.119177
3	-.557 LOG S + 4.277	86956 u-moles/l	NA	1.52581015	33.55909	0.041613
4	.544 LOG Kow + 1.377	NA	1.67	2.28548	192.9656	0.239277
5	.937 LOG Kow -.006	NA	1.67	1.55879	36.20679	0.044896
6	1.00 LOG Kow -.21	NA	1.67	1.46	28.84032	0.035762
7	.94 LOG Kow +.02	NA	1.67	1.5898	38.8866	0.048219
8	1.029 LOG Kow -.18	NA	1.67	1.53843	34.54856	0.04284
9	.524 LOG Kow + .855	NA	1.67	1.73008	53.71307	0.066604
				MAXIMUM	192.9656	0.239277
				MINIMUM	24.91439	0.030894

CONCLUSION: EQUATION USED TO DETERMINE THE Koc VALUE FOR EXHIBIT A WAS EQ. NO. 1, WHICH YIELDS THE MOST CONSERVATIVE ESTIMATE OF Kd. THIS RESULTS IN THE LOWEST VALUES OF ACCEPTABLE SOIL CONCENTRATIONS WHEN COMPARED TO ALL EQUATIONS EVALUATED ABOVE.

* REFERENCE:"HANDBOOK OF CHEMICAL PROPERTY ESTIMATION METHODS"; LYMAN, REEHL, AND ROSENBLATT MCGRAW-HILL, 1982; p.4-9

** REFERENCE: "TOXICOLOGICAL PROFILE FOR ISOPHORONE", CLEMENT AND ASSOCIATES (CONTRACTOR; U.S. PUBLIC HEALTH SERVICE - AGENCY FOR TOXIC SUBSTANCES AND DISESSE REGISTRY; CONTRACT NO. 205-88-0608, p.57

ERM-North Central, Inc.
Environmental Resources Management

102 Wilmot Road • Suite 300 • Deerfield, Illinois 60015 ☎ (312) 940-7200

July 21, 1989

Karen Vendl
Remedial Project Manager
U.S. Environmental Protection Agency
Region V (5HS-11)
230 South Dearborn Street
Chicago, IL 60604

RE: ECC Site

Dear Karen:

Attached please find 1 copy of the revised Exhibit A. Jerry Amber at Ford Motors, Dave Schlott and I will be available on Monday afternoon to answer questions you might have regarding the changes made to the document.

Very truly yours,

ERM-NORTH CENTRAL, INC.

Elsie F. Millano, Ph.D., P.E.
Senior Project Engineer

jas
Att.

cc: Al Sloan, CH2M-Hill
P. Kasarabada, IDEM
Barbara Rogers, Department of Justice
Helen Keplinger, EPA, Washington
ECC Steering Committee

EXHIBIT A

ENVIRONMENTAL CONSERVATION AND CHEMICAL CORPORATION (ECC) SITE ZIONSVILLE, INDIANA

JULY, 1989

PREPARED FOR:

ECC SETTLING DEFENDANTS

PREPARED BY:

ENVIRONMENTAL RESOURCES MANAGEMENT-NORTH CENTRAL, INC.
102 WILMOT ROAD, SUITE 300
DEERFIELD, ILLINOIS 60015
PROJECT NO.: 9041

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EXHIBIT A

1.0 INTRODUCTION

This document is a Remedial Action Plan (hereafter, "Remedial Action Plan", "Exhibit A" or the "Document") and describes the work to be performed by the Settling Defendants at the Environmental Conservation and Chemical Corporation ("ECC") Superfund site as required by the attached Consent Decree ("Consent Decree" or "Decree"). This document is attached as Exhibit A to, and is incorporated by reference into and made an enforceable part of, that Decree.

The purpose of this Exhibit A is to set forth those remedial activities to be performed at the ECC site. The Settling Defendants under the Consent Decree ("Settling Defendants") shall arrange to have the work required hereunder performed by a Contractor or Contractors ("Contractor") in accordance with the requirements and specifications set forth herein.

2.0 REMEDIAL ACTION PLAN

2.1 Elements of the RAP

2.1.1 Soil Vapor Extraction, Concentration and Destruction

The objective of the soil vapor extraction activity is to remove and destroy VOCs and selected base neutral/acid organics from the soils (as provided herein).

By systematically and uniformly moving air through the zone of contamination, volatilization and hence removal of organics are accelerated. For the ECC site, air movement through the soil will be controlled by a network of vertical trenches installed throughout the zone of treatment. The process also involves the continuous extraction of organics-laden air from the trench system and treatment of the air by activated carbon to remove the organics. The organics so collected will then be destroyed off-site in conformance with applicable Federal and State requirements.

The effectiveness of vapor extraction for organics removal from the ECC soils was demonstrated during a pilot test conducted by Terra Vac in June, 1988. The description of the pilot test, including the results obtained, was previously submitted to USEPA and the State of Indiana, and is specifically incorporated by reference herein and made a part hereof. The test showed an initial high organics extraction rate of 1.9 pounds per day per foot of trench that decreased over the course of the pilot test to a steady state rate of approximately 0.25 pounds per day per foot of trench. Although the Terra Vac pilot study provides the foundation for the system designed herein for ECC, during the conceptual and preliminary engineering phase, several engineering and operational enhancements were developed which should improve overall performance and effectiveness of the vacuum extraction system to be implemented under this Remedial Action Plan. These system enhancements are the result of consultations among ERM-North Central, Inc., Midwest Water Resource, Inc. (MWRI), and Terra Vac, Inc. A summary of the key improvements and the associated measures employed for this enhanced vapor extraction system are as follows:

- Reduction of surface water infiltration within the zone of treatment by construction of the RCRA-compliant (Subtitle C) cover system;

- Reduction in the volume of air required for effective remediation by reducing air infiltration into the vapor extraction system by constructing the RCRA-compliant (Subtitle C) cover;

- Reduction of atmospheric discharges of treated extraction air by reinjecting the air through a network of injection trenches installed as part of the vapor extraction system;

- Positive control (collection and removal) of subsurface till water encountered in the zone of treatment by providing sufficient vacuum and/or supplemental air to remove water which accumulates in the extraction trenches; and

- Essentially uniform horizontal movement of air through the zone of treatment resulting in enhanced contact between the air and the VOCs in the soil during operation of the soil vapor extraction system by utilizing a network of injection and extraction trenches in conjunction with the impervious cover provided by the RCRA-compliant (Subtitle C) cover system.

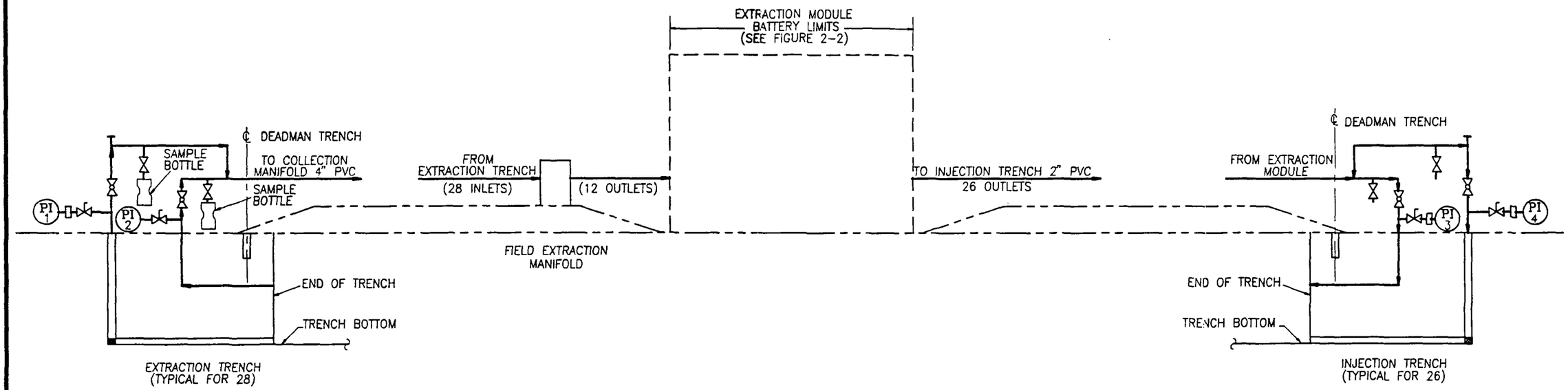
The following discussion and drawings show concepts and details of the design and operation of the soil vapor extraction system.

The soil vapor extraction process is illustrated in Figures 2-1 and 2-2. The basic operation consists of extraction of air using a single vacuum pump from a network of 28 extraction trenches located throughout the site. Free liquid entrained in the air is removed by gravity in an entrainment separator. Periodically, water which accumulates in the entrainment separator is pumped to an on-site storage tank for subsequent transport to an off-site facility for treatment as necessary, in accordance with applicable Federal, State and local regulations. From the vacuum pump, air passes through the carbon adsorption system, which consists of two upflow carbon columns connected in series. Off-gases from the carbon adsorption system are withdrawn by a pump which boosts the pressure and reinjects air into a network of 26 injection trenches located throughout the site. Each injection trench is located between and parallel to a pair of extraction trenches. The injected air then migrates from the injection trench through the soil towards the extraction trench. As the air migrates through the soil towards the extraction trench, the organics are vaporized into the air stream. As described in Section 2.1.2, the RCRA-compliant (Subtitle C) cover will be placed over the entire trench network to prevent air and water infiltration into the system during operation.

The major system components are:

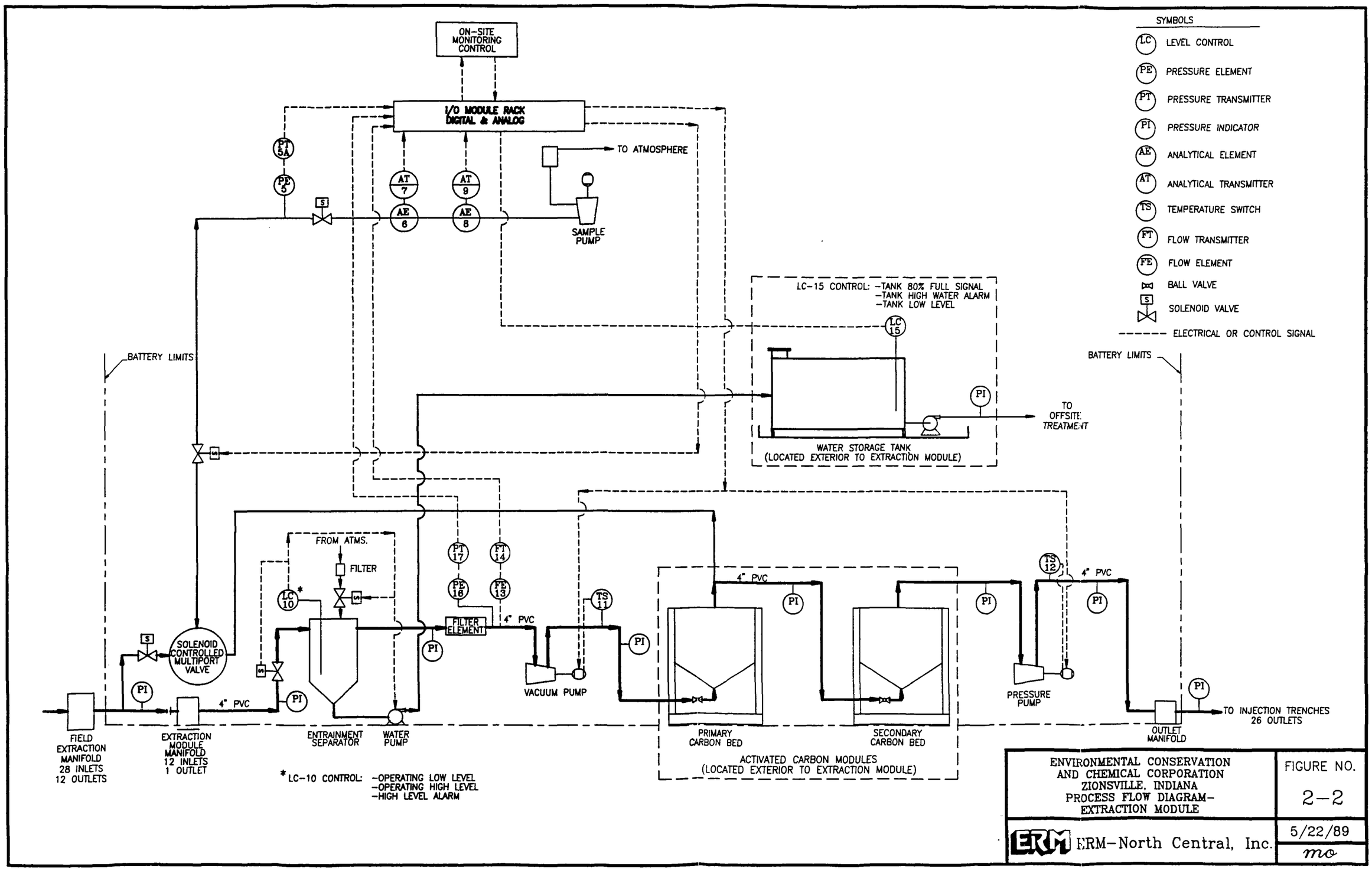
- Extraction and injection trenches;

- Soil vapor extraction system;



SYMBOLS	
⋈	BALL VALVE (FULLY PORTED)
PI	PRESSURE INDICATOR WITH DIAPHRAGM SEAL & SHUTOFF COCK
⋈	GATE VALVE

ENVIRONMENTAL CONSERVATION AND CHEMICAL CORPORATION ZIONSVILLE, INDIANA PROCESS FLOW AND INSTRUMENT DIAGRAM	FIGURE NO. 2-1
ERM ERM-North Central, Inc.	6/23/89 cs



ENVIRONMENTAL CONSERVATION AND CHEMICAL CORPORATION
ZIONSVILLE, INDIANA
PROCESS FLOW DIAGRAM-
EXTRACTION MODULE

FIGURE NO. 2-2

ERM ERM-North Central, Inc.

5/22/89

mo

- Water collection system;
- Carbon adsorption system;
- Air injection system; and
- RCRA-compliant (Subtitle C) cover.

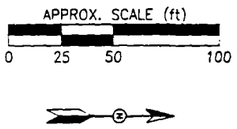
A description of the design and operational features of each of these components is presented below.

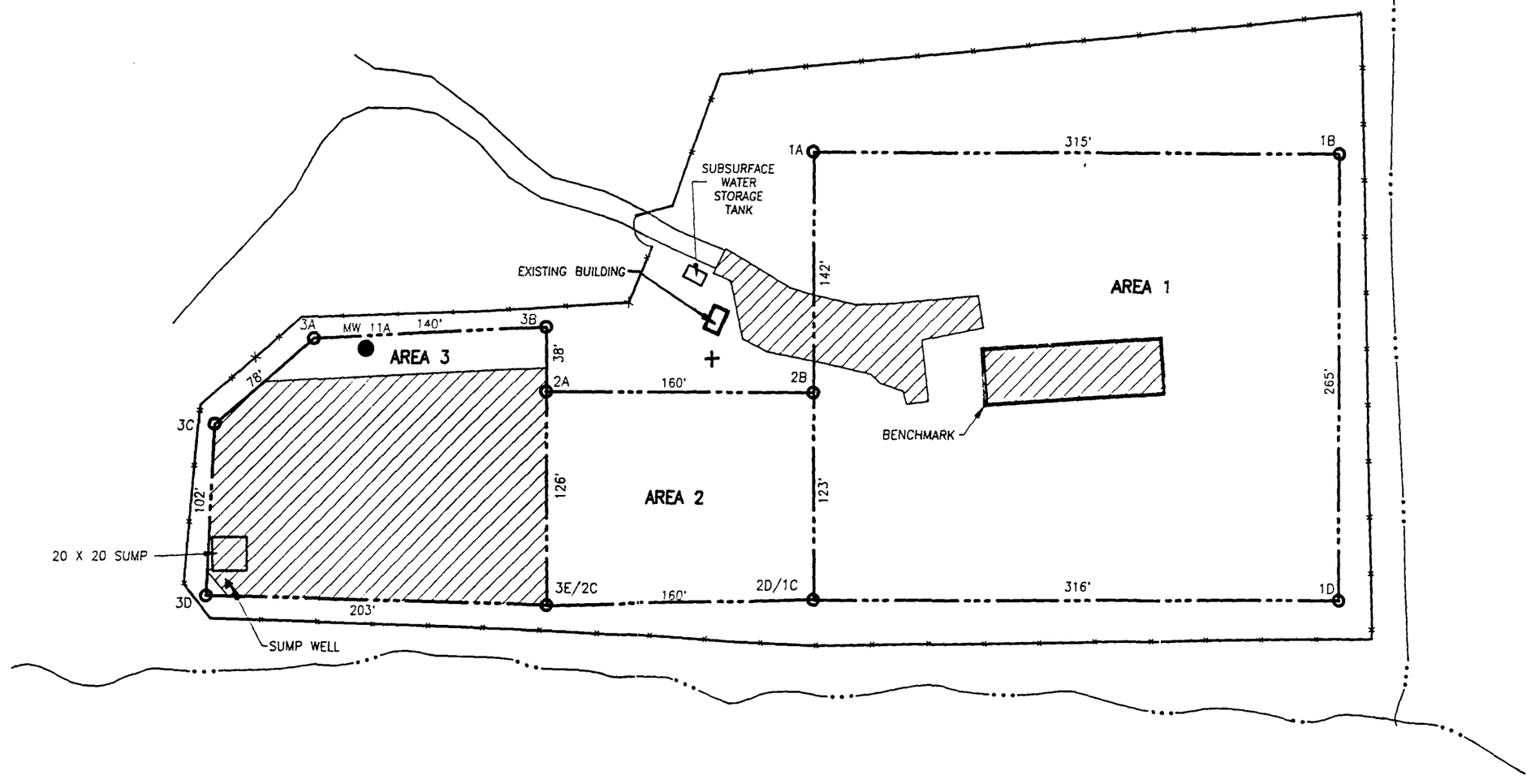
Extraction and Injection Trenches

The area where remedial activity will occur is depicted in Figure 2-3. The west boundary of Area 1 encompasses the extent of ECC activities as verified by an examination of aerial photographs and coincides with a pre-existing earthen berm which formed the western boundary of ECC's water containment system for this area.

The layout and construction details for the network of 28 extraction trenches and 26 injection trenches are presented in Figures 2-4 and 2-5. Trench spacing will be 18 feet, and trench length varies depending on the configuration of the site. Construction details of extraction trenches and injection trenches are identical. By implementing minor above-ground piping changes, injection trenches can and will be utilized as extraction trenches. The work required under this Remedial Action Plan will initially involve using the original extraction trenches for extraction; at some point in the process, the extraction trenches will be converted to injection trenches, and vice versa, to ensure complete vapor extraction of the soil.

LOCATION COORDINATES		
POINT	N/S	E/W
1A	0+60 N	1+22 W
1B	3+76 N	1+22 W
1C	0+60 N	1+42 E
1D	3+76 N	1+42 E
2A	1+00 S	0+20 E
2B	0+60 N	0+20 E
2C	1+00 S	1+46 E
2D	0+60 N	1+42 E
3A	2+38 S	0+11 W
3B	1+00 S	0+18 W
3C	2+98 S	0+39 E
3D	3+03 S	1+40 E
3E	1+00 S	1+46 E
MW 11A	2+08 S	0+06 W
SUMP WELL	2+86 S	1+34 E
BENCHMARK	1+62 N	0+27 E





LEGEND:

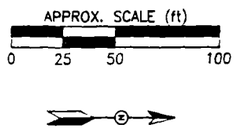
- FENCE LINE
- BUILDING LINE
- PAVEMENT EDGES
- BOUNDARY LINES
- DRAINAGE DITCH
- CONCRETE
- BOUNDARY CORNER

+ REFERENCE POINT FROM CH M-HILL TECHNICIAL DOCUMENT NO. 2 DATE 9/16/88 (921700 N; 725900 E)

ENVIRONMENTAL CONSERVATION AND CHEMICAL CORPORATION ZIONSVILLE, INDIANA REMEDIAL ACTIVITY AREA	FIGURE NO. 2-3
ERM ERM-North Central, Inc.	7/21/89
	cs

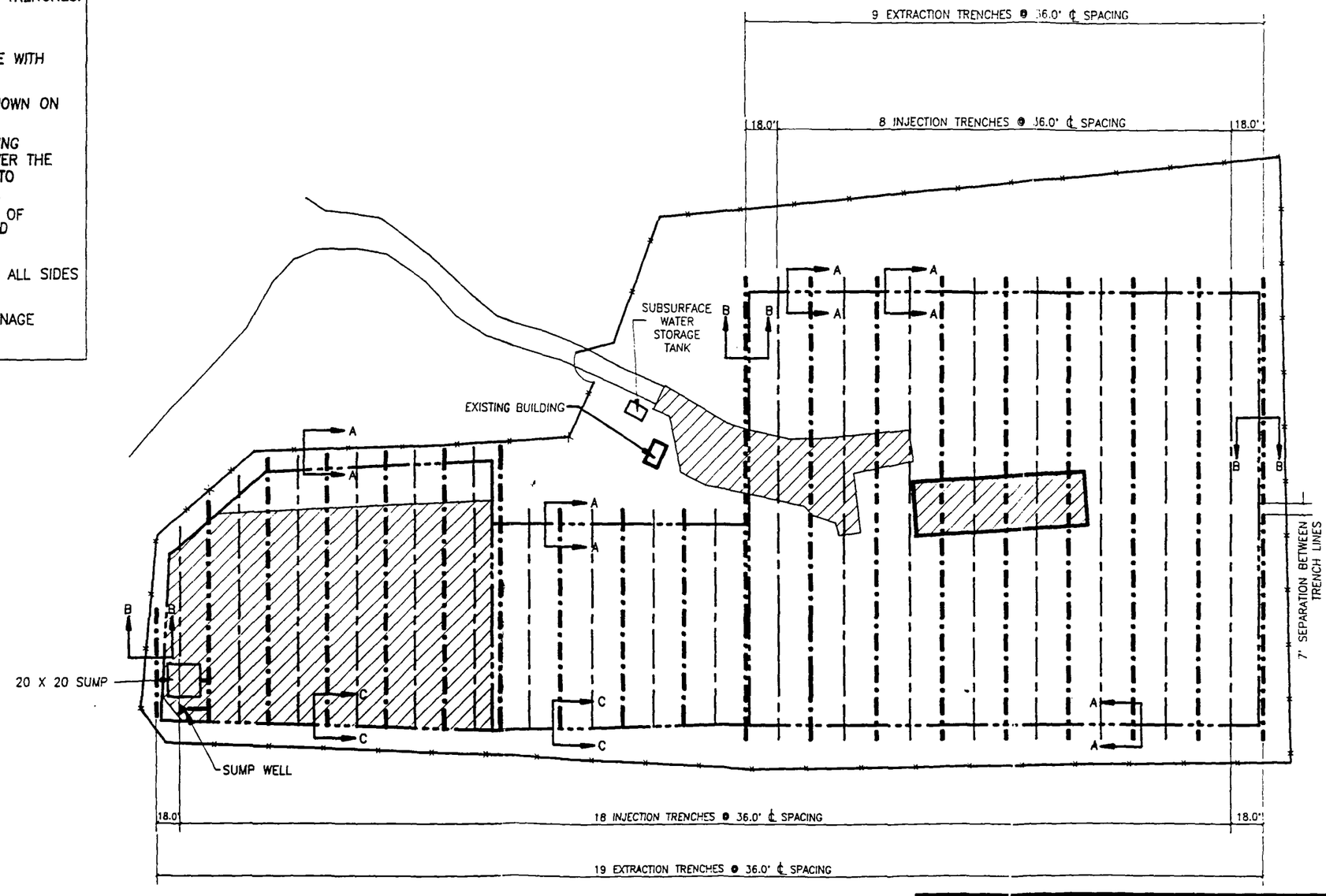
SEQUENCE OF CONSTRUCTION ACTIVITIES:

1. GRADE EXISTING TREATMENT SITE (AREA NOS. 1,2, & 3) TO EVEN SLOPE.
2. EXCAVATE INJECTION AND EXTRACTION TRENCHES.
3. FILL INJECTION TRENCHES WITH FLOAT STONE AS SHOWN ON FIGURE 2–5.
4. FILL EXTRACTION TRENCHES TO GRADE WITH FLOAT STONE AS SHOWN ON FIGURE 2–5.
5. EXCAVATE DEADMAN TRENCHES AS SHOWN ON FIGURE 2–6.
6. SOIL REMOVED FROM TRENCHES DURING CONSTRUCTION SHALL BE GRADED OVER THE SURFACE IN AREAS 1 AND 2 PRIOR TO INSTALLATION OF THE COVER SYSTEM.
7. COVER TREATMENT SITE WITH 1 FOOT OF NATIVE SOIL IN 6" LAYERS COMPACTED TO 95% PROCTOR DENSITY.
8. COVER TREATMENT SITE WITH 60 mil HDPE PLASTIC MEMBRANE ANCHORING ALL SIDES IN DEADMAN TRENCH AS SHOWN ON FIGURE 2–5.
9. COVER TREATMENT SITE WITH 6" DRAINAGE LAYER OF SAND AS SHOWN ON FIGURE 2–5.

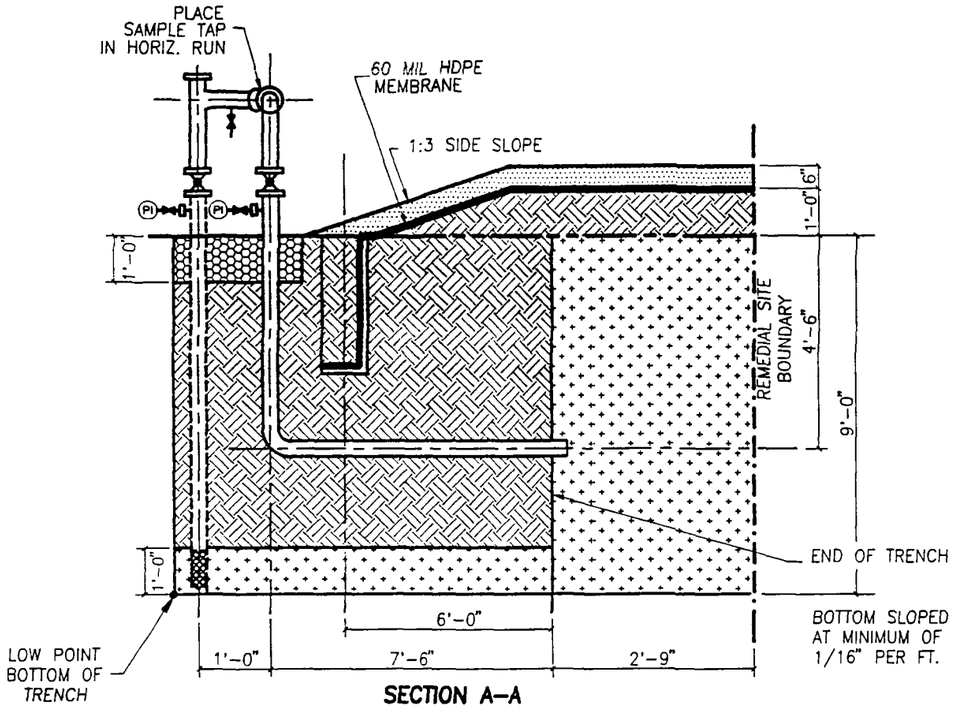


LEGEND:

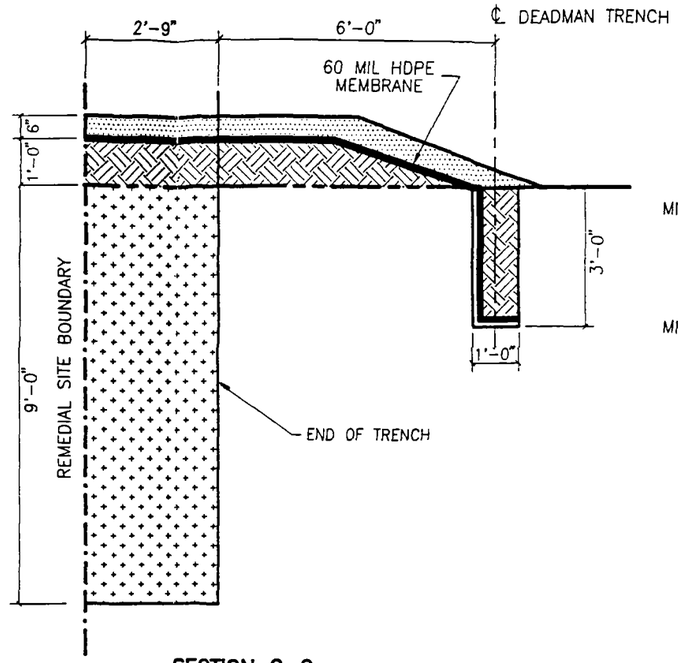
- FENCE LINE
- BUILDING LINE
- PAVEMENT EDGES
- BOUNDARY LINES
- INJECTION TRENCHES
- EXTRACTION TRENCHES
- CONCRETE



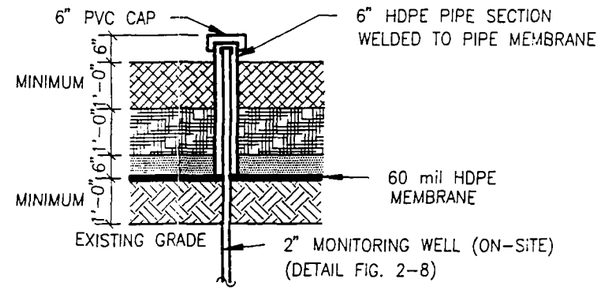
ENVIRONMENTAL CONSERVATION AND CHEMICAL CORPORATION ZIONSVILLE, INDIANA SOIL VAPOR EXTRACTION–TRENCH PLAN	FIGURE NO. 2–4
ERM ERM–North Central, Inc.	7/21/89 cs



SECTION A–A
(TYPICAL OF INJECTION AND EXTRACTION TRENCHES)

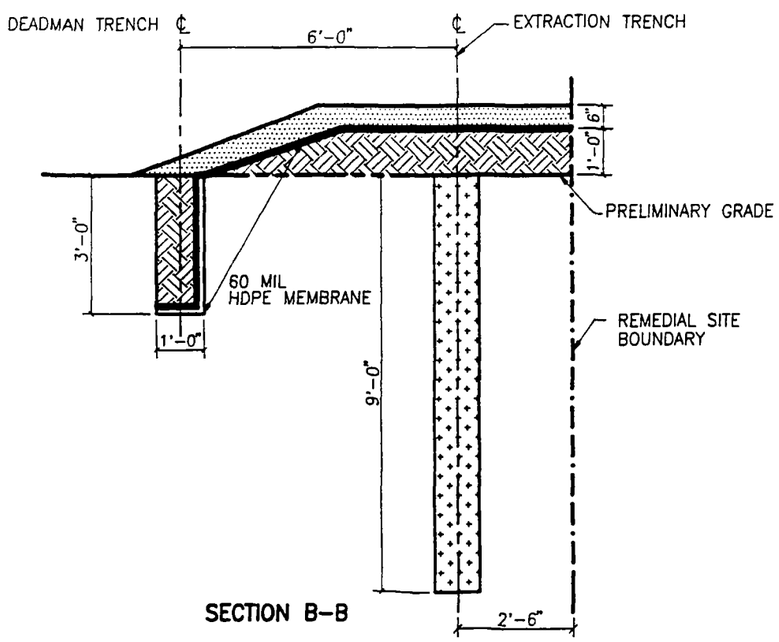


SECTION C–C

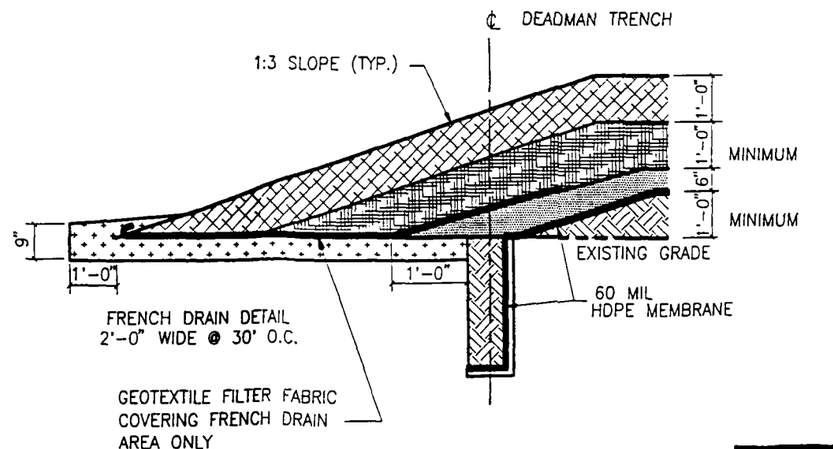


SAMPLING PORT DETAIL

NOTE: SECTIONS REFER TO PLAN SHOWN IN FIGURE 2-4.

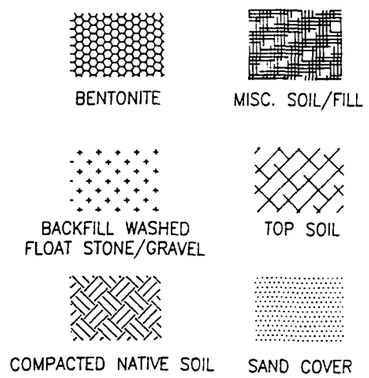


SECTION B–B



NOTE: FINAL COVER SLOPE 2% MINIMUM. SEED WITH APPROPRIATE SEED MIXTURE OF GRASSES.

FINAL RCRA–COMPLIANT COVER



NOTE: NOT TO SCALE

ENVIRONMENTAL CONSERVATION AND CHEMICAL CORPORATION ZIONSVILLE, INDIANA VAPOR EXTRACTION–TRENCH DETAIL	FIGURE NO. 2–5
ERM ERM–North Central, Inc.	7/21/89 cs

All trenches are to be a minimum of 9-feet deep as measured from existing grade, and will be backfilled with washed "float" stone. The trench width will be 12-15 inches. The bottom elevation for both injection and extraction trenches will be sloped at a minimum of 1/16-inch per foot to a low point located at the water collection pipe as noted in Section A-A of Figure 2-5.

Soil removed from the trench excavation will be spread over the surface prior to construction of the cover system and covered in accordance with the final RCRA-compliant (Subtitle C) cover detail illustrated in Figure 2-5. Soil removed from the trenches constructed in the areas of the concrete pad (Area 3) will be spread over the surface in Areas 1 and 2 with trench spoils from those areas.

Each trench will be equipped at one end with a vapor extraction pipe and a water collection pipe as illustrated in Section A-A of Figure 2-5. Both pipes will be 4-inch diameter, Schedule 40 PVC. Each pipe segment will be equipped with pressure/vacuum indicator, isolating valve and sample tap. A "T" at the top of the water collection pipe will permit the future installation of air piping to air lift water from the trench network, if necessary. Individual 4-inch, Schedule 40 PVC pipes will be routed from each extraction trench to the extraction module. The extraction module will be located adjacent to the existing concrete pad near the site entrance. Alternatively, two or three extraction trenches will be manifolded together and conveyed to the extraction module via a 4-inch, Schedule 40 PVC pipe. Injection trench piping is identical to the extraction trench piping and, as previously described, will permit it to be utilized as an extraction trench during the operation of the

vapor extraction system. To minimize field piping from the extraction module to the injection trenches, 4 to 8 injection trenches will be manifolded together. Four-inch, Schedule 40 PVC pipe will be used to convey air returned from the extraction module to the injection trench.

The Sump Well installed by EPA will be backfilled with the material used to backfill trenches (i.e, float stone) and a 4-inch PVC pipe will be installed between the sump and the nearest extraction trench, thereby tying the Sump Well directly into the vapor extraction system. The existing 20 ft. x 20 ft. sump will be handled similarly, and will be dewatered prior to installing the RCRA-compliant (Subtitle C) cover system. All water removed from this sump will be handled in accordance with applicable Federal, State and local requirements.

Soil Vapor Extraction System

The vacuum pump will have a nominal capacity of 500 standard cubic feet per minute (SCFM) and will be capable of developing a vacuum of 18 inches Hg. The normal operating vacuum is anticipated to be 12 inches Hg. Based on MWRI's experience with soils characteristic of the ECC site and on the Terra Vac pilot study results at the ECC site, the zone of influence at the operating vacuum will be at least 40 feet (20 feet either side of the trench). The pilot test results showed an initial radius of influence of 15 feet during trench development. Under continuous operation, the radius of influence increased to about 20 feet. The enhanced operating efficiency obtained by installing an impervious cover and injecting air will increase the radius of influence to over 20 feet. To be conservative, a spacing between trenches of 18 feet was selected.

The vacuum will be applied at the trench outlet and will be distributed throughout the entire length and vertical dimension of the trench. The highly porous backfill material used will assure this uniform distribution of vacuum throughout the extraction trench. The reinjection pressure of air in each adjacent injection trench will be approximately 37.4 inches Hg (1.25 atm). Therefore, the pressure differential and driving force for air movement between injection and extraction trenches under normal operating conditions is approximately 19.4 inches Hg (0.65 atm).

The selection of the design air volume of 500 SCFM is based upon MWRI's experience and is consistent with the Terre Vac pilot plant test results. The criteria established is to provide at least one air volume change per soil pore volume per day. Based upon an area of treatment of 150,000 square feet, a depth of contamination of 9 feet, and a soil porosity of 10%, 500 SCFM exceeds the MWRI criteria by 400%.

The vapor extraction process will operate continuously and will shut down automatically only in the event of an operating problem or malfunction. The following are conditions which will shut down normal operating sequence of the vapor extraction system:

- High vapor temperatures above the estimated acceptable range of 150 to 180°F prior to activated carbon treatment;

- Low vapor temperatures below the estimated acceptable range of 75 to 85°F prior to activated carbon treatment indicating relative humidity above the estimated acceptable range;

- High water level in water entrainment separator indicating operating problems with liquid transfer operation;

- High water level in subsurface water storage tank;

- High or low pressure conditions on vacuum or injection pumps under normal operating conditions; and

- Power interruptions for the site.

During normal operation, vapor extraction will be stopped to facilitate carbon vessel change out as described later in this section and during transfer of water from the entrainment separator to the on-site subsurface water storage tank, or to conduct restart spike tests.

The air extracted from the system will be continuously monitored by in-line instrumentation as shown on the process flow diagram (Figure 2-2) and described on Table 2-1 (Instrument Summary Sheet). The capability will exist to sample individual trench exhausts or the combined air stream. Sample taps will be provided to collect vapor samples for detailed chemical analysis. The on-line instrumentation will consist of a photoionization

TABLE 2-1
ERM-NORTH CENTRAL, INC.
INSTRUMENT SUMMARY SHEET

CLIENT: Environmental Conservation and Chemical Corporation

PROJECT NO.: 9041

DATE: 2/28/89 REVISED: 5/23/89

TAG NO.	SERVICE	REFERENCES MOUNTING PANEL	REFERENCES MOUNTING FIELD	REFERENCES SPEC SHEET	FLOW DIA.
PI	Pressure Indicator		X		2-1 2-2
PI-1 thru PI-4	Pressure Indicator with diaphram Seal and shutoff cock		X		2-1
PE-5	Pressure sensing element				
PT-5A	Pressure transmitter		X		2-2
AE-6	Moisture sensing element		X		2-2
AT-7	Moisture transmitter	X			2-2
AE-8	Volatile organics detector and quantifier	X			2-2
AT-9	Volatile organics quantified signal transmitter	X			2-2
LC-10	3-point water level control and alarm		X		2-2
TS-11	Gas temperature sensor with high level system shutdown switch		X		2-2
TS-12	Gas temperature sensor with high level system shutdown switch		X		2-2
FE-13	Gas flow measuring element		X		2-2
FT-14	Gas flow signal transmitter		X		2-2
LC-15	3-point water level control and alarm		X		2-2
PE-16	Pressure sensing element		X		2-2
PT-17	Pressure transmitter		X		2-2

detector (PID) and moisture analyzer. The vacuum pump, controls and instrumentation will be located in the Vapor Extraction Module Building.

Water Collection System

The high vacuum vapor extraction system selected will be capable of entrainment and movement of water which accumulates in the extraction trenches. Any free liquid in the extracted vapor will be separated by gravity in an entrainment separator located in the Vapor Extraction Module Building. A level control system will be utilized to control the removal of water which accumulates in the entrainment separator as required. The separator tank is equipped with a vacuum breaker system which will open the tank to the atmosphere to permit water to be transferred by pump from the separator to an on-site water storage tank as necessary. The time required to make this transfer will depend upon the equipment supplied by the vapor extraction system vendor selected.

The size of the storage tank will depend upon the off-site handling/treatment option selected. If water collected from the soil vapor extraction system is to be discharged to the Northside Sanitary Landfill (NSL) pipeline, a 1,000-gallon storage tank will be used; or if water collected is to be hauled off-site by tank truck for disposal, a 10,000-gallon tank will be used. The tank will be equipped with level measurement and control to advise operating personnel to the status of liquid accumulation in the storage tank. Periodically, the contents of the water storage tank will need to be removed. The removed water will either be sent to the Indianapolis POTW via the NSL pipeline or truck, or to another off-site facility for handling and treatment

as necessary, in accordance with applicable Federal, State and local regulations.

Carbon Adsorption System

From the water entrainment tank, the air passes through a particulate filter preceding the vacuum pump. The pressure drop across the filter will be monitored and used as the signal for determining servicing of the filter element. The exhaust from the vacuum pump will be piped directly to a two-stage carbon adsorption system (primary and secondary). This system will consist of two vessels in series each containing approximately 1,800 pounds of granular activated carbon. The organics contained in the extracted air will be adsorbed on the activated carbon. The moisture content of the air stream will be less than 50% relative humidity and temperatures will be approximately 150°F, both acceptable for efficient operation of carbon adsorption.

During the initial phases of operation, when organics concentrations in the air stream will be highest, the carbon capacity for the organics is expected to be about 25% by weight. During the latter phases of remediation as organic concentration of vapor decreases, the projected carbon capacity for organics will range between 10-15% by weight. Based upon an assumed total mass of organics of about 5,000 pounds (Appendix A), the total quantity of activated carbon required for the entire remediation program is 25,000 pounds. This equates to fourteen 1800-pound carbon vessels for the entire program. The actual amount of carbon used will depend upon the total mass of organics extracted during operation of the soil vapor extraction system and the carbon adsorption capacity.

The vapor from the primary carbon vessel will be monitored frequently (approximately once per hour) by an on-line PID analyzer. When the PID analyzer detects organic vapor in the air stream between the primary and secondary carbon vessels, the vacuum extraction system will shut down automatically to permit the removal and replacement of the "spent" primary carbon vessel. An operator will be alerted to this condition, and will disconnect the primary carbon bed from service. The spent carbon vessel will be removed and replaced by a carbon vessel containing fresh activated carbon. The unit previously serving as the secondary carbon bed will become the primary carbon bed and the unit just placed in operation will be the secondary carbon bed. Once this switch is complete, the soil vapor extraction system (i.e., vacuum pump and injection pump) will be restarted, and the system operation resumed. The arrangement of two activated carbon vessels in series (i.e., primary and secondary) will permit optimal utilization of the activated carbon, and efficient capture of the organics.

The spent carbon vessels will be stored on-site. The vessels will be stored on the existing concrete pad adjacent to the vapor extraction module building, inside the fenced area. An approximate location of this area is shown in Figure 2-4. The inlet and outlet connections to each vessel will be capped and sealed appropriately. Periodically when a truckload quantity of vessels has accumulated, and at the conclusion of the vacuum extraction program, the vessels containing the spent carbon will be transported in accordance with applicable Federal, State and local requirements to an off-site facility where the carbon will be regenerated by high temperature incineration, and in the process, the organics adsorbed on the carbon will be destroyed.

Air Injection System

The exhaust air from the secondary carbon bed will be piped to the injection pump located in the extraction module building. The injection pump will be capable of delivering 500 SCFM at 10 psig (1.65 atm). The discharge from the injection pump will be distributed to the 26 injection trenches via a system of manifolds. Control of the injection pump will be interlocked with the vacuum extraction pump. The pipe at each injection trench will be equipped with a pressure/vacuum gauge so that injection pressure at the trench can be periodically monitored.

During the soil vapor extraction program, the injection trenches will be utilized as extraction trenches and vice versa. This can be accomplished by minor above ground manifold piping modifications. It is also planned that as the Cleanup Standards set forth in Table 3-1 below are met for individual trench "areas", the corresponding extraction and injection trenches will be isolated from the extraction and injection operation by closing the shut off valves located at each trench. This will permit the soil vapor extraction system to concentrate on any remaining areas which have not fully achieved the Cleanup Standards specified in Table 3-1, thereby accelerating cleanup of those areas.

RCRA-Compliant (Subtitle C) Cover

The operation of the vapor extraction system will be enhanced by the installation of the RCRA-compliant (Subtitle C) cover over the entire site. Details and a schedule for installation of the final RCRA-compliant (Subtitle C) cover are presented in Section 2.1.2.

Miscellaneous

- Each extraction trench is equipped with two sample taps, one on the vacuum pipe and one on the water collection pipe. Each of these taps can be fitted with a sample bottle for the collection of free moisture.

- Electrical service required for the site remediation work is anticipated to be 3-phase 460 volt. Total electrical demand will be approximately 100 KVA. Power distribution will be to the extraction module building. Operating voltage for the extraction and injection pumps is anticipated to be 460 volts. A 110 volt supply will be provided for miscellaneous site lighting, equipment, instrumentation and controls. Power distribution to any site construction and office trailers will also be provided.

- Prior to construction of the trenches, the following activities will be conducted:

    1. The existing buildings within the area currently fenced will be demolished and disposed of off-site;

2. The existing tanks removed and properly disposed of off-site; and

3. The site will be graded to fill existing depressions and to eliminate any sharp grade changes.

2.1.2 RCRA-Compliant (Subtitle C) Cover

The RCRA-compliant (Subtitle C) cover illustrated in Figure 2-5 will consist of a minimum of 1-foot of compacted, highly impermeable native soil, a continuous welded 60 millimeter high density polyethylene (HDPE) plastic membrane, a minimum 6-inch layer of compacted sand for drainage, 1 to 3 feet of miscellaneous soil/fill material and 1 foot of top soil to support vegetation. The final grading plan will ensure a minimum slope of 2%. The native soil used will be the silty clay till available in the area, which can and will be compacted by standard methods to 95% proctor density. If soil from the NSL borrow area is not available, material with similar performance will be obtained from another source.

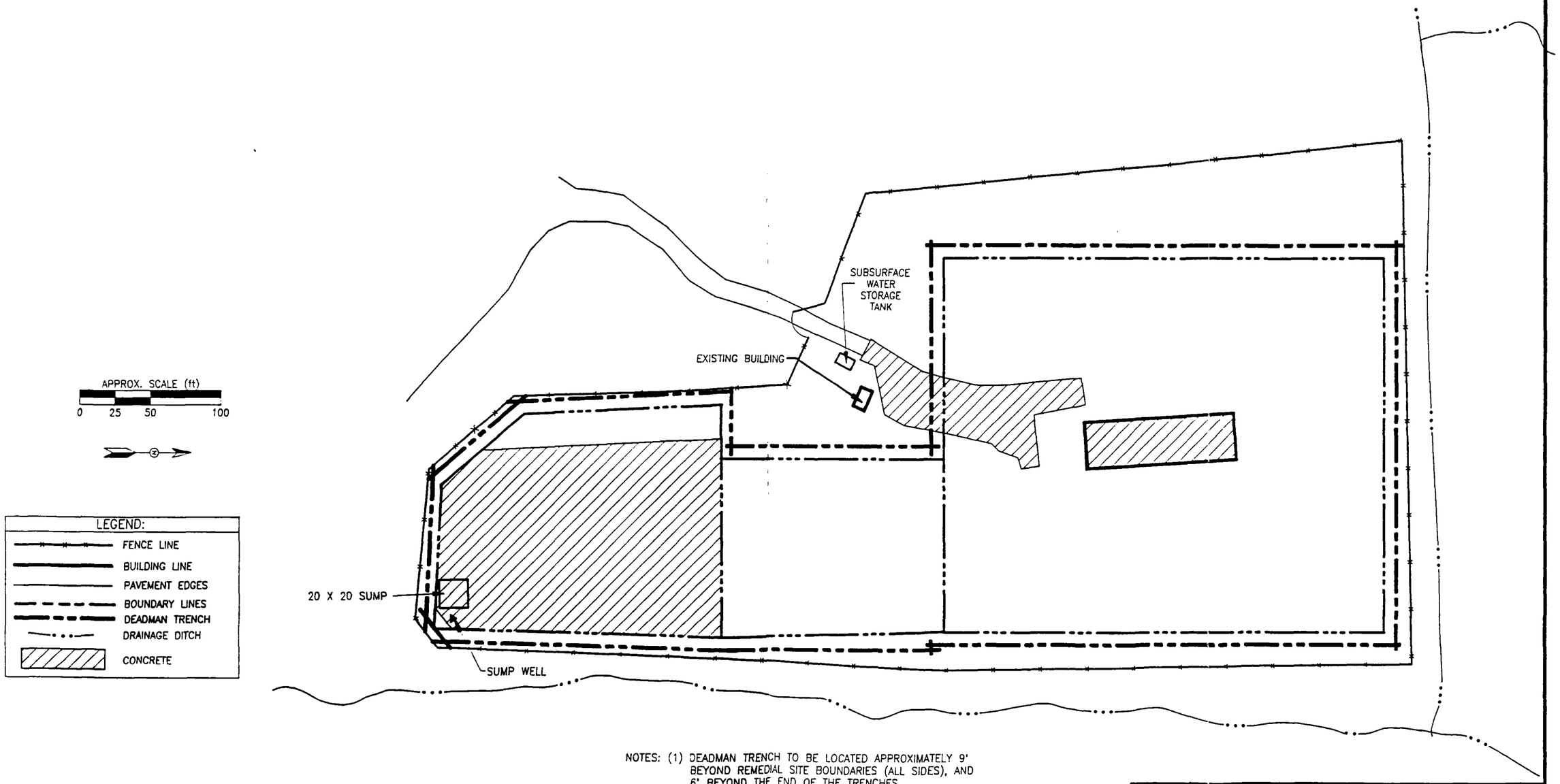
To provide a perimeter seal of the HDPE membrane, a 1-foot wide, 3-foot deep "deadman trench" will be installed around the site boundary (Figure 2-6). The HDPE membrane will be draped into this trench. The trench will then be backfilled and compacted with native soil (silty clay till) to 95% proctor density. The cover will extend approximately 6 feet beyond the deadman trench as noted on Figure 2-6 and detailed on Figure 2-5.

As previously described, the material excavated from the trenches will be graded uniformly throughout trench areas 1 and 2 and incorporated into the top layer of existing surface soil prior to the construction of the RCRA-compliant (Subtitle C) cover as shown in Figure 2-5.

The RCRA-compliant (Subtitle C) cover will be installed over the entire site, including the concrete pad. Prior to operation of the soil vapor extraction system, the following components of the RCRA-compliant (Subtitle C) cover will be installed: (1) 1-foot minimum compacted native soil; (2) a 60 mil HDPE membrane; and (3) 6 inches of sand. The remaining components (1-foot minimum miscellaneous soil/fill, 1-foot minimum topsoil and appropriate vegetation) will be installed during operation of vapor extraction in accordance with the schedule presented in Section 5.0. At completion of the soil vapor extraction program all surface piping will be removed from the site in addition to any equipment, buildings or trailers. At that time the extraction and injection trench piping may be cut off at the current grade, filled with grout, and covered with a minimum of 1 foot of topsoil, which will be vegetated. Vegetation which will be established shall include fibrous, shallow, laterally growing roots, such as grass (which may include red fescue and Kentucky blue grass).

2.1.3 Access Restrictions

Access restrictions to be implemented by the Settling Defendants will consist of a fence around the site perimeter and the posting of warning signs.



NOTES: (1) DEADMAN TRENCH TO BE LOCATED APPROXIMATELY 9' BEYOND REMEDIAL SITE BOUNDARIES (ALL SIDES), AND 6' BEYOND THE END OF THE TRENCHES.

(2) DEADMAN TRENCH DEFINES THE BOUNDARY OF THE HDPE LINER. THE RCRA-COMPLIANT (SUBTITLE C) COVER DETAIL EXTENDS APPROXIMATELY 6' BEYOND THE DEADMAN BOUNDARY AS SHOWN ON FIG 2-5.

ENVIRONMENTAL CONSERVATION AND CHEMICAL CORPORATION ZIONSVILLE, INDIANA DEADMAN TRENCHING PLAN	FIGURE NO. 2-6
ERM ERM-North Central, Inc.	7/19/89
	cs

2.1.4 Subsurface and Surface Water Monitoring

The monitoring activities will:

- Detect any migrating VOCs, base neutral/acid organics, PCBs, and heavy metals as specified in Table 3-1 in the subsurface and surface water during and after vapor extraction; and

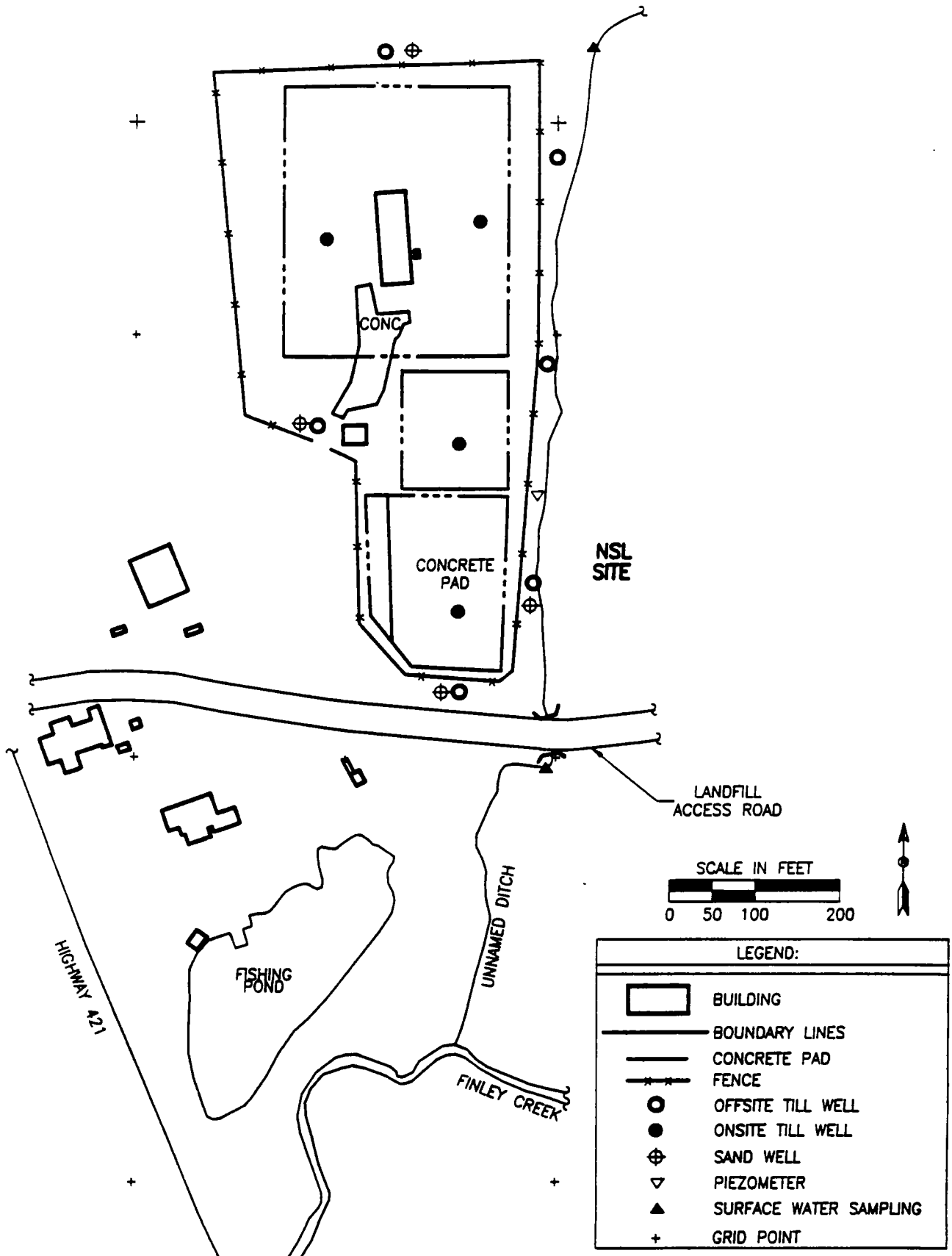
- Monitor and verify the effectiveness of the soil vapor extraction program.

Two types of subsurface water monitoring systems will be installed under this Remedial Action Plan. The first is an on-site till monitoring system consisting of four wells screened in the till. The location of these on-site till wells is shown in Figure 2-7. Sampling results from the on-site till wells will be compared to the Acceptable Subsurface Water Concentrations in Table 3-1 or the Applicable Background Concentrations defined in Table 3-1 ("Applicable Background Concentrations").

Samples from the on-site till monitoring wells will be collected at the beginning of the soil vapor extraction operation and quarterly thereafter until completion of the soil vapor extraction program. Monitoring will be continued on a semi-annual basis as specified in Section 4.0. Every time samples are collected from the on-site wells, the soil vapor extraction system will be shut down to allow water, if any, to stabilize within the till. Samples collected from the on-site wells will be analyzed for the parameters with Acceptable Subsurface Water Concentrations in Table 3-1.

The second type of subsurface water monitoring system consists of off-site wells screened in the till and offsite wells screened in the sand and gravel. Sampling results from these wells will be used to determine compliance with the Acceptable Stream Concentrations in Table 3-1 or the Applicable Background Concentrations. This second subsurface water monitoring network will consist of ten (10) wells, which will be located around the periphery of and downgradient from the ECC site (Figure 2-7). In addition, a piezometer will be installed on the east side of the site, as shown in Figure 2-7, to aid in defining the direction of till water flow. Six (6) wells will be installed in the till, completed in the saturated zone, and four (4) wells will be completed in the sand and gravel unit underlying the saturated surface till.

All wells (on-site and off-site) will be constructed of 2-inch PVC pipe. Screen length will vary for each well. Total depth for the wells completed in the till will be 1-2 feet less than total depth to the contact between the till and underlying sand and gravel. Wells completed in the sand and gravel will screen the total thickness of that sand and gravel unit. Screens will have a 0.01 inch opening. Wells will have a sand pack to one foot above the top of screen and a bentonite grout to the ground surface. For the on-site till wells, a sampling port will be fabricated in the HDPE membrane which will prevent infiltration of air via these monitoring wells during operation of the soil vapor extraction system. A detail of this sampling port is shown on Figure 2-5. Figures 2-8 and 2-9 illustrate well construction details for the subsurface water monitoring wells in the till and in the sand and gravel, respectively. Details of the piezometer construction are shown in Figure 2-10. The location of the



SUBSURFACE AND SURFACE WATER SAMPLING LOCATIONS	FIGURE 2-7
ERM ERM-North Central, Inc.	7/7/89 mo

monitoring wells is based on the subsurface water elevation contours shown in Figure 2-11.

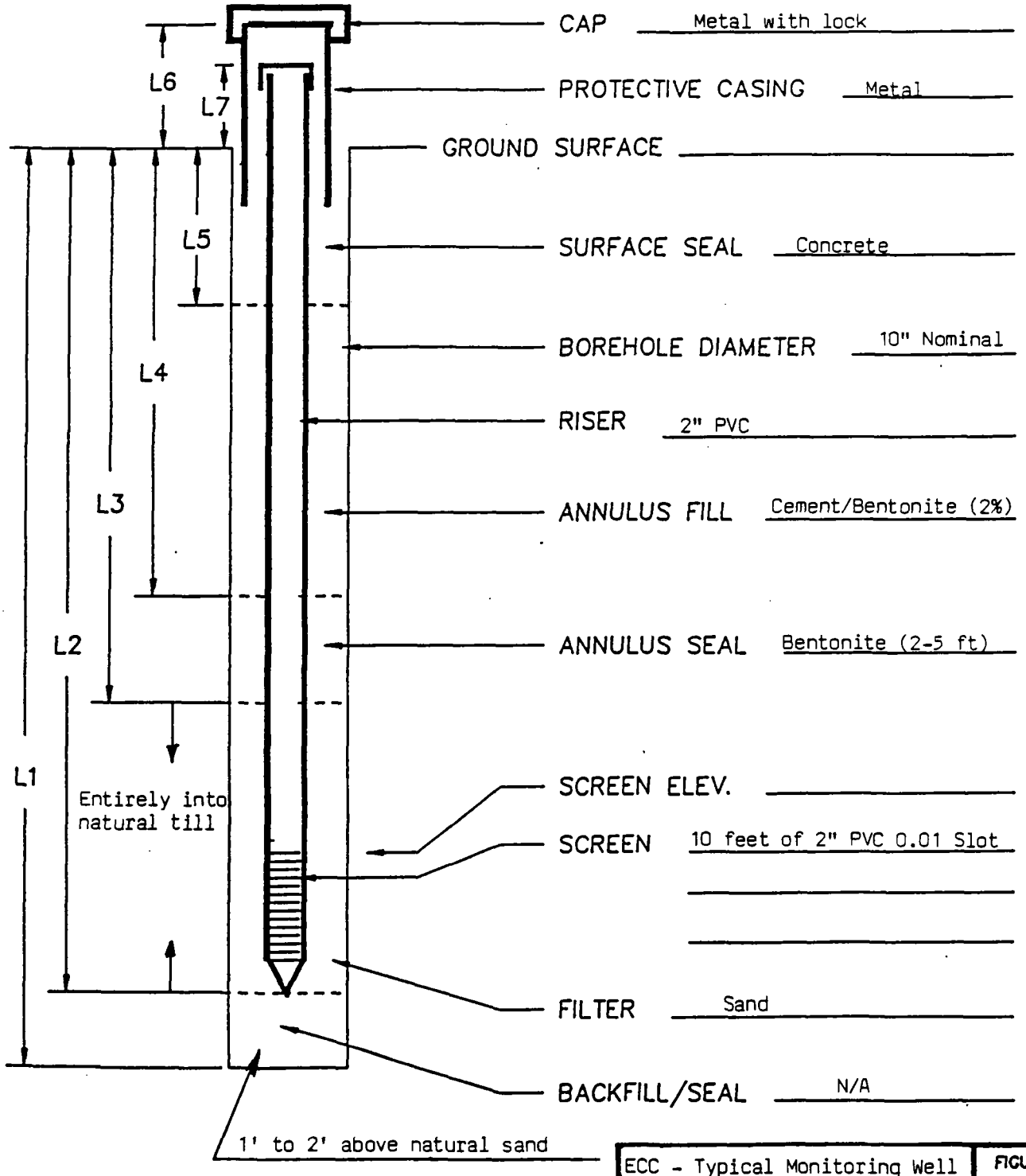
Samples from the off-site wells will be collected quarterly during operation of the vapor extraction system and analyzed for the parameters with Acceptable Stream Concentrations in Table 3-1. Monitoring will be continued on a semi-annual basis as specified in Section 4.0.

The surface water will be monitored by sampling the Unnamed Ditch just upgradient and just downgradient of the ECC site as depicted in Figure 2-7. Surface water will be sampled at the same frequency as the off-site subsurface water and analyzed for the parameters with Acceptable Stream Concentrations in Table 3-1.

3.0 REMEDIAL ACTION CLEANUP STANDARDS

This section presents site-specific Cleanup Standards to be used at the ECC site as the criteria for determining the end point of remediation activities. The Cleanup Standards in this section are the basis for establishing the criteria for Soil Cleanup Verification presented in Section 4.2, and the Post-Soil Cleanup Verification Compliance Monitoring in Section 4.3. If Soil Cleanup Verification as defined in Section 4.2 and the subsections thereof is not achieved within 5 years of commencing operation of the soil vapor extraction system, the Additional Work provisions of Section VII of the Consent Decree will apply.

MONITORING WELL CONSTRUCTION

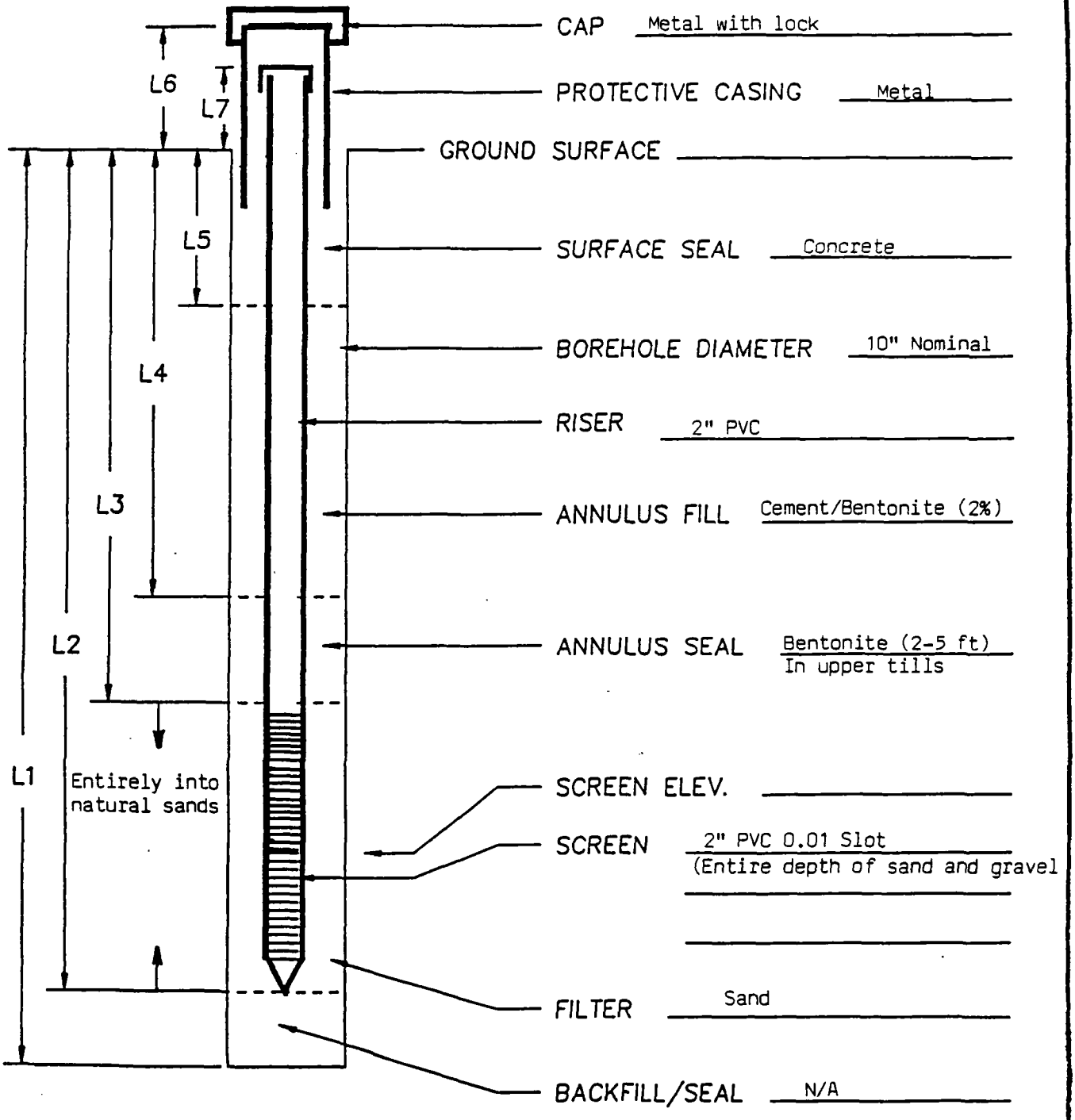


ECC - Typical Monitoring Well Construction Detail Well in Glacial Till

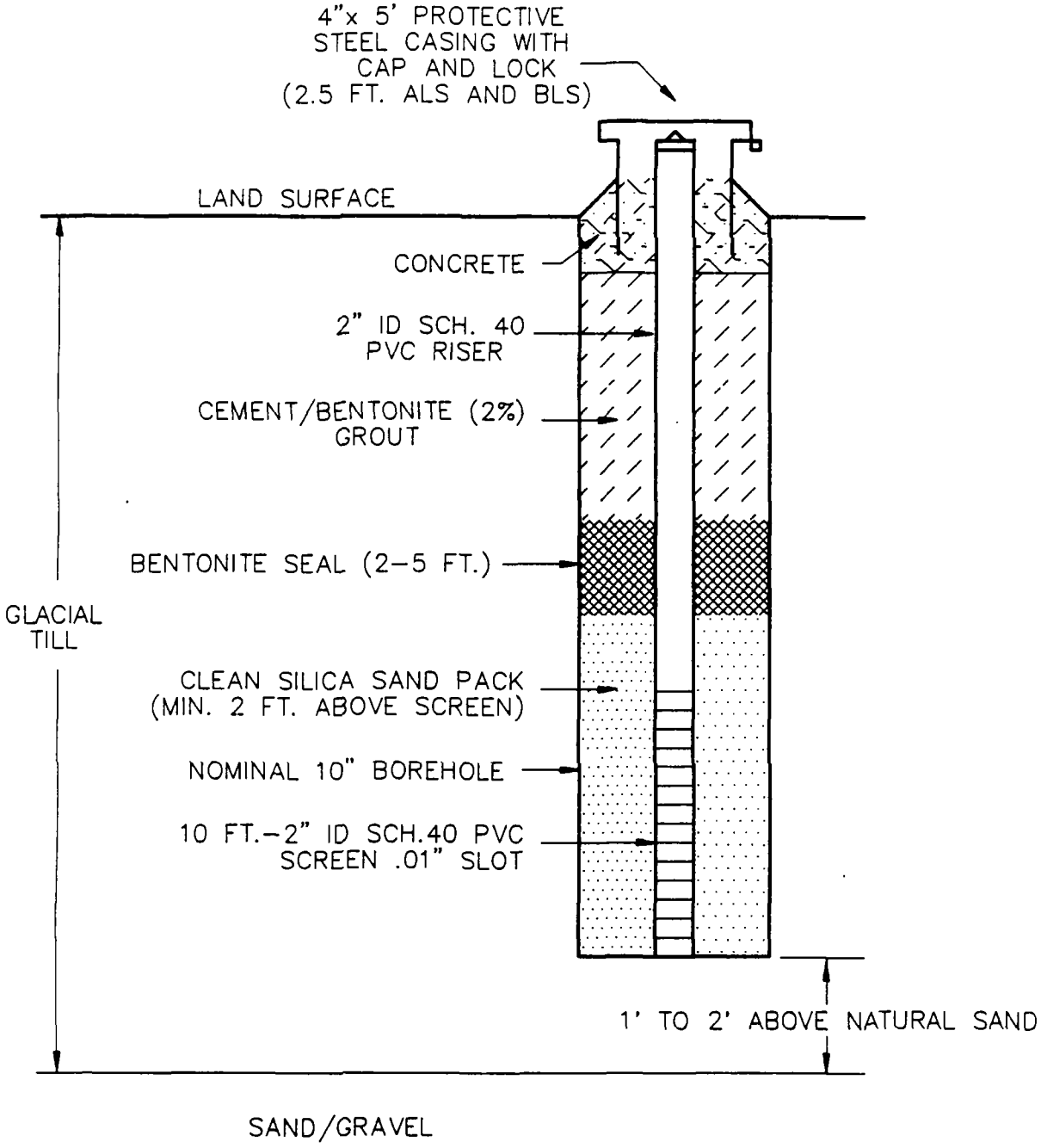
FIGURE 2-8

ERM-North Central, Inc.

MONITORING WELL CONSTRUCTION

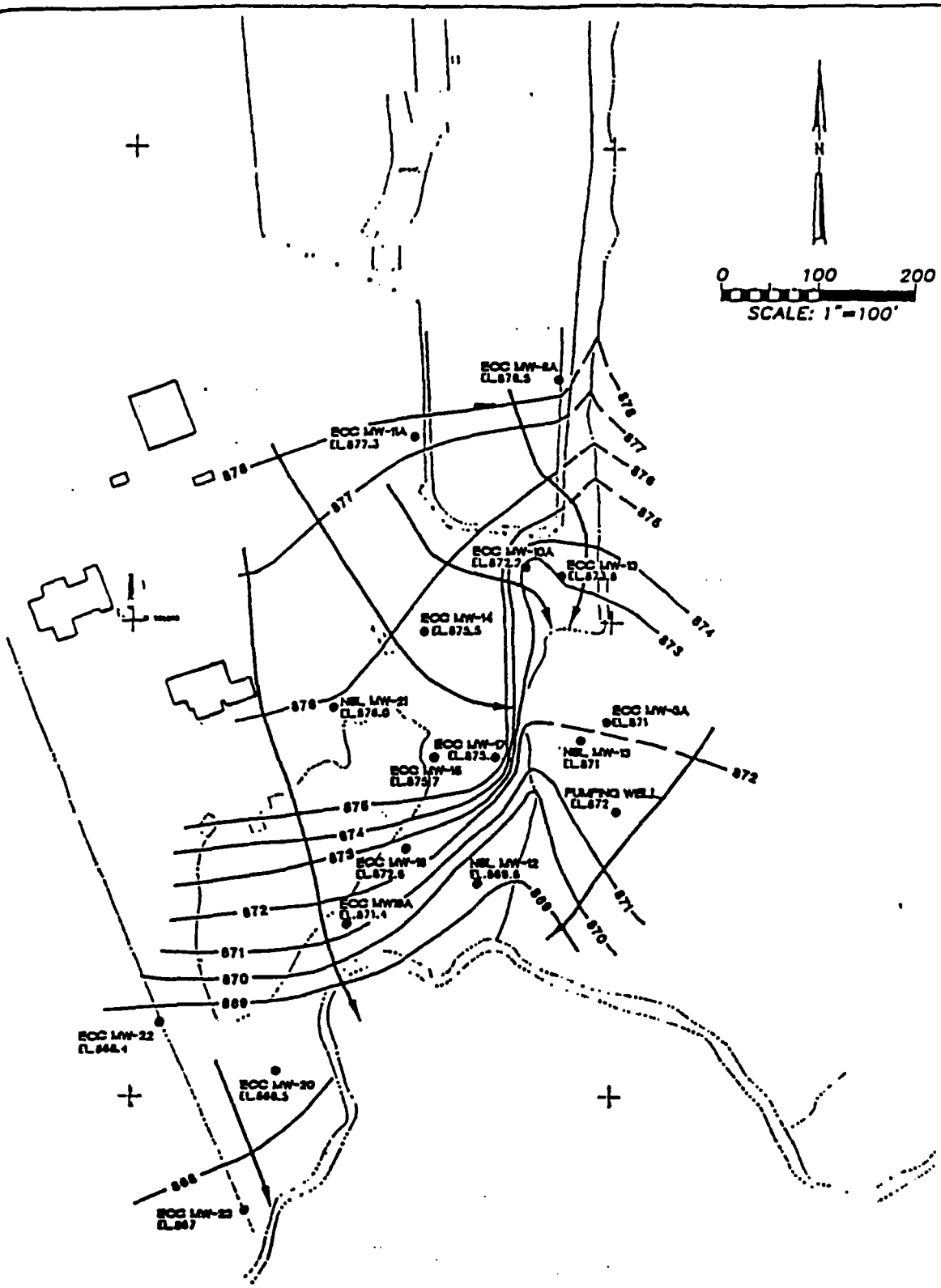


ECC - Typical Monitoring Well Construction Detail Well in Sand & Gravel	FIGURE 2-9
ERM-North Central, Inc.	



NOT TO SCALE

ECC-TYPICAL PIEZOMETER CONSTRUCTION DETAIL INSTALLED IN GLACIAL TILL	FIGURE 2-10
ERM ERM-North Central, Inc.	7/20/89 mo



LEGEND

—868— POTENTIOMETRIC SURFACE CONTOUR FOR SAND AND GRAVEL AQUIFER. CONTOUR INTERVAL: 1 FOOT.

- - 868 - - INFERRED POTENTIOMETRIC SURFACE CONTOUR

→ DIRECTION OF GROUNDWATER MOVEMENT IN SURFICIAL AQUIFER

NOTE: Contours have been drawn to suggest that the pond is not hydraulically connected to the sand and gravel aquifer. This relationship has not been fully established.

From CH2M HILL Technical Memorandum No. 2, dated September 16, 1988.

POTENTIOMETRIC SURFACE MAP OF UPPER SAND AND GRAVEL AQUIFER	FIGURE 2-11
ERM ERM-North Central, Inc.	10/27/88
	CS

3.1 Cleanup Standards

The following Cleanup Standards will be met for successful completion of the soil vapor extraction program:

- Acceptable Soil Concentrations shown in Table 3-1 will be achieved;

- Acceptable Stream Surface Concentrations shown in Table 3-1 or Applicable Background Concentrations will be achieved in Unnamed Ditch south of and adjacent to ECC;

- Acceptable Subsurface Water Concentrations in Table 3-1 or Applicable Background Concentrations in the on-site till wells will be achieved; and

- Acceptable Stream Concentrations in Table 3-1 or Applicable Background Concentrations in the off-site wells will be achieved.

The term "Table 3-1" wherever referred to or used in this Exhibit A and in the Consent Decree includes the Footnotes on page 2 of 2 of that table.

TABLE 3-1 (Page 1 of 2)
SITE-SPECIFIC ACCEPTABLE CONCENTRATIONS
ENVIRONMENTAL CONSERVATION AND CHEMICAL CORPORATION (ECC) SITE

Compounds	Acceptable Subsurface Water Concentration (1,2) (ug/l)		Acceptable Stream Concentration (3,4) (ug/l)	Acceptable Soil Concentration (5,6) (ug/kg)
VOLATILE ORGANICS (VOCs):				
Acetone	3,500	RB		490
Chlorobenzene	60	MCLGP		10,100
Chloroform	100	MCL	15.7	2,300
1,1-Dichloroethane	0.38	RB		5.7
1,1-Dichloroethene	7	MCL	1.85	120
Ethylbenzene	680	MCLGP	3,280	234,000
Methylene Chloride	4.7	RB	15.7	20
Methyl Ethyl Ketone	170	LDWHA		75
Methyl Isobutyl Ketone	1,750	RB		8,900
Tetrachloroethene	0.69	RB	8.85	130
Toluene	2,000	MCLGP	3,400	238,000
1,1,1-Trichloroethane	200	MCL	5,280	7,200
1,1,2-Trichloroethane	0.61	RB	41.8	22
Trichloroethene	5	MCL	80.7	240
Total Xylenes	440	MCLGP		195,000
BASE NEUTRAL/ACID ORGANICS:				
Bis(2-ethylhexyl)phthalate	2.5	RB	50,000	
Di-n-Butyl Phthalate	3,500	RB	154,000	
Diethyl Phthalate	28,000	RB	52,100	
Isophorone	8.5	RB		(7)
Naphthalene	14,000	RB	620	
Phenol	1,400	RB	570	9,800
INORGANICS:				
Antimony	14	RB		
Arsenic	50	MCL	0.0175	
Barium	1,000	MCL		
Beryllium	175	RB		
Cadmium	10	MCL		
Chromium VI	50	MCL	11	
Lead	50	MCL	10	
Manganese	7,000	RB		
Nickel	150	LDWHA	100	
Silver	50	MCL		
Tin	21,000	RB		
Vanadium	245	RB		
Zinc	7,000	RB	47	
Cyanide	154	LDWHA	5.2	
PESTICIDES/PCBs:				
PCBs	0.0045	RB		

TABLE 3-1 (Page 2 of 2)
SITE-SPECIFIC ACCEPTABLE CONCENTRATIONS
ENVIRONMENTAL CONSERVATION AND CHEMICAL CORPORATION (ECC) SITE

NOTES:

(1) RB = Risk-based standard. U.S. EPA, Draft RCRA Facility Investigation Guidance, 1987.
MCL = Drinking water Maximum Contaminant Level. 40 CFR 141.
MCLGP = Drinking water MCL goal, proposed. U.S. EPA, Superfund Public Health Evaluation Manual, update of November 16, 1987.
LDWHA = Lifetime drinking water health advisory. U.S. EPA, Superfund Public Health Evaluation Manual, update of November 16, 1987.

(2) In the event that higher concentrations than those set forth in this column are or have been detected in the upgradient subsurface water, then those higher upgradient concentrations and not the values set forth in this table shall constitute the Acceptable Subsurface Water Concentrations within the meaning of this Exhibit A and the Consent Decree. Those higher upgradient concentrations are referred to in this Exhibit A as "Applicable Background Concentrations."

(3) Stream Criteria, from Table 1 of the Record of Decision for the site, September 25, 1987.

(4) In the event that higher concentrations than those set forth in this column are or have been detected in the upstream surface water, then those higher upstream concentrations and not the values set forth in this table shall constitute the Acceptable Stream Concentrations within the meaning of this Exhibit A and the Consent Decree. Those higher upstream concentrations are referred to in this Exhibit A as "Applicable Background Concentrations."

(5) Acceptable Soil Concentration is based on ingestion of subsurface water at the site boundary, assuming a dilution of leachate to subsurface water of 1:196 (Appendix B).

(6) The arithmetic average of the 20 soil sample results for each parameter (except for isophorone), assigning all non-detect results a value of one-half the detection limit, will constitute the Acceptable Soil Concentrations within the meaning of this Exhibit A and the Consent Decree provided they do not exceed the values set forth in this table by more than 25 percent.

(7) Compliance for isophorone will be determined as follows: One vapor sample from each of the 28 extraction trenches and one water sample from each of the four on-site till wells will be analyzed for isophorone. The vapor results will be transformed to the soil equivalent concentrations following the procedure shown in Table D1 of Appendix D. The water results will be transformed to the soil equivalent concentrations following the procedure shown in Table B6 of Appendix B. The arithmetic average of the 32 transformed soil equivalent concentrations, assigning all non-detect results a value of one-half the vapor or water detection limit (as applicable), will constitute an "Acceptable Soil Concentration" within the meaning of this Exhibit A and the Consent Decree provided it does not exceed 52 ug/kg by more than 25 percent.

3.2 Calculation of Cleanup Standards

Table 3-1 sets forth the ECC site specific Cleanup Standards and Applicable Background Concentrations. The equations for calculation of the risks, supporting data and complete references are included in Appendix B.

The calculation of risk-based concentrations shown in Table 3-1 follows the procedures presented in the USEPA Draft RCRA Facility Investigation (RFI) Guidance, July, 1987, and in the USEPA Memorandum on Interim Final Guidance for Soil Ingestion Rates, January 27, 1989. In accordance with this latter reference, the soil ingestion rate for risk calculation was either 0.1 grams of soil per day for a 70 kilogram person for 70 years (for compounds with potency factors) or 0.2 grams of soil per day for a 17 kilogram child for 5 years (for compounds with reference doses). In accordance with the RFI Guidance document referenced above, the ingestion rate used for the risk calculation was 2 liters of water per day by a 70 kg person for 70 years.

Three columns of data, corresponding to Acceptable Concentrations for Subsurface Water, Stream and Soil are presented in Table 3-1. Additionally, Applicable Background Concentrations for Subsurface Water, and Stream Water are defined in Table 3-1. Subsurface water concentrations are based on either drinking water standards or criteria (Maximum Contaminant Level [MCL], proposed Maximum Contaminant Level Goal [MCLGP], lifetime drinking water health advisory [LDWHA]) or the appropriate risk-based concentration. These limits assume, as a worst case, that the subsurface water in the till could be utilized as a lifetime source of drinking water. However, the use of the subsurface water in the till as a source of drinking water was rejected as infeasible in the ECC

Remedial Investigation (RI), page 6-22. As a result, the use of drinking water standards and risk-based standards based upon daily, long-term human consumption of the till water for Cleanup Standards under this Remedial Action Plan represents an extremely conservative assumption when the real-life risks, if any, presented by the ECC site are considered.

Surface water concentrations are taken from the Record of Decision (ROD) for the site, dated September 25, 1987.

The Acceptable Soil Concentrations in Table 3-1 are based on the lowest of the risk-based concentrations for soil or subsurface water ingestion.

Table 3-2 presents the compounds detected in soils at the site at levels above the Acceptable Soil Concentrations specified in Table 3-1. Table 3-3 shows the vapor pressure and solubility of these compounds.

3.3 Additional Work

If Additional Work is required under Section VII of the Consent Decree, Settling Defendants shall either perform such Additional Work as the Parties may agree or shall arrange with a Contractor to perform the following additional work at the site unless the parties agree otherwise:

- Maintain the RCRA-compliant (Subtitle C) cover and the access restrictions.

TABLE 3-2
COMPOUNDS DETECTED IN THE SOIL AT CONCENTRATIONS
ABOVE THE ACCEPTABLE SOIL CONCENTRATIONS (1)

Compound	Acceptable Soil Concentration (ug/kg)	Maximum Detected Concentration (ug/kg)
VOLATILE ORGANICS (VOCs):		
Acetone	490	650,000
Chloroform	2,300	2,900
1,1-Dichloroethane	5.7	35,000
1,1-Dichloroethene	120	380
Ethylbenzene	234,000	1,500,000
Methylene Chloride	20	310,000
Methyl Ethyl Ketone	75	2,800,000
Methyl Isobutyl Ketone	8,900	190,000
Tetrachloroethene	130	650,000
Toluene	238,000	2,000,000
1,1,1-Trichloroethane	7,200	1,100,000
1,1,2-Trichloroethane	22	550
Trichloroethene	240	4,800,000
Total Xylenes	195,000	6,800,000
BASE NEUTRAL/ACID ORGANICS:		
Isophorone	52	440,000
Phenol	9,800	570,000

(1) Acceptable Soil Concentrations are determined in accordance with Footnotes 5, 6, and 7 of Table 3-1.

TABLE 3-3
CHEMICAL PROPERTIES OF ORGANIC COMPOUNDS
DETECTED IN THE SOILS AT CONCENTRATIONS
ABOVE THE ACCEPTABLE SOIL CONCENTRATIONS (1)

Compound	Solubility (ug/l)	Vapor Pressure (mm Hg)
VOLATILE ORGANICS (VOCs):		
Acetone	1,000,000,000	270
Chloroform	8,200,000	151
1,1-Dichloroethane	5,500,000	182
1,1-Dichloroethene	2,250,000	600
Ethylbenzene	152,000	7
Methylene Chloride	20,000,000	362
Methyl Ethyl Ketone	268,000,000	77.5
Methyl Isobutyl Ketone	17,000,000	6
Tetrachloroethene	200,000	17.8
Toluene	535,000	28.1
1,1,1-Trichloroethane	4,400,000	123
1,1,2-Trichloroethane	4,500,000	30
Trichloroethene	1,100,000	57.9
Total Xylenes	198,000	10
BASE NEUTRAL/ACID ORGANICS:		
Isophorone	12,000	0.38
Phenol	93,000,000	0.341

(1) Acceptable Soil Concentrations are determined in accordance with Footnotes 5, 6, and 7 of Table 3-1.

REFERENCES:

U.S. EPA, "Superfund Public Health Evaluation Manual," 1986.

U.S. EPA, "Water-Related Environmental Fate of 129 Priority Pollutants," December 1979.

- Construct a water interception trench around the south and east sides of the ECC site as depicted in Figures 3-1 and 3-2.

- Collect and transport subsurface water intercepted in this trench to the Indianapolis POTW (via the NSL pipeline or tank truck), or provide other appropriate handling and treatment of such water in accordance with applicable Federal, State and local requirements.

- Subsurface water will continue to be removed and handled in this manner until two consecutive, semi-annual subsurface water samples collected from the interception trench show that the Acceptable Stream Concentrations in Table 3-1 or Applicable Background Concentrations have been met unless the Parties to the Decree otherwise agree or the Court orders that said remedial activities may be terminated.

- Semi-annual monitoring of off-site wells and surface water will continue for five years after any additional remedial measures have achieved the Acceptable Stream Concentrations in Table 3-1 or Applicable Background Concentrations.

NOTES:

1) DEPTH OF TRENCH WILL VARY DEPENDING ON DEPTH OF GLACIAL TILL LAYER. BOTTOM OF TRENCH TO BE LOCATED ~1'-0" ABOVE UNDERLYING GLACIAL SAND.

2) INTERCEPTION TRENCH WILL BE LOCATED BETWEEN REMEDIAL AREA BOUNDARIES AND UNNAMED DITCH.

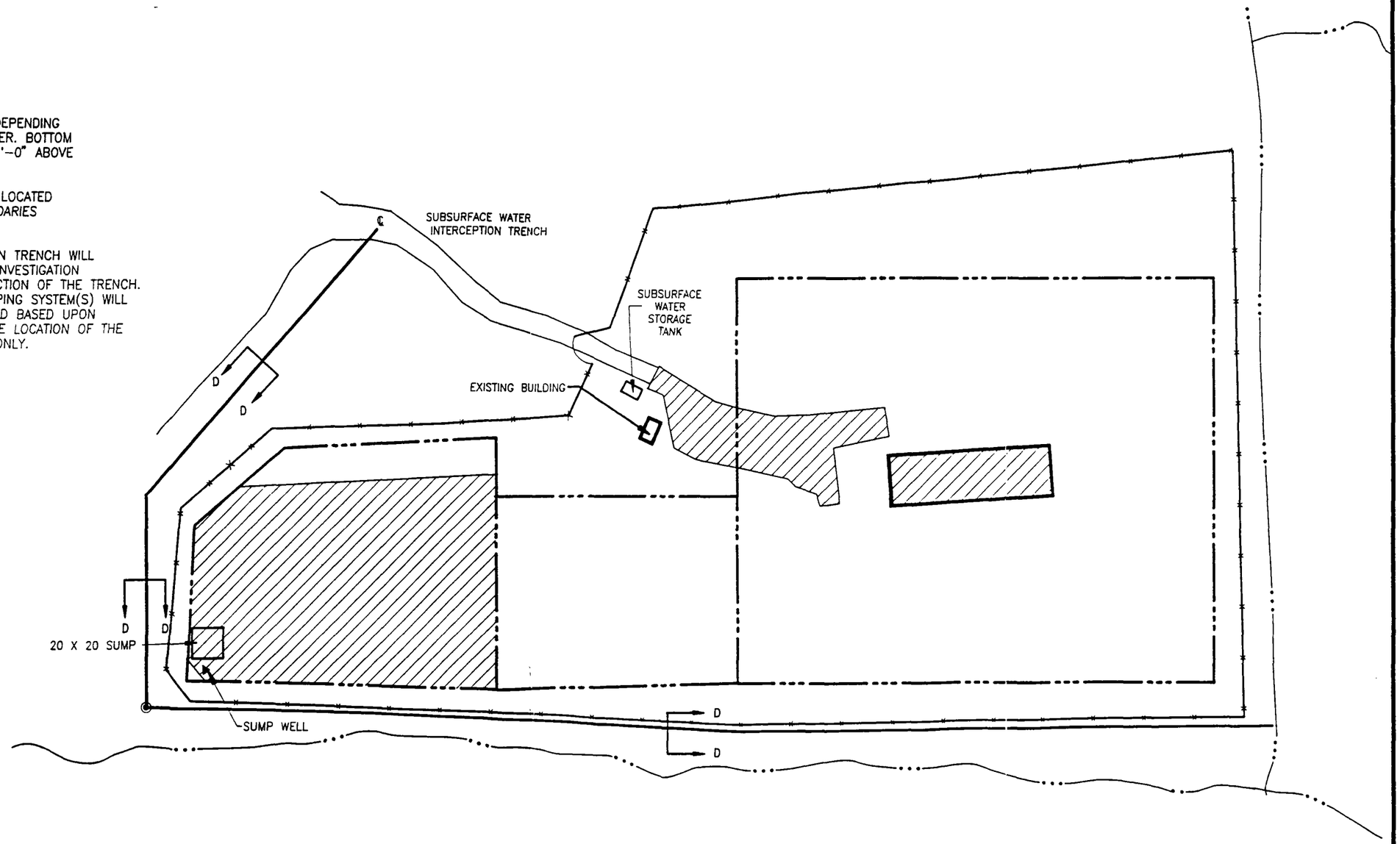
3) LOW POINT(S) FOR INTERCEPTION TRENCH WILL BE DETERMINED DURING FIELD INVESTIGATION WORK REQUIRED FOR CONSTRUCTION OF THE TRENCH. SUMP(S) AND ASSOCIATED PUMPING SYSTEM(S) WILL BE CONSTRUCTED AND INSTALLED BASED UPON LOCATION OF LOW POINT(S). THE LOCATION OF THE SUMP SHOWN IS ILLUSTRATIVE ONLY.

APPROX. SCALE (ft)

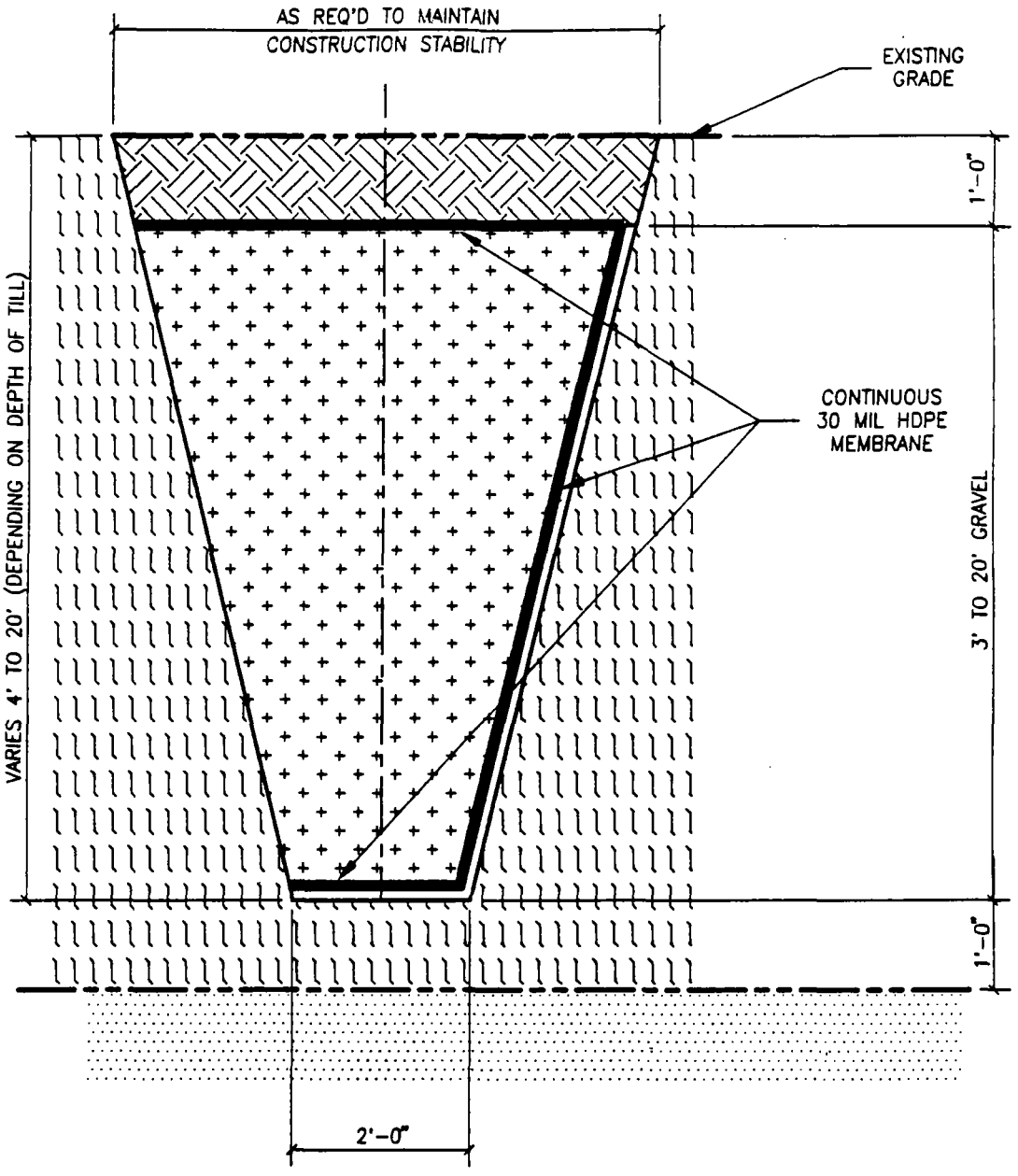
0 25 50 100

LEGEND:

- FENCE LINE
- BUILDING LINE
- PAVEMENT EDGES
- BOUNDARY LINES
- TRENCH SUMP & PUMP
- DRAINAGE DITCH
- CONCRETE
- SUBSURFACE WATER INTERCEPTION TRENCH



ENVIRONMENTAL CONSERVATION AND CHEMICAL CORPORATION ZIONSVILLE, INDIANA SUBSURFACE WATER INTERCEPTION TRENCH	FIGURE NO. 3-1
ERM ERM-North Central, Inc.	7/19/89 cs



LEGEND:

- COMPACTED NATIVE SOIL
- WASHED FLOAT STONE
- SAND
- GLACIAL TILL
- 30 MIL HDPE COVER

SUBSURFACE WATER INTERCEPTION TRENCH CROSS-SECTION	FIGURE 3-2
ERM ERM-North Central, Inc.	6/23/89

Nothing in this Section 3.3 shall prevent the Settling Defendants, at their option, from undertaking Additional Work under this section before the expiration of the 5 year period of commencing operation of the soil vapor extraction system should it become evident to them that the vapor extraction system will not achieve compliance as defined in Section 4.2 and the subsections thereof.

4.0 REMEDIAL ACTION COMPLIANCE MONITORING

The soil vapor extraction system described herein is designed to achieve the required removals of VOCs, phenol and isophorone from the soil to the standards presented in Section 3.0. The time required to accomplish this removal depends on the type of compound and soil, air flow rate and temperature, and on an efficient diffusion of air through the soil pores. The time required for treatment was estimated using a vapor extraction model, as described below and in Appendix C. Monitoring of vapor from the combined vapor stream and from individual trenches, as described below, will also be used to estimate completion of the soil vapor extraction system operation. Afterwards, verification of soil cleanup will be accomplished by: (1) soil vapor monitoring of restart spikes; (2) on-site till water monitoring; and (3) soil sampling. Additionally, compliance monitoring will consist of sampling off-site till and sand and gravel monitoring wells and surface water in Unnamed Ditch.

4.1 Estimation of Completion of Vapor Extraction System Operation

A computer model which simulates the vapor extraction system was used to estimate the time required for removal of the maximum detected soil concentrations to the Acceptable Soil Concentrations specified in Table 3-1. Appendix C summarizes the characteristics of the model and the data used. Based on the model results, it is expected that after one year of operation, all the VOCs, as well as phenol and isophorone, will be below the Acceptable Soil Concentrations in Table 3-1 in a "worst case" soil element which contains all the compounds at their maximum detected concentrations.

The vapor extraction system is designed to permit vapor samples to be obtained from each individual extraction trench and from the combined vapor stream from all operating extraction trenches.

The combined vapor flow will be sampled daily during the first week of operation, weekly for the following 4 weeks, and monthly thereafter. Samples will be analyzed for VOCs in Table 3-1, phenol, and isophorone. Also, the vapor flow rate will be monitored and recorded to provide sufficient data to calculate the mass of organics removed from the soils and the effectiveness of the system. These data will also aid in estimating the treatment time remaining, based on the calculated mass extraction rate (lbs/day) of the VOCs in Table 3-1, phenol, and isophorone.

Vapor samples from individual extraction trenches will be collected at the beginning of the vapor extraction system operation to establish a baseline of organics removal per trench. These samples will be analyzed for the VOCs in Table 3-1, phenol,

and isophorone. Once the mass rate extracted per day is reduced to 5 percent of the initial week's rate, additional vapor samples of individual trenches will be collected at least every two months, to determine when individual extraction trenches can be shut down. The criterion for shutting down individual trenches will be that two consecutive air samples from an individual trench show vapor concentrations to be in equilibrium with the Acceptable Soil Concentrations in Table 3-1. Table 4-1 shows the soil vapor concentrations in equilibrium with the Acceptable Soil Concentrations for the VOCs in Table 3-1, phenol, and isophorone. Appendix D presents the methodology used to arrive at these equilibrium vapor concentrations.

4.2 Soil Cleanup Verification

Verification of soil cleanup ("Soil Cleanup Verification") will be established when each of the following is met: (1) the soil vapor from the restart spike tests shows compliance with the calculated soil vapor concentrations in equilibrium with Acceptable Soil Concentrations for the VOCs in Table 3-1, phenol, and isophorone ("Soil Vapor Criterion"); (2) on-site till wells show compliance with the Acceptable Subsurface Water Concentrations specified in Table 3-1 or Applicable Background Concentrations ("Onsite Till Water Criterion"); and (3) soil samples show compliance with the Acceptable Soil Concentration as specified in Table 3-1 ("Soil Sample Criterion"). If Soil Cleanup Verification is not achieved, vapor extraction will be restarted. If after five years from the initial commencement of soil vapor extraction (or sooner at the option of the Settling Defendants), Soil Cleanup Verification has not been established, then the Additional Work provisions of Section VII of the Consent Decree will apply.

TABLE 4-1
SOIL VAPOR CONCENTRATIONS IN EQUILIBRIUM
WITH ACCEPTABLE SOIL CONCENTRATIONS (1)

Compound (2)	Soil Vapor Concentration (3) (mg/l)	Soil Vapor Concentration (3) ppmv	
VOLATILE ORGANICS (VOCs):			
Acetone	0.613	254	
Chloroform	2.46	496	
1,1-Dichloroethane	0.014	3.4	
1,1-Dichloroethene	2.045	515	
Ethylbenzene	0.167	42	(4)
Methylene Chloride	0.079	22.4	
Methyl Ethyl Ketone	0.408	139	
Methyl Isobutyl Ketone	0.685	233	
Tetrachloroethene	0.116	16.8	
Toluene	0.431	147	(4)
1,1,1-Trichloroethane	8.29	2,819	
1,1,2-Trichloroethane	0.0060	1.1	
Trichloroethene	0.39	71.5	
Total Xylenes	26.2	4,794	
BASE NEUTRAL/ACID ORGANICS:			
Isophorone	0.415	76.1	
Phenol	0.0053	1.4	

(1) Acceptable Soil Concentrations are determined in accordance with Footnotes 5, 6, and 7 of Table 3-1.
(2) Compounds above acceptable soil concentrations in Table 3-1 to be removed by vapor extraction.
(3) From Appendix D.
(4) Value shown is the vapor saturation concentration (see Appendix D).

4.2.1 Soil Vapor Criterion

Once the combined vapor flow and individual trench vapor samples show concentrations of Table 3-1 VOCs, phenol and isophorone at or below their respective equilibrium soil vapor concentrations shown in Table 4-1, the "restart spike" method on the combined vapor flow will be used to demonstrate that the Soil Vapor Criterion for Soil Cleanup Verification has been achieved.

The "restart spike" method consists of periodically shutting down and restarting the vapor extraction system. By shutting down the system, equilibrium conditions between the vapor space within the soil and any remaining organics amenable to vapor extraction within the soil matrix are re-established. Therefore, when the vapor extraction system is restarted, the initial organics concentration in the extracted gas will be higher than under normal operation.

The restart spike procedure will include shutting down the vapor extraction system for a period of three days. Upon restarting the vapor extraction system, all extraction and injection trenches will be operated as during normal operation. A sample of the combined soil vapor will be collected over a five-hour period starting 30 minutes after restarting the vapor extraction system. This sample will be representative of the soil vapor concentrations in equilibrium with the soil concentrations, because at 500 SCFM, the vapor extraction system will exchange one pore volume of soil every five hours.

Compliance with the Soil Vapor Criterion requires that analyses of soil vapor samples collected from four consecutive restart spikes conducted once every two weeks show that concentrations of VOCs in Table 3-1, phenol, and isophorone are at or below equilibrium soil vapor concentrations shown in Table 4-1 and therefore by calculation can be shown to be at or below the Acceptable Soil Concentrations in Table 3-1.

4.2.2 On-site Till Water Criterion

Samples of the subsurface water from the on-site till monitoring wells will be collected quarterly during operating of the soil vapor extraction system. The most recent quarterly sampling results from the four on-site till water monitoring wells following demonstration that the Soil Vapor Criterion has been achieved (Section 4.2.1) will be used to demonstrate that the On-site Till Water Criterion for Soil Cleanup Verification has been achieved.

Compliance with this criterion requires that analyses of the water samples collected from each of the four on-site till wells show that the concentrations for parameters with Acceptable Subsurface Water Concentrations in Table 3-1 are at or below the Acceptable Subsurface Water Concentrations in Table 3-1 or Acceptable Background Concentrations.

4.2.3 Soil Sample Criterion

Once the Soil Vapor Criterion and Onsite Till Water Criterion for Soil Cleanup Verification have been demonstrated as defined above, a total of sixteen soil samples from "hot" spot areas selected by EPA and the State, plus four non-background samples

from randomly selected points elsewhere onsite will be collected. The total number of soil samples used to demonstrate that the Soil Sampling Criterion for Soil Cleanup Verification will not exceed 20. Each soil sample will be analyzed for the VOCs in Table 3-1 and phenol. Compliance with this criterion for all VOCs in Table 3-1 and phenol relative to the Acceptable Soil Concentration in Table 3-1 is described in Footnote 6 of Table 3-1. Compliance with this criterion for isophorone is described in Footnote 7 of Table 3-1.

In the event that the soil sampling results do not demonstrate compliance with the Soil Sample Criterion as defined in Table 3-1, and the soil vapor extraction system is operated for an additional period of time, an additional number of samples (not to exceed 20) must be taken. The location of any additional samples will be in the same approximate location (i.e., within a 3-foot radius) as an initial sample location, and no more than one additional sample from each of the initial sample locations will be taken. Results from this second sampling will be analyzed using the identical procedure outlined above to demonstrate compliance with this criterion, except that if less than 20 additional samples are taken, analytical results from the initial sampling from any location from which an additional sample was not collected will be used in conjunction with the analytical results from any additional samples collected to determine compliance with the Acceptable Soil Concentrations in Table 3-1 as described in Footnotes 6 and 7 of Table 3-1. If any set of soil samples show compliance with this criterion then Soil Cleanup Verification will have been achieved.

4.3 Post Soil Cleanup Verification Compliance Monitoring

Once Soil Cleanup Verification has been achieved as prescribed in Section 4.2, sampling of off-site till wells, on-site till wells, off-site sand and gravel wells and surface water will be conducted for seven years on a semi-annual basis.

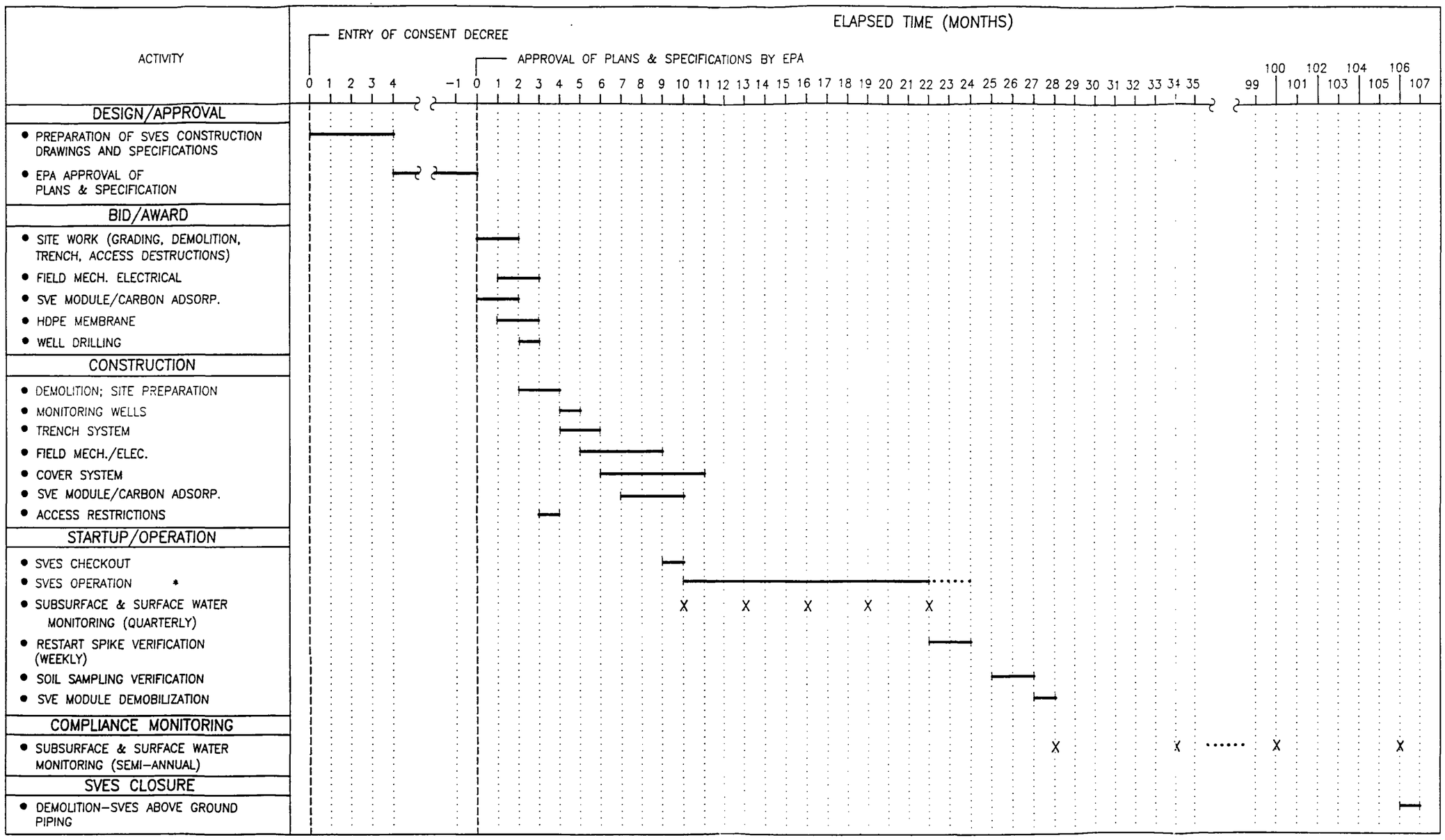
Off-site wells and surface water will be analyzed for the parameters with Acceptable Stream Concentrations in Table 3-1. Onsite wells will be analyzed for parameters with Acceptable Subsurface Water Concentrations in Table 3-1.

If the analytical results from any three consecutive semi-annual samples collected during the sampling period or the final two semi-annual samples do not show that: (1) the on-site till water exceeds any Acceptable Subsurface Water Concentrations in Table 3-1 or Applicable Background Concentrations; and (2) the off-site subsurface water and surface water exceed any Acceptable Stream Concentration in Table 3-1 or Applicable Background Concentration, then monitoring will be discontinued and the Remedial Action deemed complete.

If this demonstration cannot be made, the Additional Work provisions of Section VII of the Consent Decree will apply.

5.0 MISCELLANEOUS PROVISIONS AND SCHEDULING

The following documents have been submitted to EPA for approval: (1) Health and Safety Plan, (2) Field Sampling Plan, and (3) Quality Assurance Project Plan. Construction drawings and contract specifications will be submitted to EPA within four



NOTES TO FIGURE 5-1

- SVES ≙ SOIL VAPOR EXTRACTION SYSTEM
- * SCHEDULE ASSUMES 12 MONTH OPERATION OF SVES. ACTUAL PERIOD OF OPERATION COULD BE SHORTER OR LONGER DEPENDING ON PERFORMANCE OF SVES. THE SCHEDULE FOR EACH ACTIVITY LISTED BELOW "SVES OPERATION" WILL BE ADJUSTED ACCORDINGLY AS DESCRIBED IN SECTION 4.0 OF EXHIBIT A.

REMEDIAL ACTION IMPLEMENTATION SCHEDULE	FIGURE NO. 5-1
ERM ERM-North Central, Inc.	7/20/89 mo

months from the entry of the Consent Decree. Comments from EPA will be addressed by the Settling Defendants.

Figure 5-1 sets forth the Remedial Action Implementation Schedule for implementing the remedy required under the Consent Decree. The following milestones have been established in Section XVII (Stipulated Penalties) of the Consent Decree:

- Submission of the construction drawings and contract specifications for the Remedial Action Plan (RAP) within 4 months from the entry of the Decree.

- Completion of site preparation, including grading, removal of the tanks and buildings, repair or moving of the fence, 4 months after approval by EPA all of the above referenced documents. Completion of the site preparation shall mean that all hindrances, obstructions or obstacles to construction and security of the soil vapor extraction trenches, monitoring wells or cap have been removed.

- Completion of installation of the on-site and off-site monitoring wells 5 months after approval by EPA of all of the above referenced documents.

- Startup of the soil vapor extraction system 10 months after approval by EPA of all of the above referenced documents.

- Completion of the installation of all components of the RCRA-compliant (Subtitle C) cover 11 months after approval by EPA of all of the above referenced documents.

- Submission of all documents necessary to perform Additional Work that may be required under Section VII of the Consent Decree 6 months after written notice has been provided by EPA or Settling Defendants that Additional Work needs to be implemented.

- Completion of installation of the subsurface water interception trench on a schedule to be determined by EPA once the construction drawings and contract specifications for the Additional Work have been reviewed and approved.

APPENDIX A

ESTIMATE OF MASS OF ORGANICS IN THE SOILS TO BE REMOVED BY VAPOR EXTRACTION

APPENDIX A
ESTIMATE OF MASS OF ORGANICS IN THE SOILS
TO BE REMOVED BY VAPOR EXTRACTION

Location	Sampling depth (ft)	Assumed contamination depth (ft)	Total concentration (ug/kg)	Mass (lb)
TP-1	1 - 1.5	2	1,972	0.271
TP-2	1 - 1.5	2	28	0.004
TP-3	1 - 1.5	2	108,800	14.978
TP-4	1 - 2	2.5	99,730	17.162
TP-4	2.5 - 3.5	4	4,416	1.216
TP-5	1 - 2	2	24,287	3.343
TP-5	2 - 3	1.5	291	0.030
TP-6	1 - 2	2	12,468,000	1,716.410
TP-6	2 - 3	1.5	22,690	2.343
TP-6	4 - 5	1.5	2,416	0.249
TP-7	1 - 2.5	2.5	267,000	45.946
TP-7	2.5 - 4	2	280,090	38.559
TP-8	1 - 2.5	2.5	3,687	0.634
TP-8	2.5 - 4	2	433,600	59.692
TP-9	1 - 3	3	14,604,000	3,015.694
TP-9	3 - 5	2.5	130	0.022
TP-10	1 - 3	3	958	0.198
TP-10	3 - 5	2.5	432	0.074
TP-11	1 - 3	3	130	0.027
TP-11	3 - 5	2.5	67	0.012
TP-12	1 - 3	3	35,030	7.234
TP-12	3 - 5	2.5	3,609	0.621
SB-01	2.5 - 4	3	3,303	0.682
SB-02	2.5 - 4	3	12,900	2.664
SB-03	2.5 - 4	3	70,070	14.469
SB-04	2 - 3.5	2.5	175	0.030
SB-06	2 - 3.5	2.5	222,010	38.204
SB-08	2.5 - 4	3	3,012	0.622
SB-09	2.5 - 4	3	61,490	12.698
SB-01	5.5 - 7	2	27	0.004
SB-02	5.5 - 7	2	34	0.005
SB-04	5 - 6.5	2	51	0.007
SB-08	7 - 8.5	2	188	0.026
SB-09	5.7 - 7	2	8,069	1.111
TOTAL ORGANICS TO BE REMOVED BY VAPOR EXTRACTION, lb				4,995

* The area contaminated is assumed to be a 25'x25' square around each sampling location. TP = test pit; SB = soil boring. Soil concentrations from ECC RI, Section 4.

APPENDIX B

CALCULATION OF RISK-BASED CLEANUP STANDARDS

APPENDIX B

CALCULATION OF RISK-BASED CLEANUP STANDARDS

The equations used to calculate risk-based concentrations are shown in Table B1. The ingestion rates and acceptable risks are listed in Table B2. The potency factors and references doses for compounds without any regulatory or background level are from a memorandum from the USEPA Toxics Integration Branch, OERR, Washington, D.C., dated December 19, 1988, with the Corrections to the July, 1988 Update of the Characterization Tables in the Superfund Public Health Evaluation Manual.

Table B3 presents the calculation of risk-based acceptable subsurface water concentrations in the till for compounds without a regulatory limit (drinking water Maximum Contaminant Level, Maximum Contaminant Level Goal or lifetime health advisory or a stream criterion as listed in Table 1 of the Record of Decision for the site). Table B4 shows that the resulting concentrations of inorganic compounds at Unnamed Ditch should be below the Stream Criteria presented in Table 1 of the Record of Decision (ROD) for the site, dated September 25, 1987. The dilution obtained from discharge of the subsurface water in the till to Unnamed Ditch is 1:1800, as presented in Appendix C of the ECC Remedial Investigation. Note that most of the calculated concentrations in the ditch are below detection limits.

Tables B5 and B6 list the acceptable risk-based soil concentrations, based on soil and subsurface water ingestion, respectively. The calculation of acceptable soil concentrations based on subsurface water ingestion follows the procedures presented in Appendix C of the ECC RI. Only those organic compounds without regulatory limit (USEPA, Polychlorinated

TABLE B1

EQUATIONS USED TO CALCULATE RISK-BASED CONCENTRATIONS *

SOIL (concentrations in ug/kg):

$$\frac{\text{Risk} * \text{Body Weight (kg)} * 1000\ \text{(ug/mg)} * 1000\ \text{(g/kg)}}{\text{Ingestion rate (g/d)} * \text{Potency Factor (mg/kg/d)}^{-1}}$$

or

$$\frac{\text{Risk} * \text{Body Weight (kg)} * \text{Reference Dose (mg/kg/d)} * 1000\ \text{(ug/mg)} * 1000\ \text{(g/kg)}}{\text{Ingestion rate (g/d)}}$$

SUBSURFACE WATER (concentrations in ug/l):

$$\frac{\text{Risk} * \text{Body Weight (kg)} * 1000\ \text{(ug/mg)}}{\text{Ingestion rate (l/d)} * \text{Potency Factor (mg/kg/d)}^{-1}}$$

or

$$\frac{\text{Risk} * \text{Body Weight (kg)} * \text{Reference Dose (mg/kg/d)} * 1000\ \text{(ug/mg)}}{\text{Ingestion rate (l/d)}}$$

TABLE B2
INGESTION RATES AND ACCEPTABLE RISKS

INGESTION RATES * :

SOILS:

0.1 grams per day by a 70-kilogram person for 70 years

or

0.2 grams per day by a 17-kilogram child for 5 years

SUBSURFACE WATER:

2 liters of water per day by a 70-kilogram person for 70 years

ACCEPTABLE RISKS:

COMPOUNDS WITH POTENCY FACTORS:

10^{-6}

COMPOUNDS WITH REFERENCE DOSES:

1

* From U.S. EPA, RCRA Facility Investigation Guidance, 1987, and U.S. EPA, Office of Solid Waste and Emergency Response, Memorandum on Interim Final Guidance for Soil Ingestion Rates, January 27, 1989.

TABLE B3

ECC - ACCEPTABLE HEALTH-BASED SUBSURFACE WATER CONCENTRATIONS

Compound (1)	Potency Factor (2) (mg/kg/d)-1	Reference Dose (2) (mg/kg/d)	Acceptable Health-Based Subsurface Water Concentration (3) (ug/l)
VOLATILE ORGANICS (VOCs):			
Acetone		0.1	3,500
1,1-Dichloroethane	0.091		0.38
Methylene Chloride	0.0075		4.7
Methyl Isobutyl Ketone		0.05	1,750
Tetrachloroethene	0.051		0.69
1,1,2-Trichloroethane	0.057		0.61
BASE NEUTRAL/ACID ORGANICS:			
Bis(2-ethylhexyl)phthalate	0.014		2.5
Di-n-Butyl Phthalate		0.1	3,500
Diethyl Phthalate		0.8	28,000
Isophorone	0.0041		8.5
Naphthalene		0.4	14,000
Phenol		0.04	1,400
PESTICIDES/PCBs:			
Aroclor-1232	7.7		0.0045
Aroclor-1260	7.7		0.0045
INORGANICS:			
Antimony		0.0004	14
Beryllium		0.005	175
Manganese		0.2	7,000
Tin		0.6	21,000
Vanadium		0.007	245
Zinc		0.2	7,000

(1) Only compounds without a regulatory limit (drinking water Maximum Contaminant Level [40 CFR 141], Maximum Contaminant Level Goal or lifetime health advisory) are shown.

(2) From USEPA Toxics Integration Branch, OERR, Washington, D.C. December 1988 correction to the July 1988 Update of the Risk Characterization Tables in the Superfund Public Health Evaluation Manual.

(3) Acceptable subsurface water concentrations calculated using an ingestion rate of 2 liters per day by a 70 kg adult for 70 years. Acceptable risk = 1E-06 for compounds with potency factor and 1 for compounds with reference dose.

TABLE B4
COMPARISON OF ACCEPTABLE STREAM CONCENTRATIONS
WITH STREAM CONCENTRATIONS BASED ON NATURAL
DISCHARGE OF SUBSURFACE WATER FROM THE TILL

Compounds (1)	Acceptable Stream Concentration (1) (ug/l)	Concentration at Unnamed Ditch due to Discharge of Till Water at Acceptable Concentrations (2) (ug/l)
VOLATILE ORGANICS (VOCs):		
Chloroform	15.7	0.056
1,1-Dichloroethene	1.85	0.0039
Ethylbenzene	3,280	1.9
Methylene Chloride	15.7	0.0026
Tetrachloroethene	8.85	0.00038
Toluene	3,400	5.8
1,1,1-Trichloroethane	5,280	0.11
1,1,2-Trichloroethane	41.8	0.00034
Trichloroethene	80.7	0.0028
BASE NEUTRAL/ACID ORGANICS:		
Bis(2-ethylhexyl)phthalate	50,000	0.0014
Di-n-Butyl Phthalate	154,000	1.9
Diethyl Phthalate	52,100	15.6
Naphthalene	620	7.8
Phenol	570	0.78
INORGANICS:		
Arsenic	0.0175	0.028
Chromium	11	0.028
Lead	10	0.028
Nickel	100	0.39
Zinc	47	3.9
Cyanide	5.2	0.39

(1) From Table 1 of the Record of Decision (ROD) for the site, September 25, 1987. Only those compounds detected in ECC soil samples that are listed in this table are shown.
(2) Assuming a dilution of 1:1800 for natural discharge of till water at acceptable concentrations into Unnamed Ditch (from ECC Remedial Investigation, Appendix C).

TABLE B5
ECC - ACCEPTABLE SOIL CONCENTRATIONS BASED ON SOIL INGESTION

Compounds (1)	Potency Factor (2) (mg/kg/d)-1	Reference Dose (2) (mg/kg/d)	Acceptable Soil Concentrations Based on Soil Ingestion (3) (ug/kg)	Range of Acceptable Soil Concentrations Based on Soil Ingestion (4) (ug/kg)
VOLATILE ORGANICS (VOCs):				
Acetone		0.1	8,500,000	8,500,000
Chlorobenzene		0.03	2,550,000	2,550,000
Chloroform	0.0061		114,754	11,475-11,475,400
1,1-Dichloroethane	0.091		7,692	769-769,200
1,1-Dichloroethene	0.6		1,167	116.7-116,700
Ethylbenzene		0.1	8,500,000	8,500,000
Methylene Chloride	0.0075		93,333	9,333-9,333,300
Methyl Ethyl Ketone		0.05	4,250,000	4,250,000
Methyl Isobutyl Ketone		0.05	4,250,000	4,250,000
Tetrachloroethene	0.051		13,725	1,373-1,372,500
Toluene		0.3	25,500,000	25,500,000
1,1,1-Trichloroethane		0.09	7,650,000	7,650,000
1,1,2-Trichloroethane	0.057		12,281	1,228-1,228,100
Trichloroethene	0.011		63,636	6,364-6,363,600
Total Xylenes		2	170,000,000	170,000,000
BASE NEUTRAL/ACID ORGANICS:				
Bis(2-ethylhexyl)phthalate	0.014		50,000	5,000-5,000,000
Di-n-Butyl Phthalate		0.1	8,500,000	8,500,000
Diethyl Phthalate		0.8	68,000,000	68,000,000
Isophorone	0.0041		170,732	17,073-17,073,200
Naphthalene		0.4	34,000,000	34,000,000
Phenol		0.04	3,400,000	3,400,000

NOTES:

(1) Only organic compounds without a regulatory limit in soils (USEPA, "Polychlorinated Biphenyls Spill Cleanup Policy Rule," 40 CFR Part 761) are shown.

(2) From USEPA Toxics Integration Branch, OERR, Washington, D.C. December 19, 1988, "Corrections to the July 1988 Update of the Characterization Tables in the Superfund Public Health Evaluation Manual."

(3) Intake for compounds with potency factor: 0.1 g of soil/d by 70 kg resident adults. Intake for compounds with reference dose: 0.2 g of soil/d by 17 kg resident children. Acceptable risks: 1E-06 for compounds with potency factor; 1 for compounds with reference dose.

(4) Range shown is for risks of 10-4 to 10-7 for compounds with potency factor. The value shown for compounds without potency factor is for a risk of 1.

TABLE B6 (Page 1 of 2)

ECC - ACCEPTABLE SOIL CONCENTRATIONS BASED ON THEORETICAL SUBSURFACE WATER INGESTION AT THE SITE (10-6 RISK)

Compound (1)	Solubility (2) (ug/l)	Log Kow (2)	Kd (3)	Acceptable Subsurface Water Concentration (4) (ug/l)		Acceptable Leachate Concentration (5) (ug/l)	Acceptable Soil Concentration Based on Water Ingestion (6) (ug/kg)
VOLATILE ORGANICS (VOCs):							
Acetone	1,000,000,000	-0.24	0.00071	3,500	RB	686,275	490
Chlorobenzene	466,000	2.84	0.858	60	MCLGP	11,765	10,093
Chloroform	8,200,000	1.97	0.116	100	MCL	19,608	2,269
1,1-Dichloroethane	5,500,000	1.79	0.076	0.38	RB	74.5	5.7
1,1-Dichloroethene	2,250,000	1.84	0.086	7	MCL	1,373	118
Ethylbenzene	152,000	3.15	1.75	680	MCLGP	133,333	233,540
Methylene Chloride	20,000,000	1.25	0.022	4.7	RB	922	20.3
Methyl Ethyl Ketone	268,000,000	0.26	0.00226	170	LDWHA	33,333	75
Methyl Isobutyl Ketone	17,000,000		0.02604	1,750	RB	343,137	8,935
Tetrachloroethene	200,000	2.88	0.941	0.69	RB	135	127
Toluene	535,000	2.69	0.607	2,000	MCLGP	392,157	238,167
1,1,1-Trichloroethane	4,400,000	2.17	0.183	200	MCL	39,216	7,193
1,1,2-Trichloroethane	4,500,000	2.17	0.183	0.61	RB	120	21.9
Trichloroethene	1,100,000	2.29	0.242	5	MCL	980	237
Total Xylenes	198,000	3.26	2.26	440	MCLGP	86,275	194,672
BASE NEUTRAL/ACID ORGANICS:							
Bis(2-ethylhexyl)phthalate	1,300	8.7	621472	2.5	RB	490	304,643,220
Di-n-Butyl Phthalate	13,000	5.2	197	3,500	RB	686,275	134,871,303
Diethyl Phthalate	4,320,000	3.22	2.06	28,000	RB	5,490,196	11,298,207
Isophorone	12,000		0.031	8.5	RB	1,667	51.7
Naphthalene	30,000	3.01	1.269	14,000	RB	2,745,098	3,483,209
Phenol	93,000,000	1.46	0.036	1,400	RB	274,510	9,817

TABLE B6 (Page 2 of 2)

ECC - ACCEPTABLE SOIL CONCENTRATIONS BASED ON THEORETICAL SUBSURFACE WATER INGESTION AT THE SITE (10-6 RISK)

(1) Only organic compounds without a regulatory limit in soils (USEPA, "Polychlorinated Biphenyls Spill Cleanup Policy Rule," 40 CFR Part 761) are shown.

(2) From ECC RI, Table 4-4, and Verschueren, 1983, "Handbook of Environmental Data on Organic Chemicals".

(3) From ECC RI, Table 4-4. Calculated as 10^log Kow * OC, where OC= organic carbon content = 0.00124. For isophorone and methyl isobutyl ketone, the Kd is obtained as Kd = Koc * OC, where Koc = organic carbon-water partition coefficient, obtained from log Koc = (-0.55 * log S) + 3.64 (Exhibit A-1 of "Superfund Public Health Evaluation Manual," 1986).

(4) RB = risk-based concentration, from Table B3; MCL = Maximum Contaminant Level, from 40 CFR 141; MCLGP = proposed MCL goal, from 40 CFR 141; LDWHA = lifetime drinking water health advisory, from "Superfund Public Health Evaluation Manual," 1986.

(5) Leachate discharge/subsurface water discharge = 0.0051 (Appendix C of the ECC RI; and reduction of the 7.8 in/yr recharge used in the RI under the current conditions [page 5-8] by 99 percent due to the cap).

(6) Soil concentration (ug/kg) = Kd * Concentration in leachate (ug/l).

Biphenyls Spill Cleanup Police Rule, 40 CFR Part 761) in soils are listed in Tables B5 and B6. It is conservatively assumed that the volume of leachate from the soils will be reduced by 99 percent from the 7.8 in/yr used in the RI, by installing the RCRA-compliant (Subtitle C) cover over the site.

A range of acceptable soil concentrations based on water ingestion using the published ranges for organic carbon content of till soils and the SARA range of risk for Superfund site cleanups, is presented in Table B7. A list of organic carbon content in soil is shown in Table B8, with the respective reference. The concentrations shown in Table B6 were used to determine the Acceptable Soil Concentrations specified in Table 3-1, using a risk of 10^{-6} and a soil organic carbon content of 0.12%, as presented in the RI. This soil organic carbon content was deemed conservative when compared to the values shown in Table B8.

Table B9 lists the solubility and vapor pressure of the organic compounds detected in the soils above the limits shown in Tables B5 and B6. All compounds, except bis(2-ethylhexyl)phthalate and Aroclor-1260, are amenable to removal by soil vapor extraction.

Finally, Table B10 presents the complete list of references used for the calculation of the Acceptable Soil Concentrations specified in Table 3-1.

TABLE B7
ECC - ACCEPTABLE SOIL CONCENTRATIONS BASED ON THEORETICAL SUBSURFACE WATER INGESTION AT THE SITE (RANGE OF RISKS)

Compound (1)	Range of Kd (2)	Acceptable Soil Concentration Based on Water Ingestion (3)		
		Range for 10-4 risk	Range for 10-7 risk	
VOLATILE ORGANICS (VOCs):				
Acetone	0.000058-0.0044	40-3,019	40-3,019	(4)
Chlorobenzene	0.069-5.24	814-61,600	814-61,600	(5)
Chloroform	0.0093-0.71	182-13,900	182-13,900	(5)
1,1-Dichloroethane	0.0062-0.47	46-3,500	0.046-3.50	
1,1-Dichloroethene	0.0069-0.52	9.47-714	9.47-714	(5)
Ethylbenzene	0.14-10.7	18,800-1,431,000	18,800-1,431,000	(5)
Methylene Chloride	0.0018-0.14	166-12,900	0.166-12.9	
Methyl Ethyl Ketone	0.00018-0.014	6.07-461	6.07-461	(5)
Methyl Isobutyl Ketone	0.0021-0.16	721-54,900	721-54,900	(4)
Tetrachloroethene	0.076-5.78	1,028-78,200	1.03-78.2	
Toluene	0.049-3.72	19,200-1,460,000	19,200-1,460,000	(5)
1,1,1-Trichloroethane	0.015-1.14	588-44,700	588-44,700	(5)
1,1,2-Trichloroethane	0.015-1.14	179-13,600	0.179-13.6	
Trichloroethene	0.020-1.52	19.6-1,490	19.6-1,490	(5)
Total Xylenes	0.18-13.7	15,700-1,193,000	15,700-1,193,000	(5)
BASE NEUTRAL/ACID ORGANICS:				
Bis(2-ethylhexyl)phthalate	50100-3810000	2,460,000,000-187,000,000,000	2,460,000-187,000,000	
Di-n-Butyl Phthalate	15.8-1200	10,800,000-824,000,000	10,800,000-824,000,000	(4)
Diethyl Phthalate	0.17-12.9	933,000-70,800,000	933,000-70,800,000	(4)
Isophorone	0.0025-0.19	417-31,700	0.417-31.7	
Naphthalene	0.1-7.6	275,000-20,900,000	275,000-20,900,000	(4)
Phenol	0.0029-0.22	796-60,400	796-60,400	(4)

NOTES:

(1) Only organic compounds without a regulatory limit in soils (USEPA, "Polychlorinated Biphenyls Spill Cleanup Policy Rule," 40 CFR Part 761) are shown.

(2) For a range of organic carbon content of 0.0001 to 0.0076 obtained from: U.S. Department of Agriculture, "Soil Classification - A Comprehensive System". Soil Conservation Service, 7th Approximation, 1960. Calculated as presented in Table B6.

(3) Acceptable Soil Concentrations at the risk shown (for compounds with potency) for a range of organic carbon content of 0.0001 to 0.0076. Calculated as presented in Table B6.

(4) Acceptable Soil Concentration range does not change because the compound does not have a potency factor.

(5) Acceptable Soil Concentration range does not change because the value is based on regulatory limits (drinking water Maximum Contaminant Level, Maximum Contaminant Level Goal, or lifetime health advisory).

TABLE B8 (Page 1 of 5)
ORGANIC CARBON CONTENT OF SOILS - REFERENCES

Organic Carbon Content, %	Type of Soil (depth)	Geographic Area	Reference
0.125 (avg over 1.5 acre site)	Loamy sand (4 ft)	Etiwanda, CA (arid region)	Elabd, H., and W.A. Jury. 1986. "Spatial variability of Pesticide Adsorption Parameters." Environmental Science and Technology, Vol. 20, No. 3, pp. 256-260.
0.2 (avg over 1.5 acre site)	Loamy sand (2 and 3 ft)	Ibid	Ibid
0.26 (avg over 1.5 acre site)	Loamy sand (1 ft)	Ibid	Ibid
1.9	Silt loam	Corvallis, OR	Chiou, C.T., P.E. Porter, and D.W. Schmeddign. 1983. "Partition Equilibria of Nonionic Organic Compounds between Soil Organic Matter and Water." Environmental Science and Technology, Vol. 17, No. 4, pp. 227-231.
0.15	Sand close to river	Switzerland	Schwarzenbach, R.P., and J. Westall. 1981. "Transport of Nonpolar Organic Compounds from Surface Water to Groundwater. Laboratory Sorption Studies." Environmental Science and Technology, Vol. 15, No. 11, pp. 1360-1367.
2.1	Air-dried soil	Iowa	Wu, S., and P.M. Gschwend. 1986. "Sorption Kinetics of Hydrophobic Organic Compounds to Natural Sediments and Soils." Environmental Science and Technology, Vol. 20, No. 7, pp. 717-725.
0.11	Loess sample	Turin, Iowa	Karickhoff, S.W. 1984. "Organic Pollutant Sorption in Aquatic Systems." Journal of Hydraulic Engineering, Vol. 110, No. 6, pp. 707-735.
1.3	Soil	Fern Clyffe State Park, IL	Ibid
0.02	Aquifer -- water table zone 98 % sand	Borden, Canada	Abdul, A.S., T.L. Gibson, and D.N. Rai. 1986. "The Effect of Organic Carbon on the Adsorption of Fluorene by Aquifer Materials." Hazardous Waste and Hazardous Materials. Vol. 3, No. 4, pp. 429-440.
0.52	Aquifer -- water table zone 87 % sand	Flint, MI	Ibid
1.8	Aquifer -- water table zone 91 % sand	Flint, MI	Ibid

TABLE B8 (Page 2 of 5)
ORGANIC CARBON CONTENT OF SOILS - REFERENCES

Organic Carbon Content, %	Type of Soil (depth)	Geographic Area	Reference
0.05	Fine-sand soil	Wilmington, DE	Stokman, S.K. 1987. "Estimates of Concentrations of Soluble Petroleum Hydrocarbons Migrating into Ground Water from Contaminated Soil Sources." Proceedings of the National Water Well Association/American Petroleum Institute Conference on Petroleum Hydrocarbons and Organic Chemicals in Ground Water - Prevention, Detection and Restoration. Houston, TX, pp. 541-558.
0.1	Shaly-silt soil	Philadelphia, PA	Ibid
0.05	Fine to coarse sand, 96% sand	Michigan	Chiang, C.Y., C.L. Klein, J.P. Salanitro, and H.L. Wisniewski. 1986. "Data Analyses and Computer Modelling of the Benzene Plume in an Aquifer Beneath a Gas Plant." Proceedings of the National Water Well Association/American Petroleum Institute Conference on Petroleum Hydrocarbons and Organic Chemicals in Ground Water - Prevention, Detection and Restoration. Houston, TX, pp. 157-176.
0.27	Lincoln fine sand (surface soil)	Little Sandy Creek near Ada, OK	Clark, G.L., A.T. Kan, and M.B. Tomson. 1986. "Kinetic Interaction of Neutral Trace Level Organic Compounds with Soil Organic Material." Proceedings of the National Water Well Association/American Petroleum Institute Conference on Petroleum Hydrocarbons and Organic Chemicals in Ground Water - Prevention, Detection and Restoration. Houston, TX, pp. 151-156.
0.74	Fine to medium grained sand (3 ft)	Indian River County, FL	Kemblowski, M.W., J.P. Salinatro, G.M. Deeley, and C.C. Stanley. 1987. "Fate and Transport of Residual Hydrocarbon in Groundwater - A Case Study." Proceedings of the National Water Well Association/ American Petroleum Institute Conference on Petroleum Hydrocarbons and Organic Chemicals in Ground Water - Prevention, Detection and Restoration. Houston, TX, pp. 207-231.
0.44	Fine to medium grained sand (7 ft)	Indian River County, FL	Ibid
0.12	Fine to medium grained sand (13 ft)	Indian River County, FL	Ibid

TABLE B8 (Page 3 of 5)
ORGANIC CARBON CONTENT OF SOILS - REFERENCES

Organic Carbon Content, %	Type of Soil (depth)	Geographic Area	Reference
0.36	Fine to medium grained sand (3 ft)	Indian River County, FL	Ibid
0.15	Fine to medium grained sand (13 ft)	Indian River County, FL	Ibid
1.08	Fine to medium grained sand (2 ft)	Indian River County, FL	Ibid
0.16	Fine to medium grained sand (11 ft)	Indian River County, FL	Ibid
0.72	Fine to medium grained sand (3 ft)	Indian River County, FL	Ibid
0.26	Fine to medium grained sand (10 ft)	Indian River County, FL	Ibid
0.74	Glacial till (1-2 ft)	Sargent County, ND	"Soil Classification - A Comprehensive System." 1960. U.S. Department of Agriculture, Soil Conservation Service, 7th Approximation.
0.33	Glacial till (2-3 ft)	Sargent County, ND	Ibid
0.18	Glacial till (4.5-5 ft)	Sargent County, ND	Ibid
0.1	Till (1-2 ft)	Strafford County, New Hampshire	Ibid
0.08	Till (2-3 ft)	Strafford County, New Hampshire	Ibid
0.03	Till (4-5 ft)	Strafford County, New Hampshire	Ibid
0.01	Till (5-7 ft)	Strafford County, New Hampshire	Ibid

TABLE B8 (Page 4 of 5)
ORGANIC CARBON CONTENT OF SOILS - REFERENCES

Organic Carbon Content, %	Type of Soil (depth)	Geographic Area	Reference
0.59	Calcareous, glacial till (1-2 ft)	Greenbrier County, West Virginia	Ibid
0.27	Calcareous, glacial till (2-3 ft)	Greenbrier County, West Virginia	Ibid
0.08	Calcareous, glacial till (4-5 ft)	Greenbrier County, West Virginia	Ibid
0.38	Calcareous, glacial till (1-2 ft)	Tomkins County, New York	Ibid
0.16	Calcareous, glacial till (2-3 ft)	Tomkins County, New York	Ibid
0.17	Calcareous, glacial till (4.5-6.5 ft)	Tomkins County, New York	Ibid
0.14	Calcareous, glacial till (6.5-7 ft)	Tomkins County, New York	Ibid
0.76	Glacial till (1-2 ft)	Waseca County, Minnesota	Ibid
0.3	Glacial till (2-3 ft)	Waseca County, Minnesota	Ibid
0.19	Glacial till (> 4 ft)	Waseca County, Minnesota	Ibid
0.51	Glacial till (1-2 ft)	Sargent County, ND	Ibid
0.18	Glacial till (2-3 ft)	Sargent County, ND	Ibid
0.16	Glacial till (3.5-5 ft)	Sargent County, ND	Ibid

TABLE B8 (Page 5 of 5)
ORGANIC CARBON CONTENT OF SOILS - REFERENCES

Organic Carbon Content, %	Type of Soil (depth)	Geographic Area	Reference
0.64	Firm, glacial till (1-2 ft)	Spink County, SD	Ibid
0.36	Firm, glacial till (2-3 ft)	Spink County, SD	Ibid
0.31	Firm, glacial till (4-5 ft)	Spink County, SD	Ibid
0.46	Glacial till (1-2 ft)	Renville County, ND	Ibid
0.24	Glacial till (2-3 ft)	Renville County, ND	Ibid
0.13	Glacial till (4-5 ft)	Renville County, ND	Ibid
0.25	Glacial till (2-3 ft)	Adair County, Iowa	Ibid
0.08	Glacial till (> 6 ft)	Adair County, Iowa	Ibid
0.74	Calcareous, glacial till (1-2 ft)	Ward County, ND	Ibid
0.2	Calcareous, glacial till (2-3 ft)	Ward County, ND	Ibid
0.19	Calcareous, glacial till (4-5 ft)	Ward County, ND	Ibid
0.35	Glacial till (1-2 ft)	Cayuga County, NY	Ibid
0.1	Glacial till (2-3 ft)	Cayuga County, NY	Ibid
0.12	Glacial till (6-7 ft)	Cayuga County, NY	Ibid

TABLE B9
CHEMICAL PROPERTIES OF ORGANIC COMPOUNDS
DETECTED IN THE SOILS AT CONCENTRATIONS
ABOVE THE ACCEPTABLE SOIL CONCENTRATIONS (1)

Compound	Solubility (ug/l)	Vapor Pressure (mm Hg)
VOLATILE ORGANICS (VOCs):		
Acetone	1,000,000,000	270
Chloroform	8,200,000	151
1,1-Dichloroethane	5,500,000	182
1,1-Dichloroethene	2,250,000	600
Ethylbenzene	152,000	7
Methylene Chloride	20,000,000	362
Methyl Ethyl Ketone	268,000,000	77.5
Methyl Isobutyl Ketone	17,000,000	6
Tetrachloroethene	200,000	17.8
Toluene	535,000	28.1
1,1,1-Trichloroethane	4,400,000	123
1,1,2-Trichloroethane	4,500,000	30
Trichloroethene	1,100,000	57.9
Total Xylenes	198,000	10
BASE NEUTRAL/ACID ORGANICS:		
Bis(2-ethylhexyl)phthalate	1,300	0.0000002
Isophorone	12,000	0.38
Phenol	93,000,000	0.341
PESTICIDES/PCBs:		
Aroclor-1260 (2)	2.7	0.0000405

(1) Acceptable Soil Concentrations are determined in accordance with Footnotes 5, 6, and 7 of Table 3-1.
(2) Soil limit assumed for PCBs is 10,000 ug/kg (40 CFR Part 761.125, "Polychlorinated Biphenyls Spill Cleanup Policy Rule").

REFERENCES:

U.S. EPA, "Superfund Public Health Evaluation Manual," 1986.
U.S. EPA, "Water-Related Environmental Fate of 129 Priority Pollutants," December 1979.

TABLE B10

REFERENCES

Abdul A.S., T.L. Gibson, and D.N. Rai. 1986. "The Effect of Organic Carbon on the Adsorption of Fluorene by Aquifer Materials." Hazardous Waste and Hazardous Materials. Vol. 3, No. 4, pp. 429-440.

CH2MHILL, "Environmental Conservation and Chemical Corporation Feasibility Study," December, 1986.

CH2MHILL, "Environmental Conservation and Chemical Corporation Remedial Investigation," March, 1986.

Chiang, C.Y., C.L. Klein, J.P. Salanitro, and H.L. Wisniewski. 1986. "Data Analyses and Computer Modelling of the Benzene Plume in an Aquifer Beneath a Gas Plant." Proceedings of the National Water Well Association/American Petroleum Institute Conference on Petroleum Hydrocarbons and Organic Chemicals in Ground Water-Prevention, Detection and Restoration. Houston, TX, pp. 157-176.

Chiou, C.T., P.E. Porter, and D.W. Schmeddign. 1983. "Partition Equilibria of Nonionic Organic Compounds between Soil Organic Matter and Water." Environmental Science and Technology, Vol. 17, No. 4, pp. 227-231.

Clark, G.L., A.T. Kan, and M.B. Tomson. 1986. "Kinetic Interaction of Neutral Trace Level Organic Compounds with Soil Organic Material." Proceedings of the National Water Well Association/American Petroleum Institute Conference on Petroleum Hydrocarbons and Organic Chemicals in Ground Water - Prevention, Detection and Restoration. Houston, TX, pp. 151-156.

Elabd, H., and W.A. Jury. 1986. "Spatial variability of Pesticide Adsorption Parameters." Environmental Science and Technology, Vol. 20, No. 3, pp. 256-260.

Karickhoff, S.W. 1984. "Organic Pollutant Sorption in Aquatic Systems." Journal of Hydraulic Engineering, Vol. 110, No. 6, pp. 707-735.

Kemblowski, M.W., J.P. Salinatro, G.M. Deeley, and C.C. Stanley. 1987. "Fate and Transport of Residual Hydrocarbon in Groundwater-A Case Study." Proceedings of the National Water Well Association/American Petroleum Institute Conference on Petroleum Hydrocarbons and Organic Chemicals in Ground Water-Prevention, Detection and Restoration. Houston, TX, pp. 207-231.

TABLE B10

REFERENCES

Schwarzenbach, R.P., and J. Westall. 1981. "Transport of Nonpolar Organic Compounds from Surface Water to Groundwater. Laboratory Sorption Studies." Environmental Science and Technology, Vol. 15, No. 11, pp. 1360-1367.

Stokman, S.K. 1987. "Estimates of Concentrations of Soluble Petroleum Hydrocarbons Migrating into Ground Water from Contaminated Soil Sources." Proceedings of the National Water Well Association/American Petroleum Institute Conference on Petroleum Hydrocarbons and Organic Chemicals in Ground Water-Prevention, Detection and Restoration. Houston, Tx, pp. 541-558.

Wu, S., and P.M. Gschwend. 1986. "Sorption Kinetics of Hydrophobic Organic Compounds to Natural Sediments and Soils." Environmental Science and Technology, Vol. 20, No. 7, pp. 717-725.

U.S. Department of Agriculture, Soil Conservation Service, "Soil Classification - A Comprehensive System." 1960, 7th Approximation.

USEPA, Office of Solid Waste and Emergency Response, "Memorandum on Interim Final Guidance for Soil Ingestion Rates," January 27, 1989.

USEPA, Region V, "Record of Decision for Environmental Conservation and Chemical Corporation, and Northside Sanitary Landfill, Zionsville, Indiana," September 25, 1987.

USEPA, "Draft RCRA Facility Investigation Guidance," July, 1987, OSWER Directive 9502.00-6C.

USEPA, "National Primary Drinking Water Regulations," 40 CFR 141, last amended by 53 FR 37408, September 26, 1988.

USEPA, "Polychlorinated Biphenyls Spill Cleanup Policy Rule," 40 CFR Part 761, published in the Federal Register on April 2, 1987.

USEPA, "Superfund Public Health Evaluation Manual," October, 1986, PB87-183125 with updates of November 16, 1987 and July, 1988.

USEPA, Toxics Integration Branch, OERR, Washington, D.C., December, 1988. "Memorandum with Corrections to the July, 1988 Update of the Risk Characterization Tables in the Superfund Public Health Evaluation Manual."

TABLE B10

REFERENCES

USEPA, "Water-Related Environmental Fate of 129 Priority Pollutants," December, 1979 PB80-204381.

US Geological Survey, "Background Geochemistry of Some Rocks, Soils, Plans, and Vegetables in the Conterminous United States," Professional Paper 574-F, 1975.

Veschueren, K., "Handbook of Environmental Data on Organic Chemicals," 1983.

APPENDIX C

ECC - VAPOR EXTRACTION MODEL

APPENDIX C

ECC - VAPOR EXTRACTION MODEL

This program was written in FORTRAN by Michael C. Marley and George E. Hoag and reported in "Induced Soil Venting for Recovery/Restoration of Gasoline Hydrocarbons in the Vadose Zone," Proceedings, Petroleum Hydrocarbons and Organic Chemicals in Ground Water Conference, Houston, TX, 1984.

The program is based on the concentration of each component in the vapor phase in the soil, using the partial pressure exerted by each compound, as expressed by the following equation:

$$ZT = \frac{VP * X * V * MW}{R * T}$$

where:

ZT = concentration of the component in the vapor phase, mg/l
VP = vapor pressure of compound, mm Hg
X = mole fraction = moles of component/total moles of organics in soil
V = volume of element, liters
MW = molecular weight of component
R = gas constant = 82.4 atm - cm^3/gmoles^oK
T = temperature = 294.25^oK

The program uses the finite difference method to calculate the change in number of moles of each component during a small time interval (i) and then recalculate over the next time interval (i+1), using the reduced number of moles resulting from subtracting the change in number of moles calculated for interval i from the number of moles present in the soil at the beginning of interval i.

The program runs for a finite length of time or until all the components are removed. The program was rewritten in BASIC and applied to the ECC site.

Table C-1 shows the chemical data used to run the model. The compounds to be evaluated are those shown in Table 3-2, which are amenable to removal by vapor extraction. The maximum detected soil concentrations were taken from Section 4 of the ECC RI, while the vapor pressure and molecular weight data are from USEPA, "Superfund Public Health Evaluation Manual," 1986.

As there was significant variation of compounds concentrations between soil samples at the site, a theoretical block size was chosen. This theoretical soil block is 10 ft x 10 ft x 2 ft deep and was assumed to contain all components of interest at their maximum detected concentrations (Table C-1). Furthermore, it was conservatively assumed that the air flow through the soil would only be 15% efficient in removing the organics. In effect, this represents a worst case estimate of the time required to remove the organics from the soils. The mass of this block was estimated as 10,200 kg.

TABLE C1
CHEMICAL DATA OF COMPOUNDS

Compound (1)	Molecular Weight (2)	Vapor Pressure (2) (mm Hg)	Maximum Detected Soil Concentration (3) (ug/kg)
VOLATILE ORGANICS:			
Acetone	58.1	270	650,000
Chloroform	119	151	2,900
1,1-Dichloroethane	99	182	35,000
1,1-Dichloroethene	97	600	380
Ethylbenzene	106	7	1,500,000
Methylene Chloride	85	362	310,000
Methyl Ethyl Ketone	72.1	77.5	2,800,000
Methyl Isobutyl Ketone	100	6	190,000
Tetrachloroethene	166	17.8	650,000
Toluene	92.1	28.1	2,000,000
1,1,1-Trichloroethane	133	123	1,100,000
1,1,2-Trichloroethane	133	30	550
Trichloroethene	132	57.9	4,800,000
BASE NEUTRAL/ACID ORGANICS:			
Phenol	94.1	0.341	570,000
Isophorone	138	0.38	440,000

(1) Compounds shown are those amenable to soil vapor extraction.
(2) From U.S. EPA, "Superfund Public Health Evaluation Manual," 1986.
(3) From ECC RI, March 1986.

The air flow rate was estimated as a fraction of the total air flow rate to be used at the site (500 SCFM), based on the length of injection trench influencing the assumed soil block (10 ft) as a ratio of the total length of injection trenches (3,800 ft). This represents an air flow rate of 37.26 liters per minute.

The results, summarized in Figure C1, show that essentially no VOCs will be present in the hypothetical soil element after 130 days of soil vapor extraction. To remove phenol and isophorone to the Acceptable Soil Concentrations in Table 3-1, operation of the vapor extraction system for a total of approximately 360 days is necessary.

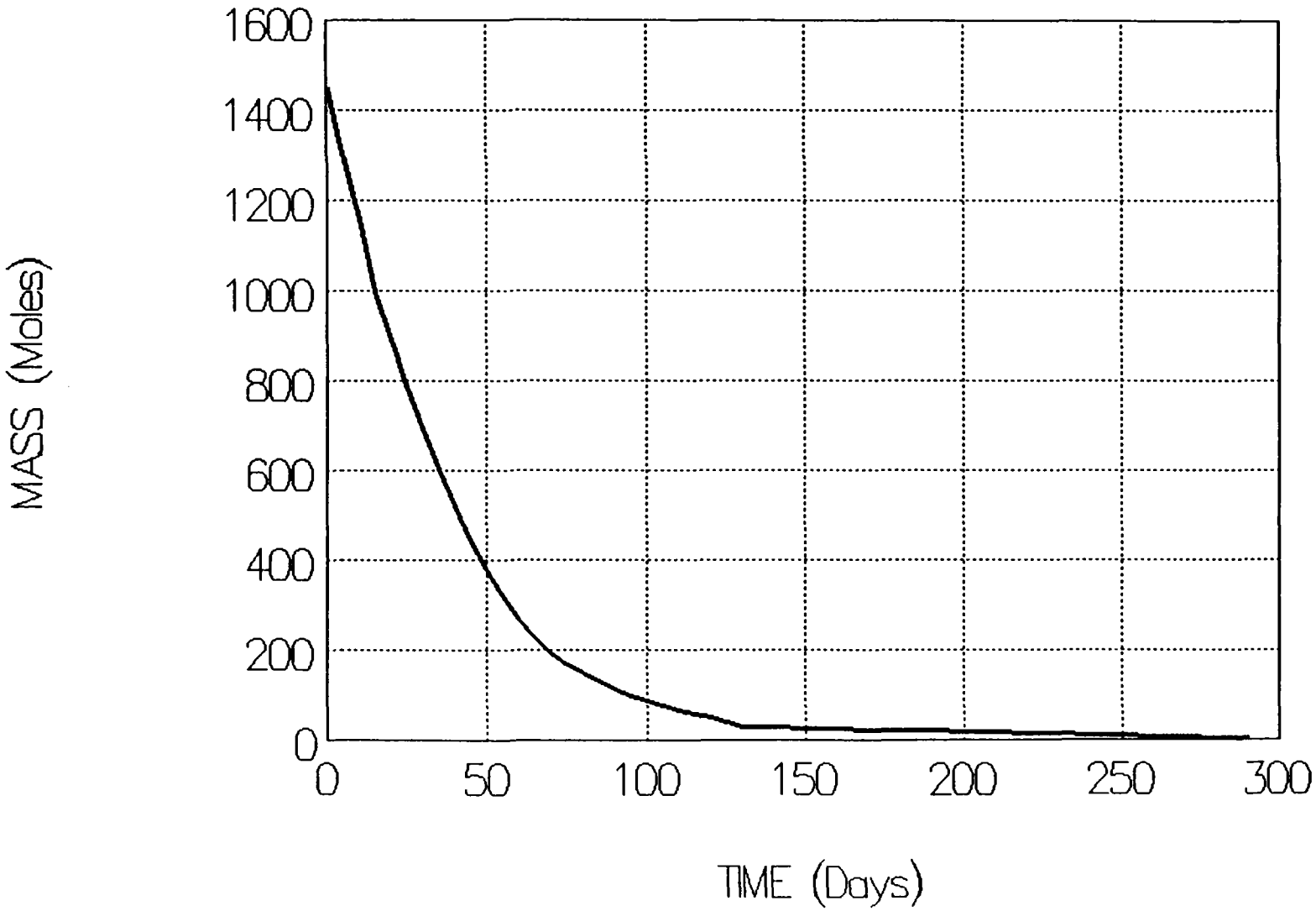
Actual large-scale soil vapor extraction systems have been operated with excellent removals of compounds such as tetrachloroethene, trichloroethene, 1,3-dichloropropene, methyl ethyl ketone, methyl isobutyl ketone, toluene, and xylenes. Some published references are:

- Lisiecki, J.B., and F.C. Payne. "Enhanced Volatilization: Possibilities, Practicalities, and Performance." Presented at the Engineering Foundation Conference, Mercersburg, PA, August 7-12, 1988.

- Regalbuto, D.P., J.A. Barrera and J.B. Lisiecki. "In-Situ Removal of VOCs by Means of Enhanced Volatilization." Proceedings of the Conference on Petroleum Hydrocarbons and Organic Chemicals in Ground Water: Prevention, Detection, and Restoration, Houston, TX, November 9-11, 1988.

Figure C1

ECC VAPOR EXTRACTION MODEL RESULTS



- Johnson, J.J., and R.J. Sterrett. "Analysis of In-Situ Soil Air Stripping Data." Proceedings of the 5th National Conference on Hazardous Wastes and Hazardous Materials, Las Vegas, Nevada, April 19-21, 1988.

A full-scale vapor extraction system (Lisiecki and Payne, 1988) was able to remove tetrachloroethene from 5,600,000 ug/kg to 17 ug/kg, as found by soil sample analysis, in 280 days. Therefore, both theoretical models and actual results show that the required removals will be accomplished by vapor extraction.

APPENDIX D

CALCULATION OF SOIL VAPOR CONCENTRATIONS

APPENDIX D

CALCULATION OF SOIL VAPOR CONCENTRATIONS

The methodology to determine the soil vapor concentrations in equilibrium with Acceptable Soil Concentrations in Table 3-1 is presented below.

The soil vapor concentration of a chemical in equilibrium with the concentration in the soil particles is a function of the soil to water partition coefficient and of the air to water partition coefficient [Lyman, W.J., W.F. Reehl and D.H. Rosenblatt, "Handbook of Chemical Property Estimation Methods," McGraw-Hill, Inc., 1982].

Since not all soil moisture will be evaporated during operation of the vapor extraction system (the soil's hygroscopic water will not be removed by the anticipated operating pressures), a relationship between soil vapor and soil moisture concentrations for the site's soils can be expressed as [Ibid] =

$$C_{sv} = H \cdot C_{sm}$$

where:

C_{sv} = concentration of compound in soil vapor, mg/l

H = Henry's Law Coefficient (nondimensional)

$$= \frac{Vp \cdot MW}{S \cdot R \cdot T}$$

Vp	=	vapor pressure of compound, mm Hg
MW	=	molecular weight of the compound, g/gmole
S	=	solubility of the compound, g/cm^3
R	=	gas law constant = 62,361 mm Hg - cm^3/gmole-^oK
T	=	soil temperature = 283 ^oK
C_{sm}	=	concentration of compound in soil moisture, mg/l

Similarly, the concentration in soil moisture in equilibrium with the concentration in soil particles can be calculated as [Ibid] =

$$C_{sm} = \frac{C_{sp}}{K_d}$$

where:

C_{sp}	=	concentration of compound in soil samples, mg/kg
K_d	=	soil-water partition coefficient, l/kg [from Appendix B, Table B6]

Combining the two equations, a relationship between soil vapor and soil samples concentration is obtained [Silka, L.R., "Simulation of the Movement of Volatile Organic Vapor Through the Unsaturated Zone as it Pertains to Soil-Gas Surveys," Proceedings of the NWWA/API Conference on Petroleum Hydrocarbons and Organic Chemicals in Ground Water, 1986, p.204] =

$$C_{sv} = C_{sp} \cdot \frac{H}{K_d}$$

Table D1 presents the data and calculations of the soil vapor concentration in equilibrium with the Acceptable Soil Concentrations in Table 3-1. The results for ethylbenzene and toluene are above the corresponding vapor saturation concentration, or the concentration in vapor in equilibrium with the pure compound. For these organics, the vapor saturation concentration is presented in the column of soil vapor concentrations in Table 4-1. The vapor saturation concentrations for the compounds in Table D1, assuming each compound is present by itself in the soil vapor (i.e., molar fraction is equal to 1), are shown in Table D2. The vapor saturation concentration is calculated as:

$$C_{sat} = \frac{Vp \cdot X \cdot MW}{R \cdot T} \times 10^6$$

where:

Csat	=	vapor saturation concentration, mg/l
X	=	molar fraction of compound in vapor, assumed to be 1
10^6	=	factor to convert g/cm^3 to mg/l

TABLE D1 (Page 1 of 2)
SOIL VAPOR CONCENTRATIONS IN EQUILIBRIUM
WITH ACCEPTABLE SOIL CONCENTRATIONS (1)

Compound (2)	Molecular Weight (3) (g/gmole)	Vapor Pressure (3) (mm Hg)	Solubility (3) (ug/l)	Henry's Law Constant (4) (dimensionless)	Soil-water Partition Coefficient (5) (l/kg)	Acceptable Soil Concentration (6) (ug/kg)	Soil Vapor Concentration (7) (mg/l)	Soil Vapor Concentration (7) ppmv
VOLATILE ORGANICS (VOCs):								
Acetone	58.1	270	1,000,000,000	0.000889	0.00071	490	0.613	254
Chloroform	119	151	8,200,000	0.124	0.116	2,300	2.46	496
1,1-Dichloroethane	99	182	5,500,000	0.186	0.076	5.7	0.014	3.39
1,1-Dichloroethene	97	600	2,250,000	1.47	0.086	120	2.045	515
Ethylbenzene	106	7	152,000	0.277	1.75	1,200,000	190	47,776 (8)
Methylene Chloride	84.9	362	20,000,000	0.0871	0.022	20	0.079	22.4
Methyl Ethyl Ketone	72.1	77.5	268,000,000	0.00118	0.00226	780	0.408	139
Methyl Isobutyl Ketone	100	6	17,000,000	0.00200	0.026	8,900	0.685	233
Tetrachloroethene	166	17.8	200,000	0.837	0.941	130	0.116	16.8
Toluene	92.1	28.1	535,000	0.274	0.607	1,250,000	564	191,994 (8)
1,1,1-Trichloroethane	133	123	4,400,000	0.211	0.183	7,200	8.29	2,819
1,1,2-Trichloroethane	133	30	4,500,000	0.0502	0.183	22	0.0060	1.09
Trichloroethene	132	57.9	1,100,000	0.394	0.242	240	0.39	71.5
Total Xylenes	106	10	198,000	0.303	2.26	195,000	26.2	4,794
BASE NEUTRAL/ACID ORGANICS:								
Isophorone	138	0.38	12,000	0.248	0.031	52	0.415	76.1
Phenol	94.1	0.341	93,000,000	0.0000196	0.036	9,800	0.0053	1.36

TABLE D1 (Page 2 of 2)
SOIL VAPOR CONCENTRATIONS IN EQUILIBRIUM
WITH ACCEPTABLE SOIL CONCENTRATIONS (1)

NOTES:
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(1) Acceptable Soil Concentrations are determined in accordance with Footnotes 5,6, and 7 of Table 3-1.
(2) Compounds above Acceptable Soil Concentrations in Table 3-1 to be removed by vapor extraction.
(3) Data from U.S. EPA, "Superfund Public Health Evaluation Manual," 1986.
(4) Calculated as:

$$\text{Henry's Law Constant (nondimensional)} = \frac{\text{(Vapor Pressure, mm Hg)} * \text{(Molecular Weight, g/gmole)} * \text{(1,000,000 ug/g)} * \text{(1,000 cm3/l)}}{\text{(Solubility, ug/l)} * \text{(R, mm Hg-cm3/gmole-K)} * \text{(T, K)}}$$

where: R = gas law constant = 62,361 mm Hg-cm3/gmole-K; and T = soil temperature = 283 K.
(5) From Appendix B, Table B6.
(6) From Table 3-1.
(7) Calculated as:

$$\text{Concentration in soil vapor (mg/l)} = \frac{\text{(Concentration in soil, ug/kg)} * \text{(Henry's Law Constant, nondimensional)}}{\text{(Partition coefficient, l/kg)} * \text{(1000 ug/mg)}}$$

Concentration in soil vapor (ppmv) = (Concentration in soil vapor, mg/l) * (1000 l/m3) / (Factor, mg/m3/ppmv)

The factors for conversion of mg/m3 to parts per million by volume (ppmv) were obtained from Vershueren, K., "Handbook of Environmental Environmental Data on Organic Chemicals," 2nd Edition, 1983.
(8) Value shown is higher than the vapor saturation concentration shown in Table D2.

TABLE D2
CALCULATION OF VAPOR SATURATION CONCENTRATIONS

Compound (1)	Vapor Pressure (2) (mm Hg)	Molecular Weight (2) (g/gmole)	Vapor Saturation Concentration (3) (mg/l)
VOLATILE ORGANICS (VOCs):			
Acetone	270	58.1	888.9
Chloroform	151	119	1018.2
1,1-Dichloroethane	182	99	1021.0
1,1-Dichloroethene	600	97	3297.8
Ethylbenzene	7	106	42.0
Methylene Chloride	362	84.9	1741.5
Methyl Ethyl Ketone	77.5	72.1	316.6
Methyl Isobutyl Ketone	6	100	34.0
Tetrachloroethene	17.8	166	167.4
Toluene	28.1	92.1	146.6
1,1,1-Trichloroethane	123	133	927.0
1,1,2-Trichloroethane	30	133	226.1
Trichloroethene	57.9	132	433.1
Total Xylenes	10	106	60.1
BASE NEUTRAL/ACID ORGANICS:			
Isophorone	0.38	138	2.97
Phenol	0.341	94.1	1.8

(1) Compounds above Acceptable Soil Concentrations in Table 3-1 to be removed by vapor extraction.
(2) Data from U.S. EPA, "Superfund Public Health Evaluation Manual," 1986.
(3) Calculated as:

$$Csat = \frac{Vp * X * MW}{R * T} * 1E+06$$

Where: Csat = vapor saturation concentration, mg/l; X = molar fraction of compound in vapor, assumed to be 1; 1E+06 = factor to convert g/cm3 to mg/l; MW = molecular weight of the compound, g/gmole; R = gas law constant, 62,361 mm Hg-cm3/gmole-K; and T = soil temperature, 283 K.

ERM-North Central, Inc.

MEMORANDUM

DATE: August 31, 1989

TO: Al Sloan - CH_2MHill

FROM: Roy O. Ball EFM

Subject: Technical Issues For Exhibit A

We propose that the following be added to Footnote 2: "all subsurface samples for inorganic and PCB analysis will be filtered."

Also, we propose that the following be added starting at line 774: "The procedures used to obtain "Confirmed" data shall include reanalysis, resampling and the analysis of only undiluted samples, unless dilution is required for quantification of a specific compound. Sample results will be considered as positive results only if the concentrations in the sample exceed ten times the maximum amount detected in any blank."

Please call with your comments ASAP.

lmf
cc: ECC Negotiating Committee

ERM-North Central, Inc.

MEMORANDUM

DATE: August 31, 1989

TO: Al Sloan

FROM: Roy Ball

SUBJECT: ECC Exhibit A

We agree that only subsurface water samples should be filtered, and that the reference to filtering the samples should be added to both Footnotes 2 and 4.

We also agree with the wording changes you made, and will like to slightly alter the language to read: "The procedures used to obtain "Confirmed" data shall include reanalysis, resampling and the analysis of only undiluted samples if a concentration is qualified with a "J" (estimated concentration). If after reanalysis and/or resampling using an undiluted sample the concentration of a compound is still qualified with a "J", than the result produced from undiluted samples will be used. "B" qualified sample results will be considered as "Confirmed" data <u>only</u> if the concentrations in the sample exceed ten times the maximum amount detected in any blank for the media being analyzed."

lmf
cc: ECC Negotiating Committee