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Formerly Utilized Sites Remedial Action Program (FUSRAP)
Contract No. DE-AC05-91OR21949

SITE SUITABILITY STUDY FOR THE ST. LOUIS AIRPORT SITE

St. Louis, Missouri

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SITE SUITABILITY STUDY

FOR THE

ST. LOUIS AIRPORT SITE

ST. LOUIS, MISSOURI

FEBRUARY 1994

Prepared for

United States Department of Energy

Oak Ridge Operations Office

Under Contract No. DE-AC05-91OR21949

By

Bechtel National, Inc.

Oak Ridge, Tennessee

Bechtel Job No. 14501

EXECUTIVE SUMMARY

The St. Louis Airport Site (SLAPS) is part of the U.S. Department of Energy's (DOE) Formerly Utilized Sites Remedial Action Program (FUSRAP). FUSRAP was established to identify and decontaminate or otherwise control sites where residual radioactive materials remain from the early years of the nation's atomic energy program or from commercial operations causing conditions that Congress has authorized DOE to remedy. The Energy and Water Development Appropriations Act, passed by Congress in 1985, directed DOE to acquire the SLAPS property from the City of St. Louis for use as a permanent disposal site. As a result, the placement of contaminated materials in a disposal facility at SLAPS is being considered as one of several possible remedies for the cleanup of FUSRAP waste in St. Louis. After Congress directed DOE to consider SLAPS as a disposal site, it was added to the National Priorities List.

The SLAPS site suitability study has been performed to assess the suitability of SLAPS as a location for a disposal facility. This report addresses the potential for seismic activity at or near the site and the ability of the site to withstand it; the suitability of the soils at the site to be the foundation for a disposal facility; the potential for, impact of, and migration pathways for seepage of waste materials from the disposal facility; and the potential for flooding at the site. Information used to evaluate the suitability of the site came from published literature on the geologic conditions of the region and analyses of samples from existing geologic boreholes and groundwater monitoring wells at the site. Evaluation of this information was aided by the construction of contour maps and cross sections, conceptual models, and computer models.

The body of evidence leading to the conclusion that SLAPS is suitable for the location of a waste disposal facility included the following:

- Groundwater immediately underlying the site is isolated from deeper groundwater by a low-permeability clay layer.

- The effects of a contaminant release are very minimal because groundwater flow rates are low, and the clays present in the soils underlying the site would decrease contaminant migration rates significantly.

- The potential for catastrophic failure caused by seismic or seismic-related events is very low.

- Failure caused by cave formation is not considered credible given site geology.

- The effect of a waste facility on wetlands and the effect of wetlands on thc facility would be negligible.

- Site design features would eliminate any effect of flooding at the site.

Further data that need to be collected before completing a facility design are soil foundation properties (for design and construction), confirmatory cave evaluations (direct, onsite data), and vadose zone properties (to supplement modeling). With regard to this final point, discharge of shallow groundwater to Coldwater Creek will require special attention during facility design. However, based on what is known about the site, these issues are not critical to the determination of site suitability.

This study was conducted to support evaluations being made as part of the feasibility study-environmental impact statement process. The study is not intended to prejudice selection of a disposal option; rather, it provides information to better evaluate the requirements of Congressional direction.

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(continued)

FIGURES

FIGURES

(continued)

TABLES

ACRONYMS

BNI	Bechtel National, Inc.
CEC	cation exchange capacity
COE	Corps of Engineers
CREAMS	Chemicals, Runoff, and Erosion from Agricultural Management Systems
DAF	dilution/attenuation factor
DOE	Department of Energy
EPA	Environmental Protection Agency
EPRI	Electric Power Research Institute
FUSRAP	Formerly Utilized Sites Remedial Action Program
HEC	Hydrologic Engineering Center
HELP	Hydrologic Evaluation of Landfill Performance
MMI	Modified Mercalli Intensity
MSL	mean sea level
MUSLE	Modified Universal Soil Loss Equation
NCEER	National Center for Earthquake Engineering Research
NWI	National Wetlands Inventory
SCS	Soil Conservation Service
SLAPS	St. Louis Airport Site
TDS	total dissolved solid
USCGS	United States Coast and Geodetic Survey
USDA	United States Department of Agriculture

UNITS OF MEASURE

cfs	cubic feet per second
cm	centimeter
ft	foot
g	acceleration due to gravity
gal	gallon
gm	gram
gpm	gallons per minute
h	hour
ha	hectare
in.	inch
km	kilometer
L	liter
lb	pound
m	meter
m_b	body wave magnitude
meq	milliequivalent
mg	milligram
mi	mile
min	minute
ml	milliliter
mm	millimeter
mM	millimolar
mrad	millirad
pcf	pounds per cubic foot
ppm	parts per million
s	second
yd	yard
yr	year

1.0 INTRODUCTION

The purpose of this report is to determine the suitability of the St. Louis Airport Site (SLAPS) as a location for a disposal facility. SLAPS is part of the Formerly Utilized Sites Remedial Action Program (FUSRAP), which is managed by the U.S. Department of Energy (DOE). The objective of FUSRAP is to identify and clean up or otherwise control sites where residual radioactive contamination (exceeding current guidelines) remains from the early years of the nation's atomic energy program or from commercial operations causing conditions that Congress has authorized DOE to remedy.

The stability of the site with respect to seismic activity, soil compaction, and loading and the ability of the soils to prevent the migration of contaminants away from the site were examined to determine the suitability of the site for a disposal facility. This was accomplished by evaluating the conditions at the site and identifying those conditions that are suitable in their natural state and those that require engineered features. After presenting this information, along with other data and interpretations about the geologic and hydrogeologic conditions at SLAPS, the report examines how these conditions affect the suitability of the site with respect to the siting of a disposal facility.

SLAPS is located in St. Louis County, Missouri, approximately 24 km (15 mi) west of downtown St. Louis (Figure 1-1). The site consists of an 8.78-ha (21.7-acre) tract of land and, for the purposes of this report, includes the ball field area, which is an adjacent tract of land of approximately 32.4 ha (80 acres).

The Manhattan Engineer District acquired the site in 1946 and stored uranium-bearing residues there until 1966. Stored residues included barium sulfate cake, pitchblende raffinate residues, radium-bearing residues, Colorado raffinate residues, and contaminated scrap. Most were stored in bulk on open ground, and others were buried. During 1966 and 1967, the stored residues were sold and removed from the site. After the residues were removed from SLAPS, the existing structures were demolished and buried on the property, and 0.3 to 1 m (1 to 3 ft) of clean fill material was spread over the entire area. All areas, except for one, were restored to a condition where the radiation level at the ground surface was less than 1 mrad/h; in the one area, however, the surface beta-gamma dose rate was about 3 mrad/h because of residual contamination (Goldsmith et al. 1979). A detailed historical account of activities at SLAPS can be found in the remedial investigation report (BNI 1992).

Figure 1-2 is a map of SLAPS showing the approximate boundary of a possible disposal facility. The approximate dimensions would be 494 m (1,620 ft) long, 110 m (360 ft) wide at the western end, 274 m (900 ft) wide in the middle, and 274 m (900 ft) wide on the eastern end. The facility would have a maximum height of 12.2 m (40 ft) above existing grade. This configuration assumes complete encapsulation of contaminated material from SLAPS and other nearby St. Louis FUSRAP properties. Other estimates of facility size assume that the waste is not completely encapsulated. These estimates indicate that the facility would be smaller than that shown in Figure 1-2, which is an approximate configuration of the largest facility envisioned.

Soil sampling and monitoring well installation at SLAPS were conducted in four phases from 1980 to 1992. Descriptions of the work performed, including the procedures used, have been documented (Weston 1982, BNI 1993a).

FIGURES FOR SECTION 1.0

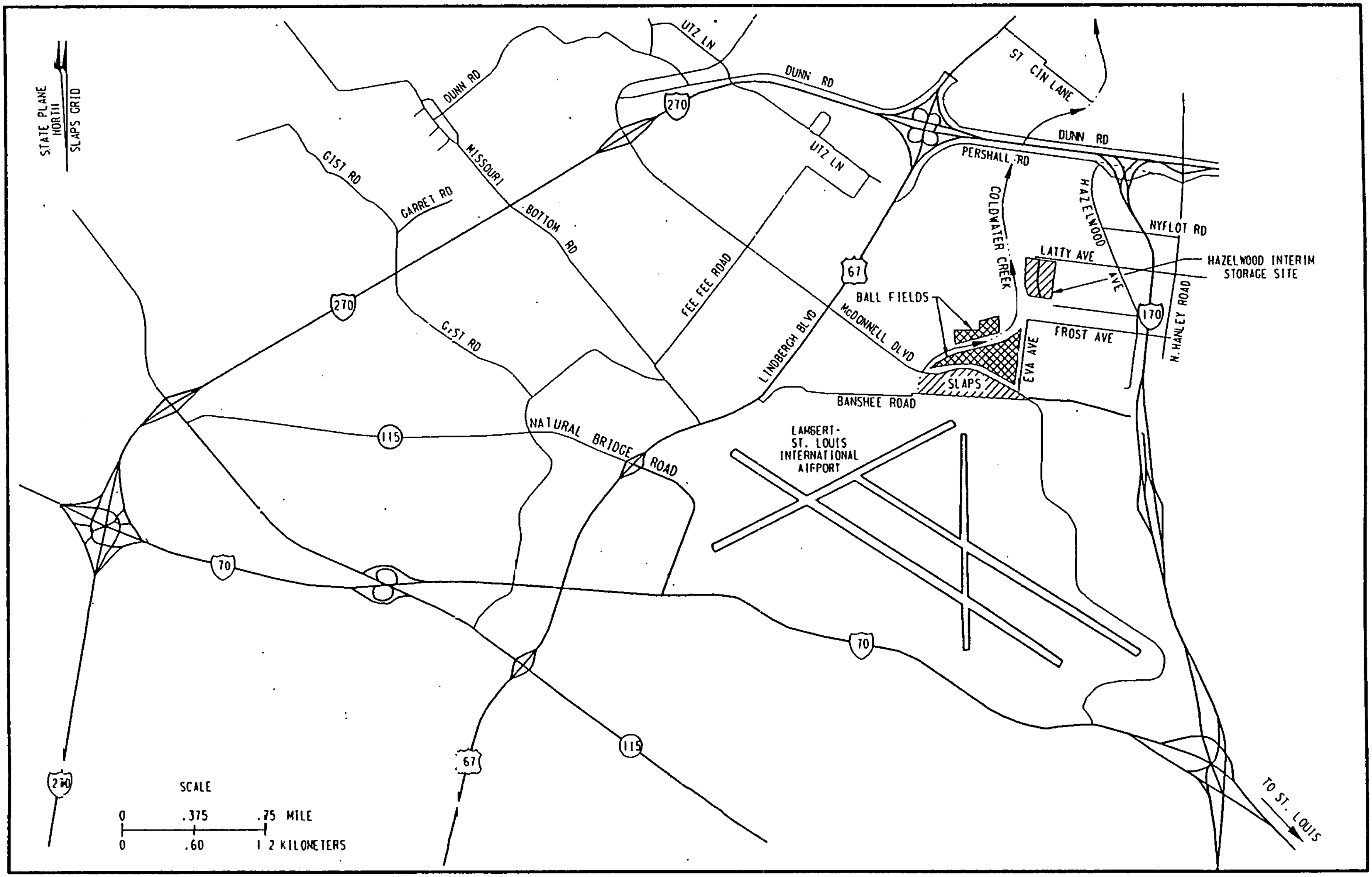

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Figure 1-1
Location of SLAPS and the Ball Fields

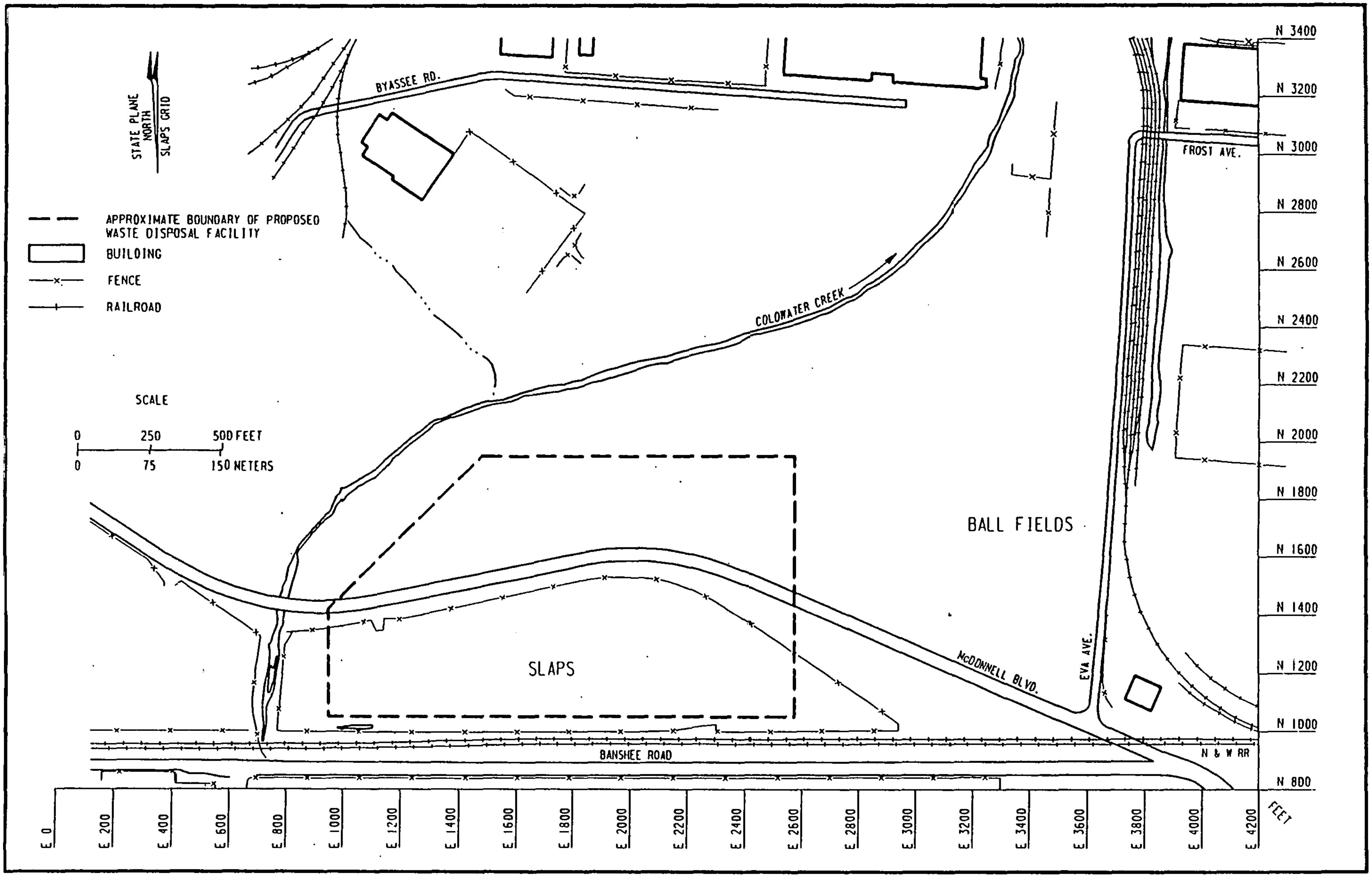

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Figure 1-2
Site Map Showing Approximate Location of Proposed Waste Disposal Facility

2.0 REGIONAL GEOLOGY

SLAPS lies in the Dissected Till Plains region of the Central Lowlands Province. Near the Missouri and Mississippi rivers, the region is characterized by mature, rugged topography with short, steep valleys draining into large streams. In other areas, stream development is distinct; floodplains are broad, and streams are flood-prone. In some cases, streams may follow buried, preglacial channels (Stohr, St. Ivany, and Williams 1981).

SLAPS is surrounded by an upland area of rolling hills. Surfacial soils are typically moderately thick loess deposits. In northern St. Louis County, the upland area surrounds a topographic depression known as the Florissant Basin. SLAPS lies on the southeastern edge of the basin, which was filled with fine-grained sediments so that the present surface topography in the area is essentially flat (Goodfield 1965).

Section 2.1 describes the stratigraphy of the St. Louis area. Section 2.2 describes the structural history of Missouri and the geologic structures in St. Louis that are important to the geologic development of the local area. Section 2.3 discusses regional seismicity and earthquake potential, and Section 2.4 addresses cave and sinkhole formation.

2.1 STRATIGRAPHY

A stratigraphic column for the St. Louis region is shown in Figure 2-1. The stratigraphy of the area consists of variable thicknesses of unconsolidated Pleistocene outwash, loess, and alluvial deposits on top of Paleozoic carbonates and clastic sedimentary rock units. Thick sequences of fine-grained sediments accumulated primarily between periods of uplift in the Paleozoic era when much of the Mid-continent was covered by shallow epicontinental seas. During periods of emergence associated with the movement of the Ozark uplift, erosion removed strata representing a large portion of the stratigraphic record from the area. Figure 2-2 shows a generalized geologic map of the St. Louis area including the approximate western limit of Illinoisan glaciation. The approximate southern limit of Kansan and Nebraskan glaciation was just north of the Missouri River (Howe and Koenig 1961).

The following discussion regarding bedrock (based largely on Saeger 1975 and Howe and Koenig 1961) covers only the units that are shown in Figure 2-2. The other units (shown in Figure 2-1) are discussed in detail by Howe and Koenig (1961).

2.1.1 Mississippian System

Meramecian Series

The Meramecian Series consists of four formations: Warsaw, Salem, St. Louis, and Ste. Genevieve. These formations, with the exception of the Warsaw whose upper part in eastern Missouri is shale, are composed mainly of limestone and some dolomite. Chert is not common but does occur in all of the formations. All four formations are present in east-central Missouri, which is regarded as the type area (i.e., has typical features) for the St. Louis and Ste. Genevieve Formations. Warsaw and Salem are the only formations of this series that have been definitely identified in central Missouri. Limestones of the Mississippian System are reportedly subject to the development of karst features in the St. Louis area (Goodfield 1965). The Warsaw and Salem Formations are not covered in the following discussion because they do not occur near SLAPS.

St. Louis Limestone. The St. Louis Limestone reaches its greatest thickness and displays all of its stratigraphic features within Missouri in its type area in St. Louis County and in adjacent parts of east-central and southeastern Missouri. Here, the formation is a gray lithologic to finely crystalline, medium- to massively bedded limestone as much as 304.8 m (1,000 ft) thick. Limestone breccia is common in, but not necessarily confined to, the lower part of the formation. Shale occurs as a matrix between the blocks of breccia. Blue and bluish-gray shales also form thin beds throughout the formation and increase in abundance in the northeastern part of the state. Chert is uncommon, and parts of the formation are locally dolomitic.

The compound corals Lithostrotionella castelnaui and Lithostrotion proliferum are considered to be diagnostic, and the coral Syringopora is common. The contact between the

St. Louis and Salem Formations appears to be gradational. Limestone from the St. Louis Limestone is quarried in the St. Louis area for manufacturing cement and aggregate.

Ste. Genevieve Limestone. The Ste. Genevieve Limestone overlies the St. Louis Limestone and is typically present in the east-central and southeastern parts of Missouri in Ste. Genevieve and St. Louis counties and in eastern Perry County. It is also present in adjacent parts of Illinois and Kentucky, where it has been subdivided into members. In the St. Louis area, the Ste. Genevieve is a white, massively bedded, sandy, clastic limestone. It is generally coarsely crystalline and oolitic but also contains a few beds of finely crystalline limestone. Fossils are irregularly distributed throughout the formation. The lower part of the formation is sandy, cross-bedded, and ripple-marked. The middle portion of the formation contains layers of chert, as well as lenses and beds of sandstone. The lithology of Ste. Genevieve changes laterally, which makes individual units difficult to trace.

The formation is 9.1 m (30 ft) thick in St. Louis County. Its nonconforming contact with the underlying St. Louis Limestone is marked by a basal conglomerate, and solution channels are present in numerous places. A significant erosional surface marks the top of the Ste. Genevieve Limestone.

Outside of the St. Louis area, the Ste. Genevieve is an important aquifer. In the St. Louis area, the formation is overlain by either beds of the Pennsylvanian System or Pleistocene deposits. The Ste. Genevieve Limestone is one of the bedrock units that occurs immediately underneath the sediments at SLAPS.

2.1.2 Pennsylvanian System

Desmoinsian Series

The Cherokee and Marmaton Groups compose the Desmoinsian Series.

Cherokee Group. This group consists of all of the strata included in the Krebs and Cabaniss Subgroups.

The Krebs Subgroup is made up of sandstone, siltstone, shale, limestone, and coal beds. In many places, the Krebs consists predominantly of sandstone.

The strata in the Cabaniss Subgroup consist of sandstone, siltstone, shale, underclay, limestone, and coal beds. These strata occur in 12 widely recognized successions, each of which (with certain exceptions as noted in formational descriptions elsewhere) is a cyclic unit that includes a coal bed at the top. Each succession has been named and is treated as a formation. The Lagonda Formation, which constitutes most of the Cherokee Group in the St. Louis area (Saeger 1975), consists of shales that are locally sandy and micaceous. Interbeds of sandstone and siltstone that are up to 3 m (10 ft) thick, plant remains, and fossils may also be present.

Marmaton Group. The Marmaton consists of a succession of shale, limestone, clay, and coal beds with more abundant limestone units, which are thicker and more laterally continuous, than in the Cabaniss Subgroup. The Marmaton Group in Missouri is divided into the Fort Scott and Appanoose Subgroups.

Missourian Series

The Missourian Series does not underlie SLAPS but is described here because it is in the SLAPS region. The Missourian Series is divided into four successively younger groups: Pleasanton, Kansas City, Lansing, and Pedee. The rocks forming these groups are present in a broad belt that underlies the Kansas City area and extends northeastward across western and northern Missouri. The series comprises a number of prominent formations that are composed principally of alternating beds of limestone and shale and are separated by comparatively thicker formations of shale and sandstone.

The Pleasanton Group includes all the strata that lie below the base of the Kansas City Group and above the regional disconformity that separates the Desmoinsian from the Missourian Series. Pleasanton strata are dominantly clastic. The group is represented by channel-fill deposits in the Warrensburg and Moberly channels in western and central Missouri and by sandstone outliers in St. Louis County.

Any younger Mesozoic and Tertiary sediments that may have been deposited in the St. Louis area have been removed by subaerial erosion.

2.1.3 Post-Paleozoic Sediments

Plio-Pliestocene sediments, which overlie Paleozoic deposits in the SLAPS area, consist of unconsolidated clay, silt, sand, and gravel that were deposited by glacial, alluvial, and eolian processes (Howe and Koenig 1961). These sediments were deposited during several glacial stages (from oldest to youngest, these stages are the pre-Illinoisan, Illinoisan, and Wisconsinian) and associated interglacial stages. The interglacial stages, which are characterized by the development of soil horizons, are not described in the following sections because of their limited occurrence.

Pre-Illinoisan Deposits

Because of the complex nature of pre-Illinoisan sedimentation, time stratigraphic and lithostratigraphic correlations are difficult (Richmond and Fullerton 1986). Because most of the sediments in St. Louis were deposited during this period, it is difficult to assign unit names to sediments occurring in the area. Lithologic descriptions indicate that most of the sediments at SLAPS were deposited during the pre-Illinoisan stage. For the purpose of this report, these sediments are assumed to belong to the Wolf Creek and Alburnett Formations (not shown on the stratigraphic column) (described by Hallberg 1986 and Johnson 1986).

Sediments overlying Mississippian or Pennsylvanian bedrock are generally cherty gravels and gravelly clay remnants of glaciation. These sediments consist of chert and quartzite material embedded in a coarse clayey sand or silty clay matrix. The relative amounts of each constituent vary widely (Goodfield 1965, Saeger 1975). Overlying till units are typified by clayey, highly weathered, grayish materials that contain weathered cobbles of igneous and metamorphic rocks and chert fragments. Pre-Illinoisan deposits in the St. Louis area reach a maximum thickness of 12.8 m (42 ft).

Illinoisan Stage

The Loveland Loess is the only recognized deposit associated with Illinoisan glaciation. This loess in the St. Louis area is composed of medium- to coarse-grained, noncalcareous silt. The unit reaches a maximum thickness of 6.1 m (20 ft) thick in St. Louis County.

Wisconsinian Stage

Deposits associated with Wisconsinian glaciation consist of several loess units. The Roxana Silt and the Peoria Loess are the most widespread glacial units in the St. Louis area. Both units are composed of well-sorted, medium to coarse silt with some sand. The Peoria Loess also contains occasional carbonate and manganese nodules and limonite tubes. The Peoria Loess reaches a maximum thickness of 15.2 m (50 ft) in the St. Louis area and is probably the uppermost sedimentary unit at SLAPS.

2.2 STRUCTURAL DEVELOPMENT

Most of the faulting and folding in Missouri was created by lateral tectonic forces from the southwest. As a result, the structural grain of basement crystalline rocks is aligned in a predominantly northwest/southeast pattern. A subordinate northeast/southwest structural pattern has been described by numerous investigators (such as McCracken 1971). The presence of these patterns is important in understanding the geologic and structural history of the region; the orientation of fractures in bedrock underlying SLAPS is expected to be similar to the predominant regional structural orientation.

The Ozark uplift, a region of repeated upward movement, is south of the St. Louis area. Six episodes of regional deformation that resulted from continued uplift have been identified. The initial and most intense structural deformation episode occurred in the Precambrian era. In response to this tectonic activity, extensive block fault systems developed along northwestern-trending lineaments (McCracken 1971).

Northwest of the St. Louis area, the Cap Au Gres fault system developed in response to the second episode of Ozark uplift in mid-Ordovician time, continued with deformation in the Devonian era (third episode), and culminated with minor deformation in the pre-Pennsylvanian period (fourth episode). Vertical movement of the Cap Au Gres fault created the Lincoln fold and a broad asymmetrical anticline known as the Eureka-House Springs anticline (Ruby 1952). Developed above a Precambrian lineament, the Eureka-House Springs anticline trends northwest to southeast and is approximately 24.1 km (15 mi) southwest of SLAPS. The fifth Paleozoic deformation period occurred at the end of the Pennsylvanian (McCracken 1971) in conjunction with movements along existing fault systems in the Precambrian basement. Rejuvenation of uplift of the Ozark region (sixth episode) with differential depression of the Mississippi Embayment occurred in pre-Pliocene time. Only minor movements along existing structures have been attributed to this final episode. Intermittent uplift appears to be continuing, as evidenced by entrenched meanders and Pleistocene terrace remnants.

Because much of Missouri moved as a block in response to tectonic pressures, folding of bedrock formations was minimal. Steeply dipping beds are restricted to the immediate vicinity of faults, and the regional dip of strata is generally less than three degrees.

The St. Louis fault (see Figure 2-2) developed as an offset or secondary stress feature in response to the Ozark tectonics. The present course of the Mississippi River parallels this structural feature. The Dupo-Waterloo anticline and the Cheltenham syncline of East St. Louis and Illinois also parallel this structure. The convergence of these two regional features has created the Florissant Dome.

The Florissant Basin (Figure 2-2) has formed independent of these features. Faulting is not evident at the site; bedrock at depth appears to be almost flat, dipping 11.4 m/km (60 ft/mi) to the north-northeast into the Cheltenham syncline, which formed because of tectonic episodes related to the Ozark uplift. The Florissant Basin consists of a variable thickness of unconsolidated Pleistocene sand, silt, and clay deposited on Paleozoic bedrock. These deposits represent a wide variety of origins, including glacially derived outwash or loess and alluvial deposits of the Mississippi and Missouri river systems.

The Florissant Basin was created through erosion of the bedrock surface by a tributary to the Mississippi River (Goodfield 1965). The river and tributary were blocked by glacial advance during the Illinoisan period, creating a lake. As a result, sediment-laden waters flowed into the area from the northeast, slowly filling the former tributary channel that cut into the top of the bedrock surface. During the subsequent, glacial readvance 10,000 to 15,000 years ago, a loess cover blanketed the lake sediments.

This depositional history is supported by the fine texture and lithology of the lake sediments observed in soil borings from the basin and by the very flat nature of the topography. Correlation of terrace remnants in the basin northeast of the study area with high-level (flow) terrace remnants at the same elevation along the Mississippi, Missouri, and Illinois rivers also supports this theory of origin.

2.3 REGIONAL SEISMICITY AND EARTHQUAKE POTENTIAL

SLAPS lies within the Central Stable Region, an area generally considered to be tectonically quiet, although from the site southward toward the border with the Mississippi Embayment, seismic activity is at an elevated level relative to most of the Central Stable Region. Farther to the south and within the Mississippi Embayment, the New Madrid Seismic Zone is the most seismically active area within the site region.

Analyses used in determining potentially damaging earthquake ground motion include: (1) assessing the historic earthquake data and estimating future credible earthquakes, (2) characterizing the site foundation conditions, and (3) incorporating the information from (1) and (2) into professional judgement for assigning an estimate for potentially damaging earthquake ground motion.

Published studies on earthquakes and earthquake effects indicate a range of reasonable site design intensities from VII to IX on the Modified Mercalli Intensity (MMI) scale. These intensities are associated with either near-site earthquakes of magnitude 5.3 to 6.3 on the Richter scale or with earthquakes at some distance from the site that are higher on the scale. Conventional correlations indicate that this range of MMIs can be associated with expected surface accelerations from about 0.13 to 0.5 g. Direct estimates of firm foundation acceleration associated either with levels of conservatism generally considered appropriate for the design of conventional structures or with the occurrence of maximum credible earthquakes confined to the New Madrid Seismic Zone are 0.10 g or less.

2.3.1 Seismotectonic Setting

The Central Stable Region of the North American craton, the Mississippi Embayment, and the New Madrid Seismic Zone are the areas of interest for geologic and seismic evaluation of SLAPS. These areas are shown in Figure 2-3.

The Central Stable Region consists of a veneer of sediments overlying Precambrian crystalline rocks that have been formed into arches, basins, and other structures primarily as a result of Paleozoic epeirogenic activity (Eardley 1962). It extends from the eastern Appalachian Mountain Chain to the western Rocky Mountains and from the Canadian Shield in the North to the onlapping Cretaceous and Tertiary sediments of the Coastal Plain in the South.

The Central Stable Region is generally considered to be tectonically quiet, although some scattered earthquake activity is known to occur in the area. With a few exceptions [e.g., the Anna, Ohio, and Manhattan, Kansas, areas, which are more than 322 km (200 mi) from SLAPS], earthquakes in the Central Stable Region, corresponding to MMI VII or less, have not caused more than minor or moderate damage.

The Mississippi Embayment, south of the site, is a major area of structural reentry for the Coastal Plain sediments into the upper Mississippi River drainage basin of the Central Stable Region. This embayment began forming during the middle and late Mesozoic (Stearns and Wilson 1972).

The New Madrid Seismic Zone is within the Mississippi Embayment. Numerous studies show that the embayment has been the site of frequent Cenozoic epeirogenic movements (Stearns and Wilson 1972, Stearns and Marcher 1962, Ervin and McGinnis 1975, Russ 1979, Zoback et al. 1980). The most dramatic evidence of crustal instability in the northern portion is the abundance of earthquakes that have occurred throughout history. Beginning with the great New Madrid series of 1811-1812, more than 1,000 earthquakes of body wave magnitude (m_b) 3.0 or greater have occurred in this area (Nuttli 1979). Clearly, the embayment is tectonically active (see Figure 2-4).

With recent improvements in seismographic coverage of this area, smaller earthquakes have been located accurately, and their distribution has revealed a distinct pattern. For example, 808 earthquakes occurred in the New Madrid area between October 1981 and December 1986 (Herrmann, Taylor, and Nguyen 1988). A plot of these microearthquakes (see Figure 2-5) confirms earlier indications (Nuttli and Herrmann 1978) that most seismic activity in the northern portion of the embayment occurs along several relatively narrow linear trends, in and near the New Madrid Seismic Zone (as outlined in Figures 2-3, 2-4, and 2-5). Earthquakes in this seismic zone appear to be associated with the Reelfoot Rift, a buried, continental paleorift subsurface structure that has been studied using aeromagnetic, gravity, seismic reflection, seismic refraction, and petrologic data (Russ 1981).

2.3.2 Historic Earthquakes

The National Center for Earthquake Engineering Research (NCEER)-91 catalog (Armbruster and Seeber 1992) covers primarily earthquakes of magnitude 3 or greater in the eastern United States. The catalog was derived from the earthquake catalog developed by the Electric Power Research Institute (EPRI) for its statistical analyses of earthquake activity in the central and eastern United States (EPRI 1988). For regions east of the New Madrid Seismic Zone (east of 85.5° W), the NCEER-91 catalog includes data from unpublished archival searches and from published compilations not fully incorporated in the EPRI catalog. For the remainder of the area, NCEER-91 lists the same events as the EPRI catalog but calculates a preferred magnitude (see Sibol, Bollinger, and Birch 1987).

All earthquakes in the NCEER-91 catalog that occurred within 322 km (200 mi) of SLAPS through 1985 are shown in Figure 2-4, and those within the same distance and of 4.0 m_b or greater or MMI V or greater are also listed in Table 2-1. This table contains 176 events that occurred from 1795 to 1984.

Earthquakes in the New Madrid Seismic Zone have approached MMI XII and 7.0 to 7.4 m_b (Nuttli 1973a, Hamilton and Johnston 1990). Earthquakes not in this zone but in or around the immediate periphery of the Mississippi Embayment have reached up to MMI VIII (Figure 2-4, Table 2-1).

The largest earthquake (7.4 m_b) within a 322-km (200-mi) radius of SLAPS occurred on February 7, 1812, near New Madrid; it was the largest of a series of four earthquakes with magnitudes of 7.0 or greater that began on December 16, 1811. The closest earthquake to the site with a magnitude of greater than 4.0 occurred on June 30, 1947, at 4.2 m_b and at an epicentral distance of about 42 km (26 mi). The earthquake on September 11, 1953, was closer to SLAPS [about 23 km (14 mi)] with the same reported maximum intensity as the 1947 event (VI) but with a somewhat smaller magnitude of 3.9 m_b.

The primary data for estimating the size of preinstrumental earthquakes consist of felt reports of effects from the event and the subsequent assessment of intensity using an established scale, such as the MMI. (Felt reports are accounts of what people felt and observed during an earthquake.) It is useful to review the effects of significant earthquakes that occurred in the preinstrumental time period (predominantly before the 1960s). For continuity and comparison, it is also useful to consider felt effects of events occurring during the instrumental period, when the Richter magnitude of an earthquake can be directly measured. Comparison of intensities for preinstrumental and instrumental earthquakes has allowed for the development of correlations among magnitude, intensity level, and distribution. The date, location (latitude and longitude), maximum MMI (I_o), magnitude, epicentral distance from the site (to the nearest mile), and description of each significant earthquake are provided as follows.

1811-1812 series. This sequence, made up of thousands of events, had four principal shocks:

1811, December 16. 90° W, 36° N; I_0 = XI; 7.2; 190 mi.
1811, December 16. 90° W, 36° N; I_0 = XI; 7.0; 190 mi.
1812, January 23. 89.6° W, 36.3° N; I_0 = X to XI; 7.1; 174 mi.
1812, February 7. 89.6° W, 36.5° N; I_0 = XI to XII; 7.4; 160 mi.

Because of its importance in the central United States, the literature on this sequence is extensive. A good popular account was written by Penick (1981). A concise description of the major effects of the earthquakes was given by Coffman, von Hake, and Stover (1982), from which the following highlights are extracted:

> Very early in the morning of December 16, citizens of New Madrid, Missouri, were suddenly awakened by the sound of groaning, creaking, and cracking of the timbers of their houses, the sounds of furniture being thrown down, and the crashing of falling chimneys. Repeated shocks occurred throughout the night. With daylight, another shock of similar severity as the initial event struck. The ground was observed to rise and fall as earth waves. Considerable areas were uplifted, and still larger areas sank and became covered with water emerging from below through fissures or craterlets (liquefaction), or accumulating from the obstruction of the surface drainage. Great waves developed on the Mississippi River that overwhelmed and washed ashore many boats; the returning current broke off thousands of trees. High banks along the Mississippi River caved; sand bars, points of islands, and even whole islands disappeared.
>
> Shocks continued with diminishing intensity until January 23 when the third large earthquake struck with intensity similar to the two events of December 16. Two weeks later on February 7, the largest event of the series occurred. Aftershocks continued for at least two years.

All houses in New Madrid were destroyed or badly damaged, and other damage from various causes over the entire townsite led to its abandonment.

Significant disturbances of the ground over large areas were reported. An area of 30,000 to 50,000 mi^2 in extent was characterized by raised and sunken lands, fissures, sinks, sand blows, and large landslides. Tiptonville Dome, 15 mi long by 5 to 8 mi wide, was raised 15 to 20 ft. As with the formations of Lake St. Francis in eastern Arkansas and Reelfoot Lake in Tennessee, large areas dropped commonly 5 to 8 ft and as much as 15 ft. Sand blows, indicative of liquefaction, occurred frequently over an area of 1,400 mi. Normally nearly circular and 8 to 15 ft across, some of the sand blows reached 100 ft in diameter.

One or more of the shocks were distinctly felt over an area of about one million square miles, from Canada to New Orleans to Boston. Chimneys were knocked down as far away as Cincinnati, Ohio.

A detailed scientific compilation and analysis of the intensity distribution of the first earthquake of the series and a compilation of selected reports of the last (and largest) event of the four show that St. Louis had MMIs of VII to VIII and VIII to XI, respectively, based on the limited local information of the time (Nuttli 1973a). These intensities presumably were for structures founded on river sediments under the original town on the banks of the Mississippi River.

1838, June 9. 88.0° W, 38.5° N; I_o = VII; 5.0; 128 mi.

This earthquake in St. Louis threw down part of a chimney and was quite noticeable in upper stories of buildings. It was also reported to be severe in St. Charles, Missouri (Coffman, von Hake, and Stover 1982). A shaking duration of 30 s was reported (Docekal 1970).

1857, October 8. 89.2° W, 38.7° N; I_0 = VII; 5.1; 62 mi.

In St. Louis, two shocks were felt a few minutes apart. The largest buildings rocked, plaster fell, bricks dislocated, and windows rattled. The river was in tumult, and animals were frightened. There was a great rumbling like that of a heavily loaded vehicle passing over rough pavement. Houses with walls 18 in. thick were affected by the horizontal movement. The earthquake was felt at many places in Illinois and on the Mississippi River to the south of Hannibal, Missouri. A well that was 2,265 ft deep was not affected. The earthquake was strong in Centralia, Illinois, where three shocks were reported (Coffman, von Hake, and Stover 1982).

1882, September 27. 89.5° W, 38.7° N; I_0 = VI; 4.4; 46 mi.

The area affected by this severe earthquake extended from Mexico, Missouri, to Washington and Henderson, Kentucky, in a west-east direction; and from Springfield to Pinckneyville, Illinois, in a north-south direction, an ellipse of 250 by 160 mi. In southern Illinois, there were rumblings in many places, chimneys were cracked, small objects fell over, and pictures vibrated. The shock was also felt in St. Louis and St. Charles, Missouri (Coffman, von Hake, and Stover 1982).

1891, September 27. 88.5° W, 38.3° N; I_0 = VII; 5.5; 105 mi.

This earthquake near Cairo, Illinois, began slowly, became stronger in a few seconds, and was felt in the Mississippi Valley. Movable objects jiggled, and trees swayed as if the wind were blowing. It was also felt in Amana, Cedar Rapids, and Keokuk, Iowa (Coffman, von Hake, and Stover 1982).

1895, October 31. 89.4° W, 37.0° N; I_0 = VIII; 5.4; 131 mi.

Considered the severest shock in the entire region since the New Madrid (1811-1812) earthquake, this earthquake near Charleston, Missouri, sank 4 acres of ground and formed a lake. In Cairo, Illinois, buildings swayed, chimneys cracked (many were demolished), and church steeples twisted. Near Bertrand, Missouri, hundreds of mounds of sand (i.e., sand volcanos) were formed, ranging from 12 in. to 10 ft in circumference. Water coming from the resulting volcanoes filled nearby ditches because there had been no rain to fill them for nearly 2 months. Near Big Lake, 4 mi north of Charleston, two small holes were formed in the earth, from which water spouted to a height of 3 ft. In Dunkin County, shocks were much lighter. The shock was felt from Canada to Mississippi and Louisiana, and from Georgia and Virginia to Kansas and South Dakota, in a total of 23 states (Coffman, von Hake, and Stover 1982).

1903, February 9. 89.3° W, 37.8° N; I_o = VII; 4.8; 87 mi.

In St. Louis, this earthquake was felt sharply, and explosive sounds were heard. From Jeffersonville, Missouri, to Louisville, Kentucky, and from Cairo, Illinois, to Hannibal, Missouri, a strong shock was felt, with a roaring noise heard over 20,000 mi^2 (Coffman, von Hake, and Stover 1982).

1940, November 23. 90.1° W, 38.2° N; I_o = VI; 5.0; 41 mi.

This widely felt earthquake centered near Griggs, Illinois, caused slight damage. Bottles rattled, and trembling was felt in Tiptonville and Memphis, Tennessee. Extensive areas were affected in Illinois, Kentucky, Missouri, and Arkansas (Docekal 1970).

On November 23, 1939, an earthquake of similar size occurred at 15:15 (the 1940 event was at 21:15) at essentially the same location. While Coffman, von Hake, and Stover (1982) list only the 1939 event, Bodle (1941) and Neumann (1942) list both events, with the 1940 event having a higher epicentral intensity (VI) than the 1939 event (V); however, the 1939 event had a "rather large (affected) area (150,000 mi^2) for a shock of intensity V." Although the two events may appear suspiciously coincidental (as if they may have been the same event but were confused in the catalogs), this possibility has not been raised in any literature, and, in fact, both events were instrumentally recorded (Bodle 1941, Neumann 1942).

1947, June 30. 90.2° W, 38.4° N; I_o = VI; 4.2; 26 mi.

This earthquake was felt strongly in St. Louis; several chimneys toppled, and sidewalks cracked (Coffman, von Hake, and Stover 1982).

1953, September 11. 90.1° W, 38.8° N; I_o = VI; 3.9; 14 mi.

This earthquake in southwestern Illinois caused minor damage in Roxana and frightened many in Edwardsville. It was also felt in eastern Missouri (Coffman, von Hake, and Stover 1982). Intensity IV was reported in Berkeley, Bridgeton, and Florissant, Missouri (Murphy and Cloud 1955).

1955 April 9. 89.78° W, 38.23° N; I_o = VI; 4.3; 48 mi.

West of Sparta, Illinois, this earthquake caused minor damage in Evansville, Illinois, and in Lemay, University City, and Webster Groves, Missouri. It was felt in over 20,000 mi^2 of Illinois, Kentucky, and Missouri (Coffman, von Hake, and Stover 1982). Docekal (1970) reports that "some believed the disturbance was associated with one of a series of faults running northwest-southeast in the area," but this has not been substantiated in other literature reviewed. Intensity V was reported in St. Louis, and IV was reported in St. Charles (Murphy and Cloud 1957).

1965, October 21. 90.94° W, 37.48° N; I_o = VI; 4.9; 93 mi.

This earthquake in eastern Missouri was felt in nine states. To date, the only earthquakes in Missouri history that have exceeded this felt area (160,000 mi^2) were the 1811-1812 earthquake, an intensity VIII shock in October 1895, and an intensity VI earthquake in April 1917 (Coffman, von Hake, and Stover 1982). St. Louis experienced intensity VI, and Jerseyville, Illinois, reported intensity V (von Hake and Cloud 1967); although Florissant, Missouri, reported only intensity IV, SLAPS is located within the V to VI contour of the intensity map.

1967, July 21. 90.44° W, 37.44° N; I_o = VI; 4.6; 91 mi.

Felt considerably in southeastern Missouri and southern Illinois, the earthquakes caused some plaster damage in Elvins, Fredericktown, and Poplar Bluff, Missouri

(Coffman, von Hake, and Stover 1982). St. Louis experienced intensity IV (von Hake and Cloud 1969).

1968, November 9. 88.37° W, 37.91° N; I_o = VII; 5.5; 122 mi.

This was the strongest earthquake in south-central Illinois since 1895; it was felt in 23 states, from eastern Minnesota to northwestern Florida, and from western North Carolina to central Kansas (approximately 580,000 mi^2) (Coffman and Cloud 1970). There were isolated felt reports from people in tall buildings at more distant localities such as Boston, Massachusetts, and southern Ontario, Canada. Earthquake damage in south-central Illinois consisted primarily of bricks being thrown from chimneys, broken windows, toppled television aerials, and cracked and fallen plaster (Coffman, von Hake, and Stover 1982).

Intensity VII was recorded in St. Louis. The press reported that several people were injured by falling debris. Walls cracked, chimneys fell, and windows broke. A 15- by 20-ft section of the southwestern wall at Mid-American Metal Company collapsed. The Civil War Museum Jefferson Barracks closed because of a large crack in the museum wall, causing bricks and plaster to fall. Many objects crashed to floors. Intensity VII was reported in St. Charles; the earthquake was felt by and frightened all residents. Chimneys were knocked down, an overhang above a service counter and one light fixture were knocked loose in a post office, and there were moderate earth noises. Intensity V was recorded in Florissant. The isoseismal map shows SLAPS to be within the intensity VI area (Coffman and Cloud 1970). The extensive descriptions of effects and damage by this earthquake do not indicate any liquefaction effects.

1977, January 3. 89.71° W, 37.58° N; I_o = VI; 3.6; 88 mi.

In the Cape Girardeau, Missouri, region, plaster cracked and small objects fell in Old Appleton, and small objects were displaced in Farrar and Millersville. The earthquake was also felt in Illinois (Coffman, von Hake, and Stover 1982).

2.3.3 Probabilistic Ground Motion Estimates

In recent years, several procedures have been developed that allow formal determination of probabilistic earthquake design parameters (Cornell 1968, Cornell and Vanmarke 1969), and a number of studies have been performed using these procedures (Algermissen et al. 1990, Cornell and Merz 1975, Shah et al. 1975). In typical seismic hazard studies of this kind, the region of interest is divided into seismic sources in which future earthquakes are considered equally likely to occur at any location. For each seismic source, the occurrence rate (i.e., source activity rate) is estimated for earthquakes larger than a threshold level. The sizes of successive events for each source are assumed to be independent and exponentially distributed. The slope of the log number versus frequency is estimated from the relative frequency of different sizes of events observed in the historical data. This slope, often termed the b value (Richter 1958), is determined either for each seismic source individually or for all sources in the region jointly. Finally, the maximum possible size of earthquakes for each source zone is determined using judgment and the historical record (McGuire 1977).

Probabilities of peak dynamic acceleration and intensities have been evaluated for the SLAPS area in several recent studies. Donovan, Bolt, and Whitman (1976) show a 475-yr effective peak acceleration of about 0.11 g at SLAPS (Figure 2-6). Schaefer and Herrmann (1977) show 475-yr site intensities ranging from about VII to VIII 1/2 using three different characterizations of earthquake sources in and around the Mississippi Embayment (Figure 2-6). Using their preferred source configuration, they calculate a 2,373-yr site intensity of between VII 1/2 and VIII. Nuttli and Herrmann (1981) find a value of 0.09 g for the acceleration with a 10 percent expectation during 50-yr and 250-yr periods (hazard equivalent approximately to a 475-yr return period) (Figure 2-6). Algermissen et al. (1990) calculate accelerations with a 10 percent expectation during 50-yr and 250-yr periods (approximately 475-yr and 2,373-yr return periods, respectively) (Figure 2-6). Their results for SLAPS are a 475-yr peak acceleration of between 0.10 and 0.105 g, and a 2,373-yr peak acceleration of between 0.23 and 0.24 g.

A time-dependent stochastic model was used to estimate the seismic hazard in St. Louis caused by earthquake activity in the New Madrid fault zone (Kiremidjian and Suzuki 1986). This model reflects the hypothesis that large earthquake events depend on when the last major earthquake occurred. Because of the long interval between major event sequences (on the order of 700 $\pm$ 250 years for an event of m_b greater than or equal to 7.5) and the relatively short time since the last such sequence (in 1811 and 1812), hazard estimates for the St. Louis area using the time-dependent model are lower than estimates from earlier studies where this factor was not used. Specifically, the time-dependent acceleration (on rock) in St. Louis with a 10 percent chance of exceedance in the next 50 years is estimated to be about 0.06 g (Figure 2-6).

The principal differences in these derived accelerations and intensities arise from different characterizations of the source zones. The higher estimates are derived from those calculations that assume that the Mississippi Embayment earthquake source zones extend northward to the site.

2.3.4 Maximum Intensity, Magnitude, and Ground Motions

Two distinct estimates of maximum site intensity (and magnitude associated with a near-site earthquake of this maximum intensity) are possible: maximum historical intensity and maximum credible intensity.

Figure 2-7 shows maximum historical site area intensities through 1965. SLAPS is near the VI to VII isointensity line within the MMI VI area. No earthquake from 1966 through 1980 resulted in a higher site intensity, although there is some ambiguity about interpretation of the site effects of the November 9, 1968, earthquake. Nearby reported intensities were VII for St. Louis and St. Charles and V for Florissant. These variations were considered in developing the isoseismal map where all three locations, as well as SLAPS, were interpreted to be located within intensity VI (Coffman and Cloud 1970). Since 1980 no regional earthquakes have been nearer the site than 64.6 km (40 mi) or of maximum intensity greater than MMI VI.

The maximum historical site intensity is based on earthquakes within the New Madrid Seismic Zone (and in particular the New Madrid earthquake series of 1811-1812), as can be seen by comparing Figures 2-3, 2-4, and 2-7. A reinterpretation of the isoseismals of the first earthquake in December 1811 (Nuttli 1973a) suggests a maximum historical site intensity of VII for this event. Nuttli notes that it is difficult to untangle the damage reports of the four largest earthquakes of the 1811-1812 series. He was able to develop an isoseismal map only for the first December 1811 event. The February 1812 event, however, was the largest of the four events and is cataloged as being 257 km (160 mi) from the site, whereas the 1811 events were 306 km (190 mi) away. Nuttli notes that the reported intensities in St. Louis were VII to VIII for the December 1811 event and VIII to IX for the February 1812 event.

A recent characterization of estimated maximum intensities in the site region from a hypothetical recurrence of the largest of this series anywhere in the New Madrid Seismic Zone (Algermissen and Hopper 1984) shows the largest estimated intensity in St. Louis County to be MMI IX (see Figure 2-8). This estimate is substantiated by O'Rourke (1988) who considers the much smaller area of St. Louis County only. O'Rourke estimates that MMI IX shaking will occur in the major river channel areas and that the SLAPS area will have a lower MMI VIII level of shaking because of its better foundation materials (see Figure 2-9).

Characterization of maximum credible site intensity depends on the seismic source zone configuration in and around the Mississippi Embayment. Several characterizations of these source zones have been published (Algermissen and Perkins 1976, Nuttli 1973b, Schaefer and Herrmann 1977, Dames and Moore 1981, Bernreuter et al. 1989, McGuire et al. 1989). Estimates for maximum credible site intensity from these characterizations range from extreme values approaching XI to XII (for a hypothetical recurrence of the 1811-1812 earthquake at the site) to VIII (for a recurrence of the 1811-1812 earthquake near New Madrid or for a random intensity VIII earthquake at or very near the site).

The possibility of the 1811-1812 event reoccurring at the site is not considered to be supported by the historical and instrumental observations of the seismicity of the New Madrid Seismic Zone. However, a moderate event of epicentral intensity VIII is considered seismologically credible. The preferred estimate for the maximum credible site intensity ranges from VIII to IX. These intensities could be caused by either the 1811-1812 event reoccurring in the New Madrid Seismic Zone or by a more moderate event close to the site.

Estimates of magnitudes for nearby earthquakes associated with these intensities may be derived from a magnitude-intensity relation, such as that proposed by Nuttli and Herrmann (1978):

$$I_o = 2\ m_b - 3.5$$

This relation implies body-wave magnitudes of about 5.8 and 6.3 for intensities of VIII and IX, respectively. As correlated by Trifunac and Brady (1975), estimates of peak ground acceleration of about 0.25 and 0.50 g may be made from the intensities VIII and IX, respectively.

Site firm-foundation ground motions associated with these same intensities but with a larger and more distant earthquake in the New Madrid Seismic Zone can be estimated using attenuation relations developed for the region, such as those by Nuttli and Herrmann (1978). These relations are semiempirical, meaning that because of the scarcity of recorded strong motions in the eastern United States, some of the parameters that compose the attenuation relationships are based on theoretical considerations. The Nuttli and Herrmann relation for acceleration predicts an acceleration of about 0.10 g for the St. Louis area from a repeat of the largest earthquake of the 1811-1812 series at the closest approach [about 209 km (130 mi)] of the New Madrid Seismic Zone to the site.

2.4 CAVE AND SINKHOLE FORMATION

Caves and sinkholes are relatively common in the St. Louis area. A study of caves in Missouri includes descriptions of 12 caves in St. Louis County (Bretz 1956). Since the publication of that report, the number of known caves in Missouri has increased from 437 in 1952 to 5,012 in 1990. More than 140 new caves are discovered in Missouri each year, and the state estimates that there may be thousands more (Gaynor 1990).

Caves and sinkholes are most commonly found in the southern, west-central, and northern parts of St. Louis County. Typically, they are developed in areas where the shallowest rock is Ordovician-age or Mississippian-age limestone. In areas where Pennsylvanian shales overlie the limestone, no sinkholes are present (Brucker 1970).

Solution features in limestones in the St. Louis area are generally restricted to beds nearest the surface. However, they could extend deeper. These solution features may become caverns large enough to collapse and form sinkholes. However, surface manifestation of sinkholes may not be apparent because of the thick loess cover that is present in the St. Louis area. The occurrence of caves in the SLAPS area is discussed further in Section 5.0.

FIGURES FOR SECTION 2.0

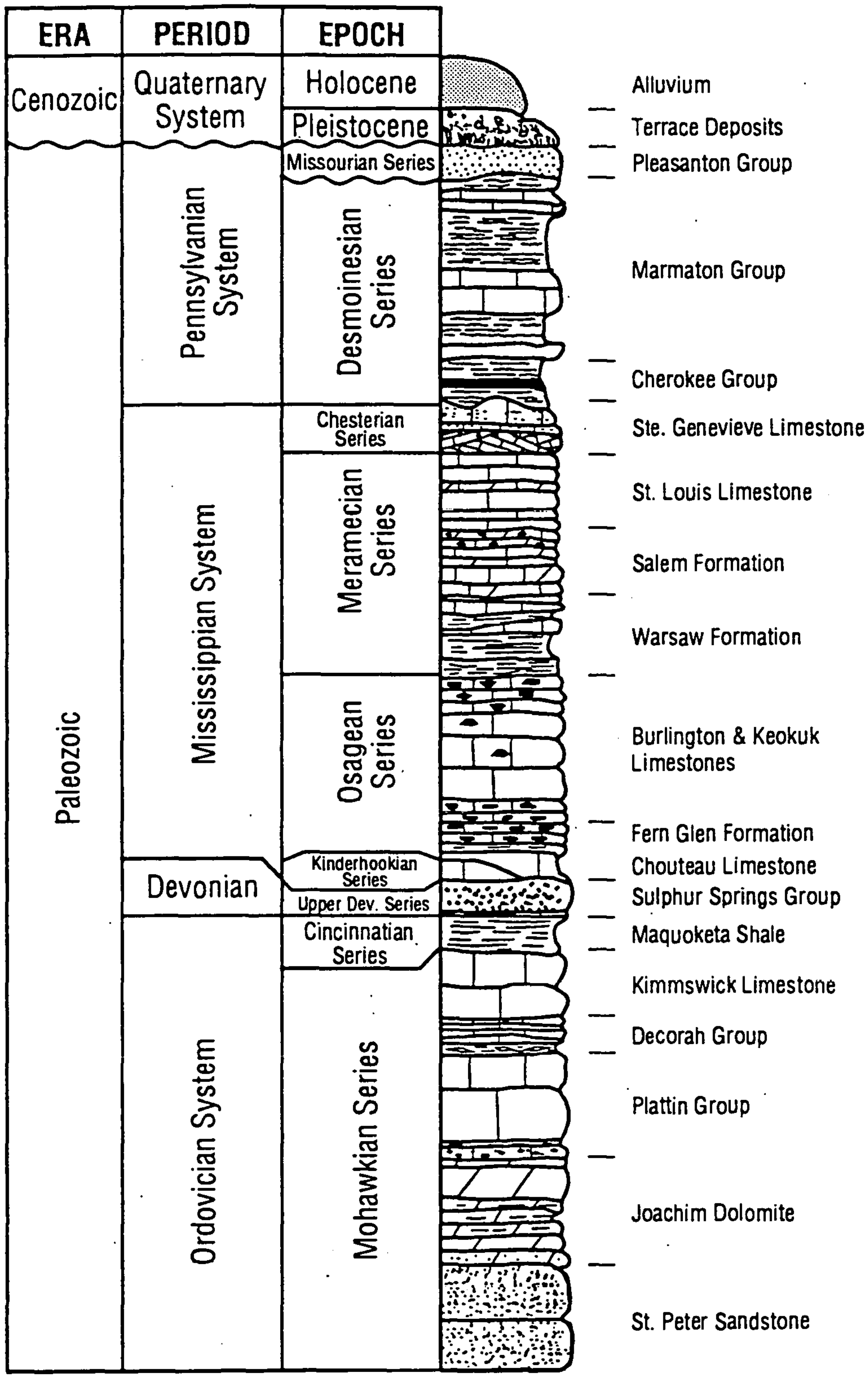
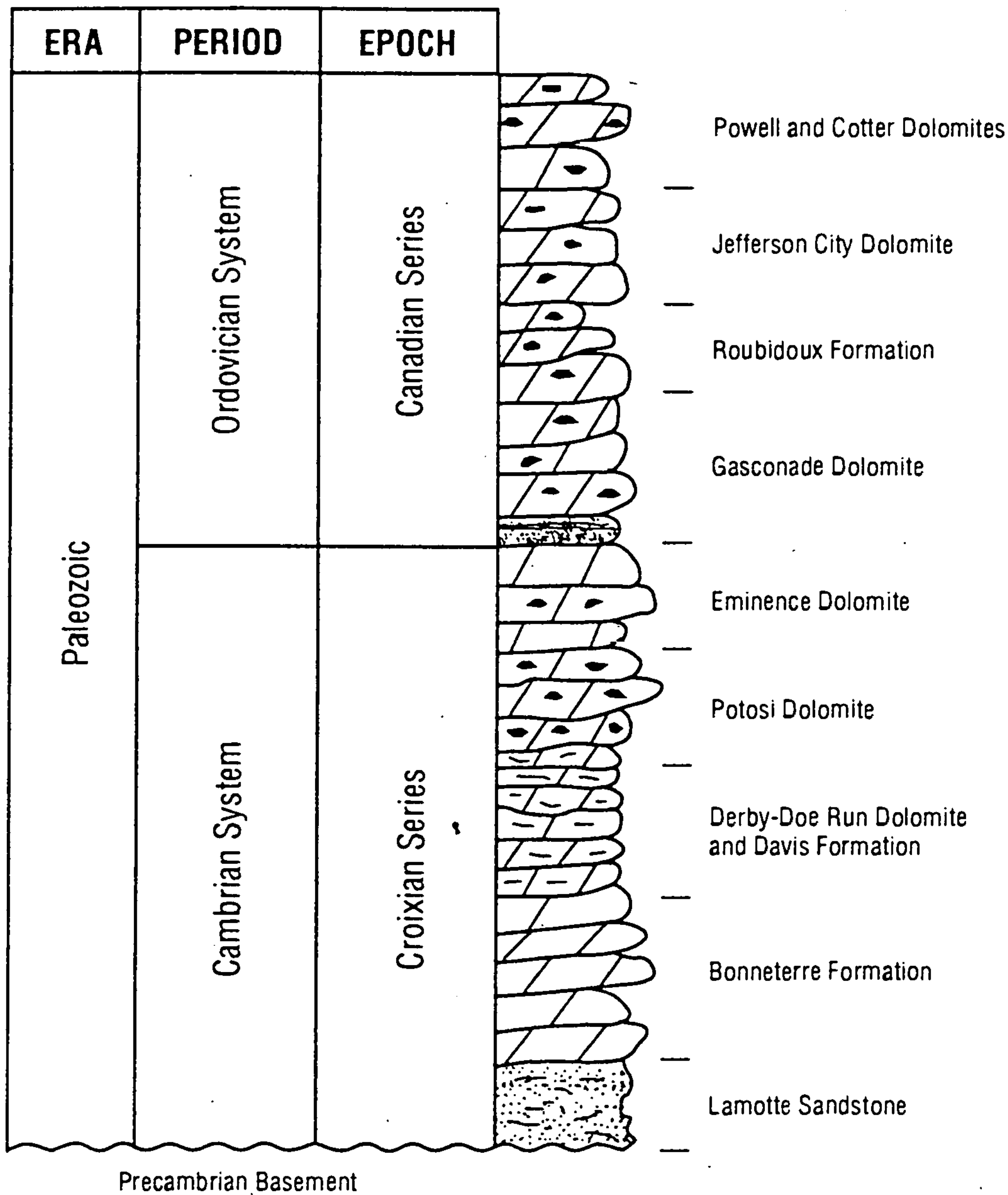


Figure continued on following page.

Sources: Brill 1991, Howe and Koenig 1961 and modified from MDNR 1993.

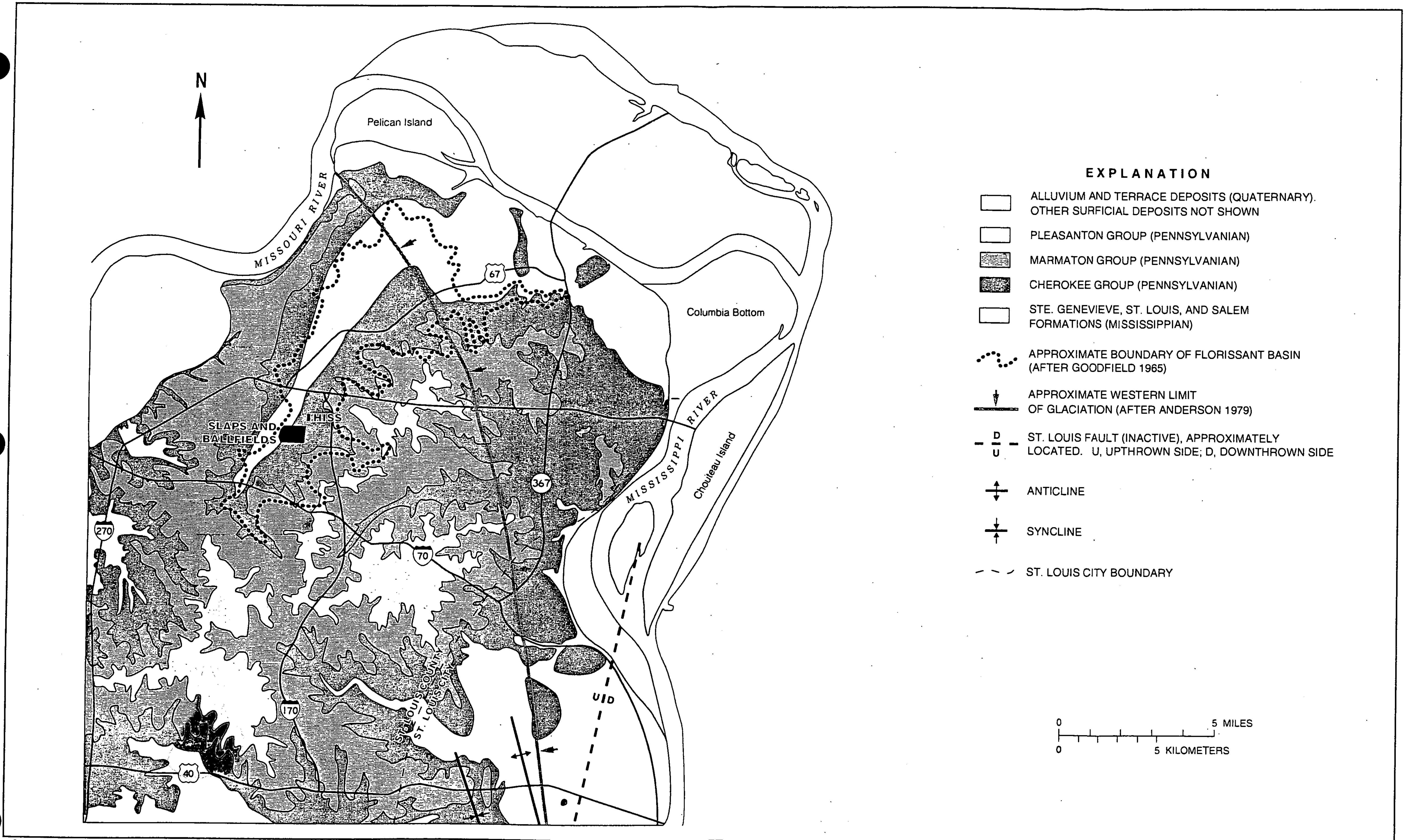
Figure 2-1
Generalized Stratigraphic Column for the
St. Louis Region (Page 1 of 2)

Figure continued from previous page.



Sources: Brill 1991, Howe and Koenig 1963 and modified from MDNR (1993).

Figure 2-1
Generalized Stratigraphic Column for the St. Louis Region (Page 2 of 2)



Source: Adapted from Brill 1991.

Figure 2-2
Generalized Geologic Map of the St. Louis Area

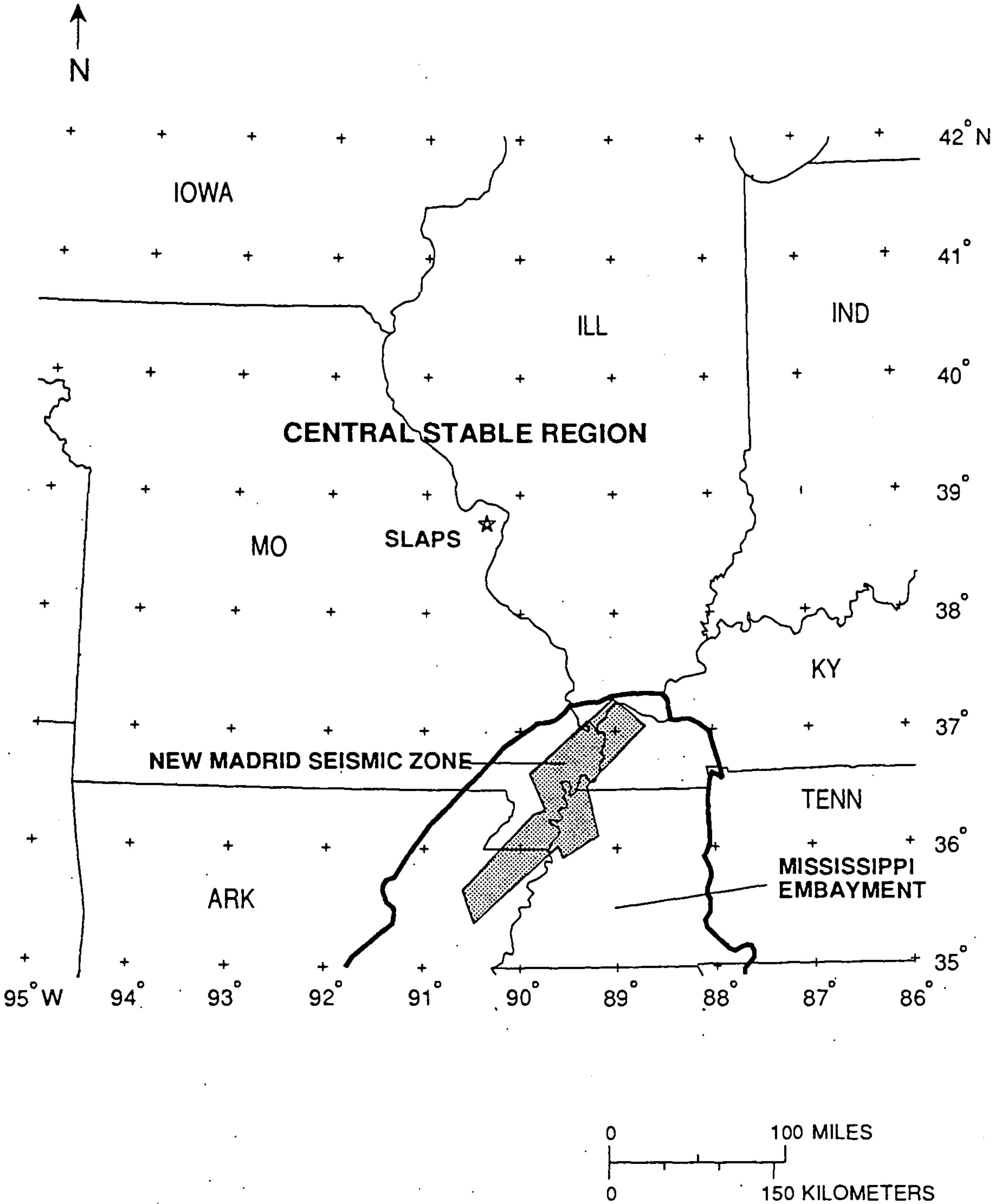
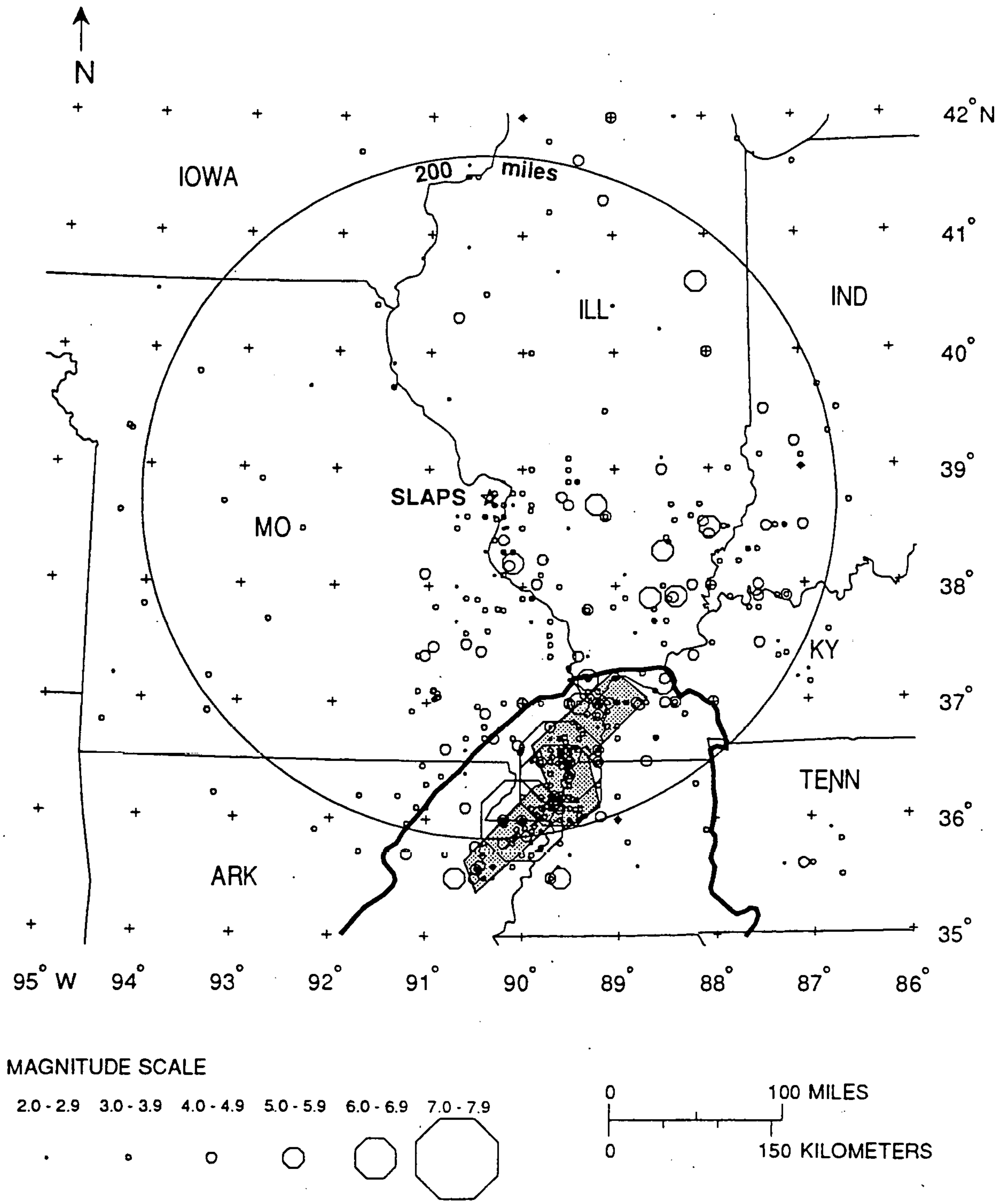


Figure 2-3
Tectonic Elements of the SLAPS Region

4.85 6155.5

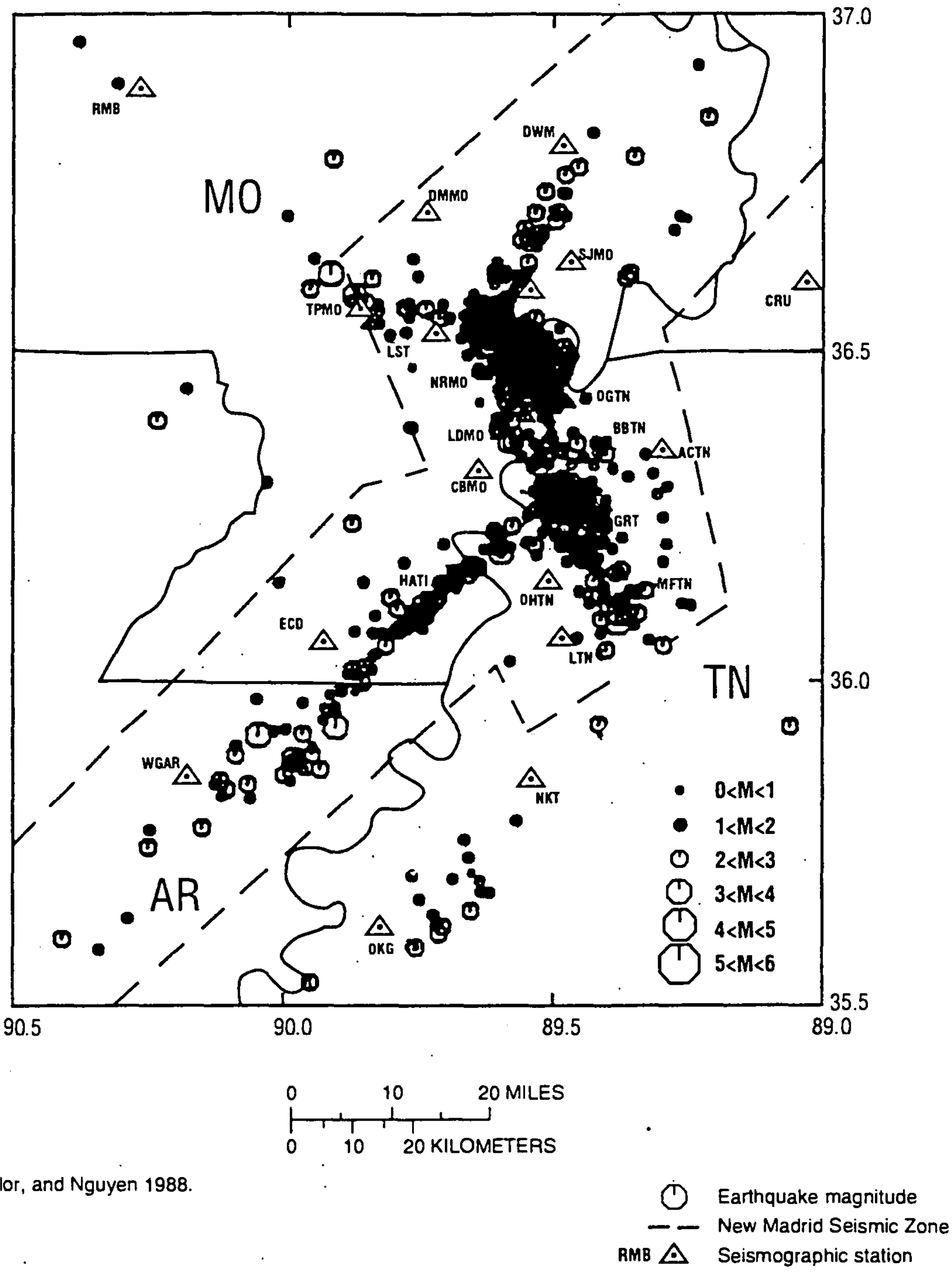


Source: Armbruster and Seeber 1992.

Shaded area represents the New Madrid Seismic Zone. Heavier line shows the margin of the Mississippi Embayment.

Figure 2-4
Seismicity of the SLAPS Region
Through February 1985

4.85 6155.6



Source: Hermann, Taylor, and Nguyen 1988.

Figure 2-5
Earthquakes that Occurred Between October 1, 1981, and December 31, 1986, In and Near the New Madrid Seismic Zone

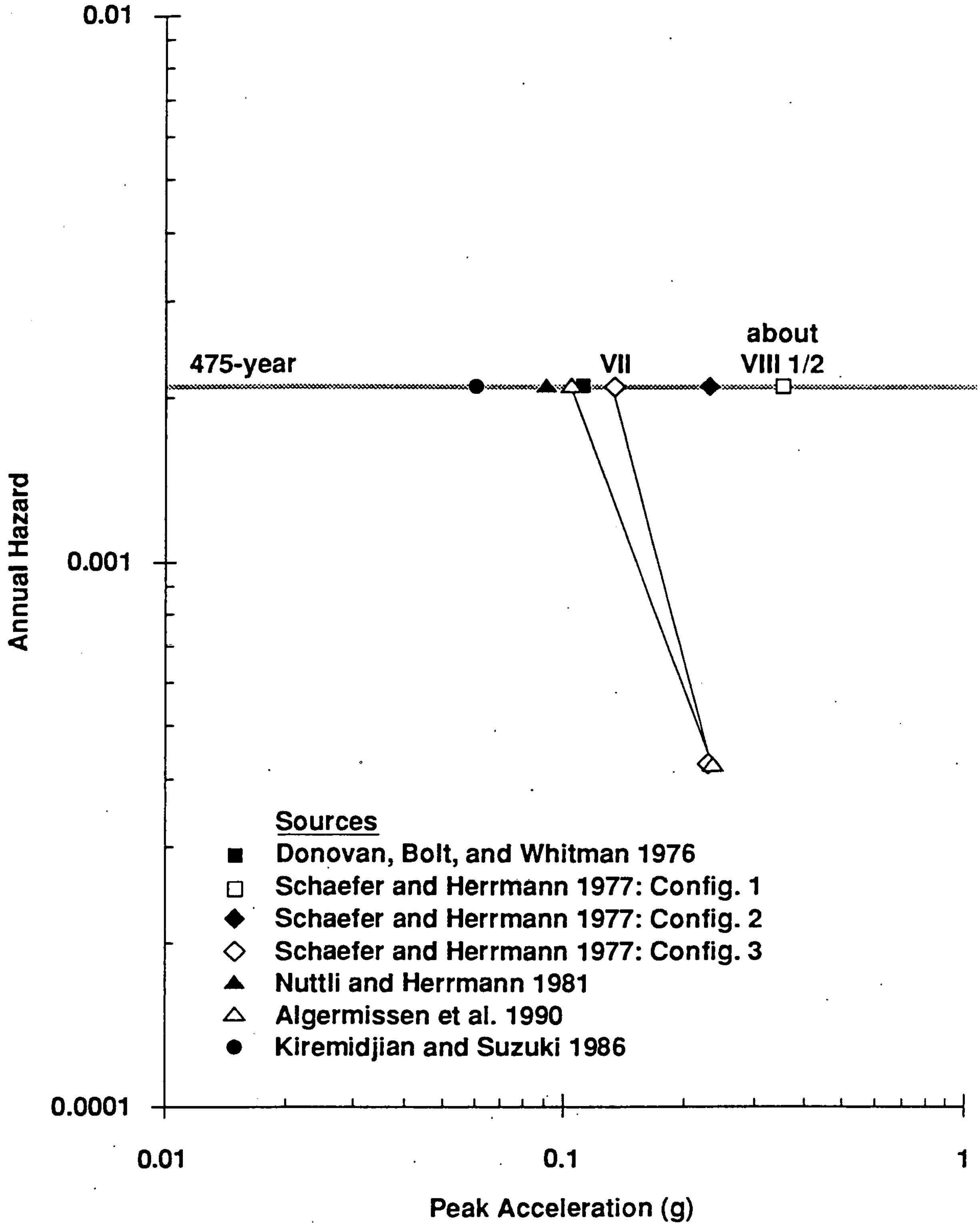
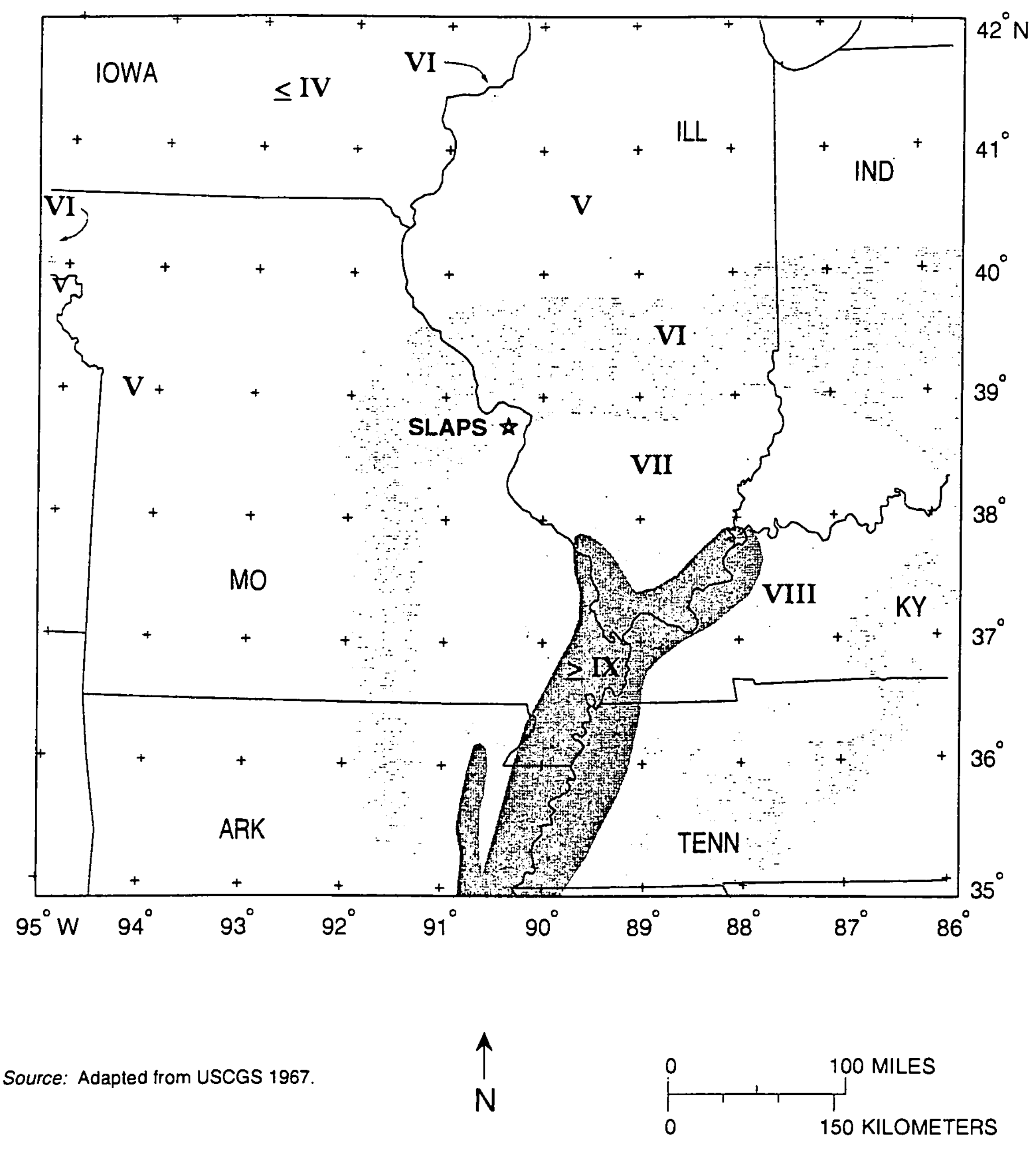


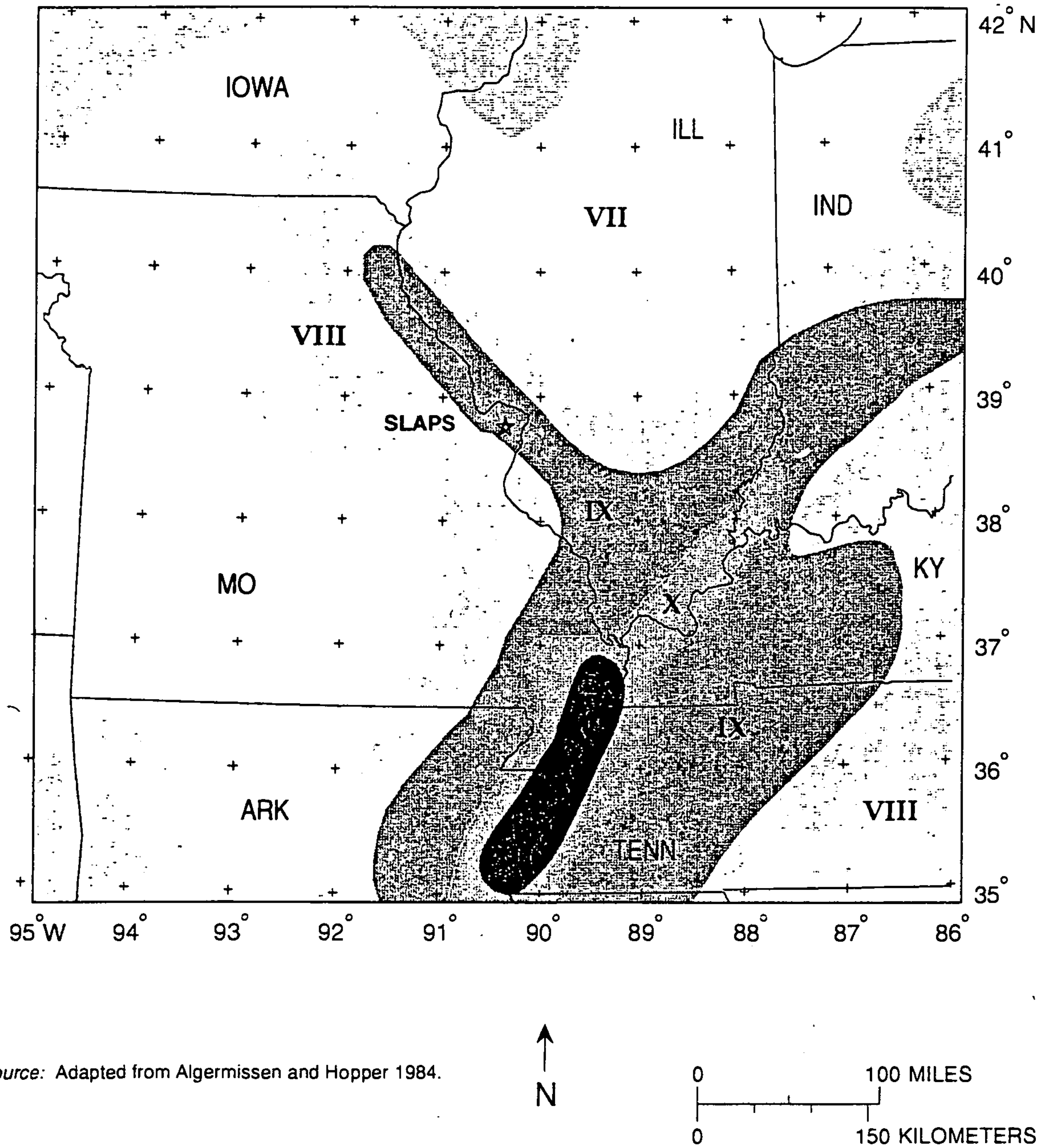
Figure 2-6
Seismic Hazard for SLAPS Based on Various Published Regional Studies



Source: Adapted from USCGS 1967.

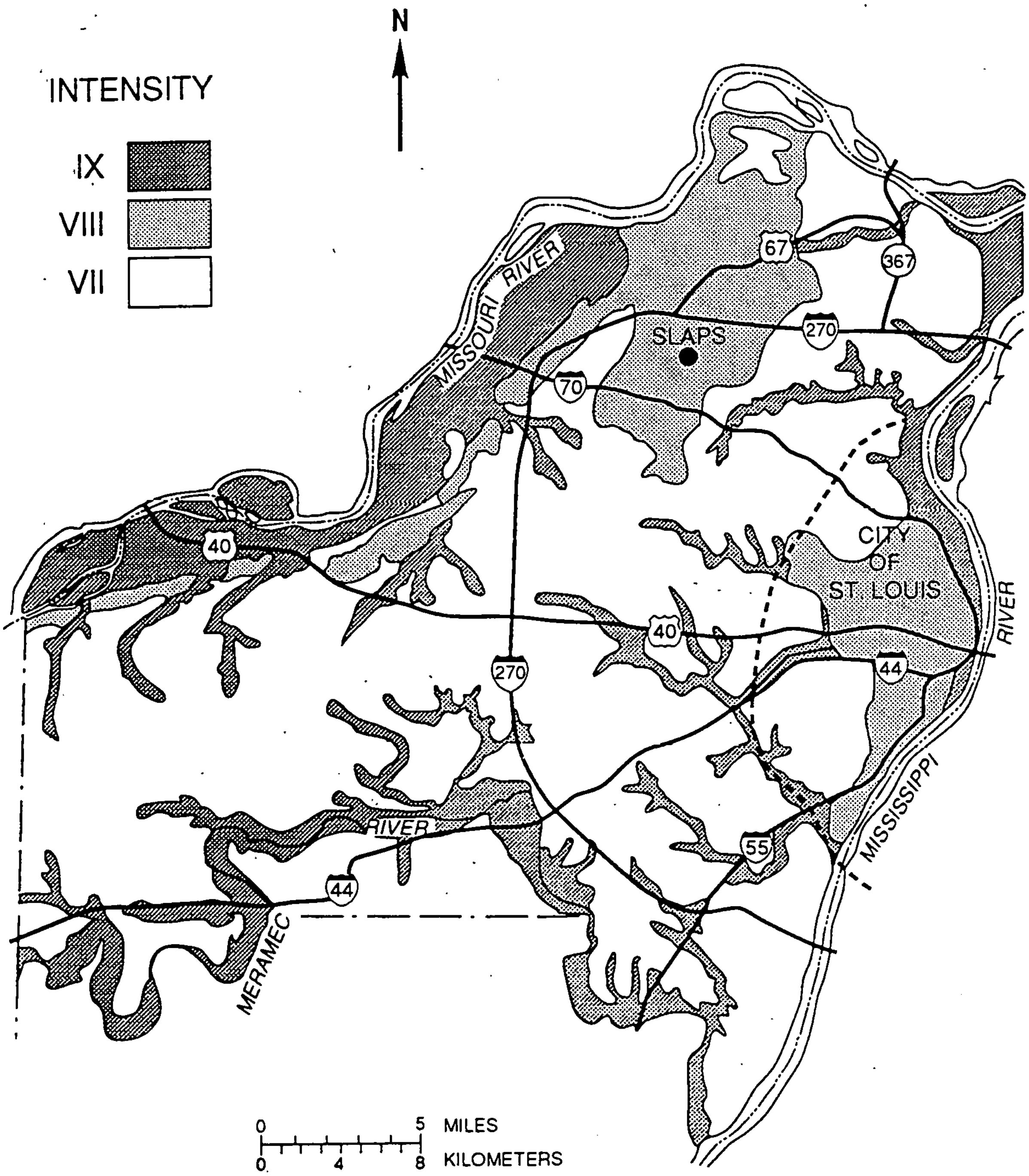
Figure 2-7
Reported Maximum MMIs for the Historical Record Through 1965

4.85 6155.4c



Source: Adapted from Algermissen and Hopper 1984.

Figure 2-8
Estimated Maximum MMIs for a Hypothetical Earthquake of Richter Magnitude 8.6 Anywhere along the New Madrid Seismic Zone —



Source: O'Rourke 1988.

Figure 2-9
Estimated MMIs for a Hypothetical Earthquake of Richter Magnitude 8.6 Near the Northern End of the New Madrid Seismic Zone

TABLE FOR SECTION 2.0

Table 2-1

All Earthquakes of Magnitude 4 or Greater or Intensity V or Greater Within 322 km (200 mi) of SLAPS

Year	Universal Time Month/ Day	Universal Time Hour:Minute: Second	Latitude (North)	Longitude (East)	Focal Depth (km)	Distance from SLAPS (mi)	MMI[a]	Richter Magnitude (m_b)
1795	01/08	9:0	39.00	89.90		29.5	V	3.4
1804	08/24	20:10	42.00	89.00		233.6	VI	4.2
1811	12/16	8:15	36.00	90.00		190.4	XI[b]	7.2
1811	12/16	14:15	36.00	90.00		190.4	XI[b]	7.0
1812	01/23	15:0	36.30	89.60		173.8	X-XI[b]	7.1
1812	02/07	9:45	36.50	89.60		160.4	XI-XII[b]	7.4
1819	09/02	8:0	37.70	89.70		80.9	V	3.4
1819	09/02	12:0	37.70	89.70		80.9	V	3.4
1820	11/09	22:0	37.30	89.50		110.4	V	3.4
1827	07/05	11:30	38.00	87.50		162.8	VI	4.8
1827	08/07	4:30	38.00	88.00		137.5	V	4.8
1838	06/09	14:45	38.50	88.00		128.1	VII	5.0
1841	12/28	5:50	36.60	89.20		161.0	VI	4.2
1842	11/04	6:30	36.60	89.20		161.0	V	3.4
1842	11/04	8:30	36.60	89.20		161.0	V	3.4
1843	01/05	2:45	35.50	89.60		227.5	VII	5.4
1843	02/17	5:0	35.50	90.50		223.9	V	4.4
1843	08/09	0:0	35.60	87.10		281.1	IV	4.1
1849	01/24	0:0	36.60	89.20		161.0	V	3.4
1850	04/05	2:5	37.00	88.00		176.1	V	4.3
1853	12/12	0:0	36.60	89.20		161.0	IV	4.1
1856	11/09	10:0	36.60	89.50		155.4	V	4.1
1857	10/08	10:0	38.70	89.20		62.3	VII	5.1
1858	09/21	0:0	36.50	89.20		167.4	VI	4.0
1860	08/07	15:30	37.50	87.50		177.3	VI	4.3
1865	08/17	15:0	36.50	89.50		161.9	VI	4.6
1875	10/07	0:0	36.10	89.60		187.1	IV	4.1
1876	09/25	6:0	38.50	87.00		181.5	VI	4.5
1876	09/25	6:15	38.50	87.00		181.5	VII	4.7
1877	07/15	0:40	36.80	89.70		139.1	IV	4.2
1878	03/12	10:0	36.80	89.10		150.9	V	3.9
1878	11/19	5:52	35.50	90.70		224.5	VII	5.2
1881	05/27	0:0	41.30	89.10		186.6	VI	4.0
1882	07/20	10:0	36.90	89.20		142.3	V	3.4
1882	09/27	10:20	38.70	89.50		46.2	VI	4.4
1882	10/15	5:50	39.00	89.50		48.8	V	3.8
1882	10/15	10:35	39.00	89.50		48.8	V	3.8
1883	01/11	7:12	37.00	88.50		157.4	VI	4.7
1883	04/12	8:30	37.00	89.20		136.1	VI	4.5
1883	12/05	15:20	35.70	91.20		215.0	VI	4.0
1886	03/18	5:59	37.00	89.20		136.1	VI	4.2
1887	02/06	22:15	39.00	88.50		100.9	VI	4.5
1887	08/02	18:36	37.20	88.50		147.0	VI	4.6
1891	07/27	2:28	37.90	87.50		165.3	VI	4.2
1891	09/27	4:55	38.30	88.50		104.9	VII	5.5
1895	10/31	11:8	37.00	89.40		131.4	VIII	5.4

Table 2-1

(continued)

Year	Universal Time Month/ Day	Universal Time Hour:Minute: Second	Latitude (North)	Longitude (East)	Focal Depth (km)	Distance from SLAPS (mi)	MMI[a]	Richter Magnitude (m_b)
1898	06/14	15:6	36.50	88.70		179.5	IV	4.0
1899	04/30	2:5	38.50	87.40		160.1	VII	4.6
1901	01/04	3:12	37.80	94.00		207.8	V	3.5
1903	02/09	0:21	37.80	89.30		87.2	VII	4.8
1903	10/05	2:56	38.30	90.20		32.6	V	3.7
1903	11/04	18:18	36.50	89.50		161.9	VI	4.6
1903	11/04	19:14	36.50	89.80		158.0	VII	4.9
1903	11/27	7:0	37.00	89.50		129.4	V	3.9
1903	11/27	9:20	36.50	89.50		161.9	V	4.3
1905	08/22	5:8	37.20	89.30		121.4	VI	5.2
1906	05/21	19:0	38.70	88.40		105.2	V	3.4
1907	01/30	0:0	38.90	89.50		47.0	V	3.4
1907	01/30	5:30	39.50	86.60		207.1	V	3.4
1909	05/26	14:42	40.60	88.10		174.0	VII	5.0
1909	07/19	4:34	40.30	90.70		107.3	VI	4.3
1909	09/22	0:0	38.70	86.50		207.3	V	3.7
1909	09/27	9:45	39.50	87.40		166.0	VII	4.8
1909	10/23	7:10	37.00	89.50		129.4	VI	4.3
1909	10/23	9:47	39.00	87.80		138.1	V	3.9
1915	10/26	7:40	36.70	88.60		170.7	V	3.4
1915	12/27	18:40	36.00	90.00		190.4	VI	4.4
1916	12/19	5:42	36.60	89.20		161.0	VI	3.7
1917	04/09	20:52	37.00	90.00		122.3	VII	4.9
1918	10/13	9:30	36.10	91.00		185.9	V	3.5
1918	10/16	2:15	36.00	90.00		190.4	V	4.2
1919	05/25	9:45	38.30	87.50		157.1	V	3.8
1920	05/01	15:15	38.00	89.60		66.2	V	3.9
1921	03/14	12:15	40.00	88.00		151.7	IV	4.0
1922	03/22	22:30	37.90	88.40		121.1	VII	4.6
1922	03/23	4:30	37.40	89.40		106.7	VI	4.5
1922	11/27	3:31	37.40	88.20		149.6	VII	4.6
1923	11/10	4:0	40.00	89.90		88.6	V	3.3
1924	01/01	3:5	36.00	90.00		190.4	VI	4.3
1924	04/02	11:15	37.00	88.80		147.4	V	4.0
1924	06/07	5:42	36.50	89.80		158.0	V	3.7
1925	04/27	4:5	38.00	88.20		127.6	VII	4.9
1925	07/13	0:0	38.80	90.00		19.3	V	3.8
1925	09/02	11:55	37.90	87.20		180.5	VI	4.5
1927	05/07	8:28	36.00	90.20		189.6	VI	4.7
1927	08/13	16:10	36.40	89.50		168.5	V	4.1
1930	09/01	20:27:24	36.60	89.40		157.1	V	3.7
1931	01/06	4:51	39.00	87.00		180.8	V	3.3
1933	12/09	8:50	35.80	90.20		203.3	VI	4.0
1934	08/20	0:47	36.90	89.20		142.3	VI	4.3
1934	11/12	14:45	41.50	90.50		188.3	VI	3.9
1937	05/17	0:49:46	36.10	90.60		183.0	IV	4.0
1937	11/17	17:4	38.60	89.10		68.5	V	4.0
1938	02/12	6:27	41.60	87.00		263.2	V	3.8
1939	11/23	15:14:52	38.18	90.14		41.4	V	4.9
1940	05/31	19:3	37.10	88.60		148.6	V	3.4

Table 2-1

(continued)

Year	Universal Time Month/ Day	Universal Time Hour:Minute: Second	Latitude (North)	Longitude (East)	Focal Depth (km)	Distance from SLAPS (mi)	MMI[a]	Richter Magnitude (m_b)
1940	11/23	21:15	38.20	90.10		40.8	VI	5.0
1941	11/17	3:8	35.50	89.70		226.6	VI	4.2
1946	05/15	6:10	36.60	90.80		150.1	IV	4.0
1946	10/08	1:12:2	37.50	90.60		87.4	IV	4.0
1947	03/26	0:0	37.00	88.40		160.9	VI	4.0
1947	06/30	4:23:53	38.40	90.20		26.0	VI	4.2
1947	12/15	3:27	35.60	90.10		217.3	V	3.7
1949	01/14	3:49	36.40	89.70		165.8	V	3.5
1949	01/31	0:0	36.30	89.70		172.5	V	3.5
1950	02/08	10:37	37.70	92.70		146.2	V	3.7
1952	02/20	22:34:39	36.40	89.50		168.5	V	3.9
1952	07/16	23:48:10	36.20	89.60		180.4	VI	4.0
1953	09/11	18:26:28	38.80	90.10		14.1	VI	3.9
1954	02/02	16:53	36.70	90.30		141.3	VI	4.3
1955	01/25	7:24:39.1	36.07	89.83	8	186.8	VI	4.3
1955	03/29	9:3	36.00	89.50		195.1	VI	3.9
1955	04/09	13:1:23.3	38.23	89.78	11	47.8	VI	4.3
1955	09/06	1:45	36.00	89.50		195.1	V	3.4
1955	12/13	7:43	36.00	89.50		195.1	V	3.4
1956	01/29	4:44:15.5	35.76	89.80	16	208.1	VI	3.9
1956	10/29	9:23:44	36.10	89.70		186.0	V	3.4
1956	11/26	4:12:43.3	36.91	90.39	1	126.9	VI	4.3
1958	01/26	16:55:37	36.10	89.70		186.0	V	3.8
1958	01/28	5:56:40	37.10	89.20		130.0	V	3.9
1958	04/08	22:25:33	36.30	89.20		180.2	V	3.4
1958	11/08	2:41:12.6	38.44	88.01	5	128.2	VI	4.4
1959	02/13	8:37	36.10	89.50		188.4	V	3.2
1959	12/21	16:23:39.6	36.03	89.34	5	195.4	V	3.4
1960	01/28	21:38	36.00	89.50		195.1	V	3.2
1960	04/21	10:45	36.00	89.50		195.1	V	3.4
1961	12/25	12:58:16.8	39.32	94.24	9	211.4	V	3.9
1962	02/02	6:43:30	36.37	89.51	4	170.4	VI	4.3
1962	06/27	1:28:59.3	37.90	88.64		109.9	VI	5.4
1962	07/23	6:5:15.7	36.04	89.40	8	193.8	VI	3.6
1963	03/03	17:30:10.6	36.64	90.05	15	146.4	VI	4.8
1963	08/03	0:37:49.1	36.98	88.77	7	149.5	V	4.4
1965	03/06	21:8:50.3	37.40	91.03	7	100.2	III	4.0
1965	08/14	13:13:56.9	37.23	89.31	1	119.3	VII	3.8
1965	08/15	4:19:1	37.20	89.30		121.4	V	3.5
1965	08/15	6:7:29	37.22	89.30	2	120.2	V	3.4
1965	10/21	2:4:39.1	37.48	90.94	5	93.3	VI	4.9
1967	07/21	9:14:48.8	37.44	90.44	15	90.6	VI	4.6
1968	03/31	17:58:9.6	38.02	89.85	1	57.6	V	4.5
1968	11/09	17:1:40.5	37.91	88.37	21	122.1	VII	5.5
1968	12/11	15:0	37.80	87.60		163.0	V	3.4
1970	11/17	2:13:54.1	35.86	89.95	16	200.2	VI	4.4
1971	10/01	18:49:38.5	35.77	90.49	9	205.3	VI	4.1
1972	03/29	20:38:31.7	36.12	89.74	7	184.2	V	3.7
1972	06/19	16:15:18.8	37.00	89.08	13	139.3	IV	4.5
1972	09/15	5:22:15.9	41.64	89.37	10	204.5	VI	4.4

Table 2-1

(continued)

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Year	Universal Time Month/ Day	Universal Time Hour:Minute: Second	Latitude (North)	Longitude (East)	Focal Depth (km)	Distance from SLAPS (mi)	MMI[a]	Richter Magnitude (m_b)
1974	01/08	1:12:38.1	36.18	89.47	7	183.5	V	3.9
1974	04/03	23:5:2.8	38.55	88.07	15	123.9	VI	4.7
1974	05/13	6:52:18.7	36.74	89.36	4	148.8	VI	3.8
1974	06/05	8:6:10.7	38.65	89.91	12	25.1	V	3.2
1974	08/11	14:29:45.4	36.93	91.16	6	132.9	V	3.2
1975	02/13	19:43:58	36.55	89.59	3	157.3	V	3.4
1975	06/13	22:40:27.5	36.54	89.68	9	156.7	V	3.9
1975	12/03	3:6:33.7	36.56	89.60	8	156.5	VI	2.8
1976	01/16	19:42:56.9	35.90	92.16	7	219.7	V	3.4
1976	03/25	0:41:20.8	35.58	90.48	17	218.3	VI	4.9
1976	03/25	1:0:12.4	35.61	90.44	14	216.2	II	4.3
1976	04/08	7:38:53	39.30	86.70		199.2	V	3.0
1976	04/15	7:3:34.4	37.38	87.31	4	190.4	V	3.3
1976	05/22	7:40:46.1	36.03	89.83	9	189.5	V	3.2
1976	09/25	14:6:55.8	35.58	90.47	8	218.3	V	3.5
1976	12/11	7:5:1.1	38.10	91.04		58.4		4.2
1976	12/13	8:35:55.1	37.81	90.26	9	65.3	V	3.5
1977	01/03	22:56:48.5	37.58	89.71	5	88.2	VI	3.6
1978	06/02	2:7:28.9	38.41	88.46	20	104.9	V	3.2
1978	08/31	0:31:0.6	36.09	89.44	1	189.9	V	3.5
1978	12/05	1:48:2	38.56	88.37	23	107.7	V	3.5
1979	02/27	22:54:54.8	35.96	91.20	10	197.6	V	3.4
1980	12/02	8:59:29.7	36.17	89.43	5	184.8	VI	3.8
1981	06/09	14:15:47.8	37.82	89.03	19	96.4	V	3.4
1981	06/26	8:33:27	35.85	90.07	9	200.3	V	3.5
1981	08/07	11:53:44	36.03	89.18	11	198.1	VI	4.0
1983	05/15	5:16:22	38.77	89.57		42.3	IV	4.3
1984	06/29	7:58:29.3	37.70	88.47	2	125.3	VI	3.8
1984	07/28	23:39:27.4	39.22	87.07	10	178.8	V	4.0
1984	08/29	6:50:59.5	39.11	87.45	10	157.6	V	3.1

Source: Armbruster and Seeber 1992.

[a]MMI - Modified Mercalli Intensity.

[b]Intensities from Hamilton and Johnston 1990.

3.0 SITE GEOLOGY

SLAPS lies on the southeastern edge of the Florissant Basin in a north-draining valley, which is occupied by Coldwater Creek. This basin has been filled by glaciolacustrine and alluvial sediments. The deepest part of the Florissant Basin is underlain by Mississippian-age limestone that was exposed by erosion before the basin fill sediments were deposited. Pennsylvanian-age bedrock surrounds the basin.

3.1 STRATIGRAPHY

Figure 3-1 shows the locations of monitoring wells and geologic boreholes at SLAPS. Based on data from these wells and boreholes, the site stratigraphy has been divided into the six units shown in Figure 3-2 and described below. The areal distribution, nature of contacts between units, and environment of deposition for each unit are discussed in Section 3.1.1. A complete list of geotechnical analyses of samples from SLAPS is provided in Appendix A.

Unit 6 is encountered in only two onsite wells. The formation in these borings is described as a dense, hard, sandy limestone with interbedded shale laminations and a few shell fragments. The limestone is well cemented and has little to no void space. Shale layers tend to be friable or fissile. Based on a geologic map (Brill 1991) and on lithologic descriptions of the unit, Unit 6 has been identified as the Ste. Genevieve Limestone. The amount of data on Unit 6 is very limited and may not be fully representative of the unit characteristics.

Whether Unit 5 is bedrock is ambiguous; some features of the unit suggest bedrock, but these features are underlain by unconsolidated sediments. For the purpose of this report, it is considered bedrock. If Unit 5 is not bedrock, it will not have any effect on the conclusions of this report. Unit 5 consists of interbedded layers of silty clay and shale, lignite and coal, sandstone, and siltstone. The shale is massive but has random zones of fissility. Joints observed in a few samples were inclined at angles of 30 to 45°. Based on a geologic map (Brill 1991) and on lithologic descriptions of the unit, Unit 5 has been tentatively identified as the Cherokee Group. A significant erosional unconformity occurs between the Ste.

Genevieve Limestone and the Cherokee Group (Howe and Koenig 1961). This unconformity was observed in geologic logs.

Unit 4 consists of clayey and sandy gravels and clayey sands. The gravel is generally angular to subangular chert that is up to 5 cm (2 in.) in size in a fine- to medium-grained sand and clay matrix. The sands are described as very coarse-grained and commonly occur with clay and silt. Sieve analysis values for sediments from Unit 4 indicate an average composition that is 34 percent sand and 53 percent fines. The average porosity is about 44 percent, and the vertical geometric mean permeability (from laboratory tests) is 1.3×10^{-6} cm/s (1.3 ft/yr). Grain size and soil classification data for Unit 4 are summarized in Table 3-1. Unit 4 unconformably overlies Unit 5. This unconformity represents either a period of erosion during which sediments that were deposited during the Mesozoic and Cenozoic were removed, or a period of nondeposition.

Unit 3 is a thick sequence of glaciolacustrine silty clays and clays. The unit has been subdivided into three subunits based on stratigraphic position, differing lithologies, and geotechnical properties. The subunits are: subunit 3B, the basal unit, which is a silty clay; subunit 3M, a highly plastic clay; and subunit 3T, also a silty clay. A summary of soil classification and grain size data for Unit 3 is included in Table 3-1. The sediments in Unit 3 were probably deposited during Illinoisan glaciation as part of the Brussels Terrace. At some locations, Unit 3 conformably overlies Unit 4, but at other locations Unit 4 is missing, and Unit 3 lies directly on bedrock.

Subunits 3B and 3T are both silty clays with minor amounts of very fine- to fine-grained sand. Both subunits are moderately plastic and moist to saturated, although sediments in subunit 3B (i.e., in B53W06D and B53G14) are sometimes dry. In some places subunit 3T contains organic blebs, peat stringers, varve-like laminations, and mottling, which are not present in subunit 3B. Both subunits contain an average of 14 percent or less sand and 86 to 93 percent fines. The average porosity is approximately 40.5 percent, and vertical permeabilities (measured in the laboratory) range from 7×10^{-5} to 3×10^{-8} cm/s (72 to 0.031 ft/yr).

Subunit 3M is a stiff, moist, and highly plastic clay, which is locally varved. It has an average of 8 percent sand and 92 percent fines. The average porosity is 45.3 percent, and the geometric mean vertical laboratory permeability is 5.5×10^{-8} cm/s (0.056 ft/yr). Subunit 3M unconformably overlies subunit 3B. The contact between subunits 3M and 3T is generally gradational. Samples from subunit 3M yielded higher values for liquid limits and plasticity indexes and are one to two orders of magnitude less permeable than samples from subunits 3T and 3B.

Unit 2 is Pleistocene loess (windblown silts and clays), which contains small amounts of fine-grained sand. This unit typically contains scattered pods of organic material and iron concretions. Staining by iron oxide and manganese is common but decreases with depth. A few root tubules or burrows filled with iron-oxide-stained silt and scattered layers of shell fragments are present. Unit 2 contains an average of 9 percent sand and 91 percent fines. The average porosity is 41.6 percent, and the geometric mean vertical laboratory permeability is 2.5×10^{-6} cm/s (2.6 ft/yr). Table 3-1 summarizes the grain size and soil classification data. Unit 2 conformably overlies Unit 3.

Unit 1 consists of both disturbed topsoil, fill, and undisturbed topsoil. Undisturbed topsoil is combined with fill material in this discussion of the site stratigraphy. The fill is composed of construction rubble, rebar, scrap metal, asphalt, reinforced concrete, glass, wood, ceramic material, and slag distributed within loose to compacted silt, sand, and gravel. Sediments from Unit 1 typically have low moisture content and are nonplastic to slightly plastic. The topsoil at the base of the fill is composed of both disturbed and undisturbed organic silts and clays and contains roots. The topsoil typically has a low moisture content and is slightly plastic.

The U.S Soil Conservation Service has identified three different soils at SLAPS: the Nevin-Urban land complex, the Nevin silt loam, and the Menfro silt loam (USDA 1982). The Nevin-Urban land complex consists of nearly level, poorly drained, black silt loams intermixed with areas of urban growth. The Nevin silt loam is composed of nearly level, poorly drained, dark gray, friable silt loam. The Menfro silt loam is moderately sloping, well drained, and brown. A map showing the distribution of topsoils at SLAPS is provided in Figure 3-3.

Geotechnical analyses of topsoil samples from SLAPS revealed that characteristics of the topsoils are consistent with reported values (USDA 1982). Three of the four samples were from the Nevin silt loam, and one was from the Nevin-Urban land complex. The samples from the Nevin silt loam had a liquid limits ranging from 34 to 35 percent and plasticity indexes of 13 to 14; this agrees with reported values of 35 to 40 percent for liquid limits and 10 to 20 for plasticity indexes (USDA 1982). One subsoil sample [collected from the 0.61- to 1.22-m (2- to 4-ft) deep interval] from the Nevin silt loam had values of 51 percent for liquid limit and 28 percent for plasticity index; reported values for this interval are 40 to 50 percent for liquid limits and 20 to 30 percent for plasticity indexes (USDA 1982). The sample from the Nevin-Urban land complex had a liquid limit of 35 percent and a plasticity index of 14 percent, which also agree with reported values (USDA 1982).

3.1.1 Distribution of Stratigraphic Units

The stratigraphy at SLAPS can be characterized as a buried preglacial valley in which sediments lap onto bedrock highs. This is illustrated with cross sections and contour maps presented in this section. A map showing the locations of geologic cross sections is provided in Figure 3-4. The cross sections of SLAPS are shown in Figures 3-5 and 3-6.

A structure contour map showing the top of bedrock and the distribution of bedrock lithologies (shale and limestone) is presented in Figure 3-7. As shown in this figure, limestone (probably Ste. Genevieve) is the first bedrock unit encountered in areas where the depth to bedrock is greatest. In the areas where bedrock is shallow, shale and other terrigenous deposits are encountered above the limestone unit. In some areas, the top of the shale unit is difficult to differentiate from the overlying sediments. The boundary between shale and limestone is shown in both cross sections (Figures 3-5 and 3-6). As mentioned earlier, the boundary between the two units is an unconformity. Definition of this boundary and the orientation of the units is defined by a limited number of subsurface data points. As shown in the cross sections and Figure 3-7, the surface of the bedrock forms a topographic depression (probably caused by erosion) across the center of the southern portion of the site. In the areas where limestone is the first bedrock unit encountered, erosion has completely removed the overlying shale. The erosional feature is related to the northward-draining valley in which SLAPS is located, which was filled with glaciolacustrine sediments. Coldwater Creek is an entrenched stream channel in this drainage valley.

The erosional surface topography of the bedrock units directly influences the distribution of the overlying sediments. Unit 4 is probably a layer of bedrock residuum or glacial material that overlies Mississippian bedrock at SLAPS. The distribution of Unit 4 is shown in Figure 3-8. The unit most commonly occurs filling low areas in the bedrock surface (Figure 3-6). Unit 4 is absent in an area underlying Coldwater Creek in the northern half of the site. Sediments were probably removed from this area by erosion.

Subunit 3B exhibits a channel-like morphology (see the contour map, Figure 3-9) similar to that of bedrock. The cross sections (Figures 3-5 and 3-6), however, reveal that subunit 3B is thinnest in the areas overlying the erosional low in the bedrock surface, suggesting that subunit 3B was thicker but has been extensively modified by stream erosion. Subunit 3B is thickest at the eastern edge of the site where it overlies shale, and the overlying unit, subunit 3M, is absent. In these areas subunit 3B fills a buried tributary to the erosional bedrock low. Subunit 3B appears to have been deposited as glacial outwash or as alluvium in a lake environment.

Subunit 3M is not present in the eastern part of the site (as shown in Figures 3-5 and 3-6). The cross sections show that the top of subunit 3M is essentially flat. Subunit 3M is thickest in areas corresponding to the bedrock low, but it thins onto bedrock highs. The flat upper surface and distribution of subunit 3M and the unconformable nature of the contact with subunit 3B suggest that subunit 3M was deposited in a glacial environment where it filled a previously existing stream channel. The fine-grained lithologies that make up the subunit are the result of deposition in a low-energy environment such as a lake or an abandoned stream channel. Subunit 3M onlaps subunit 3B, onto the shale bedrock high located in the southeastern part of the site. An erosional stream valley and associated floodplain developed in the 3B surface during the interval of time before deposition of the 3M subunit. The erosion was controlled in part by the morphology of the bedrock. Low-energy stream or lake depositional environments are consistent with interpretations of the local geology (Hoffman 1987) that place SLAPS on the edge of a northward-draining valley near the southeastern edge of the Florissant Basin. An isopach map of subunit 3M is shown in Figure 3-10. This subunit is important to the interpretation of the groundwater hydrology of the site because it is an aquitard. The significance of subunit 3M is discussed further in Section 4.2.

A structure contour map of the top of Unit 3 (subunit 3T) is shown in Figure 3-11. Similar to the units below, the top of subunit 3T exhibits a slight depression centered over the erosional feature in the bedrock surface. However, the depression is not as pronounced at the southern boundary of the site. The cross sections (Figures 3-5 and 3-6) reveal the contact between Units 2 and 3 to be an irregular contact that probably developed as a result of stream erosion of the upper surface of Unit 3. The similarity of lithologies for subunits 3B and 3T suggests that they were deposited in similar depositional environments. The fine-grained nature of the sediments that make up these subunits suggests that deposition of the subunits was in a low-energy environment.

The cross sections show that the thickness of Unit 2 is relatively consistent across the site, sloping gently to the west. Unit 2 has been classified as a loess deposit (Weston 1982). Before fill was placed at SLAPS, Unit 2 was subjected to a period of erosion.

An isopach map of Unit 1 is presented in Figure 3-12. This map reflects surface topography; areas where the fill is thin correspond to depressions in the surface, and areas where the fill is thick tend to be under areas of higher surface elevation. The isopach map also shows that the thickest sections of fill material were placed south of Coldwater Creek. Unit 1 ranges in thickness from absent to 0.15 m (0.5 ft) near the center of SLAPS to 4.25 m (14 ft) near where the drainage ditch that crosses the ball fields enters Coldwater Creek. The proposed location of the disposal facility (shown in Figure 1-2) overlies some of the thickest areas of fill material.

In summary, the surface of the bedrock underlying SLAPS was eroded to form a valley. In the deepest part of this valley, limestone is the first bedrock unit encountered; away from the axis of the erosional valley, shale is the first bedrock unit encountered. The valley has been filled by young fluvial/glacial sediments. A thin layer of unevenly distributed residuum (Unit 4) occurs in the deeper parts of the valley. This unit is overlain by a thick sequence of glaciolacustrine sediments (Unit 3), which are thickest over the deepest part of the bedrock erosional low. Unit 2, a loess unit that overlies Unit 3, has a consistent thickness across the site. The uppermost unit, Unit 1, which consists of fill material, is irregularly distributed across the site and is thickest south and east of Cold Water Creek.

3.2 GEOTECHNICAL ANALYSIS OF SITE SOILS

A primary consideration of site suitability is the determination of the ability of the soils to support a disposal facility. This determination requires an estimation of possible settlement consolidation and an evaluation of the safety margin against shear failure of the base material. Consolidation and shear strength data were not obtained for SLAPS soils during previous investigations. The geotechnical properties of these soils will need to be investigated before the ability of the soils to support a disposal facility can be further evaluated.

Geologic borings indicate that a thick layer of heterogeneous fill (rubble) as much as 4.3 m (14 ft) thick overlies the virgin soils at the site. The density and state of compaction of the fill is variable throughout the site, making extrapolations based on isolated soil tests uncertain.

Three alternatives have been proposed to improve the long-term stability of the site for construction of a disposal facility. The alternatives for treatment of existing rubble fill (both contaminated and uncontaminated) and contaminated virgin soil (below contaminated fill, but within the boundary of the proposed facility) are:

1. Leaving the contaminated materials (fill and soil) in place and compacting the fill in situ by means of controlled dynamic consolidation. This would create a uniform base over which to place imported contaminated soils. The materials in the facility would not be fully encapsulated, but leaching would be limited.

2. Excavating the contaminated fill and contaminated virgin soils and replacing them with clean compacted soil. The remaining (uncontaminated) onsite fill would be compacted in situ by controlled dynamic consolidation. The excavated contaminated fill and soil would be placed in the facility as part of the contaminated imported soils. Leaching would be more limited than in alternative (1) because much of the contaminated groundwater would be removed during excavation, and imported clean fill would increase the capacity for cation exchange, thereby retarding the migration of contamination. This alternative would also increase the long-term stability of the facility.

3. Fully encapsulating the contaminated, onsite or imported materials. This alternative is similar to alternative (2), except that after the contaminated soil and rubble material has been replaced by clean backfill and the remaining clean rubble fill has been dynamically compacted, a bottom liner [i.e., 0.9 m (3 ft) of clay] would be constructed. The imported contaminated soils, together with the contaminated fill and virgin soil, would then be placed in the facility on top of the clay liner.

To evaluate the cost impact of the three alternatives, volumes of fill and contaminated virgin soil were calculated. The known values for fill thicknesses throughout the site were used to prepare an isopach map (Figure 3-12) from which volumes of rubble fill were calculated using the method of average squares. Many additional borings were drilled to establish the depth or thickness of contaminated fill and virgin soils. The resulting data were used to calculate the volumes of contaminated rubble fill (see Table 3-2).

If SLAPS is used as a location for a disposal facility, the virgin soil that would remain following site preparation must be tested to determine its compressibility, shear strength, and other engineering properties.

3.3 POROSITY AND PERMEABILITY OF SITE SOILS

Porosity and permeability data for sediments in Units 2, 3, 4, 5, and 6 at SLAPS are summarized in Table 3-3. Permeability data were obtained for Unit 5 during the December field program. The complete list of data is presented in Appendix A. Total porosity was calculated from data presented in Appendix A using the relation:

$$e = \left(\frac{G \times \gamma_w}{\gamma_d}\right) - 1$$

where: e = void ratio

G = specific gravity (Appendix A)

γ_w = 62.4 pcf = unit weight of water

γ_d = dry unit weight (Appendix A)

and:

$$n = \frac{e}{1 + e} \times 100\%$$

where: n = total porosity

Geometric mean permeability data, which are believed to reflect a more accurate measure of the central tendency of the data than arithmetic means do, are presented in Table 3-3. Field permeability tests were conducted following prescribed procedures (Weston 1982, BNI 1985 and 1989a).

Two constant-head, single-packer permeability tests were conducted on the limestone bedrock (Unit 6); the permeabilities were 7.5×10^{-7} and 1.1×10^{-5} cm/s (0.78 and 11 ft/yr), which is comparable to published values for the permeability of limestones (Freeze and Cherry 1979). Flow through limestone is variable and may occur through interstitial void spaces and/or along joints, fractures, or bedding planes in the rock.

Two slug tests were performed in wells installed in the shale bedrock (Unit 5). The permeabilities were 7.5 x 10^{-8} and 1.6 x 10^{-7} cm/s (7.7 x 10^{-2} and 1.7 x 10^{-1} ft/yr). These values fall within the ranges of published permeabilities for shale (Freeze and Cherry, 1979). Flow through shale, as through limestone, is variable, occurring through fractures and joints or along bedding planes.

Porosity values for Unit 4 ranged from 41.8 to 46.8 percent. Three falling-head permeability tests were performed in the field; the results ranged from 4.1 x 10^{-6} to 2.2 x 10^{-4} cm/s (4.2 to 231 ft/yr). Falling-head permeability tests are conducted to determine mean permeability, which is a measure of both horizontal and vertical permeability in a unit. Vertical triaxial cell laboratory permeabilities ranged from 2 x 10^{-8} to 2 x 10^{-5} cm/s (0.021 to 20.1 ft/yr). This wide range of permeabilities reflects the heterogeneity of sediments composing Unit 4.

Porosities in subunit 3B (36.2 to 39.4 percent) are slightly lower than those in Unit 4. The mean field permeability was determined in one borehole through the use of a falling-head, open-hole test. Similar to Unit 4, the permeability was 2 x 10^{-4} cm/s (200 ft/yr), which is higher than expected. Horizontal field permeabilities, determined by slug tests, were from 1.2 x 10^{-6} to 2.9 x 10^{-6} cm/s (1.2 to 3 ft/yr). Triaxial cell vertical permeabilities determined in the laboratory ranged from 1.7 x 10^{-7} to 5.7 x 10^{-7} cm/s (0.18 to 0.59 ft/yr).

Subunit 3M had the highest values (33.4 to 51.7 percent) for porosity of any unit. Vertical permeabilities, measured in a laboratory triaxial cell, ranged from 1.4 x 10^{-8} to 7 x 10^{-7} cm/s (0.014 to 0.72 ft/yr). The permeability values for subunit 3M are the same order of magnitude as values reported for lake clay sediments in the area (Hoffman 1987) but an order of magnitude less than vertical permeabilities measured for subunits 3B and 3T. The relatively high porosity and low permeability values for subunit 3M are common for clays.

Values calculated for porosities in subunit 3T ranged from 34.4 to 46.7 percent. Horizontal permeabilities, calculated from slug tests, ranged from 1.2 x 10^{-6} to

1.5×10^{-4} cm/s (1.2 to 155 ft/yr). Vertical permeabilities, measured in the laboratory, ranged from 3.0×10^{-8} to 7.0×10^{-5} cm/s (0.03 to 72.4 ft/yr). The range of values for horizontal and vertical permeabilities in subunit 3T is greater than that in subunit 3B. Permeability values for subunits 3B and 3T are the same order of magnitude as values reported for silty clay lake sediments in the area (Hoffman 1987).

Porosities in Unit 2 (32.3 to 50.9 percent) are similar to those in subunit 3T. The horizontal permeabilities of the soils in Unit 2, measured by field tests, ranged from 4.8×10^{-5} to 3×10^{-4} cm/s (50 to 310 ft/yr). Vertical permeabilities, measured in a laboratory triaxial cell, ranged from 1.4×10^{-8} to 2.0×10^{-4} cm/s (0.02 to 206.9 ft/yr). The large difference between the horizontal and vertical permeabilities may reflect variations in the depositional environment of the unit.

3.4 GEOCHEMICAL PROPERTIES OF SITE SOILS

In considering SLAPS as a potential permanent storage site, the geochemical characteristics of the natural materials must be evaluated to determine the capacity of the sediments to inhibit the transport of radionuclides in groundwater if a release occurs. A detailed description of the sedimentary strata underlying SLAPS is presented in Section 3.1. Additional information on the composition of natural materials can be found in Weston (1982) and BNI (1989a).

The radionuclides of concern at SLAPS include thorium-232, thorium-230, radium-226, and uranium-238. Other radionuclides at SLAPS that were identified in the source term analysis (BNI 1993a) to be potentially significant contributors to risk are actinium-227 and protactinium-231. The important factors that govern the fate and transport of radionuclides are decay rate, solubility, and sorption. Table 3-4 shows the half-lives, solubility, and distribution coefficients of the radionuclides of concern. The table shows that distribution coefficients are highest in neutral to near-neutral pH environments and in soils that are high in clay content.

Site-specific distribution ratios for uranium and radium measured in SLAPS soils are presented in Appendix A. Site-specific thorium distribution ratios were not measured, but the data in Table 3-4 indicate that thorium distribution coefficients are similar to or greater than the uranium and radium distribution coefficients.

Site-specific uranium distribution ratios were measured in Units 1, 2, 4, and 5 and subunits 3T, 3M, and 3B. Subunit 3T has the highest geometric mean distribution ratio (982 ml/gm), and subunit 3M has the lowest geometric mean distribution ratio (21 ml/gm). Units 1, 2, and 4 and subunit 3B have geometric mean distribution ratios of 45, 102, 441, and 112 ml/gm, respectively. A single uranium distribution ratio measurement of 2,100 ml/gm was obtained for Unit 5. Laboratory measurements used a uranyl sulfate compound that has lower solubility and lower standard distribution coefficient values than a uranyl oxide form. Uranyl oxide is the form most likely to exist in the environment at SLAPS. Therefore values used in the model are based on a compound that has a low distribution coefficient and are conservative for the purposes of simulation.

The distribution ratios probably reflect the variations in clay mineralogy among the units and, to a lesser extent, the presence of organic materials. The saturated sedimentary section at SLAPS contains groundwater low in total dissolved solids (TDSs) and of neutral pH. The sedimentary section at the site is composed of clay-rich, unconsolidated sediments overlying Pennsylvanian-age shales and Mississippian-age limestones. X-ray analyses of soils at SLAPS (Weston 1982) revealed that Unit 3 (as defined above) unconsolidated sediments contain significant percentages of illite (35 to 55 percent) and smectite (25 to 45 percent) clays with lesser amounts of kaolinite and chlorite. Unit 3M is significantly lower in percent illite and correspondingly higher in kaolinite percentage. This compositional difference may be the reason for distinctively different distribution coefficient values for the 3T and 3M units. Unit 2 contains as much as 10 percent chlorite and slightly smaller percentages of illite and smectite. Clays retard the movement of radionuclides by a variety of processes including adsorption, coprecipitation, and cation exchange. Cation exchange capacities (CECs) were measured in site soil samples, and the results are presented in Table 3-5.

Comparison of these site-specific measurements with published CEC values for clay minerals (Grim 1968) indicates that the site-specific values fall within the range of CECs for illite and chlorite, 10 to 40 meq/100 gm each.

Site-specific radium distribution ratios were measured in a single sample from subunit 3T. The arithmetic mean of distribution ratio measurements on the sample is 910 ml/gm. Comparison of this value with the uranium distribution ratios suggests that radium distribution ratios in SLAPS soils are approximately the same as the uranium distribution ratios.

In summary, the stratigraphic section underlying SLAPS is composed of clay-rich sediments, which tend to retard the transport of radionuclides in the subsurface via groundwater. Clays and organic materials also retard the movement of dissolved metals and some organic compounds that may be associated with the materials that may be stored at SLAPS.

FIGURES FOR SECTION 3.0

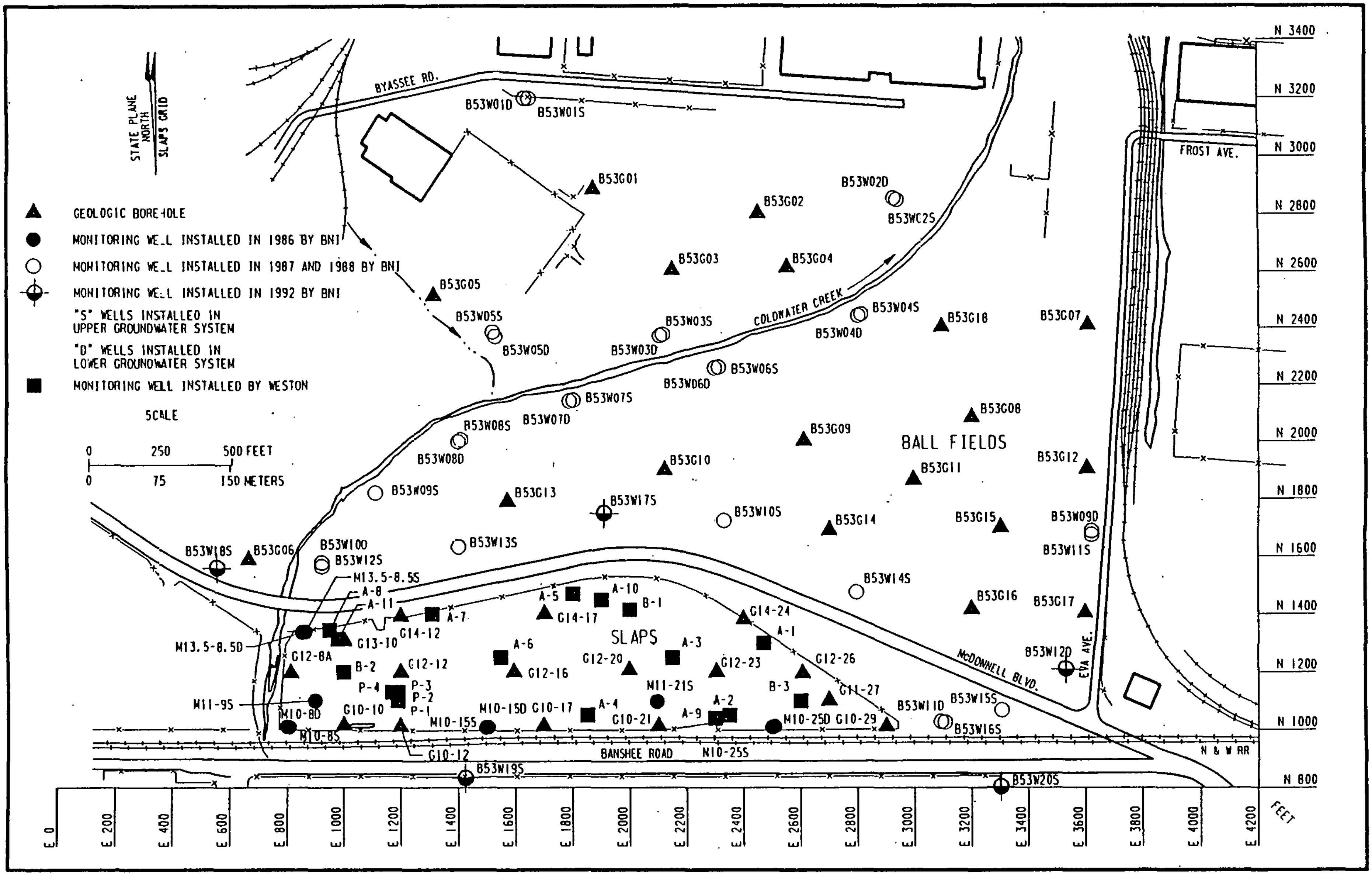

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Figure 3-1
Borehole and Monitoring Well Locations

Period	Epoch	Stratigraphic Unit	Columnar Section	Thickness (ft)	Description
Quaternary	Holocene	FILL/TOPSOIL		0-14	**UNIT 1** Fill – Sand, silt, clay, concrete, rubble. Topsoil – Organic silts, clayey silts, wood, fine sand.
	Pleistocene	LOESS (CLAYEY SILT)		11-32	**UNIT 2** Clayey silts, fine sands, commonly mottled with iron oxide staining. Scattered roots and organic material, and a few fossils.
		GLACIO-LACUSTRINE SERIES: SILTY CLAY		19-75 (3) 9-27 (3T)	**UNIT 3** Silty clay with scattered organic blebs and peat stringers. Moderate plasiticity. Moist to saturated. **(3T)**
		VARVED CLAY		0-8	Alternating layers of dark and light clay as much as 1/16 inch thick. **(3M)**
		CLAY		0-26	Dense, stiff, moist, highly plastic clay. **(3M)**
		SILTY CLAY		10-29	Similiar to upper silty clay. Probable un-conformable contact with highly plastic clay. **(3B)**
		BASAL CLAYEY & SANDY GRAVEL		0-6	**UNIT 4** Glacial clayey gravels, sands, and sandy gravels. Mostly chert.
PENNSYLVANIAN		CHEROKEE (?) GROUP (undifferentiated)		0-35	**UNIT 5** BEDROCK: Interbedded silty clay/shale, lignite/coal, sandstone, and siltstone. Erosionally truncated by glaciolacustrine sequences.
MISSISSIPPIAN		STE. GENEVIEVE (?) LIMESTONE		10+	**UNIT 6** BEDROCK: Hard, white to olive, well-cemented, sandy limestone with interbedded shale laminations.

Figure 3-2
Generalized Stratigraphic Column for the SLAPS/Ball Field Area

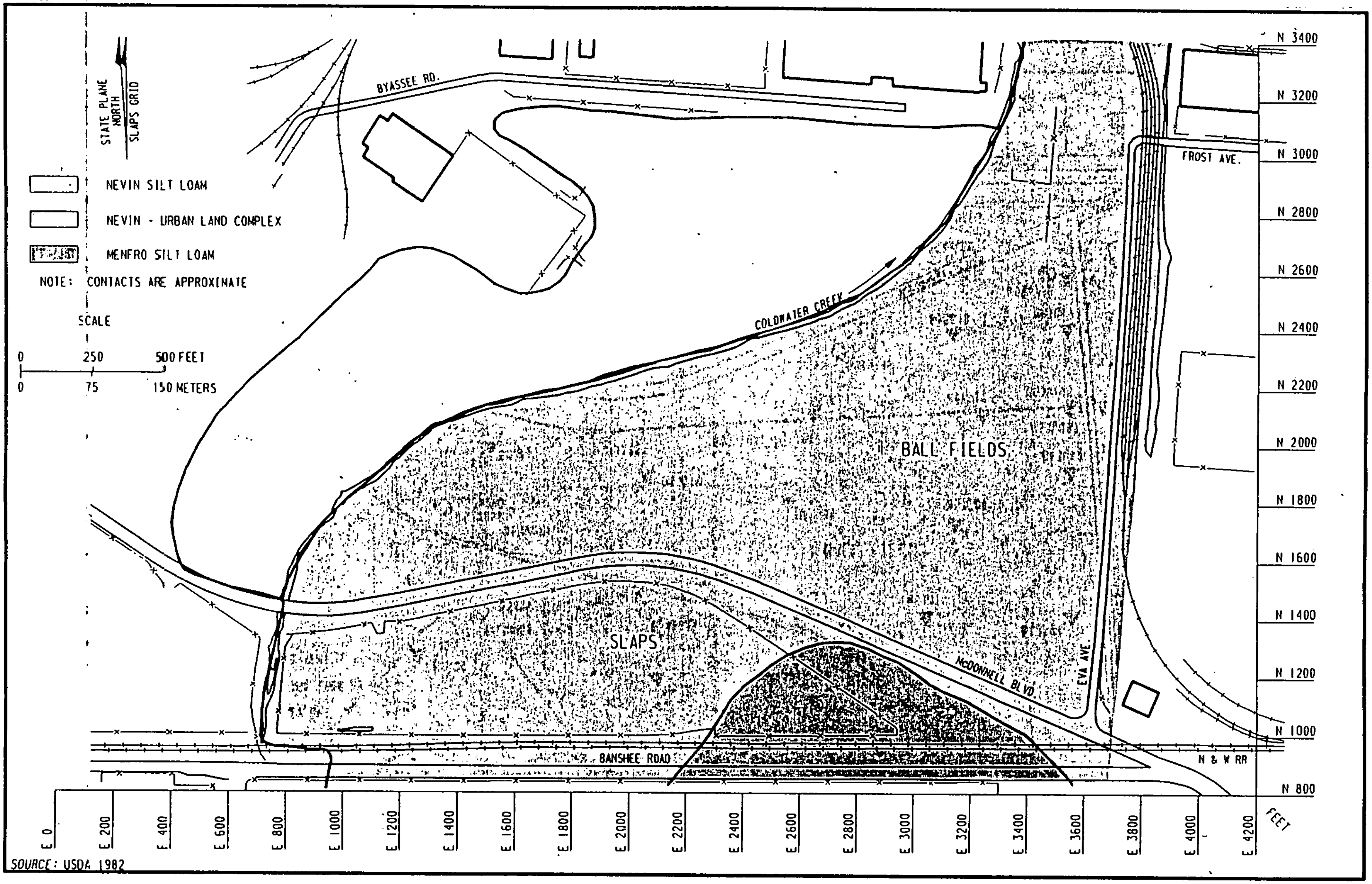

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Figure 3-3
Soil Map of SLAPS and Vicinity

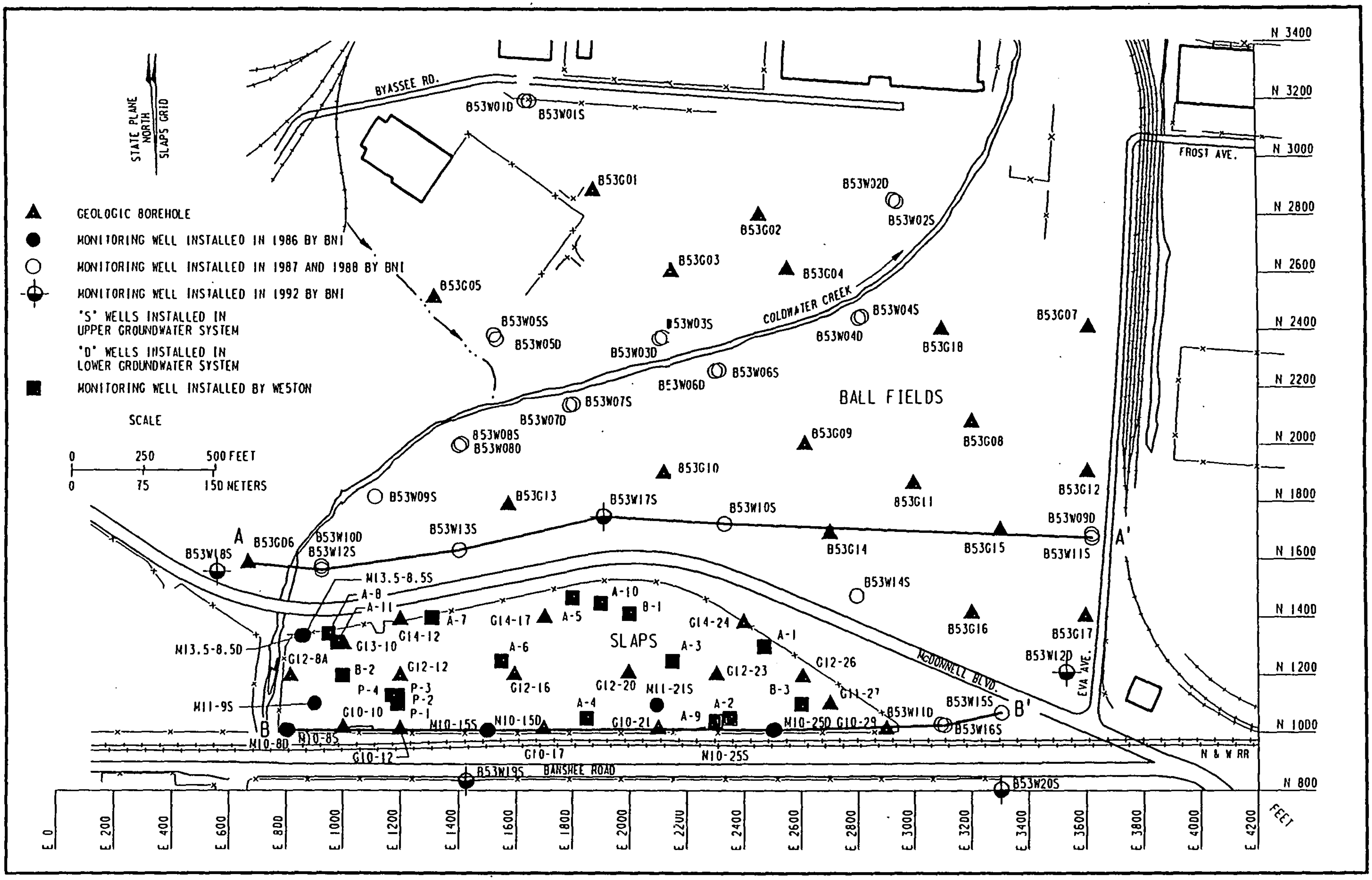

Figure 3-4
Locations of Cross Sections

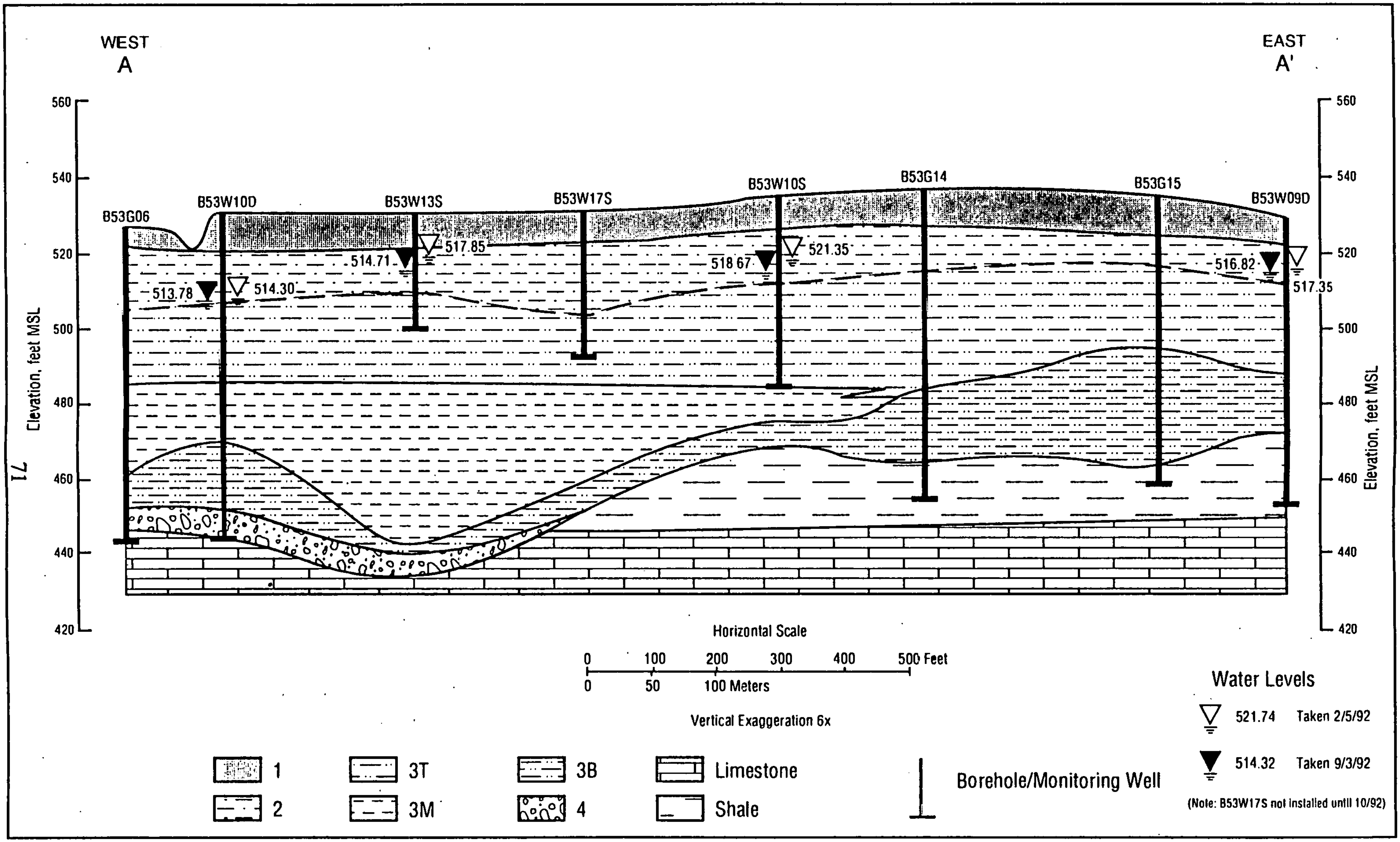

Figure 3-5
Cross Section A – A'

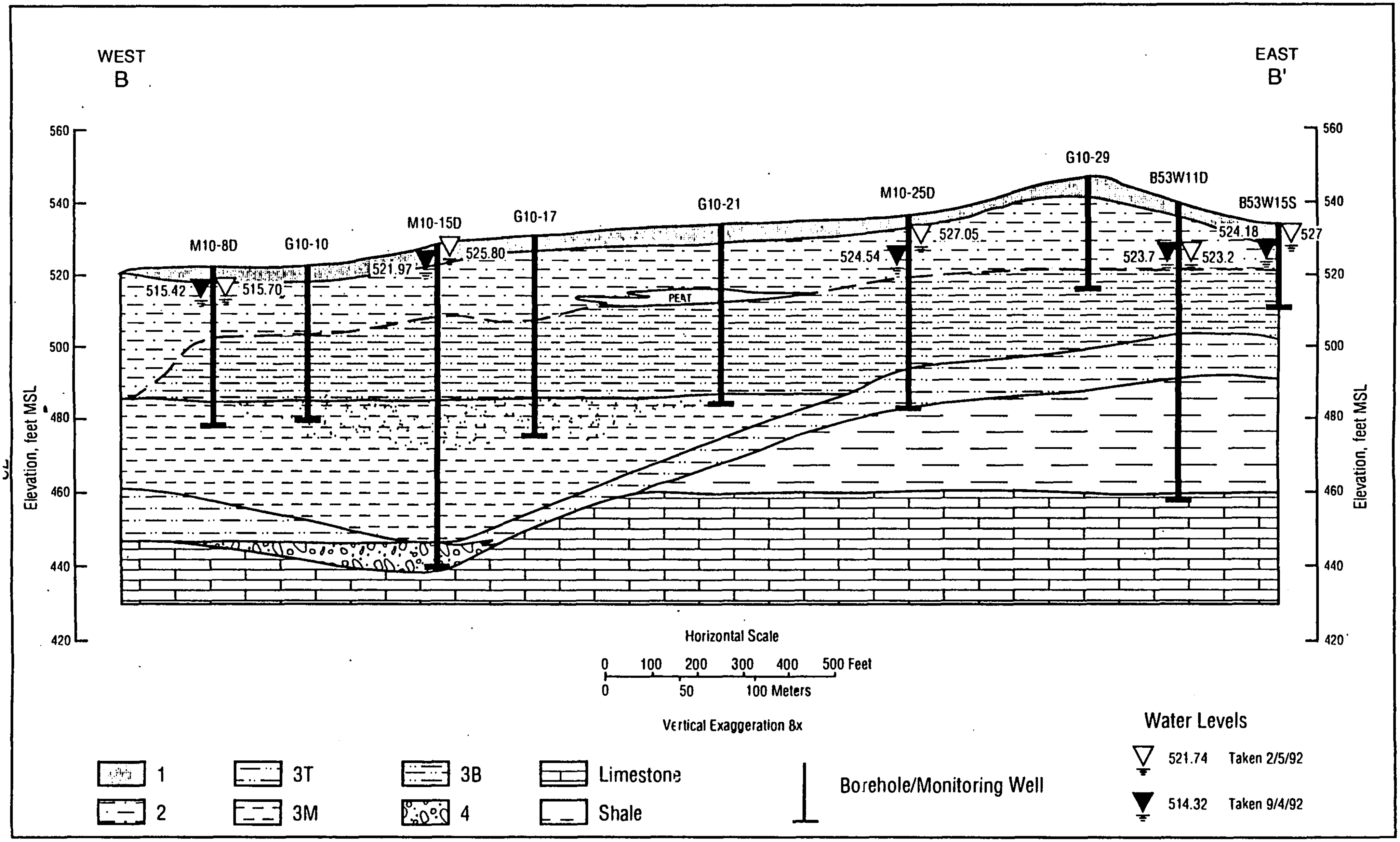

Figure 3-6
Cross Section B – B'

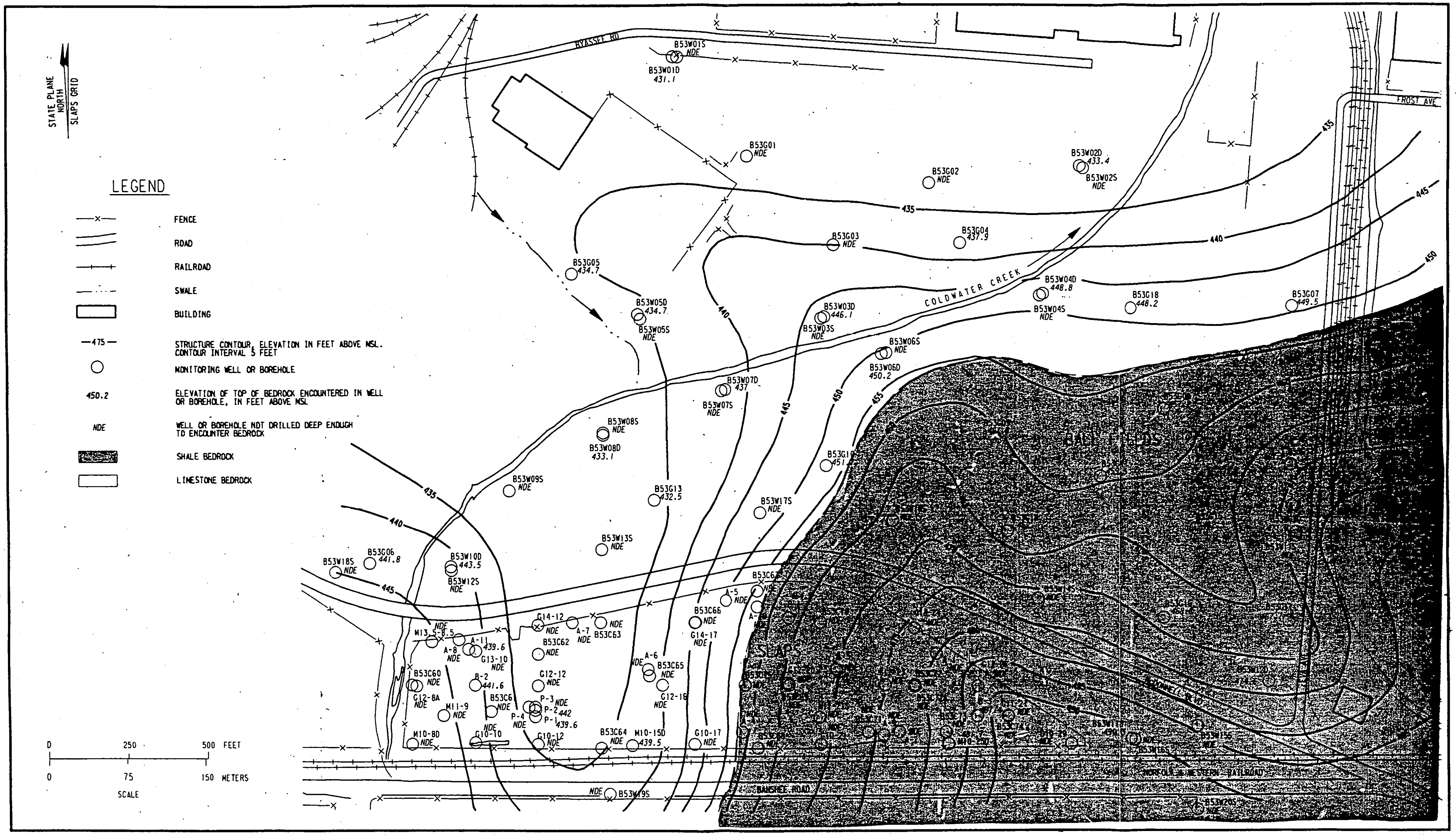

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Figure 3-7
Structure Contour Map of Top of Bedrock

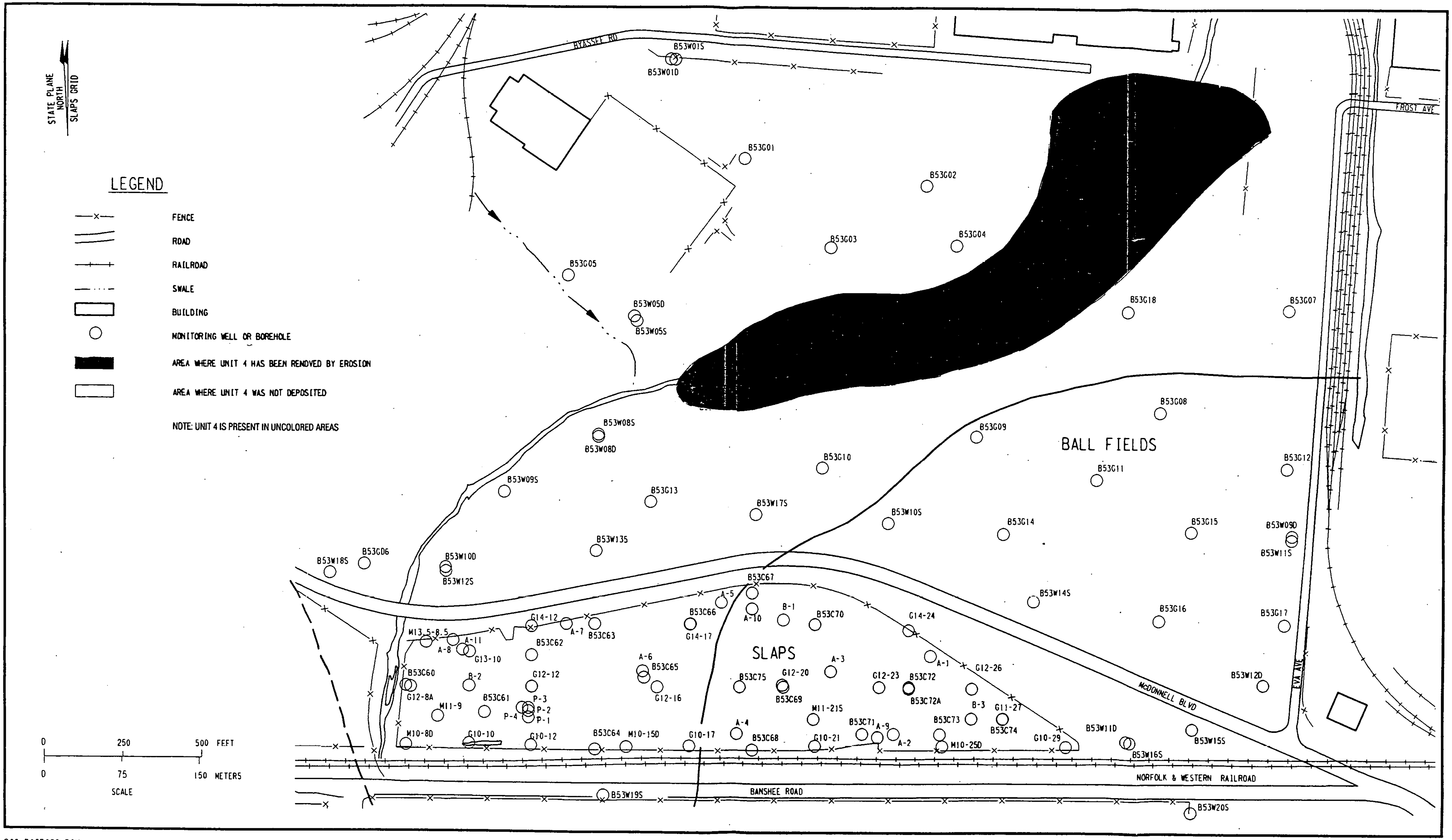

Figure 3-8
Distribution of Unit 4

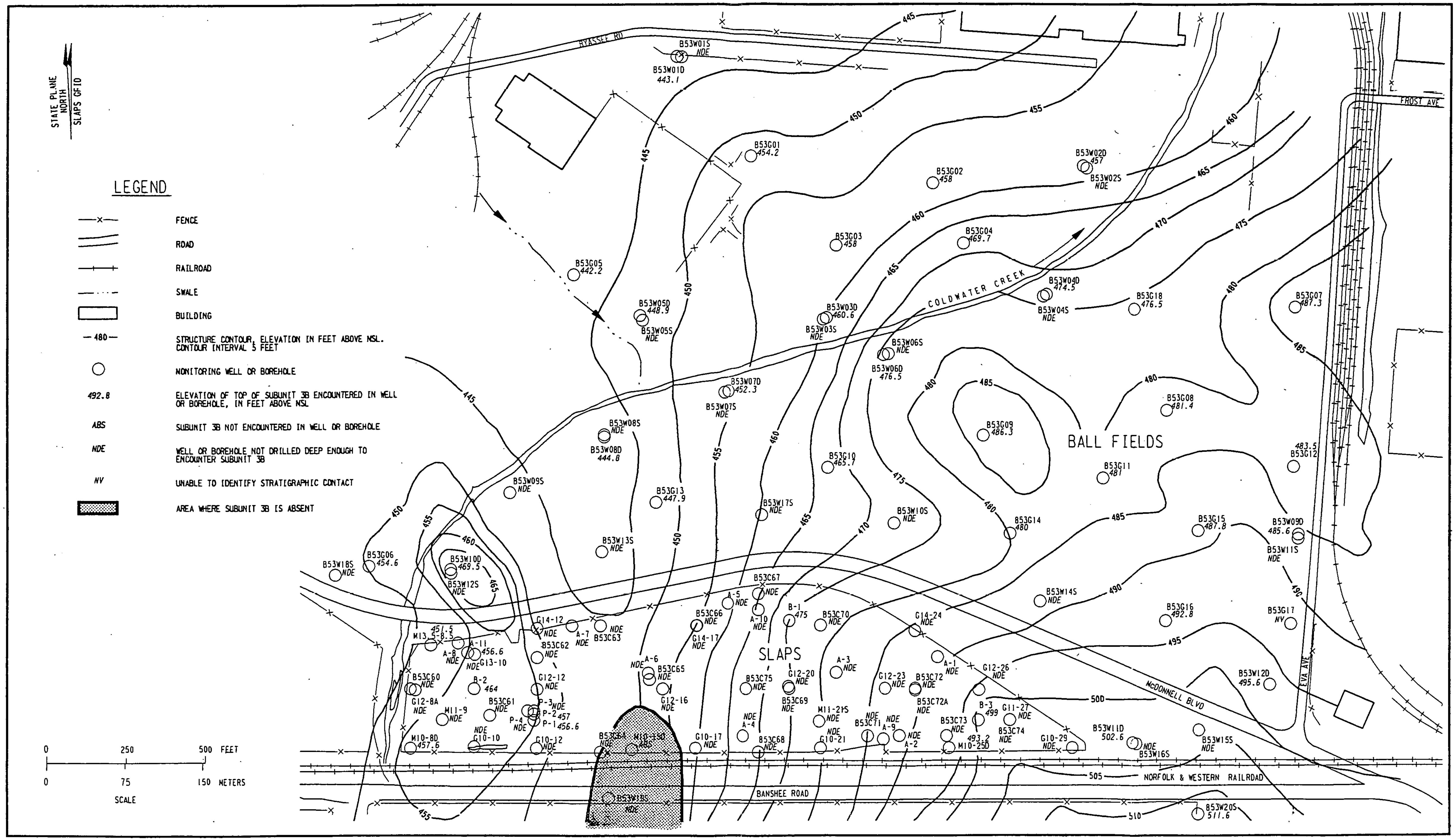

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Figure 3-9
Structure Contour Map of Top of Subunit 3B

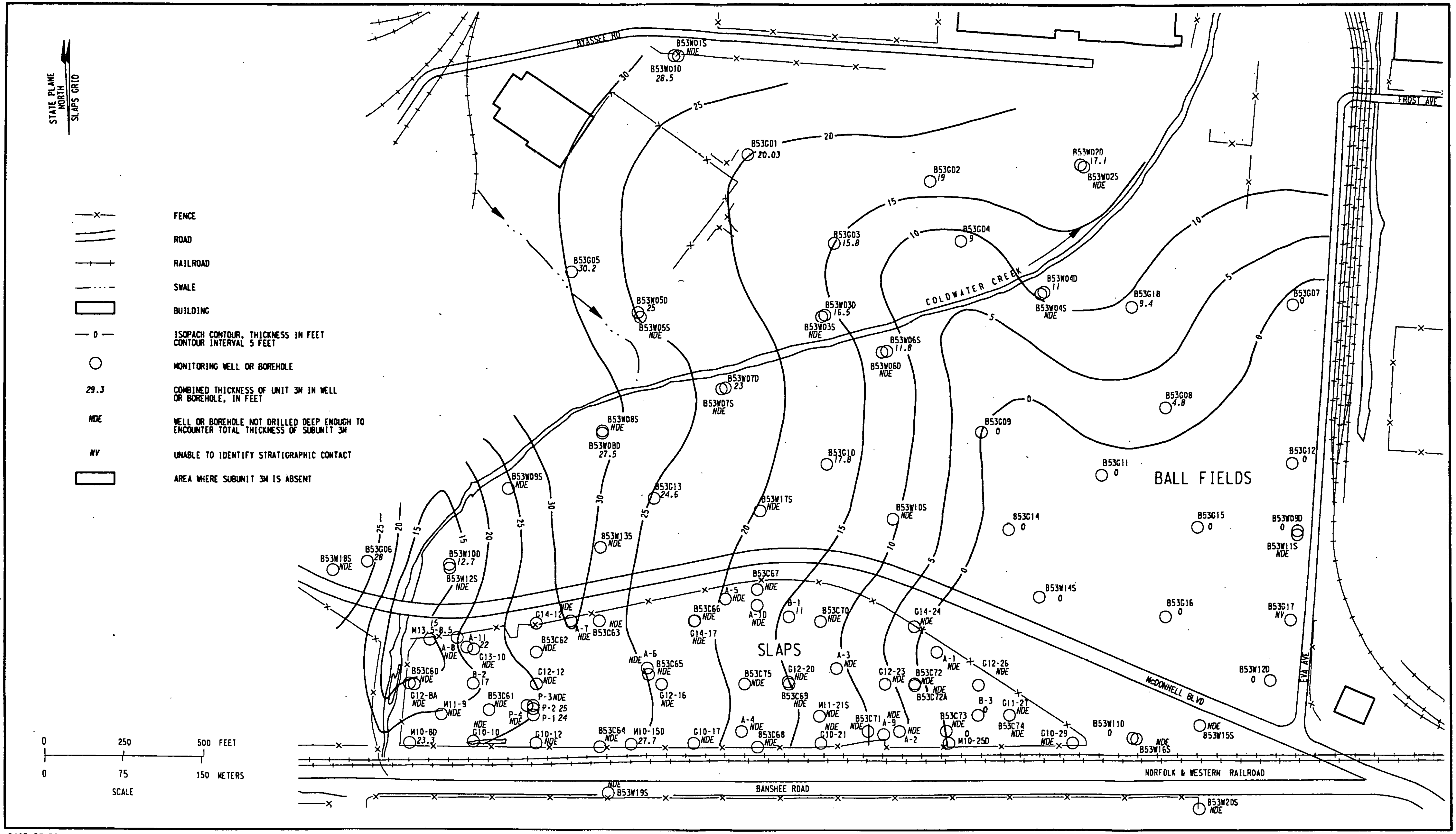

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Figure 3-10
Isopach Map of Subunit 3M

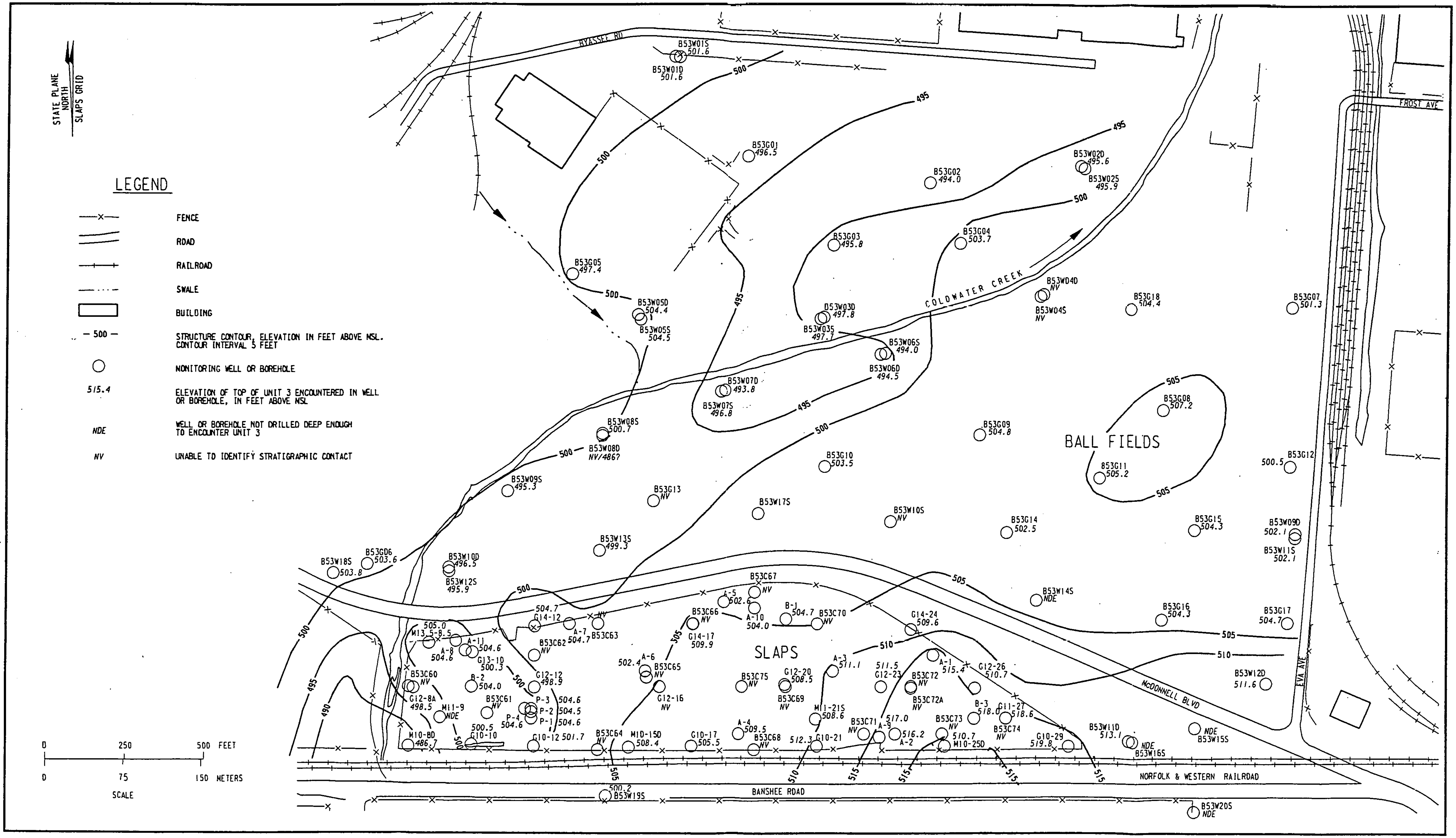

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Figure 3-11
Structure Contour Map of Top of Unit 3

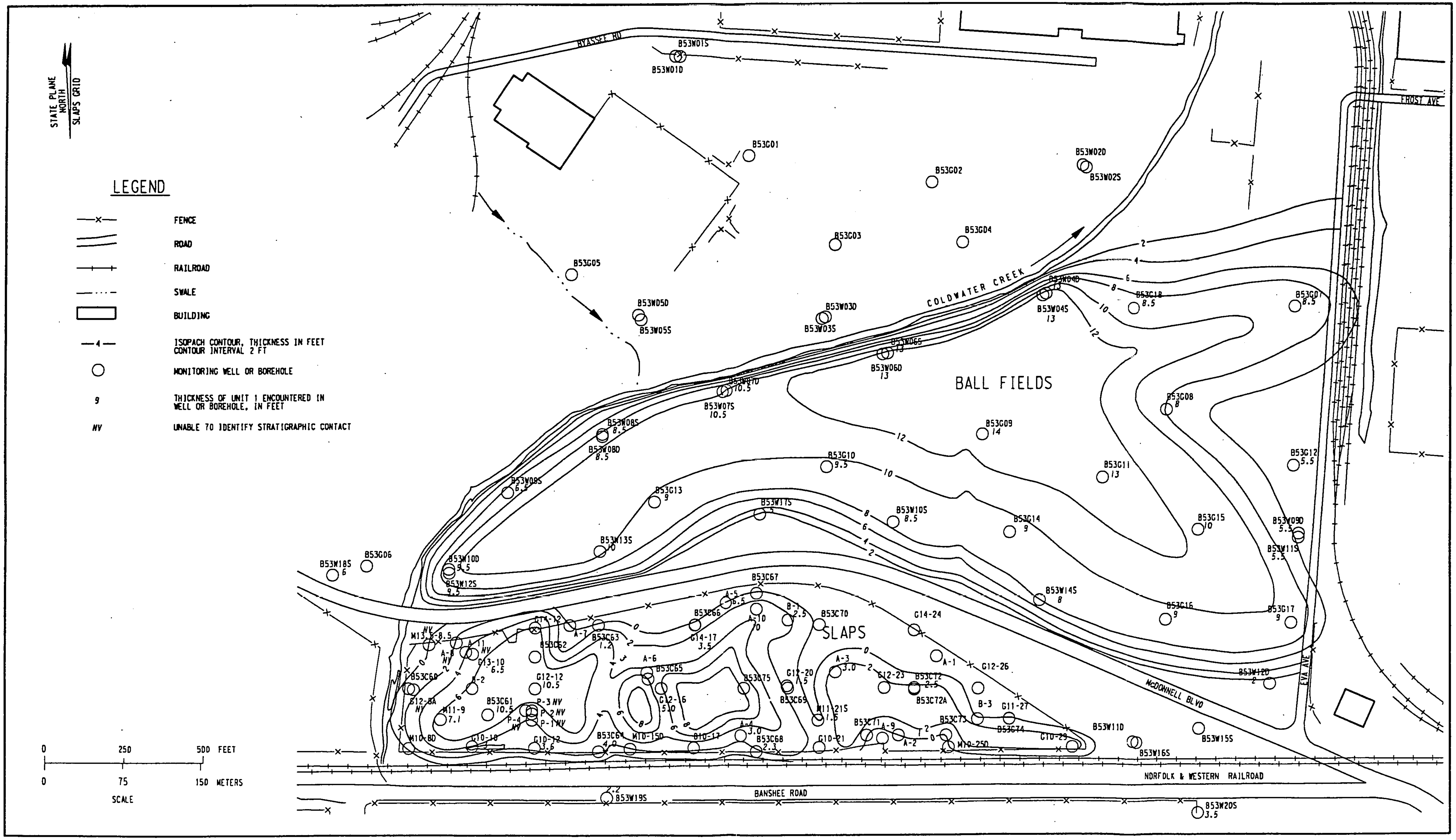

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Figure 3-12
Isopach Map of Rubble

TABLES FOR SECTION 3.0

Table 3-1

Characteristics of Unconsolidated Sediments[a] at SLAPS

Unit	Grain Size: sand (%)	Grain Size: fines[b] (%)	Atterberg Limits[c]: LL	Atterberg Limits[c]: PL	Atterberg Limits[c]: PI	Unified Soil Classification[d]
2	9	91	33	24	9	ML-CL
3T	7	93	35	21	14	CL
3M	8	92	66	25	41	CH
3B	14	86	38	22	16	CL
4	47	53	[e]	[e]	[e]	GC-SM-ML

Note: Includes data collected by BNI (1992) and Weston (1982). A complete list of all data can be found in Appendix A of this report.

[a]All values are arithmetic means.

[b]Fines represent the percentage of the sample finer than the number 200 sieve (0.074 mm).

[c]Atterberg Limits:
LL = liquid limit.
PL = plastic limit.
PI = plasticity index.

[d]Unified Soil Classification:
ML = Inorganic silts, silty or clayey fine-grained sands.
CL = Low-plasticity clays, gravelly clays, silty clays, sandy clays.
CH = High-plasticity clays, fat clays.
GC = Clayey gravels, poorly graded gravel-sand-clay mixtures.
SM = Silty sand, sand-silt mixtures.

[e]Not tested because of high sand content.

Table 3-2

Calculated Volumes of Rubble Fill

Rubble Fill/Contaminated Clay (Within Boundary of Proposed Pile)		Volume (yd^3)
Alternative 1:	Volume of rubble fill to be dynamically compacted	602,407.4
Alternative 2:	A - Volume of contaminated fill at SLAPS and ball fields to be replaced with clean compacted backfill	79,185.2
	B - Volume of contaminated virgin soil at SLAPS and ball fields to be replaced with clean compacted backfill	46,537.0
		125,722.2
	C - Volume of clean rubble fill to be dynamically compacted	523,222.2
Alternative 3:	Volume of bottom clay liner (assumed to be 3 ft. thick) over an area of about 1,885,000 ft^2 to be added to the same volumes of alternative 2	210,000.0

Note: There is additional contaminated virgin soil that is not under the boundary of the proposed disposal cell.

Table 3-3

Porosity and Permeability of Sediments[a] at SLAPS

Unit	Mean Porosity[b] (%)	Geometric Mean Vertical Laboratory Permeability (cm/s)	Geometric Mean Field Permeability (cm/s)
2	41.6 (10)[c]	2.5×10^{-6} (9)	1.2×10^{-4} (5)
3T	41.0 (11)	2.7×10^{-6} (13)	1.1×10^{-5} (8)
3M	45.3 (4)	5.5×10^{-8} (4)	3.1×10^{-5} (1)
3B	37.8 (2)	3.1×10^{-7} (2)	1.5×10^{-5} (7)
4	44.3 (2)	1.3×10^{-6} (4)	3.7×10^{-5} (3)
5	[d]	[d]	1.1×10^{-7} (2)
6	[d]	[d]	2.9×10^{-6} (2)

[a]A complete list of all data is presented in Appendix A.

[b]Porosity is calculated from dry unit weight and specific gravity.

[c]The numbers in parentheses represent the number of analyses.

[d]Test not performed on unit.

Table 3-4

Distribution Coefficients for Radionuclides of Concern at SLAPS

Radionuclide	Half-Life (years)	Solubility[a] (mg/L)	pH	Distribution Coefficient[b] (ml/gm)	Source[c]	Notes
Uranium	4.5×10^9	6	2	0	A	
		(Uranyl peroxide)	8	100		
			10	600		
			13	50		
			2.2	1.3	B	
			7.7	23,000		
			4 - 9	45	C	Geometric mean; geometric standard deviation = 3.7
			6.5	62,000	D	Silt loam; hexavalent uranium; calcium saturated
			6.5	4,400		Clay soil; hexavalent uranium; with calcium nitrate
			5.5	300		Clay soil; 1 ppm uranium oxide ion
			10	2,000		Clay soil; 1 ppm uranium oxide ion
			12	270		Clay soil; 1 ppm uranium oxide ion
Thorium	1.41×10^{10}	16,500	2	500	A	
		(Thorium sulfate)	5	3,000		
			7	50,000		
			13	50		
			2.2	1.2	B	
			7.7	80,000		

Table 3-4

(continued)

Radionuclide	Half-Life (years)	Solubility[a] (mg/L)	pH	Distribution Coefficient[b] (ml/gm)	Source[c]	Notes
Thorium (continued)	1.41×10^{10}	16,500	4 - 9	60,000	C	Geometric mean; geometric standard deviation = 4.5
		(Thorium sulfate)	6.5	160,000	D	Silt loam; calcium-saturated clay
			6.5	400,000		Montmorillonite; calcium saturated
			6.5	160,000		Clay soil; 5 mM calcium nitrate
			8.15	270 - 10,000		Silt/clay
			3.2	120		Illite; 1 gm/L thorium
			3.2	1,000		Illite; 0.1 gm/L thorium
			>6	<100,000		Illite; 0.1 gm/L thorium
Radium	1,620	0.02	2	0	E	
		(Radium sulfate)	4	12		
			6	60		
			7	100		
			2.2	13	B	
			7.7	2,400		

[a]Source: CRC 1985.
[b]Distribution coefficient is measured for all isotopes of the same valence state of a given element; it is not isotope-specific.
[c]Sources: A = Rancon 1973.
B = Gee et al. 1980.
C = Baes and Sharp 1983.
D = Isherwood 1981.
E = U.S. Nuclear Regulatory Commission 1980

Table 3-5

Cation Exchange Capacities of Soils at SLAPS

Borehole	Depth (ft)	Sedimentary Unit	Cation Exchange Capacity (meq/100 gm)
B-2[a]	19	2	18.30
B53W19S[b]	6 - 8	2	24.69
B53W19S[b]	12 - 14	2	14.57
B53W20S[b]	14-16	2	17.62
B53W20S[b]	17 - 19	2	16.80
B-2[a]	26.5	3T	17.10
B-2[a]	29	3T	13.50
B-2[a]	39	3T	12.60
B53W12D[b]	38 - 40	3T	22.40
B53W12D[b]	52.5 - 54.5	3T	19.90
B53W17S[b]	24 - 26	3T	21.42
B53W17S[b]	28 - 30	3T	25.77
B53W18S[b]	25 - 27	3T	26.97
B53W18S[b]	30 - 32	3T	19.47
B-1[a]	47.5	3M	26.10
B-2[a]	49	3M	30.60
B-2[a]	56.5	3M	26.70

[a]Source: Weston 1982.
[b]Source: Appendix A.

4.0 SITE HYDROGEOLOGIC CHARACTERISTICS

4.1 REGIONAL HYDROGEOLOGY

The water-bearing bedrock of the St. Louis area (see Figure 2-1) has been separated into five groups based on lithology, geographic distribution, and overall water quality. The groups are: 1) Post-Maquoketa (all bedrock units above the late-Ordovician Maquoketa Shale), 2) Kimmswick-Joachim (all units below the Maquoketa but above the Joachim Dolomite), 3) St. Peter-Everton (the St. Peter Sandstone and the Everton Formation), 4) Powell-Gasconade (all units in the Canadian series of early-Ordovician age), and 5) Eminence-Lamotte (all units below the bottom of the Gasconade Formation) (Miller 1974).

The Post-Maquoketa is potentially the most important aquifer underlying SLAPS. It is the shallowest aquifer capable of yielding appreciable water and the deepest aquifer yielding potable water. Water-bearing zones in the Post-Maquoketa primarily contain limestones. Locally, the water-bearing zones in the post-Maquoketa are overlain by low-permeability Pennsylvanian strata. Wells installed in Post-Maquoketa rocks typically yield 3.8×10^{-3} to 1.1×10^{-2} L/min (1 to 3 gpm) (Vandike 1992). The aquifers below the Post-Maquoketa are capable of yielding more than 0.19 L/min (50 gpm), but the water is high in chloride, sulfate, and TDSs (Miller 1974, Fuller 1962). These aquifer groups become important to the west and south of SLAPS.

Another important water-bearing unit is the water-saturated basal alluvium underlying the floodplains of the Mississippi, Missouri, and Meramec rivers (Miller 1974). Well yields as high as 1.9 L/min (500 gpm) are typical of alluvial aquifers, but alluvium does not occur at SLAPS.

Bedrock aquifers in the SLAPS area receive recharge indirectly from the infiltration of precipitation. Alluvial aquifers are recharged by infiltration of water during flooding and sustained high river stages, infiltration of precipitation, and underflow from underlying bedrock (Miller 1974).

Wells installed in bedrock aquifers in the St. Louis area tend to encounter confined conditions, and the predominant direction of groundwater flow in bedrock is to the north or northeast. Groundwater movement in the alluvial aquifer is generally toward the major streams with which the aquifer is hydraulically connected (Miller 1974).

4.2 SITE HYDROSTRATIGRAPHY

Based on the hydrogeologic properties of the soils, the sediments underlying SLAPS have been subdivided into three hydrostratigraphic units. The first unit, a zone referred to as the upper groundwater system, consists of stratigraphic units: Unit 1, Unit 2, and subunit 3T. The second hydrostratigraphic unit, made up of subunit 3M, is a fine-grained zone that acts as an aquitard. The third hydrostratigraphic unit, a zone referred to as the lower groundwater system, is made up of subunit 3B, Unit 4, and bedrock. The porosity and permeability of each of the units are discussed in Section 3.3.

The delineation of the two groundwater systems is primarily recognized on the basis of stratigraphic position and differences in hydrostatic heads. The upper and lower groundwater systems are separated by a low-permeability clay layer, an aquitard that consists of subunit 3M (with parts of subunits 3B and 3T also contributing to it). Subunit 3M is absent in the southeastern part of the site, and recharge to the lower system may be occurring in these areas. Sediments in subunit 3M are so effective at isolating the groundwater in the upper groundwater system from the lower groundwater system that sediment in some areas of the site in subunit 3B are dry (in B53W06D and B53G14). Water levels in wells installed in the lower groundwater system are not directly influenced by precipitation, but water levels in wells installed in the upper groundwater system are (see Section 4.3.1). Although the upper and lower groundwater systems are recognized as two separate systems, water quality data (see Section 4.3.1) suggest that they may be interconnected outside the immediate area of the site and in the far southeastern corner of the study area. Comparison of groundwater level measurements and water quality in two monitoring wells screened in shale with those in wells screened in subunit 3B and Unit 4 suggests that groundwater in the shale bedrock has the same source as groundwater in the unconsolidated deposits. The recharge source for groundwater is to the southeast both onsite and offsite.

4.3 SITE SATURATED AND VADOSE ZONE HYDROGEOLOGY

4.3.1 Saturated Zone

Typical hydrographs for monitoring wells screened in the upper and lower portions of the unconsolidated deposits are shown in Figures 4-1 and 4-2, respectively. The hydrographs for monitoring wells screened in the upper system show as much as 2.7 m (9 ft) of variation in groundwater levels over the course of a year. The hydrographs for monitoring wells screened in the lower groundwater system show that water levels in these wells are not as variable, approximately 1.5 m (5 ft) or less during a year. The higher variability in the upper system is thought to be a result of the greater direct influence of individual precipitation events and evapotranspiration effects on this system.

Results from an automatic water level recorder installed at B53W11D and B53W16S (locations shown in Figure 3-1) are shown in Figure 4-3. The hydrograph covers the period from November 1992 to January 1993. The hydrograph for B53W11D is relatively flat with two sharp water level drops, which were caused by the removal of water when the well was cleaned out. In both cases, the well recovered rapidly in the first 12 hours following pump down, and then finished re-equilibrating during the next 48 hours. The hydrograph for B53W16S shows several sudden rises, all of which correspond to precipitation, which is also shown on the hydrograph. It is apparent from the hydrograph that water levels in shallow monitoring wells respond relatively rapidly to precipitation events.

Figures 4-4 and 4-5 are potentiometric surface (i.e., water level) maps of the upper and lower groundwater systems for December 3 and December 4, 1992, respectively. The upper groundwater system shows north-northwest and north-northeast flow directions, generally toward Coldwater Creek. Movement of groundwater in sediments, towards local surface water features, is typical of surficial groundwater flow in the St. Louis area (Miller 1974). The lower groundwater system flows to the northeast and west, away from a groundwater high that crosses the center of the site. Both potentiometric surfaces indicate that the southeastern corner of SLAPS is the upgradient area of the site.

Comparison of groundwater levels in shallow and deep monitoring well pairs shown on the potentiometric surface maps indicates a head differential between the upper and lower systems. In the southern and eastern parts of SLAPS, the groundwater levels show a head differential that indicates a downward flow potential (from the upper to the lower groundwater system). Along Coldwater Creek and in the northern part of SLAPS, head differentials indicate an upward flow potential (from the lower to the upper groundwater system). Along Coldwater Creek, the flow potential is a result of a lowering of the hydraulic head (i.e., decrease in the water table elevation) in the upper groundwater system by discharge of groundwater into Coldwater Creek. North of Coldwater Creek, the upward flow potential is a remnant of recharge of the confined aquifer from a source at a higher elevation.

Available hydrogeologic data for the site were used to develop a conceptual model of groundwater flow at SLAPS (Figure 4-6). Recharge to the upper groundwater system is thought to occur from offsite inflow of groundwater, infiltration of precipitation, vertical seepage from the lower groundwater system where upward flow potentials exist, and creek bed infiltration during high creek stages. Discharge from the upper groundwater system probably occurs by offsite outflow, seepage into Coldwater Creek, and vertical seepage into the lower groundwater system in areas of downward flow potential. Recharge to the lower groundwater system is thought to occur by offsite inflow and vertical seepage from the upper groundwater system where a downward flow potential exists. Discharge from the lower groundwater system probably occurs by offsite groundwater outflow and vertical seepage into the upper groundwater system in areas of upward flow potential.

As shown in Figure 4-6, in some areas at SLAPS, the potentiometric head in the lower groundwater system results in a potentiometric surface that is at a higher elevation than the water table. In other places, the potentiometric head results in a lower potentiometric surface than the water table. Therefore, the one-dimensional representation of the water table crosses the potentiometric surface on the conceptual diagram. The areas where the potentiometric surface is higher than the water table exhibit artesian conditions. These are areas where an upward flow gradient exists.

Table 4-1 presents groundwater chemistry data for wells B53W01D, B53W01S, B53W09D, B53W11D, B53W11S, and B53W16S. The data also are shown graphically on a trilinear diagram in Figure 4-7 and a Stiff plot, which shows the distribution of cations and anions, in Figure 4-8.

Values for alkalinity are moderately high, ranging from 220 to nearly 500 mg/L of calcium carbonate. The bicarbonate concentration was calculated using the geochemical model MINTEAQ2. B53W01D and B53W01S, the wells with the highest alkalinities, are in an area where bedrock is limestone.

A charge balance was run using the model MINTEAQ2. Results of the charge balances (Table 4-1) for all the wells are below 5 percent, indicating that the data are valid. The trilinear diagram (Figure 4-7) and Stiff plots (Figure 4-8) show that the cations in samples from the wells are largely calcium and magnesium. Anions in samples are dominated by bicarbonates except in the sample from B53W16S, which contained high concentrations of chloride and sulfate. The sulfate concentrations are also relatively high in well B53W11S. These two wells are in an area where bedrock is shale. The phosphate concentrations in most of the wells are above the saturation limit (i.e., the groundwater is supersaturated). MINTEAQ2 indicates that hydroxylapatite precipitates are likely to form.

The TDS content was calculated using the data in Table 4-1. Although the conductances for the samples were not measured, they are estimated using the calculated TDS values and TDS-conductance relationship given in Driscoll (1986).

The trilinear diagram (Figure 4-7) reveals that water types in the upper and lower groundwater systems range from sodium-bicarbonate to calcium-bicarbonate. The trilinear diagram and the Stiff plots (Figure 4-8) show that the groundwater chemistry of samples from the upper and lower groundwater systems is very similar, which indicates that the two groundwater systems probably have the same recharge area. Except for the magnesium values, which are slightly high, cation and anion concentrations in groundwater samples from wells at SLAPS are typical of those occurring in groundwater in alluvial sediments in the St. Louis area (Miller 1974).

4.3.2 Vadose Zone

The water table beneath the site generally lies in Unit 2. The vadose zone comprises Unit 1 and the upper part of Unit 2 and is typically 3 to 5 m (9.8 to 16.4 ft) thick. Geologic borings indicate that a layer of heterogeneous fill (rubble) as much as about 4 m (13.1 ft) thick overlies the virgin soils in many places within Unit 1. Some of the rubble and virgin soils are contaminated. If SLAPS is to be used as a location for a disposal facility, the contaminated soils outside of the facility boundaries will be excavated and replaced by clean, compacted backfill.

The virgin soils at SLAPS belong predominantly to the Nevin-Urban land complex. The particles are silt-sized or finer. The total porosities of this type of soil are typically 0.4 to 0.45 (Todd 1980). The effective porosities for fine-particle soils are generally only a fraction of the total porosities. The saturated hydraulic conductivities are typically on the order of 1.2×10^{-5} to 1.2×10^{-6} cm/s (1.2 to 12 ft/yr) (Todd 1980). Depending on the moisture content, the unsaturated hydraulic conductivities may be only a fraction of the saturated hydraulic conductivities.

4.4 SITE SURFACE WATER HYDROLOGY

This section describes the site surface water hydrology including information on the water balance, flood frequency and extent, erosion of soil from the site, and wetlands.

4.4.1 Drainage Characteristics

SLAPS

SLAPS is bounded on the north and west by Coldwater Creek (Figure 4-9) and on the south by the Lambert-St. Louis International Airport. The SLAPS area covers about 32.4-ha (80 acres), is covered with grass, and has no buildings.

The land surface across most of the site is flat, except for some relief on the banks of the drainage ditches and Coldwater Creek, the main waste storage pile, and small mounds of waste. Generally, the site slopes to the northwest, toward Coldwater Creek. The average slope of the land surface is 3.1 percent with a mean elevation of 161 m (528 ft) above mean sea level (MSL). The site is at an elevation of 4.6 m (15 ft) above the Coldwater Creek bed. The creek bank rises sharply with a slope of about 25 to 30 percent. The elevation ranges from a minimum of 153 m (503 ft) next to the edge of Coldwater Creek to a maximum of 166 m (543 ft) in the southeastern corner of SLAPS.

The overland flow at SLAPS is collected in one of four drainage ditches or drains directly into Coldwater Creek (Figure 4-8). The drainage ditches are wide, shallow channels with top widths of approximately 6 m (20 ft) at bankfull capacity and depths ranging from 1.2 to 1.8 m (4 to 6 ft). All of the ditches discharge into Coldwater Creek.

Coldwater Creek

Coldwater Creek drains an area of 122 km^2 (47 mi^2) in the northern section of St. Louis County. The creek flows northeastward for approximately 32 km (20 mi) before joining the Missouri River. The average channel slope is 0.3 percent.

The Coldwater Creek watershed is highly developed with residential, commercial, and industrial areas; its uses are (SAIC 1992):

- Urban - 76 percent
- Agricultural - 13 percent
- Open space - 6 percent
- Forested - 4 percent

Approximately 20 percent of thc watershed is impervious.

Urbanization has resulted in increased surface runoff; therefore, Coldwater Creek floods almost annually (SAIC 1992). Most floods result from high-intensity thunderstorms that cause flash floods. Recent major floods that caused damage to buildings in the area occurred in 1957, 1970, 1978, and 1979.

Little gauging data are available for Coldwater Creek. The U.S. Geological Survey established a continuous recording station (6-9365) on the downstream side of the U.S. Highway 287 bridge, 10 km (6 mi) north of the St. Louis city limits. The periods of record for this station were between September 1959 and July 1961 and between July 1962 and September 1965, when recording was discontinued. The drainage area for this station was approximately 113 km^2 (43.6 mi^2). From October 1964 to September 1965, the average flow of the creek was 40.8 cfs with a peak discharge of 3,000 cfs. The peak discharge for both periods of record was 6,170 cfs on June 29, 1960. Average runoff for the entire basin, based on these records, is estimated to be 59 cm/yr (22 in./yr) (76 cfs) (SAIC 1992).

The creek flows under the Lambert-St. Louis International Airport through a double 3- by 4.5-m (10- by 15-ft) box culvert. The double culvert discharges at Banshee Road at the northern boundary of the airport on the western side of SLAPS. Coldwater Creek then flows approximately 1 km (0.6 mi) along the boundary of SLAPS. The channel of Coldwater Creek is approximately 6 m (20 ft) wide as it flows beside SLAPS.

4.4.2 Water Balance

The average annual precipitation in the vicinity of SLAPS is estimated to be 95.5 cm (37.6 in.) based on a 27-yr rainfall record (1964 to 1990) at the airport. The maximum annual precipitation during this period was 139.7 cm (55 in.) in 1982, and the minimum was 55.59 cm (21.89 in.) in 1976. On the average, the winter months have the least amount of precipitation, and the spring and early summer months have the greatest.

The average annual evapotranspiration and deep percolation at SLAPS were estimated using "Chemicals, Runoff, and Erosion from Agricultural Management Systems" (CREAMS), a well-tested, field-verified, and well-documented model developed by the U.S. Department of Agriculture (Knisel 1980). CREAMS models surface runoff, evapotranspiration, and deep percolation using data for precipitation, temperature, solar radiation, and physical properties of the soil zone. A fraction of each storm rainfall becomes surface runoff, and the remainder infiltrates the upper soil layer and either evaporates or percolates to the groundwater. CREAMS results are presented in Appendix C.

Hourly precipitation data from the airport for 1964 to 1990 were input to the model. The mean monthly temperatures were from airport data, and the mean monthly solar radiation data were from Columbia, Missouri, approximately 210 km (130 mi) west of SLAPS.

The site soils in general belong to the Nevin Series. The top layer is composed of silt loam, which is underlain by silty clay loam. The water table is a few feet below the ground surface, and the soil is somewhat poorly drained. The site has a grass cover with no impervious areas.

The soil parameters used in CREAMS are based on averages developed for silt loam (USDA 1984). The porosity of the soil is 0.53 in./in. with a wilting point of 0.07 in./in. The hydrologic soil group for the Nevin series is "B." A saturated conductivity of 0.5 cm/h (0.2 in./h) and a capillary tension of 22.9 cm (9 in.) were estimated from this group. The root zone was estimated to be 61 cm (24 in.) deep based on average pasture conditions (Knisel 1980).

The average overland flow length of the site was estimated to be 61 m (200 ft), and the slope is 0.031 ft/ft. A value of 0.046 was used for the Manning's "n" (i.e., coefficient for bed roughness or resistance to flow) for overland flow over a well-established area of grass.

The estimated average annual water balance elements at SLAPS (expressed in inches per unit area) are precipitation (37.4), surface runoff (0.8), evapotranspiration (28.7), and percolation (7.9). Approximately 98 percent of the precipitation infiltrates. More than three-quarters of the infiltration becomes evapotranspiration, and the remaining quarter becomes recharge to the groundwater.

4.4.3 Flood Frequency

The peak flows at SLAPS were estimated using the U.S. Army Corps of Engineer's (COE) Hydrologic Engineering Center (HEC)-1 computer model (COE 1985), which simulates storm runoff in a drainage basin from a precipitation event. HEC-1 was used to estimate the 2- and 10-yr frequency peak flows at SLAPS.

The precipitation amounts (in inches) for the St. Louis area for the 2- and 10-yr return period storms are (COE 1987):

	Return Period	
Duration	2 yr	10 yr
5 min	0.45	0.59
15 min	0.90	1.10
1 h	1.55	2.26
2 h	1.91	2.76
3 h	2.15	3.10
6 h	2.57	3.64
12 h	3.07	4.30
24 h	3.50	4.96

HEC-1 generates a hypothetical 24-h storm hydrograph from the input precipitation amounts given above. The Soil Conservation Service (SCS) dimensionless hydrograph procedure, the SCS-TR55 method (SCS 1986), was used in generating the storm runoff hydrographs for each of the four ditches shown in Figure 4-9. The model parameters are curve number and lag time. A curve number of 61 was used to determine the amount of surface runoff, and the lag times computed by the SCS-TR55 method, ranging from 14 to 21 min, were used to estimate the runoff hydrograph. The peak storm runoff in each of the ditches is given below.

		Runoff (in ft^3/s)	
Ditch #	Drainage Area (acres)	2-yr Return Period	10-yr Return Period
1	7.4	2	6
2	3.6	1	4
3	25.2	7	22
4	17.8	5	14

The depth of flow in ditch #3 during the peak flow from the 10-yr storm is 0.12 m (0.4 ft).

4.4.4 Coldwater Creek 100-Year Floodplain

COE performed a feasibility study for controlling the flooding along Coldwater Creek (COE 1987). As part of that study, the 100-yr floodplain of Coldwater Creek was determined for future conditions based on projected development and population growth in the Coldwater Creek watershed. Figures 4-10 and 4-11 show the 100-yr floodplain of Coldwater Creek at SLAPS without and with the COE flood control plan, respectively. The COE plan involves channel widening and improvements.

The peak flows (in ft^3/s) in Coldwater Creek at the SLAPS boundary are (COE 1987):

Return Period	Peak Flows
2 yr	3,900
5 yr	4,200
10 yr	4,400
25 yr	4,600
50 yr	4,800
100 yr	4,900
500 yr	5,100

Without implementation of the COE flood control plan, the flood elevations will range from 159.4 m (523 ft) at SLAPS to 158.6 m (520.4 ft) at the end of the ball field property. The COE plan will lower the flood elevation at SLAPS to 158.2 m (519.1 ft) and at the end of the ball field property to 157.6 m (517.1 ft). The COE plan to control flooding of Coldwater Creek will not be initiated until after remediation of SLAPS. The only flooding at the site occurs from Coldwater Creek backing up into the drainage channels. However, all flooding is contained within the channels and should not inundate the site.

4.4.5 Soil Erosion

Although the soils at SLAPS erode easily, the property has well-established grass cover and, therefore, is not subject to excessive erosion. The only evident erosion is along the bank of Coldwater Creek. A gabion wall was constructed along the western boundary of SLAPS to control erosion on the creek bank. The Modified Universal Soil Loss Equation (MUSLE) (EPA 1988) was used to estimate the average annual sediment yield from SLAPS based on the volume of runoff, peak runoff, ability of the soil to erode, length and gradient of the ground surface, and ground cover. The erodibility of the site soil is 0.32 (USDA 1982). The erosion control practice factor was estimated to be 0.003 for a well-established area of grass. Hourly precipitation data from the airport for 1964 to 1990 were used to estimate the volumes of runoff and peak flows generated by individual storms. The SCS-TR55 method was used to calculate the runoff volume, and the Rational Method (Chow, Maidment, and Mays 1988) was used to estimate the peak flow from each storm. The amount of sediment delivered to Coldwater Creek for each of the individual storms was calculated for the 27-yr period; the average annual sediment yield from SLAPS is estimated to be 0.36 metric tons/yr (0.4 tons/yr).

4.4.6 Wetlands

The Fish and Wildlife Service has identified two wetlands along Coldwater Creek beside SLAPS (Figure 4-12). The wetlands are classified as Palustrine/Forested/Broad-leafed/Deciduous/Temporarily Flooded. A visit to the area in May 1992 confirmed that broad-leafed communities are present in the wetland areas, but no wetlands were identified on the SLAPS property (SAIC 1992).

FIGURES FOR SECTION 4.0

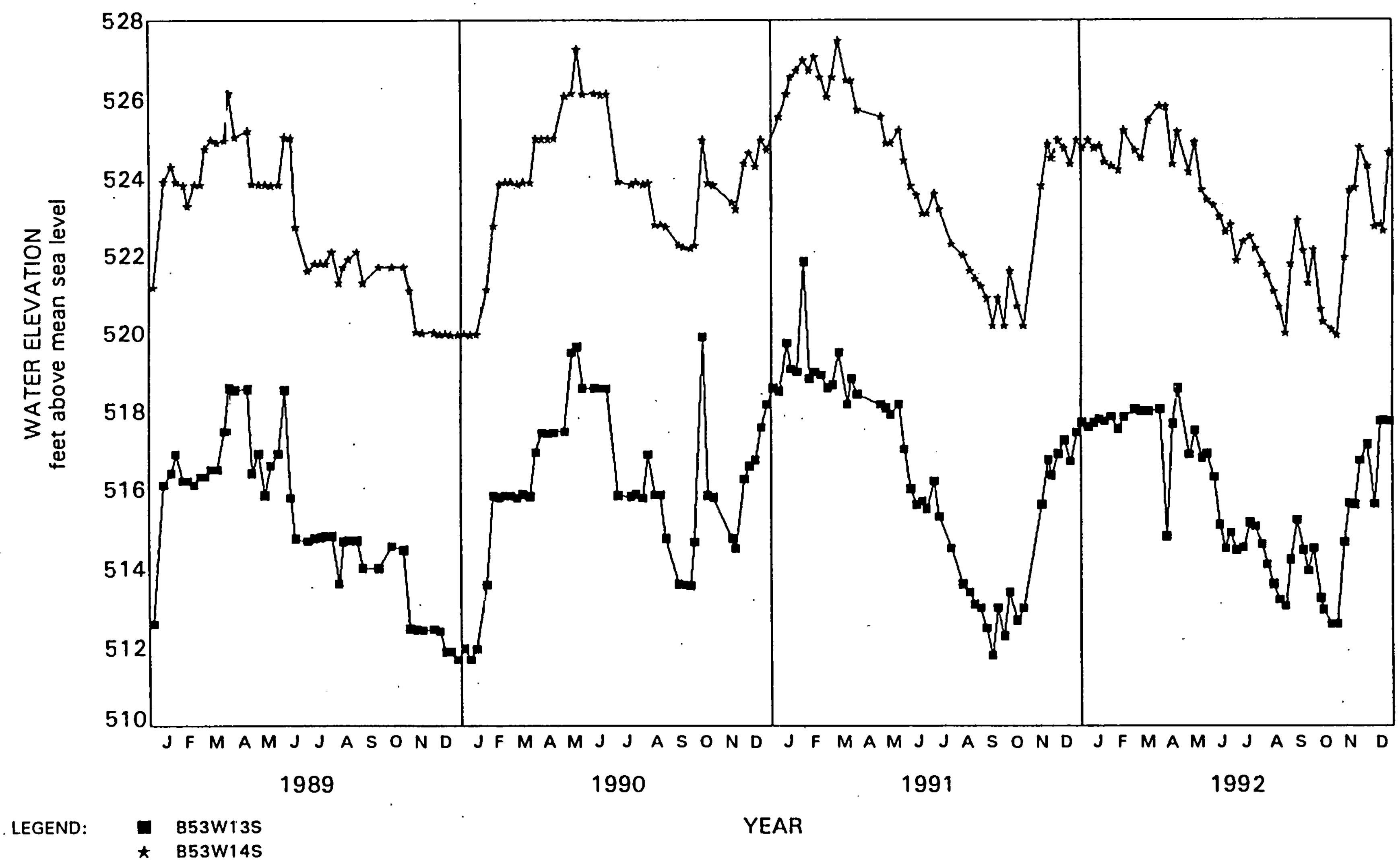


Figure 4-1
Hydrograph of Upper Groundwater System Wells B53W13S and B53W14S

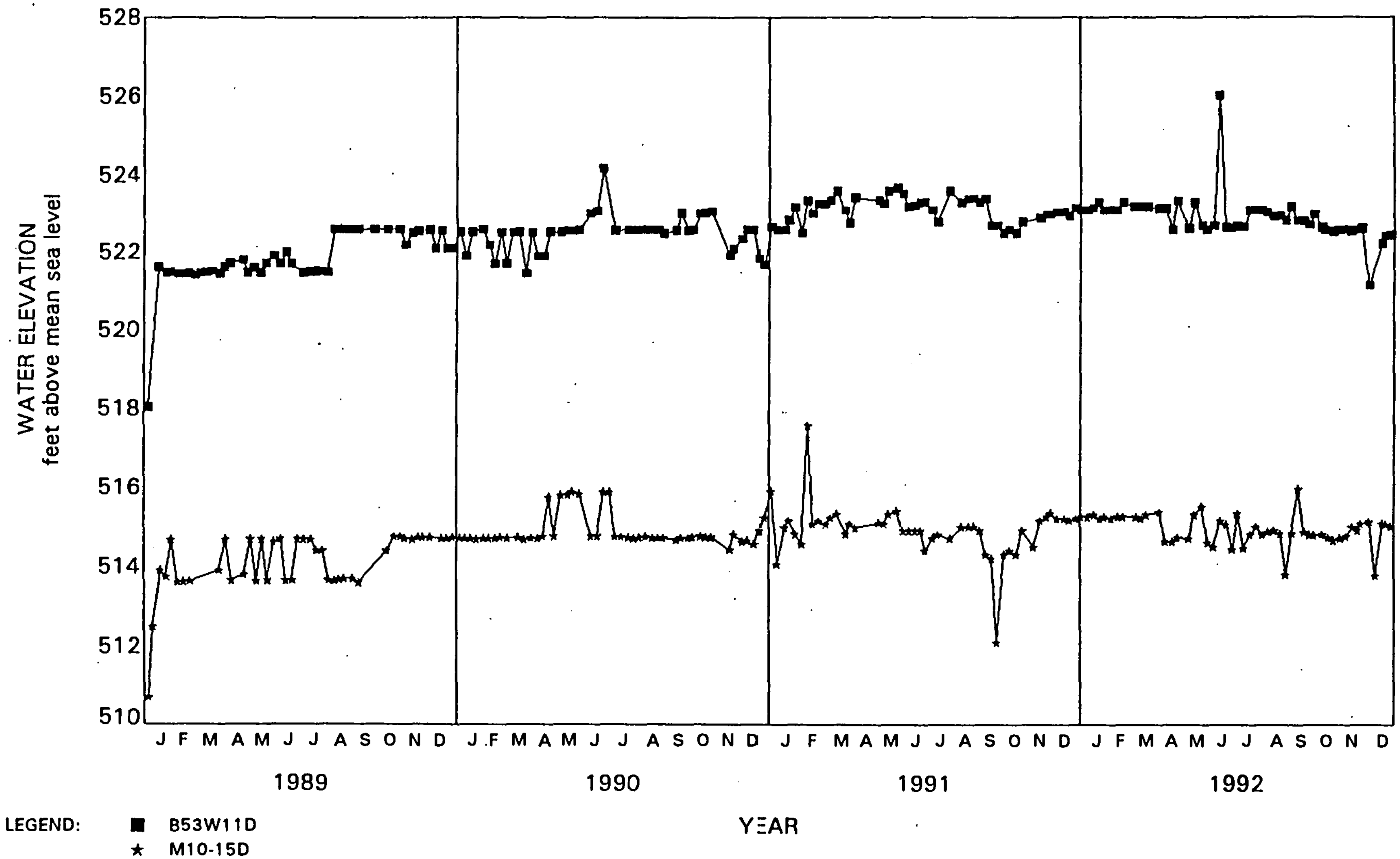
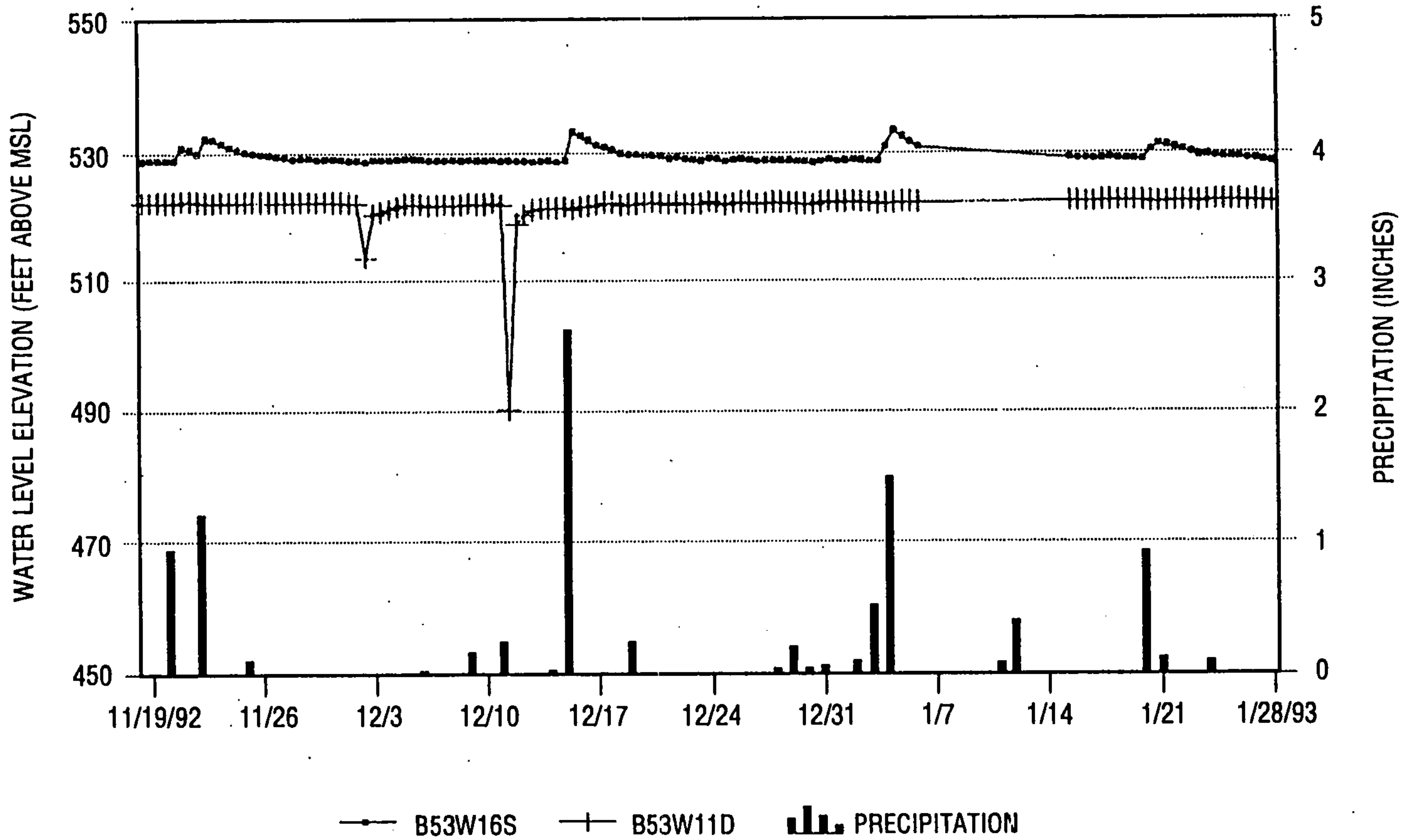


Figure 4-2
Hydrograph of Lower Groundwater System Wells B53W11D and M10-15D



Water level elevations obtained using automatic water level recorder

Figure 4-3
Hydrograph of Wells B53W11D and B53W16S

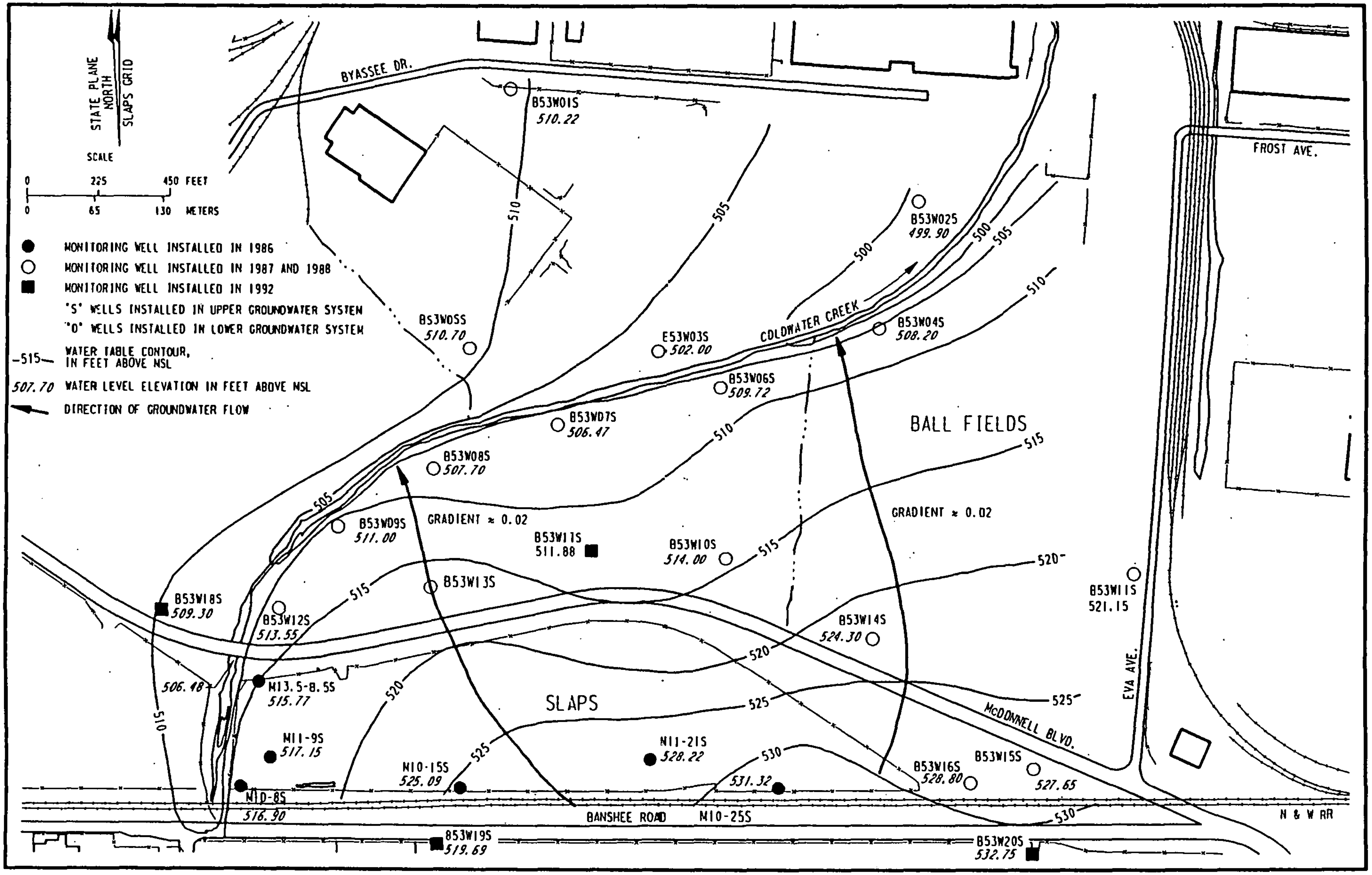
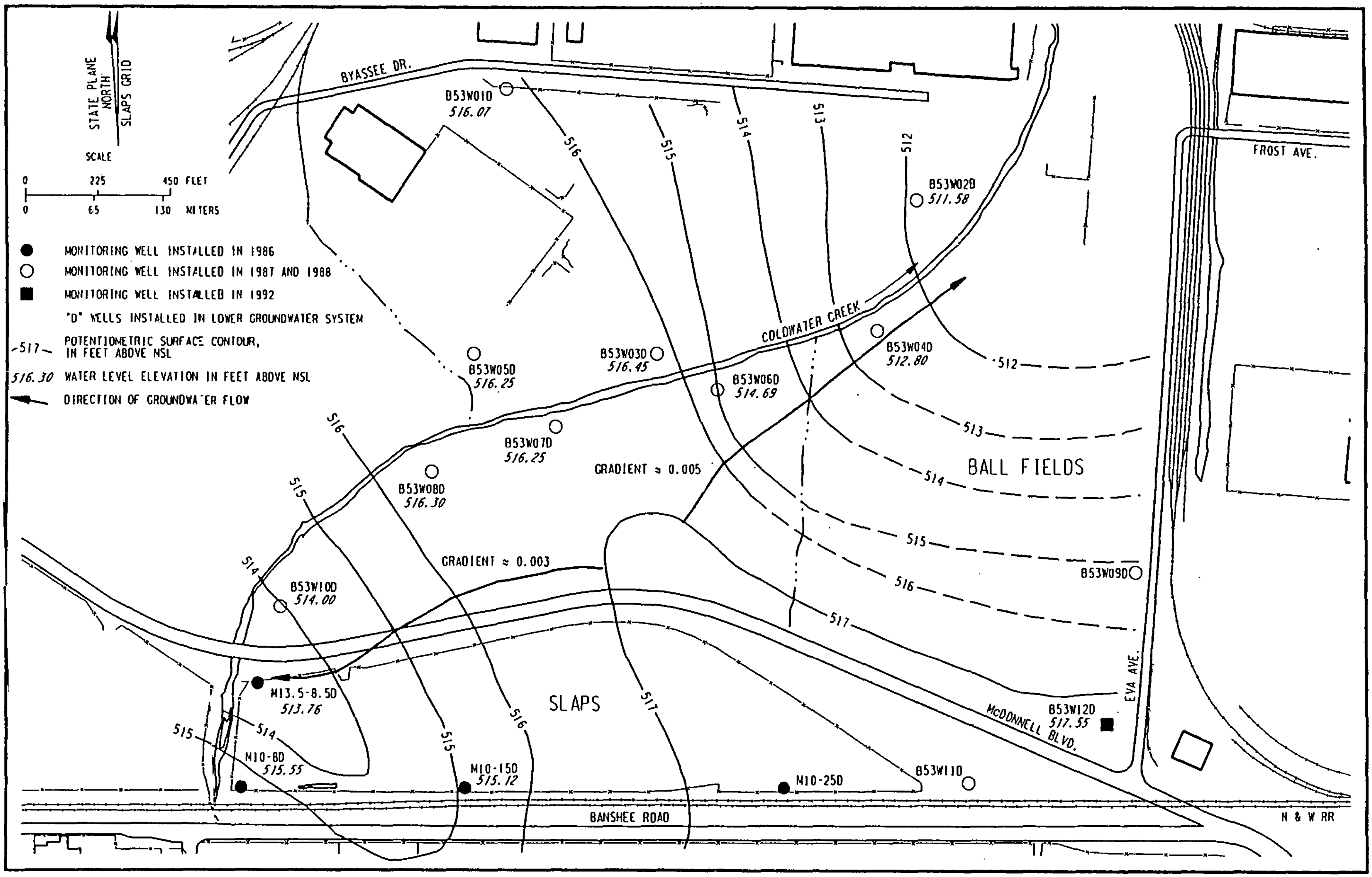


Figure 4-4
Potentiometric Surface Map of the Upper Groundwater System (12/3/92)



R02F025.DGN

Figure 4-5
Potentiometric Surface Map of the Lower Groundwater System (12/4/92)

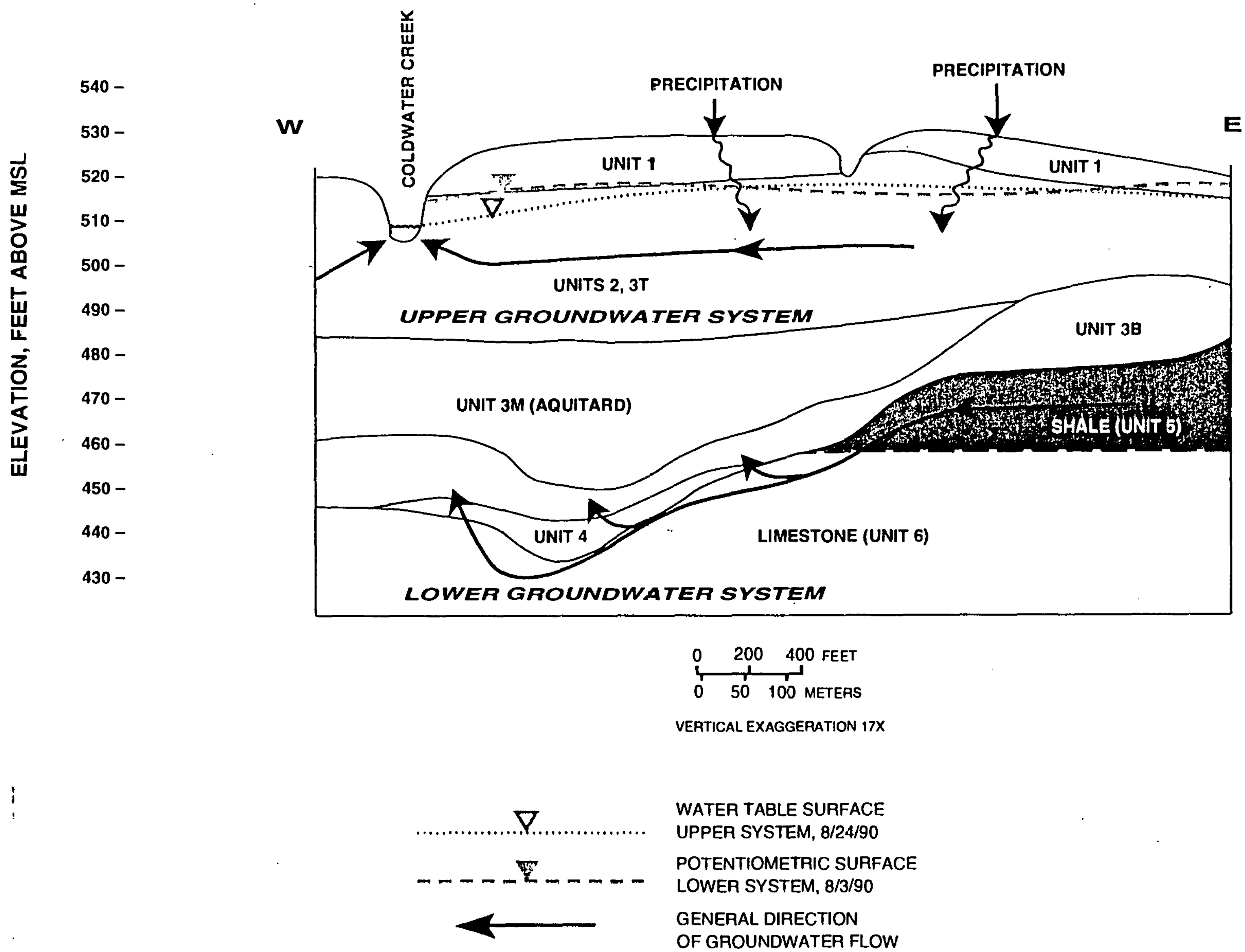
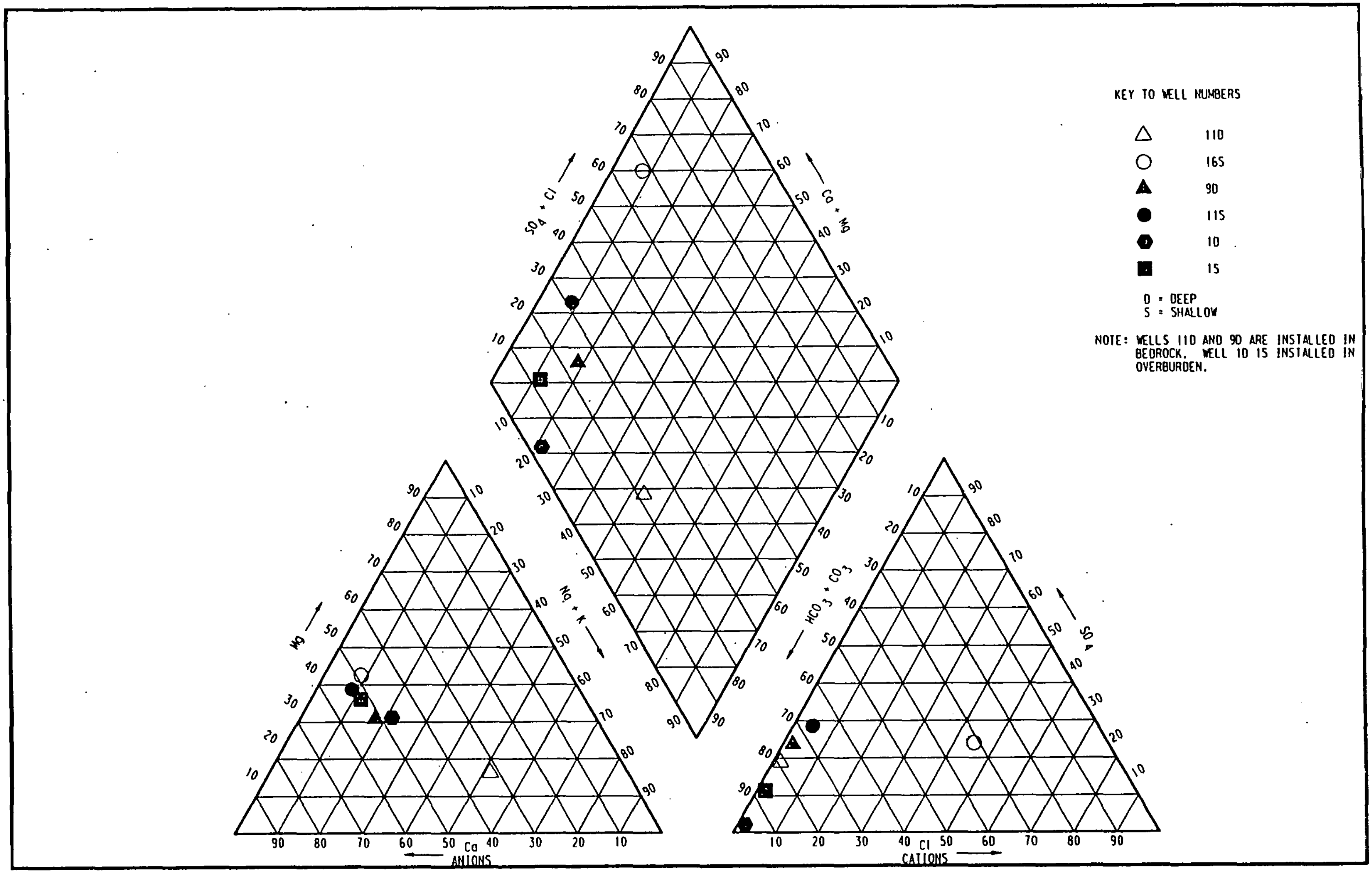


Figure 4-6
Conceptual Model of Groundwater Flow at SLAPS

4.104 0462



134 R02F009.DGN

Figure 4-7
Trilinear Water Chemistry Diagram for Well Pairs in the Ball Fields Area

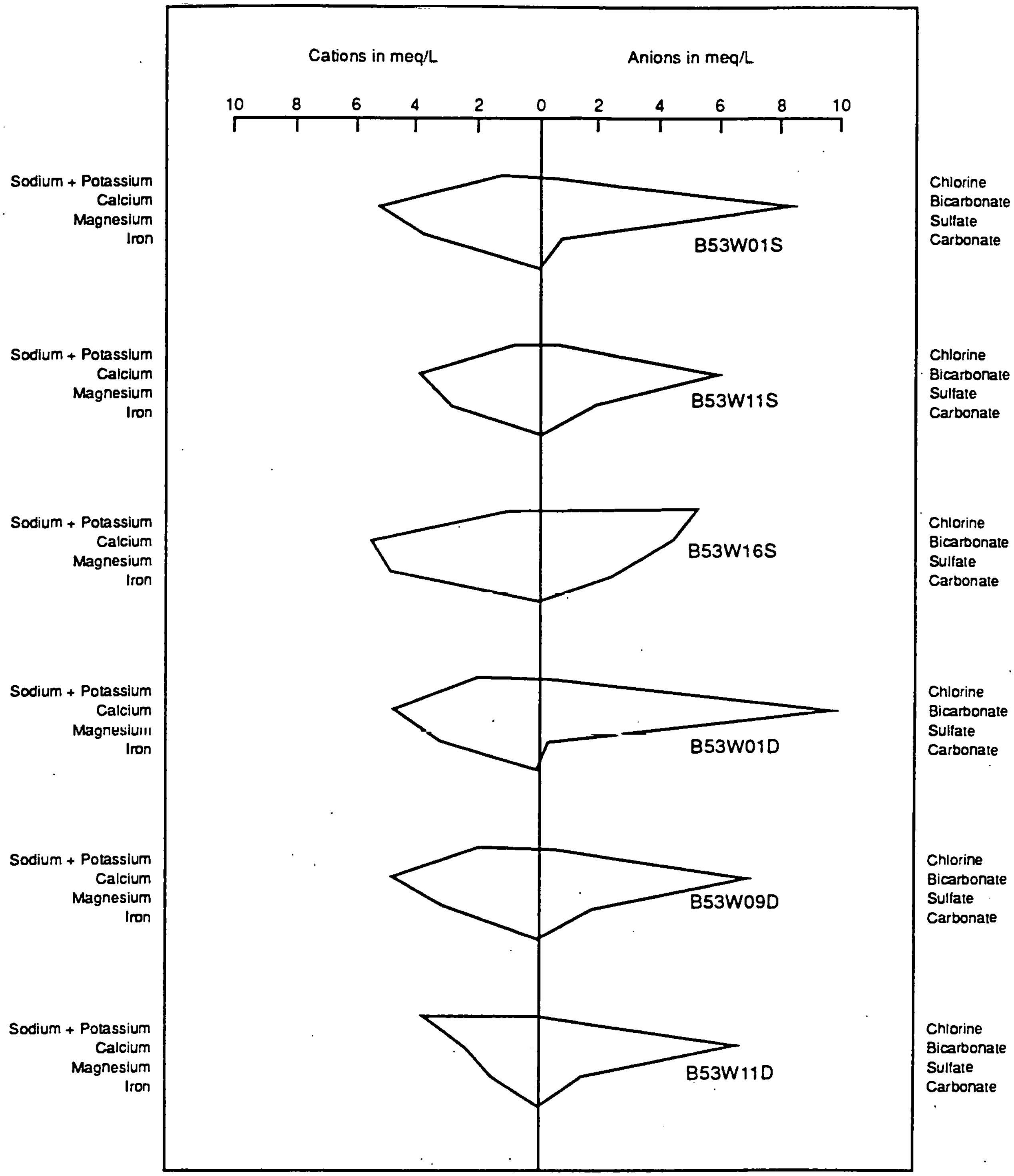
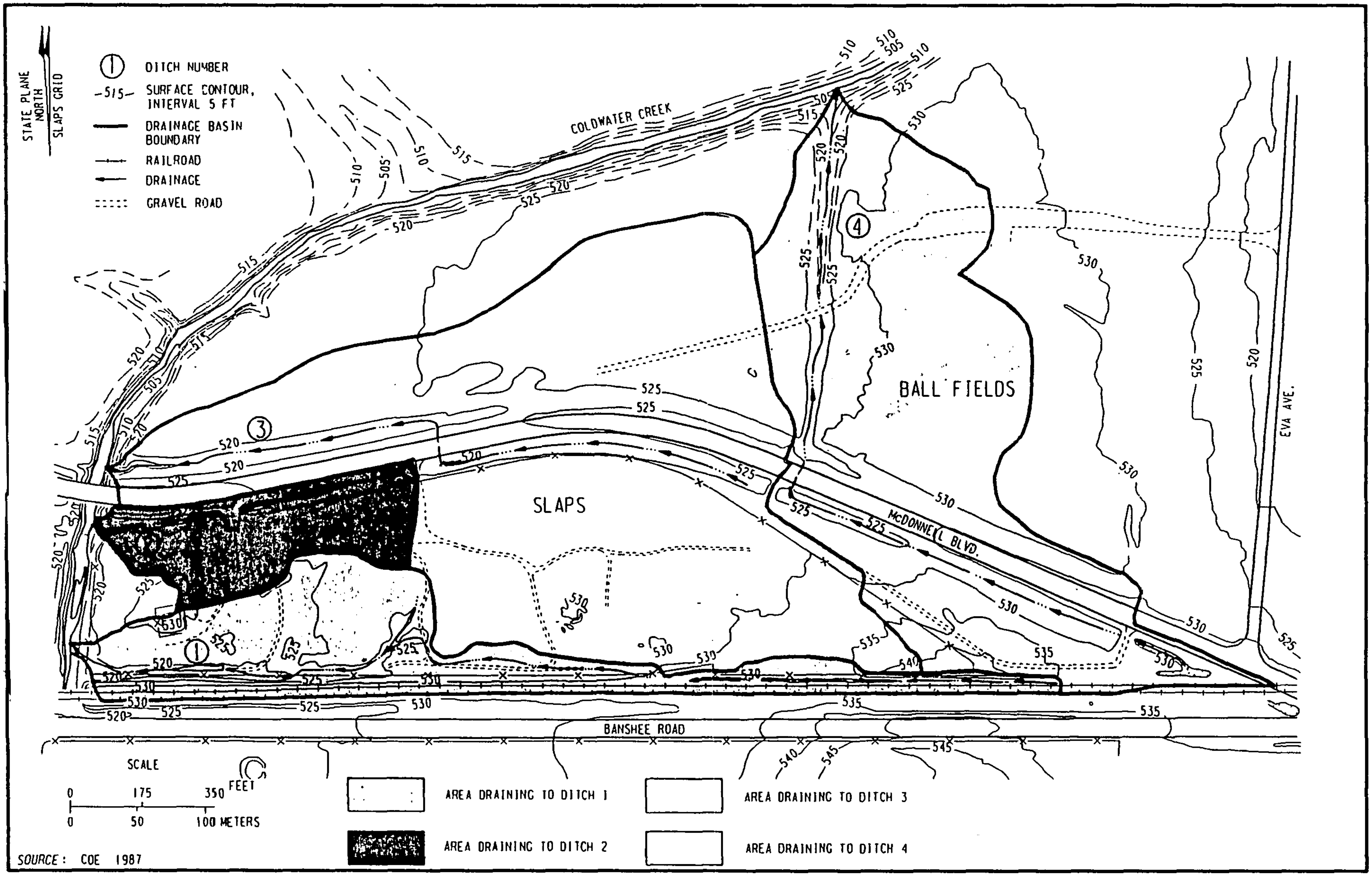
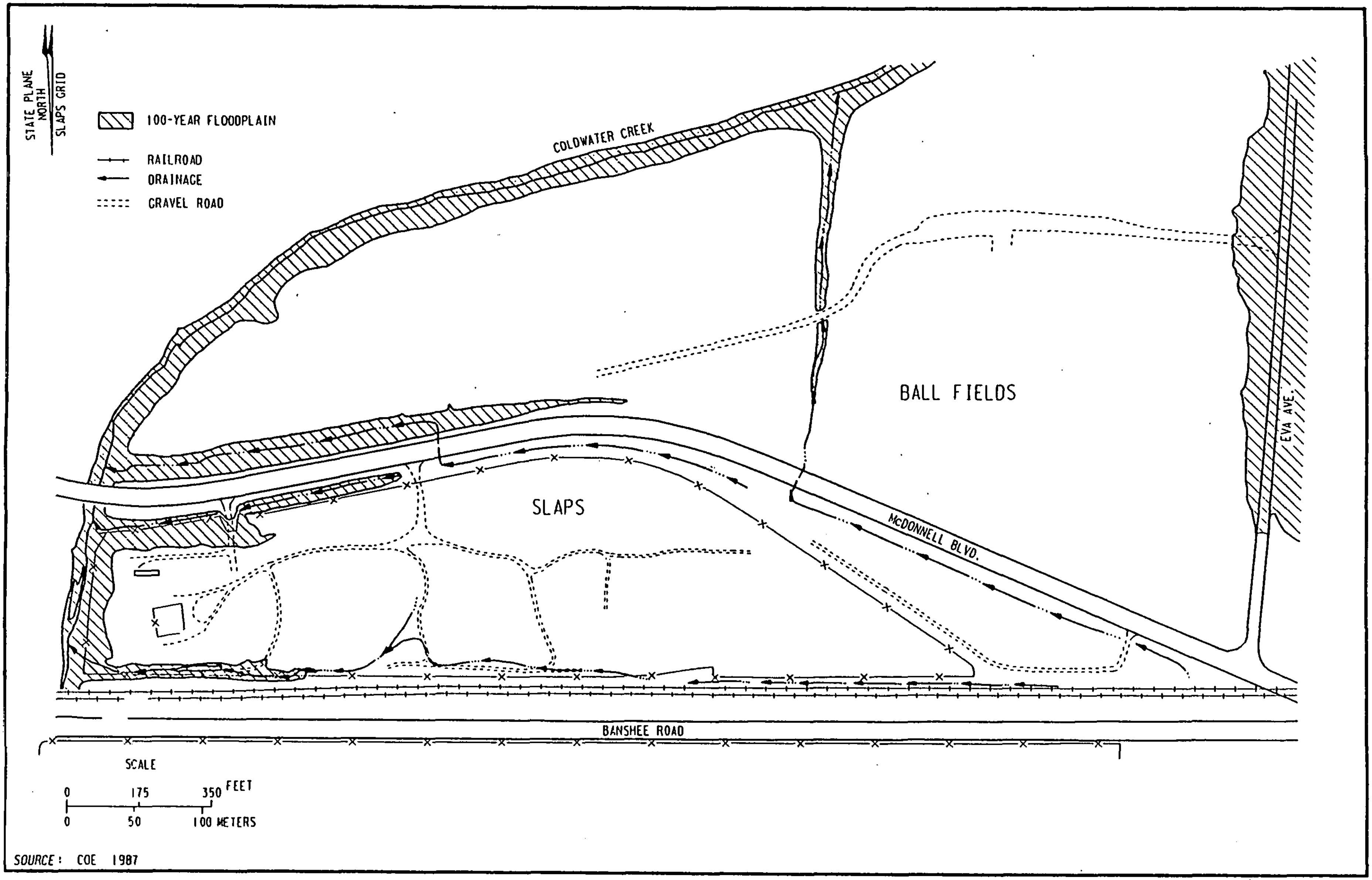


Figure 4-8
Stiff Plots for SLAPS Groundwater Chemistry



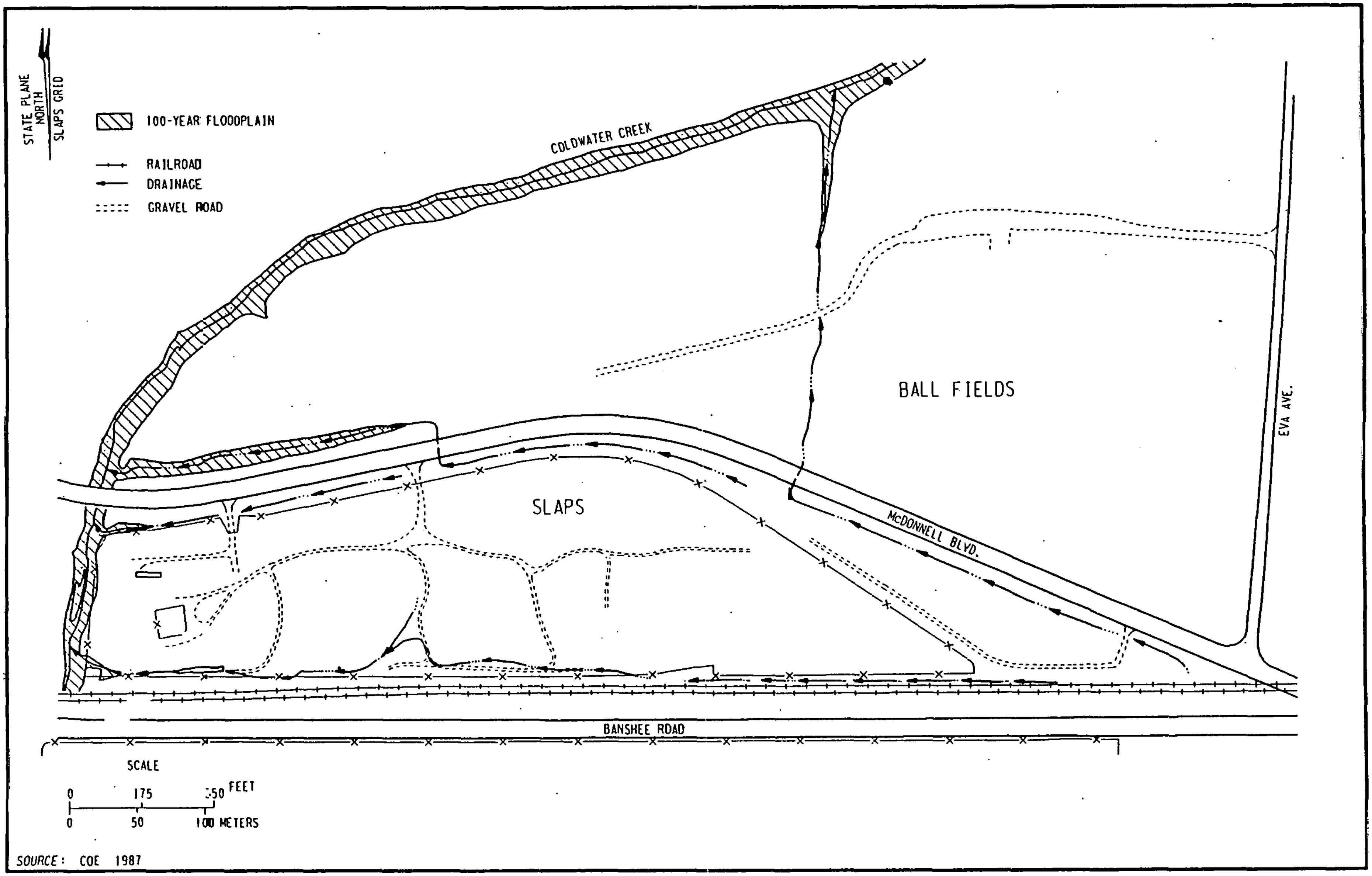
153 R02F002.DGN F1

Figure 4-9
Site Drainage Areas



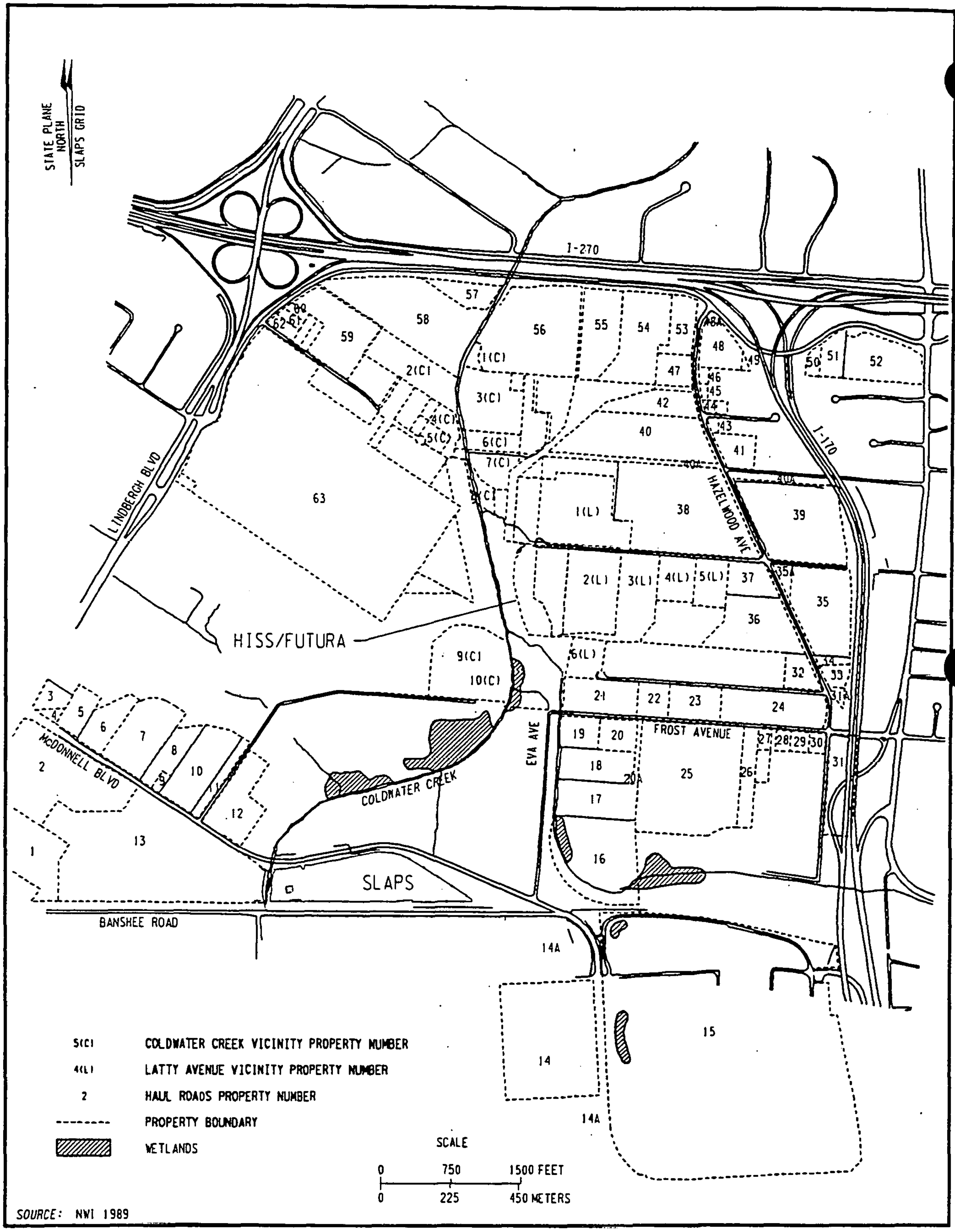
153 R02F002.DGN F2

Figure 4-10
100-Year Floodplain without Implementation of the COE Plan



153 R02F002.DGN F3

Figure 4-11
100-Year Floodplain with Implementation of the COE Plan



134 R02F003.DGN

Figure 4-12
Wetlands in the Vicinity of SLAPS

TABLE FOR SECTION 4.0

Table 4-1

Groundwater Geochemistry Data[a] for SLAPS

Parameters	B53W11D	B53W16S	B53W11S	B53W09D	B53W01D	B53W01S
Cations (mg/L)						
Calcium	47.7	112	80	98	95.6	104
Magnesium	18.1	59.3	36.3	35.5	37.5	44.4
Sodium	83.9	21.4	14.6	43	46.7	23.7
Potassium	7.4	BDL[b]	BDL	BDL	BDL	BDL
Iron	BDL	0.4	0.2	BDL	1.2	BDL
Anions (mg/L)						
Bicarbonate (calculated)	403.2	266.4	352.8	417.6	588	508.8
Carbonate	BDL	BDL	BDL	BDL	BDL	BDL
Chlorine	4.3	183	10.5	4.3	3.3	5.9
Sulfate	64.1	133	95.2	87.7	9.3	39.2
Phosphate	1.1	0.56	0.063	0.89	0.56	1.5
Nitrate	BDL	0.49	0.24	0.13	BDL	0.21
Alkalinity (calcium carbonate)	336	222	294	348	490	424
Charge imbalance (%)	3.11	4.12	3.43	4.04	0.76	1.9
Calculated TDS	425	641	410	475	484	469
Estimated specific conductance (μmhos)	675 - 775	1017 - 1165	650 - 745	755 - 865	770 - 880	745 - 855
Possible precipitate	Hydroxylapatite	Hydroxylapatite	None	Hydroxylapatite	Hydroxylapatite	Hydroxylapatite
Saturation index	2.6	3	-0.3	3.6	3	4.4

[a]Calculation assumed temperature of 12°C and pH of 7.0.

[b]BDL = below detection limits.

5.0 EVALUATION OF SITE SUITABILITY

The ability of a site to meet performance criteria for a disposal facility must be examined to determine whether that site is suitable for its intended usage. The performance criteria include environmental, physical, and engineering issues. The following items must be examined to evaluate the suitability of the site (modified from Bedinger 1989).

1. The ability of the natural materials and subsurface conditions to minimize discharge of contaminants and limit the potential for harm to human health and/or the environment
   a. Isolation of groundwater below the disposal facility from the local groundwater system
   b. Capacity of the soils and underlying material to retard the movement of contaminants in the event of a release
   c. Relationship of the 100-yr floodplain with respect to the facility
   d. Proximity and potential impact on wetlands from a potential contaminant release
2. Potential for a contaminant release caused by catastrophic failure
   a. Presence or absence of recent faults
   b. Presence or absence of unstable soils beneath the site
   c. Potential for cave development
3. Ability of site soils to support a disposal facility

5.1 POTENTIAL FOR DISCHARGES

According to a report on the hydrogeologic aspects of waste disposal facilities (Bedinger 1989), the hydrogeologic system under consideration should include geochemical and hydraulic characteristics that retard migration and transport of radionuclides, slow groundwater flow velocities, and long flow paths. These factors are important if the engineered structures fail. Flow characteristics of the groundwater system at SLAPS are discussed in Section 3.0. The length of the flow path to discharge points will depend on the actual location of the disposal facility. The following discussion of radionuclide transport demonstrates that if contaminants are released to groundwater, the natural characteristics of the materials underlying the site will prevent the migration of contamination through the groundwater system. Contaminant transport modeling presented in Appendix D confirms that the soils at SLAPS strongly affect the movement of contaminants because of the high distribution coefficients of site soils (see Section 3.0). The resultant estimates for contaminant travel times indicate that it would take hundreds to hundreds of thousands of years for contamination to reach an offsite receptor [assumed to be at Coldwater Creek, 55 m (180 ft) from the facility]. The calculated dilution-attenuation factor of 3.6 indicates that contaminant concentrations in groundwater at the receptor would be approximately 28 percent of the concentration in contaminated groundwater at the source.

Radionuclide transport analyses represent an idealized transport situation; factors such as colloid formation, organometallic complexation, and anisotropy could result in more rapid migration of radionuclides. Groundwater monitoring data collected to date do not indicate that these facilitated transport mechanisms are occurring at the site, and these factors are also offset by seasonal variations in infiltration. Therefore, they have not been considered in the following discussion.

5.1.1 Contaminant Transport Through the Vadose Zone

Approximate flow and transport velocities and travel times in the vadose zone can be calculated using the techniques presented in Section 5.1.2 and the data in Section 4.3.2. Because there are no site-specific data on the vadose zone, typical values for permeability and porosity have been used from Todd (1980). Assuming a hydraulic gradient of one for vertical flow, and an unsaturated hydraulic conductivity of 1.2×10^{-6} cm/s (1.2 ft/yr), the Darcy velocity is determined to be 1.2×10^{-6} cm/s (1.2 ft/yr). Using an effective porosity of 0.1, the flow (seepage) velocity is 1.2×10^{-5} cm/s (12 ft/yr). To traverse a distance of 3 to 5 m (9.8 to 16.4 ft) in the vadose zone, infiltrating water would take approximately one year to reach the water table.

Because thorium and uranium can sorb onto the surfaces of a solid matrix with which they come in contact, the actual transport velocities of these radionuclides would be less than the flow velocities. Using a soil bulk density of 1.5 gm/cm^3 (94 lb/ft^3), a total porosity of 0.40 (see Table 5-1), and a distribution coefficient of 270 for uranium and thorium (see

Table 3-4), a retardation factor of 1,014 is calculated. Thus, assuming an average vadose zone thickness of 4 m (13.1 ft), and a flow veriocity of 1.2×10^{-5} cm/s (12 ft/yr) (see above) the first molecules of uranium and thorium contamination at the ground surface would take approximately 1,000 years to reach groundwater.

5.1.2 Contaminant Transport Through the Saturated Zone

Available permeability tests indicate that subunit 3M has the lowest vertical permeability of any unit at SLAPS. The geometric mean vertical permeability, as determined in the laboratory, was 5.5×10^{-8} cm/s (5.5×10^{-2} ft/yr). Subunit 3B has the next lowest vertical permeability of any unit at SLAPS. The geometric mean vertical permeability, as determined in the laboratory, was 3.1×10^{-7} cm/s (0.32 ft/yr). The thickness of subunit 3M is shown in Figure 3-10. The geochemical properties of SLAPS soils, including distribution coefficients and CECs, are discussed in Section 3.4 and are part of the basis for the following discussion.

Investigations conducted at SLAPS include measurement of hydrogeologic and hydrogeochemical parameters to determine the groundwater flow and solute transport characteristics of the site materials. These measurements are summarized in Table 5-1. Measurement methodologies and individual test results are presented in BNI (1989a) and Weston (1982). Table 5-1 presents site-specific distribution ratios for uranium and radium. Published distribution coefficient data for uranium, radium, and thorium, such as the data presented in Table 3-4, indicate that radium and thorium distribution coefficients are generally similar to or greater than the distribution coefficients for uranium. Thus, uranium transport in groundwater is used in the following discussion to evaluate radionuclide transport at the site. Uranium transport velocities represent a conservative scenario.

The calculated average linear groundwater velocities (given in Table 5-1) for the upper groundwater system range from two to ten times faster than those for the lower groundwater system. The slower groundwater velocity in the lower system appears to reflect the heterogeneity of the deposits (Unit 4), which range from a clayey gravel to a silty clay. Calculation of vertical velocity through the aquitard (subunit 3M) was not included in the table because of the number of variables associated with this unit (e.g., thickness, hydraulic gradient, flow direction, depth of monitored intervals relative to the aquitard, and hydraulic conductivity). An estimate of the vertical velocity downward through the aquitard at well pair M10-15S and D (which are located in the area of downward flow) assumes an aquitard thickness of 8.4 m (27.7 ft) and a head differential of 2.1 m (7 ft). The resulting average linear velocities (based on vertical hydraulic conductivities in Table 5-1) range from 0.59 to 0.012 m/yr (0.18 to 3.7×10^{-3} ft/yr). Thus, it would take a water molecule between 64 and 3,600 years to pass through the aquitard.

The distribution ratios presented in Table 5-1 indicate that uranium migration is retarded relative to groundwater flow. The retardation factors for the upper groundwater system and aquitard can be estimated, assuming that the distribution ratio approximates the distribution coefficient, from:

$$R = (1 + (\rho/n)\ K_d)$$

where: R = retardation factor (dimensionless)

ρ = bulk density (gm/cm^3)

n = porosity (dimensionless)

K_d = distribution coefficient ≈ distribution ratio (cm^3/gm) (Gillham 1982)

The solute transport velocity is related to the average linear groundwater velocity and the retardation factor by the expression:

$$V_s = V_g/R$$

where: V_s = velocity of solute transport (length/time)

V_g = average linear groundwater velocity (length/time)

R = retardation factor (dimensionless)

The retardation factors for the upper groundwater system range from 100 to 7,738, and the range for the aquitard is 20 to 670. Thus, the uranium migration rates are between

100 and 7,738 times slower than the average linear groundwater velocity. The uranium migration rate through the aquitard is between 20 and 670 times slower than groundwater movement. Thus, for the previously described conditions at wells M10-15S and D, a molecule of dissolved uranium would take from 1,000 to several orders of magnitude greater than 10,000 years to migrate through the aquitard.

As discussed previously, the distribution coefficients for radium and thorium are similar to or greater than the values for uranium. Consequently, the retardation factors for radium and thorium would be similar to or greater than the retardation factors for uranium, and thus the transport time for radium and thorium would be similar to or longer than the transport time for uranium. Similar calculations were performed for well M10-25D, a well where the aquitard is absent. The results of the calculations indicate that it would also take between 1,000 and 10,000 years for a uranium molecule to migrate from the bottom of the screen in well M10-25S to the top of the screen in well M10-25D, a distance of 4.7 m (15.3 ft).

More detailed modeling of contaminant fate and transport conducted using MULTIMED is presented in Appendix D. The results of this modeling indicate that transport of uranium, radium, and thorium is strongly affected by the neutral materials at the site that have high distribution coefficients. Modeling further indicates that it would take hundreds to hundreds of thousands of years for contaminants to reach an offsite receptor. The model computed a dilution-attenuation factor of 3.6 at the receptor [assumed to be at Coldwater Creek, 55 m (180 ft) from the edge of the proposed location of the facility]. This indicates that contaminant concentrations in groundwater at the receptor would be approximately 28 percent of the concentration of the liquid phase at the source.

There is a concern that groundwater in the bedrock is interconnected with groundwater in the overlying sediments. Some of the areas where interconnection between the two systems has been investigated show a downward gradient. However, the sediments immediately overlying bedrock under the area of the proposed cell are isolated from the upper groundwater system by subunit 3M. The sediments may be interconnected upgradient (southeast) of the site where bedrock is close to the surface. As a result, the potential for

The potential for liquefaction was evaluated for silty sand units encountered in two sampling locations [boreholes G12-12 and G12-26 (see Figure 3-1)]. The silty sand was assumed to contain 35 percent fines. The maximum ground acceleration considered in the evaluation ranged from 0.2 to 0.25 g for a 7.5 (Richter scale) magnitude earthquake, providing a conservative estimate of liquefaction potential (the maximum credible earthquake magnitude is m_b = 6.3 for the SLAPS area). The liquefaction analysis was performed assuming existing ground elevation.

The liquefaction evaluation was performed using procedures that are based on standard penetration blow count values (Seed et al. 1984, Seed and Harder 1990). The results of the evaluation are as follows:

- Using the blow count data available for boring G12-12 [elevation 149.4 m (490 ft) above MSL], the factor of safety against liquefaction is less than 1 for the range of acceleration levels considered (0.2 to 0.25 g).

- Based on the blow count data for boring G12-26 [elevation 157 m (515 ft) above MSL], the factor of safety against liquefaction ranges from 1 to 1.3 for horizontal accelerations of 0.25 and 0.2 g, respectively.

Available data indicate that Unit 2 consists of silt and clayey silt, which are not susceptible to liquefaction. Two localized sandy layers that are potentially liquefiable have been identified. Conservative assumptions were made to reflect soil properties and the maximum credible earthquake. The resulting calculations reveal that during an earthquake, the site would remain stable. The only areas where liquefaction is possible are in Area 1 (see Figure 5-1) at the acceleration levels considered. Liquefaction could occur in Area 2 (see Figure 5-1) at the higher acceleration level of 0.25 g or greater.

The potentially liquefiable layers are overlain by fine-grained soils (ML or CL, see Table 3-1) and fill materials. If the silty sand layers liquefy during an earthquake, the potential for surface manifestation of liquefaction is probably low because of the presence of fine-grained, compacted, overlying soils. These soils would prevent the underlying sediments from liquefying during an earthquake.

5.2.2 Failure Caused by Cave Formation

The Missouri Master Cave file reveals that no caves are in the SLAPS area (BNI 1993b). This confirms maps compiled by Goodfield (1965) and maps published by Lutzen and Rockaway (1971), which indicate that no soils in the SLAPS area are subject to the formation of sinkholes. The closest cave to SLAPS is approximately 9.7 km (6 mi) to the northeast (BNI 1993b).

Subsurface data collected by FUSRAP agree with maps of the surface except for one hole. The 30 deep borings drilled at SLAPS were examined for evidence of cave formation. Six never reached bedrock (limestone). Boring B53W09D encountered shale at 15.2 m (50 ft), which was 7.3 m (24 ft) thick, and then limestone; similar stratigraphy is described for boring B53W11D, with shale and siltstone from 14 to 24.3 m (46 to 79.6 ft) deep. Shale was found at 15.8 m (51.8 ft) in M10-25D. The remaining 21 borings reached limestone following the unconsolidated clayey sediments at depths varying from 21.6 to 28.7 m (71 to 94 ft). With the exception of two borings, those reaching limestone penetrated it only a few inches. Borings B53G16 and B53G18 penetrated it 4.8 and 9.4 m (15.8 and 14.3 ft), respectively; the limestone was interbedded with shale. Only a small [2.5 by 5 cm (1 by 2 in.)] cavity was found at the beginning of the limestone in B53G18. The only anomaly of interest was found in boring B53G13, which reached the limestone at only 28.7 m (94 ft); approximately 1.1 m^3 (300 gal) of grout was pumped into the hole without filling it. Although a literature search and results for 29 of 30 borings at the site suggest that no caves are present, a geophysical survey (e.g., seismic refraction) should be conducted before completion of the facility design to verify that no caves are present. If a cave did form under SLAPS, the thick sequence of sediments overlying bedrock at SLAPS would attenuate the effects of all but the largest solution feature.

contaminants to reach deeper groundwater beneath the site is believed to be minimal. See Appendix F for more detailed discussion of site permeability characteristics.

The substantial travel times for uranium through the sediments underlying the proposed disposal facility indicate that discharge of contaminated groundwater from the site to potential drinking water sources is unlikely.

5.1.3 Contaminant Transport to Coldwater Creek

If a release occurs, contamination could enter Coldwater Creek through horizontal migration of contaminated shallow groundwater. Groundwater moving towards Coldwater Creek has a maximum calculated average linear velocity of 1.75 m/yr (5.74 ft/yr) (Table 5-1). Using data from Table 5-1 and the methodology presented in Section 5.1.2, the linear flow velocities for uranium would range from 5.3×10^{-5} m/yr (1.7×10^{-4} ft/yr) to 1.75 m/yr (5.74 ft/yr). Modeling presented in Appendix D provides the most probable scenario; uranium would take between 110 and 365 years to travel 10 m (32.8 ft).

5.1.4 Other Considerations

The presence of a capped, engineered structure would affect infiltration rates, which would affect groundwater flow rates. The present annual infiltration rate at SLAPS is estimated to be 20.1 cm/unit area (7.9 in./unit area) (Section 4.4.2). Infiltration rates for the preferred cap designs were estimated using the Hydrologic Evaluation of Landfill Performance (HELP) model. The results are presented in Appendix B; rates were identical for both caps and were less than 2.7 cm/unit area (1.1 in./unit area) annually. The decrease in infiltration would affect recharge to the groundwater at SLAPS; modeling (presented in Appendix D) has shown that the water table would actually rise 0.1 m (0.3 ft). The rise in the water table would result from an increase in capillary pressure caused by the storage facility. Thc increase in the capillary pressure would offset the decrease in infiltration.

Four small ditches that underlie the proposed location of the disposal facility are within the 100-yr floodplain of Coldwater Creek (see Figure 4-10). These ditches represent a very small portion of the surface area of the site. Before construction, drainage in these areas would have to be diverted to ensure that the proposed facility would not be subject to flooding. COE is planning to enlarge the culvert between SLAPS and the airport. If these plans are implemented, the frequency of flooding is expected to be reduced, and the elevation of the 100-yr floodplain would become 1.1 to 1.2 m (3.6 to 3.9 ft) lower (COE 1987). The elevation of the water table would probably also decrease, but the extent has not been determined.

Two wetlands have been identified in the vicinity of SLAPS; both are on the opposite side of Coldwater Creek (see Figure 4-12). The proposed location of the storage facility would not affect the wetlands, nor would the wetlands affect the facility.

5.2 POTENTIAL FOR CATASTROPHIC FAILURE

5.2.1 Faulting and Fault-Related Failure

The closest faults to SLAPS are a series of inactive faults associated with the Dupo Anticline and the Cheltenham Syncline. One of these faults, the St. Louis fault (location shown in Figure 2-2), is approximately 16 km (10 mi) east of SLAPS. The maximum reported displacement along these faults is reported to be 30.5 m (100 ft) with deformation occurring into Pennsylvanian units (Saeger 1975). Although dating of the displacement along the faults is not exact, displacement does not appear to have extended into recent sediments and, therefore, is not expected to have any effect on the proposed disposal facility.

A more detailed study of the effects of seismicity on SLAPS is presented in Section 2.3. Preferred estimates for the maximum credible earthquake at SLAPS range from MMI VII to IX, which corresponds to peak ground accelerations of 0.25 to 0.50 g and a Richter magnitude of 6.3. These values were estimated based on the magnitude-intensity relations of Nuttli and Herrmann (1978) and the implications of the relations to body wave magnitude. The proposed disposal facility would be designed to withstand a design basis earthquake as dictated by regional design specifications.

5.3 ABILITY OF SITE SOILS TO SUPPORT A DISPOSAL FACILITY

Additional data on the ability of the soils underlying the proposed facility location to withstand stresses imposed by the weight of the facility are needed before final design and construction. Literature studies indicate that the soils underlying SLAPS are somewhat compressible and may be subject to drainage problems. In general, soils in St. Louis County similar to those underlying SLAPS have been viewed positively for citing sanitary landfills and for excavating where required. The placement of foundations in these soils may have some associated problems with settlement, but these problems can be eliminated by proper design (Lutzen and Rockaway 1971). Injection grouting and dynamic compaction are appropriate techniques for site preparation under these conditions.

FIGURE FOR SECTION 5.0

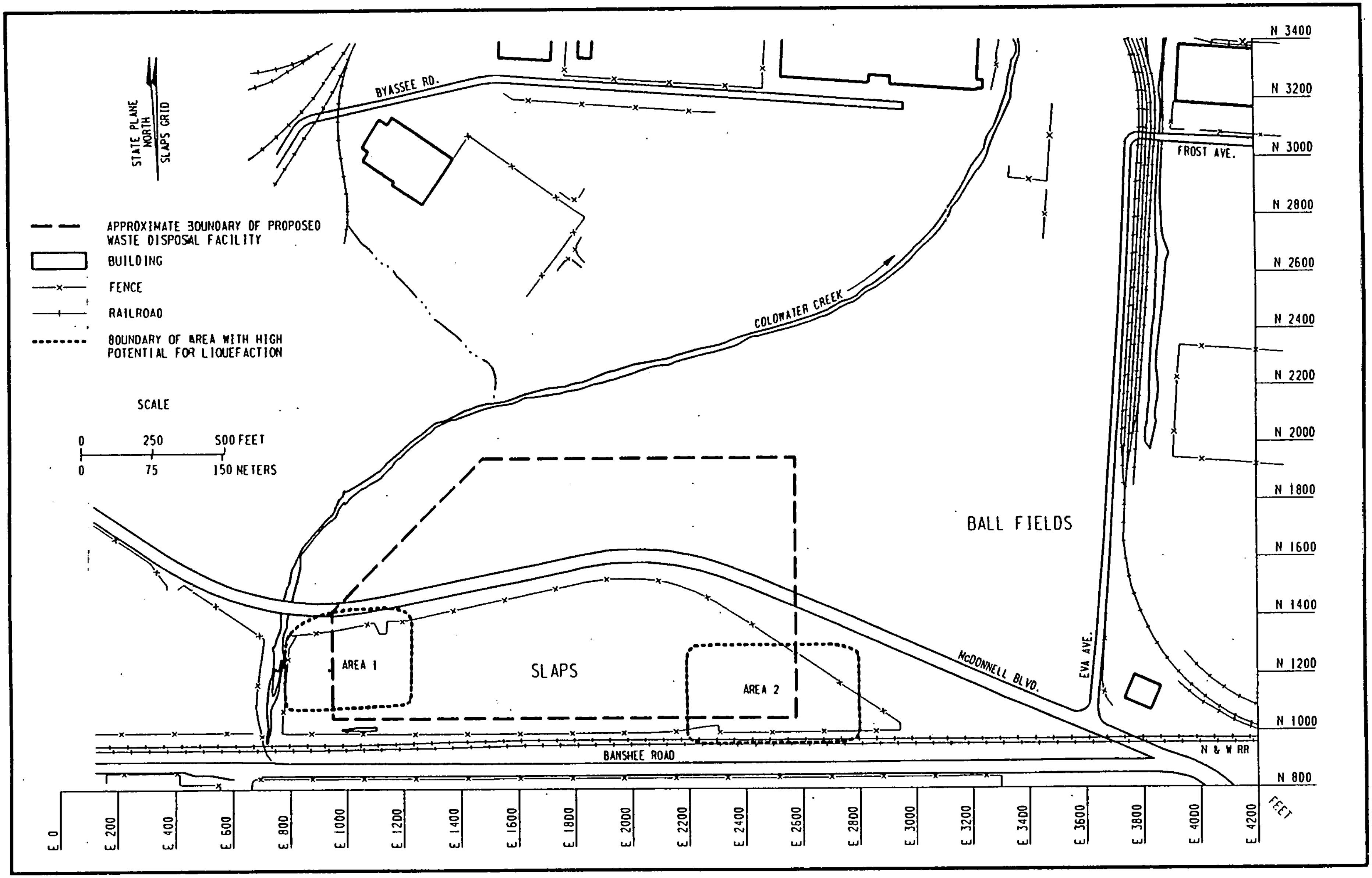


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Figure 5-1
Areas of High Potential for Liquefaction

TABLE FOR SECTION 5.0

Table 5-1

Summary of Hydrogeologic and Transport Parameters for SLAPS

Parameter	Number of Tests	Measurement Units	Arithmetic Mean	Standard Deviation	Geometric Mean	Range	
						Minimum	Maximum
Upper Groundwater System (Units 1 and 2 and Subunit 3T)							
Saturated thickness		m				7.9	13.7
Mean hydraulic conductivity[a]	12	cm/s	1.2×10^{-4}	1.5×10^{-4}	3.6×10^{-5}	1.2×10^{-6}	5.3×10^{-4}
Laboratory vertical hydraulic conductivity	22	cm/s	2.1×10^{-5}	4.3×10^{-6}	2.6×10^{-6}	1.4×10^{-8}	2.0×10^{-4}
Hydraulic gradient						0.0071	0.015
Uranium distribution ratio	66	ml/gm	616.2	1,185.0	114.4	0.02	5,900
Radium distribution ratio	2	ml/gm	910	30		880	940
Cation exchange capacity	14	meq/100 gm	19.37	4.31		12.60	26.97
Effective cation exchange capacity	7	meq/100 gm	148.57	32.14		98	200
Bulk density	21	gm/cm^3	1.54	0.12		1.33	1.81
Total porosity[b]	21	%	41.2	4.5		32.3	50.9
Average linear velocity[c]		m/yr				0.005	7.8

Table 5-1

(continued)

Parameter	Number of Tests	Measurement Units	Arithmetic Mean	Standard Deviation	Geometric Mean	Range	
						Minimum	Maximum
Aquitard (Subunits 3M and 3B)							
Thickness		m				3.5	13.4
Mean hydraulic conductivity[a]	5	cm/s	5.2×10^{-5}	7.5×10^{-5}	1.4×10^{-5}	1.2×10^{-6}	2.0×10^{-4}
Laboratory vertical hydraulic conductivity	6	cm/s	2.5×10^{-7}	2.8×10^{-7}	9.8×10^{-8}	1.4×10^{-8}	7.0×10^{-7}
Head differential across aquitard[d]		m				-1.2	2.4
Uranium distribution ratio	12	ml/gm	207.3	285.0	58.5	8	780
Cation exchange capacity	3	meq/100 gm	27.8	2.0		26.1	30.6
Effective cation exchange capacity	3	meq/100 gm	208	15.3		187	223
Bulk density	6	gm/cm^3	1.42	0.20		1.13	1.68
Total porosity[b]	6	%	42.8	6.9		33.4	51.7

Table 5-1
(continued)

Parameter	Number of Tests	Measurement Units	Arithmetic Mean	Standard Deviation	Geometric Mean	Range Minimum	Range Maximum
Lower Groundwater System (Unit 4)							
Saturated thickness		m				0	2.8
Mean hydraulic conductivity[a]	1	cm/s				2.2×10^{-4}	2.2×10^{-4}
Laboratory vertical hydraulic conductivity	4	cm/s	7.2×10^{-6}	8.0×10^{-6}	1.3×10^{-7}	2.0×10^{-8}	2.0×10^{-5}
Hydraulic gradient						0.0034	0.0064
Uranium distribution ratio	3	ml/gm	837.7	903.8	112.0	33	2100
Bulk density	2	gm/cm^3	1.48	0.07		1.41	1.54
Total porosity[b]	2	%	44.3	2.5		41.8	46.8
Average linear velocity[c]		m/yr				0.5	1.1

[a]The mean hydraulic conductivity (K_m) = $(K_h \times K_v)^{0.5}$, where K_h is the horizontal hydraulic conductivity and K_v is the vertical hydraulic conductivity.

[b]Total porosity is determined from bulk density and specific gravity data presented in Appendix A.

[c]Average linear velocity = $(K_m \times i)/n$, where K_m is the mean hydraulic conductivity, i is the hydraulic gradient, and n is the total porosity.

[d]Based on 6/28/89 groundwater level measurements. Negative values indicate upward flow potential, and positive values indicate downward flow potential.

6.0 SUMMARY AND CONCLUSIONS

A thick package of Pleistocene glacial sediment, consisting of interlayered silty clays, clays, and silts, underlies SLAPS. Deposition of sediments probably occurred in a low-energy lake environment. Underlying the unconsolidated sediments are Pennsylvanian shales of the Cherokee Group and Mississippian limestones of the Ste. Genevieve Formation. Preferred estimates for the maximum credible earthquake at SLAPS range from MMI VIII to IX, which correspond to magnitudes of 5.8 to 6.3 on the Richter scale and would result in peak ground accelerations at the site of 0.25 to 0.50 g. Ground accelerations in this range could cause liquefaction of sediments at depth; however, sediments overlying potentially liquefiable soils would attenuate the effects of liquefaction.

Based on geologic and hydrogeologic characteristics, groundwater underlying SLAPS has been divided into the upper and lower groundwater systems separated by a low-permeability layer. In areas where an upward flow potential is apparent, the upper groundwater system discharges to Coldwater Creek. Surface water drains from west to east and north and ultimately discharges to Coldwater Creek.

The existing conditions at SLAPS are favorable for the citing of a disposal facility. The following points are considered to be positive factors in the determination of SLAPS site suitability.

- The presence of a disposal facility will have minimal effect on groundwater at the site.
- Groundwater immediately underlying SLAPS is isolated from groundwater in deeper sediments by a low-permeability layer.
- Groundwater flow rates in the upper groundwater system are slow, ranging from 0.04 to 1.75 m/yr (0.13 to 5.7 ft/yr).
- The sediments underlying SLAPS retard contaminant movement, providing an additional factor of safety.
- The potential for catastrophic collapse is very low.
- There are no wetlands that would be affected by or would affect the facility.

As part of disposal facility design and construction, the following supplemental data would be useful: soil foundation properties, confirmatory exploration for the presence of caves, and information on vadose zone properties. With regard to this last item, the discharge of groundwater into Coldwater Creek will require special attention during facility design.

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APPENDIX A Soil Testing Data for the SLAPS/Ball Field Area

Table A-1

SOIL TESTING DATA FOR THE SLAPS/BALL FIELD AREA

BORING	DEPTH TOP (ft)	DEPTH BOTTOM (ft)	UNIT	ATTERBERG LIMITS LIQUID LIMIT	ATTERBERG LIMITS PLASTIC LIMIT	ATTERBERG LIMITS PLASTICITY INDEX	DRY DENSITY (pcf)	SPECIFIC GRAVITY	WATER CONTENT (%)	VOID RATIO	GRADATION SAND (%)	GRADATION FINES[a] (%)	DISTRIBUTION RATIO[b] (ml/gm)	ECEC OR CEC[c] (meq/100 gm soil)	LABORATORY VERTICAL PERMEABILITY (cm/s)
A-1	20.5	d	3T												5.0×10^{-06}
A-1	27.5		3T	40	21	19									2.0×10^{-08}
A-3	15.5		2	32	25	7	84.3	2.63							8.0×10^{-07}
A-5	26.5		3T	31	22	9									9.0×10^{-07}
B-1	9		2										29		
B-1	9.5		2										83		
B-1	10		2										230		
B-1	11		2										140		
B-1	11.5		2										300		
B-1	12.3		2										110		
B-1	13		2										96		
B-1	13.5		2										100		
B-1	15		2										150		
B-1	17		2										170		
B-1	21		2										5900		
B-1	25		3T										2600		
B-1	29		3T										2000		
B-1	31.5		3T										2100		
B-1	31.5		3T										Ra 880		
B-1	31.5		3T										Ra 940		
B-1	38		3T										4300		
B-1	57		3B										560		
B-1	47.5		3M											26.1	
B-1	48		3M										21		
B-1B	1		1										24		
B-1B	2		1										19		
B-1B	3		2										52		
B-1B	4		2										1800		
B-1B	5		2										32		
B-1B	5.7		2										28		

Table A-1
(continued)

BORING	DEPTH TOP (ft)	DEPTH BOTTOM (ft)	UNIT	ATTERBERG LIMITS LIQUID LIMIT	PLASTIC LIMIT	PLASTICITY INDEX	DRY DENSITY (pcf)	SPECIFIC GRAVITY	WATER CONTENT (%)	VOID RATIO	GRADATION SAND (%)	GRADATION FINES[a] (%)	DISTRIBUTION RATIO[b] (ml/gm)	ECEC OR CEC[c] (meq/100 gm soil)	LABORATORY VERTICAL PERMEABILITY (cm/s)
B-1B	6.3		2										750		
B-1B	7		2										3200		
B-1B	7.7		2										3600		
B-1B	8.3		2										130		
B-1B	9		2										65		
B-1B	9.5		2										63		
B-1B	10		2										52		
B-1B	10.5		2										120		
B-1B	53.5		3B										760		
B-1B	61		3B										120		
B-1B	51		3M										25		
B-1B	69		4										380		
B-2	0		1										38		
B-2	0.5		1										25		
B-2	1		1										49		
B-2	6		1										460		
B-2	6.5		1										53		
B-2	7		2										61		
B-2	7.5		2										54		
B-2	8		2										19		
B-2	8.5		2										150		
B-2	9		2										1600		
B-2	10		2										12		
B-2	10.3		2										3500		
B-2	11		2										26		
B-2	14.5		2										43		
B-2	16.5		2				90.7		29.5	0.823					2.0×10^{-04}
B-2	17		2										16		
B-2	19		2											16.3	
B-2	19.5		2										18		

Table A-1
(continued)

BORING	DEPTH TOP (ft)	DEPTH BOTTOM (ft)	UNIT	ATTERBERG LIMITS LIQUID LIMIT	ATTERBERG LIMITS PLASTIC LIMIT	ATTERBERG LIMITS PLASTICITY INDEX	DRY DENSITY (pcf)	SPECIFIC GRAVITY	WATER CONTENT (%)	VOID RATIO	GRADATION SAND (%)	GRADATION FINES[a] (%)	DISTRIBUTION RATIO[b] (ml/gm)	ECEC OR CEC[c] (meq/100 gm soil)	LABORATORY VERTICAL PERMEABILITY (cm/s)
B-2	22		2										99		
B-2	26.5		3T											17.1	
B-2	29.0		3T				95.6		27.6	0.730				13.5	7.0×10^{-05}
B-2	34.5		3T										950		
B-2	39		3T											12.6	
B-2	41.5		3T				91.2		29.8	0.813					5.0×10^{-05}
B-2	49		3M										17		
B-2	49.0		3M				82.5		38.5	1.004				30.6	7.0×10^{-07}
B-2	56.5		3M											26.7	
B-2	59.5		3M										37		
B-2	66.5		3B				88.0		32.4	0.679					2.0×10^{-05}
B-2	72		3B										720		
B-2	79.0		4				96.2		24.7	0.719					8.0×10^{-06}
B-2	83.5		4										33		
B-3	0		1										38		
B-3	2.5		1										44		
B-3	3		1										38		
B-3	3.5		2										28		
B-3	4		2										0.02		
B-3	4.5		2										35		
B-3	5		2										1100		
B-3	5.5		2										110		
B-3	6		2										15		
B-3	8		2										22		
B-3	10.5		2										750		
B-3	15.5		2										220		
B-3	20.5		3T										1800		
B-3	33		3M										180		
B-3	45.5		5										2100		
P-2	69.5		4	29	24	5									8.0×10^{-07}

Table A-1
(continued)

BORING	DEPTH TOP (ft)	DEPTH BOTTOM (ft)	UNIT	ATTERBERG LIMITS LIQUID LIMIT	ATTERBERG LIMITS PLASTIC LIMIT	ATTERBERG LIMITS PLASTICITY INDEX	DRY DENSITY (pcf)	SPECIFIC GRAVITY[*]	WATER CONTENT (%)	VOID RATIO	GRADATION SAND (%)	GRADATION FINES[a] (%)	DISTRIBUTION RATIO[b] (ml/gm)	ECEC OR CEC[c] (meq/100 gm soil)	LABORATORY VERTICAL PERMEABILITY (cm/s)
P-2	83.5		4												2.0×10^{-08}
P-4	20.5		2	33	23	10	90.7	2.66							2.0×10^{-07}
G10-17	52.0	54.0	3M	70	25	45		2.34	23		15	85	11	223	
G12-12	49.5	51.5	3M	70	26	44		2.38	29		5	95	8.1	214	
G13-10	45.0	47.0	3M	70	28	42		2.35	28		1	99	8	187	
M13.5-8.5D	36.0	38.0	3T	30	21	9		2.31	22		6	94	11	150	
G11-27	31.0	33.0	3T	39	19	20		2.40	25		17	83		144	
M10-15D	80.0	82.0	4	26	NP[e]	NP		2.38	29		20	80			
M13.5-8.5D	52.0	54.0	3M	43	20	23		2.32	32		12	88			
M11-21	10.0	12.0	2	30	25	5		2.33	25		31	69			
M10-6D	53.0	55.0	3B	29	23	6		2.53	27		13	87			
M10-6S	18.0	20.0	2	35	NP	NP		2.34	28		9	91			
G10-21	30.0	32.0	3T	27	NP	NP		2.42	23		3	97			
G10-29	27.0	29.0	3T	37	20	17		2.27	28		10	90			
G10-12	10.0	12.0	2	31	24	7		2.48	26		13	87			
M10-25D	28.5	30.5	3T	38	15	23		2.47	23		7	93			
M11-9	22.5	24.5	2	31	NP	NP		2.38	38		36	64			
G13-10	17.0	19.0	2	27	26	1		2.38	28		6	94			
M13.5-8.5S	22.0	24.0	2	37	NP	NP		2.57	38		19	81			
M10-15S	12.0	17.0	2	32	23	9		2.59	25		19	81			
G12-12	34.0	38.0	2					2.66	24		14	86			
M10-6D	33.1	33.3	3T	37	14	23		2.42	28		5	95			
G10-10	36.5	37.3	3T	29	23	6		2.35	13		6	94			
G10-12	32.9	33.6	3T	30	21	9		2.37	18		7	93			
G10-17	20.7	21.0	2	27	24	3		2.41	18		12	88			
M10-25D	46.5	49.2	3T	37	21	16		2.38	29		10	90			
M13.5-8D	61.1	61.8	3B	30	22	8		2.57	22		15	85			
G14-24	33.5	34.0	3M	59	23	36		2.52	12		18	82			
M10-6D	46.0	46.8	3M					2.31	20		6	94			
M10-6D	68.0	70.0	3B					2.60	17		30	70			

Table A–1
(continued)

BORING	DEPTH TOP (ft)	DEPTH BOTTOM (ft)	UNIT	ATTERBERG LIMITS LIQUID LIMIT	ATTERBERG LIMITS PLASTIC LIMIT	ATTERBERG LIMITS PLASTICITY INDEX	DRY DENSITY (pcf)	SPECIFIC GRAVITY	WATER CONTENT (%)	VOID RATIO	GRADATION SAND (%)	GRADATION FINES[a] (%)	DISTRIBUTION RATIO[b] (ml/gm)	ECEC OR CEC[c] (meq/100 gm soil)	LABORATORY VERTICAL PERMEABILITY (cm/s)
M10-15D	86.4	87.1	4					2.21	12		44	56			
G10-17	28.2	28.8	3T					2.48	14		12	88			
G10-21	27.5	27.8	3T	39	19	20		2.31	18		10	90			
G10-21	39.0	39.3	3M					2.26	8		12	88			
G10-21	42.9	43.7	3M					2.27	25		6	94			
M10-25S	20.0	20.3	2					2.29	20		37	63			
M10-25D	37.0	37.5	3M					2.33	21		14	86			
G10-29	20.5	20.8	2	32	22	10		2.41	14		8	92			
M10-25S	13.5	13.8	1					2.33	26		52	48			
G12-8A	28.3	28.5	3T					2.44	10		32	68			
G12-12	39.9	40.4	3M					2.37	14		5	95			
G12-12	43.3	43.6	3M					2.34	26		11	89			
M12.5-8.5D	70.0	71.3	3B					2.35	18		15	85			
M13.5-8.5D	72.4	73.2	3B					2.53	14		31	69			
G14-12	16.4	16.8	1	25	23	1		2.46	21		22	78			
G14-12	21.7	21.9	2					2.38	3		9	91			
B53G16	8.0	13.0	2	36	23	13		2.54	22						
B53G06	0.0	2.5	2	34	20	14			18						
B53G06	2.5	7.5	2	35	22	13			21						
B53G06	13.5	18.5	2	33	21	12			24						
B53G06	18.5	23.5	2	40	28	12			27						
B53G06	28.5	33.5	3T	31	20	11			25						
B53G06	45.5	48.5	3M	77	26	51			37						
B53W02S	0.0	4.0	2	51	23	28			24						
B53W02S	4.6	9.0	2	37	18	19			22						
B53W02S	14.0	19.0	2	33	20	13			22						
B53W02S	19.5	22.0	3T	28	17	11			20						
B53W02D	44.0	49.0	3M	78	26	52			29						
B53W02D	59.0	64.0	3B	32	20	12			25						
B53G01	18.0	20.0	2				102.9		26	0.528					8.8×10^{-07}

Table A-1
(continued)

BORING	DEPTH TOP (ft)	DEPTH BOTTOM (ft)	UNIT	ATTERBERG LIMITS LIQUID LIMIT	ATTERBERG LIMITS PLASTIC LIMIT	ATTERBERG LIMITS PLASTICITY INDEX	DRY DENSITY (pcf)	SPECIFIC GRAVITY	WATER CONTENT (%)	VOID RATIO	GRADATION SAND (%)	GRADATION FINES[a] (%)	DISTRIBUTION RATIO[b] (ml/gm)	ECEC OR CEC[c] (meq/100 gm soil)	LABORATORY VERTICAL PERMEABILITY (cm/s)
B53G02	54.0	56.0	3M				97.3		28	0.501					5.9×10^{-08}
B53G03	28.0	30.0	3T				102.4		24	0.475					1.6×10^{-08}
B53G04	29.0	31.0	3T				83.2		31	0.815					2.7×10^{-07}
B53G05	49.0	51.0	3M				70.5		50	1.071					1.4×10^{-08}
B53G06	43.5	45.5	3M				79.0		39	0.846					1.6×10^{-08}
B53G07	10.0	13.5	2										35.2	122	
B53G10	9.5	14.0	2										329.3	184	
B53W10S	8.5	13.5	2										126.7	200	
B53W10D	9.5	14.0	2										329.3	142	
B53G12	38.5	40.5	3T				94.4		26	0.800					1.8×10^{-08}
B53G13	29.0	31.0	2				102.5		24	0.534					1.4×10^{-08}
B53G13	49.0	51.0	3T				95.7		31	0.576					9.0×10^{-07}
B53W14S	14.5	16.5	2										19.1	98	
B53G18	58.0	68.0	3B				99.5		29	0.518					1.7×10^{-07}
B53G15	13.5	18.5	2	33	23	10		2.63	24		2	98			
B53G18	8.0	13.0	2	36	23	13		2.54	22		1	99			
B53W13S	9.5	14.5	2	39	24	15		2.59	28		5	95			
B53W11D	15.5	18.5	3T	36	22	14			23		5	95			
B53W11D	4.5	9.5	2	36	23	13		2.63	25		3	97			
B53G18	43.0	48.0	3M	78	28	50			32		0	100			
B53G16	25.0	28.0	3T	37	19	18			25		1	99			
B53G18	13.0	18.0	2	33	23	10		2.58	21		0	100			
B53G17	36.0	38.0	3B	29	25	4			19		1	99			
B53G17	19.5	23.0	3T	42	19	23			28		0	100			
B53G17	13.0	18.0	2	39	22	17		2.56	27		0	100			
B53G16	13.5	18.5	2	32	25	7		2.57	27		0	100			
B53G11	34.5	39.5	3T	29	21	8			22		0	100			
B53G11	19.5	24.5	2	34	23	11		2.61	23		0	100			
B53G09	53.0	58.0	3B	53	20	33			27		1	99			
B53G08	14.5	17.0	2	32	24	8		2.51	23		2	98			

Table A–1
(continued)

BORING	DEPTH TOP (ft)	DEPTH BOTTOM (ft)	UNIT	ATTERBERG LIMITS LIQUID LIMIT	ATTERBERG LIMITS PLASTIC LIMIT	ATTERBERG LIMITS PLASTICITY INDEX	DRY DENSITY (pcf)	SPECIFIC GRAVITY	WATER CONTENT (%)	VOID RATIO	GRADATION SAND (%)	GRADATION FINES[a] (%)	DISTRIBUTION RATIO[b] (ml/gm)	ECEC OR CEC[c] (meq/100 gm soil)	LABORATORY VERTICAL PERMEABILITY (cm/s)
B53G14	28.5	32.0	3T	48	81	25			26		3	97			
B53G14	23.5	26.5	3T	35	22	13			25		0	100			
B53G14	8.5	13.5	2	36	24	12		2.44	22		0	100			
B53G13	89.0	94.0	4						16		77	23			
B53G13	9.0	13.5	2	32	22	10		2.53	24		14	86			
B53G12	40.5	43.5	3B	31	19	12			25		25	75			
B53G03	49.0	54.0	3M	71	26	45			21		0	100			
B53G03	64.0	69.0	3B	33	20	13			20		7	93			
B53G12	23.5	28.5	3T	40	18	22			28		5	95			
B53G12	8.5	13.5	2	33	23	10		2.62	26		4	96			
B53G03	23.0	28.0	3T	29	21	8			20		7	93			
B53G03	3.0	8.0	2	34	24	11		2.73	24		2	98			
B53W12D	38	40	3T	32	23	9	96.1	2.70	29.7		1	99		22.40	3.8×10^{-05}
B53W12D	52.5	54.5	3B	42	27	15	104.7	2.77	28.8		2	93		19.90	5.7×10^{-07}
B53W17S	8	10	2	34	25	9	82.7	2.70	42.5		2	98			
B53W17S	24	26	3T	35	21	14	104.5	2.76	23.7		2	98		21.42	8.5×10^{-06}
B53W17S	28	30	3T	43	22	21	98.3	2.70	26.6		2	96		24.77	1.1×10^{-07}
B53W18S	25	27	3T	31	23	8	100.8	2.68	25.4		2	98		26.97	1.2×10^{-05}
B53W18S	30	32	3T	29	23	8	99.1	2.68	25.3		4	96		19.47	2.5×10^{-06}
B53W19S	6	8	2	36	25	11	100.3	2.68	27.0		5	95		24.69	3.8×10^{-05}
B53W19S	12	14	2	32	27	5	97.1	2.72	26.0		3	97		14.57	2.4×10^{-05}
B53W20S	14	16	2	31	25	6	113.3	2.68	12.2		1	99		17.62	3.9×10^{-06}
B53W20S	17	19	2	32	24	8	93.6	2.70	27.1		4	96		16.60	2.4×10^{-06}

[a]Fines = percent of sample finer than the No. 200 sieve (0.074 mm).

[b]Distribution ratios are for uranium unless otherwise noted (Ra = radium).

[c]ECEC = Effective cation exchange capacity; CEC = cation exchange capacity.

[d]Blank spaces indicate no data or data not available.

[e]NP = nonplastic.

Table A-2

Field Permeability Test Data

Borehole	Test Interval (ft)	Unit	Field Permeability (cm/s)	Test Method[a]
P-7	?	2	3.0×10^{-4}	Slug-Ah
P-6	?	2	4.8×10^{-5}	Slug-Ah
B53G02	13.2	2	1.5×10^{-4}	Fh-Oe
B53W17S	20-30	2/3T	2.0×10^{-4}	Slug-W
B53W18S	10-20	2	1.8×10^{-4}	Slug-W
B53W19S	7-17	2/3T	5.3×10^{-4}	Slug-W
B53W20S	10-20	2	2.8×10^{-5}	Slug-W
M10-25S	14-24	2	2.8×10^{-4}	Slug-W
B53W06S	30.3-35.3	2/3T	7.2×10^{-4}	Slug-W
B53W11S	15.9-20.9	2/3T	1.3×10^{-4}	Slug-W
M10-15S	14.2-24.2	2/3T	2.4×10^{-4}	Slug-W
B53W08S	31.3-36.3	3T	8.4×10^{-5}	Slug-W
B53W12S	28.5-33.5	3T	1.6×10^{-4}	Slug-W
M13.5-8.5S	19.3-29.3	3T	7.8×10^{-6}	Slug-W
B53W04S	42.8-47.8	3T/3M	8.4×10^{-6}	Slug-W
B52W10S	40.9-45.9	3T/3M	6.0×10^{-6}	Slug-W
P-5	?	3T	6.1×10^{-6}	Slug-Ah
A-2	12-27	3T	2.4×10^{-5}	Slug-W
A-6	20-40	3T	5.0×10^{-6}	Slug-W
A-7	20-40	3T	1.2×10^{-6}	Slug-W
A-8	19-39	3T	4.5×10^{-6}	Slug-W
B53G16	38.8	3M	3.1×10^{-5}	Fh-Oe
P-1	69-82	3B	2.9×10^{-6}	Slug-W
P-2	69-82	3B	1.2×10^{-6}	Slug-W
B53G02	69.2	3B	2.0×10^{-4}	Fh-Oe
B53W12D	44-54	3B	2.3×10^{-5}	Slug-W
B53W04D	67.8-77.8	3B	1.9×10^{-5}	Slug-W
B53W06D	60.3-70.3	3B	2.9×10^{-4}	Slug-W
M10-25D	39.3-49.3	3B	2.8×10^{-6}	Slug-W
B53W08D	80.9 - 90.9	3B/4	6.6×10^{-3}	Slug-W
M13.5-8.5D	64.4-69.4	3B/4	1.2×10^{-4}	Slug-W

Table A-2

(continued)

Borehole	Test Interval (ft)	Unit	Field Permeability (cm/s)	Test Method[a]
B53W10D	71.1-81.1	4	5.8×10^{-5}	Slug-W
M10-15D	80-85	4	4.1×10^{-6}	Slug-W
B53G04	79	4	2.2×10^{-4}	Fh-Oe
B53W09D	61.1-71.1	5	7.5×10^{-8}	Slug-W
B53W11D	68.5-78.5	5	1.6×10^{-7}	Slug-W
B53G16	89-99.6	6	7.5×10^{-7}	Ch-P
B53G18	83.6-95.5	6	1.1×10^{-5}	Ch-P

[a]Test Methods:

Slug-Ah = Slug test in open auger hole (horizontal permeability)
Fh-Oe = Falling head in open end casing (mean permeability)
Slug-W = Slug test in monitoring well (horizontal permeability)
Ch-P = Constant-head packer test in rock (horizontal permeability)

The Hydrologic Evaluation of Landfill Performance (HELP) model is used to determine the average annual percolation through the waste pile (Schroeder 1988). The HELP computer model is a quasi-two-dimensional hydrologic model of water movement across, into, through, and out of landfills. The model is widely used and has been tested extensively using both field and laboratory data. HELP uses climatological, soil, and design data to estimate the runoff, infiltration, percolation, evapotranspiration, and lateral drainage from a landfill.

Two onsite disposal alternatives are being considered for SLAPS. The first alternative involves leaving the contaminated materials (fill and soil) in place at SLAPS and compacting the fill in situ by means of controlled dynamic consolidation. This will create a uniform base over which contaminated soils from the vicinity properties could be placed. A cover will then be placed over the waste pile.

The second alternative involves removing all of the contaminated material at SLAPS and replacing it with clean backfill. A bottom clay liner would be constructed, and all of the contaminated material would be placed on top. The same pile cover design would be used for both alternatives.

In both design alternatives, the waste pile cover is the controlling factor in the amount of percolation through the pile. Over a period of time, an equilibrium will be reached in the pile so that the average annual percolation through the pile bottom will become the same as the average annual percolation through the pile cover.

The pile cover design is based on the design for a generic FUSRAP permanent waste pile (BNI 1989b). Figure B-1 shows a typical cross section of the waste pile cover. A 1.2-m (4-ft) layer of compacted, low-permeability clay will be placed on top of the waste material. A 23-cm (9-in.) layer of sand and gravel will be placed over the clay to support lateral drainage and protect the clay layer from the riprap above. The riprap layer will be 0.9 m (3 ft) thick to serve as a barrier to human intrusion and to prevent root disturbance of the clay layer. The top surface of the clay layer will be filled with gravel to provide a base for the overlying sand layer. Another 23-cm (9-in.) sand layer will provide a transition layer

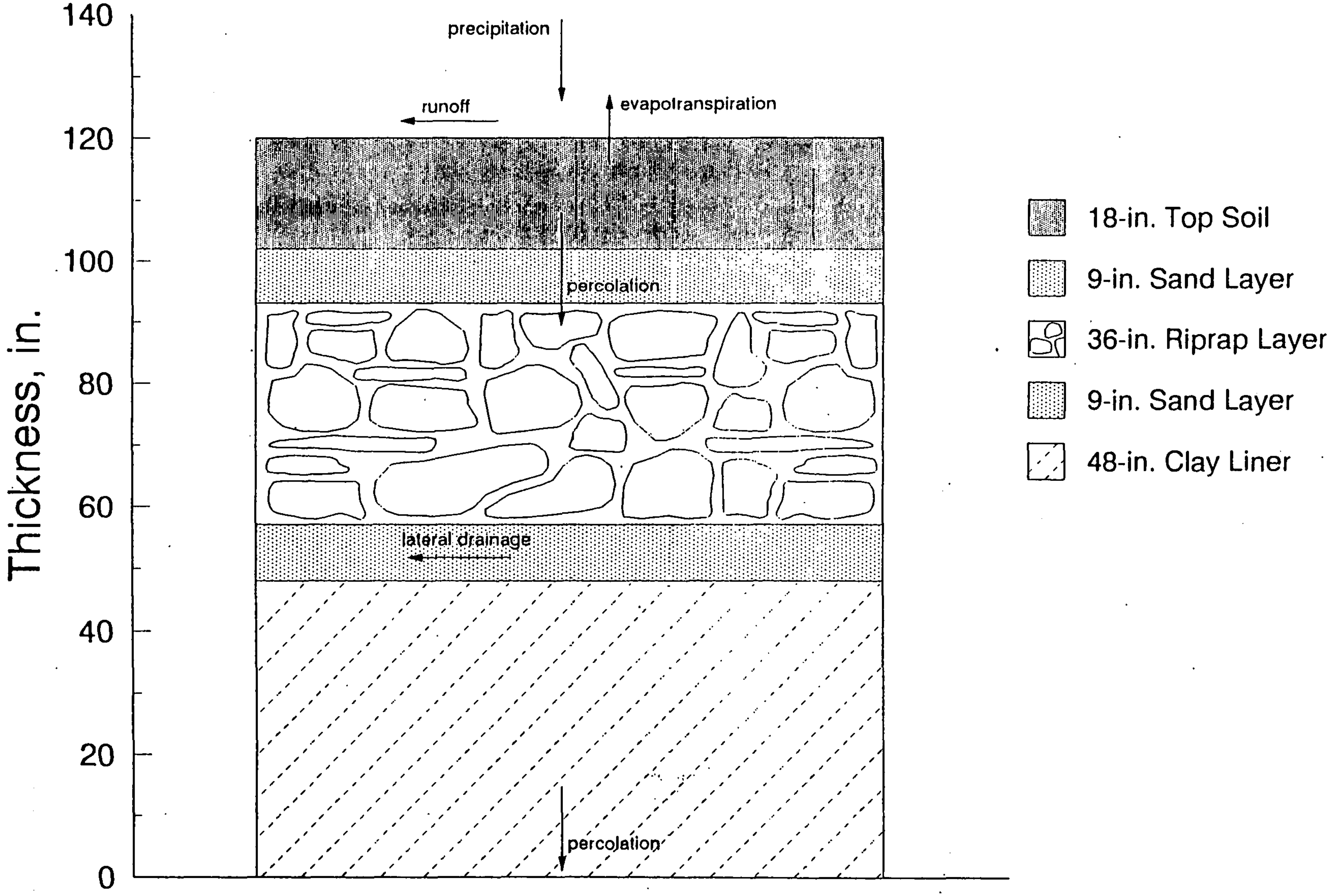

Figure B-1
Cross Section of Proposed Waste Pile Cover

APPENDIX B Results of HELP Modeling

between the topsoil and the riprap. A 46-cm (18-in.) layer of top soil will be placed on top of the cover to support grass growth.

The pile cover consists of five layers. Because specific information on each soil layer is not available, default soil parameters provided within the HELP model were used in the simulation. The parameters for each of the soil layers in the pile cover are:

Layer 1 - Top Soil

Soil type	silt loam
Thickness	18 in.
Layer type	vertical percolation
Porosity	0.501
Field capacity	0.284
Wilting point	0.136
Saturated hydraulic conductivity	5.7×10^{-4} cm/s

Layer 2 - Sand and Gravel

Soil type	coarse sand
Thickness	9 in.
Layer type	vertical percolation
Porosity	0.417
Field capacity	0.046
Wilting point	0.020
Saturated hydraulic conductivity	1.0×10^{-2} cm/s

Layer 3 - Riprap

Soil type	riprap
Thickness	36 in.
Layer type	lateral drainage
Porosity	0.400
Field capacity	0.030
Wilting point	0.020
Saturated hydraulic conductivity	100 cm/s

Layer 4 - Sand and Gravel

Soil type	coarse sand
Thickness	9 in.
Layer type	lateral drainage
Porosity	0.417
Field capacity	0.046
Wilting point	0.020
Saturated hydraulic conductivity	1.0×10^{-2} cm/s

Layer 5 - Clay Barrier

Soil type	compacted clay
Thickness	48 in.
Layer type	barrier
Porosity	0.430
Field capacity	0.367
Wilting point	0.280
Saturated hydraulic conductivity	1.0×10^{-7} cm/s

Thirty-four years (1950-1983) of daily precipitation, temperature, and solar radiation data recorded at the Lambert-St. Louis International Airport were used as input to the HELP model. The airport borders SLAPS to the south.

A complete summary of the annual results is given in Table B-1. The average annual results (in inches) for the 34-year simulation is:

Precipitation	35.29
Runoff	0.81
Evapotranspiration	27.14
Lateral drainage from Layer 4	6.08
Percolation from Layer 5	1.08

The HELP model output follows the table.

Table B-1

Cap Performance Summary

Year	Precipitation, in.	Runoff, in.	Evapotranspiration, in.	Lateral Drainage Layer 4, in.	Percolation From Layer 5, in.
50	37.63	1.116	28.310	7.1124	1.0566
51	36.34	0.160	30.891	2.8904	0.8311
52	25.67	0.189	22.662	2.8321	0.9363
53	20.59	0.042	19.718	0.7584	0.7249
54	27.61	0.244	24.508	0.5648	0.3491
55	31.33	0.063	28.599	3.2455	0.9855
56	34.43	0.538	28.812	1.1778	0.9823
57	47.16	2.465	32.882	11.3519	1.2969
58	37.38	0.795	33.135	3.2818	1.1436
59	28.31	0.333	22.845	3.2996	1.1083
60	31.78	0.717	29.060	2.2472	1.1425
61	41.20	1.779	32.815	4.3271	0.9965
62	34.63	0.383	29.405	5.0235	1.1606
63	28.62	0.355	25.112	1.4848	0.8365
64	32.16	0.494	26.582	3.4326	1.0917
65	27.73	0.021	24.193	3.0446	0.9784
66	32.34	0.727	24.232	6.1817	1.1134
67	41.30	0.515	30.118	7.5172	1.2321
68	32.49	0.859	22.762	6.5969	1.2389
69	43.72	1.285	28.681	14.2793	1.3612
70	36.20	0.900	30.108	5.4557	1.2861
71	33.73	1.012	24.875	3.8050	1.1441
72	33.72	0.908	24.085	6.4130	1.2043
73	39.82	0.359	29.498	9.0277	1.2114
74	36.83	0.800	27.906	9.6289	1.3008
75	40.21	0.637	29.081	9.6619	1.0876
76	23.46	0.108	21.877	1.9291	0.9738
77	43.41	0.741	30.923	6.8905	1.1653
78	37.71	0.865	25.850	10.6352	1.1971
79	29.48	1.672	20.245	8.0209	1.0382
80	27.48	0.201	26.041	1.6523	0.9138
81	45.52	1.816	32.783	7.6714	1.0810
82	54.97	3.193	31.280	16.5430	1.3349
83	44.80	1.364	22.878	18.7870	1.3514
mean	35.29	0.81	27.14	6.08	1.08

CAP EVALUATION

USING

HELP MODEL

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ST. LOUIS SITE
PROPOSED WASTE PILE COVER (YEARS 50-69)
MARCH 11, 1993

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                              FAIR GRASS

                               LAYER  1
                               --------

                       VERTICAL PERCOLATION LAYER
THICKNESS                           =      18.00 INCHES
POROSITY                            =       0.5010 VOL/VOL
FIELD CAPACITY                      =       0.2844 VOL/VOL
WILTING POINT                       =       0.1357 VOL/VOL
INITIAL SOIL WATER CONTENT          =       0.1909 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY    =       0.0005700000329 CM/SEC


                               LAYER  2
                               --------

                       VERTICAL PERCOLATION LAYER
THICKNESS                           =       9.00 INCHES
POROSITY                            =       0.4170 VOL/VOL
FIELD CAPACITY                      =       0.0457 VOL/VOL
WILTING POINT                       =       0.0200 VOL/VOL
INITIAL SOIL WATER CONTENT          =       0.0500 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY    =       0.0099999997765 CM/SEC


                               LAYER  3
                               --------

                         LATERAL DRAINAGE LAYER
THICKNESS                           =      36.00 INCHES
POROSITY                            =       0.4000 VOL/VOL
FIELD CAPACITY                      =       0.0300 VOL/VOL
WILTING POINT                       =       0.0200 VOL/VOL
INITIAL SOIL WATER CONTENT          =       0.0284 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY    =     100.0000000000000 CM/SEC


                               LAYER  4
                               --------

                         LATERAL DRAINAGE LAYER
THICKNESS                           =       9.00 INCHES
POROSITY                            =       0.4170 VOL/VOL
FIELD CAPACITY                      =       0.0457 VOL/VOL
WILTING POINT                       =       0.0200 VOL/VOL
INITIAL SOIL WATER CONTENT          =       0.0457 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY    =       0.0099999997765 CM/SEC
SLOPE                               =       7.50 PERCENT
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DRAINAGE LENGTH = 500.0 FEET

LAYER 5

BARRIER SOIL LINER

THICKNESS	=	48.00 INCHES
POROSITY	=	0.4300 VOL/VOL
FIELD CAPACITY	=	0.3667 VOL/VOL
WILTING POINT	=	0.2804 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4300 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.0000001000000 CM/SEC

GENERAL SIMULATION DATA

SCS RUNOFF CURVE NUMBER	=	81.48
TOTAL AREA OF COVER	=	1800000. SQ FT
EVAPORATIVE ZONE DEPTH	=	20.00 INCHES
UPPER LIMIT VEG. STORAGE	=	9.8520 INCHES
INITIAL VEG. STORAGE	=	3.5779 INCHES

SOIL WATER CONTENT INITIALIZED BY PROGRAM.

CLIMATOLOGICAL DATA

USER SPECIFIED RAINFALL WITH SYNTHETIC DAILY TEMPERATURES AND SOLAR RADIATION FOR ST. LOUIS MISSOURI

MAXIMUM LEAF AREA INDEX	=	2.00
START OF GROWING SEASON (JULIAN DATE)	=	109
END OF GROWING SEASON (JULIAN DATE)	=	298

NORMAL MEAN MONTHLY TEMPERATURES, DEGREES FAHRENHEIT

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
29.10	39.50	51.50	61.00	68.80	78.80
78.00	75.10	65.30	53.70	38.80	29.70

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ANNUAL TOTALS FOR YEAR 50

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	37.63	5644500.	100.00
RUNOFF	1.116	167394.	2.97
EVAPOTRANSPIRATION	28.310	4246463.	75.23
LATERAL DRAINAGE FROM LAYER 4	7.1124	1066859.	18.90
PERCOLATION FROM LAYER 5	1.0566	158493.	2.81
CHANGE IN WATER STORAGE	0.035	5291.	0.09
SOIL WATER AT START OF YEAR	25.96	3894093.	

SOIL WATER AT END OF YEAR	26.00	3899384.	
SNOW WATER AT START OF YEAR	0.00	0.	
SNOW WATER AT END OF YEAR	0.00	0.	
ANNUAL WATER BUDGET BALANCE	0.00	0.	0.00

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ANNUAL TOTALS FOR YEAR 51

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	36.34	5451001.	100.00
RUNOFF	0.160	23989.	0.44
EVAPOTRANSPIRATION	30.891	4633725.	85.01
LATERAL DRAINAGE FROM LAYER 4	2.8904	433559.	7.95
PERCOLATION FROM LAYER 5	0.8311	124663.	2.29
CHANGE IN WATER STORAGE	1.567	235062.	4.31
SOIL WATER AT START OF YEAR	26.00	3899384.	
SOIL WATER AT END OF YEAR	27.56	4134445.	
SNOW WATER AT START OF YEAR	0.00	0.	
SNOW WATER AT END OF YEAR	0.00	0.	
ANNUAL WATER BUDGET BALANCE	0.00	4.	0.00

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ANNUAL TOTALS FOR YEAR 52

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	25.67	3850501.	100.00
RUNOFF	0.189	28371.	0.74
EVAPOTRANSPIRATION	22.662	3399283.	88.28
LATERAL DRAINAGE FROM LAYER 4	2.8321	424820.	11.03
PERCOLATION FROM LAYER 5	0.9363	140439.	3.65
CHANGE IN WATER STORAGE	-0.949	-142411.	-3.70
SOIL WATER AT START OF YEAR	27.56	4134445.	
SOIL WATER AT END OF YEAR	26.61	3992034.	
SNOW WATER AT START OF YEAR	0.00	0.	
SNOW WATER AT END OF YEAR	0.00	0.	

ANNUAL WATER BUDGET BALANCE	0.00	0.	0.00

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ANNUAL TOTALS FOR YEAR 53

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	20.59	3088500.	100.00
RUNOFF	0.042	6307.	0.20
EVAPOTRANSPIRATION	19.718	2957638.	95.76
LATERAL DRAINAGE FROM LAYER 4	0.7584	113764.	3.68
PERCOLATION FROM LAYER 5	0.7249	108735.	3.52
CHANGE IN WATER STORAGE	-0.653	-97944.	-3.17
SOIL WATER AT START OF YEAR	26.61	3992034.	
SOIL WATER AT END OF YEAR	25.96	3894090.	
SNOW WATER AT START OF YEAR	0.00	0.	
SNOW WATER AT END OF YEAR	0.00	0.	
ANNUAL WATER BUDGET BALANCE	0.00	0.	0.00

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ANNUAL TOTALS FOR YEAR 54

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	27.61	4141501.	100.00
RUNOFF	0.244	36619.	0.88
EVAPOTRANSPIRATION	24.508	3676128.	88.76
LATERAL DRAINAGE FROM LAYER 4	0.5648	84723.	2.05
PERCOLATION FROM LAYER 5	0.3491	52370.	1.26
CHANGE IN WATER STORAGE	1.944	291660.	7.04
SOIL WATER AT START OF YEAR	25.96	3894090.	
SOIL WATER AT END OF YEAR	27.90	4185749.	
SNOW WATER AT START OF YEAR	0.00	0.	
SNOW WATER AT END OF YEAR	0.00	0.	
ANNUAL WATER BUDGET BALANCE	0.00	1.	0.00

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ANNUAL TOTALS FOR YEAR 55

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	31.33	4699500.	100.00
RUNOFF	0.063	9458.	0.20
EVAPOTRANSPIRATION	28.599	4289914.	91.28
LATERAL DRAINAGE FROM LAYER 4	3.2455	486822.	10.36
PERCOLATION FROM LAYER 5	0.9855	147831.	3.15
CHANGE IN WATER STORAGE	-1.563	-234524.	-4.99
SOIL WATER AT START OF YEAR	27.90	4185749.	
SOIL WATER AT END OF YEAR	26.34	3951225.	
SNOW WATER AT START OF YEAR	0.00	0.	
SNOW WATER AT END OF YEAR	0.00	0.	
ANNUAL WATER BUDGET BALANCE	0.00	0.	0.00

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ANNUAL TOTALS FOR YEAR 56

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	34.43	5164499.	100.00
RUNOFF	0.538	80752.	1.56
EVAPOTRANSPIRATION	28.812	4321771.	83.68
LATERAL DRAINAGE FROM LAYER 4	1.1778	176663.	3.42
PERCOLATION FROM LAYER 5	0.9823	147346.	2.85
CHANGE IN WATER STORAGE	2.920	437967.	8.48
SOIL WATER AT START OF YEAR	26.34	3951225.	
SOIL WATER AT END OF YEAR	29.26	4389192.	
SNOW WATER AT START OF YEAR	0.00	0.	
SNOW WATER AT END OF YEAR	0.00	0.	
ANNUAL WATER BUDGET BALANCE	0.00	0.	0.00

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ANNUAL TOTALS FOR YEAR 57

	(INCHES)	(CU. FT.)	PERCENT

PRECIPITATION	47.16	7074000.	100.00
RUNOFF	2.465	369702.	5.23
EVAPOTRANSPIRATION	32.882	4932358.	69.73
LATERAL DRAINAGE FROM LAYER 4	11.3519	1702787.	24.07
PERCOLATION FROM LAYER 5	1.2969	194540.	2.75
CHANGE IN WATER STORAGE	-0.836	-125388.	-1.77
SOIL WATER AT START OF YEAR	29.26	4389192.	
SOIL WATER AT END OF YEAR	28.43	4263804.	
SNOW WATER AT START OF YEAR	0.00	0.	
SNOW WATER AT END OF YEAR	0.00	0.	
ANNUAL WATER BUDGET BALANCE	0.00	0.	0.00

ANNUAL TOTALS FOR YEAR 58

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	37.38	5607001.	100.00
RUNOFF	0.795	119211.	2.13
EVAPOTRANSPIRATION	33.135	4970241.	88.64
LATERAL DRAINAGE FROM LAYER 4	3.2818	492276.	8.78
PERCOLATION FROM LAYER 5	1.1436	171538.	3.06
CHANGE IN WATER STORAGE	-0.975	-146264.	-2.61
SOIL WATER AT START OF YEAR	28.43	4263804.	
SOIL WATER AT END OF YEAR	27.45	4117540.	
SNOW WATER AT START OF YEAR	0.00	0.	
SNOW WATER AT END OF YEAR	0.00	0.	
ANNUAL WATER BUDGET BALANCE	0.00	0.	0.00

ANNUAL TOTALS FOR YEAR 59

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	28.31	4246500.	100.00
RUNOFF	0.333	50024.	1.18
EVAPOTRANSPIRATION	22.845	3426757.	80.70

	(INCHES)	(CU. FT.)	PERCENT
LATERAL DRAINAGE FROM LAYER 4	3.2996	494933.	11.66
PERCOLATION FROM LAYER 5	1.1083	166251.	3.92
CHANGE IN WATER STORAGE	0.724	108533.	2.56
SOIL WATER AT START OF YEAR	27.45	4117540.	
SOIL WATER AT END OF YEAR	28.17	4226073.	
SNOW WATER AT START OF YEAR	0.00	0.	
SNOW WATER AT END OF YEAR	0.00	0.	
ANNUAL WATER BUDGET BALANCE	0.00	1.	0.00

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ANNUAL TOTALS FOR YEAR 60

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	31.78	4767000.	100.00
RUNOFF	0.717	107539.	2.26
EVAPOTRANSPIRATION	29.060	4358962.	91.44
LATERAL DRAINAGE FROM LAYER 4	2.2472	337075.	7.07
PERCOLATION FROM LAYER 5	1.1425	171373.	3.59
CHANGE IN WATER STORAGE	-1.386	-207949.	-4.36
SOIL WATER AT START OF YEAR	28.17	4226073.	
SOIL WATER AT END OF YEAR	26.79	4018124.	
SNOW WATER AT START OF YEAR	0.00	0.	
SNOW WATER AT END OF YEAR	0.00	0.	
ANNUAL WATER BUDGET BALANCE	0.00	1.	0.00

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ANNUAL TOTALS FOR YEAR 61

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	41.20	6180000.	100.00
RUNOFF	1.779	266777.	4.32
EVAPOTRANSPIRATION	32.815	4922310.	79.65
LATERAL DRAINAGE FROM LAYER 4	4.3271	649063.	10.50
PERCOLATION FROM LAYER 5	0.9965	149482.	2.42
CHANGE IN WATER STORAGE	1.282	192366.	3.11

SOIL WATER AT START OF YEAR	26.79	4018124.	
SOIL WATER AT END OF YEAR	28.07	4210489.	
SNOW WATER AT START OF YEAR	0.00	0.	
SNOW WATER AT END OF YEAR	0.00	0.	
ANNUAL WATER BUDGET BALANCE	0.00	2.	0.00

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ANNUAL TOTALS FOR YEAR 62

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	34.63	5194498.	100.00
RUNOFF	0.383	57431.	1.11
EVAPOTRANSPIRATION	29.405	4410679.	84.91
LATERAL DRAINAGE FROM LAYER 4	5.0235	753523.	14.51
PERCOLATION FROM LAYER 5	1.1606	174084.	3.35
CHANGE IN WATER STORAGE	-1.341	-201217.	-3.87
SOIL WATER AT START OF YEAR	28.07	4210489.	
SOIL WATER AT END OF YEAR	26.73	4009272.	
SNOW WATER AT START OF YEAR	0.00	0.	
SNOW WATER AT END OF YEAR	0.00	0.	
ANNUAL WATER BUDGET BALANCE	0.00	-2.	0.00

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ANNUAL TOTALS FOR YEAR 63

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	28.62	4293000.	100.00
RUNOFF	0.355	53178.	1.24
EVAPOTRANSPIRATION	25.112	3766827.	87.74
LATERAL DRAINAGE FROM LAYER 4	1.4848	222717.	5.19
PERCOLATION FROM LAYER 5	0.8365	125480.	2.92
CHANGE IN WATER STORAGE	0.832	124798.	2.91
SOIL WATER AT START OF YEAR	26.73	4009272.	
SOIL WATER AT END OF YEAR	27.56	4134070.	
SNOW WATER AT START OF YEAR	0.00	0.	

SNOW WATER AT END OF YEAR	0.00	0.	
ANNUAL WATER BUDGET BALANCE	0.00	0.	0.00

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ANNUAL TOTALS FOR YEAR 64

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	32.16	4824000.	100.00
RUNOFF	0.494	74061.	1.54
EVAPOTRANSPIRATION	26.582	3987283.	82.66
LATERAL DRAINAGE FROM LAYER 4	3.4326	514891.	10.67
PERCOLATION FROM LAYER 5	1.0917	163759.	3.39
CHANGE IN WATER STORAGE	0.560	84008.	1.74
SOIL WATER AT START OF YEAR	27.56	4134070.	
SOIL WATER AT END OF YEAR	28.12	4218078.	
SNOW WATER AT START OF YEAR	0.00	0.	
SNOW WATER AT END OF YEAR	0.00	0.	
ANNUAL WATER BUDGET BALANCE	0.00	-1.	0.00

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ANNUAL TOTALS FOR YEAR 65

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	27.73	4159500.	100.00
RUNOFF	0.021	3121.	0.08
EVAPOTRANSPIRATION	24.193	3628982.	87.25
LATERAL DRAINAGE FROM LAYER 4	3.0446	456683.	10.98
PERCOLATION FROM LAYER 5	0.9784	146764.	3.53
CHANGE IN WATER STORAGE	-0.507	-76050.	-1.83
SOIL WATER AT START OF YEAR	28.12	4218078.	
SOIL WATER AT END OF YEAR	27.61	4142028.	
SNOW WATER AT START OF YEAR	0.00	0.	
SNOW WATER AT END OF YEAR	0.00	0.	
ANNUAL WATER BUDGET BALANCE	0.00	-1.	0.00

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ANNUAL TOTALS FOR YEAR 66

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	32.34	4850999.	100.00
RUNOFF	0.727	109025.	2.25
EVAPOTRANSPIRATION	24.232	3634869.	74.93
LATERAL DRAINAGE FROM LAYER 4	6.1817	927256.	19.11
PERCOLATION FROM LAYER 5	1.1134	167014.	3.44
CHANGE IN WATER STORAGE	0.086	12835.	0.26
SOIL WATER AT START OF YEAR	27.61	4142028.	
SOIL WATER AT END OF YEAR	27.70	4154863.	
SNOW WATER AT START OF YEAR	0.00	0.	
SNOW WATER AT END OF YEAR	0.00	0.	
ANNUAL WATER BUDGET BALANCE	0.00	0.	0.00

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ANNUAL TOTALS FOR YEAR 67

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	41.30	6195002.	100.00
RUNOFF	0.515	77210.	1.25
EVAPOTRANSPIRATION	30.118	4517750.	72.93
LATERAL DRAINAGE FROM LAYER 4	7.5172	1127584.	18.20
PERCOLATION FROM LAYER 5	1.2321	184819.	2.98
CHANGE IN WATER STORAGE	1.918	287634.	4.64
SOIL WATER AT START OF YEAR	27.70	4154863.	
SOIL WATER AT END OF YEAR	29.62	4442496.	
SNOW WATER AT START OF YEAR	0.00	0.	
SNOW WATER AT END OF YEAR	0.00	0.	
ANNUAL WATER BUDGET BALANCE	0.00	5.	0.00

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ANNUAL TOTALS FOR YEAR 68

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	32.49	4873500.	100.00
RUNOFF	0.859	128805.	2.64
EVAPOTRANSPIRATION	22.762	3414249.	70.06
LATERAL DRAINAGE FROM LAYER 4	6.5969	989528.	20.30
PERCOLATION FROM LAYER 5	1.2389	185841.	3.81
CHANGE IN WATER STORAGE	1.034	155075.	3.18
SOIL WATER AT START OF YEAR	29.62	4442496.	
SOIL WATER AT END OF YEAR	30.65	4597571.	
SNOW WATER AT START OF YEAR	0.00	0.	
SNOW WATER AT END OF YEAR	0.00	0.	
ANNUAL WATER BUDGET BALANCE	0.00	1.	0.00

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ANNUAL TOTALS FOR YEAR 69

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	43.72	6557999.	100.00
RUNOFF	1.285	192799.	2.94
EVAPOTRANSPIRATION	28.681	4302147.	65.60
LATERAL DRAINAGE FROM LAYER 4	14.2793	2141900.	32.66
PERCOLATION FROM LAYER 5	1.3612	204183.	3.11
CHANGE IN WATER STORAGE	-1.887	-283028.	-4.32
SOIL WATER AT START OF YEAR	30.65	4597571.	
SOIL WATER AT END OF YEAR	28.76	4314543.	
SNOW WATER AT START OF YEAR	0.00	0.	
SNOW WATER AT END OF YEAR	0.00	0.	
ANNUAL WATER BUDGET BALANCE	0.00	-3.	0.00

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 50 THROUGH 69

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC

PRECIPITATION

TOTALS	2.01	2.27	2.89	3.50	3.64	4.04
	3.75	2.29	2.43	2.39	2.41	1.97
STD. DEVIATIONS	1.68	1.31	1.20	1.57	1.81	2.65
	2.10	1.14	1.34	1.38	1.34	1.40

RUNOFF

TOTALS	0.070	0.048	0.013	0.019	0.124	0.136
	0.130	0.004	0.035	0.024	0.029	0.022
STD. DEVIATIONS	0.247	0.100	0.022	0.047	0.294	0.329
	0.192	0.011	0.090	0.056	0.059	0.072

EVAPOTRANSPIRATION

TOTALS	1.021	1.514	2.334	2.682	3.002	4.461
	3.716	2.735	1.814	1.715	1.300	0.974
STD. DEVIATIONS	0.316	0.376	0.400	0.816	0.997	1.407
	1.778	1.293	1.042	0.807	0.423	0.263

LATERAL DRAINAGE FROM LAYER 4

TOTALS	0.3183	0.4762	0.5807	0.5592	0.7499	0.5170
	0.4427	0.2536	0.1056	0.0737	0.1024	0.3532
STD. DEVIATIONS	0.3656	0.4911	0.4143	0.3686	0.9257	0.4019
	0.4660	0.3347	0.1677	0.2075	0.2872	0.7996

PERCOLATION FROM LAYER 5

TOTALS	0.0793	0.0806	0.0969	0.1010	0.1058	0.1017
	0.1043	0.0985	0.0802	0.0631	0.0479	0.0692
STD. DEVIATIONS	0.0417	0.0377	0.0324	0.0226	0.0232	0.0223
	0.0231	0.0257	0.0321	0.0341	0.0353	0.0414

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 50 THROUGH 69

	(INCHES)		(CU. FT.)	PERCENT
PRECIPITATION	33.62	(6.536)	5043150.	100.00
RUNOFF	0.654	(0.620)	98089.	1.94
EVAPOTRANSPIRATION	27.266	(3.856)	4089917.	81.10
LATERAL DRAINAGE FROM LAYER 4	4.5325	(3.5082)	679871.	13.48
PERCOLATION FROM LAYER 5	1.0283	(0.2267)	154250.	3.06
CHANGE IN WATER STORAGE	0.140	(1.362)	21023.	0.42

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PEAK DAILY VALUES FOR YEARS 50 THROUGH 69

	(INCHES)	(CU. FT.)
PRECIPITATION	4.16	624000.0
RUNOFF	1.155	173294.4
LATERAL DRAINAGE FROM LAYER 4	2.3339	350086.5
PERCOLATION FROM LAYER 5	0.0040	605.3
HEAD ON LAYER 5	9.0	
SNOW WATER	0.85	127800.4

MAXIMUM VEG. SOIL WATER (VOL/VOL) 0.3760

MINIMUM VEG. SOIL WATER (VOL/VOL) 0.1237

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FINAL WATER STORAGE AT END OF YEAR 69

LAYER	(INCHES)	(VOL/VOL)
1	5.07	0.2815
2	0.67	0.0742
3	1.19	0.0330
4	1.20	0.1334
5	20.64	0.4300
SNOW WATER	0.00	

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ST. LOUIS SITE
PROPOSED WASTE PILE COVER (YEARS 70-83)
MARCH 11, 1993

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FAIR GRASS

LAYER 1

VERTICAL PERCOLATION LAYER

THICKNESS	=	18.00 INCHES
POROSITY	=	0.5010 VOL/VOL
FIELD CAPACITY	=	0.2844 VOL/VOL
WILTING POINT	=	0.1357 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.2815 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.0005700000329 CM/SEC

LAYER 2

VERTICAL PERCOLATION LAYER

THICKNESS	=	9.00 INCHES
POROSITY	=	0.4170 VOL/VOL
FIELD CAPACITY	=	0.0457 VOL/VOL
WILTING POINT	=	0.0200 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0742 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.0099999997765 CM/SEC

LAYER 3

LATERAL DRAINAGE LAYER

THICKNESS	=	36.00 INCHES
POROSITY	=	0.4000 VOL/VOL
FIELD CAPACITY	=	0.0300 VOL/VOL
WILTING POINT	=	0.0200 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.0330 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	100.0000000000000 CM/SEC

LAYER 4

LATERAL DRAINAGE LAYER

THICKNESS	=	9.00 INCHES
POROSITY	=	0.4170 VOL/VOL
FIELD CAPACITY	=	0.0457 VOL/VOL
WILTING POINT	=	0.0200 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.1334 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.0099999997765 CM/SEC
SLOPE	=	7.50 PERCENT

DRAINAGE LENGTH = 500.0 FEET

LAYER 5

BARRIER SOIL LINER

THICKNESS	=	48.00 INCHES
POROSITY	=	0.4300 VOL/VOL
FIELD CAPACITY	=	0.3667 VOL/VOL
WILTING POINT	=	0.2804 VOL/VOL
INITIAL SOIL WATER CONTENT	=	0.4300 VOL/VOL
SATURATED HYDRAULIC CONDUCTIVITY	=	0.0000001000000 CM/SEC

GENERAL SIMULATION DATA

SCS RUNOFF CURVE NUMBER	=	81.48
TOTAL AREA OF COVER	=	1800000. SQ FT
EVAPORATIVE ZONE DEPTH	=	20.00 INCHES
UPPER LIMIT VEG. STORAGE	=	9.8520 INCHES
INITIAL VEG. STORAGE	=	5.2154 INCHES

SOIL WATER CONTENT INITIALIZED BY USER.

CLIMATOLOGICAL DATA

USER SPECIFIED RAINFALL WITH SYNTHETIC DAILY TEMPERATURES AND
SOLAR RADIATION FOR ST. LOUIS MISSOURI

MAXIMUM LEAF AREA INDEX	=	2.00
START OF GROWING SEASON (JULIAN DATE)	=	109
END OF GROWING SEASON (JULIAN DATE)	=	298

NORMAL MEAN MONTHLY TEMPERATURES, DEGREES FAHRENHEIT

JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
29.10	39.50	51.50	61.00	68.80	78.80
78.00	75.10	65.30	53.70	38.80	29.70

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ANNUAL TOTALS FOR YEAR 70

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	36.20	5429999.	100.00
RUNOFF	0.900	135007.	2.49
EVAPOTRANSPIRATION	30.108	4516155.	83.17
LATERAL DRAINAGE FROM LAYER 4	5.4557	818351.	15.07
PERCOLATION FROM LAYER 5	1.2861	192920.	3.55
CHANGE IN WATER STORAGE	-1.550	-232434.	-4.28
SOIL WATER AT START OF YEAR	28.76	4314510.	

SOIL WATER AT END OF YEAR	27.21	4082076.	
SNOW WATER AT START OF YEAR	0.00	0.	
SNOW WATER AT END OF YEAR	0.00	0.	
ANNUAL WATER BUDGET BALANCE	0.00	0.	0.00

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ANNUAL TOTALS FOR YEAR 71

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	33.73	5059501.	100.00
RUNOFF	1.012	151729.	3.00
EVAPOTRANSPIRATION	24.875	3731197.	73.75
LATERAL DRAINAGE FROM LAYER 4	3.8050	570754.	11.28
PERCOLATION FROM LAYER 5	1.1441	171613.	3.39
CHANGE IN WATER STORAGE	2.895	434206.	8.58
SOIL WATER AT START OF YEAR	27.21	4082076.	
SOIL WATER AT END OF YEAR	30.11	4516281.	
SNOW WATER AT START OF YEAR	0.00	0.	
SNOW WATER AT END OF YEAR	0.00	0.	
ANNUAL WATER BUDGET BALANCE	0.00	2.	0.00

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ANNUAL TOTALS FOR YEAR 72

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	33.72	5058000.	100.00
RUNOFF	0.908	136251.	2.69
EVAPOTRANSPIRATION	24.085	3612681.	71.43
LATERAL DRAINAGE FROM LAYER 4	6.4130	961947.	19.02
PERCOLATION FROM LAYER 5	1.2043	180650.	3.57
CHANGE IN WATER STORAGE	1.110	166472.	3.29
SOIL WATER AT START OF YEAR	30.11	4516281.	
SOIL WATER AT END OF YEAR	31.22	4682753.	
SNOW WATER AT START OF YEAR	0.00	0.	
SNOW WATER AT END OF YEAR	0.00	0.	

ANNUAL WATER BUDGET BALANCE	0.00	-1.	0.00

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ANNUAL TOTALS FOR YEAR 73

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	39.82	5973000.	100.00
RUNOFF	0.359	53821.	0.90
EVAPOTRANSPIRATION	29.498	4424734.	74.08
LATERAL DRAINAGE FROM LAYER 4	9.0277	1354150.	22.67
PERCOLATION FROM LAYER 5	1.2114	181706.	3.04
CHANGE IN WATER STORAGE	-0.276	-41412.	-0.69
SOIL WATER AT START OF YEAR	31.22	4682753.	
SOIL WATER AT END OF YEAR	29.94	4491423.	
SNOW WATER AT START OF YEAR	0.00	0.	
SNOW WATER AT END OF YEAR	1.00	149918.	
ANNUAL WATER BUDGET BALANCE	0.00	2.	0.00

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ANNUAL TOTALS FOR YEAR 74

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	36.83	5524499.	100.00
RUNOFF	0.800	119963.	2.17
EVAPOTRANSPIRATION	27.906	4185890.	75.77
LATERAL DRAINAGE FROM LAYER 4	9.6289	1444330.	26.14
PERCOLATION FROM LAYER 5	1.3008	195124.	3.53
CHANGE IN WATER STORAGE	-2.805	-420808.	-7.62
SOIL WATER AT START OF YEAR	29.94	4491423.	
SOIL WATER AT END OF YEAR	28.14	4220533.	
SNOW WATER AT START OF YEAR	1.00	149918.	
SNOW WATER AT END OF YEAR	0.00	0.	
ANNUAL WATER BUDGET BALANCE	0.00	-1.	0.00

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ANNUAL TOTALS FOR YEAR 75

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	40.21	6031500.	100.00
RUNOFF	0.637	95588.	1.58
EVAPOTRANSPIRATION	29.081	4362086.	72.32
LATERAL DRAINAGE FROM LAYER 4	9.6619	1449281.	24.03
PERCOLATION FROM LAYER 5	1.0876	163141.	2.70
CHANGE IN WATER STORAGE	-0.257	-38598.	-0.64
SOIL WATER AT START OF YEAR	28.14	4220533.	
SOIL WATER AT END OF YEAR	27.88	4181935.	
SNOW WATER AT START OF YEAR	0.00	0.	
SNOW WATER AT END OF YEAR	0.00	0.	
ANNUAL WATER BUDGET BALANCE	0.00	2.	0.00

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ANNUAL TOTALS FOR YEAR 76

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	23.46	3519001.	100.00
RUNOFF	0.108	16198.	0.46
EVAPOTRANSPIRATION	21.877	3281536.	93.25
LATERAL DRAINAGE FROM LAYER 4	1.9291	289363.	8.22
PERCOLATION FROM LAYER 5	0.9738	146077.	4.15
CHANGE IN WATER STORAGE	-1.428	-214174.	-6.09
SOIL WATER AT START OF YEAR	27.88	4181935.	
SOIL WATER AT END OF YEAR	26.45	3967761.	
SNOW WATER AT START OF YEAR	0.00	0.	
SNOW WATER AT END OF YEAR	0.00	0.	
ANNUAL WATER BUDGET BALANCE	0.00	0.	0.00

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ANNUAL TOTALS FOR YEAR 77

	(INCHES)	(CU. FT.)	PERCENT

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	43.41	6511500.	100.00
RUNOFF	0.741	111190.	1.71
EVAPOTRANSPIRATION	30.923	4638452.	71.23
LATERAL DRAINAGE FROM LAYER 4	6.8905	1033570.	15.87
PERCOLATION FROM LAYER 5	1.1653	174800.	2.68
CHANGE IN WATER STORAGE	3.690	553487.	8.50
SOIL WATER AT START OF YEAR	26.45	3967761.	
SOIL WATER AT END OF YEAR	30.14	4521248.	
SNOW WATER AT START OF YEAR	0.00	0.	
SNOW WATER AT END OF YEAR	0.00	0.	
ANNUAL WATER BUDGET BALANCE	0.00	1.	0.00

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ANNUAL TOTALS FOR YEAR 78

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	37.71	5656501.	100.00
RUNOFF	0.865	129756.	2.29
EVAPOTRANSPIRATION	25.850	3877574.	68.55
LATERAL DRAINAGE FROM LAYER 4	10.6352	1595274.	28.20
PERCOLATION FROM LAYER 5	1.1971	179558.	3.17
CHANGE IN WATER STORAGE	-0.838	-125661.	-2.22
SOIL WATER AT START OF YEAR	30.14	4521248.	
SOIL WATER AT END OF YEAR	29.30	4395587.	
SNOW WATER AT START OF YEAR	0.00	0.	
SNOW WATER AT END OF YEAR	0.00	0.	
ANNUAL WATER BUDGET BALANCE	0.00	0.	0.00

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ANNUAL TOTALS FOR YEAR 79

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	29.48	4422001.	100.00
RUNOFF	1.672	250738.	5.67
EVAPOTRANSPIRATION	20.245	3036753.	68.67

LATERAL DRAINAGE FROM LAYER 4	8.0209	1203128.	27.21
PERCOLATION FROM LAYER 5	1.0382	155736.	3.52
CHANGE IN WATER STORAGE	-1.496	-224356.	-5.07
SOIL WATER AT START OF YEAR	29.30	4395587.	
SOIL WATER AT END OF YEAR	27.81	4171231.	
SNOW WATER AT START OF YEAR	0.00	0.	
SNOW WATER AT END OF YEAR	0.00	0.	
ANNUAL WATER BUDGET BALANCE	0.00	3.	0.00

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ANNUAL TOTALS FOR YEAR 80

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	27.48	4122001.	100.00
RUNOFF	0.201	30182.	0.73
EVAPOTRANSPIRATION	26.041	3906172.	94.76
LATERAL DRAINAGE FROM LAYER 4	1.6523	247846.	6.01
PERCOLATION FROM LAYER 5	0.9138	137067.	3.33
CHANGE IN WATER STORAGE	-1.328	-199269.	-4.83
SOIL WATER AT START OF YEAR	27.81	4171231.	
SOIL WATER AT END OF YEAR	26.48	3971962.	
SNOW WATER AT START OF YEAR	0.00	0.	
SNOW WATER AT END OF YEAR	0.00	0.	
ANNUAL WATER BUDGET BALANCE	0.00	3.	0.00

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ANNUAL TOTALS FOR YEAR 81

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	45.52	6827998.	100.00
RUNOFF	1.816	272371.	3.99
EVAPOTRANSPIRATION	32.783	4917388.	72.02
LATERAL DRAINAGE FROM LAYER 4	7.6714	1150711.	16.85
PERCOLATION FROM LAYER 5	1.0810	162145.	2.37
CHANGE IN WATER STORAGE	2.169	325384.	4.77

SOIL WATER AT START OF YEAR	26.48	3971962.	
SOIL WATER AT END OF YEAR	28.65	4297346.	
SNOW WATER AT START OF YEAR	0.00	0.	
SNOW WATER AT END OF YEAR	0.00	0.	
ANNUAL WATER BUDGET BALANCE	0.00	-1.	0.00

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ANNUAL TOTALS FOR YEAR 82

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	54.97	8245500.	100.00
RUNOFF	3.193	478922.	5.81
EVAPOTRANSPIRATION	31.280	4691981.	56.90
LATERAL DRAINAGE FROM LAYER 4	16.5430	2481447.	30.09
PERCOLATION FROM LAYER 5	1.3349	200233.	2.43
CHANGE IN WATER STORAGE	2.619	392915.	4.77
SOIL WATER AT START OF YEAR	28.65	4297346.	
SOIL WATER AT END OF YEAR	31.27	4690261.	
SNOW WATER AT START OF YEAR	0.00	0.	
SNOW WATER AT END OF YEAR	0.00	0.	
ANNUAL WATER BUDGET BALANCE	0.00	1.	0.00

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ANNUAL TOTALS FOR YEAR 83

	(INCHES)	(CU. FT.)	PERCENT
PRECIPITATION	44.80	6719998.	100.00
RUNOFF	1.364	204544.	3.04
EVAPOTRANSPIRATION	22.878	3431715.	51.07
LATERAL DRAINAGE FROM LAYER 4	18.7870	2818043.	41.94
PERCOLATION FROM LAYER 5	1.3514	202715.	3.02
CHANGE IN WATER STORAGE	0.420	62982.	0.94
SOIL WATER AT START OF YEAR	31.27	4690261.	
SOIL WATER AT END OF YEAR	31.15	4672900.	
SNOW WATER AT START OF YEAR	0.00	0.	

SNOW WATER AT END OF YEAR	0.54	80343.	
ANNUAL WATER BUDGET BALANCE	0.00	-1.	0.00

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AVERAGE MONTHLY VALUES IN INCHES FOR YEARS 70 THROUGH 83

	JAN/JUL	FEB/AUG	MAR/SEP	APR/OCT	MAY/NOV	JUN/DEC
PRECIPITATION						
TOTALS	1.83	1.85	3.83	3.88	3.89	3.59
	3.88	3.24	3.05	2.49	3.19	2.94
STD. DEVIATIONS	1.65	1.10	1.50	2.52	1.82	1.60
	2.79	1.96	1.84	1.29	1.97	2.08
RUNOFF						
TOTALS	0.036	0.017	0.074	0.179	0.089	0.066
	0.199	0.062	0.060	0.039	0.073	0.148
STD. DEVIATIONS	0.093	0.043	0.164	0.461	0.128	0.132
	0.435	0.096	0.094	0.124	0.178	0.359
EVAPOTRANSPIRATION						
TOTALS	0.830	1.205	2.264	2.614	2.784	4.208
	3.554	2.867	2.639	1.745	1.289	0.960
STD. DEVIATIONS	0.247	0.385	0.380	0.705	0.711	1.007
	1.825	1.380	1.236	0.534	0.286	0.167
LATERAL DRAINAGE FROM LAYER 4						
TOTALS	0.7037	0.8689	1.0828	0.9713	1.0764	0.8676
	0.8368	0.4171	0.2011	0.1116	0.3844	0.7728
STD. DEVIATIONS	0.6462	1.1090	1.2006	0.8828	0.9279	0.5220
	0.9840	0.4825	0.2631	0.1659	1.0235	1.0758
PERCOLATION FROM LAYER 5						
TOTALS	0.0930	0.0930	0.1072	0.1086	0.1129	0.1093
	0.1108	0.1089	0.0982	0.0761	0.0637	0.0818
STD. DEVIATIONS	0.0368	0.0259	0.0178	0.0040	0.0037	0.0044
	0.0037	0.0040	0.0153	0.0351	0.0420	0.0433

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AVERAGE ANNUAL TOTALS & (STD. DEVIATIONS) FOR YEARS 70 THROUGH 83

	(INCHES)		(CU. FT.)	PERCENT
PRECIPITATION	37.67	(8.146)	5650071.	100.00
RUNOFF	1.041	(0.792)	156161.	2.76

APPENDIX C Results of CREAMS Modeling

C R E A M S HYDROLOGY OPTION TWO

(BREAKPOINT OR HOURLY PRECIPITATION VALUES)

VERSION 1.8/PC MAY 1, 1985

SLAPS - HOURLY PRECIPITATION; SILT LOAM
WATER BALANCE, CALENDER YEARS 1964 - 1990
PRECIPITATION AND TEMPERATURE AT ST.L.AIRPORT; SOLAR RADIATION AT COLUMBIA, MO

MONTHLY MEAN TEMPERATURES, DEGREES FAHRENHEIT

32.23	34.73	42.88	54.49	66.45	75.56
79.37	76.87	68.72	57.11	45.15	36.04

MONTHLY MEAN RADIATION, LANGLEYS PER DAY

178.81	234.93	329.83	438.06	530.64	582.75
580.43	524.30	429.41	321.17	228.60	176.49

LEAF AREA INDEX TABLE

IRFLG.	DATE	LAI
0	1	.00
0	100	.00
0	120	.92
0	140	1.50
0	220	1.50
0	240	1.35
0	260	.98
0	280	1.07
0	300	.25
0	366	.00

WINTER C FACTOR = .50
LAI-DAYS = 247.15

EFFECTIVE HYDROLOGIC LENGTH	=	200.000 FT
EFFECTIVE HYDROLOGIC SLOPE	=	.031
EFFECTIVE MANNINGS N	=	.046
DEPTH OF SURFACE LAYER	=	2.000 IN
DEPTH OF REMAINING ROOT ZONE	=	24.000 IN
EFFECTIVE CAPILLARY TENSION	=	9.000 IN
EVAPORATION COEFFICIENT	=	4.500
SAT. CONDUCTIVITY CULTIVATED	=	.200 IN/HR
SAT. CONDUCTIVITY FALLOW	=	.160 IN/HR
SOIL POROSITY	=	.530
IMMOBILE SOIL WATER CONTENT	=	.070 IN/IN
UPPER LIMIT OF STORAGE	=	4.563 IN
INITIAL SURFACE STORAGE	=	.460 IN
INITIAL REMAINING STORAGE	=	1.822 IN
TOTAL INITIAL STORAGE	=	2.282 IN

ANNUAL TOTALS FOR 1964

PRECIPITATION	=	32.160
PREDICTED RUNOFF	=	.701
DEEP PERCOLATION	=	4.684
TOTAL ET	=	25.302
BEGIN SOIL WATER	=	2.282
FINAL SOIL WATER	=	3.680
IRRIGATION APPLIED	=	.000
WATER BUDGET BAL.	=	.075

ANNUAL TOTALS FOR 1965

PRECIPITATION	=	28.260
PREDICTED RUNOFF	=	.000
DEEP PERCOLATION	=	3.421
TOTAL ET	=	25.691
BEGIN SOIL WATER	=	3.680
FINAL SOIL WATER	=	2.766
IRRIGATION APPLIED	=	.000
WATER BUDGET BAL.	=	.061

ANNUAL TOTALS FOR 1966

PRECIPITATIDN	=	32.340
PREDICTED RUNOFF	=	.326
DEEP PERCOLATION	=	4.974
TOTAL ET	=	26.098
BEGIN SOIL WATER	=	2.766
FINAL SOIL WATER	=	3.589
IRRIGATION APPLIED	=	.000
WATER BUDGET BAL.	=	.119

ANNUAL TOTALS FOR 1967

PRECIPITATION	=	41.300
PREDICTEO RUNOFF	=	.000
DEEP PERCOLATION	=	8.617
TOTAL ET	=	31.880
BEGIN SOIL WATER	=	3.589
FINAL SOIL WATER	=	4.322
IRRIGATION APPLIED	=	.000
WATER BUDGET BAL.	=	.070

ANNUAL TOTALS FOR 1968

PRECIPITATION	=	32.490
PREDICTED RUNOFF	=	.089
DEEP PERCOLATION	=	5.043
TOTAL ET	=	27.144
BEGIN SOIL WATER	=	4.322
FINAL SOIL WATER	=	4.441
IRRIGATION APPLIED	=	.000
WATER BUDGET BAL.	=	.095

ANNUAL TOTALS FOR 1969

PRECIPITATION	=	43.720
PREDICTED RUNOFF	=	1.088
DEEP PERCOLATION	=	8.072
TOTAL ET	=	34.395
BEGIN SOIL WATER	=	4.441
FINAL SOIL WATER	=	4.440
IRRIGATION APPLIED	=	.000
WATER BUDGET BAL.	=	.166

ANNUAL TOTALS FOR 1970

PRECIPITATION	=	36.200

PREDICTED RUNOFF	=	.819
DEEP PERCOLATION	=	4.982
TOTAL ET	=	32.613
BEGIN SOIL WATER	=	4.440
FINAL SOIL WATER	=	2.008
IRRIGATION APPLIED	=	.000
WATER BUDGET BAL.	=	.218

ANNUAL TOTALS FOR 1971

PRECIPITATION	=	33.730
PREDICTED RUNOFF	=	.000
DEEP PERCOLATION	=	3.642
TOTAL ET	=	27.502
BEGIN SOIL WATER	=	2.008
FINAL SOIL WATER	=	4.243
IRRIGATION APPLIED	=	.000
WATER BUDGET BAL.	=	.350

ANNUAL TOTALS FOR 1972

PRECIPITATION	=	33.720
PREDICTED RUNOFF	=	.560
DEEP PERCOLATION	=	6.438
TOTAL ET	=	26.417
BEGIN SOIL WATER	=	4.243
FINAL SOIL WATER	=	4.441
IRRIGATION APPLIED	=	.000
WATER BUDGET BAL.	=	.107

ANNUAL TOTALS FOR 1973

PRECIPITATION	=	39.820
PREDICTED RUNOFF	=	.079
DEEP PERCOLATION	=	9.930
TOTAL ET	=	29.716
BEGIN SOIL WATER	=	4.441
FINAL SOIL WATER	=	4.466
IRRIGATION APPLIED	=	.000
WATER BUDGET BAL.	=	.070

ANNUAL TOTALS FOR 1974

PRECIPITATION	=	36.830
PREDICTED RUNOFF	=	.131
DEEP PERCOLATION	=	7.363
TOTAL ET	=	30.351
BEGIN SOIL WATER	=	4.466
FINAL SOIL WATER	=	3.419
IRRIGATION APPLIED	=	.000
WATER BUDGET BAL.	=	.032

ANNUAL TOTALS FOR 1975

PRECIPITATION	=	40.210
PREDICTED RUNOFF	=	.546
DEEP PERCOLATION	=	10.715

TOTAL ET	=	29.366
BEGIN SOIL WATER	=	3.419
FINAL SOIL WATER	=	2.953
IRRIGATION APPLIED	=	.000
WATER BUDGET BAL.	=	.051

ANNUAL TOTALS FOR 1976

PRECIPITATION	=	23.460
PREDICTED RUNOFF	=	.110
DEEP PERCOLATION	=	1.489
TOTAL ET	=	22.715
BEGIN SOIL WATER	=	2.953
FINAL SOIL WATER	=	2.085
IRRIGATION APPLIED	=	.000
WATER BUDGET BAL.	=	.013

ANNUAL TOTALS FOR 1977

PRECIPITATION	=	43.410
PREDICTED RUNOFF	=	1.039
DEEP PERCOLATION	=	7.394
TOTAL ET	=	32.987
BEGIN SOIL WATER	=	2.085
FINAL SOIL WATER	=	4.012
IRRIGATION APPLIED	=	.000
WATER BUDGET BAL.	=	.063

ANNUAL TOTALS FOR 1978

PRECIPITATION	=	37.710
PREDICTED RUNOFF	=	1.283
DEEP PERCOLATION	=	8.062
TOTAL ET	=	27.819
BEGIN SOIL WATER	=	4.012
FINAL SOIL WATER	=	4.504
IRRIGATION APPLIED	=	.000
WATER BUDGET BAL.	=	.054

ANNUAL TOTALS FOR 1979

PRECIPITATION	=	29.480
PREDICTED RUNOFF	=	1.428
DEEP PERCOLATION	=	7.332
TOTAL ET	=	22.502
BEGIN SOIL WATER	=	4.504
FINAL SOIL WATER	=	2.706
IRRIGATION APPLIED	=	.000
WATER BUDGET BAL.	=	.016

ANNUAL TOTALS FOR 1980

PRECIPITATION	=	27.480
PREDICTED RUNOFF	=	.000
DEEP PERCOLATION	=	1.454
TOTAL ET	=	26.595
BEGIN SOIL WATER	=	2.706

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FINAL SOIL WATER  =   2.077
IRRIGATION APPLIED=    .000
WATER BUDGET BAL. =    .060


   ANNUAL TOTALS FOR 1981
PRECIPITATION     =  45.520
PREDICTED RUNOFF  =   2.008
DEEP PERCOLATION  =   3.597
TOTAL ET          =  37.528
BEGIN SOIL WATER  =   2.077
FINAL SOIL WATER  =   4.304
IRRIGATION APPLIED=    .000
WATER BUDGET BAL. =    .161


   ANNUAL TOTALS FOR 1982
PRECIPITATION     =  54.970
PREDICTED RUNOFF  =   3.575
DEEP PERCOLATION  =  12.705
TOTAL ET          =  38.576
BEGIN SOIL WATER  =   4.304
FINAL SOIL WATER  =   4.307
IRRIGATION APPLIED=    .000
WATER BUDGET BAL. =    .111


   ANNUAL TOTALS FOR 1983
PRECIPITATION     =  44.800
PREDICTED RUNOFF  =    .665
DEEP PERCOLATION  =  16.754
TOTAL ET          =  27.207
BEGIN SOIL WATER  =   4.307
FINAL SOIL WATER  =   4.287
IRRIGATION APPLIED=    .000
WATER BUDGET BAL. =    .194


   ANNUAL TOTALS FOR 1984
PRECIPITATION     =  51.650
PREDICTED RUNOFF  =   2.782
DEEP PERCOLATION  =  19.736
TOTAL ET          =  28.807
BEGIN SOIL WATER  =   4.287
FINAL SOIL WATER  =   4.514
IRRIGATION APPLIED=    .000
WATER BUDGET BAL. =    .098


   ANNUAL TOTALS FOR 1985
PRECIPITATION     =  45.500
PREDICTED RUNOFF  =    .509
DEEP PERCOLATION  =  17.411
TOTAL ET          =  27.957
BEGIN SOIL WATER  =   4.514
FINAL SOIL WATER  =   4.011
IRRIGATION APPLIED=    .000
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WATER BUDGET BAL. = .125

ANNUAL TOTALS FOR 1986		
PRECIPITATION	=	34.880
PREDICTED RUNOFF	=	.853
DEEP PERCOLATION	=	6.547
TOTAL ET	=	27.225
BEGIN SOIL WATER	=	4.011
FINAL SOIL WATER	=	3.805
IRRIGATION APPLIED	=	.000
WATER BUDGET BAL.	=	.461

ANNUAL TOTALS FOR 1987		
PRECIPITATION	=	38.380
PREDICTED RUNOFF	=	.421
DEEP PERCOLATION	=	7.991
TOTAL ET	=	29.435
BEGIN SOIL WATER	=	3.805
FINAL SOIL WATER	=	4.327
IRRIGATION APPLIED	=	.000
WATER BUDGET BAL.	=	.012

ANNUAL TOTALS FOR 1988		
PRECIPITATION	=	33.930
PREDICTED RUNOFF	=	.179
DEEP PERCOLATION	=	11.066
TOTAL ET	=	22.591
BEGIN SOIL WATER	=	4.327
FINAL SOIL WATER	=	4.404
IRRIGATION APPLIED	=	.000
WATER BUDGET BAL.	=	.016

ANNUAL TOTALS FOR 1989		
PRECIPITATION	=	28.600
PREDICTED RUNOFF	=	.130
DEEP PERCOLATION	=	6.622
TOTAL ET	=	26.032
BEGIN SOIL WATER	=	4.404
FINAL SOIL WATER	=	.204
IRRIGATION APPLIED	=	.000
WATER BUDGET BAL.	=	.016

ANNUAL TOTALS FOR 1990		
PRECIPITATION	=	45.090
PREDICTED RUNOFF	=	.000
DEEP PERCOLATION	=	10.806
TOTAL ET	=	29.966
BEGIN SOIL WATER	=	.204
FINAL SOIL WATER	=	4.443
IRRIGATION APPLIED	=	.000
WATER BUDGET BAL.	=	.079

AVERAGE ANNUAL VALUES

PRECIPITATION	=	37.616
PREDICTED RUNOFF	=	.716
DEEP PERCOLATION	=	8.031
TOTAL ET	=	28.682

MINIMUM TOTAL STORAGE WAS .000 ON 64174
MAXIMUM TOTAL STORAGE WAS 4.527 ON 79101

1 C R E A M S HYDROLOGY SUMMARY

VERSION 1.8/PC MAY 1, 1985

SLAPS - HOURLY PRECIPITATION; SILT LOAM

WATER BALANCE, CALENDER YEARS 1964 - 1990

PRECIPITATION AND TEMPERATURE AT ST.L.AIRPORT; SOLAR RADIATION AT COLUMBIA, MO

1964

MONTH	RAIN	RUNOFF	ET	PERC	AVG SW	IRRIG
JAN	1.700	.000	.745	.000	2.524	.000
FEB	2.300	.000	.955	.537	3.964	.000
MAR	3.840	.000	1.642	2.221	4.255	.000
APR	4.990	.030	3.089	1.961	4.122	.000
MAY	2.680	.000	4.756	.000	2.299	.000
JUN	2.730	.000	4.378	.000	.626	.000
JUL	4.250	.617	3.840	.000	.488	.000
AUG	2.390	.010	2.096	.000	.329	.000
SEP	1.470	.000	1.271	.000	.199	.000
OCT	.730	.000	.783	.000	.137	.000
NOV	3.840	.084	.945	.000	1.081	.000
DEC	1.240	.000	.802	.000	3.654	.000
TOT	32.160	.741	25.302	4.719	1.973	.000

1965

MONTH	RAIN	RUNOFF	ET	PERC	AVG SW	IRRIG
JAN	2.510	.000	.745	1.097	4.273	.000
FEB	1.160	.000	.915	.517	4.225	.000
MAR	2.340	.000	1.582	.967	4.177	.000
APR	3.670	.000	3.027	.901	4.043	.000
MAY	1.380	.000	4.491	.000	1.936	.000
JUN	3.030	.000	3.169	.000	.330	.000
JUL	3.170	.000	3.357	.000	.296	.000
AUG	3.590	.000	2.597	.000	.288	.000
SEP	3.000	.000	3.841	.000	.576	.000
OCT	.460	.000	.698	.000	.128	.000
NOV	.780	.000	.545	.000	.244	.000
DEC	3.170	.000	.723	.000	.973	.000
TOT	28.260	.000	25.691	3.483	1.791	.000

1966

MONTH	RAIN	RUNOFF	ET	PERC	AVG SW	IRRIG
JAN	.650	.000	.739	.000	2.767	.000
FEB	4.120	.000	.905	1.417	3.908	.000

MAR	1.090	.000	1.354	.568	4.086	.000
APR	6.030	.100	2.559	3.009	4.122	.000
MAY	4.590	.326	6.211	.000	3.271	.000
JUN	1.590	.000	3.648	.000	.668	.000
JUL	1.260	.000	1.066	.000	.046	.000
AUG	3.720	.000	3.841	.000	.545	.000
SEP	2.150	.000	1.662	.000	.287	.000
OCT	2.180	.000	2.200	.000	.742	.000
NOV	2.470	.000	1.103	.000	1.363	.000
DEC	2.490	.000	.808	.000	3.464	.000
TOT	32.340	.426	26.098	4.993	2.106	.000

1967

MONTH	RAIN	RUNOFF	ET	PERC	AVG SW	IRRIG
JAN	2.890	.020	.738	1.446	3.747	.000
FEB	1.720	.000	.899	.931	4.075	.000
MAR	2.770	.000	1.605	1.544	4.204	.000
APR	3.400	.000	3.074	.036	4.075	.000
MAY	4.730	.000	6.114	.181	3.396	.000
JUN	4.460	.000	6.707	.000	1.023	.000
JUL	3.840	.000	3.531	.000	.357	.000
AUG	1.360	.000	1.933	.000	.185	.000
SEP	4.330	.000	2.348	.000	.906	.000
OCT	3.450	.000	2.765	.000	1.828	.000
NOV	2.150	.000	1.328	.000	2.850	.000
DEC	6.200	.000	.837	4.529	4.535	.000
TOT	41.300	.020	31.880	8.667	2.598	.000

1968

MONTH	RAIN	RUNOFF	ET	PERC	AVG SW	IRRIG
JAN	1.860	.000	.745	1.001	4.244	.000
FEB	1.090	.000	.863	1.020	3.997	.000
MAR	2.060	.000	1.315	.582	4.013	.000
APR	1.480	.000	2.089	.220	3.663	.000
MAY	6.780	.096	5.481	.025	2.728	.000
JUN	.900	.000	4.882	.000	1.560	.000
JUL	3.920	.000	3.114	.000	.360	.000
AUG	1.600	.000	2.543	.000	.203	.000
SEP	3.740	.053	2.789	.000	.851	.000
OCT	.690	.000	1.260	.000	.535	.000
NOV	5.740	.000	1.241	.488	2.575	.000
DEC	2.630	.000	.821	1.743	4.344	.000
TOT	32.490	.149	27.144	5.078	2.423	.000

1969

MONTH	RAIN	RUNOFF	ET	PERC	AVG SW	IRRIG
JAN	3.610	.010	.745	2.876	4.319	.000
FEB	2.040	.000	.915	1.042	4.291	.000
MAR	2.470	.000	1.613	1.312	4.186	.000
APR	4.010	.020	2.954	1.795	4.105	.000
MAY	2.110	.000	4.804	.000	2.069	.000
JUN	8.650	.570	6.702	.000	1.162	.000
JUL	7.080	.456	7.965	.000	2.467	.000
AUG	.520	.000	1.154	.000	.163	.000
SEP	5.030	.012	2.967	.000	1.400	.000
OCT	5.770	.171	2.926	.699	3.330	.000
NOV	.440	.000	.963	.000	3.656	.000

DEC	1.990	.000	.688	.364	4.103	.000
TOT	43.720	1.238	34.395	8.088	2.938	.000

1970

MONTH	RAIN	RUNOFF	ET	PERC	AVG SW	IRRIG
JAN	.220	.000	.737	.163	4.077	.000
FEB	.640	.000	.747	.000	3.777	.000
MAR	2.170	.000	1.603	.150	4.100	.000
APR	9.090	.809	3.120	4.718	4.238	.000
MAY	2.040	.000	5.572	.000	2.865	.000
JUN	5.080	.000	5.915	.000	.794	.000
JUL	.600	.000	.748	.000	.031	.000
AUG	6.440	.180	5.690	.000	1.521	.000
SEP	5.540	.000	4.010	.000	1.452	.000
OCT	2.210	.000	2.738	.000	1.455	.000
NOV	.770	.000	1.292	.000	1.342	.000
DEC	1.400	.000	.442	.000	1.577	.000
TOT	36.200	.989	32.613	5.030	2.269	.000

1971

MONTH	RAIN	RUNOFF	ET	PERC	AVG SW	IRRIG
JAN	.660	.000	.744	.000	2.195	.000
FEB	3.080	.000	.915	.000	3.386	.000
MAR	1.810	.000	1.472	.783	4.093	.000
APR	1.650	.000	2.154	.034	3.733	.000
MAY	5.660	.000	5.959	.000	3.316	.000
JUN	2.430	.000	5.085	.000	1.323	.000
JUL	4.700	.270	4.348	.000	.477	.000
AUG	.080	.000	.312	.000	.009	.000
SEP	3.980	.000	3.307	.000	.826	.000
OCT	1.510	.000	1.438	.000	.599	.000
NOV	1.670	.000	.931	.000	.744	.000
DEC	6.500	.080	.837	2.824	3.671	.000
TOT	33.730	.350	27.502	3.642	2.031	.000

1972

MONTH	RAIN	RUNOFF	ET	PERC	AVG SW	IRRIG
JAN	.770	.000	.737	.166	4.130	.000
FEB	.720	.000	.950	.009	3.944	.000
MAR	2.930	.060	1.378	.910	4.029	.000
APR	4.490	.000	3.215	1.759	4.239	.000
MAY	1.020	.000	4.527	.000	2.108	.000
JUN	1.190	.000	1.503	.000	.220	.000
JUL	3.100	.020	3.073	.000	.285	.000
AUG	2.690	.000	2.845	.000	.296	.000
SEP	6.210	.560	4.256	.000	1.221	.000
OCT	1.470	.000	1.795	.000	.602	.000
NOV	5.590	.000	1.310	1.119	4.100	.000
DEC	3.540	.000	.827	2.502	4.466	.000
TOT	33.720	.640	26.417	6.465	2.470	.000

1973

MONTH	RAIN	RUNOFF	ET	PERC	AVG SW	IRRIG

-----	------	------	------	------	------	------
JAN	1.400	.000	.745	.877	4.306	.000
FEB	1.040	.000	.900	.484	4.243	.000
MAR	5.810	.060	1.618	3.503	4.354	.000
APR	4.250	.000	3.034	2.281	4.248	.000
MAY	3.920	.000	5.564	.428	3.019	.000
JUN	4.230	.079	5.425	.000	.801	.000
JUL	2.850	.000	2.491	.000	.338	.000
AUG	2.460	.000	2.883	.000	.319	.000
SEP	3.520	.000	2.640	.000	.619	.000
OCT	2.330	.000	2.317	.000	.454	.000
NOV	3.650	.000	1.274	.000	1.308	.000
DEC	4.360	.000	.826	2.368	4.402	.000
TOT	39.820	.139	29.716	9.940	2.368	.000

1974

MONTH	RAIN	RUNOFF	ET	PERC	AVG SW	IRRIG
-----	------	------	------	------	------	------
JAN	3.510	.000	.745	2.892	4.381	.000
FEB	4.170	.000	.915	3.333	4.320	.000
MAR	2.580	.000	1.624	.895	4.325	.000
APR	2.400	.000	3.130	.265	4.134	.000
MAY	5.900	.131	5.863	.000	2.416	.000
JUN	3.450	.000	6.609	.000	1.328	.000
JUL	.900	.000	.655	.000	.093	.000
AUG	5.050	.010	2.474	.000	.501	.000
SEP	2.500	.000	3.722	.000	1.453	.000
OCT	1.510	.000	2.514	.000	.959	.000
NOV	3.150	.000	1.263	.000	2.209	.000
DEC	1.710	.000	.837	.000	2.709	.000
TOT	36.830	.141	30.351	7.385	2.402	.000

1975

MONTH	RAIN	RUNOFF	ET	PERC	AVG SW	IRRIG
-----	------	------	------	------	------	------
JAN	5.380	.200	.745	3.350	4.135	.000
FEB	3.590	.000	.915	2.917	4.364	.000
MAR	4.080	.000	1.601	2.491	4.251	.000
APR	4.560	.155	2.742	1.977	3.953	.000
MAY	3.230	.000	6.204	.000	2.580	.000
JUN	3.780	.000	4.540	.000	.516	.000
JUL	2.560	.000	2.718	.000	.216	.000
AUG	5.440	.221	3.570	.000	.530	.000
SEP	2.480	.000	3.857	.000	.824	.000
OCT	.210	.000	.397	.000	.159	.000
NOV	2.620	.000	1.258	.000	.795	.000
DEC	2.280	.000	.819	.000	2.124	.000
TOT	40.210	.576	29.366	10.735	2.037	.000

1976

MONTH	RAIN	RUNOFF	ET	PERC	AVG SW	IRRIG
-----	------	------	------	------	------	------
JAN	.830	.000	.745	.000	2.974	.000
FEB	1.080	.000	.948	.000	3.340	.000
MAR	4.280	.000	1.642	1.486	4.213	.000
APR	1.370	.000	2.380	.016	3.811	.000
MAY	3.900	.000	4.698	.000	1.964	.000
JUN	2.320	.110	4.312	.000	.801	.000
JUL	2.280	.000	1.838	.000	.177	.000
AUG	1.270	.000	2.106	.000	.185	.000

SEP	.900	.000	.657	.000	.069	.000
OCT	3.370	.000	1.684	.000	.658	.000
NOV	.730	.000	.910	.000	1.483	.000
DEC	1.130	.000	.794	.000	2.216	.000
TOT	23.460	.110	22.715	1.502	1.824	.000

1977

MONTH	RAIN	RUNOFF	ET	PERC	AVG SW	IRRIG
JAN	2.380	.000	.742	.000	3.348	.000
FEB	2.470	.030	.908	.754	3.762	.000
MAR	6.280	.588	1.616	4.319	4.279	.000
APR	.990	.000	2.105	.057	3.719	.000
MAY	2.130	.000	4.736	.000	1.956	.000
JUN	5.470	.320	3.870	.000	.724	.000
JUL	4.280	.030	5.814	.000	.743	.000
AUG	5.340	.121	4.777	.000	.903	.000
SEP	3.640	.000	3.879	.000	.677	.000
OCT	3.760	.000	2.397	.000	1.380	.000
NOV	4.330	.000	1.318	.273	2.809	.000
DEC	2.340	.000	.826	2.005	4.434	.000
TOT	43.410	1.089	32.987	7.407	2.395	.000

1978

MONTH	RAIN	RUNOFF	ET	PERC	AVG SW	IRRIG
JAN	1.700	.000	.743	.715	4.139	.000
FEB	1.600	.000	.915	.626	4.187	.000
MAR	6.670	.000	1.624	5.270	4.351	.000
APR	3.210	.000	3.101	.715	4.055	.000
MAY	3.690	.000	6.109	.000	2.727	.000
JUN	2.390	.000	3.308	.000	.437	.000
JUL	6.030	.969	5.004	.000	.519	.000
AUG	.760	.000	.900	.000	.028	.000
SEP	3.100	.314	2.046	.000	.662	.000
OCT	2.280	.000	2.343	.000	.930	.000
NOV	4.470	.000	.895	.025	2.106	.000
DEC	1.810	.000	.831	.765	4.327	.000
TOT	37.710	1.283	27.819	8.116	2.372	.000

1979

MONTH	RAIN	RUNOFF	ET	PERC	AVG SW	IRRIG
JAN	1.950	.000	.745	1.331	4.395	.000
FEB	1.480	.000	.915	.592	4.224	.000
MAR	3.630	.000	1.624	1.957	4.296	.000
APR	7.470	1.428	3.070	3.467	4.196	.000
MAY	1.620	.000	4.868	.000	2.276	.000
JUN	1.670	.000	1.798	.000	.219	.000
JUL	3.670	.000	2.663	.000	.415	.000
AUG	2.260	.000	3.371	.000	.412	.000
SEP	.000	.000	.425	.000	.025	.000
OCT	1.810	.000	1.100	.000	.427	.000
NOV	2.070	.000	1.125	.000	.830	.000
DEC	1.850	.000	.799	.000	1.740	.000
TOT	29.480	1.428	22.502	7.348	1.955	.000

1980

MONTH	RAIN	RUNOFF	ET	PERC	AVG SW	IRRIG
JAN	.630	.000	.745	.000	2.596	.000
FEB	1.540	.000	.955	.000	2.931	.000
MAR	3.980	.010	1.642	1.093	3.699	.000
APR	1.540	.000	2.515	.361	3.943	.000
MAY	3.400	.000	5.158	.000	1.988	.000
JUN	2.190	.050	2.916	.000	.321	.000
JUL	3.560	.000	4.100	.000	.495	.000
AUG	2.720	.000	2.578	.000	.249	.000
SEP	3.120	.000	2.643	.000	.692	.000
OCT	2.890	.000	1.510	.000	.964	.000
NOV	1.250	.000	1.013	.000	1.683	.000
DEC	.660	.000	.819	.000	2.311	.000
TOT	27.480	.060	26.595	1.454	1.823	.000

1981

MONTH	RAIN	RUNOFF	ET	PERC	AVG SW	IRRIG
JAN	.640	.000	.556	.000	1.954	.000
FEB	2.180	.000	.906	.000	2.971	.000
MAR	2.970	.000	1.186	.892	3.859	.000
APR	3.400	.000	3.081	.489	4.124	.000
MAY	6.790	.100	6.629	1.707	3.801	.000
JUN	5.820	.767	6.617	.000	1.525	.000
JUL	10.710	1.290	6.495	.349	1.760	.000
AUG	3.310	.000	5.313	.000	1.561	.000
SEP	1.170	.000	2.658	.000	.353	.000
OCT	3.810	.000	2.015	.000	1.148	.000
NOV	2.710	.000	1.267	.000	2.352	.000
DEC	2.010	.000	.805	.170	3.615	.000
TOT	45.520	2.158	37.528	3.608	2.419	.000

1982

MONTH	RAIN	RUNOFF	ET	PERC	AVG SW	IRRIG
JAN	4.900	.000	.745	3.952	4.319	.000
FEB	1.370	.000	.910	.987	4.305	.000
MAR	2.880	.000	1.588	.967	4.156	.000
APR	2.550	.000	3.097	.411	4.136	.000
MAY	4.850	.000	4.623	.000	2.245	.000
JUN	5.960	.715	7.817	.000	2.795	.000
JUL	7.910	2.309	6.160	.000	1.829	.000
AUG	5.270	.181	4.879	.000	.818	.000
SEP	5.270	.369	4.116	.000	1.576	.000
OCT	2.300	.000	2.757	.000	1.271	.000
NOV	3.890	.000	1.046	.000	1.703	.000
DEC	7.820	.100	.837	6.400	4.466	.000
TOT	54.970	3.675	38.576	12.716	2.801	.000

1983

MONTH	RAIN	RUNOFF	ET	PERC	AVG SW	IRRIG
JAN	.720	.000	.745	.137	4.143	.000
FEB	.950	.000	.815	.637	4.034	.000
MAR	3.540	.000	1.444	1.476	4.204	.000
APR	7.300	.010	3.042	4.007	4.238	.000
MAY	6.320	.358	6.341	1.405	3.628	.000

JUN	4.320	.000	6.232	.365	2.364	.000
JUL	1.230	.000	1.321	.000	.216	.000
AUG	2.240	.130	2.155	.000	.371	.000
SEP	1.240	.000	1.361	.000	.240	.000
OCT	5.400	.010	1.681	.040	1.799	.000
NOV	7.790	.317	1.264	5.716	4.353	.000
DEC	3.750	.000	.807	3.006	4.525	.000
TOT	44.800	.825	27.207	16.788	2.843	.000

1984

MONTH	RAIN	RUNOFF	ET	PERC	AVG SW	IRRIG
JAN	.840	.000	.745	.312	4.226	.000
FEB	3.430	.000	.955	2.168	4.292	.000
MAR	5.370	.000	1.651	3.848	4.379	.000
APR	6.290	.000	3.190	3.592	4.141	.000
MAY	5.190	.000	6.597	.000	2.688	.000
JUN	2.740	.070	4.476	.000	.951	.000
JUL	.760	.000	1.304	.000	.081	.000
AUG	.640	.000	.640	.000	.031	.000
SEP	8.880	1.857	4.409	.000	2.422	.000
OCT	7.120	.860	2.703	1.871	3.733	.000
NOV	5.500	.000	1.310	4.165	4.349	.000
DEC	4.890	.066	.827	3.808	4.485	.000
TOT	51.650	2.852	28.807	19.764	2.982	.000

1985

MONTH	RAIN	RUNOFF	ET	PERC	AVG SW	IRRIG
JAN	.530	.000	.745	.260	4.163	.000
FEB	3.770	.000	.907	2.552	4.175	.000
MAR	5.180	.000	1.614	3.468	4.280	.000
APR	3.600	.000	3.054	1.486	4.182	.000
MAY	3.300	.060	5.179	.071	3.147	.000
JUN	9.430	.529	7.921	.857	3.163	.000
JUL	.000	.000	1.600	.000	.351	.000
AUG	3.660	.000	3.528	.000	.479	.000
SEP	.430	.000	.553	.000	.023	.000
OCT	1.960	.000	.786	.000	.219	.000
NOV	9.950	.020	1.264	5.476	3.211	.000
DEC	3.690	.000	.807	3.266	4.432	.000
TOT	45.500	.609	27.957	17.437	2.652	.000

1986

MONTH	RAIN	RUNOFF	ET	PERC	AVG SW	IRRIG
JAN	.100	.000	.468	.000	3.739	.000
FEB	4.680	.010	.912	3.487	4.274	.000
MAR	1.220	.000	1.464	.027	3.882	.000
APR	1.230	.000	1.655	.000	3.609	.000
MAY	2.420	.000	5.201	.000	1.946	.000
JUN	4.430	.000	4.613	.000	.669	.000
JUL	2.610	.000	2.856	.000	.257	.000
AUG	2.220	.000	2.228	.000	.205	.000
SEP	7.990	1.122	3.022	.000	.857	.000
OCT	5.340	.150	2.654	2.433	3.763	.000
NOV	1.580	.000	1.320	.054	4.128	.000
DEC	1.060	.000	.833	.577	4.293	.000
TOT	34.880	1.283	27.225	6.578	2.635	.000

1987

MONTH	RAIN	RUNOFF	ET	PERC	AVG SW	IRRIG
JAN	1.980	.000	.744	.929	4.204	.000
FEB	1.400	.000	.898	.112	3.984	.000
MAR	2.160	.000	1.617	.911	4.201	.000
APR	1.740	.000	2.349	.404	3.791	.000
MAY	2.000	.000	4.368	.000	2.507	.000
JUN	3.590	.000	3.955	.000	.455	.000
JUL	5.040	.315	4.935	.000	1.240	.000
AUG	5.560	.106	5.350	.000	.754	.000
SEP	1.620	.000	1.120	.000	.121	.000
OCT	1.740	.000	2.260	.000	.443	.000
NOV	4.090	.000	1.028	.000	.946	.000
DEC	7.460	.000	.811	5.646	4.261	.000
TOT	38.380	.421	29.435	8.003	2.242	.000

1988

MONTH	RAIN	RUNOFF	ET	PERC	AVG SW	IRRIG
JAN	3.300	.000	.745	2.370	4.196	.000
FEB	2.270	.000	.955	1.808	4.317	.000
MAR	4.730	.000	1.629	2.793	4.241	.000
APR	1.150	.000	2.286	.182	3.786	.000
MAY	1.440	.000	4.154	.000	1.736	.000
JUN	1.970	.000	1.859	.000	.195	.000
JUL	3.020	.000	3.218	.000	.385	.000
AUG	2.310	.000	2.345	.000	.281	.000
SEP	1.990	.000	1.070	.000	.207	.000
OCT	1.860	.000	2.272	.000	.745	.000
NOV	6.650	.179	1.258	1.611	2.785	.000
DEC	3.240	.000	.800	2.318	4.275	.000
TOT	33.930	.179	22.591	11.082	2.262	.000

1989

MONTH	RAIN	RUNOFF	ET	PERC	AVG SW	IRRIG
JAN	2.580	.000	.745	1.921	4.302	.000
FEB	1.430	.000	.915	.730	4.338	.000
MAR	4.530	.037	1.598	2.592	4.231	.000
APR	2.100	.010	1.973	1.384	3.767	.000
MAY	4.110	.093	5.100	.000	2.126	.000
JUN	2.340	.000	4.185	.000	.614	.000
JUL	4.590	.000	3.402	.000	.422	.000
AUG	3.000	.000	3.890	.000	.561	.000
SEP	1.690	.000	2.199	.000	.215	.000
OCT	.950	.000	.718	.000	.093	.000
NOV	.590	.000	.791	.000	.157	.000
DEC	.690	.000	.517	.000	.084	.000
TOT	28.600	.140	26.032	6.628	1.742	.000

1990

MONTH	RAIN	RUNOFF	ET	PERC	AVG SW	IRRIG
JAN	1.420	.000	.691	.000	.510	.000
FEB	3.530	.000	.915	.000	2.764	.000

MAR	2.660	.000	1.624	.179	3.830	.000
APR	3.070	.000	3.086	.718	4.121	.000
MAY	9.590	.040	6.669	3.697	3.779	.000
JUN	3.020	.000	5.671	.000	1.612	.000
JUL	3.340	.000	3.488	.000	.409	.000
AUG	2.840	.000	2.895	.000	.285	.000
SEP	.780	.000	.564	.000	.151	.000
OCT	4.960	.010	2.422	.000	2.680	.000
NOV	3.360	.000	1.131	.648	3.703	.000
DEC	6.520	.020	.811	5.572	4.498	.000
TOT	45.090	.070	29.966	10.815	2.362	.000

ANNUAL AVERAGES

MONTH	RAIN	RUNOFF	ET	PERC	AVG SW	IRRIG
JAN	1.839	.009	.725	.955	3.641	.000
FEB	2.180	.001	.908	.987	3.940	.000
MAR	3.483	.028	1.555	1.748	4.155	.000
APR	3.594	.095	2.747	1.342	4.011	.000
MAY	3.881	.045	5.407	.278	2.612	.000
JUN	3.673	.119	4.745	.045	1.007	.000
JUL	3.602	.232	3.374	.013	.546	.000
AUG	2.916	.036	2.922	.000	.445	.000
SEP	3.177	.159	2.496	.000	.700	.000
OCT	2.669	.045	1.894	.187	1.155	.000
NOV	3.401	.022	1.126	.725	2.180	.000
DEC	2.960	.009	.755	1.566	3.314	.000
TOT	37.375	.799	28.652	7.848	2.309	.000

APPENDIX D Radionuclide Transport Simulation

EXECUTIVE SUMMARY

Radionuclide transport modeling was performed to determine the relationship between radionuclide releases from the proposed disposal facility and downgradient radionuclide concentrations in groundwater at a hypothetical receptor. Travel times to the hypothetical receptor were also evaluated. A conceptual model was developed to integrate site hydrogeology, source configuration assumptions, and definition of the hypothetical receptor. Input parameters for the model were developed from site-specific data or, where site-specific data were not available, published values for similar geologic environments.

Steady-state modeling was performed using the Monte Carlo technique to determine the source/receptor concentration relationship and to evaluate the sensitivity of the model response to input parameters that lack a quantified uncertainty. Transient modeling was performed to estimate the travel times from the source to the hypothetical receptor for the contaminants of concern.

Results of the modeling effort were used to determine the dilution/attenuation factor (DAF), which is a ratio of source concentration to receptor concentration. The DAF for the conceptualized groundwater system at SLAPS is 3.6. Transient simulations indicate that contaminant travel times to the hypothetical receptor range from 500 to 100,000 years.

Based on an analysis of the groundwater transport pathway, the use of SLAPS as a disposal facility is a viable option when coupled with a groundwater monitoring and remedial response plan.

CONTENTS

FIGURES

FIGURES

(continued)

TABLES

D1.0 INTRODUCTION

Transport of the contaminants of concern (uranium, radium, and thorium) from the proposed SLAPS disposal area was evaluated as part of the SLAPS site suitability study (hereinafter referred to as "the study"). The simplified analysis of radionuclide transport, presented in Subsection 5.1 of the study, was expanded using analytical unsaturated and saturated transport modeling. The objectives of this modeling effort were to develop a relationship between radionuclide releases from the proposed disposal facility and downgradient radionuclide concentrations in groundwater, and to estimate travel times to a hypothetical downgradient receptor.

The model selected for SLAPS was MULTIMED, a multimedia exposure assessment model developed for the U.S. Environmental Protection Agency's Center for Exposure Assessment Modeling. The model includes modules for unsaturated flow and transport, saturated flow and transport, atmospheric releases, and surface water interaction. For the SLAPS model, the unsaturated and saturated flow and transport portions of the program were used. The MULTIMED model has several advantages:

- Coupled unsaturated and saturated transport
- An internal Monte Carlo simulation algorithm
- Computationally efficient equation solutions
- A simplified data input preprocessor and data output postprocessor

The most advantageous feature for the SLAPS modeling is the Monte Carlo simulation algorithm. The Monte Carlo method allows inclusion of spatially or temporally variable or uncertain data into the transport simulation. The use of computationally efficient analytical equations with the Monte Carlo approach allows rapid execution of the large number of simulations needed to create the dataset for statistical evaluation.

The following sections present the work performed during the MULTIMED modeling effort for SLAPS. Section D2.0 describes the conceptual model of the site, including a summary of hydrogeologic conditions and the assumptions made regarding the proposed waste disposal area and a hypothetical downgradient receptor. Section D3.0 presents the mathematical equations used in the MULTIMED model along with the assumptions inherent in their usage. Section D4.0 describes the input parameters used in the model. Section D5.0 presents the results of simulations of sensitivity, transport of contaminants of concern, and transient model. Section D6.0 relates the results of the MULTIMED simulations to the suitability of the site for waste disposal.

D2.0 CONCEPTUAL MODEL

Descriptions of the geologic and hydrogeologic information and conceptual hydrogeologic model development are presented in Sections 3.0 and 4.0 of the study. The following paragraphs summarize this information and relate it to radionuclide transport simulation.

Interpretation of site geologic and hydrogeologic data indicates that two groundwater systems are present in the unconsolidated deposits beneath SLAPS. These groundwater systems are separated by an aquitard, which has a vertical hydraulic conductivity two to four orders of magnitude lower than the horizontal hydraulic conductivities in the groundwater systems. The water table map for the upper groundwater system (Figure 4-4 in the study) indicates that Coldwater Creek is a groundwater discharge area. The potentiometric surface map for the lower groundwater system (Figure 4-5 in the study) shows that Coldwater Creek also influences groundwater flow in the lower groundwater system. Comparison of groundwater level elevations in the two groundwater systems indicates that upward hydraulic gradients are present in most of the area of the proposed disposal facility, suggesting an upward flow potential from the lower groundwater system.

Evaluation of this groundwater flow conceptualization with respect to the proposed disposal facility configuration suggests that the maximum concentrations of contaminants emanating from the proposed disposal area would occur in the upper groundwater system. The exclusion of the lower groundwater system from consideration in contaminant transport modeling is based on the following.

- The absence of steep downward vertical hydraulic gradients would preclude potential vertical spreading of contaminants.

- Gelhar, Welty, and Rehfeldt (1992) concluded that vertical dispersivity is typically two orders of magnitude lower than longitudinal dispersivity, which suggests that there is typically only a small vertical mixing component during transport.

- The presence of a discharge area along Coldwater Creek would minimize the downward vertical migration within the upper groundwater system.

Based on conceptualized groundwater flow and transport and the proposed disposal facility configuration, the maximum offsite contaminant concentrations would be observed in a monitoring well screened at the water table adjacent to Coldwater Creek or in seepage entering the creek. Using the proposed disposal facility layout, the length of the transport pathway would be approximately 55 m (180 ft) from the disposal facility to the creek. For the purpose of transport simulation, a hypothetical well (receptor) is placed 55 m (180 ft) downgradient of the proposed disposal area (at Coldwater Creek). The simulated contaminant concentrations at this hypothetical well would be representative of the exposure to groundwater users or of contaminant concentrations in seepage entering the creek.

The proposed SLAPS disposal facility has a surface area of approximately 122,000 m^2 (145,912 yd^2). However, because the hypothetical receptor is located so close to the disposal area (source), the MULTIMED model cannot simulate the entire waste disposal facility. The limiting factor is that the ratio of the square root of the surface area of the source and the distance to the hypothetical receptor must be less than or equal to one. Thus, for a 55-m (180-ft) distance to the hypothetical receptor, the maximum source surface area is approximately 3,000 m^2 (3,588 yd^2). Therefore, only a 3,000-m^2 (3,588-yd^2) portion of the total area of the proposed facility can be used in the simulation. Because the proposed facility is approximately 150 m (492 ft) long (measured parallel to the direction of groundwater flow), and the source is assumed to be rectangular, the total disposal area would be conceptually subdivided into a series of rectangles 20 m (65.6 ft) wide (measured perpendicular to the direction of groundwater flow) by 150 m (492 ft) long. Because the distance from the source to the receptor is small, the effects of transverse dispersion are also small. Therefore, contaminant concentrations emanating from the disposal area can be simulated by placing the hypothetical receptor at the point of maximum concentration (the axis of the plume) downgradient of one of these 150- by 20-m (492- by 65.6-ft) rectangles.

D3.0 MATHEMATICAL MODEL

The equations used in the MULTIMED model are divided into five groups:

- Unsaturated flow (FUNSAT module)
- Unsaturated transport (TUNSAT module)
- Saturated flow and transport module
- Coupling of the unsaturated and saturated modules
- Monte Carlo technique

A detailed discussion of these equations is presented in Salhotra et al. (1990) and is summarized in the following sections.

D3.1 UNSATURATED FLOW

The governing equation for flow in the unsaturated zone is a modified form of Darcy's law:

$$-K_v\, k_{rw} \left(\frac{\partial \psi}{\partial z}\right) = Q \qquad [EQ.\ 1]$$

where: ψ = pressure head (m)

z = depth coordinate, taken as positive downward (m)

K_v = vertical saturated hydraulic conductivity (m/yr)

k_{rw} = relative hydraulic conductivity (dimensionless)

Q = percolation rate (m/yr)

The key relationships in unsaturated flow are relative hydraulic conductivity versus water saturation and pressure head versus water saturation. The relationship between pressure head and water saturation is described by the equations:

$$S_e = [1 + (\alpha|\psi - \psi_a|)^{\beta}]^{-\gamma} \qquad [EQ.\ 2]$$

where: S_e = effective saturation (dimensionless fraction)

β = soil-specific empirical parameter (dimensionless)

γ = 1 - 1/β

α = soil-specific empirical parameter (1/m)

ψ_a = air entry pressure head, assumed to be zero (m)

and:

$$S_e = \frac{S_w - S_{wr}}{1 - S_{wr}} \qquad [EQ.\ 3]$$

where: S_{wr} = residual water saturation (dimensionless fraction)

S_w = water saturation (dimensionless fraction)

The relationship between relative hydraulic conductivity and water saturation is:

$$k_{rw} = S_e^{\frac{1}{2}} [1 - (1 - S_e^{\frac{1}{\gamma}})^{\gamma}]^2 \qquad [EQ.\ 4]$$

The unsaturated zone pressure-head distribution can be computed by using these relationships and the backward finite difference approximation to solve the partial derivative $\partial\psi/\partial z$ in equation 1. The model computes the pressure-head distribution by starting at the water table, where $\psi = 0$, and working upward. After the pressure-head distribution is computed, equations 2 and 3 are used to determine the water saturation associated with each pressure head.

The major assumptions used in the unsaturated flow model are:

- The fluid-phase flow field is isothermal, one-dimensional, and governed by Darcy's law.
- The flow field is to be considered steady.
- Multiphase flow can be disregarded.
- Hysteresis effects are neglected in the specification of soil-water characteristic curves.

D3.2 UNSATURATED TRANSPORT

Transport of contaminants in the unsaturated zone is described by the equation:

$$R_v \frac{\partial C}{\partial t} = D_v \frac{\partial^2 C}{\partial z^2} - V_v \frac{\partial C}{\partial z} - \lambda_v R_v C \qquad [EQ.\ 5]$$

where:

C = dissolved-phase contaminant concentration (mg/L)

D_v = dispersion coefficient (m^2/yr)

λ_v = first-order degradation rate (1/yr)

R_v = retardation factor (dimensionless)

V_v = unsaturated zone seepage velocity (m/yr)

t = time (yr)

z = vertical coordinate, taken as positive downward (m)

The retardation factor is defined by:

$$R_v = 1 + \frac{\rho_{bv} K_{dv}}{\theta S_w} \qquad [EQ.\ 6]$$

where:

ρ_{bv} = bulk density (gm/cm^3)

K_{dv} = distribution coefficient (gm/cm^3)

θ = porosity (dimensionless fraction)

S_w = saturation (dimensionless fraction)

Seepage velocity in the unsaturated zone is defined by:

$$V_v = \frac{Q}{\theta S_w} \qquad [EQ. 7]$$

where: Q = steady-state percolation rate (m/yr)

The analytical solution for equation 5 can be expressed as:

$$\frac{C}{C_o} = \frac{1}{2}\exp\left[\frac{(v_v - \Gamma)z}{2D_v}\right] erfc\left[\frac{R_v z - \Gamma t}{2\sqrt{D_v R_v t}}\right] + \frac{1}{2}\exp\left[\frac{(V_v + \Gamma)z}{2D_v}\right] erfc\left[\frac{R_v z + \Gamma t}{2\sqrt{D_v R_v t}}\right] \qquad [EQ. 8]$$

where: $\Gamma = (V_v^2 + 4D_v\lambda_v)^{1/2}$

For a steady-state continuous source, equation 5 may be simplified to:

$$D_v\frac{\partial^2 C}{\partial z^2} - V_v\frac{\partial C}{\partial z} - \lambda_v C R_v = 0 \qquad [EQ. 9]$$

The analytical solution to this equation is:

$$C(z) = C_o \exp\left[\frac{z}{2\alpha_z} - \frac{z}{2\alpha_z}\left(1 + \frac{4\lambda_v\alpha_z R_v}{V_v}\right)^{\frac{1}{2}}\right] \qquad [EQ. 10]$$

where: C(z) = concentration at z coordinate (mg/L)

C_o = source concentration (mg/L)

α_z = vertical dispersivity (m)

The major assumptions in the unsaturated transport model are:

- The flow field is at steady-state.
- Each layer is homogeneous and isotropic.
- Transport is assumed to be strictly one-dimensional, in the vertical direction.

- Adsorption and decay may be described by a linear equilibrium isotherm and a first-order decay constant, respectively.
- Each layer is approximated as being infinite in thickness.

D3.3 SATURATED FLOW AND TRANSPORT

The three-dimensional solute transport equation used by the model is:

$$D_x \frac{\partial^2 C}{\partial x^2} + D_y \frac{\partial^2 C}{\partial y^2} + D_z \frac{\partial^2 C}{\partial z^2} - V_s \frac{\partial C}{\partial x} = R_s \frac{\partial C}{\partial t} + R_s \lambda_s C + R_s \frac{qC}{B\theta} \qquad [EQ.\ 11]$$

where:

x,y,z	=	coordinates in the longitudinal, lateral, and vertical directions, respectively (m)
C	=	dissolved concentration (mg/L)
D_x,D_y,D_z	=	dispersion coefficients in the x,y, and z directions (m^2/yr)
V_s	=	one-dimensional seepage velocity in the x direction (m/yr)
R_s	=	retardation factor (dimensionless)
t	=	elapsed time (yr)
λ_s	=	first-order decay coefficient (1/yr)
q	=	net recharge outside the facility, diluting the plume (m/yr)
B	=	thickness of saturated zone (m)
θ	=	effective porosity (dimensionless)

The retardation factor is defined by:

$$R_s = 1 + \frac{\rho_b K_d}{\theta} \qquad [EQ.\ 12]$$

where:

ρ_b	=	bulk density (gm/cm^3)
K_d	=	distribution coefficient (cm^3/gm)

The one-dimensional seepage velocity is obtained from Darcy's law:

$$V_s = \frac{Ki}{\theta} \qquad [EQ.\ 13]$$

where: K = hydraulic conductivity (m/yr)

i = hydraulic gradient (dimensionless)

The model code allows a choice of analytical solutions for equation 11, which are based on the source boundary condition for the saturated zone. The source boundary conditions available are a gaussian-type contaminant distribution and a rectangular patch source. The analytical solutions for these two boundary conditions are described in Salhotra et al. (1990). The gaussian-type distribution assumes that the maximum contaminant concentration occurs at the centerline of the source, and that concentrations decrease away from the centerline. The rectangular patch source assumes a uniform concentration over the effective width of the source.

The major assumptions associated with the saturated flow and transport module are:

- A single homogeneous and isotropic aquifer of uniform thickness is modeled.
- Groundwater flow velocity is steady and uniform.
- Contaminant sorption follows a linear adsorption isotherm. Adsorption occurs instantaneously, and the adsorbed phase is in local equilibrium.
- The initial contaminant concentration in the aquifer is zero.

D3.4 COUPLING OF THE UNSATURATED AND SATURATED MODULES

The coupling of the unsaturated and saturated transport modules is accomplished using a mass balance approach. The mass of contaminant that reaches the saturated zone is:

$$M_L = A_w Q_f C_L \qquad [EQ.\ 14]$$

where: M_L = mass leaching from the facility (gm/yr)

A_w = area of the facility (m^2)

Q_f = percolation rate (m/yr)

C_L = concentration at the bottom of the unsaturated zone (gm/m^3)

The mass flux entering the saturated zone is determined by integrating over the source area to calculate the advective and dispersive fluxes entering the saturated zone. As with saturated zone transport, separate analytical solutions for mass balance are used for the gaussian and rectangular patch boundary conditions.

D3.5 MONTE CARLO TECHNIQUE

The transport model calculation can be expressed as:

$$C_w = g(X_1, X_2, X_3, \ldots X_n) \qquad [EQ.\ 15]$$

where: C_w = downgradient receptor concentration

g = computational transport algorithms

$X_1 \ldots X_n$ = a set of deterministic input parameters

The Monte Carlo method is used when one or more of the input parameters are uncertain and this uncertainty can be quantified with a cumulative probability distribution. A Monte Carlo application involves repeated deterministic model simulations using pseudorandom input values, which are drawn from the specified probability distributions of the uncertain parameters. The results of these deterministic simulations are statistically analyzed to develop a cumulative probability distribution of model response.

Data input to the model for Monte Carlo applications can be a mixture of constants and one or more of seven probability distributions included in the model. An input parameter is assigned a constant value when:

1) the value is known with a high degree of certainty, or
2) the value is part of the conceptual assumptions used in the model, or
3) the value is uncertain, but a probability distribution has not been quantified.

Values that fall in the third category are evaluated using sensitivity analyses to determine their impact on model response. Three of the seven probability distribution functions included with the model were used in the SLAPS model. These distributions are normal, log-normal, and uniform. A normal distribution is characterized by a bell-shaped probability distribution. The distribution is symmetrical about a mean value, with values farther from the mean occurring less frequently. The normal distribution is defined by specifying an arithmetic mean and standard deviation and upper and lower bounds. A log-normal distribution occurs when the natural log of a variable is normally distributed. The relationship between mean and standard deviation in arithmetic and log-normal space is:

$$m_x = \exp[m_y + 0.5(S_y)^2] \qquad [EQ.\ 16]$$

$$S_x = m_x^2\,[\exp(S_y^2) - 1] \qquad [EQ.\ 17]$$

where:
- m_x = mean in arithmetic space
- m_y = mean in lognormal space
- S_y = standard deviation in log-normal space
- S_x = standard deviation in arithmetic space

The log-normal distribution is defined by specifying an arithmetic mean and standard deviation and upper and lower bounds. The program converts the mean and standard deviation from arithmetic space to log-normal space using the relationships in equations 16 and 17. A uniform distribution is a probability distribution where all values within a specified range have an equal probability of occurrence. The uniform distribution is defined by specifying upper and lower bounds.

D4.0 MODEL INPUT PARAMETERS

The values used in the MULTIMED model input are based on site-specific measurements or, when these are not available, on published data ranges or empirical relationships. The presentation of input parameters is subdivided into the following groups:

- Unsaturated zone flow and transport
- Chemical-specific data
- Source-specific data
- Aquifer data

D4.1 UNSATURATED ZONE FLOW AND TRANSPORT

The parameters used in the SLAPS model to define flow and contaminant transport in the unsaturated zone are presented in Table D-1.

The saturated hydraulic conductivity distribution is based on laboratory vertical hydraulic conductivity measurements in stratigraphic Unit 2 (see Appendix A of the study). The unsaturated zone porosity distribution is based on an effective porosity distribution for silt (Boutwell et al. 1985). The air entry pressure head at the top of the unsaturated zone is assumed to be zero. The depth of the unsaturated zone is assigned a constant value of 1 m (3.3 ft) based on assumptions made regarding excavation and backfilling of contaminated areas. The residual water content, α coefficient, and β exponent were obtained from the Data Base Analyzer and Parameter Estimator program (Imhoff et al. 1990). The program uses the National Soils Data Base to develop unsaturated flow parameter estimates. The values shown in the table were estimated for the Nevin soil series in St. Louis County.

Longitudinal dispersivity was derived using the empirical relation presented in Sharp-Hansen et al. (1990):

$$\alpha_v = 0.02 + 0.022L \qquad [EQ.\ 18]$$

where: α_v = vertical (longitudinal) dispersivity (m)

L = depth of the unsaturated zone (1 m)

The percentage of organic matter in the unsaturated zone is not directly applicable to radionuclide transport; however, the model requires input of a value for use in determining the distribution coefficient for the unsaturated zone. The value presented in the table was obtained from the DBAPE program for the Nevin soil series. The distribution of soil bulk density was obtained from site-specific measurements in stratigraphic Unit 2 (see Appendix A of the study).

D4.2 CHEMICAL-SPECIFIC DATA

The MULTIMED model contains a variety of parameters to describe degradation, decay, and sorption rates of chemicals. The long-lived radionuclides present at SLAPS are assumed to undergo negligible degradation or decay over the period of simulation. The sorption factors considered are the distribution coefficient and the normalized distribution coefficient for each radionuclide of concern. These parameter distributions are presented in Table D-2.

The distribution coefficient values are used by the model as distribution coefficients in the saturated transport model. These values are used in equation 12 to determine the retardation factor. The uranium distribution coefficient distribution was determined from site-specific distribution ratio measurements in the upper groundwater system. These measurements are presented in Appendix A of the study. Distribution coefficient data for radium and thorium were taken from published data presented in Table 3-4 in the study.

The model treats the normalized distribution coefficient as the organic carbon partition coefficient (K_{oc}) for determining the distribution coefficient in the unsaturated zone. The relationship between K_{oc} and the distribution coefficient (K_d) is:

$$K_d = K_{oc} \times f_{oc} \qquad [EQ.\ 19]$$

where:

$$f_{oc} = \frac{percent\ organic\ matter}{172.4} = fraction\ of\ organic\ carbon$$

Because this relationship is not applicable to radionuclide sorption, "artificial" normalized distribution coefficients were created by dividing the distribution coefficients by the fraction of organic carbon. Thus, the distribution coefficient used by the unsaturated transport module is the same as that used by the saturated transport module. It is important to note, however, that the retardation factor used in the unsaturated module differs from that used in the saturated module by the inclusion of a saturation factor as shown in equation 6.

D4.3 SOURCE-SPECIFIC DATA

The source-specific data include parameters required to define the contaminant source term. These parameters are shown in Table D-3. The infiltration rate is the rate of percolation of water into the source. This value was obtained from HELP model output for the bottom liner case (Appendix B of the study). The area, length, and width of the facility are used to define the area over which the mass flux of contaminants is integrated. The assumptions used to derive these parameters are discussed in Section D2.0 of this appendix. The recharge rate is the rate at which clean water is added to the system to dilute contaminants. This parameter is applied to areas outside the source area. Because of the assumptions made during source conceptualization, this value is assumed to be equal to the infiltration rate. This results in only a fraction of the dilution that would occur if current site recharge rates were used. The initial source concentration was established at 1 mg/L to allow convenient computation of a DAF. The DAF is a dimensionless ratio of source concentration to receptor concentration:

$$DAF = \frac{C_0}{C_w} = \frac{1}{C_w} \qquad [EQ. 20]$$

where: C_0 = source concentration (mg/L) = 1 mg/L

C_w = concentration at the receptor (mg/L)

The DAF can be used to determine the maximum source concentration for a given receptor concentration or the steady-state concentration at the receptor for a given source concentration.

D4.4 AQUIFER DATA

Aquifer data are used to provide parameters for the saturated zone flow and transport module in the model. The parameter distributions are presented in Table D-4. The aquifer porosity distribution is based on effective porosities for silt presented in Boutwell et al. (1985). The bulk density and aquifer thickness distributions are based on site-specific measurements in the upper groundwater system (Table 5-1 in the study). The hydraulic conductivity distribution is based on field tests in the upper groundwater system that were performed before 1993. Table 5-1 in the study includes results from field tests performed in 1993, which were not available when this modeling effort was completed. The hydraulic gradient distribution is based on site-specific determinations for the upper groundwater system (Table 5-1 in the study). Dispersivity parameters were determined from empirical relationships presented in Sharp-Hansen et al. (1990):

$$\alpha_L = 0.1X_r \qquad [EQ. 21]$$

$$\alpha_T = \frac{\alpha_L}{3.0} \qquad [EQ. 22]$$

$$\alpha_V = 0.056\alpha_L \qquad [EQ. 23]$$

The MULTIMED model processor requires that a time dimension be added to the source definition for transient simulations. A finite pulse duration temporal source condition was chosen. The duration of the pulse was made sufficiently long to allow development of pseudo-steady-state conditions at the receptor. The pulse durations were determined by trial and error for each of the contaminants of concern:

Contaminant	Pulse duration (years)
Uranium	10,000
Radium	20,000
Thorium	1,000,000

The long pulse durations resulted in coupling problems between the unsaturated and saturated transport modules when using the patch source boundary condition. However, the coupling problem was resolved by using the gaussian source boundary condition. A comparison was made by performing a decoupled (saturated zone transport only) simulation with the patch source boundary condition and a coupled (unsaturated and saturated transport) simulation with the gaussian source boundary condition. The results of this comparison indicate a similar concentration/time history at the receptor. Therefore the gaussian source boundary condition was used for the transient simulations to allow examination of concentration changes over time in the unsaturated and saturated zones.

Uranium transport simulation results are depicted in Figures D-29 and D-30. Figure D-29 provided a key to understanding the lack of steady-state model sensitivity to the absence of the unsaturated zone (sensitivity case 1G). The unsaturated transport equations consider only vertical dispersivity, ignoring horizontal dispersivity components. Thus, the source concentration will eventually migrate through the unsaturated zone, at a rate controlled by the vertical dispersivity and retardation. Therefore, in the SLAPS steady-state simulations, transport through the unsaturated zone does not affect the receptor concentration. Figure D-29 indicates that breakthrough of the source concentration of uranium occurs approximately 1,100 years after source placement. Figure D-30 presents uranium concentrations versus time at the receptor. Uranium concentrations reach a pseudo-steady-state at the receptor approximately 3,000 years after the placement of the source. The pseudo-steady-state concentration is lower than the steady-state concentration because the Monte Carlo analyses used in the steady-state simulations are based on statistical parameter distributions, whereas the transient simulations are based on a data set that has been conservatively biased toward higher seepage velocity and lower retardation. Although this bias results in faster transport of the contaminants, it also results in lower concentrations at the receptor because of dispersion. The dispersion coefficient is defined as the product of dispersivity and seepage velocity; thus, as the seepage velocity increases, the dispersion of the contaminant plume increases. Figures D-31, D-32, D-33, and D-34 present the unsaturated zone and receptor concentrations versus time for radium and thorium.

Table D-7 summarizes the results of the transient transport simulations for the contaminants of concern. The time periods to reach pseudo-steady-state concentrations at the receptor range from 3,000 years for uranium to 800,000 years for thorium. Based on the transient simulations, it is apparent that all contaminants of concern migrate slowly. Thus, sufficient time is available to detect contaminant releases before offsite receptors would be exposed.

The Pearsonian coefficient of skewness [S_K] (Arkin and Colton 1970) is computed from:

$$S_K = \frac{mean\ -\ mode}{standard\ deviation} \qquad [EQ.\ 25]$$

Positive values of the skewness coefficient indicate that the distribution is right skewed, and negative values indicate that the distribution is left skewed. In a right-skewed distribution, the arithmetic mean is greater than the mode because of the influence of large values on the mean. A left-skewed distribution is characterized by an arithmetic mean less than the mode because of the influence of small values on the mean.

The frequency distribution histogram and cumulative frequency graph for the uranium transport simulation are shown in Figures D-1 and D-2, and histograms and graphs for radium (case 2) and thorium (case 3) are shown in Figures D-23, D-24, D-25, and D-26. The three sets of figures show that the frequency distributions are almost identical. The differences in input parameters among the three cases are the distribution coefficients and the normalized distribution coefficients. Because the distribution coefficients are related to retardation of contaminant movement, they do not affect the steady-state concentrations at the receptor. Summary statistics for the three cases are presented in Table D-6. The skewness coefficients indicate that the distributions are right skewed. The objective of the statistical analysis is to provide a basis for selecting a concentration value for determining the DAF. Based on this analysis, a conservative estimate of receptor concentration would be the arithmetic mean concentration because it is biased toward higher receptor concentrations. The mean concentration was used in equation 20 to calculate the DAFs presented in the table.

D5.3 TRANSIENT TRANSPORT

To evaluate the temporal component of contaminant transport, transient simulations were performed for the contaminants of concern. The MULTIMED model does not allow transient simulation with the Monte Carlo processor. Transient simulations were performed in the deterministic model using arithmetic means from the input parameter distributions, except for the following parameters:

- aquifer hydraulic conductivity
- saturated vertical hydraulic conductivity in the unsaturated zone
- aquifer hydraulic gradient
- normalized distribution coefficient
- distribution coefficient

Hydraulic conductivities for the aquifer and unsaturated zone and hydraulic gradient parameters for the aquifer were assigned the values of the maximum limit for each of these parameter distributions. The one-dimensional seepage velocity in the saturated zone, obtained from using these values in equation 13, is 9.5 m/yr. The normalized distribution coefficient and distribution coefficient parameters were assigned the minimum limit for each of these parameter distributions. The normalized distribution coefficient and distribution coefficient for uranium were an exception to this assignment rationale. The uranium distribution ratio data for the upper groundwater system (Appendix A of the study) indicate that the minimum distribution ratio for uranium (0.02 ml/gm) is nearly two orders of magnitude lower than the second lowest distribution ratio (11 ml/gm). Comparison of the uranium distribution ratio data with the uranium distribution coefficients in Table 3-4 of the study also indicates that the minimum value is anomalously low. The lower limit for the uranium distribution ratio was rejected, and the second lowest value (11 ml/gm) was used in the transient simulation. Saturated zone retardation factors, calculated using the distribution coefficients and equation 12, are 114 for uranium, 617 for radium, and 30,800 for thorium. The input parameters used to define seepage velocity and retardation were biased toward higher, and hence more conservative, rates of contaminant movement.

The definition of the unsaturated flow system is the same for the three transient simulation cases. Figures D-27 and D-28 show the simulated steady-state saturation and pressure-head distributions versus depth in the unsaturated zone. Figure D-27 indicates that, based on the defined physical system, the unsaturated zone thickness decreases to 0.94 m (3.1 ft), thus indicating a 0.04 m (0.13 ft) rise in the water table beneath the facility. Saturation and pressure-head distributions are sensitive to infiltration through the facility and porosity. Variations in either of these parameters will alter the distribution of saturation and pressure head.

Case 1G was devised to evaluate the impact on the model response of removing the unsaturated zone. Because the configuration of the disposal facility has not been finalized and the unsaturated zone is relatively thin, this case was designed to evaluate the impact of placing the facility at the water table. The frequency distribution histogram and cumulative frequency graph are presented in Figures D-15 and D-16. Comparison of the figures and summary statistics for this case with the base case information suggests that the data sets are similar. A discussion of the impact of the unsaturated zone on contaminant transport is provided in Section D5.3 of this appendix.

Cases 1H and 1I were prepared to evaluate the sensitivity of model response to variations in recharge. The recharge parameter is used by the model to simulate dilution of the contaminant plume. Because case 1H assumes no recharge, no dilution occurs. Case 1I uses the recharge value obtained from the CREAMS model (Appendix C of the study) for current site conditions. The frequency distribution histogram and cumulative frequency graph for case 1H are shown in Figures D-17 and D-18 and for case 1I in Figures D-19 and D-20. Comparison of the figures and summary statistics for these two cases with the base case information indicates that the model is sensitive to recharge variations. The results for these cases also suggest that the assumption of recharge rate equivalence to infiltration rate would result in conservatively high estimates of contaminant concentration at the receptor.

Case 1J was formulated to evaluate the impact of a partial failure of the disposal area cap on the model output. This case uses the CREAMS model recharge rate for both infiltration rate and recharge rate parameters. Figures D-21 and D-22 present the frequency distribution histogram and cumulative frequency distribution graph for case 1J. Comparison of the figures and summary statistics with the base case information indicates that the data sets are similar, but the case 1J data set has a lower dispersion than the base case.

The sensitivity analyses indicate that model response is sensitive to variations in dispersion and recharge parameters. Site-specific and published data indicate that the parameter values used in the base case are either representative of site conditions or produce results that conservatively overestimate receptor exposure.

D5.2 TRANSPORT OF CONTAMINANTS OF CONCERN

The simulations performed for the sensitivity analyses and transport of the contaminants of concern use steady-state transport conditions. Steady-state conditions are achieved when the contaminant concentration at the receptor reaches a constant value. The use of steady-state transport conditions assumes that there is a sufficiently large mass of contaminants at the source to ensure a continuous and constant supply of contaminants. The steady-state transport simulations for SLAPS do not include consideration of time in the transport simulation. Thus, for a given hydrogeologic system, steady-state transport simulations for two chemicals may result in the same receptor concentrations, but one chemical may reach the steady-state concentration in 10 years and the other in 10,000 years. In effect, these steady-state simulations reflect the effects of dilution and dispersion and ignore the effects of retardation.

The Monte Carlo simulation results are presented as a frequency distribution of concentration class intervals. To interpret these results, simple statistical analysis techniques are used. For an ideal frequency distribution, the bell-shaped curve, the arithmetic mean, and the mode (the most frequently occurring concentration class interval) are coincident. The uranium base case frequency distribution histogram (Figure D-1) and summary statistics (Table D-5) indicate that the arithmetic mean is greater than the modal class interval. This indicates that the frequency distribution is asymmetrical or skewed. The degree of skewness can be quantified using the arithmetic mean, the mode, and the standard deviation. A deterministic value for the mode may be estimated from the formula (Arkin and Colton 1970):

$$mode = L_{mo} + \frac{f_a}{f_a + f_b} C \qquad [EQ.\ 24]$$

where:

- L_{mo} = lower limit of modal class interval
- f_a = frequency of the class interval above the modal group
- f_b = frequency of the class interval below the modal group
- C = size of class interval

where: α_L = longitudinal dispersivity (m)

X_r = distance to receptor (m) = 55 m (180 ft)

α_T = transverse dispersivity (m)

α_V = vertical dispersivity (m)

The final three parameters in the table relate to the configuration of the hypothetical receptor well. The conceptualization of the site, described in Section D2.0 of this appendix, assumes that the receptor is located 55 m (180 ft) from the waste disposal area. The angle off center refers to the orientation of the receptor relative to the source. An angle of zero degrees was chosen to orient the receptor downgradient of the source area. The well vertical distance is used to define the vertical position of the well intake with respect to the water table. A value of zero was assigned to place the well intake at the water table.

D5.0 RESULTS

This section describes the results of sensitivity, transport of the contaminants of concern, and transient transport simulations. Model output files for sensitivity and steady-state transport simulations are included in Attachment D-1. Model output files for transient transport simulations are included in Attachment D-2. All Monte Carlo model simulations, except case 1B, were performed using 500 Monte Carlo simulations to create the data sets for evaluation. Based on conceptualization of the contaminant source, the patch source boundary condition was selected. All sensitivity and transport simulations for contaminants of concern, except for case 1A, were performed using the patch source boundary condition.

D5.1 SENSITIVITY ANALYSES

The distribution coefficient data for the radionuclides of concern indicate that uranium has the lowest minimum range value, which suggests that uranium is the most mobile of the radionuclides of concern. Thus, uranium data were used in the analysis of the sensitivity of model input parameters. The base case uranium simulation was performed using the parameters described in Section D4.0 of this appendix. The base case model results were compared with the various input parameter sensitivity simulations. Figures D-1 and D-2 present the frequency distribution histogram and cumulative frequency graph for the base case. Ten sensitivity cases were devised to test the model response to variations in parameters. Table D-5 presents a summary of these cases and their statistical results.

Case 1A was selected to examine the model sensitivity to the source boundary condition. For this case, a gaussian source boundary condition was used. The gaussian source requires specification of a source width standard deviation, which was assigned a value of ± 10 m (33 ft) to represent the conceptualized source. Figures D-3 and D-4 present the frequency distribution histogram and cumulative frequency distribution graph for this case. Comparison of the figures and the summary statistics for this case with the base case indicates that the mean concentrations are in close agreement. The standard deviation and coefficient of variation values, which provide an indication of the statistical dispersion or "spread" of the data, indicate that the gaussian source produces greater dispersion in the data set.

Case 1B was devised to evaluate the model sensitivity to the number of Monte Carlo simulations performed. If an insufficient number of simulations are performed, the model output may not accurately reflect the distributions of the input parameters. The impact on model results was evaluated by increasing the number of Monte Carlo simulations to 1,000. The frequency distribution histogram and cumulative frequency graph for the simulation are shown in Figures D-5 and D-6, respectively. Comparison of these figures and the summary statistics with the base case results indicates that there is no significant difference between the data sets. The standard deviation and coefficient of variation values indicate that the case 1B data set is slightly less dispersed than the base case, but the difference in dispersion is negligible.

Cases 1C and 1D were prepared to evaluate the model sensitivity to aquifer dispersivity. The distribution of aquifer dispersivity is perhaps the least understood model input parameter. The two sensitivity cases were formulated to evaluate aquifer dispersivity extremes and their impact on the model output. The following values were used:

Parameter	Base case	Case 1C	Case 1D
α_L (m)	5.5	0.55	55.0
α_T (m)	1.83	0.183	18.3
α_V (m)	0.308	0.0308	3.08

The frequency distribution histogram and cumulative frequency graph for case 1C are shown in Figures D-7 and D-8 and for case 1D in Figures D-9 and D-10. The means from these two cases and the base casc suggests that multiplication or division of the aquifer dispersivity by a factor of ten results in multiplication or division of the mean by a factor of two. Comparison of the base case aquifer dispersivity values with data presented in Gelhar et al. (1992) for similar transport scales and geologic conditions suggests that the values used in the base case are representative of the transport conditions.

Case 1E was prepared to evaluate the sensitivity of the model response to changes in the aquifer hydraulic conductivity distribution. Data from Boutwell et al. (1985) for silt/loess were used to develop an alternate aquifer hydraulic conductivity distribution:

	Base case	Case 1E
mean (m/yr)	21.14	140
standard deviation	31.24	198
minimum (m/yr)	0.39	0.0298
maximum (m/yr)	94.67	298

The frequency distribution histogram and cumulative frequency graph for the case 1E model output are shown in Figures D-11 and D-12, respectively. Comparison of the figures and summary statistics for case 1E with information from the base case indicates that similar mean concentrations occur, but the case 1E data set has much higher statistical dispersion. This dispersion is thought to result from a range in hydraulic conductivity values in case 1E that is nearly two orders of magnitude larger.

Case 1F was formulated to test the impact of using total porosity instead of effective porosity for the aquifer porosity. The total porosity distribution in the upper groundwater system, as presented in Table 5-1 of the study, is:

	Base case	Case 1F
mean	0.15	0.412
standard deviation	0.14	0.045
minimum	0.01	0.323
maximum	0.39	0.509

The case 1F frequency distribution histogram and cumulative frequency graph are shown in Figures D-13 and D-14. Comparison of the figures and summary statistics with those from the base case indicates that the data sets are similar. Thus, it can be concluded that the model is not sensitive to variations in porosity distribution.

D6.0 CONCLUSIONS

The results of the steady-state simulations indicate that, for the hydrogeologic system and hypothetical receptor scenario simulated, the DAF is 3.6. One advantage of using the DAF is that it represents a dimensionless concentration ratio, so that source/receptor units can be in mg/L, μg/L, or pCi/L. For example, if the hypothetical receptor concentration is fixed at the total uranium derived concentration guide of 600 pCi/L, then the maximum source concentration of total uranium would be 2,160 pCi/L.

The results of the transient simulations indicate that travel times from the facility to the hypothetical receptor, for the contaminant of concern, range from hundreds to hundreds of thousands years. Thus, there is sufficient time to detect and respond to radionuclide releases that exceed concentration guidelines before exposure of offsite receptors would occur.

Evaluation of the modeling results suggests that a properly designed disposal facility coupled with a groundwater monitoring and remedial response program would protect offsite groundwater receptors from exposure to the contaminants of concern.

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Imhoff, J. C., et al., 1990. *Data Base Analyzer and Parameter Estimator (DBAPE) Interactive Computer Program User's Manual*, Environmental Research Laboratory, U.S. Environmental Protection Agency, Office of Research and Development, EPA/600/3-89/083.

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FIGURES FOR APPENDIX D

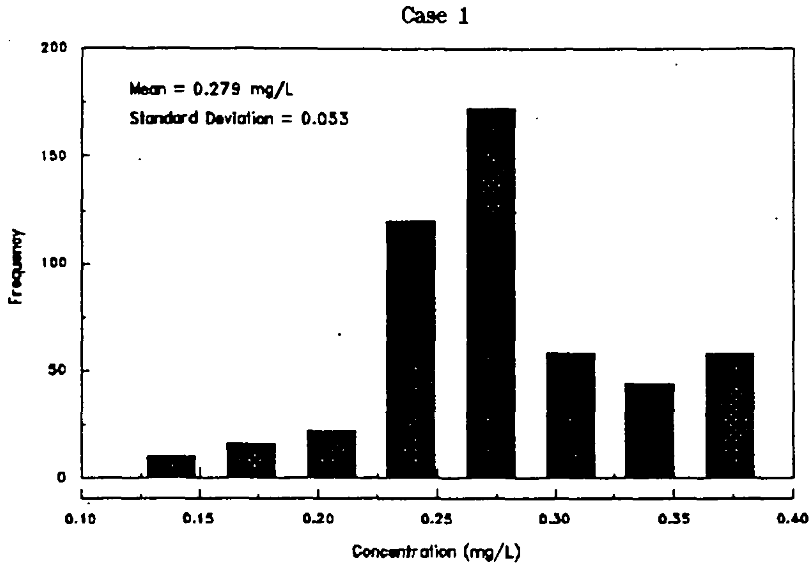


Figure D-1 **Frequency Distribution Histogram for Base Case Uranium Transport**

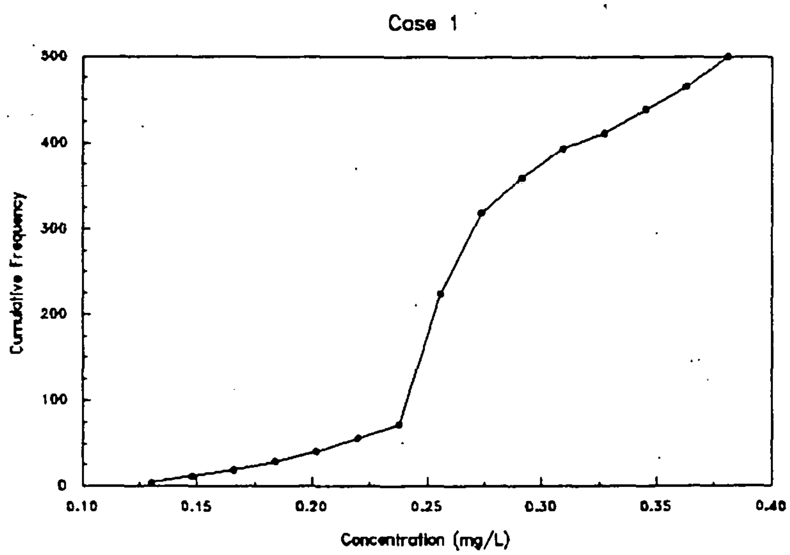


Figure D-2 **Cumulative Frequency Distribution for Base Case Uranium Transport**

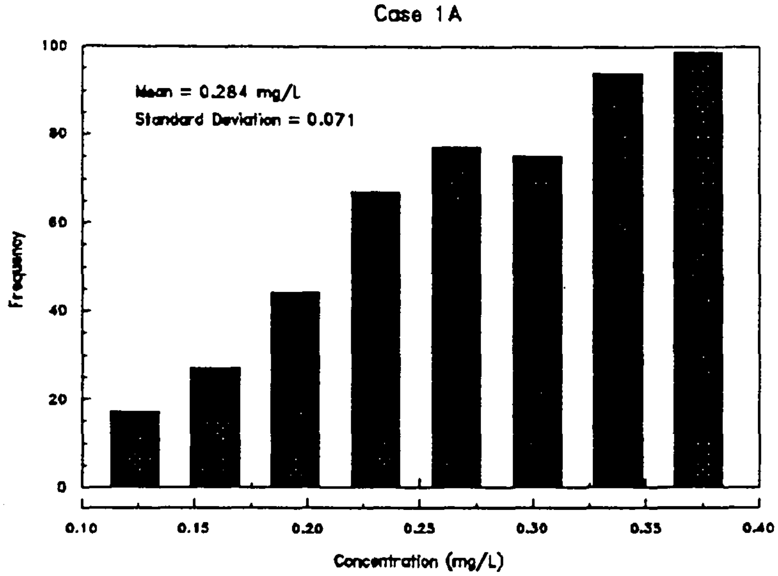


Figure D-3 **Frequency Distribution Histogram for Gaussian Source**

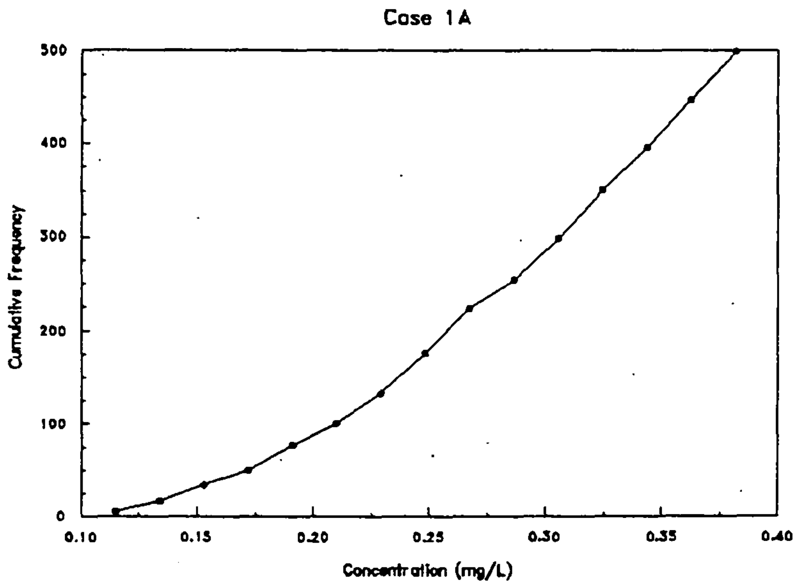


Figure D-4 **Cumulative Frequency Distribution for Gaussian Source**

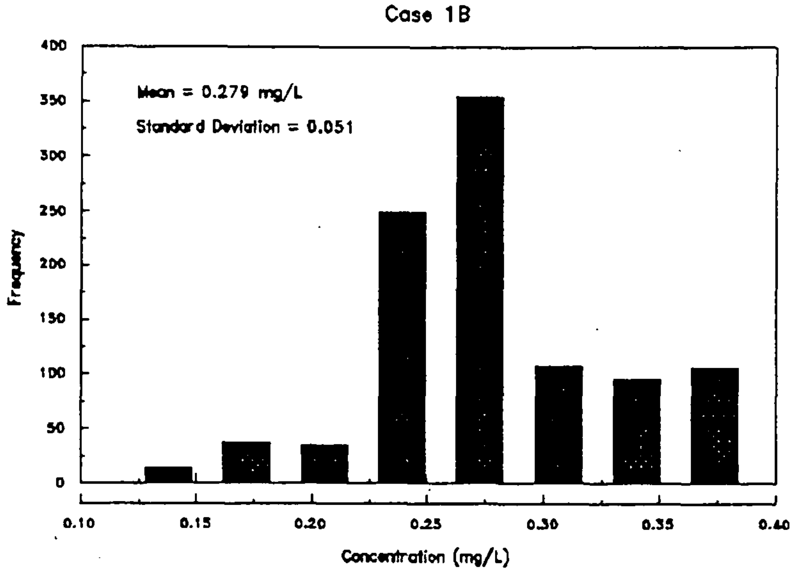


Figure D-5 Frequency Distribution Histogram for 1,000 Monte Carlo Simulations

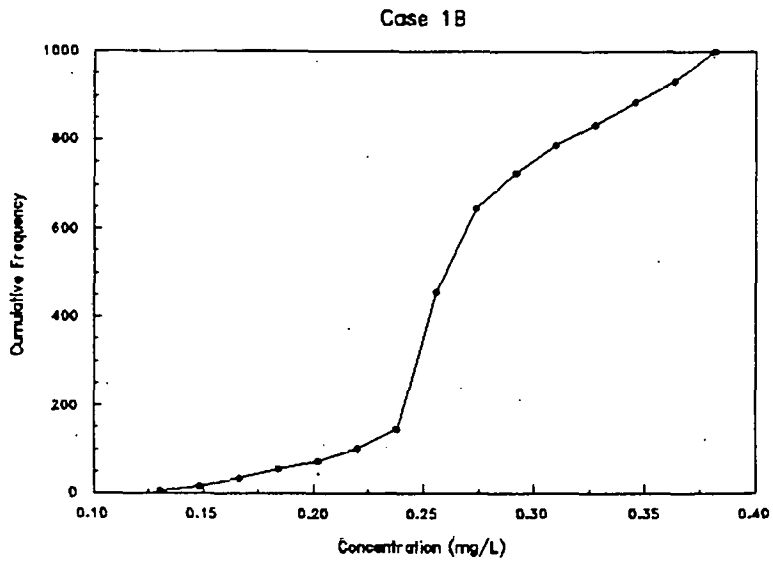


Figure D-6 Cumulative Frequency Distribution for 1,000 Monte Carlo Simulations

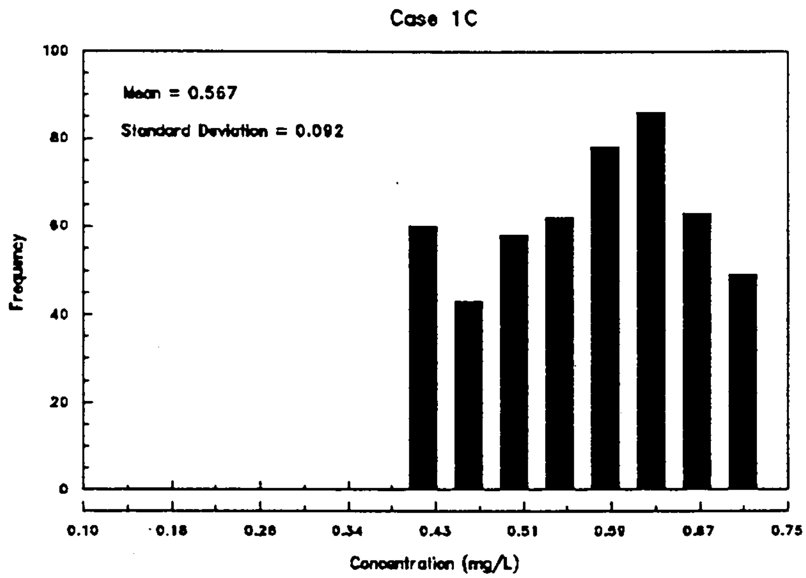


Figure D-7 Frequency Distribution Histogram for Low Extreme Aquifer Dispersivity

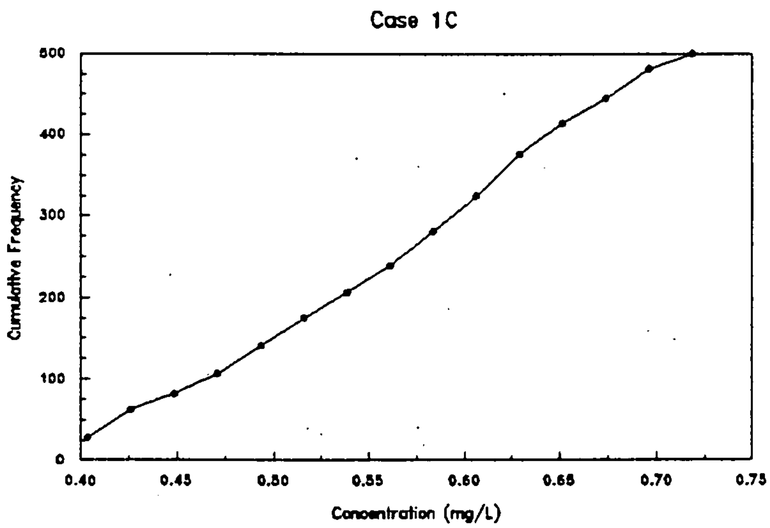


Figure D-8 Cumulative Frequency Distribution for Low Extreme Aquifer Dispersivity

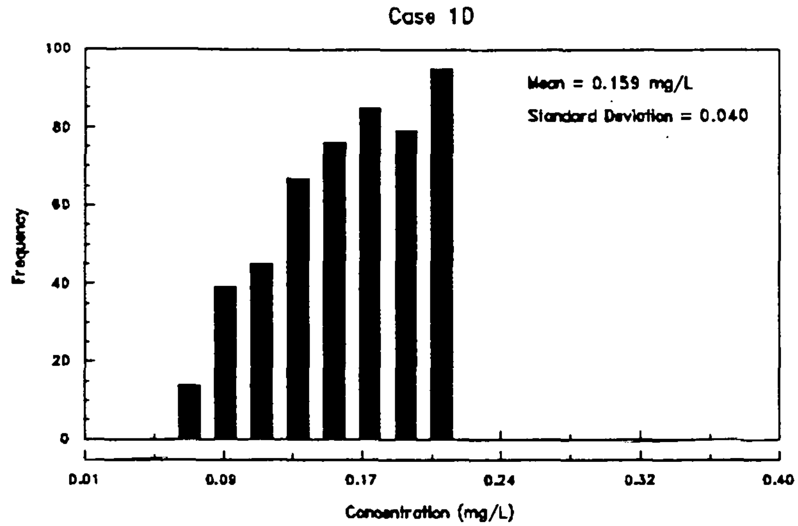


Figure D-9 Frequency Distribution Histogram for High Extreme Aquifer Dispersivity

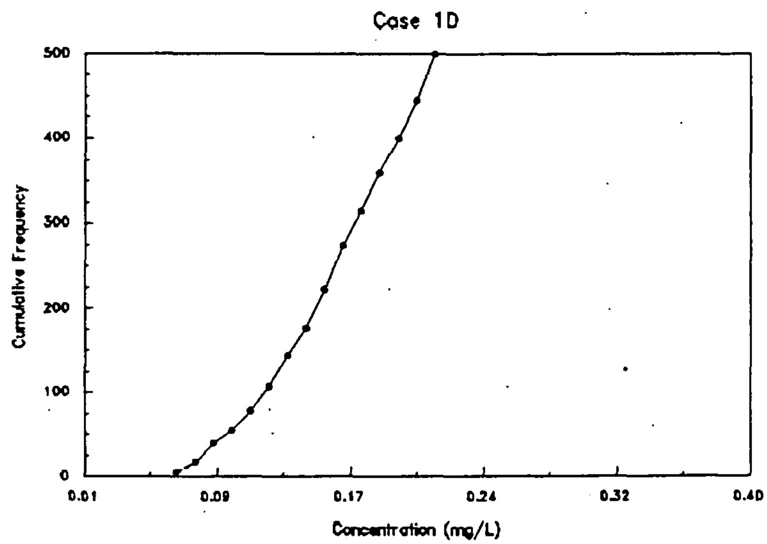


Figure D-10 Cumulative Frequency Distribution for High Extreme Aquifer Dispersivity

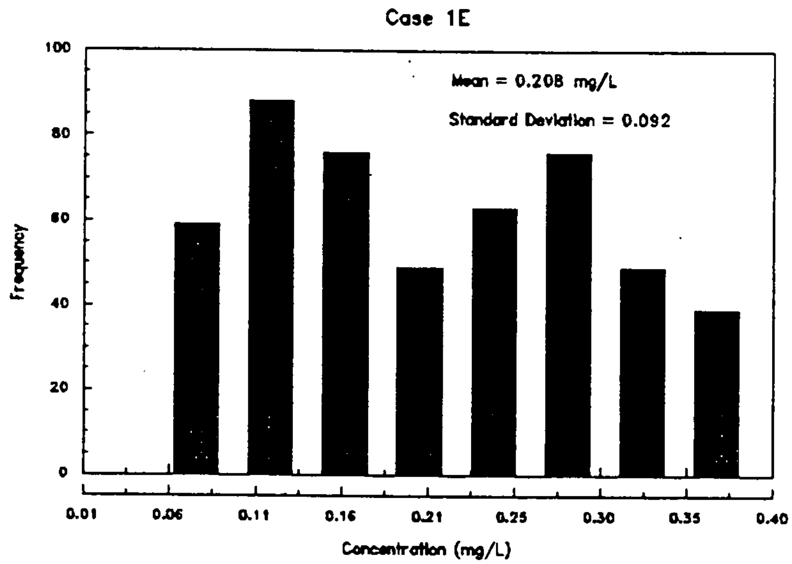


Figure D-11 **Frequency Distribution Histogram for Loess Hydraulic Conductivity Distribution**

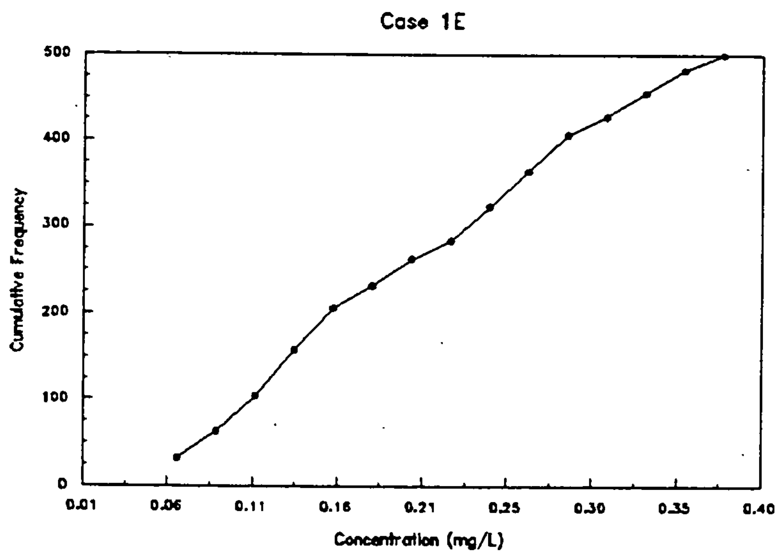


Figure D-12 **Cumulative Frequency Distribution for Loess Hydraulic Conductivity Distribution**

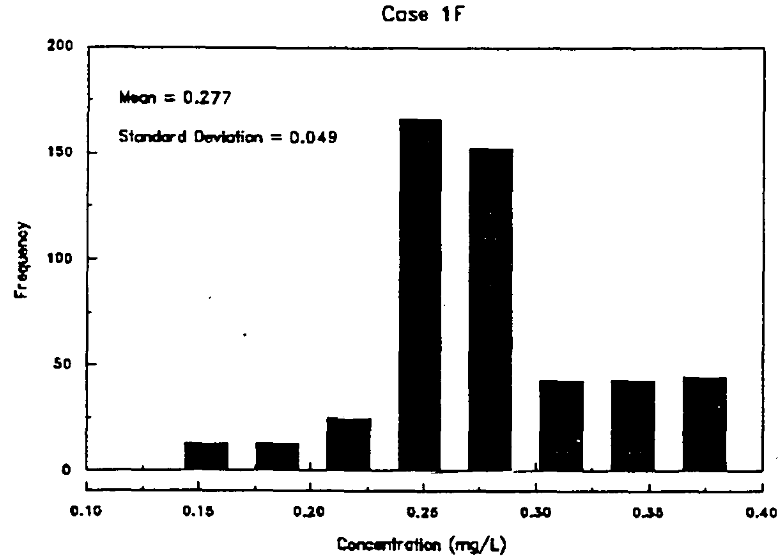


Figure D-13 Frequency Distribution Histogram for Aquifer Porosity Using Total Porosity Distribution

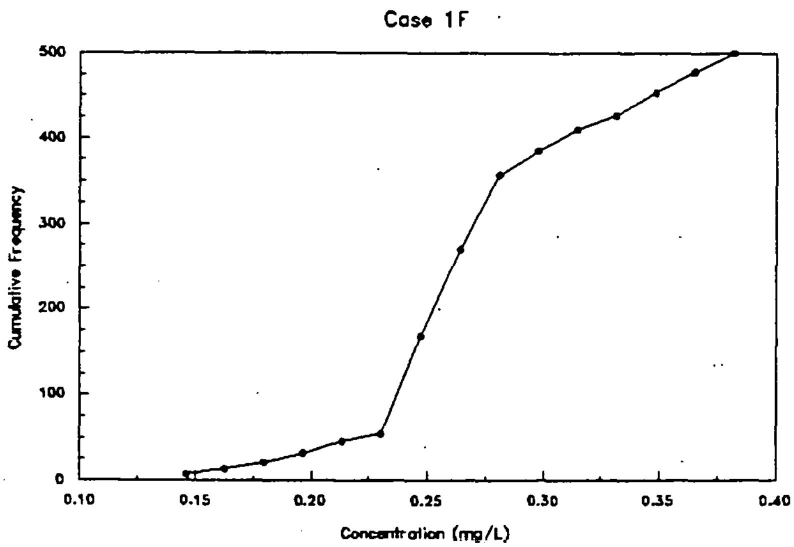


Figure D-14 Cumulative Frequency Distribution for Aquifer Porosity Using Total Porosity Distribution

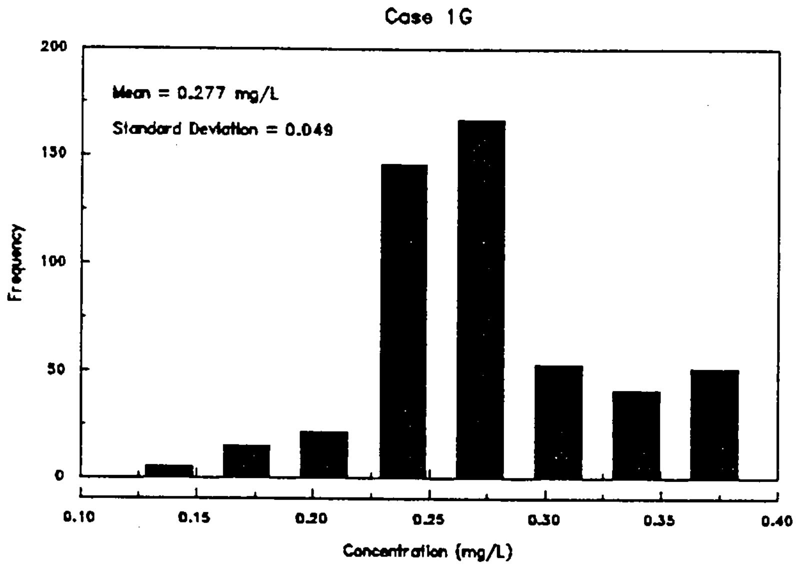


Figure D-15 Frequency Distribution Histogram for Transport with No Unsaturated Zone

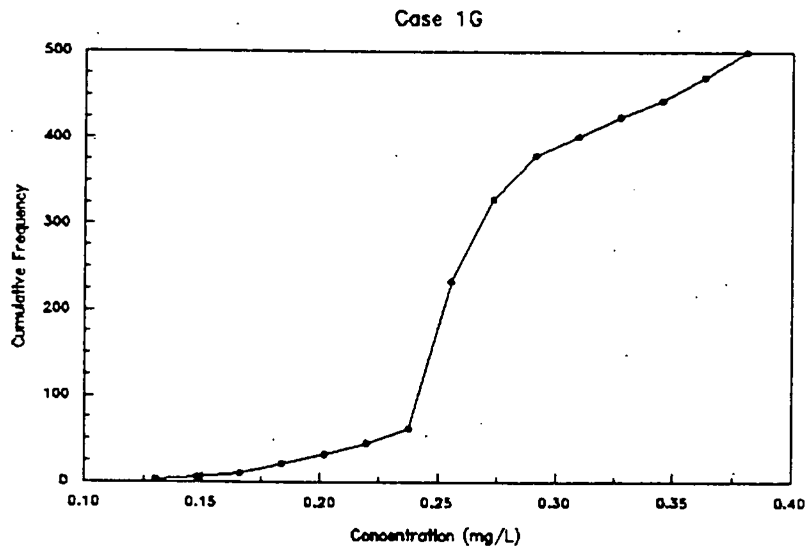


Figure D-16 Cumulative Frequency Distribution for Transport with No Unsaturated Zone

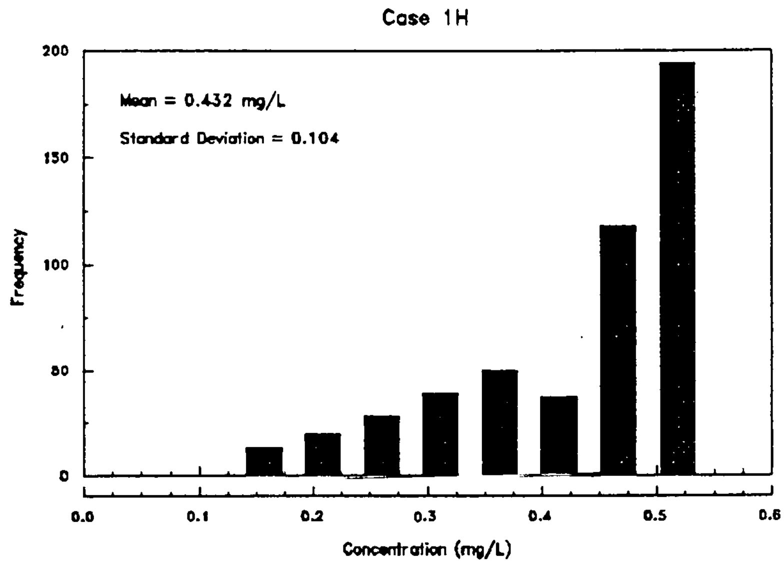


Figure D-17 Frequency Distribution Histogram for Transport with No Recharge

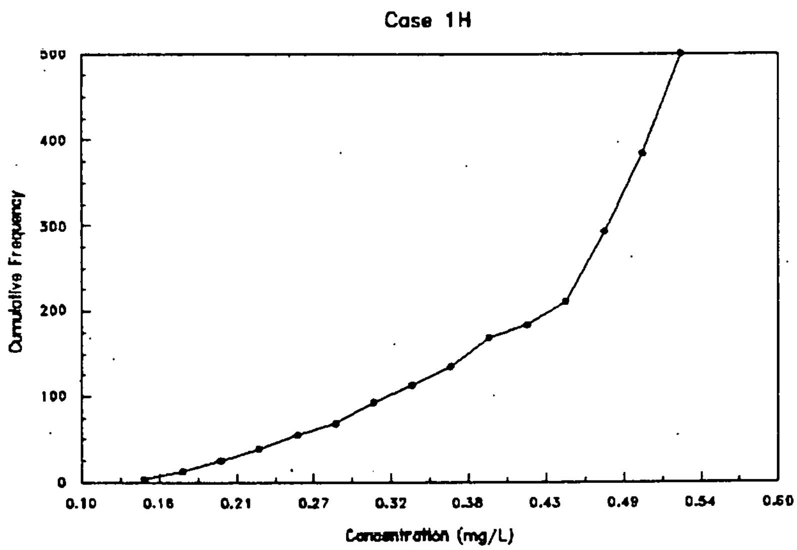


Figure D-18 Cumulative Frequency Distribution for Transport with No Recharge

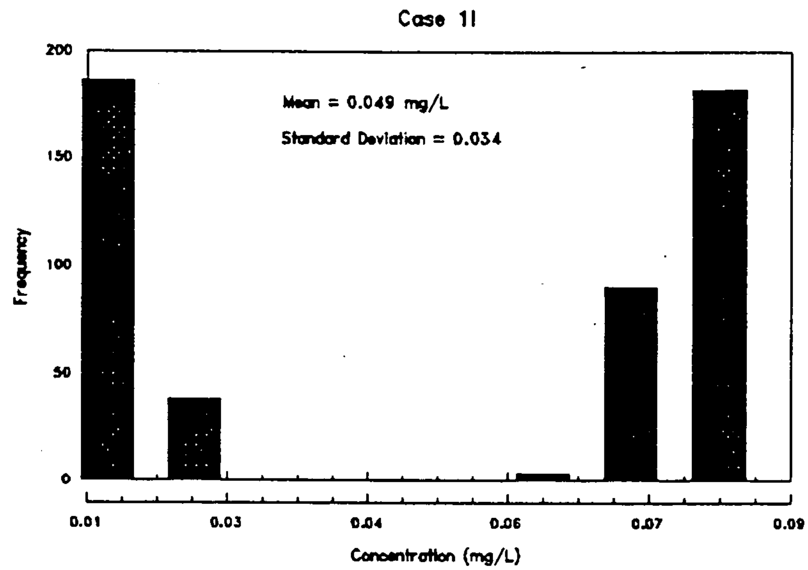


Figure D-19 Frequency Distribution Histogram for Transport with CREAMS Recharge Rate

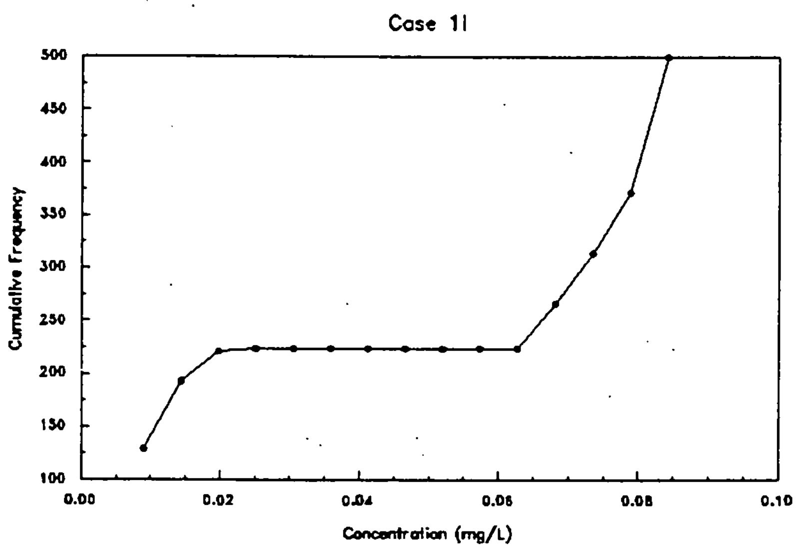


Figure D-20 Cumulative Frequency Distribution for Transport with CREAMS Recharge Rate

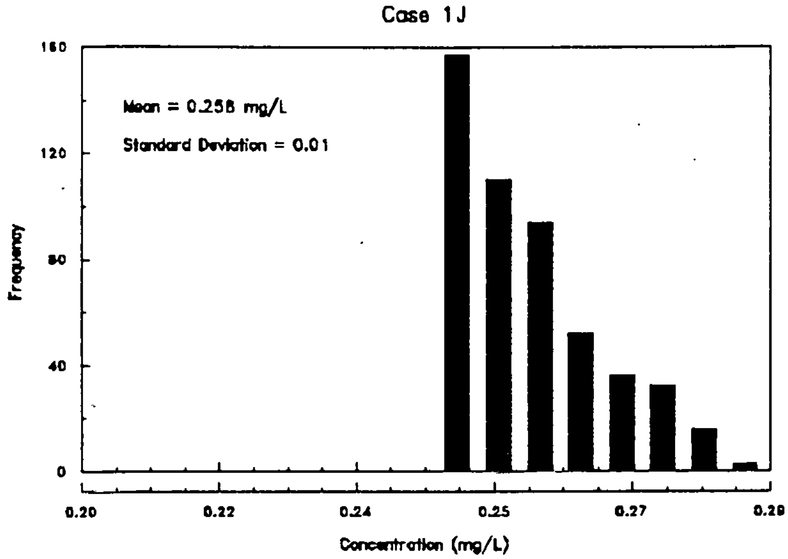


Figure D-21 Frequency Distribution Histogram for Transport with CREAMS Recharge and Infiltration Rates

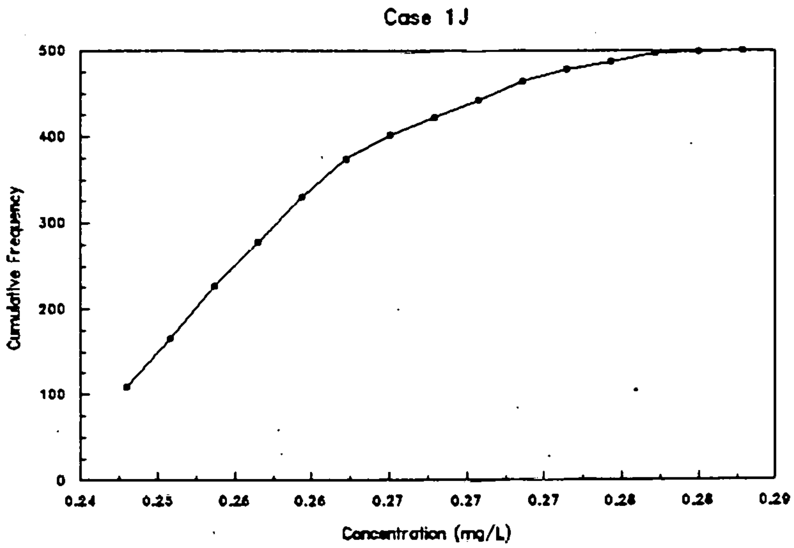


Figure D-22 Cumulative Frequency Distribution for Transport with CREAMS Recharge and Infiltration Rates

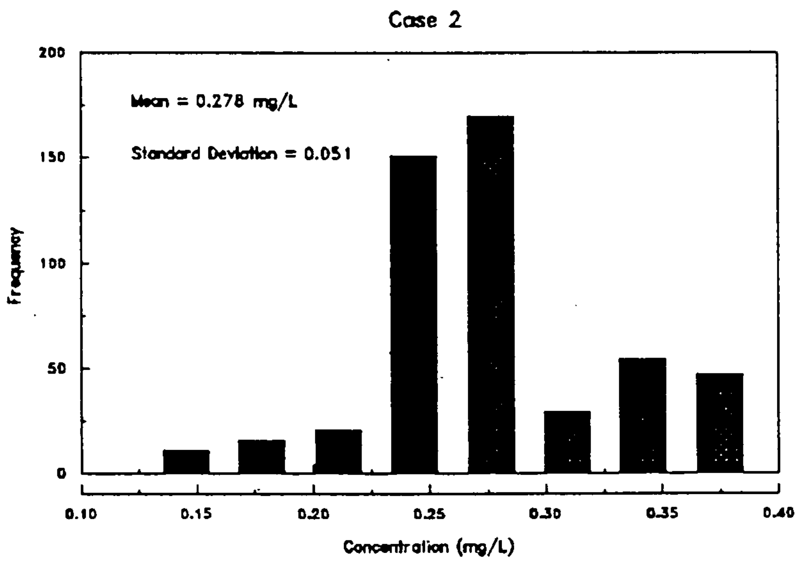


Figure D-23 **Frequency Distribution Histogram for Radium Transport**

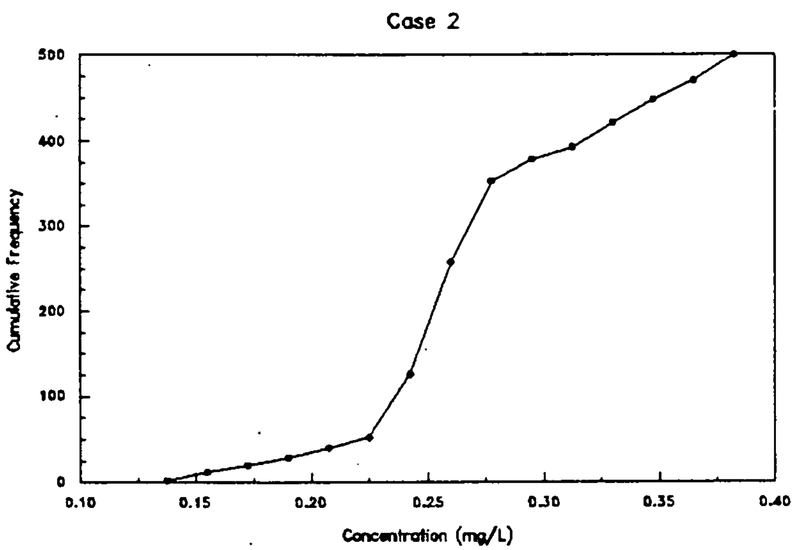


Figure D-24 **Cumulative Frequency Distribution for Radium Transport**

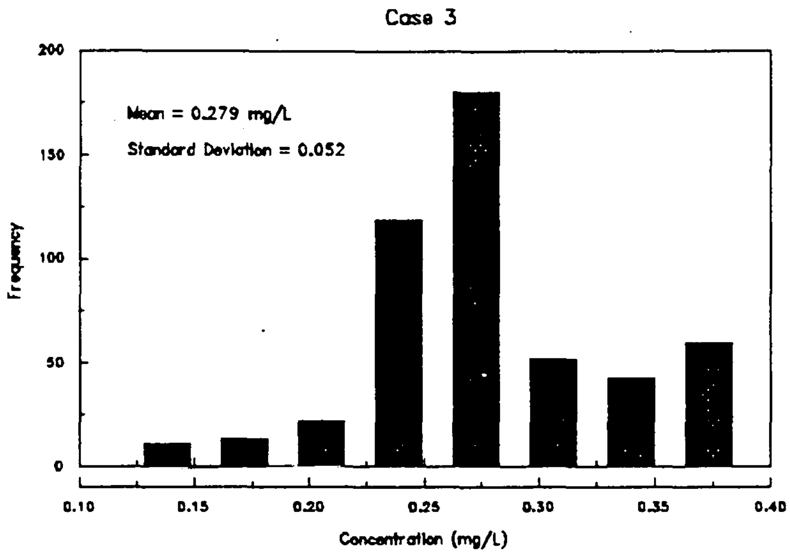


Figure D-25 Frequency Distribution Histogram for Thorium Transport

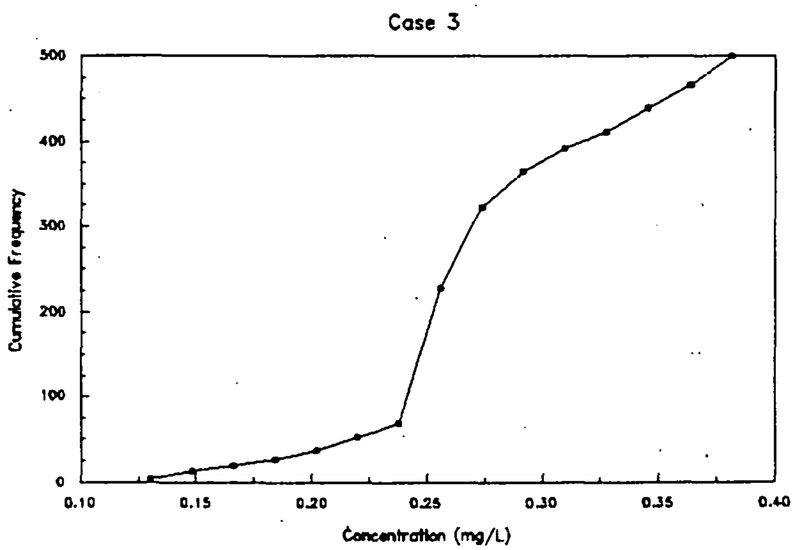


Figure D-26 Cumulative Frequency Distribution for Thorium Transport

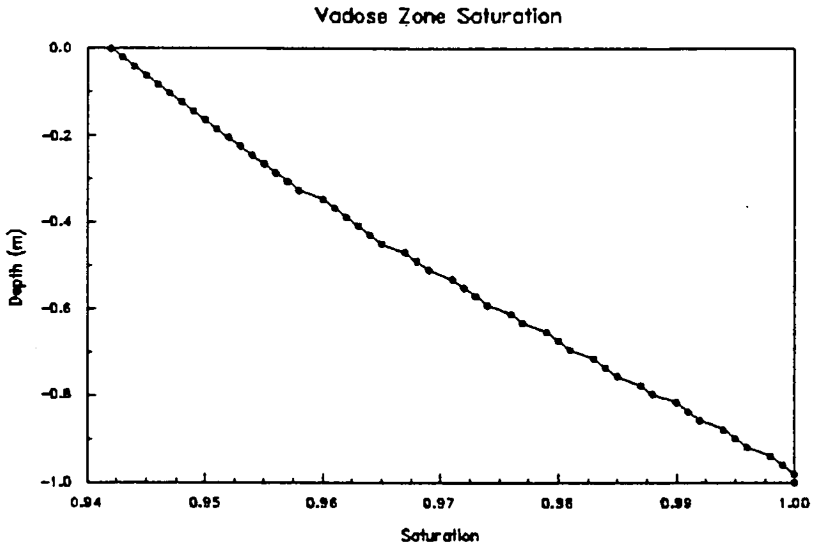


Figure D-27 **Distribution of Saturation in the Unsaturated Zone**

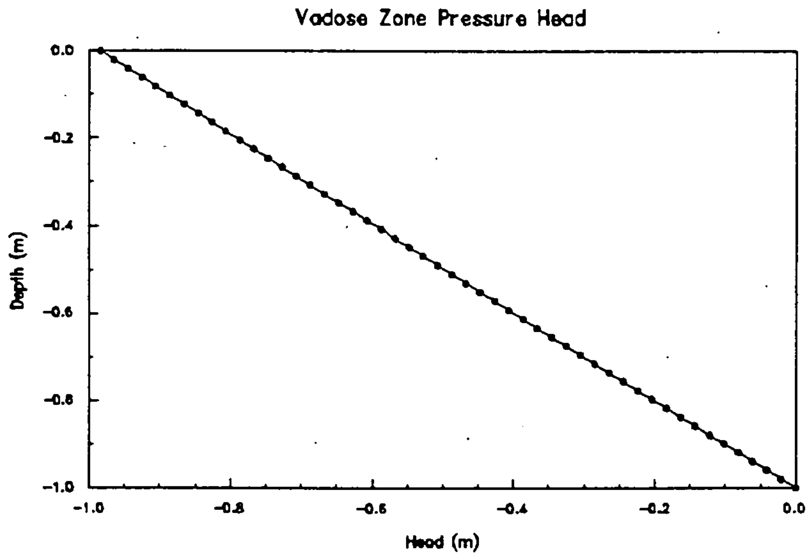


Figure D-28 **Distribution of Pressure Head in the Unsaturated Zone**

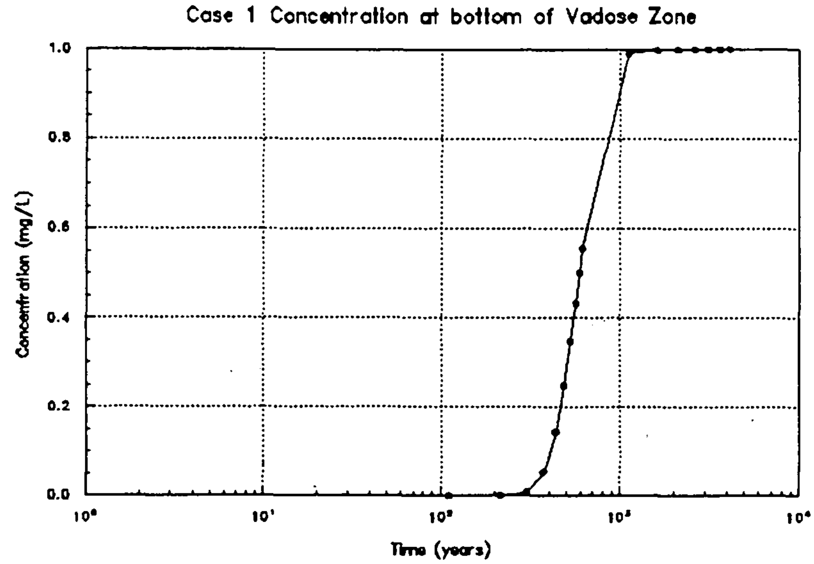


Figure D-29 Uranium Concentration Versus Time at the Bottom of the Unsaturated Zone

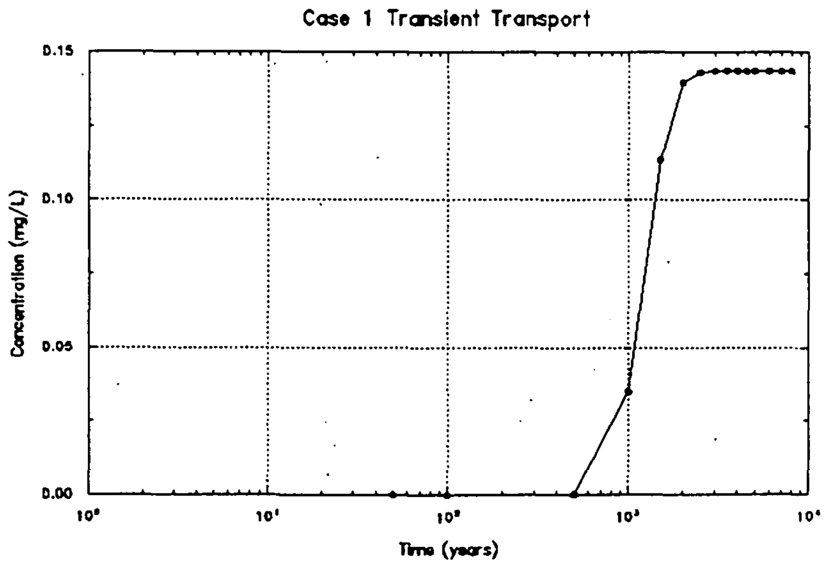


Figure D-30 Uranium Concentration Versus Time at the Receptor

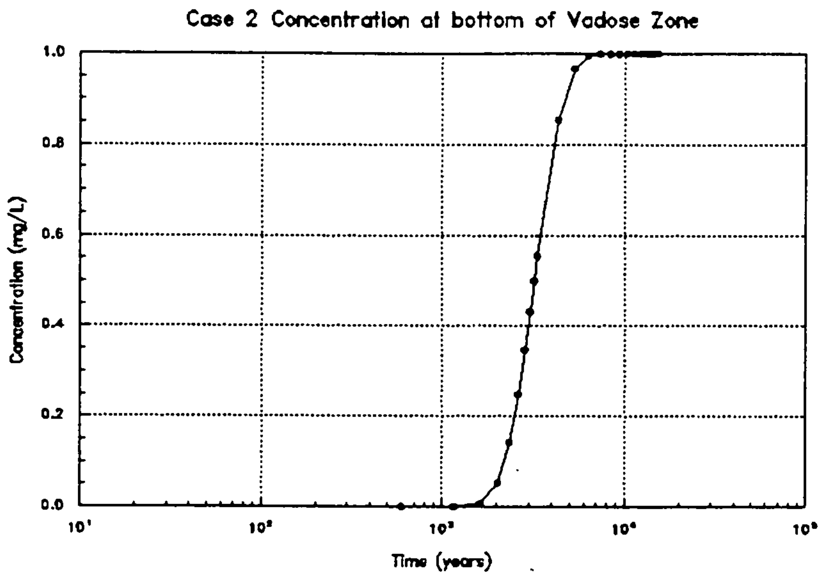


Figure D-31 **Radium Concentration Versus Time at the Bottom of the Unsaturated Zone**

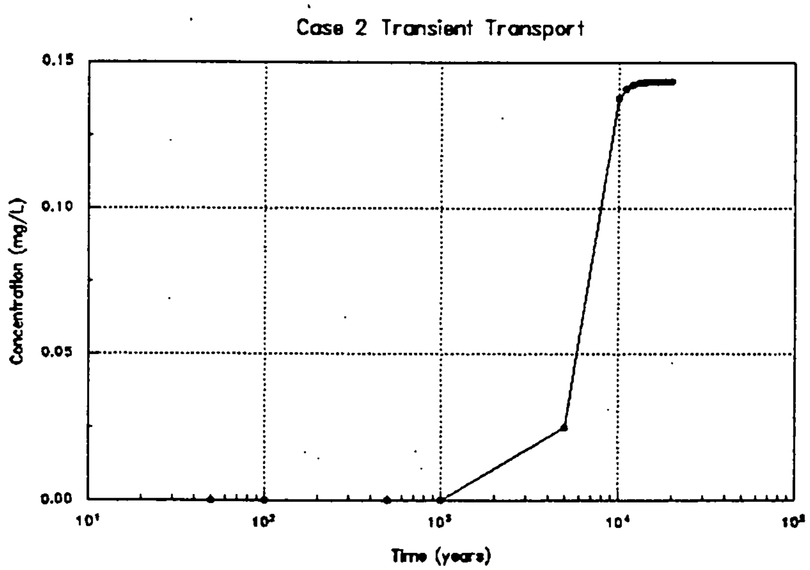


Figure D-32 **Radium Concentration Versus Time at the Receptor**

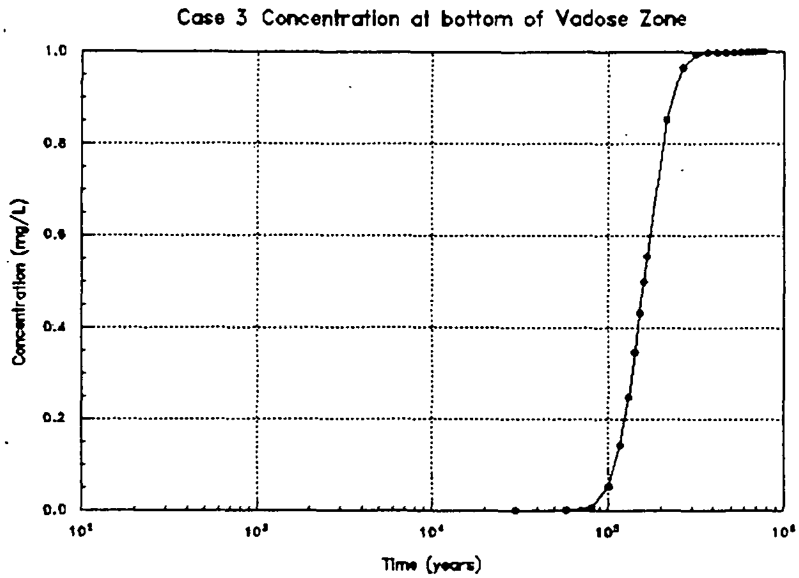


Figure D-33 Thorium Concentration Versus Time at the Bottom of the Unsaturated Zone

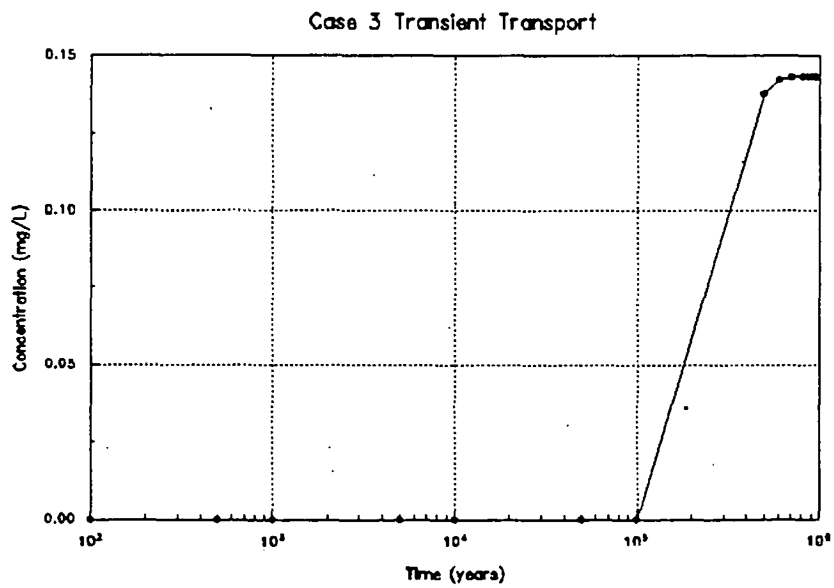


Figure D-34 Thorium Concentration Versus Time at the Receptor

TABLES FOR APPENDIX D

Table D-1

Unsaturated Zone Flow and Transport

Parameter	Units	Distribution	Mean	Standard Deviation	Limits	
					Minimum	Maximum
Flow						
Saturated hydraulic conductivity	cm/h	Log normal	0.1072	0.23	5×10^{-5}	0.72
Unsaturated zone porosity		Normal	0.15	0.14	0.01	0.39
Air entry pressure head	m	Constant	0			
Depth of unsaturated zone	m	Constant	1			
Residual water content		Uniform			0.0834	0.0966
α coefficient	1/cm	Uniform			0.00987	0.0152
β exponent		Uniform			1.21	1.29
Transport						
Longitudinal dispersivity	m	Constant	0.042			
Percent organic matter		Constant	0.8			
Bulk density of soil	gm/cm^3	Normal	1.53	0.1	1.33	1.81

Table D-2

Chemical-Specific Data

Parameter	Units	Distribution	Mean	Standard Deviation	Limits	
					Minimum	Maximum
Uranium normalized distribution coefficient[a]	ml/gm	Log normal	114,861	249,549	4.3	1,271,450
Radium normalized distribution coefficient[b]	ml/gm	Log normal	138,566	252,566	12,930	517,200
Thorium normalized distribution coefficient[b]	ml/gm	Log normal	40,071,794	224,335	646,500	86,200,000
Uranium distribution coefficient[a]	ml/gm	Log normal	533	1,158	0.02	5,900
Radium distribution coefficient[b]	ml/gm	Log normal	643	1,172	60	2,400
Thorium distribution coefficient[b]	ml/gm	Log normal	185,948	1,041	3,000	400,000

[a]Based on site-specific measurements presented in Appendix A of the study.

[b]Based on data in Table 3-4 of the study.

Table D-3

Source-Specific Data

Parameter	Units	Distribution	Mean[a]
Infiltration rate[b]	m/yr	Constant	0.0276
Area of waste disposal unit	m^2	Constant	3,000
Recharge rate[b]	m/yr	Constant	0.0276
Initial concentration at landfill	mg/L	Constant	1
Length scale of facility	m	Constant	150
Width scale of facility	m	Constant	20

[a]Mean value is a constant.

[b]HELP model results for bottom liner option, Appendix B of the study.

Table D-4

Aquifer Data

Parameter	Units	Distribution	Mean	Standard Deviation	Limits	
					Minimum	Maximum
Aquifer porosity	unitless	Normal	0.15	0.14	0.01	0.39
Bulk density	gm/cm^3	Normal	1.54	0.12	1.33	1.81
Aquifer thickness	m	Uniform	NA[a]	NA	7.9	13.7
Conductivity (hydraulic)	m/yr	Log normal	21.14	31.24	0.39	94.67
Gradient (hydraulic)	unitless	Uniform	NA	NA	0.0071	0.015
Longitudinal dispersivity	m	Constant	5.50[b]	--[b]	--[b]	--[b]
Transverse dispersivity	m	Constant	1.83[b]	--[b]	--[b]	--[b]
Vertical dispersivity	m	Constant	0.308[b]	--[b]	--[b]	--[b]
Well distance from site	m	Constant	55[b]	--[b]	--[b]	--[b]
Angle off center	degrees	Constant	0[b]	--[b]	--[b]	--[b]
Well vertical distance	m	Constant	0[b]	--[b]	--[b]	--[b]

[a]NA - not applicable; because the distribution is uniform, the mean and standard deviation cannot be calculated.

[b]The mean value is derived (see text) or assumed and, therefore, is constant.

Table D-5

Sensitivity Analyses Summary

Case	Description	Mean (mg/L)	Standard Deviation	Coefficient of Variation
1	Base case uranium transport	0.279	0.053	0.189
1A	Uranium transport with a gaussian source	0.284	0.071	0.250
1B	Uranium transport with 1,000 Monte Carlo simulations	0.279	0.051	0.185
1C	Uranium transport with aquifer dispersivities one order of magnitude lower	0.567	0.092	0.161
1D	Uranium transport with aquifer dispersivities one order of magnitude higher	0.159	0.040	0.255
1E	Uranium transport with aquifer hydraulic conductivity based on published values for loess	0.208	0.092	0.444
1F	Uranium transport using total porosity for aquifer porosity	0.277	0.049	0.178
1G	Uranium transport with no unsaturated zone	0.277	0.049	0.177
1H	Uranium transport with no recharge	0.432	0.104	0.240
1I	Uranium transport with CREAMS recharge	0.049	0.034	0.692
1J	Uranium transport with infiltration using CREAMS recharge value	0.258	0.096	0.037

Table D-6

Summary of Transport Simulations for the Contaminants of Concern

Case	Contaminant	Mean (mg/L)	Standard Deviation	Coefficient of Variation	Mode (mg/L)	Skewness Coefficient	DAF
1	Uranium	0.279	0.053	0.189	0.267	+0.226	3.6
2	Radium	0.278	0.051	0.183	0.265	+0.255	3.6
3	Thorium	0.279	0.052	0.188	0.266	+0.250	3.6

Table D-7

Summary of Transient Simulations

		Approximate time, in years		
Case	Contaminant	Unsaturated zone breakthrough	Detection at receptor	Pseudo-steady-state
1T	Uranium	1,100	500	3,000
2T	Radium	6,300	1,000	16,000
3T	Thorium	316,000	100,000	800,000

ATTACHMENT D-1

STEADY-STATE MODEL RESULTS

1

U. S. ENVIRONMENTAL PROTECTION AGENCY

EXPOSURE ASSESSMENT

MULTIMEDIA MODEL

MULTIMED (Version 1.01, June 1991)

1

Run options

--- -------

SLAPS Site Suitability Study - Case 1

Monte Carlo simulation.
Chemical simulated is Uranium

Option Chosen	Saturated and unsaturated zone models
Run was	MONTE
Infiltration input by user	
Number of monte carlo simulations	500
Run was steady-state	
Reject runs if Y coordinate outside plume	
Reject runs if Z coordinate outside plume	
Patch source used in saturated zone model	

1
1

UNSATURATED ZONE FLOW MODEL PARAMETERS
(input parameter description and value)

NP	- Total number of nodal points	240
NMAT	- Number of different porous materials	1
KPROP	- Van Genuchten or Brooks and Corey	1
IMSHGN	- Spatial discretization option	1
NVFLAYR	- Number of layers in flow model	1

OPTIONS CHOSEN

------- ------

Van Genuchten functional coefficients
User defined coordinate system

1

Layer information

LAYER NO.	LAYER THICKNESS	MATERIAL PROPERTY
1	1.00	1

DATA FOR MATERIAL 1

VADOSE ZONE MATERIAL VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Saturated hydraulic conductivity	cm/hr	LOG NORMAL	0.107	0.230	0.500E-04	0.720
Unsaturated zone porosity	--	NORMAL	0.150	0.140	0.100E-01	0.390
Air entry pressure head	m	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Depth of the unsaturated zone	m	CONSTANT	1.00	-999.	0.100E-08	-999.

DATA FOR MATERIAL 1

VADOSE ZONE FUNCTION VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Residual water content	--	UNIFORM	0.920E-01	-999.	0.834E-01	0.966E-01
Brook and Corey exponent,EN	--	CONSTANT	0.500	-999.	0.000E+00	10.0
ALFA coefficient	1/cm	UNIFORM	0.123E-01	-999.	0.987E-02	0.152E-01
Van Genuchten exponent, ENN	--	UNIFORM	1.25	-999.	1.21	1.29

1

UNSATURATED ZONE TRANSPORT MODEL PARAMETERS

NLAY	- Number of different layers used		1
NTSTPS	- Number of time values concentration calc		40
DUMMY	- Not presently used		1
ISOL	- Type of scheme used in unsaturated zone		1
N	- Stehfest terms or number of increments		18
NTEL	- Points in Lagrangian interpolation		3
NGPTS	- Number of Gauss points		104
NIT	- Convolution integral segments		2
IBOUND	- Type of boundary condition		1
ITSGEN	- Time values generated or input		1
TMAX	- Max simulation time	--	0.0
WTFUN	- Weighting factor	--	1.2

OPTIONS CHOSEN

------- ------

Stehfest numerical inversion algorithm
Nondecaying continuous source
Computer generated times for computing concentrations

1

DATA FOR LAYER 1

---- --- -----

VADOSE TRANSPORT VARIAELES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Thickness of layer	m	CONSTANT	1.00	-999.	0.100E-08	-999.
Longitudinal dispersivity of layer	m	CONSTANT	0.420E-01	-999.	0.100E-02	0.100E+05
Percent organic matter	--	CONSTANT	0.800	-999.	0.000E+00	100.
Bulk dersity of soil for layer	g/cc	NORMAL	1.53	0.100	1.33	1.81
Biological decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.

1

CHEMICAL SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Solid phase decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Dissolved phase decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Overall chemical decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Acid catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Neutral hydrolysis rate constant	1/yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Base catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Reference temperature	C	CONSTANT	25.0	0.000E+00	0.000E+00	100.
Normalized distribution coefficient	ml/g	LOG NORMAL	0.115E+06	0.250E+06	4.30	0.127E+07
Distribution coefficient	--	LOG NORMAL	533.	0.116E+04	0.200E-01	0.590E+04
Biodegradation coefficient (sat. zone)	1/yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Air diffusion coefficient	cm2/s	CONSTANT	0.000E+00	0.645E-02	0.000E+00	10.0
Reference temperature for air diffusion	C	CONSTANT	0.000E+00	0.000E+00	0.000E+00	100.
Molecular weight	g/M	CONSTANT	-999.	0.000E+00	0.000E+00	-999.
Mole fraction of solute	--	CONSTANT	-999.	0.100E-01	0.100E-08	1.00
Vapor pressure of solute	mm Hg	CONSTANT	-999.	0.230E-01	0.000E+00	100.
Henry's law constant	atm-m^3/M	CONSTANT	-999.	0.000E+00	0.100E-09	1.00
Overall 1st order decay sat. zone	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	1.00	0.000E+00	0.000E+00	1.00
Not currertly used		CONSTANT	1.00	0.000E+00	0.000E+00	1.00

1

SOURCE SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Infiltration rate	m/yr	CONSTANT	0.276E-01	-999.	0.100E-09	0.100E+11
Area of waste disposal unit	m^2	CONSTANT	0.300E+04	-999.	0.100E-01	-999.
Duration of pulse	yr	CONSTANT	-999.	-999.	0.100E-08	-999.
Spread of contaminant source	m	DERIVED	-999.	-999.	0.100E-08	0.100E+11
Recharge rate	m/yr	CONSTANT	0.276E-01	-999.	0.000E+00	0.100E+11
Source decay constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Initial concentration at landfill	mg/l	CONSTANT	1.00	-999.	0.000E+00	-999.
Length scale of facility	m	CONSTANT	150.	-999.	0.100E-08	0.100E+11
Width scale of facility	m	CONSTANT	20.0	-999.	0.100E-08	0.100E+11
Near field dilution		DERIVED	1.00	0.000E+00	0.000E+00	1.00

1

AQUIFER SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Particle diameter	cm	CONSTANT	0.235E-02	-999.	0.100E-08	100.
Aquifer porosity	--	NORMAL	0.150	0.140	0.100E-01	0.390
Bulk density	g/cc	NORMAL	1.54	0.120	1.33	1.81
Aquifer thickness	m	UNIFORM	10.8	-999.	7.90	13.7
Source thickness (mixing zone depth)	m	DERIVED	-999.	-999.	0.100E-08	0.100E+06
Conductivity (hydraulic)	m/yr	LOG NORMAL	21.1	31.2	0.390	94.7
Gradient (hydraulic)		UNIFORM	0.110E-01	-999.	0.710E-02	0.150E-01
Groundwater seepage velocity	m/yr	DERIVED	-999.	-999.	0.100E-09	0.100E+09
Retardation coefficient	--	DERIVED	-999.	-999.	1.00	0.100E+09
Longitudinal dispersivity	m	CONSTANT	5.50	15.0	0.100E-02	0.100E+05
Transverse dispersivity	m	CONSTANT	1.83	-999.	0.100E-02	0.100E+05
Vertical dispersivity	m	CONSTANT	0.308	-999.	0.100E-02	0.100E+05
Temperature of aquifer	C	CONSTANT	19.0	-999.	0.000E+00	100.
pH	--	UNIFORM	-999.	-999.	6.70	7.05
Organic carbon content (fraction)		CONSTANT	0.464E-02	-999.	0.100E-05	1.00
Well distance from site	m	CONSTANT	55.0	-999.	1.00	-999.
Angle off center	degree	CONSTANT	0.000E+00	-999.	0.000E+00	360.
Well vertical distance	m	CONSTANT	0.000E+00	-999.	0.000E+00	1.00

1 1373 Values generated which exceeded the specified bounds.

1

----- RESULTS -----

SATURATED ZONE TRANSPORT

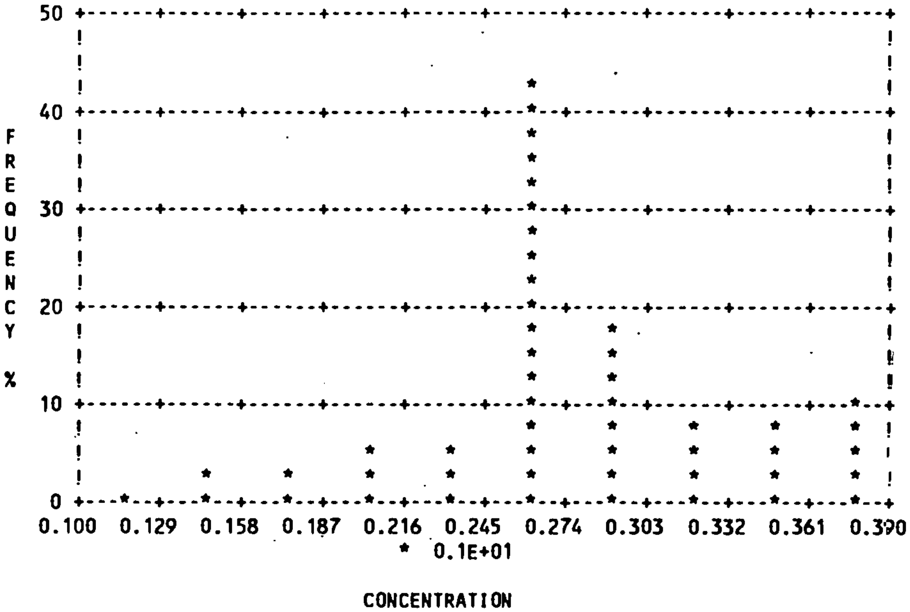
SLAPS Site Suitability Study - Case 1

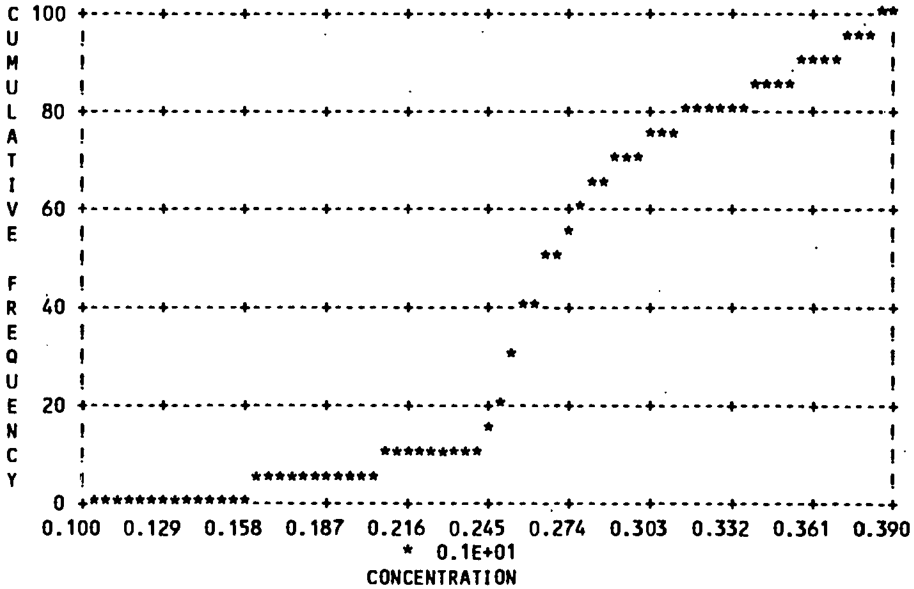
Monte Carlo simulation.

N	=	500		
MEAN	=	0.279		
STANDARD DEVIATION	=	0.527E-01		
COEFFICIENT OF VARIATION	=	0.189		
MINIMUM VALUE	=	0.121		
MAXIMUM VALUE	=	0.390		
50th PERCENTILE	=	0.268	0.265	0.272
80th PERCENTILE	=	0.327	0.313	0.339
85th PERCENTILE	=	0.343	0.338	0.354
90th PERCENTILE	=	0.362	0.354	0.371
95th PERCENTILE	=	0.378	0.374	0.382

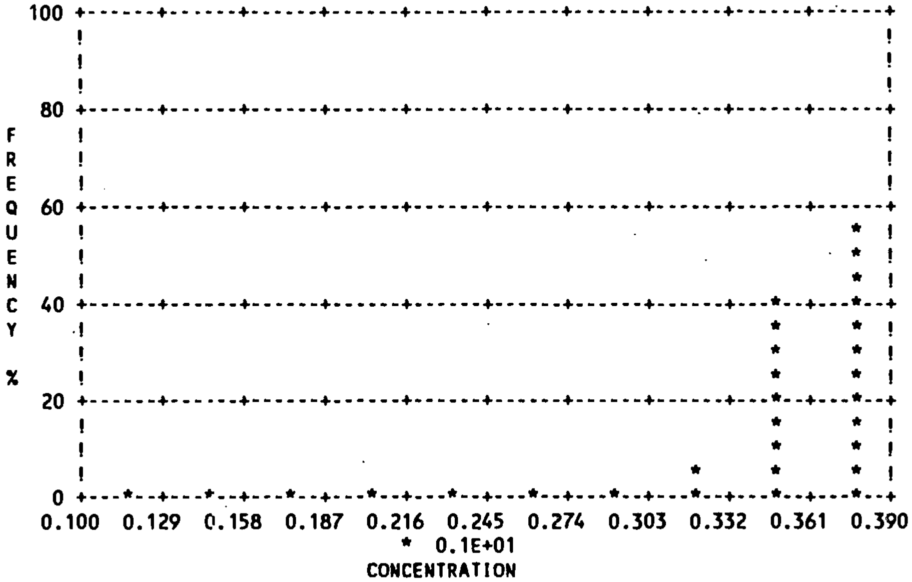
-999 UNABLE TO COMPUTE CONFIDENCE BOUND DUE TO INSUFFICIENT DATA

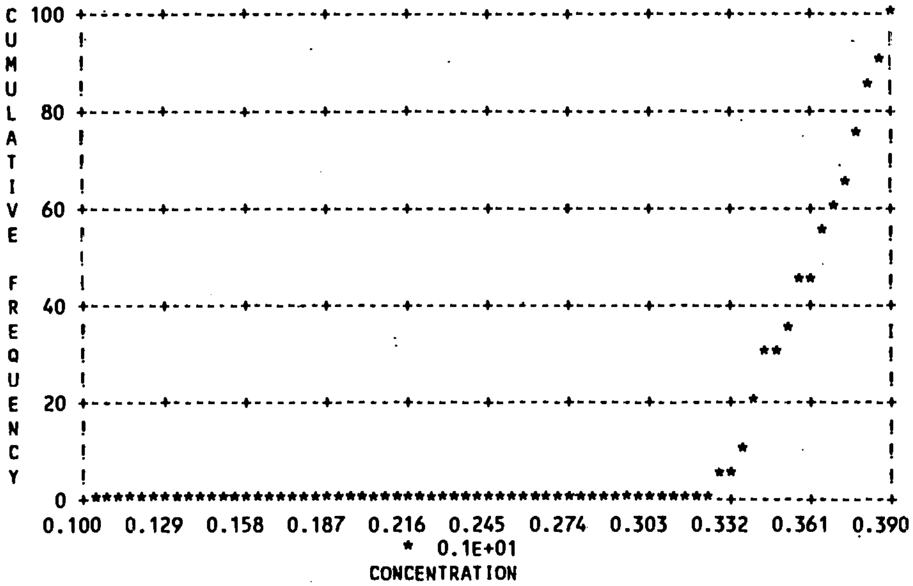
VALUE	% OF TIME EQUALLED OR EXCEEDED	% OF TIME IN INTERVAL
0.100	100.000	
		0.200
0.129	99.800	
		2.200
0.158	97.600	
		2.600
0.187	95.000	
		3.800
0.216	91.200	
		4.400
0.245	86.800	
		42.400
0.274	44.400	
		17.600
0.303	26.800	
		8.200
0.332	18.600	
		8.000
0.361	10.600	
		10.400
0.390	0.200	


FREQUENCY %
0
10
20
30
40
50
0.100 0.129 0.158 0.187 0.216 0.245 0.274 0.303 0.332 0.361 0.390
* 0.1E+01
CONCENTRATION


CUMULATIVE FREQUENCY
0
20
40
60
80
100
0.100 0.129 0.158 0.187 0.216 0.245 0.274 0.303 0.332 0.361 0.390
* 0.1E+01
CONCENTRATION

FOLLOWING GRAPHS ARE FOR THE TOP 20% OF THERESULTS





1

U. S. ENVIRONMENTAL PROTECTION AGENCY

EXPOSURE ASSESSMENT

MULTIMEDIA MODEL

MULTIMED (Version 1.01, June 1991)

1

Run options
--- -------

SLAPS Site Suitability Study - Case 1A

Monte Carlo simulation.
Chemical simulated is Uranium

Option Chosen	Saturated and unsaturated zone models
Run was	MONTE
Infiltration input by user	
Number of monte carlo simulations	500
Run was steady-state	
Reject runs if Y coordinate outside plume	
Reject runs if Z coordinate outside plume	
Gaussian source used in saturated zone model	

1
1

UNSATURATED ZONE FLOW MODEL PARAMETERS
(input parameter description and value)

NP	- Total number of nodal points	240
NMAT	- Number of different porous materials	1
KPROP	- Van Genuchten or Brooks and Corey	1
IMSHGN	- Spatial discretization option	1
NVFLAYR	- Number of layers in flow model	1

OPTIONS CHOSEN
------- ------

Van Genuchten functional coefficients
User defined coordinate system

1

Layer information

LAYER NO.	LAYER THICKNESS	MATERIAL PROPERTY
1	1.00	1

DATA FOR MATERIAL 1

VADOSE ZONE MATERIAL VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Saturated hydraulic conductivity	cm/hr	LOG NORMAL	0.107	0.230	0.500E-04	0.720
Unsaturated zone porosity	--	NORMAL	0.150	0.140	0.100E-01	0.390
Air entry pressure head	m	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Depth of the unsaturated zone	m	CONSTANT	1.00	-999.	0.100E-08	-999.

DATA FOR MATERIAL 1

VADOSE ZONE FUNCTION VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Residual water content	--	UNIFORM	0.920E-01	-999.	0.834E-01	0.966E-01
Brook and Corey exponent,EN	--	CONSTANT	0.500	-999.	0.000E+00	10.0
ALFA coefficient	1/cm	UNIFORM	0.123E-01	-999.	0.987E-02	0.152E-01
Van Genuchten exponent, ENN	--	UNIFORM	1.25	-999.	1.21	1.29

1

UNSATURATED ZONE TRANSPORT MODEL PARAMETERS

NLAY	- Number of different layers used		1
NTSTPS	- Number of time values concentration calc		40
DUMMY	- Not presently used		1
ISOL	- Type of scheme used in unsaturated zone		1
N	- Stehfest terms or number of increments		18
NTEL	- Points in Lagrangian interpolation		3
NGPTS	- Number of Gauss points		104
NIT	- Convolution integral segments		2
IBOUND	- Type of boundary condition		1
ITSGEN	- Time values generated or input		1
TMAX	- Max simulation time	--	0.0
WTFUN	- Weighting factor	--	1.2

OPTIONS CHOSEN
------- ------
Stehfest numerical inversion algorithm
Nondecaying continuous source
Computer generated times for computing concentrations
1

DATA FOR LAYER 1
---- --- -----
VADOSE TRANSPORT VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Thickness of layer	m	CONSTANT	1.00	-999.	0.100E-08	-999.
Longitudinal dispersivity of layer	m	CONSTANT	0.420E-01	-999.	0.100E-02	0.100E+05
Percent organic matter	--	CONSTANT	0.800	-999.	0.000E+00	100.
Bulk density of soil for layer	g/cc	NORMAL	1.53	0.100	1.33	1.81
Biological decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.

1

CHEMICAL SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Solid phase decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Dissolved phase decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Overall chemical decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Acid catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Neutral hydrolysis rate constant	1/yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Base catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Reference temperature	C	CONSTANT	25.0	0.000E+00	0.000E+00	100.
Normalized distribution coefficient	ml/g	LOG NORMAL	0.115E+06	0.250E+06	4.30	0.127E+07
Distribution coefficient	--	LOG NORMAL	533.	0.116E+04	0.200E-01	0.590E+04
Biodegradation coefficient (sat. zone)	1/yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Air diffusion coefficient	cm2/s	CONSTANT	0.000E+00	0.645E-02	0.000E+00	10.0
Reference temperature for air diffusion	C	CONSTANT	0.000E+00	0.000E+00	0.000E+00	100.
Molecular weight	g/M	CONSTANT	-999.	0.000E+00	0.000E+00	-999.
Mole fraction of solute	--	CONSTANT	-999.	0.100E-01	0.100E-08	1.00
Vapor pressure of solute	mm Hg	CONSTANT	-999.	0.230E-01	0.000E+00	100.
Henry's law constant	atm-m^3/M	CONSTANT	-999.	0.000E+00	0.100E-09	1.00
Overall 1st order decay sat. zone	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	1.00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	1.00	0.000E+00	0.000E+00	1.00

1

SOURCE SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Infiltration rate	m/yr	CONSTANT	0.276E-01	-999.	0.100E-09	0.100E+11
Area of waste disposal unit	m^2	CONSTANT	0.300E+04	-999.	0.100E-01	-999.
Duration of pulse	yr	CONSTANT	-999.	-999.	0.100E-08	-999.
Spread of contaminant source	m	CONSTANT	10.0	-999.	0.100E-08	0.100E+11
Recharge rate	m/yr	CONSTANT	0.276E-01	-999.	0.000E+00	0.100E+11
Source decay constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Initial concentration at landfill	mg/l	CONSTANT	1.00	-999.	0.000E+00	-999.
Length scale of facility	m	CONSTANT	150.	-999.	0.100E-08	0.100E+11
Width scale of facility	m	CONSTANT	20.0	-999.	0.100E-08	0.100E+11
Near field dilution		DERIVED	1.00	0.000E+00	0.000E+00	1.00

1

AQUIFER SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Particle diameter	cm	CONSTANT	0.235E-02	-999.	0.100E-08	100.
Aquifer porosity	--	NORMAL	0.150	0.140	0.100E-01	0.390
Bulk density	g/cc	NORMAL	1.54	0.120	1.33	1.81
Aquifer thickness	m	UNIFORM	10.8	-999.	7.90	13.7
Source thickness (mixing zone depth)	m	DERIVED	-999.	-999.	0.100E-08	0.100E+06
Conductivity (hydraulic)	m/yr	LOG NORMAL	21.1	31.2	0.390	94.7
Gradient (hydraulic)		UNIFORM	0.110E-01	-999.	0.710E-02	0.150E-01
Groundwater seepage velocity	m/yr	DERIVED	-999.	-999.	0.100E-09	0.100E+09
Retardation coefficient	--	DERIVED	-999.	-999.	1.00	0.100E+09
Longitudinal dispersivity	m	CONSTANT	5.50	15.0	0.100E-02	0.100E+05
Transverse dispersivity	m	CONSTANT	1.83	-999.	0.100E-02	0.100E+05
Vertical dispersivity	m	CONSTANT	0.308	-999.	0.100E-02	0.100E+05
Temperature of aquifer	C	CONSTANT	19.0	-999.	0.000E+00	100.
pH	--	UNIFORM	-999.	-999.	6.70	7.05
Organic carbon content (fraction)		CONSTANT	0.464E-02	-999.	0.100E-05	1.00
Well distance from site	m	CONSTANT	55.0	-999.	1.00	-999.
Angle off center	degree	CONSTANT	0.000E+00	-999.	0.000E+00	360.
Well vertical distance	m	CONSTANT	0.000E+00	-999.	0.000E+00	1.00

1 1939 Values generated which exceeded the specified bounds.

1

----- RESULTS -----

SATURATED ZONE TRANSPORT

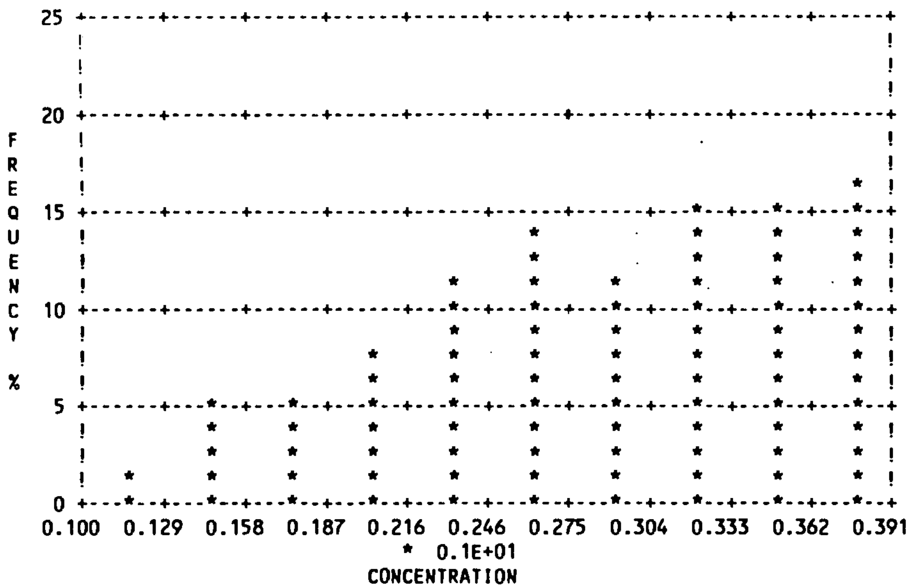
SLAPS Site Suitability Study - Case 1A

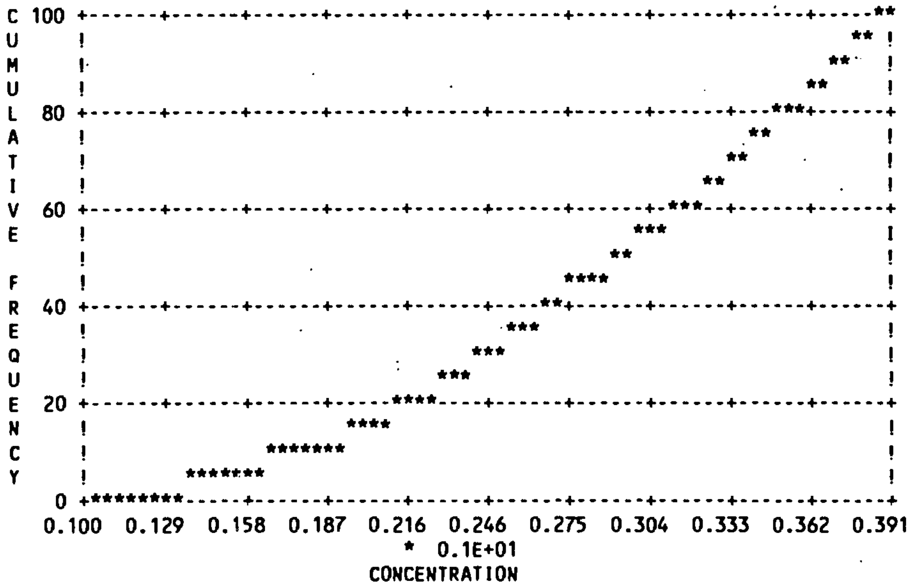
Monte Carlo simulation.

N	=	500		
MEAN	=	0.284		
STANDARD DEVIATION	=	0.710E-01		
COEFFICIENT OF VARIATION	=	0.250		
MINIMUM VALUE	=	0.105		
MAXIMUM VALUE	=	0.391		
50th PERCENTILE	=	0.294	0.284	0.299
80th PERCENTILE	=	0.355	0.348	0.359
85th PERCENTILE	=	0.363	0.359	0.369
90th PERCENTILE	=	0.373	0.369	0.375
95th PERCENTILE	=	0.380	0.376	0.386

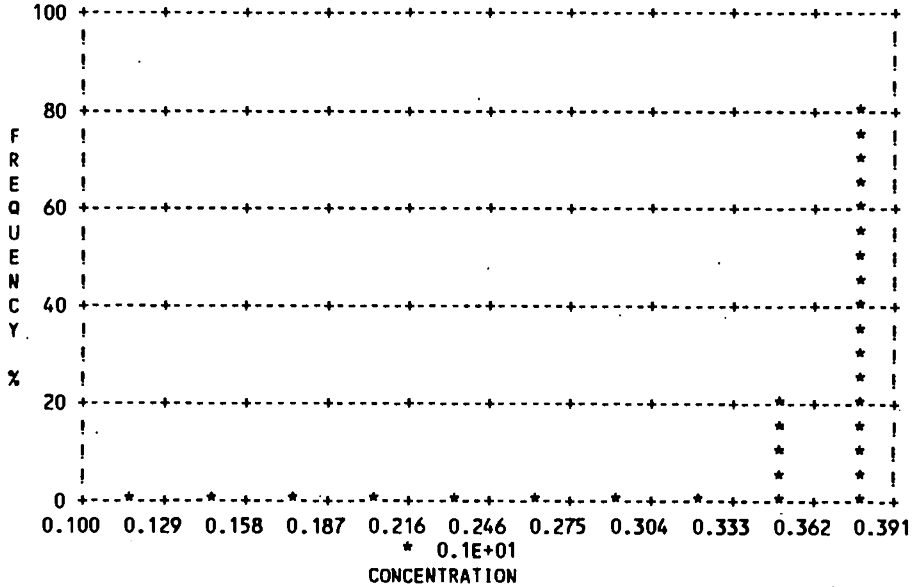
-999 UNABLE TO COMPUTE CONFIDENCE BOUND DUE TO INSUFFICIENT DATA

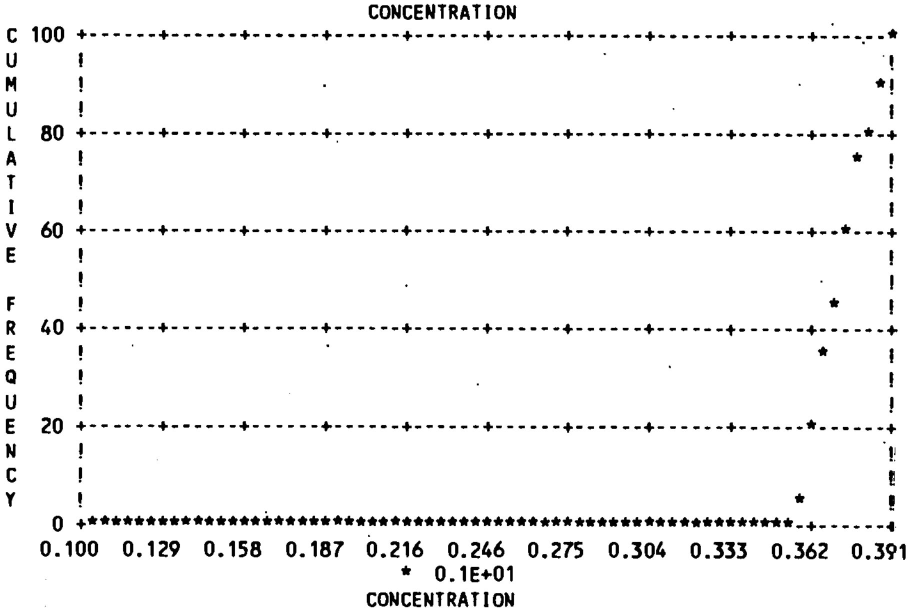
VALUE	% OF TIME EQUALLED OR EXCEEDED	% OF TIME IN INTERVAL
0.100	100.000	
		1.400
0.129	98.600	
		5.200
0.158	93.400	
		4.800
0.187	88.600	
		7.600
0.216	81.000	
		11.400
0.246	69.600	
		13.200
0.275	56.400	
		11.400
0.304	45.000	
		14.600
0.333	30.400	
		14.400
0.362	16.000	
		15.800
0.391	0.200	


FREQUENCY %
25
20
15
10
5
0
0.100 0.129 0.158 0.187 0.216 0.246 0.275 0.304 0.333 0.362 0.391
* 0.1E+01
CONCENTRATION


CUMULATIVE FREQUENCY
100
80
60
40
20
0
0.100 0.129 0.158 0.187 0.216 0.246 0.275 0.304 0.333 0.362 0.391
* 0.1E+01
CONCENTRATION

FOLLOWING GRAPHS ARE FOR THE TOP 20% OF THERESULTS





1

U. S. ENVIRONMENTAL PROTECTION AGENCY

EXPOSURE ASSESSMENT

MULTIMEDIA MODEL

MULTIMED (Version 1.01, June 1991)

1

Run options
--- -------

SLAPS Site Suitability Study - Case 1B

Monte Carlo simulation.
Chemical simulated is Uranium

Option Chosen	Saturated and unsaturated zone models
Run was	MONTE
Infiltration input by user	
Number of monte carlo simulations	1000
Run was steady-state	
Reject runs if Y ccordinate outside plume	
Reject runs if Z ccordinate outside plume	
Patch source used in saturated zone model	

1
1

UNSATURATED ZONE FLOW MODEL PARAMETERS
(input parameter description and value)

NP	- Total number of nodal points	240
NMAT	- Number of different porous materials	1
KPROP	- Van Genuchten or Brooks and Corey	1
IMSHGN	- Spatial discretization option	1
NVFLAYR	- Number of layers in flow model	1

OPTIONS CHOSEN
------- ------

Van Genuchten functional coefficients
User defined coordinate system

1

Layer information

LAYER NO.	LAYER THICKNESS	MATERIAL PROPERTY
1	1.00	1

DATA FOR MATERIAL 1

VADOSE ZONE MATERIAL VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Saturated hydraulic conductivity	cm/hr	LOG NORMAL	0.107	0.230	0.500E-04	0.720
Unsaturated zone porosity	--	NORMAL	0.150	0.140	0.100E-01	0.390
Air entry pressure head	m	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Depth of the unsaturated zone	m	CONSTANT	1.00	-999.	0.100E-08	-999.

DATA FOR MATERIAL 1

VADOSE ZONE FUNCTION VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Residual water content	--	UNIFORM	0.920E-01	-999.	0.834E-01	0.966E-01
Brook and Corey exponent,EN	--	CONSTANT	0.500	-999.	0.000E+00	10.0
ALFA coefficient	1/cm	UNIFORM	0.123E-01	-999.	0.987E-02	0.152E-01
Van Genuchten exponent, ENN	--	UNIFORM	1.25	-999.	1.21	1.29

1

UNSATURATED ZONE TRANSPORT MODEL PARAMETERS

NLAY	- Number of different layers used		1
NTSTPS	- Number of time values concentration calc		40
DUMMY	- Not presently used		1
ISOL	- Type of scheme used in unsaturated zone		1
N	- Stehfest terms or number of increments		18
NTEL	- Points in Lagrangian interpolation		3
NGPTS	- Number of Gauss points		104
NIT	- Convolution integral segments		2
IBOUND	- Type of boundary condition		1
ITSGEN	- Time values generated or input		1
TMAX	- Max simulation time	--	0.0
WTFUN	- Weighting factor	--	1.2

OPTIONS CHOSEN
------- ------
Stehfest numerical inversion algorithm
Nondecaying continuous source
Computer generated times for computing concentrations
1

DATA FOR LAYER 1
---- --- -----

VADOSE TRANSPORT VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Thickness of layer	m	CONSTANT	1.00	-999.	0.100E-08	-999.
Longitudinal dispersivity of layer	m	CONSTANT	0.420E-01	-999.	0.100E-02	0.100E+05
Percent organic matter	--	CONSTANT	0.800	-999.	0.000E+00	100.
Bulk density of soil for layer	g/cc	NORMAL	1.53	0.100	1.33	1.81
Biological decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.

1

CHEMICAL SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Solid phase decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Dissolved phase decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Overall chemical decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Acid catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Neutral hydrolysis rate constant	1/yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Base catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Reference temperature	C	CONSTANT	25.0	0.000E+00	0.000E+00	100.
Normalized distribution coefficient	ml/g	LOG NORMAL	0.115E+06	0.250E+06	4.30	0.127E+07
Distribution coefficient	--	LOG NORMAL	533.	0.116E+04	0.200E-01	0.590E+04
Biodegradation coefficient (sat. zone)	1/yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Air diffusion coefficient	cm2/s	CONSTANT	0.000E+00	0.645E-02	0.000E+00	10.0
Reference temperature for air diffusion	C	CONSTANT	0.000E+00	0.000E+00	0.000E+00	100.
Molecular weight	g/M	CONSTANT	-999.	0.000E+00	0.000E+00	-999.
Mole fraction of solute	--	CONSTANT	-999.	0.100E-01	0.100E-08	1.00
Vapor pressure of solute	mm Hg	CONSTANT	-999.	0.230E-01	0.000E+00	100.
Henry's law constant	atm-m^3/M	CONSTANT	-999.	0.000E+00	0.100E-09	1.00
Overall 1st order decay sat. zone	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	1.00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	1.00	0.000E+00	0.000E+00	1.00

SOURCE SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Infiltration rate	m/yr	CONSTANT	0.276E-01	-999.	0.100E-09	0.100E+11
Area of waste disposal unit	m^2	CONSTANT	0.300E+04	-999.	0.100E-01	-999.
Duration of pulse	yr	CONSTANT	-999.	-999.	0.100E-08	-999.
Spread of contaminant source	m	DERIVED	-999.	-999.	0.100E-08	0.100E+11
Recharge rate	m/yr	CONSTANT	0.276E-01	-999.	0.000E+00	0.100E+11
Source decay constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Initial concentration at landfill	mg/l	CONSTANT	1.00	-999.	0.000E+00	-999.
Length scale of facility	m	CONSTANT	150.	-999.	0.100E-08	0.100E+11
Width scale of facility	m	CONSTANT	20.0	-999.	0.100E-08	0.100E+11
Near field dilution		DERIVED	1.00	0.000E+00	0.000E+00	1.00

1

AQUIFER SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Particle diameter	cm	CONSTANT	0.235E-02	-999.	0.100E-08	100.
Aquifer porosity	--	NORMAL	0.150	0.140	0.100E-01	0.390
Bulk density	g/cc	NORMAL	1.54	0.120	1.33	1.81
Aquifer thickness	m	UNIFORM	10.8	-999.	7.90	13.7
Source thickness (mixing zone depth)	m	DERIVED	-999.	-999.	0.100E-08	0.100E+06
Conductivity (hydraulic)	m/yr	LOG NORMAL	21.1	31.2	0.390	94.7
Gradient (hydraulic)		UNIFORM	0.110E-01	-999.	0.710E-02	0.150E-01
Groundwater seepage velocity	m/yr	DERIVED	-999.	-999.	0.100E-09	0.100E+09
Retardation coefficient	--	DERIVED	-999.	-999.	1.00	0.100E+09
Longitudinal dispersivity	m	CONSTANT	5.50	15.0	0.100E-02	0.100E+05
Transverse dispersivity	m	CONSTANT	1.83	-999.	0.100E-02	0.100E+05
Vertical dispersivity	m	CONSTANT	0.308	-999.	0.100E-02	0.100E+05
Temperature of aquifer	C	CONSTANT	19.0	-999.	0.000E+00	100.
pH	--	UNIFORM	-999.	-999.	6.70	7.05
Organic carbon content (fraction)		CONSTANT	0.464E-02	-999.	0.100E-05	1.00
Well distance from site	m	CONSTANT	55.0	-999.	1.00	-999.
Angle off center	degree	CONSTANT	0.000E+00	-999.	0.000E+00	360.
Well vertical distance	m	CONSTANT	0.000E+00	-999.	0.000E+00	1.00

1 2748 Values generated which exceeded the specified bounds.

----- RESULTS -----

SATURATED ZONE TRANSPORT

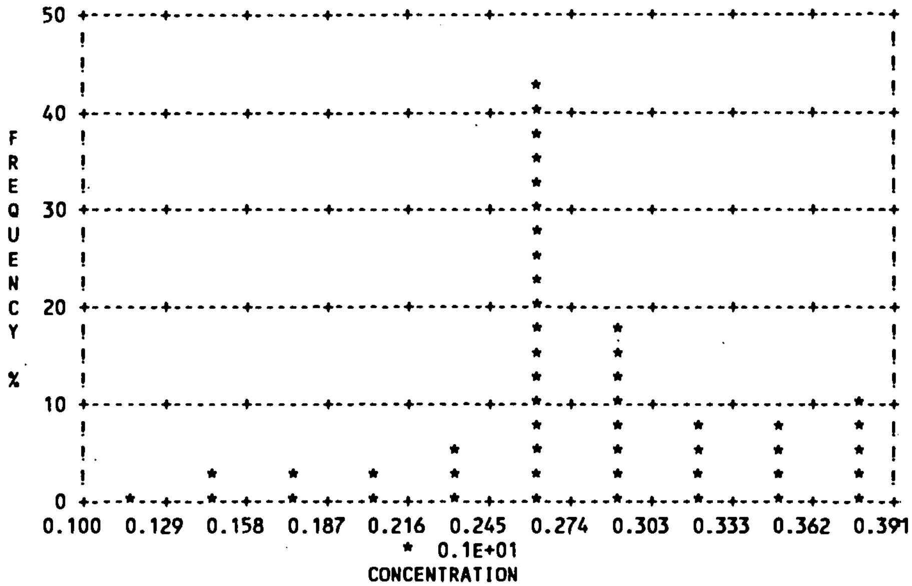
SLAPS Site Suitability Study - Case 1B

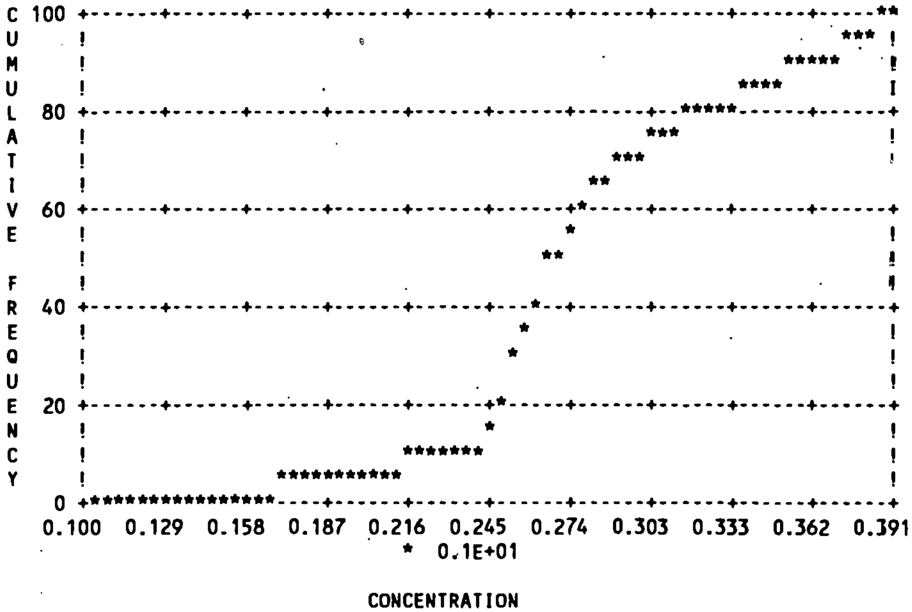
Monte Carlo simulation.

N	=	1000		
MEAN	=	0.279		
STANDARD DEVIATION	=	0.514E-01		
COEFFICIENT OF VARIATION	=	0.185		
MINIMUM VALUE	=	0.121		
MAXIMUM VALUE	=	0.391		
50th PERCENTILE	=	0.268	0.266	0.271
80th PERCENTILE	=	0.326	0.315	0.332
85th PERCENTILE	=	0.342	0.336	0.345
90th PERCENTILE	=	0.361	0.354	0.365
95th PERCENTILE	=	0.377	0.374	0.380

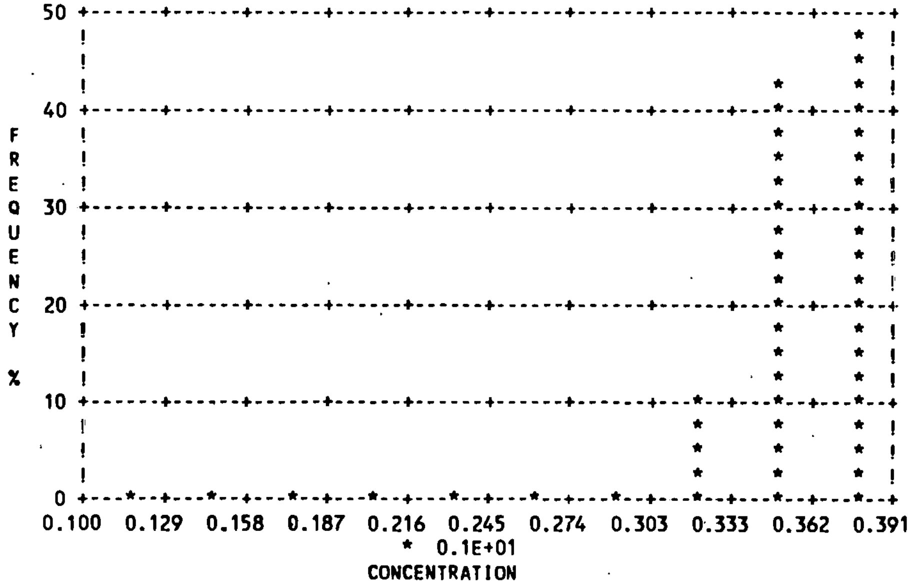
-999 UNABLE TO COMPUTE CONFIDENCE BOUND DUE TO INSUFFICIENT DATA

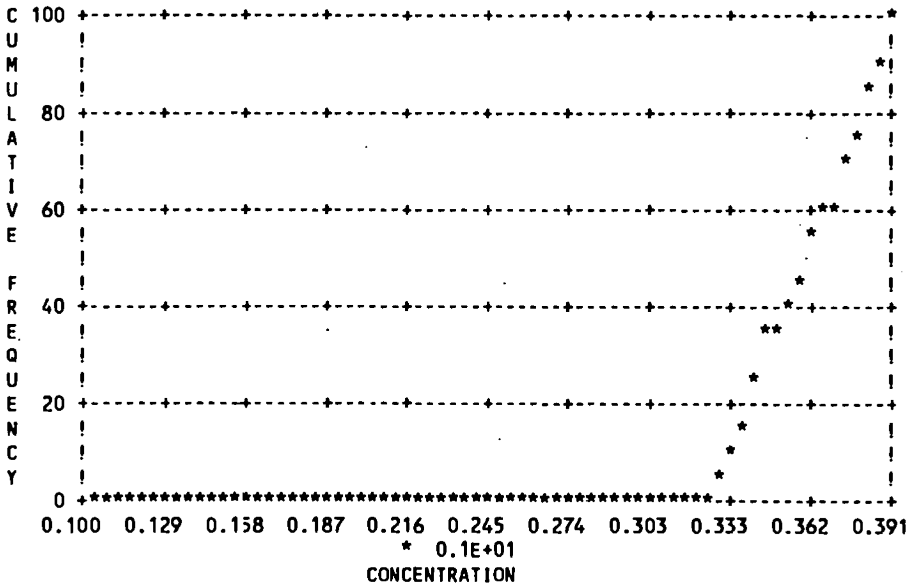
VALUE	% OF TIME EQUALLED OR EXCEEDED	% OF TIME IN INTERVAL
0.100	100.000	
		0.100
0.129	99.900	
		1.500
0.158	98.400	
		3.300
0.187	95.100	
		3.100
0.216	92.000	
		5.100
0.245	86.900	
		42.400
0.274	44.500	
		18.100
0.303	26.400	
		8.500
0.333	17.900	
		8.600
0.362	9.300	
		9.200
0.391	0.100	


FREQUENCY %
50
40
30
20
10
0
0.100 0.129 0.158 0.187 0.216 0.245 0.274 0.303 0.333 0.362 0.391
* 0.1E+01
CONCENTRATION


CUMULATIVE FREQUENCY
100
80
60
40
20
0
0.100 0.129 0.158 0.187 0.216 0.245 0.274 0.303 0.333 0.362 0.391
* 0.1E+01
CONCENTRATION

FOLLOWING GRAPHS ARE FOR THE TOP 20% OF THERESULTS





1

U. S. ENVIRONMENTAL PROTECTION AGENCY

EXPOSURE ASSESSMENT

MULTIMEDIA MODEL

MULTIMED (Version 1.01, June 1991)

1

Run options

--- -------

SLAPS Site Suitability Study - Case 1C

Monte Carlo simulation.
Chemical simulated is Uranium

```
Option Chosen                          Saturated and unsaturated zone models
Run was                                MONTE
Infiltration input by user
Number of monte carlo simulations        500
Run was steady-state
Reject runs if Y coordinate outside plume
Reject runs if Z coordinate outside plume
Patch source used in saturated zone model
1
1
UNSATURATED ZONE FLOW MODEL PARAMETERS
(input parameter description and value)
NP      - Total number of nodal points              240
NMAT    - Number of different porous materials        1
KPROP   - Van Genuchten or Brooks and Corey           1
IMSHGN  - Spatial discretization option               1
NVFLAYR - Number of layers in flow model              1
```

OPTIONS CHOSEN

------- ------

Van Genuchten functional coefficients
User defined coordinate system

1

Layer information

LAYER NO.	LAYER THICKNESS	MATERIAL PROPERTY
1	1.00	1

DATA FOR MATERIAL 1

VADOSE ZONE MATERIAL VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Saturated hydraulic conductivity	cm/hr	LOG NORMAL	0.107	0.230	0.500E-04	0.720
Unsaturated zone porosity	--	NORMAL	0.150	0.140	0.100E-01	0.390
Air entry pressure head	m	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Depth of the unsaturated zone	m	CONSTANT	1.00	-999.	0.100E-08	-999.

DATA FOR MATERIAL 1

VADOSE ZONE FUNCTION VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Residual water content	--	UNIFORM	0.920E-01	-999.	0.834E-01	0.966E-01
Brook and Corey exponent,EN	--	CONSTANT	0.500	-999.	0.000E+00	10.0
ALFA coefficient	1/cm	UNIFORM	0.123E-01	-999.	0.987E-02	0.152E-01
Van Genuchten exponent, ENN	--	UNIFORM	1.25	-999.	1.21	1.29

1

UNSATURATED ZONE TRANSPORT MODEL PARAMETERS

NLAY	- Number of different layers used		1
NTSTPS	- Number of time values concentration calc		40
DUMMY	- Not presently used		1
ISOL	- Type of scheme used in unsaturated zone		1
N	- Stehfest terms or number of increments		18
NTEL	- Points in Lagrangian interpolation		3
NGPTS	- Number of Gauss points		104
NIT	- Convolution integral segments		2
IBOUND	- Type of boundary condition		1
ITSGEN	- Time values generated or input		1
TMAX	- Max simulation time	--	0.0
WTFUN	- Weighting factor	--	1.2

OPTIONS CHOSEN
------- ------
Stehfest numerical inversion algorithm
Nondecaying continuous source
Computer generated times for computing concentrations
1

DATA FOR LAYER 1
---- --- -----
VADOSE TRANSPORT VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Thickness of layer	m	CONSTANT	1.00	-999.	0.100E-08	-999.
Longitudinal dispersivity of layer	m	CONSTANT	0.420E-01	-999.	0.100E-02	0.100E+05
Percent organic matter	--	CONSTANT	0.800	-999.	0.000E+00	100.
Bulk density of soil for layer	g/cc	NORMAL	1.53	0.100	1.33	1.81
Biological decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.

1

CHEMICAL SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Solid phase decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Dissolved phase decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Overall chemical decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Acid catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Neutral hydrolysis rate constant	1/yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Base catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Reference temperature	C	CONSTANT	25.0	0.000E+00	0.000E+00	100.
Normalized distribution coefficient	ml/g	LOG NORMAL	0.115E+06	0.250E+06	4.30	0.127E+07
Distribution coefficient	--	LOG NORMAL	533.	0.116E+04	0.200E-01	0.590E+04
Biodegradation coefficient (sat. zone)	1/yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Air diffusion coefficient	cm2/s	CONSTANT	0.000E+00	0.645E-02	0.000E+00	10.0
Reference temperature for air diffusion	C	CONSTANT	0.000E+00	0.000E+00	0.000E+00	100.
Molecular weight	g/M	CONSTANT	-999.	0.000E+00	0.000E+00	-999.
Mole fraction of solute	--	CONSTANT	-999.	0.100E-01	0.100E-08	1.00
Vapor pressure of solute	mm Hg	CONSTANT	-999.	0.230E-01	0.000E+00	100.
Henry's law constant	atm-m^3/M	CONSTANT	-999.	0.000E+00	0.100E-09	1.00
Overall 1st order decay sat. zone	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	1.00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	1.00	0.000E+00	0.000E+00	1.00

1

SOURCE SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Infiltration rate	m/yr	CONSTANT	0.276E-01	-999.	0.100E-09	0.100E+11
Area of waste disposal unit	m^2	CONSTANT	0.300E+04	-999.	0.100E-01	-999.
Duration of pulse	yr	CONSTANT	-999.	-999.	0.100E-08	-999.
Spread of contaminant source	m	DERIVED	-999.	-999.	0.100E-08	0.100E+11
Recharge rate	m/yr	CONSTANT	0.276E-01	-999.	0.000E+00	0.100E+11
Source decay constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Initial concentration at landfill	mg/l	CONSTANT	1.00	-999.	0.000E+00	-999.
Length scale of facility	m	CONSTANT	150.	-999.	0.100E-08	0.100E+11
Width scale of facility	m	CONSTANT	20.0	-999.	0.100E-08	0.100E+11
Near field dilution		DERIVED	1.00	0.000E+00	0.000E+00	1.00

1

AQUIFER SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Particle diameter	cm	CONSTANT	0.235E-02	-999.	0.100E-08	100.
Aquifer porosity	--	NORMAL	0.150	0.140	0.100E-01	0.390
Bulk density	g/cc	NORMAL	1.54	0.120	1.33	1.81
Aquifer thickness	m	UNIFORM	10.8	-999.	7.90	13.7
Source thickness (mixing zone depth)	m	DERIVED	-999.	-999.	0.100E-08	0.100E+06
Conductivity (hydraulic)	m/yr	LOG NORMAL	21.1	31.2	0.390	94.7
Gradient (hydraulic)		UNIFORM	0.110E-01	-999.	0.710E-02	0.150E-01
Groundwater seepage velocity	m/yr	DERIVED	-999.	-999.	0.100E-09	0.100E+09
Retardation coefficient	--	DERIVED	-999.	-999.	1.00	0.100E+09
Longitudinal dispersivity	m	CONSTANT	0.550	15.0	0.100E-02	0.100E+05
Transverse dispersivity	m	CONSTANT	0.183	-999.	0.100E-02	0.100E+05
Vertical dispersivity	m	CONSTANT	0.308E-01	-999.	0.100E-02	0.100E+05
Temperature of aquifer	C	CONSTANT	19.0	-999.	0.000E+00	100.
pH	--	UNIFORM	-999.	-999.	6.70	7.05
Organic carbon content (fraction)		CONSTANT	0.464E-02	-999.	0.100E-05	1.00
Well distance from site	m	CONSTANT	55.0	-999.	1.00	-999.
Angle off center	degree	CONSTANT	0.000E+00	-999.	0.000E+00	360.
Well vertical distance	m	CONSTANT	0.000E+00	-999.	0.000E+00	1.00

1 724 Values generated which exceeded the specified bounds.

----- RESULTS -----

SATURATED ZONE TRANSPORT

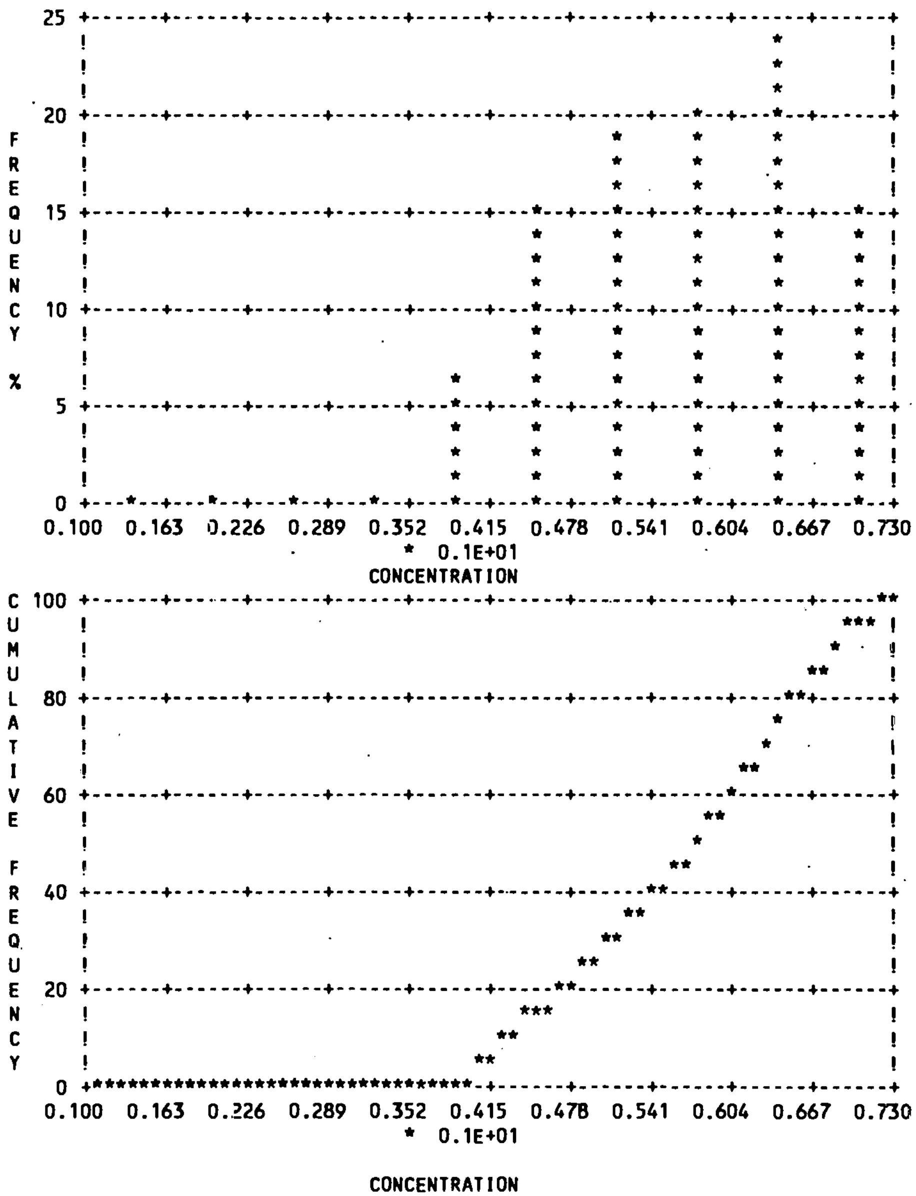
SLAPS Site Suitability Study - Case 1C

Monte Carlo simulation.

N	= 500		
MEAN	= 0.567		
STANDARD DEVIATION	= D.915E-01		
COEFFICIENT OF VARIATION	= 0.151		
MINIMUM VALUE	= 0.392		
MAXIMUM VALUE	= 0.730		
50th PERCENTILE	= 0.579	0.568	0.587
80th PERCENTILE	= 0.654	0.645	0.664
85th PERCENTILE	= 0.669	0.660	0.683
90th PERCENTILE	= 0.688	0.683	0.692
95th PERCENTILE	= 0.705	0.696	0.710

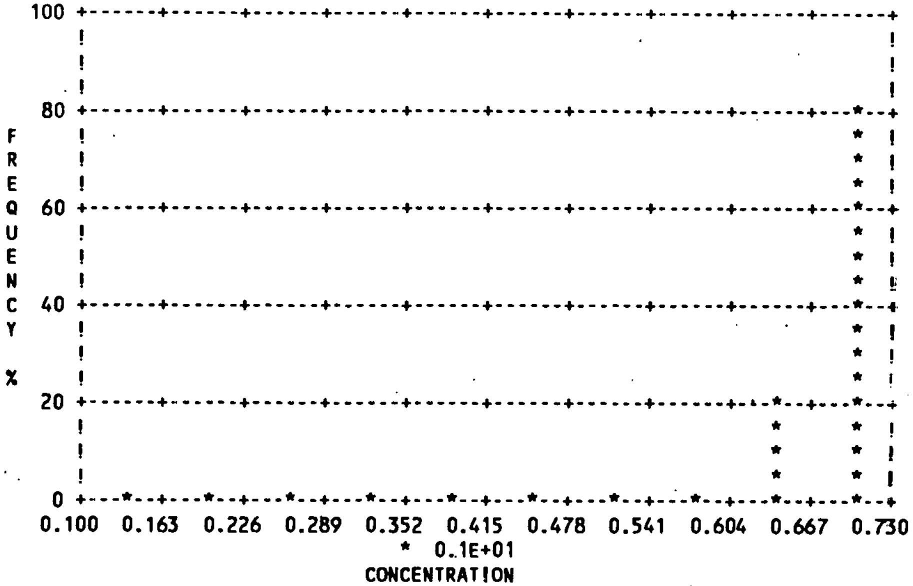
-999 UNABLE TO COMPUTE CONFIDENCE BOUND DUE TO INSUFFICIENT DATA

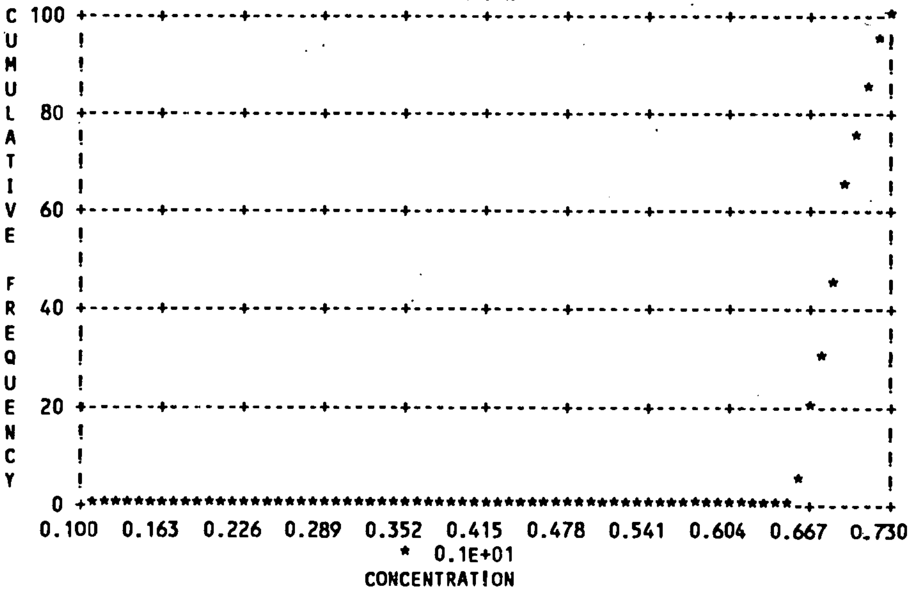
VALUE	% OF TIME EQUALLED OR EXCEEDED	% OF TIME IN INTERVAL
0.100	100.000	
		0.000
0.163	100.000	
		C.000
0.226	100.000	
		0.000
0.289	100.000	
		0.000
0.352	100.000	
		5.800
0.415	94.200	
		14.800
0.478	79.400	
		19.000
0.541	60.400	
		20.600
0.604	39.800	
		24.200
0.667	15.600	
		15.400
0.730	0.200	



FREQUENCY %
25
20
15
10
5
0
0.100 0.163 0.226 0.289 0.352 0.415 0.478 0.541 0.604 0.667 0.730
* 0.1E+01
CONCENTRATION
CUMULATIVE FREQUENCY
100
80
60
40
20
0
0.100 0.163 0.226 0.289 0.352 0.415 0.478 0.541 0.604 0.667 0.730
* 0.1E+01
CONCENTRATION

FOLLOWING GRAPHS ARE FOR THE TOP 20% OF THERESULTS





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U. S. ENVIRONMENTAL PROTECTION AGENCY

EXPOSURE ASSESSMENT

MULTIMEDIA MODEL

MULTIMED (Version 1.01, June 1991)

1

Run options
--- -------

SLAPS Site Suitability Study - Case 1D

Monte Carlo simulation.
Chemical simulated is Uranium

```
Option Chosen                          Saturated and unsaturated zone models
Run was                                MONTE
Infiltration input by user
Number of monte carlo simulations        500
Run was steady-state
Reject runs if Y coordinate outside plume
Reject runs if Z coordinate outside plume
Patch source used in saturated zone model
```
1
1

UNSATURATED ZONE FLOW MODEL PARAMETERS
(input parameter description and value)

```
NP      - Total number of nodal points               240
NMAT    - Number of different porous materials         1
KPROP   - Van Genuchten or Brooks and Corey            1
IMSHGN  - Spatial discretization option                1
NVFLAYR - Number of layers in flow model               1
```

OPTIONS CHOSEN
------- -------

Van Genuchten functional coefficients
User defined coordinate system
1

Layer information

LAYER NO.	LAYER THICKNESS	MATERIAL PROPERTY
1	1.00	1

DATA FOR MATERIAL 1

VADOSE ZONE MATERIAL VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	STD DEV	LIMITS MIN	MAX
Saturated hydraulic conductivity	cm/hr	LOG NORMAL	0.107	0.230	0.500E-04	0.720
Unsaturated zone porosity	--	NORMAL	0.150	0.140	0.100E-01	0.390
Air entry pressure head	m	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Depth of the unsaturated zone	m	CONSTANT	1.00	-999.	0.100E-08	-999.

DATA FOR MATERIAL 1

VADOSE ZONE FUNCTION VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	STD DEV	LIMITS MIN	MAX
Residual water content	--	UNIFORM	0.920E-01	-999.	0.834E-01	0.966E-01
Brook and Corey exponent,EN	--	CONSTANT	0.500	-999.	0.000E+00	10.0
ALFA coefficient	1/cm	UNIFORM	0.123E-01	-999.	0.987E-02	0.152E-01
Van Genuchten exponent, ENN	--	UNIFORM	1.25	-999.	1.21	1.29

1

UNSATURATED ZONE TRANSPORT MODEL PARAMETERS

NLAY	- Number of different layers used		1
NTSTPS	- Number of time values concentration calc		40
DUMMY	- Not presently used		1
ISOL	- Type of scheme used in unsaturated zone		1
N	- Stehfest terms or number of increments		18
NTEL	- Points in Lagrangian interpolation		3
NGPTS	- Number of Gauss points		104
NIT	- Convolution integral segments		2
IBOUND	- Type of boundary condition		1
ITSGEN	- Time values generated or input		1
TMAX	- Max simulation time	--	0.0
WTFUN	- Weighting factor	--	1.2

OPTIONS CHOSEN
------- ------
Stehfest numerical inversion algorithm
Nondecaying continuous source
Computer generated times for computing concentrations
1

DATA FOR LAYER 1
---- --- -----
VADOSE TRANSPORT VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Thickness of layer	m	CONSTANT	1.00	-999.	0.100E-08	-999.
Longitudinal dispersivity of layer	m	CONSTANT	0.420E-01	-999.	0.100E-02	0.100E+05
Percent organic matter	--	CONSTANT	0.800	-999.	0.000E+00	100.
Bulk density of soil for layer	g/cc	NORMAL	1.53	0.100	1.33	1.81
Biological decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.

1

CHEMICAL SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Solid phase decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Dissolved phase decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Overall chemical decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Acid catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Neutral hydrolysis rate constant	1/yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Base catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Reference temperature	C	CONSTANT	25.0	0.000E+00	0.000E+00	100.
Normalized distribution coefficient	ml/g	LOG NORMAL	0.115E+06	0.250E+06	4.30	0.127E+07
Distribution coefficient	--	LOG NORMAL	533.	0.116E+04	0.200E-01	0.590E+04
Biodegradation coefficient (sat. zone)	1/yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Air diffusion coefficient	cm2/s	CONSTANT	0.000E+00	0.645E-02	0.000E+00	10.0
Reference temperature for air diffusion	C	CONSTANT	0.000E+00	0.000E+00	0.000E+00	100.
Molecular weight	g/M	CONSTANT	-999.	0.000E+00	0.000E+00	-999.
Mole fraction of solute	--	CONSTANT	-999.	0.100E-01	0.100E-08	1.00
Vapor pressure of solute	mm Hg	CONSTANT	-999.	0.230E-01	0.000E+00	100.
Henry's law constant	atm-m^3/M	CONSTANT	-999.	0.000E+00	0.100E-09	1.00
Overall 1st order decay sat. zone	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	1.00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	1.00	0.000E+00	0.000E+00	1.00

1

SOURCE SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Infiltration rate	m/yr	CONSTANT	0.276E-01	-999.	0.100E-09	0.100E+11
Area of waste disposal unit	m^2	CONSTANT	0.300E+04	-999.	0.100E-01	-999.
Duration of pulse	yr	CONSTANT	-999.	-999.	0.100E-08	-999.
Spread of contaminant source	m	DERIVED	-999.	-999.	0.100E-08	0.100E+11
Recharge rate	m/yr	CONSTANT	0.276E-01	-999.	0.000E+00	0.100E+11
Source decay constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Initial concentration at landfill	mg/l	CONSTANT	1.00	-999.	0.000E+00	-999.
Length scale of facility	m	CONSTANT	150.	-999.	0.100E-08	0.100E+11
Width scale of facility	m	CONSTANT	20.0	-999.	0.100E-08	0.100E+11
Near field dilution		DERIVED	1.00	0.000E+00	0.000E+00	1.00

1

AQUIFER SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Particle diameter	cm	CONSTANT	0.235E-02	-999.	0.100E-08	100.
Aquifer porosity	--	NORMAL	0.150	0.140	0.100E-01	0.390
Bulk density	g/cc	NORMAL	1.54	0.120	1.33	1.81
Aquifer thickness	m	UNIFORM	10.8	-999.	7.90	13.7
Source thickness (mixing zone depth)	m	DERIVED	-999.	-999.	0.100E-08	0.100E+06
Conductivity (hydraulic)	m/yr	LOG NORMAL	21.1	31.2	0.390	94.7
Gradient (hydraulic)		UNIFORM	0.110E-01	-999.	0.710E-02	0.150E-01
Groundwater seepage velocity	m/yr	DERIVED	-999.	-999.	0.100E-09	0.100E+09
Retardation coefficient	--	DERIVED	-999.	-999.	1.00	0.100E+09
Longitudinal dispersivity	m	CONSTANT	55.0	15.0	0.100E-02	0.100E+05
Transverse dispersivity	m	CONSTANT	18.3	-999.	0.100E-02	0.100E+05
Vertical dispersivity	m	CONSTANT	3.08	-999.	0.100E-02	0.100E+05
Temperature of aquifer	C	CONSTANT	19.0	-999.	0.000E+00	100.
pH	--	UNIFORM	-999.	-999.	6.70	7.05
Organic carbon content (fraction)		CONSTANT	0.464E-02	-999.	0.100E-05	1.00
Well distance from site	m	CONSTANT	55.0	-999.	1.00	-999.
Angle off center	degree	CONSTANT	0.000E+00	-999.	0.000E+00	360.
Well vertical distance	m	CONSTANT	0.000E+00	-999.	0.000E+00	1.00

1 2987 Values generated which exceeded the specified bounds.

----- RESULTS -----

SATURATED ZONE TRANSPORT

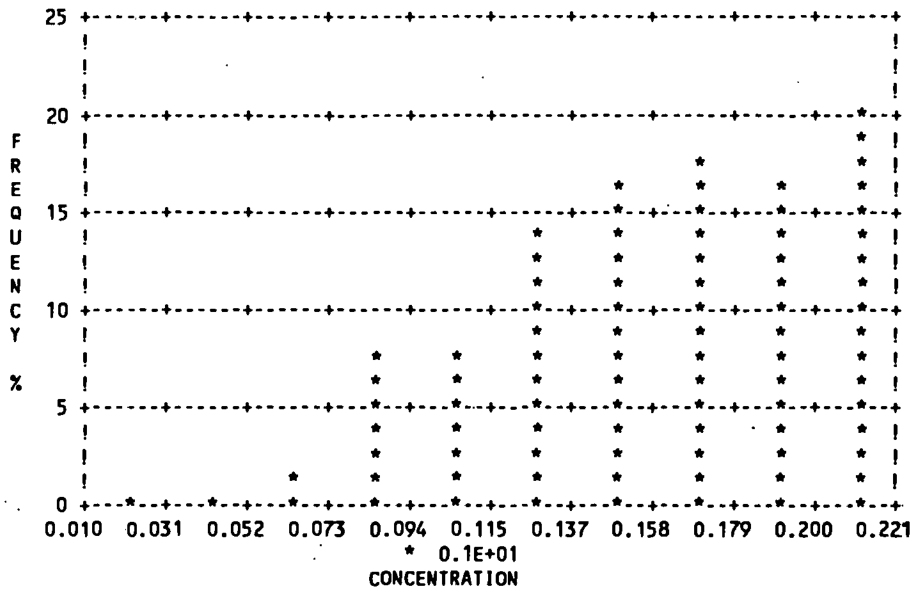
SLAPS Site Suitability Study - Case 1D

Monte Carlo simulation.

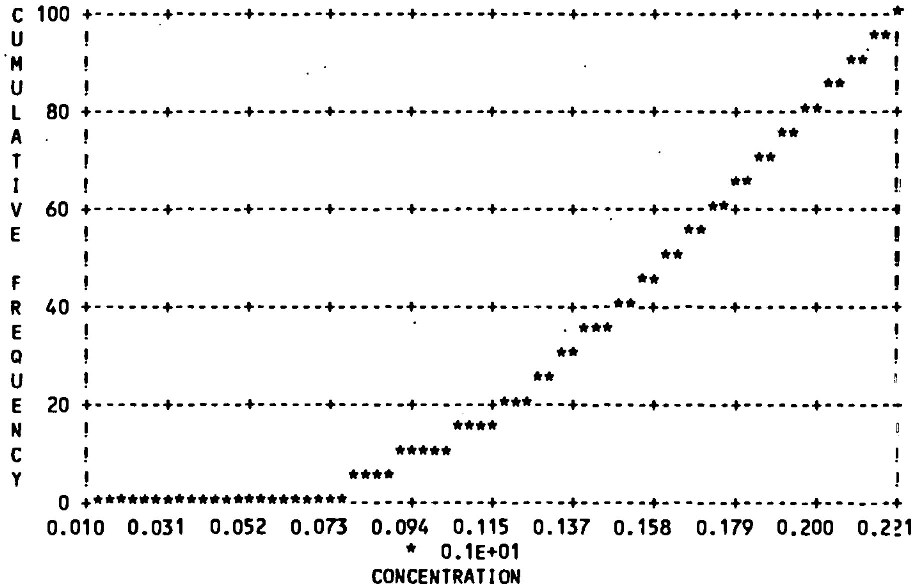
			90. PERCENT CONFIDENCE INTERVAL	
N	=	500		
MEAN	=	0.159		
STANDARD DEVIATION	=	0.404E-01		
COEFFICIENT OF VARIATION	=	0.255		
MINIMUM VALUE	=	0.590E-01		
MAXIMUM VALUE	=	0.221		
50th PERCENTILE	=	0.163	0.157	0.166
80th PERCENTILE	=	0.200	0.195	0.202
85th PERCENTILE	=	0.206	0.201	0.209
90th PERCENTILE	=	0.211	0.209	0.213
95th PERCENTILE	=	0.216	0.214	0.218

-999 UNABLE TO COMPUTE CONFIDENCE BOUND DUE TO INSUFFICIENT DATA

VALUE	% OF TIME EQUALLED OR EXCEEDED	% OF TIME IN INTERVAL
0.100E-01	100.000	
		0.000
0.311E-01	100.000	
		0.000
0.522E-01	100.000	
		1.600
0.733E-01	98.400	
		7.400
0.944E-01	91.000	
		7.800
0.115	83.200	
		13.200
0.137	70.000	
		16.600
0.158	53.400	
		17.200
0.179	36.200	
		16.600
0.200	19.600	
		19.400
0.221	0.200	

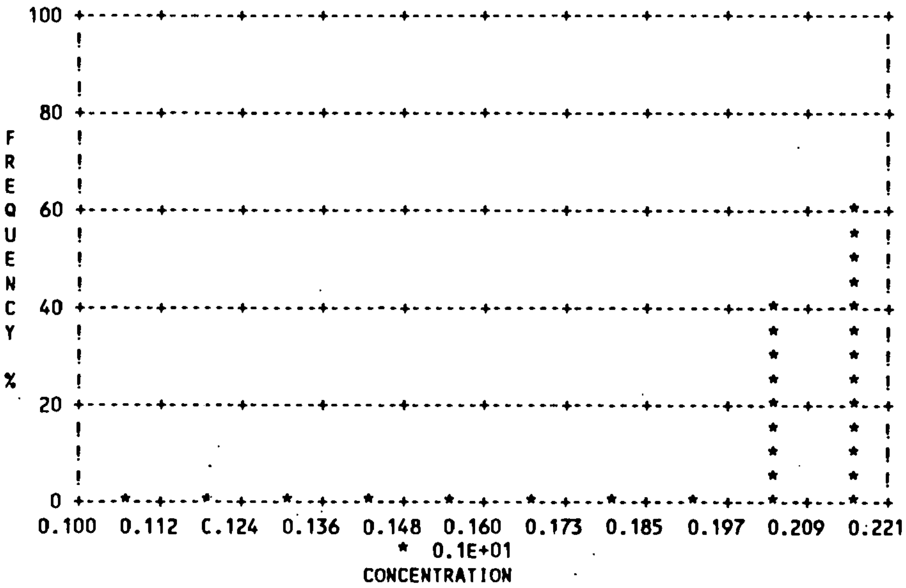


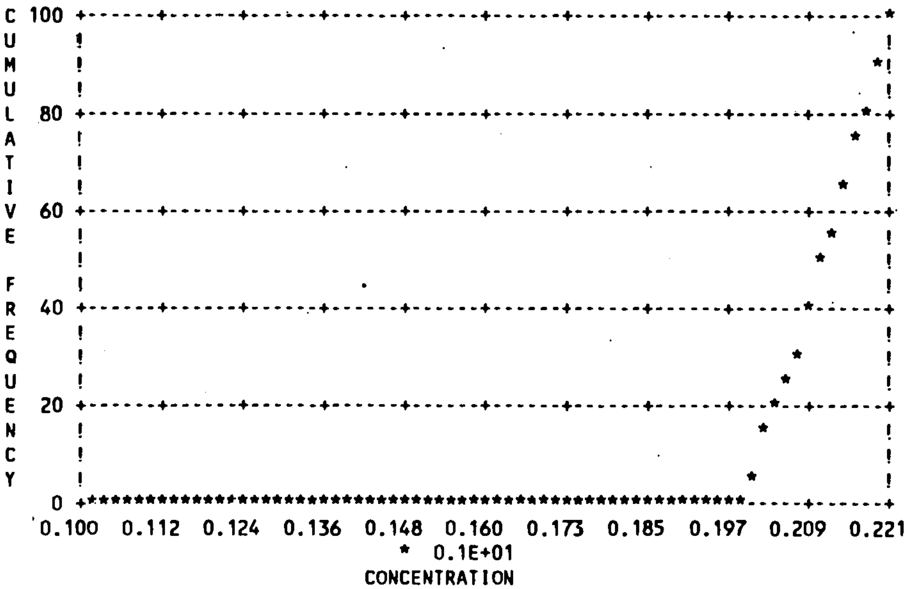
25
20
15
10
5
0
FREQUENCY %
0.010 0.031 0.052 0.073 0.094 0.115 0.137 0.158 0.179 0.200 0.221
* 0.1E+01
CONCENTRATION



100
80
60
40
20
0
CUMULATIVE FREQUENCY
0.010 0.031 0.052 0.073 0.094 0.115 0.137 0.158 0.179 0.200 0.221
* 0.1E+01
CONCENTRATION

FOLLOWING GRAPHS ARE FOR THE TOP 20% OF THERESULTS





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U. S. ENVIRONMENTAL PROTECTION AGENCY

EXPOSURE ASSESSMENT

MULTIMEDIA MODEL

MULTIMED (Version 1.01, June 1991)

1

Run options
--- -------

SLAPS Site Suitability Study - Case 1E

Monte Carlo simulation.
Chemical simulated is Uranium

Option Chosen	Saturated and unsaturated zone models
Run was	MONTE
Infiltration input by user	
Number of monte carlo simulations	500
Run was steady-state	
Reject runs if Y coordinate outside plume	
Reject runs if Z coordinate outside plume	
Patch source used in saturated zone model	

1

1

UNSATURATED ZONE FLOW MODEL PARAMETERS
(input parameter description and value)

NP	- Total number of nodal points	240
NMAT	- Number of different porous materials	1
KPROP	- Van Genuchten or Brooks and Corey	1
IMSHGN	- Spatial discretization option	1
NVFLAYR	- Number of layers in flow model	1

OPTIONS CHOSEN
------- ------

Van Genuchten functional coefficients
User defined coordinate system

1

Layer information

LAYER NO.	LAYER THICKNESS	MATERIAL PROPERTY
1	1.00	1

DATA FOR MATERIAL 1

VADOSE ZONE MATERIAL VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Saturated hydraulic conductivity	cm/hr	LOG NORMAL	0.107	0.230	0.500E-04	0.720
Unsaturated zone porosity	--	NORMAL	0.150	0.140	0.100E-01	0.390
Air entry pressure head	m	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Depth of the unsaturated zone	m	CONSTANT	1.00	-999.	0.100E-08	-999.

DATA FOR MATERIAL 1

VADOSE ZONE FUNCTION VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Residual water content	--	UNIFORM	0.920E-01	-999.	0.834E-01	0.966E-01
Brook and Corey exponent,EN	--	CONSTANT	0.500	-999.	0.000E+00	10.0
ALFA coefficient	1/cm	UNIFORM	0.123E-01	-999.	0.987E-02	0.152E-01
Van Genuchten exponent, ENN	--	UNIFORM	1.25	-999.	1.21	1.29

1

UNSATURATED ZONE TRANSPORT MODEL PARAMETERS

NLAY	- Number of different layers used		1
NTSTPS	- Number of time values concentration calc		40
DUMMY	- Not presently used		1
ISOL	- Type of scheme used in unsaturated zone		1
N	- Stehfest terms or number of increments		18
NTEL	- Points in Lagrangian interpolation		3
NGPTS	- Number of Gauss points		104
NIT	- Convolution integral segments		2
IBOUND	- Type of boundary condition		1
ITSGEN	- Time values generated or input		1
TMAX	- Max simulation time	--	0.0
WTFUN	- Weighting factor	--	1.2

OPTIONS CHOSEN
------- ------
Stehfest numerical inversion algorithm
Nondecaying continuous source
Computer generated times for computing concentrations
1

DATA FOR LAYER 1
---- --- -----
VADOSE TRANSPORT VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Thickness of layer	m	CONSTANT	1.00	-999.	0.100E-08	-999.
Longitudinal dispersivity of layer	m	CONSTANT	0.420E-01	-999.	0.100E-02	0.100E+05
Percent organic matter	--	CONSTANT	0.800	-999.	0.000E+00	100.
Bulk density of soil for layer	g/cc	NORMAL	1.53	0.100	1.33	1.81
Biological decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.

1

CHEMICAL SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Solid phase decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Dissolved phase decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Overall chemical decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Acid catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Neutral hydrolysis rate constant	1/yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Base catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Reference temperature	C	CONSTANT	25.0	0.000E+00	0.000E+00	100.
Normalized distribution coefficient	ml/g	LOG NORMAL	0.115E+06	0.250E+06	4.30	0.127E+07
Distribution coefficient	--	LOG NORMAL	533.	0.116E+04	0.200E-01	0.590E+04
Biodegradation coefficient (sat. zone)	1/yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Air diffusion coefficient	cm2/s	CONSTANT	0.000E+00	0.645E-02	0.000E+00	10.0
Reference temperature for air diffusion	C	CONSTANT	0.000E+00	0.000E+00	0.000E+00	100.
Molecular weight	g/M	CONSTANT	-999.	0.000E+00	0.000E+00	-999.
Mole fraction of solute	--	CONSTANT	-999.	0.100E-01	0.100E-08	1.00
Vapor pressure of solute	mm Hg	CONSTANT	-999.	0.230E-01	0.000E+00	100.
Henry's law constant	atm-m^3/M	CONSTANT	-999.	0.000E+00	0.100E-09	1.00
Overall 1st order decay sat. zone	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	1.00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	1.00	0.000E+00	0.000E+00	1.00

1

SOURCE SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Infiltration rate	m/yr	CONSTANT	0.276E-01	-999.	0.100E-09	0.100E+11
Area of waste disposal unit	m^2	CONSTANT	0.300E+04	-999.	0.100E-01	-999.
Duration of pulse	yr	CONSTANT	-999.	-999.	0.100E-08	-999.
Spread of contaminant source	m	DERIVED	-999.	-999.	0.100E-08	0.100E+11
Recharge rate	m/yr	CONSTANT	0.276E-01	-999.	0.000E+00	0.100E+11
Source decay constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Initial concentration at landfill	mg/l	CONSTANT	1.00	-999.	0.000E+00	-999.
Length scale of facility	m	CONSTANT	150.	-999.	0.100E-08	0.100E+11
Width scale of facility	m	CONSTANT	20.0	-999.	0.100E-08	0.100E+11
Near field dilution		DERIVED	1.00	0.000E+00	0.000E+00	1.00

1

AQUIFER SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Particle diameter	cm	CONSTANT	0.235E-02	-999.	0.100E-08	100.
Aquifer porosity	--	NORMAL	0.150	0.140	0.100E-01	0.390
Bulk density	g/cc	NORMAL	1.54	0.120	1.33	1.81
Aquifer thickness	m	UNIFORM	10.8	-999.	7.90	13.7
Source thickness (mixing zone depth)	m	DERIVED	-999.	-999.	0.100E-08	0.100E+06
Conductivity (hydraulic)	m/yr	LOG NORMAL	140.	198.	0.298E-01	298.
Gradient (hydraulic)		UNIFORM	0.110E-01	-999.	0.710E-02	0.150E-01
Groundwater seepage velocity	m/yr	DERIVED	-999.	-999.	0.100E-09	0.100E+09
Retardation coefficient	--	DERIVED	-999.	-999.	1.00	0.100E+09
Longitudinal dispersivity	m	CONSTANT	5.50	15.0	0.100E-02	0.100E+05
Transverse dispersivity	m	CONSTANT	1.83	-999.	0.100E-02	0.100E+05
Vertical dispersivity	m	CONSTANT	0.308	-999.	0.100E-02	0.100E+05
Temperature of aquifer	C	CONSTANT	19.0	-999.	0.000E+00	100.
pH	--	UNIFORM	-999.	-999.	6.70	7.05
Organic carbon content (fraction)		CONSTANT	0.464E-02	-999.	0.100E-05	1.00
Well distance from site	m	CONSTANT	55.0	-999.	1.00	-999.
Angle off center	degree	CONSTANT	0.000E+00	-999.	0.000E+00	360.
Well vertical distance	m	CONSTANT	0.000E+00	-999.	0.000E+00	1.00

1 103 Values generated which exceeded the specified bounds.

----- RESULTS -----

SATURATED ZONE TRANSPORT

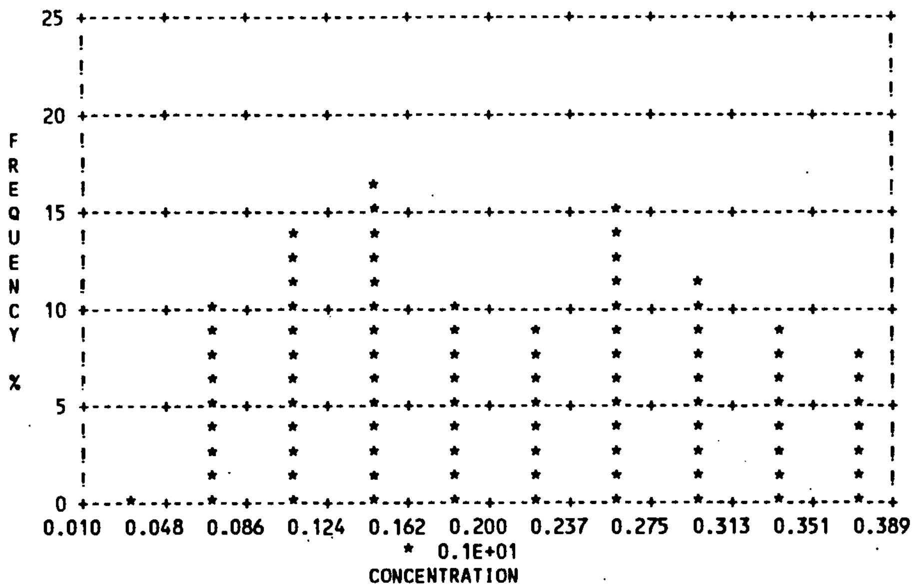
SLAPS Site Suitability Study - Case 1E

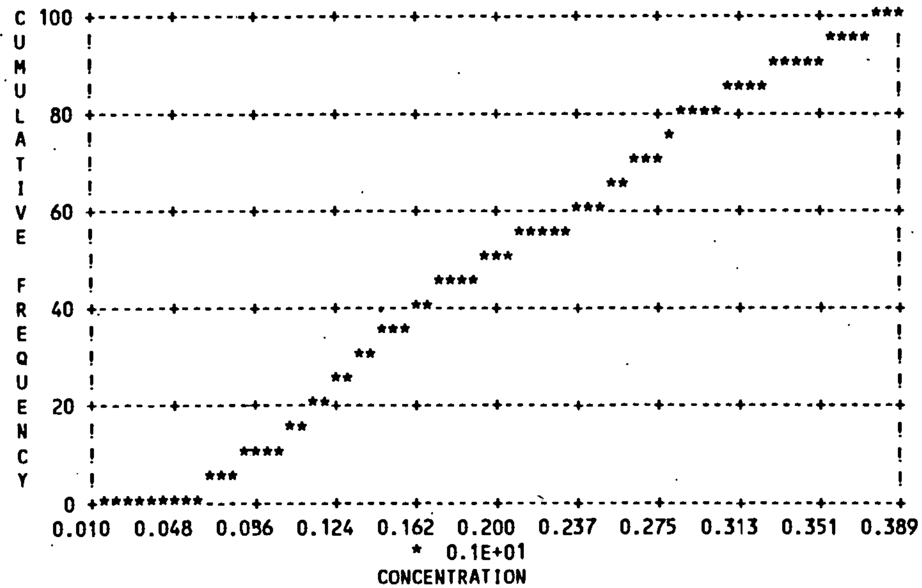
Monte Carlo simulation.

N	=	500		
MEAN	=	0.208		
STANDARD DEVIATION	=	0.923E-01		
COEFFICIENT OF VARIATION	=	0.444		
MINIMUM VALUE	=	0.531E-01		
MAXIMUM VALUE	=	0.389		
50th PERCENTILE	=	0.203	0.187	0.215
80th PERCENTILE	=	0.295	0.285	0.307
85th PERCENTILE	=	0.318	0.305	0.328
90th PERCENTILE	=	0.341	0.328	0.349
95th PERCENTILE	=	0.361	0.354	0.370

-999 UNABLE TO COMPUTE CONFIDENCE BOUND DUE TO INSUFFICIENT DATA

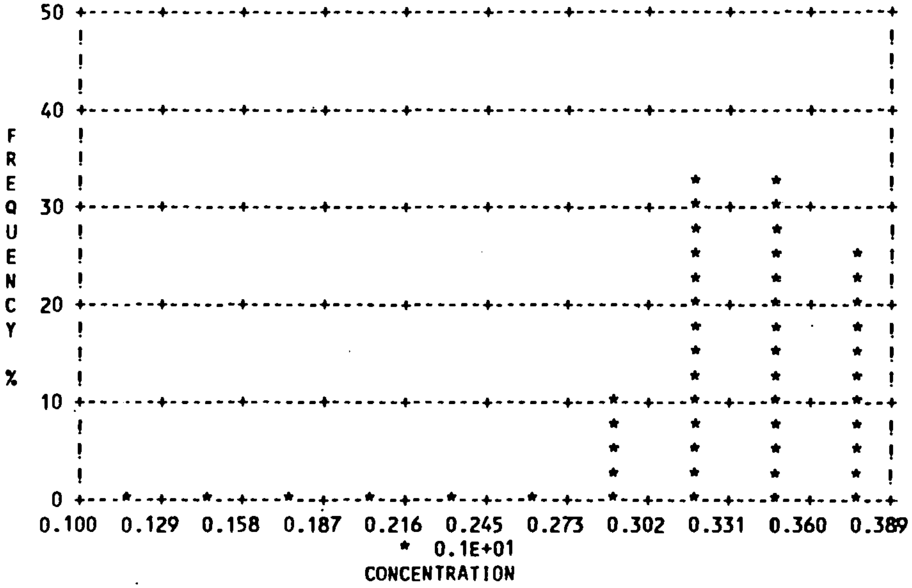
VALUE	% OF TIME EQUALLED OR EXCEEDED	% OF TIME IN INTERVAL
0.100E-01	100.000	
		0.000
0.479E-01	100.000	
		9.600
0.858E-01	90.400	
		13.200
0.124	77.200	
		16.800
0.162	60.400	
		9.400
0.200	51.000	
		9.000
0.237	42.000	
		14.400
0.275	27.600	
		11.200
0.313	16.400	
		8.800
0.351	7.600	
		7.400
0.389	0.200	

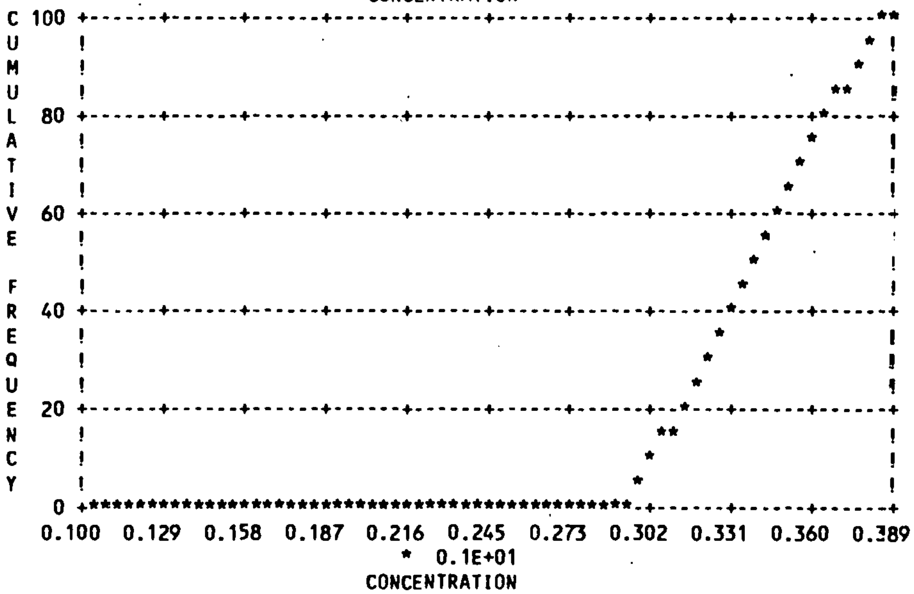

FREQUENCY %
25
20
15
10
5
0
0.010 0.048 0.086 0.124 0.162 0.200 0.237 0.275 0.313 0.351 0.389
* 0.1E+01
CONCENTRATION


CUMULATIVE FREQUENCY
100
80
60
40
20
0
0.010 0.048 0.086 0.124 0.162 0.200 0.237 0.275 0.313 0.351 0.389
* 0.1E+01
CONCENTRATION

1

FOLLOWING GRAPHS ARE FOR THE TOP 20% OF THERESULTS





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U. S. ENVIRONMENTAL PROTECTION AGENCY

EXPOSURE ASSESSMENT

MULTIMEDIA MODEL

MULTIMED (Version 1.01, June 1991)

1

Run options
--- -------

SLAPS Site Suitability Study - Case 1F

Monte Carlo simulation.
Chemical simulated is Uranium

Option Chosen	Saturated and unsaturated zone models
Run was	MONTE
Infiltration input by user	
Number of monte carlo simulations	500

Run was steady-state
Reject runs if Y coordinate outside plume
Reject runs if Z coordinate outside plume
Patch source used in saturated zone model
1
1

UNSATURATED ZONE FLOW MODEL PARAMETERS
(input parameter description and value)

NP	- Total number of nodal points	240
NMAT	- Number of different porous materials	1
KPROP	- Van Genuchten or Brooks and Corey	1
IMSHGN	- Spatial discretization option	1
NVFLAYR	- Number of layers in flow model	1

OPTIONS CHOSEN
------- ------

Van Genuchten functional coefficients
User defined coordinate system
1

Layer information

LAYER NO.	LAYER THICKNESS	MATERIAL PROPERTY
1	1.00	1

DATA FOR MATERIAL 1

VADOSE ZONE MATERIAL VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Saturated hydraulic conductivity	cm/hr	LOG NORMAL	0.107	0.230	0.500E-04	0.720
Unsaturated zone porosity	--	NORMAL	0.150	0.140	0.100E-01	0.390
Air entry pressure head	m	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Depth of the unsaturated zone	m	CONSTANT	1.00	-999.	0.100E-08	-999.

DATA FOR MATERIAL 1

VADOSE ZONE FUNCTION VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Residual water content	--	UNIFORM	0.920E-01	-999.	0.834E-01	0.966E-01
Brook and Corey exponent,EN	--	CONSTANT	0.500	-999.	0.000E+00	10.0
ALFA coefficient	1/cm	UNIFORM	0.123E-01	-999.	0.987E-02	0.152E-01
Van Genuchten exponent, ENN	--	UNIFORM	1.25	-999.	1.21	1.29

1

UNSATURATED ZONE TRANSPORT MODEL PARAMETERS

NLAY	- Number of different layers used		1
NTSTPS	- Number of time values concentration calc		40
DUMMY	- Not presently used		1
ISOL	- Type of scheme used in unsaturated zone		1
N	- Stehfest terms or number of increments		18
NTEL	- Points in Lagrangian interpolation		3
NGPTS	- Number of Gauss points		104
NIT	- Convolution integral segments		2
IBOUND	- Type of boundary condition		1
ITSGEN	- Time values generated or input		1
TMAX	- Max simulation time	--	0.0
WTFUN	- Weighting factor	--	1.2

OPTIONS CHOSEN

------- ------

Stehfest numerical inversion algorithm
Nondecaying continuous source
Computer generated times for computing concentrations

1

DATA FOR LAYER 1

---- --- -----

VADOSE TRANSPORT VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Thickness of layer	m	CONSTANT	1.00	-999.	0.100E-08	-999.
Longitudinal dispersivity of layer	m	CONSTANT	0.420E-01	-999.	0.100E-02	0.100E+05
Percent organic matter	--	CONSTANT	0.800	-999.	0.000E+00	100.
Bulk density of soil for layer	g/cc	NORMAL	1.53	0.100	1.33	1.81
Biological decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.

1

CHEMICAL SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Solid phase decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Dissolved phase decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Overall chemical decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Acid catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Neutral hydrolysis rate constant	1/yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Base catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Reference temperature	C	CONSTANT	25.0	0.000E+00	0.000E+00	100.
Normalized distribution coefficient	ml/g	LOG NORMAL	0.115E+06	0.250E+06	4.30	0.127E+07
Distribution coefficient	--	LOG NORMAL	533.	0.116E+04	0.200E-01	0.590E+04
Biodegradation coefficient (sat. zone)	1/yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Air diffusion coefficient	cm2/s	CONSTANT	0.000E+00	0.645E-02	0.000E+00	10.0
Reference temperature for air diffusion	C	CONSTANT	0.000E+00	0.000E+00	0.000E+00	100.
Molecular weight	g/M	CONSTANT	-999.	0.000E+00	0.000E+00	-999.
Mole fraction of solute	--	CONSTANT	-999.	0.100E-01	0.100E-08	1.00
Vapor pressure of solute	mm Hg	CONSTANT	-999.	0.230E-01	0.000E+00	100.
Henry's law constant	atm-m^3/M	CONSTANT	-999.	0.000E+00	0.100E-09	1.00
Overall 1st order decay sat. zone	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	1.00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	1.00	0.000E+00	0.000E+00	1.00

SOURCE SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Infiltration rate	m/yr	CONSTANT	0.276E-01	-999.	0.100E-09	0.100E+11
Area of waste disposal unit	m^2	CONSTANT	0.300E+04	-999.	0.100E-01	-999.
Duration of pulse	yr	CONSTANT	-999.	-999.	0.100E-08	-999.
Spread of contaminant source	m	DERIVED	-999.	-999.	0.100E-08	0.100E+11
Recharge rate	m/yr	CONSTANT	0.276E-01	-999.	0.000E+00	0.100E+11
Source decay constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Initial concentration at landfill	mg/l	CONSTANT	1.00	-999.	0.000E+00	-999.
Length scale of facility	m	CONSTANT	150.	-999.	0.100E-08	0.100E+11
Width scale of facility	m	CONSTANT	20.0	-999.	0.100E-08	0.100E+11
Near field dilution		DERIVED	1.00	0.000E+00	0.000E+00	1.00

1

AQUIFER SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Particle diameter	cm	CONSTANT	0.235E-02	-999.	0.100E-08	100.
Aquifer porosity	--	NORMAL	0.412	0.450E-01	0.323	0.509
Bulk density	g/cc	NORMAL	1.54	0.120	1.33	1.81
Aquifer thickness	m	UNIFORM	10.8	-999.	7.90	13.7
Source thickness (mixing zone depth)	m	DERIVED	-999.	-999.	0.100E-08	0.100E+06
Conductivity (hydraulic)	m/yr	LOG NORMAL	21.1	31.2	0.390	94.7
Gradient (hydraulic)		UNIFORM	0.110E-01	-999.	0.710E-02	0.150E-01
Groundwater seepage velocity	m/yr	DERIVED	-999.	-999.	0.100E-09	0.100E+09
Retardation coefficient	--	DERIVED	-999.	-999.	1.00	0.100E+09
Longitudinal dispersivity	m	CONSTANT	5.50	15.0	0.100E-02	0.100E+05
Transverse dispersivity	m	CONSTANT	1.83	-999.	0.100E-02	0.100E+05
Vertical dispersivity	m	CONSTANT	0.308	-999.	0.100E-02	0.100E+05
Temperature of aquifer	C	CONSTANT	19.0	-999.	0.000E+00	100.
pH	--	UNIFORM	-999.	-999.	6.70	7.05
Organic carbon content (fraction)		CONSTANT	0.464E-02	-999.	0.100E-05	1.00
Well distance from site	m	CONSTANT	55.0	-999.	1.00	-999.
Angle off center	degree	CONSTANT	0.000E+00	-999.	0.000E+00	360.
Well vertical distance	m	CONSTANT	0.000E+00	-999.	0.000E+00	1.00

1 1342 Values generated which exceeded the specified bounds.

1 ----- RESULTS -----

SATURATED ZONE TRANSPORT

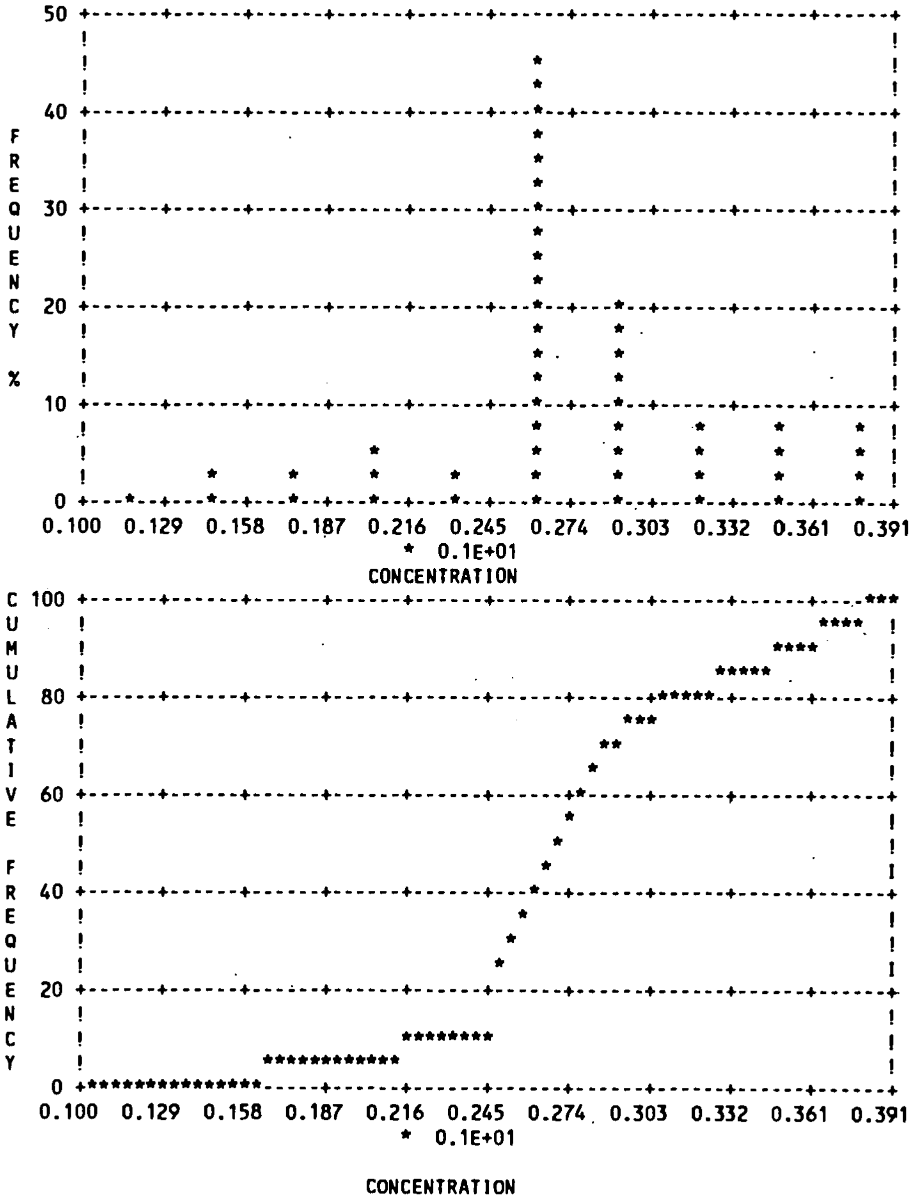
SLAPS Site Suitability Study - Case 1F

Monte Carlo simulation.

N	=	500		
MEAN	=	0.277		
STANDARD DEVIATION	=	0.492E-01		
COEFFICIENT OF VARIATION	=	0.178		
MINIMUM VALUE	=	0.138		
MAXIMUM VALUE	=	0.391		
50th PERCENTILE	=	0.269	0.266	0.272
80th PERCENTILE	=	0.317	0.306	0.328
85th PERCENTILE	=	0.339	0.327	0.348
90th PERCENTILE	=	0.355	0.348	0.365
95th PERCENTILE	=	0.371	0.366	0.378

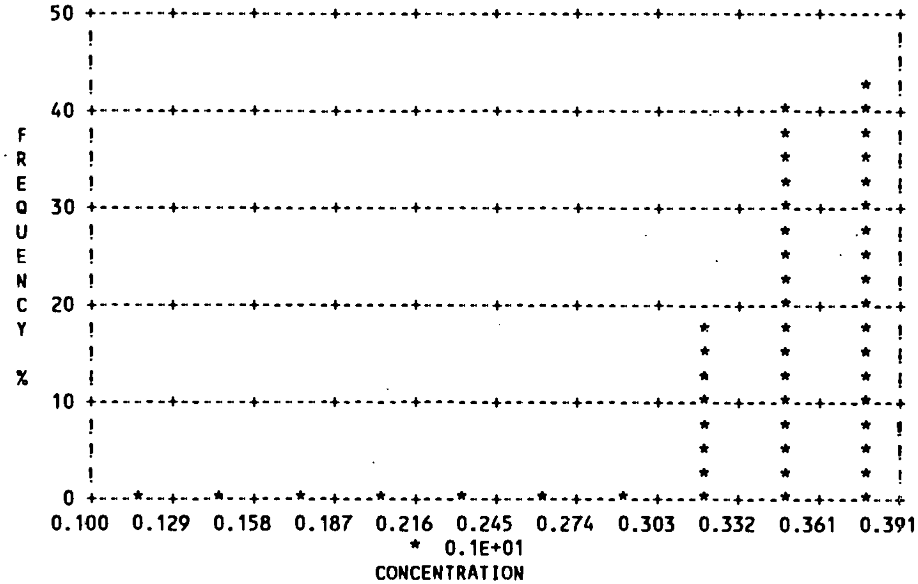
-999 UNABLE TO COMPUTE CONFIDENCE BOUND DUE TO INSUFFICIENT DATA

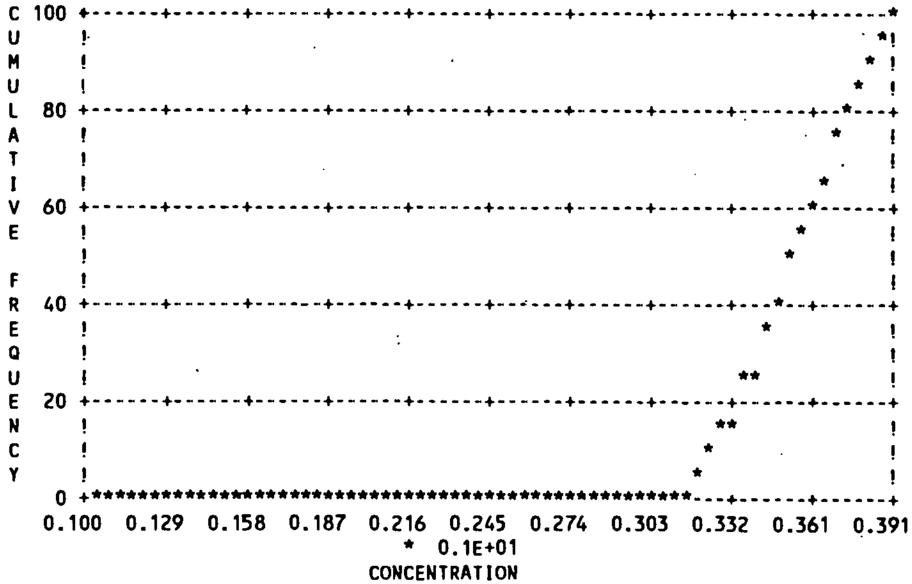
VALUE	% OF TIME EQUALLED OR EXCEEDED	% OF TIME IN INTERVAL
0.100	100.000	
		0.000
0.129	100.000	
		2.200
0.158	97.800	
		2.000
0.187	95.800	
		4.400
0.216	91.400	
		3.200
0.245	88.200	
		45.000
0.274	43.200	
		18.800
0.303	24.400	
		7.800
0.332	16.600	
		8.200
0.361	8.400	
		8.200
0.391	0.200	



FREQUENCY %
50
40
30
20
10
0
0.100 0.129 0.158 0.187 0.216 0.245 0.274 0.303 0.332 0.361 0.391
* 0.1E+01
CONCENTRATION
CUMULATIVE FREQUENCY
100
80
60
40
20
0
0.100 0.129 0.158 0.187 0.216 0.245 0.274 0.303 0.332 0.361 0.391
* 0.1E+01
CONCENTRATION

FOLLOWING GRAPHS ARE FOR THE TOP 20% OF THERESULTS





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U. S. ENVIRONMENTAL PROTECTION AGENCY

EXPOSURE ASSESSMENT

MULTIMEDIA MODEL

MULTIMED (Version 1.01, June 1991)

1

Run options
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SLAPS Site Suitability Study - Case 1G

Monte Carlo simulation.
Chemical simulated is Uranium

Option Chosen	Saturated zone model
Run was	MONTE
Infiltration input by user	
Number of monte carlo simulations	500
Run was steady-state	
Reject runs if Y coordinate outside plume	
Reject runs if Z coordinate outside plume	
Patch source used in saturated zone model	

1

1

CHEMICAL SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Solid phase decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Dissolved phase decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Overall chemical decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Acid catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Neutral hydrolysis rate constant	1/yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Base catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Reference temperature	C	CONSTANT	25.0	0.000E+00	0.000E+00	100.
Normalized distribution coefficient	ml/g	LOG NORMAL	0.115E+06	0.250E+06	4.30	0.127E+07
Distribution coefficient	--	LOG NORMAL	533.	0.116E+04	0.200E-01	0.590E+04
Biodegradation coefficient (sat. zone)	1/yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Air diffusion coefficient	cm2/s	CONSTANT	0.000E+00	0.645E-02	0.000E+00	10.0
Reference temperature for air diffusion	C	CONSTANT	0.000E+00	0.000E+00	0.000E+00	100.
Molecular weight	g/M	CONSTANT	-999.	0.000E+00	0.000E+00	-999.
Mole fraction of solute	--	CONSTANT	-999.	0.100E-01	0.100E-08	1.00
Vapor pressure of solute	mm Hg	CONSTANT	-999.	0.230E-01	0.000E+00	100.
Henry's law constant	atm-m^3/M	CONSTANT	-999.	0.000E+00	0.100E-09	1.00
Overall 1st order decay sat. zone	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	1.00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	1.00	0.000E+00	0.000E+00	1.00

1

SOURCE SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Infiltration rate	m/yr	CONSTANT	0.276E-01	-999.	0.100E-09	0.100E+11
Area of waste disposal unit	m^2	CONSTANT	0.300E+04	-999.	0.100E-01	-999.
Duration of pulse	yr	CONSTANT	-999.	-999.	0.100E-08	-999.
Spread of contaminant source	m	DERIVED	-999.	-999.	0.100E-08	0.100E+11
Recharge rate	m/yr	CONSTANT	0.276E-01	-999.	0.000E+00	0.100E+11
Source decay constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Initial concentration at landfill	mg/l	CONSTANT	1.00	-999.	0.000E+00	-999.
Length scale of facility	m	CONSTANT	150.	-999.	0.100E-08	0.100E+11
Width scale of facility	m	CONSTANT	20.0	-999.	0.100E-08	0.100E+11
Near field dilution		DERIVED	1.00	0.000E+00	0.000E+00	1.00

AQUIFER SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Particle diameter	cm	CONSTANT	0.235E-02	-999.	0.100E-08	100.
Aquifer porosity	--	NORMAL	0.150	0.140	0.100E-01	0.390
Bulk density	g/cc	NORMAL	1.54	0.120	1.33	1.81
Aquifer thickness	m	UNIFORM	10.8	-999.	7.90	13.7
Source thickness (mixing zone depth)	m	DERIVED	-999.	-999.	0.100E-08	0.100E+06
Conductivity (hydraulic)	m/yr	LOG NORMAL	21.1	31.2	0.390	94.7
Gradient (hydraulic)		UNIFORM	0.110E-01	-999.	0.710E-02	0.150E-01
Groundwater seepage velocity	m/yr	DERIVED	-999.	-999.	0.100E-09	0.100E+09
Retardation coefficient	--	DERIVED	-999.	-999.	1.00	0.100E+09
Longitudinal dispersivity	m	CONSTANT	5.50	15.0	0.100E-02	0.100E+05
Transverse dispersivity	m	CONSTANT	1.83	-999.	0.100E-02	0.100E+05
Vertical dispersivity	m	CONSTANT	0.308	-999.	0.100E-02	0.100E+05
Temperature of aquifer	C	CONSTANT	19.0	-999.	0.000E+00	100.
pH	--	UNIFORM	-999.	-999.	6.70	7.05
Organic carbon content (fraction)		CONSTANT	0.464E-02	-999.	0.100E-05	1.00
Well distance from site	m	CONSTANT	55.0	-999.	1.00	-999.
Angle off center	degree	CONSTANT	0.000E+00	-999.	0.000E+00	360.
Well vertical distance	m	CONSTANT	0.000E+00	-999.	0.000E+00	1.00

1 1370 Values generated which exceeded the specified bounds.

----- RESULTS -----

SATURATED ZONE TRANSPORT

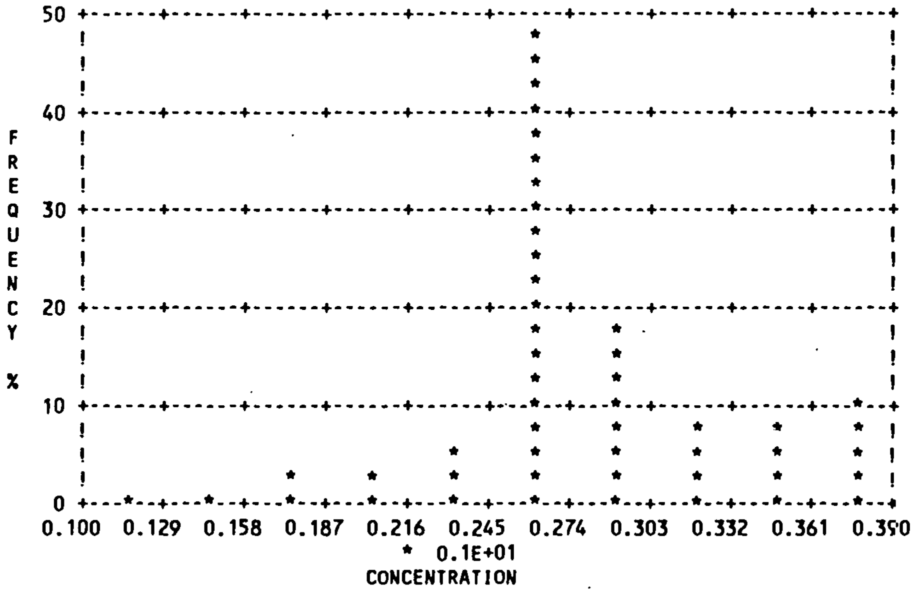
SLAPS Site Suitability Study - Case 1G

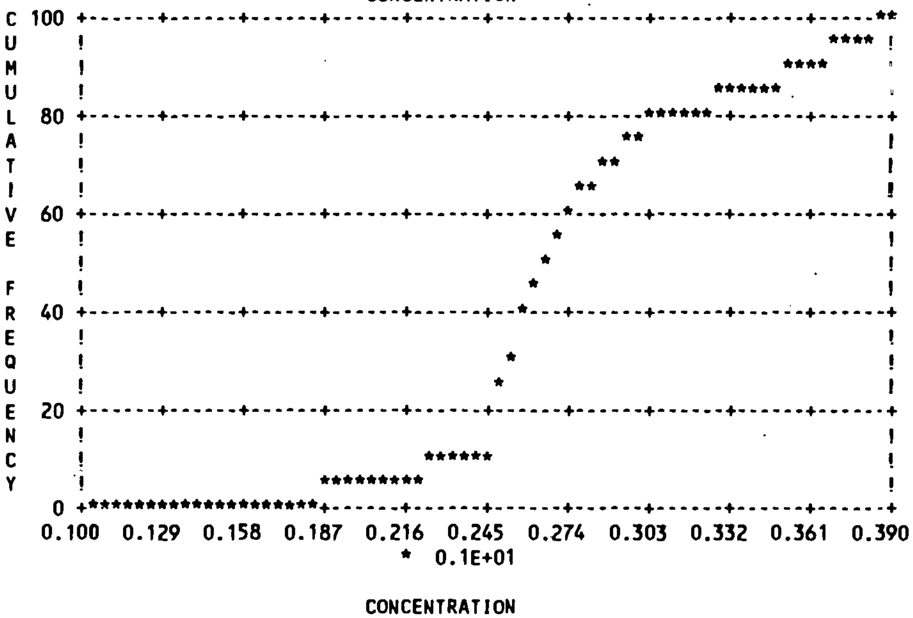
Monte Carlo simulation.

N	=	500		
MEAN	=	0.277		
STANDARD DEVIATION	=	0.489E-01		
COEFFICIENT OF VARIATION	=	0.177		
MINIMUM VALUE	=	0.121		
MAXIMUM VALUE	=	0.390		
50th PERCENTILE	=	0.267	0.264	0.270
80th PERCENTILE	=	0.315	0.302	0.329
85th PERCENTILE	=	0.334	0.327	0.349
90th PERCENTILE	=	0.358	0.349	0.367
95th PERCENTILE	=	0.376	0.369	0.383

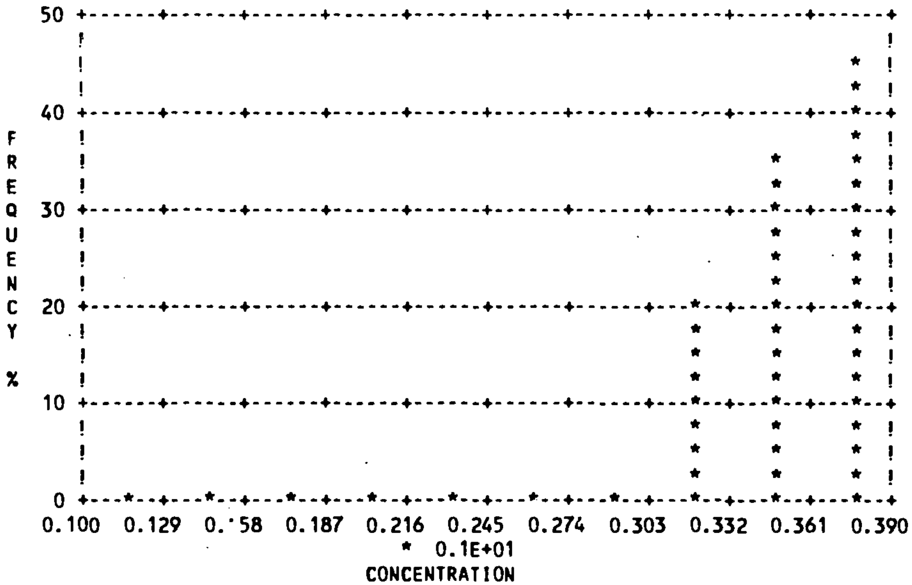
-999 UNABLE TO COMPUTE CONFIDENCE BOUND DUE TO INSUFFICIENT DATA

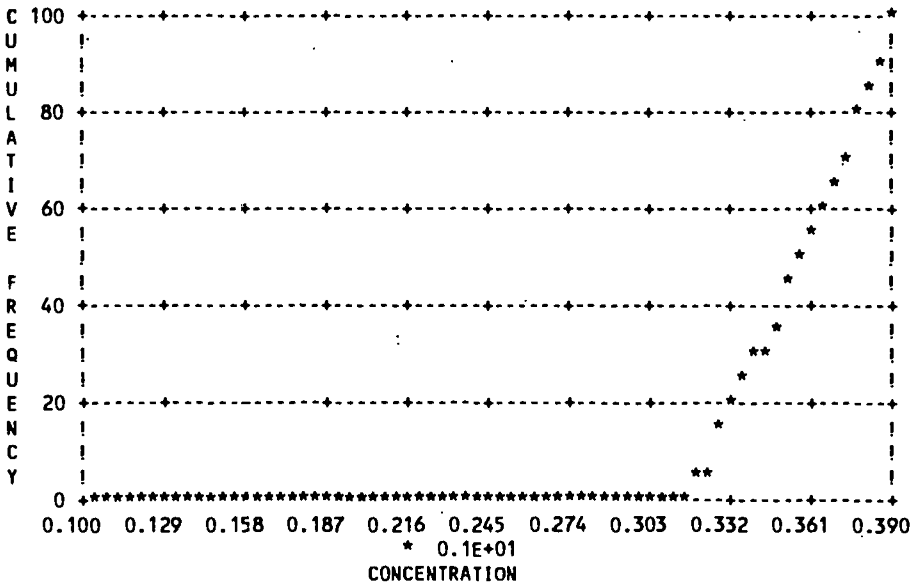
VALUE	% OF TIME EQUALLED OR EXCEEDED	% OF TIME IN INTERVAL
0.100	100.000	
		0.200
0.129	99.800	
		1.200
0.158	98.600	
		2.400
0.187	96.200	
		2.800
0.216	93.400	
		4.800
0.245	88.600	
		48.400
0.274	40.200	
		17.800
0.303	22.400	
		6.600
0.332	15.800	
		6.800
0.361	9.000	
		8.800
0.390	0.200	


FREQUENCY %
0
10
20
30
40
50
0.100 0.129 0.158 0.187 0.216 0.245 0.274 0.303 0.332 0.361 0.390
* 0.1E+01
CONCENTRATION


CUMULATIVE FREQUENCY
0
20
40
60
80
100
0.100 0.129 0.158 0.187 0.216 0.245 0.274 0.303 0.332 0.361 0.390
* 0.1E+01
CONCENTRATION

FOLLOWING GRAPHS ARE FOR THE TOP 20% OF THERESULTS





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U. S. ENVIRONMENTAL PROTECTION AGENCY

EXPOSURE ASSESSMENT

MULTIMEDIA MODEL

MULTIMED (Version 1.01, June 1991)

1

Run options
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SLAPS Site Suitability Study - Case 1H

Monte Carlo simulation.
Chemical simulated is Uranium

Option Chosen	Saturated and unsaturated zone models
Run was	MONTE
Infiltration input by user	
Number of monte carlo simulations	500
Run was steady-state	
Reject runs if Y coordinate outside plume	
Reject runs if Z coordinate outside plume	
Patch source used in saturated zone model	

1
1

UNSATURATED ZONE FLOW MODEL PARAMETERS
(input parameter description and value)

NP	- Total number of nodal points	240
NMAT	- Number of different porous materials	1
KPROP	- Van Genuchten or Brooks and Corey	1
IMSHGN	- Spatial discretization option	1
NVFLAYR	- Number of layers in flow model	1

OPTIONS CHOSEN
------- ------

Van Genuchten functional coefficients
User defined coordinate system

1

Layer information

LAYER NO.	LAYER THICKNESS	MATERIAL PROPERTY
1	1.00	1

DATA FOR MATERIAL 1

VADOSE ZONE MATERIAL VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	STD DEV	LIMITS MIN	MAX
Saturated hydraulic conductivity	cm/hr	LOG NORMAL	0.107	0.230	0.500E-04	0.720
Unsaturated zone porosity	--	NORMAL	0.150	0.140	0.100E-01	0.390
Air entry pressure head	m	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Depth of the unsaturated zone	m	CONSTANT	1.00	-999.	0.100E-08	-999.

DATA FOR MATERIAL 1

VADOSE ZONE FUNCTION VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	STD DEV	LIMITS MIN	MAX
Residual water content	--	UNIFORM	0.920E-01	-999.	0.834E-01	0.966E-01
Brook and Corey exponent,EN	--	CONSTANT	0.500	-999.	0.000E+00	10.0
ALFA coefficient	1/cm	UNIFORM	0.123E-01	-999.	0.987E-02	0.152E-01
Van Genuchten exponent, ENN	--	UNIFORM	1.25	-999.	1.21	1.29

1

UNSATURATED ZONE TRANSPORT MODEL PARAMETERS

NLAY	- Number of different layers used		1
NTSTPS	- Number of time values concentration calc		40
DUMMY	- Not presently used		1
ISOL	- Type of scheme used in unsaturated zone		1
N	- Stehfest terms or number of increments		18
NTEL	- Points in Lagrangian interpolation		3
NGPTS	- Number of Gauss points		104
NIT	- Convolution integral segments		2
IBOUND	- Type of boundary condition		1
ITSGEN	- Time values generated or input		1
TMAX	- Max simulation time	--	0.0
WTFUN	- Weighting factor	--	1.2

OPTIONS CHOSEN
------- ------
Stehfest numerical inversion algorithm
Nondecaying continuous source
Computer generated times for computing concentrations

1

DATA FOR LAYER 1
---- --- -----

VADOSE TRANSPORT VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Thickness of layer	m	CONSTANT	1.00	-999.	0.100E-08	-999.
Longitudinal dispersivity of layer	m	CONSTANT	0.420E-01	-999.	0.100E-02	0.100E+05
Percent organic matter	--	CONSTANT	0.800	-999.	0.000E+00	100.
Bulk density of soil for layer	g/cc	NORMAL	1.53	0.100	1.33	1.81
Biological decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.

1

CHEMICAL SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Solid phase decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Dissolved phase decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Overall chemical decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Acid catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Neutral hydrolysis rate constant	1/yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Base catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Reference temperature	C	CONSTANT	25.0	0.000E+00	0.000E+00	100.
Normalized distribution coefficient	ml/g	LOG NORMAL	0.115E+06	0.250E+06	4.30	0.127E+07
Distribution coefficient	--	LOG NORMAL	533.	0.116E+04	0.200E-01	0.590E+04
Biodegradation coefficient (sat. zone)	1/yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Air diffusion coefficient	cm2/s	CONSTANT	0.000E+00	0.645E-02	0.000E+00	10.0
Reference temperature for air diffusion	C	CONSTANT	0.000E+00	0.000E+00	0.000E+00	100.
Molecular weight	g/M	CONSTANT	-999.	0.000E+00	0.000E+00	-999.
Mole fraction of solute	--	CONSTANT	-999.	0.100E-01	0.100E-08	1.00
Vapor pressure of solute	mm Hg	CONSTANT	-999.	0.230E-01	0.000E+00	100.
Henry's law constant	atm-m^3/M	CONSTANT	-999.	0.000E+00	0.100E-09	1.00
Overall 1st order decay sat. zone	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	1.00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	1.00	0.000E+00	0.000E+00	1.00

1

SOURCE SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Infiltration rate	m/yr	CONSTANT	0.276E-01	-999.	0.100E-09	0.100E+11
Area of waste disposal unit	m^2	CONSTANT	0.300E+04	-999.	0.100E-01	-999.
Duration of pulse	yr	CONSTANT	-999.	-999.	0.100E-08	-999.
Spread of contaminant source	m	DERIVED	-999.	-999.	0.100E-08	0.100E+11
Recharge rate	m/yr	CONSTANT	0.000E+00	-999.	0.000E+00	0.100E+11
Source decay constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Initial concentration at landfill	mg/l	CONSTANT	1.00	-999.	0.000E+00	-999.
Length scale of facility	m	CONSTANT	150.	-999.	0.100E-08	0.100E+11
Width scale of facility	m	CONSTANT	20.0	-999.	0.100E-08	0.100E+11
Near field dilution		DERIVED	1.00	0.000E+00	0.000E+00	1.00

1

AQUIFER SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Particle diameter	cm	CONSTANT	0.235E-02	-999.	0.100E-08	100.
Aquifer porosity	--	NORMAL	0.150	0.140	0.100E-01	0.390
Bulk density	g/cc	NORMAL	1.54	0.120	1.33	1.81
Aquifer thickness	m	UNIFORM	10.8	-999.	7.90	13.7
Source thickness (mixing zone depth)	m	DERIVED	-999.	-999.	0.100E-08	0.100E+06
Conductivity (hydraulic)	m/yr	LOG NORMAL	21.1	31.2	0.390	94.7
Gradient (hydraulic)		UNIFORM	0.110E-01	-999.	0.710E-02	0.150E-01
Groundwater seepage velocity	m/yr	DERIVED	-999.	-999.	0.100E-09	0.100E+09
Retardation coefficient	--	DERIVED	-999.	-999.	1.00	0.100E+09
Longitudinal dispersivity	m	CONSTANT	5.50	15.0	0.100E-02	0.100E+05
Transverse dispersivity	m	CONSTANT	1.83	-999.	0.100E-02	0.100E+05
Vertical dispersivity	m	CONSTANT	0.308	-999.	0.100E-02	0.100E+05
Temperature of aquifer	C	CONSTANT	19.0	-999.	0.000E+00	100.
pH	--	UNIFORM	-999.	-999.	6.70	7.05
Organic carbon content (fraction)		CONSTANT	0.464E-02	-999.	0.100E-05	1.00
Well distance from site	m	CONSTANT	55.0	-999.	1.00	-999.
Angle off center	degree	CONSTANT	0.000E+00	-999.	0.000E+00	360.
Well vertical distance	m	CONSTANT	0.000E+00	-999.	0.000E+00	1.00

1 1373 Values generated which exceeded the specified bounds.

----- RESULTS -----

SATURATED ZONE TRANSPORT

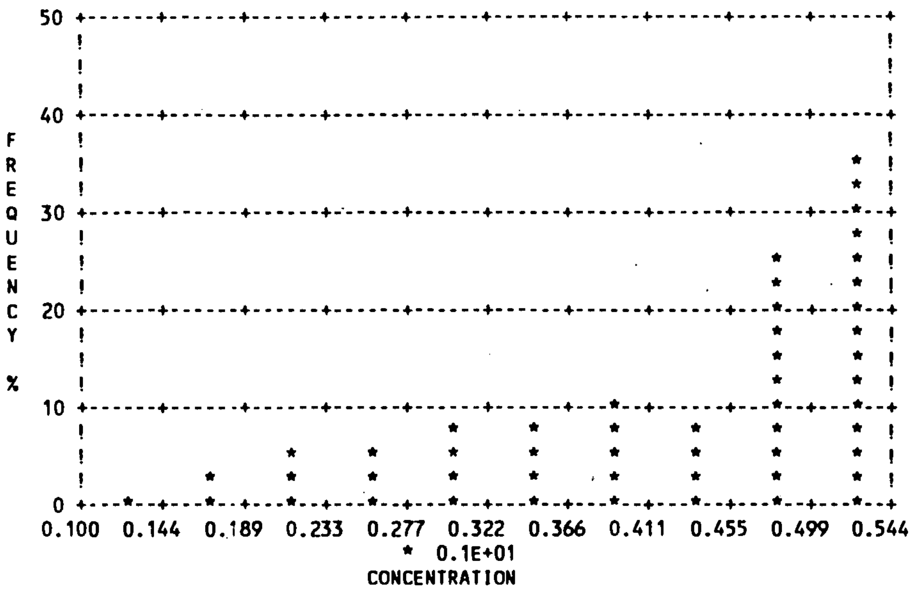
SLAPS Site Suitability Study - Case 1H

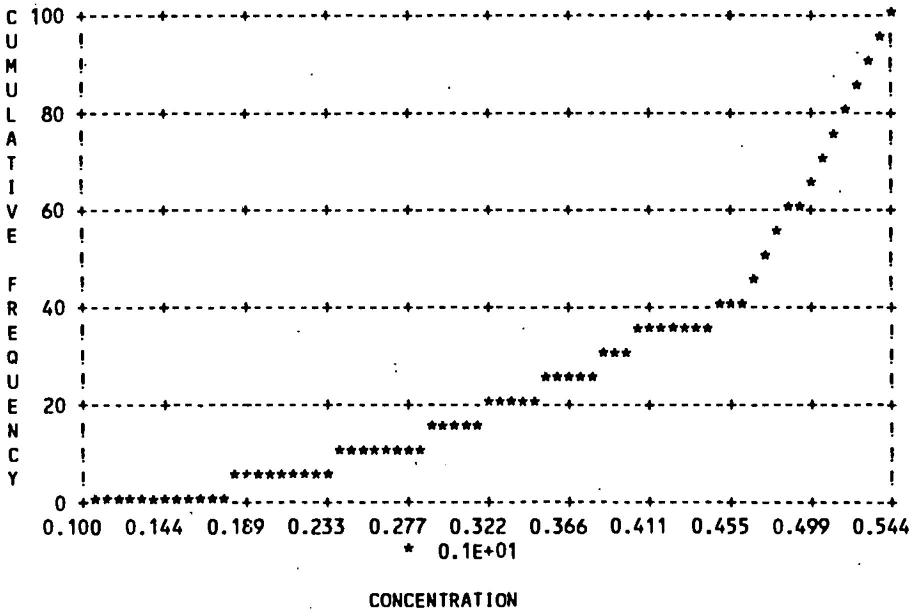
Monte Carlo simulation.

			90. PERCENT CONFIDENCE INTERVAL	
N	=	500		
MEAN	=	0.432		
STANDARD DEVIATION	=	0.104		
COEFFICIENT OF VARIATION	=	0.240		
MINIMUM VALUE	=	0.131		
MAXIMUM VALUE	=	0.544		
50th PERCENTILE	=	0.476	0.469	0.483
80th PERCENTILE	=	0.519	0.516	0.523
85th PERCENTILE	=	0.525	0.522	0.528
90th PERCENTILE	=	0.530	0.528	0.533
95th PERCENTILE	=	0.537	0.534	0.540

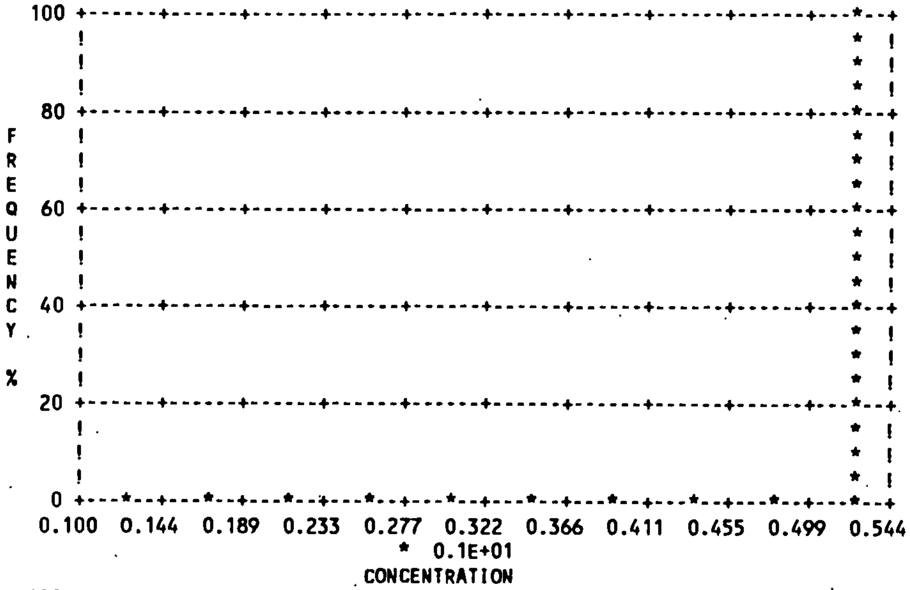
-999 UNABLE TO COMPUTE CONFIDENCE BOUND DUE TO INSUFFICIENT DATA

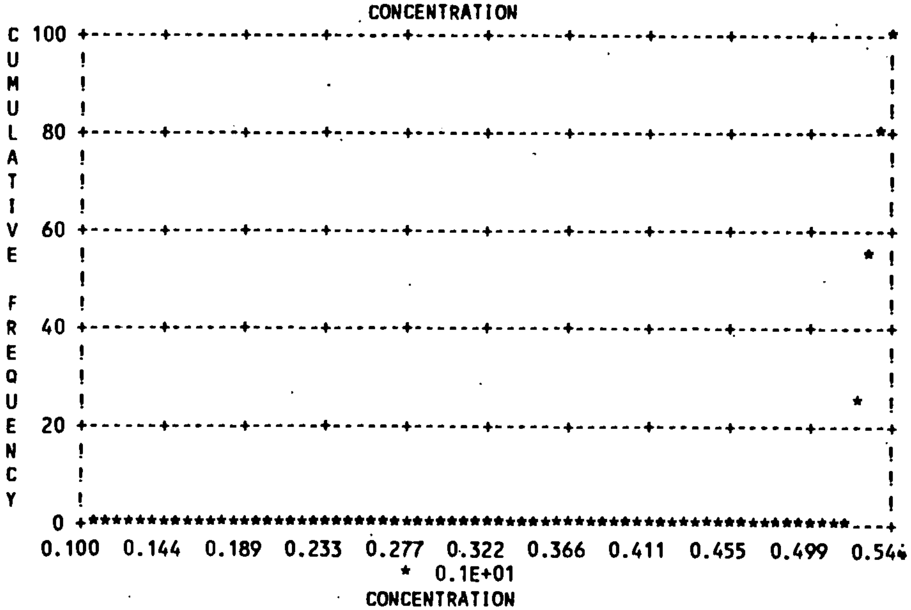
VALUE	% OF TIME EQUALLED OR EXCEEDED	% OF TIME IN INTERVAL
0.100	100.000	
		0.400
0.144	99.600	
		2.200
0.189	97.400	
		3.800
0.233	93.600	
		5.000
0.277	88.600	
		6.800
0.322	81.800	
		7.400
0.366	74.400	
		8.800
0.411	65.600	
		6.600
0.455	59.000	
		23.800
0.499	35.200	
		35.000
0.544	0.200	


50
40
30
20
10
0
FREQUENCY %
0.100 0.144 0.189 0.233 0.277 0.322 0.366 0.411 0.455 0.499 0.544
* 0.1E+01
CONCENTRATION


100
80
60
40
20
0
CUMULATIVE FREQUENCY
0.100 0.144 0.189 0.233 0.277 0.322 0.366 0.411 0.455 0.499 0.544
* 0.1E+01
CONCENTRATION

FOLLOWING GRAPHS ARE FOR THE TOP 20% OF THERESULTS





1

U. S. ENVIRONMENTAL PROTECTION AGENCY

EXPOSURE ASSESSMENT

MULTIMEDIA MODEL

MULTIMED (Version 1.01, June 1991)

1

Run options
--- -------

SLAPS Site Suitability Study - Case 1I

Monte Carlo simulation.
Chemical simulated is Uranium

```
Option Chosen                        Saturated and unsaturated zone models
Run was                              MONTE
Infiltration input by user
Number of monte carlo simulations      500
Run was steady-state
Reject runs if Y coordinate outside plume
Reject runs if Z coordinate outside plume
Patch source used in saturated zone model
1
1
UNSATURATED ZONE FLOW MODEL PARAMETERS
(input parameter description and value)
NP      - Total number of nodal points               240
NMAT    - Number of different porous materials         1
KPROP   - Van Genuchten or Brooks and Corey            1
IMSHGN  - Spatial discretization option                1
NVFLAYR - Number of layers in flow model               1
```

OPTIONS CHOSEN
------- -------

Van Genuchten functional coefficients
User defined coordinate system

1

Layer information

LAYER NO.	LAYER THICKNESS	MATERIAL PROPERTY
1	1.00	1

DATA FOR MATERIAL 1

VADOSE ZONE MATERIAL VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Saturated hydraulic conductivity	cm/hr	LOG NORMAL	0.107	0.230	0.500E-04	0.720
Unsaturated zone porosity	--	NORMAL	0.150	0.140	0.100E-01	0.390
Air entry pressure head	m	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Depth of the unsaturated zone	m	CONSTANT	1.00	-999.	0.100E-08	-999.

DATA FOR MATERIAL 1

VADOSE ZONE FUNCTION VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Residual water content	--	UNIFORM	0.920E-01	-999.	0.834E-01	0.966E-01
Brook and Corey exponent,EN	--	CONSTANT	0.500	-999.	0.000E+00	10.0
ALFA coefficient	1/cm	UNIFORM	0.123E-01	-999.	0.987E-02	0.152E-01
Van Genuchten exponent, ENN	--	UNIFORM	1.25	-999.	1.21	1.29

1

UNSATURATED ZONE TRANSPORT MODEL PARAMETERS

NLAY	- Number of different layers used		1
NTSTPS	- Number of time values concentration calc		40
DUMMY	- Not presently used		1
ISOL	- Type of scheme used in unsaturated zone		1
N	- Stehfest terms or number of increments		18
NTEL	- Points in Lagrangian interpolation		3
NGPTS	- Number of Gauss points		104
NIT	- Convolution integral segments		2
IBOUND	- Type of boundary condition		1
ITSGEN	- Time values generated or input		1
TMAX	- Max simulation time	--	0.0
WTFUN	- Weighting factor	--	1.2

OPTIONS CHOSEN
------- ------
Stehfest numerical inversion algorithm
Nondecaying continuous source
Computer generated times for computing concentrations

1

DATA FOR LAYER 1

VADOSE TRANSPORT VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Thickness of layer	m	CONSTANT	1.00	-999.	0.100E-08	-999.
Longitudinal dispersivity of layer	m	CONSTANT	0.420E-01	-999.	0.100E-02	0.100E+05
Percent organic matter	--	CONSTANT	0.800	-999.	0.000E+00	100.
Bulk density of soil for layer	g/cc	NORMAL	1.53	0.100	1.33	1.81
Biological decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.

1

CHEMICAL SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Solid phase decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Dissolved phase decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Overall chemical decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Acid catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Neutral hydrolysis rate constant	1/yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Base catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Reference temperature	C	CONSTANT	25.0	0.000E+00	0.000E+00	100.
Normalized distribution coefficient	ml/g	LOG NORMAL	0.115E+06	0.250E+06	4.30	0.127E+07
Distribution coefficient	--	LOG NORMAL	533.	0.116E+04	0.200E-01	0.590E+04
Biodegradation coefficient (sat. zone)	1/yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Air diffusion coefficient	cm2/s	CONSTANT	0.000E+00	0.645E-02	0.000E+00	10.0
Reference temperature for air diffusion	C	CONSTANT	0.000E+00	0.000E+00	0.000E+00	100.
Molecular weight	g/M	CONSTANT	-999.	0.000E+00	0.000E+00	-999.
Mole fraction of solute	--	CONSTANT	-999.	0.100E-01	0.100E-08	1.00
Vapor pressure of solute	mm Hg	CONSTANT	-999.	0.230E-01	0.000E+00	100.
Henry's law constant	atm-m^3/M	CONSTANT	-999.	0.000E+00	0.100E-09	1.00
Overall 1st order decay sat. zone	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	1.00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	1.00	0.000E+00	0.000E+00	1.00

1

SOURCE SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Infiltration rate	m/yr	CONSTANT	0.276E-01	-999.	0.100E-09	0.100E+11
Area of waste disposal unit	m^2	CONSTANT	0.300E+04	-999.	0.100E-01	-999.
Duration of pulse	yr	CONSTANT	-999.	-999.	0.100E-08	-999.
Spread of contaminant source	m	DERIVED	-999.	-999.	0.100E-08	0.100E+11
Recharge rate	m/yr	CONSTANT	0.206	-999.	0.000E+00	0.100E+11
Source decay constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Initial concentration at landfill	mg/l	CONSTANT	1.00	-999.	0.000E+00	-999.
Length scale of facility	m	CONSTANT	150.	-999.	0.100E-08	0.100E+11
Width scale of facility	m	CONSTANT	20.0	-999.	0.100E-08	0.100E+11
Near field dilution		DERIVED	1.00	0.000E+00	0.000E+00	1.00

1

AQUIFER SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Particle diameter	cm	CONSTANT	0.235E-02	-999.	0.100E-08	100.
Aquifer porosity	--	NORMAL	0.150	0.140	0.100E-01	0.390
Bulk density	g/cc	NORMAL	1.54	0.120	1.33	1.81
Aquifer thickness	m	UNIFORM	10.8	-999.	7.90	13.7
Source thickness (mixing zone depth)	m	DERIVED	-999.	-999.	0.100E-08	0.100E+06
Conductivity (hydraulic)	m/yr	LOG NORMAL	21.1	31.2	0.390	94.7
Gradient (hydraulic)		UNIFORM	0.110E-01	-999.	0.710E-02	0.150E-01
Groundwater seepage velocity	m/yr	DERIVED	-999.	-999.	0.100E-09	0.100E+09
Retardation coefficient	--	DERIVED	-999.	-999.	1.00	0.100E+09
Longitudinal dispersivity	m	CONSTANT	5.50	15.0	0.100E-02	0.100E+05
Transverse dispersivity	m	CONSTANT	1.83	-999.	0.100E-02	0.100E+05
Vertical dispersivity	m	CONSTANT	0.308	-999.	0.100E-02	0.100E+05
Temperature of aquifer	C	CONSTANT	19.0	-999.	0.000E+00	100.
pH	--	UNIFORM	-999.	-999.	6.70	7.05
Organic carbon content (fraction)		CONSTANT	0.464E-02	-999.	0.100E-05	1.00
Well distance from site	m	CONSTANT	55.0	-999.	1.00	-999.
Angle off center	degree	CONSTANT	0.000E+00	-999.	0.000E+00	360.
Well vertical distance	m	CONSTANT	0.000E+00	-999.	0.000E+00	1.00

1 1373 Values generated which exceeded the specified bounds.

----- RESULTS -----

SATURATED ZONE TRANSPORT

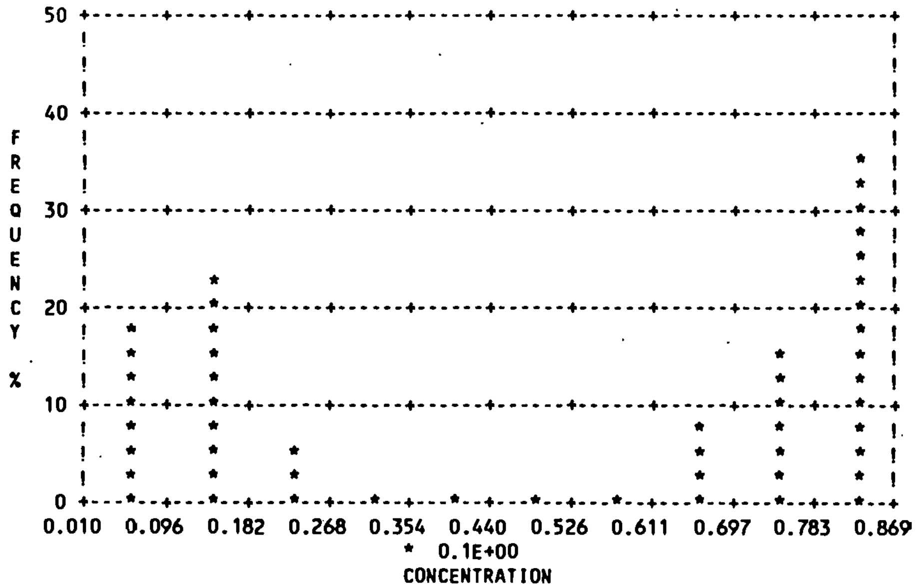
SLAPS Site Suitability Study - Case 1I

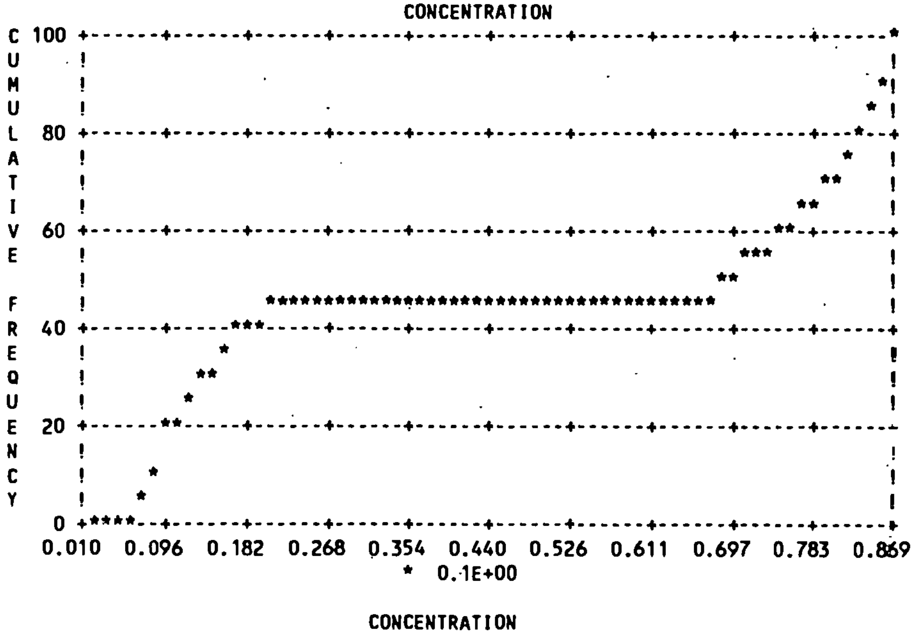
Monte Carlo simulation.

			90. PERCENT CONFIDENCE INTERVAL	
N	=	500		
MEAN	=	0.491E-01		
STANDARD DEVIATION	=	0.340E-01		
COEFFICIENT OF VARIATION	=	0.692		
MINIMUM VALUE	=	0.639E-02		
MAXIMUM VALUE	=	0.869E-01		
50th PERCENTILE	=	0.690E-01	0.673E-01	0.713E-01
80th PERCENTILE	=	0.835E-01	0.825E-01	0.841E-01
85th PERCENTILE	=	0.847E-01	0.840E-01	0.855E-01
90th PERCENTILE	=	0.859E-01	0.855E-01	0.862E-01
95th PERCENTILE	=	0.866E-01	0.864E-01	0.868E-01

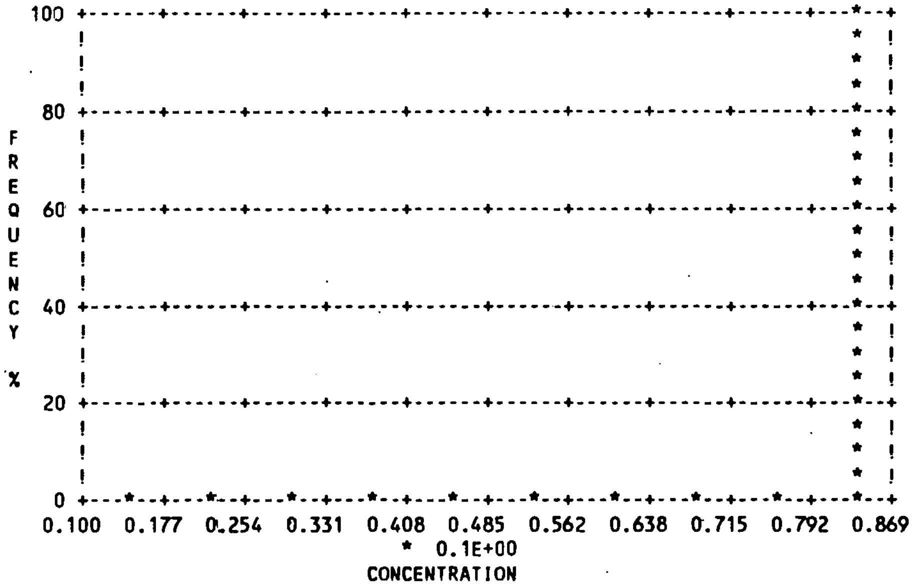
-999 UNABLE TO COMPUTE CONFIDENCE BOUND DUE TO INSUFFICIENT DATA

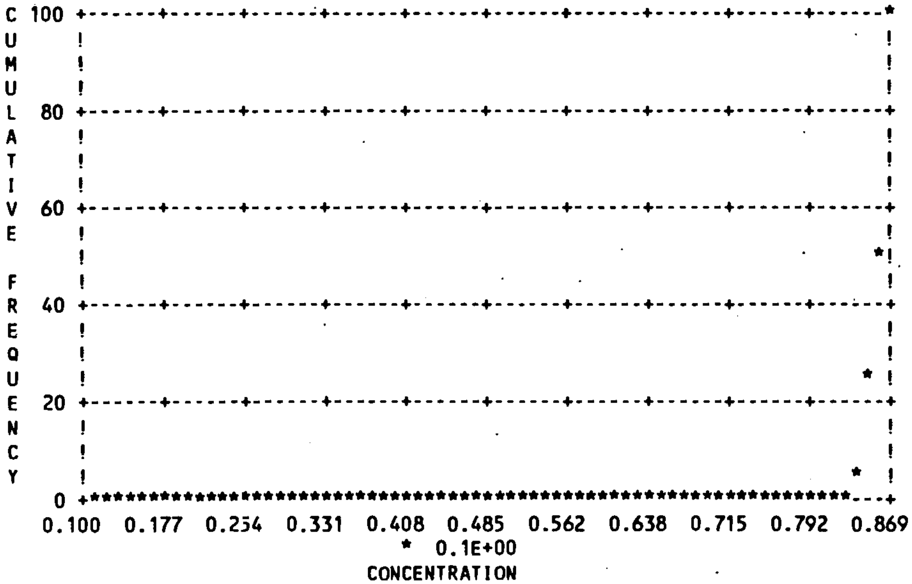
VALUE	% OF TIME EQUALLED OR EXCEEDED	% OF TIME IN INTERVAL
0.100E-02	100.000	
		18.200
0.959E-02	81.800	
		22.400
0.182E-01	59.400	
		4.200
0.268E-01	55.200	
		0.000
0.354E-01	55.200	
		0.000
0.440E-01	55.200	
		0.000
0.526E-01	55.200	
		0.000
0.611E-01	55.200	
		7.000
0.697E-01	48.200	
		14.200
0.783E-01	34.000	
		33.800
0.869E-01	0.200	


FREQUENCY %
50
40
30
20
10
0
0.010
0.096
0.182
0.268
0.354
0.440
0.526
0.611
0.697
0.783
0.869
* 0.1E+00
CONCENTRATION


CUMULATIVE FREQUENCY
100
80
60
40
20
0
0.010
0.096
0.182
0.268
0.354
0.440
0.526
0.611
0.697
0.783
0.869
* 0.1E+00
CONCENTRATION

FOLLOWING GRAPHS ARE FOR THE TOP 20% OF THERESULTS





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U. S. ENVIRONMENTAL PROTECTION AGENCY

EXPOSURE ASSESSMENT

MULTIMEDIA MODEL

MULTIMED (Version 1.01, June 1991)

1

Run options
--- -------

SLAPS Site Suitability Study - Case 1J

Monte Carlo simulation.
Chemical simulated is Uranium

Option Chosen   Saturated and unsaturated zone models
Run was   MONTE
Infiltration input by user
Number of monte carlo simulations   500
Run was steady-state
Reject runs if Y coordinate outside plume
Reject runs if Z coordinate outside plume
Patch source used in saturated zone model
1
1
UNSATURATED ZONE FLOW MODEL PARAMETERS
(input parameter description and value)

NP	- Total number of nodal points	240
NMAT	- Number of different porous materials	1
KPROP	- Van Genuchten or Brooks and Corey	1
IMSHGN	- Spatial discretization option	1
NVFLAYR	- Number of layers in flow model	1

OPTIONS CHOSEN
------- ------
Van Genuchten functional coefficients
User defined coordinate system
1

Layer information

LAYER NO.	LAYER THICKNESS	MATERIAL PROPERTY
1	1.00	1

DATA FOR MATERIAL 1

VADOSE ZONE MATERIAL VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Saturated hydraulic conductivity	cm/hr	LOG NORMAL	0.107	0.230	0.500E-04	0.720
Unsaturated zone porosity	--	NORMAL	0.150	0.140	0.100E-01	0.390
Air entry pressure head	m	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Depth of the unsaturated zone	m	CONSTANT	1.00	-999.	0.100E-08	-999.

DATA FOR MATERIAL 1

VADOSE ZONE FUNCTION VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Residual water content	--	UNIFORM	0.920E-01	-999.	0.834E-01	0.966E-01
Brook and Corey exponent,EN	--	CONSTANT	0.500	-999.	0.000E+00	10.0
ALFA coefficient	1/cm	UNIFORM	0.123E-01	-999.	0.987E-02	0.152E-01
Van Genuchten exponent, ENN	--	UNIFORM	1.25	-999.	1.21	1.29

1

UNSATURATED ZONE TRANSPORT MODEL PARAMETERS

NLAY	- Number of different layers used		1
NTSTPS	- Number of time values concentration calc		40
DUMMY	- Not presently used		1
ISOL	- Type of scheme used in unsaturated zone		1
N	- Stehfest terms or number of increments		18
NTEL	- Points in Lagrangian interpolation		3
NGPTS	- Number of Gauss points		104
NIT	- Convolution integral segments		2
IBOUND	- Type of boundary condition		1
ITSGEN	- Time values generated or input		1
TMAX	- Max simulation time	--	0.0
WTFUN	- Weighting factor	--	1.2

OPTIONS CHOSEN
------- ------
Stehfest numerical inversion algorithm
Nondecaying continuous source
Computer generated times for computing concentrations

1

DATA FOR LAYER 1

VADOSE TRANSPORT VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Thickness of layer	m	CONSTANT	1.00	-999.	0.100E-08	-999.
Longitudinal dispersivity of layer	m	CONSTANT	0.420E-01	-999.	0.100E-02	0.100E+05
Percent organic matter	--	CONSTANT	0.800	-999.	0.000E+00	100.
Bulk density of soil for layer	g/cc	NORMAL	1.53	0.100	1.33	1.81
Biological decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.

1

CHEMICAL SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Solid phase decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Dissolved phase decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Overall chemical decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Acid catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Neutral hydrolysis rate constant	1/yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Base catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Reference temperature	C	CONSTANT	25.0	0.000E+00	0.000E+00	100.
Normalized distribution coefficient	ml/g	LOG NORMAL	0.115E+06	0.250E+06	4.30	0.127E+07
Distribution coefficient	--	LOG NORMAL	533.	0.116E+04	0.200E-01	0.590E+04
Biodegradation coefficient (sat. zone)	1/yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Air diffusion coefficient	cm2/s	CONSTANT	0.000E+00	0.645E-02	0.000E+00	10.0
Reference temperature for air diffusion	C	CONSTANT	0.000E+00	0.000E+00	0.000E+00	100.
Molecular weight	g/M	CONSTANT	-999.	0.000E+00	0.000E+00	-999.
Mole fraction of solute	--	CONSTANT	-999.	0.100E-01	0.100E-08	1.00
Vapor pressure of solute	mm Hg	CONSTANT	-999.	0.230E-01	0.000E+00	100.
Henry's law constant	atm-m^3/M	CONSTANT	-999.	0.000E+00	0.100E-09	1.00
Overall 1st order decay sat. zone	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	1.00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	1.00	0.000E+00	0.000E+00	1.00

1

SOURCE SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Infiltration rate	m/yr	CONSTANT	0.206	-999.	0.100E-09	0.100E+11
Area of waste disposal unit	m^2	CONSTANT	0.300E+04	-999.	0.100E-01	-999.
Duration of pulse	yr	CONSTANT	-999.	-999.	0.100E-08	-999.
Spread of contaminant source	m	DERIVED	-999.	-999.	0.100E-08	0.100E+11
Recharge rate	m/yr	CONSTANT	0.206	-999.	0.000E+00	0.100E+11
Source decay constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Initial concentration at landfill	mg/l	CONSTANT	1.00	-999.	0.000E+00	-999.
Length scale of facility	m	CONSTANT	150.	-999.	0.100E-08	0.100E+11
Width scale of facility	m	CONSTANT	20.0	-999.	0.100E-08	0.100E+11
Near field dilution		DERIVED	1.00	0.000E+00	0.000E+00	1.00

1

AQUIFER SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Particle diameter	cm	CONSTANT	0.235E-02	-999.	0.100E-08	100.
Aquifer porosity	--	NORMAL	0.150	0.140	0.100E-01	0.390
Bulk density	g/cc	NORMAL	1.54	0.120	1.33	1.81
Aquifer thickness	m	UNIFORM	10.8	-999.	7.90	13.7
Source thickness (mixing zone depth)	m	DERIVED	-999.	-999.	0.100E-08	0.100E+06
Conductivity (hydraulic)	m/yr	LOG NORMAL	21.1	31.2	0.390	94.7
Gradient (hydraulic)		UNIFORM	0.110E-01	-999.	0.710E-02	0.150E-01
Groundwater seepage velocity	m/yr	DERIVED	-999.	-999.	0.100E-09	0.100E+09
Retardation coefficient	--	DERIVED	-999.	-999.	1.00	0.100E+09
Longitudinal dispersivity	m	CONSTANT	5.50	15.0	0.100E-02	0.100E+05
Transverse dispersivity	m	CONSTANT	1.83	-999.	0.100E-02	0.100E+05
Vertical dispersivity	m	CONSTANT	0.308	-999.	0.100E-02	0.100E+05
Temperature of aquifer	C	CONSTANT	19.0	-999.	0.000E+00	100.
pH	--	UNIFORM	-999.	-999.	6.70	7.05
Organic carbon content (fraction)		CONSTANT	0.464E-02	-999.	0.100E-05	1.00
Well distance from site	m	CONSTANT	55.0	-999.	1.00	-999.
Angle off center	degree	CONSTANT	0.000E+00	-999.	0.000E+00	360.
Well vertical distance	m	CONSTANT	0.000E+00	-999.	0.000E+00	1.00

1 ***** Values generated which exceeded the specified bounds.

1

----- RESULTS -----

SATURATED ZONE TRANSPORT

SLAPS Site Suitability Study - Case 1J

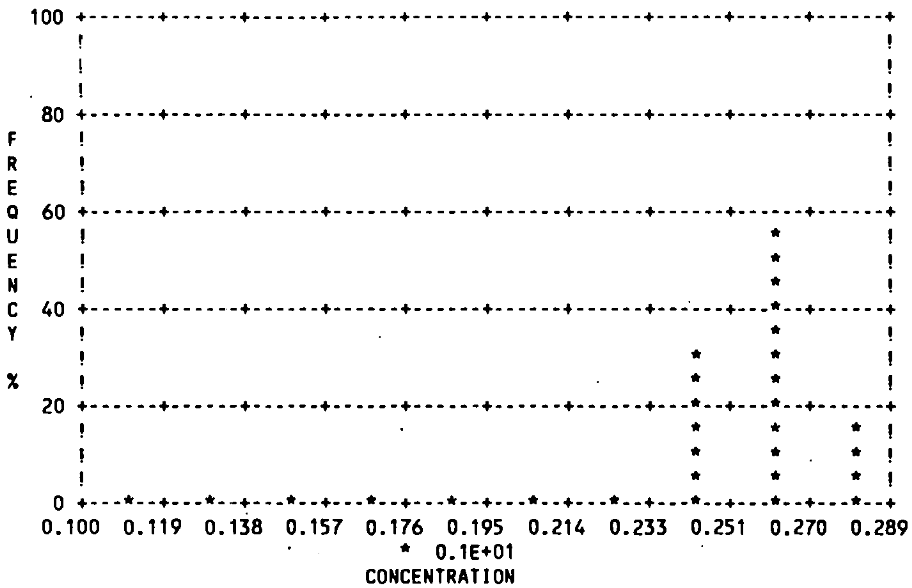
Monte Carlo simulation.

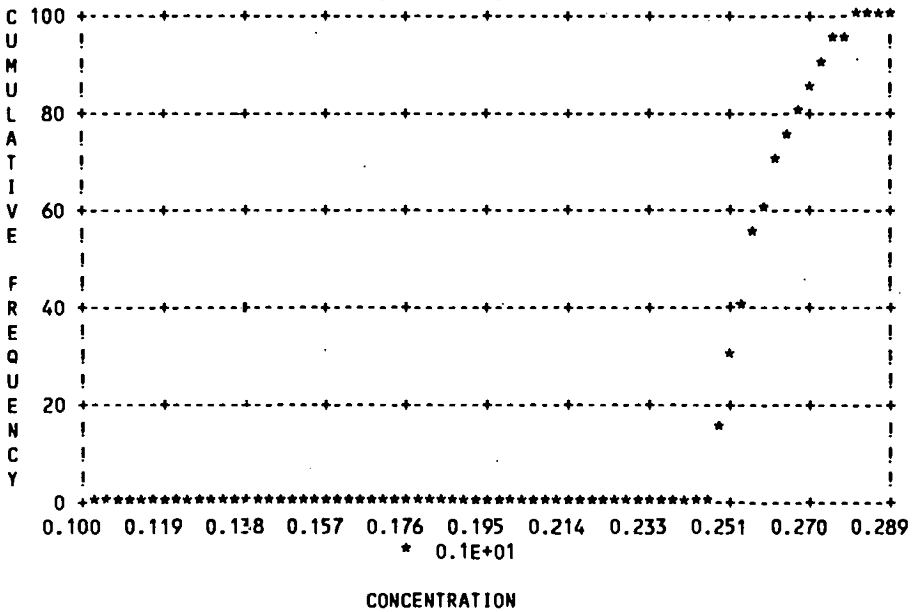
N	=	500		
MEAN	=	0.258		
STANDARD DEVIATION	=	0.955E-02		
COEFFICIENT OF VARIATION	=	0.370E-01		
MINIMUM VALUE	=	0.247		
MAXIMUM VALUE	=	0.289		
50th PERCENTILE	=	0.256	0.255	0.257
80th PERCENTILE	=	0.266	0.265	0.268
85th PERCENTILE	=	0.270	0.268	0.272
90th PERCENTILE	=	0.273	0.272	0.275
95th PERCENTILE	=	0.277	0.276	0.279

-999 UNABLE TO COMPUTE CONFIDENCE BOUND DUE TO INSUFFICIENT DATA

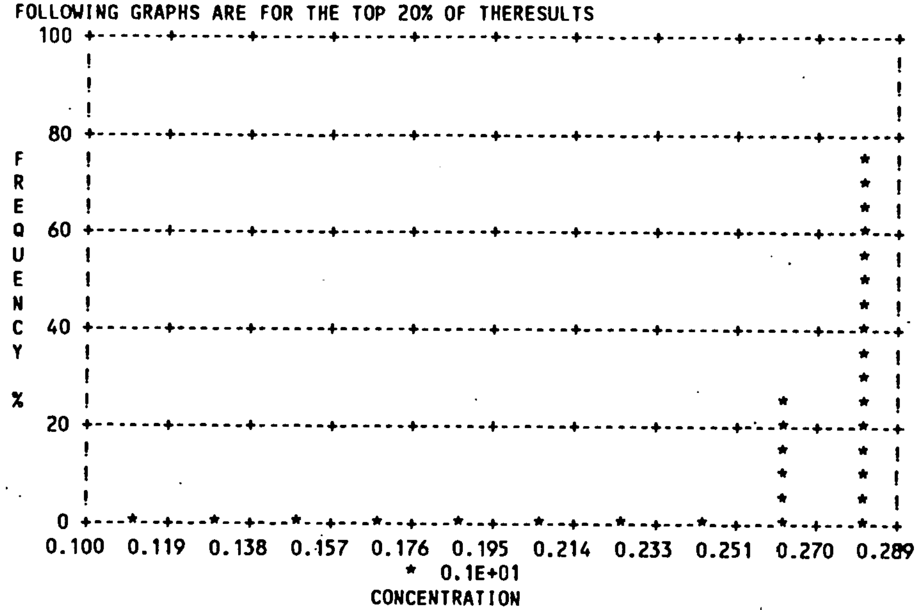
VALUE	% OF TIME EQUALLED OR EXCEEDED	% OF TIME IN INTERVAL
0.100	100.000	
		0.000
0.119	100.000	
		0.000
0.138	100.000	
		0.000
0.157	100.000	
		0.000
0.176	100.000	
		0.000
0.195	100.000	
		0.000
0.214	100.000	
		0.000
0.233	100.000	
		28.600
0.251	71.400	
		56.300
0.270	14.600	
		14.400
0.289	0.200	

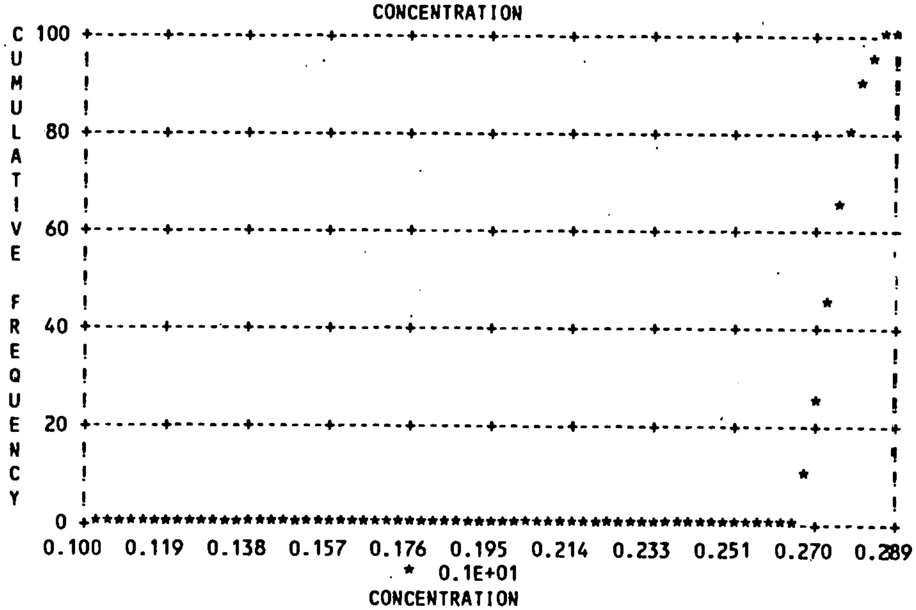
1


100
80
60
40
20
0
FREQUENCY %
0.100 0.119 0.138 0.157 0.176 0.195 0.214 0.233 0.251 0.270 0.289
* 0.1E+01
CONCENTRATION


100
80
60
40
20
0
CUMULATIVE FREQUENCY
0.100 0.119 0.138 0.157 0.176 0.195 0.214 0.233 0.251 0.270 0.289
* 0.1E+01
CONCENTRATION

FOLLOWING GRAPHS ARE FOR THE TOP 20% OF THERESULTS





1

U. S. ENVIRONMENTAL PROTECTION AGENCY

EXPOSURE ASSESSMENT

MULTIMEDIA MODEL

MULTIMED (Version 1.01, June 1991)

1

Run options

--- -------

SLAPS Site Suitability Study - Case 2

Monte Carlo simulation.
Chemical simulated is Radium

Option Chosen	Saturated and unsaturated zone models
Run was	MONTE
Infiltration input by user	
Number of monte carlo simulations	500

Run was steady-state
Reject runs if Y coordinate outside plume
Reject runs if Z coordinate outside plume
Patch source used in saturated zone model

1

1

UNSATURATED ZONE FLOW MODEL PARAMETERS
(input parameter description and value)

NP	- Total number of nodal points	240
NMAT	- Number of different porous materials	1
KPROP	- Van Genuchten or Brooks and Corey	1
IMSHGN	- Spatial discretization option	1
NVFLAYR	- Number of layers in flow model	1

OPTIONS CHOSEN

------- ------

Van Genuchten functional coefficients
User defined coordinate system

1

Layer information

LAYER NO.	LAYER THICKNESS	MATERIAL PROPERTY
1	1.00	1

DATA FOR MATERIAL 1

VADOSE ZONE MATERIAL VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Saturated hydraulic conductivity	cm/hr	LOG NORMAL	0.107	0.230	0.500E-04	0.720
Unsaturated zone porosity	---	NORMAL	0.150	0.140	0.100E-01	0.390
Air entry pressure head	m	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Depth of the unsaturated zone	m	CONSTANT	1.00	-999.	0.100E-08	-999.

DATA FOR MATERIAL 1

VADOSE ZONE FUNCTION VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Residual water content	--	UNIFORM	0.920E-01	-999.	0.834E-01	0.966E-01
Brook and Corey exponent,EN	--	CONSTANT	0.500	-999.	0.000E+00	10.0
ALFA coefficient	1/cm	UNIFORM	0.123E-01	-999.	0.987E-02	0.152E-01
Van Genuchten exponent, ENN	--	UNIFORM	1.25	-999.	1.21	1.29

1

UNSATURATED ZONE TRANSPORT MODEL PARAMETERS

NLAY	- Number of different layers used		1
NTSTPS	- Number of time values concentration calc		40
DUMMY	- Not presently used		1
ISOL	- Type of scheme used in unsaturated zone		1
N	- Stehfest terms or number of increments		18
NTEL	- Points in Lagrangian interpolation		3
NGPTS	- Number of Gauss points		104
NIT	- Convolution integral segments		2
IBOUND	- Type of boundary condition		1
ITSGEN	- Time values generated or input		1
TMAX	- Max simulation time	--	0.0
WTFUN	- Weighting factor	--	1.2

OPTIONS CHOSEN
------- ------
Stehfest numerical inversion algorithm
Nondecaying continuous source
Computer generated times for computing concentrations

1

DATA FOR LAYER 1
---- --- -----
VADOSE TRANSPORT VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Thickness of layer	m	CONSTANT	1.00	-999.	0.100E-08	-999.
Longitudinal dispersivity of layer	m	CONSTANT	0.420E-01	-999.	0.100E-02	0.100E+05
Percent organic matter	--	CONSTANT	0.800	-999.	0.000E+00	100.
Bulk density of soil for layer	g/cc	NORMAL	1.53	0.100	1.33	1.81
Biological decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.

1

CHEMICAL SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Solid phase decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Dissolved phase decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Overall chemical decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Acid catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Neutral hydrolysis rate constant	1/yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Base catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Reference temperature	C	CONSTANT	25.0	0.000E+00	0.000E+00	100.
Normalized distribution coefficient	ml/g	LOG NORMAL	0.139E+06	0.253E+06	0.129E+05	0.517E+06
Distribution coefficient	--	LOG NORMAL	643.	0.117E+04	60.0	0.240E+04
Biodegradation coefficient (sat. zone)	1/yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Air diffusion coefficient	cm2/s	CONSTANT	0.000E+00	0.645E-02	0.000E+00	10.0
Reference temperature for air diffusion	C	CONSTANT	0.000E+00	0.000E+00	0.000E+00	100.
Molecular weight	g/M	CONSTANT	-999.	0.000E+00	0.000E+00	-999.
Mole fraction of solute	--	CONSTANT	-999.	0.100E-01	0.100E-08	1.00
Vapor pressure of solute	mm Hg	CONSTANT	-999.	0.230E-01	0.000E+00	100.
Henry's law constant	atm-m^3/M	CONSTANT	-999.	0.000E+00	0.100E-09	1.00
Overall 1st order decay sat. zone	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	1.00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	1.00	0.000E+00	0.000E+00	1.00

1

SOURCE SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Infiltration rate	m/yr	CONSTANT	0.276E-01	-999.	0.100E-09	0.100E+11
Area of waste disposal unit	m^2	CONSTANT	0.300E+04	-999.	0.100E-01	-999.
Duration of pulse	yr	CONSTANT	-999.	-999.	0.100E-08	-999.
Spread of contaminant source	m	DERIVED	-999.	-999.	0.100E-08	0.100E+11
Recharge rate	m/yr	CONSTANT	0.276E-01	-999.	0.000E+00	0.100E+11
Source decay constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Initial concentration at landfill	mg/l	CONSTANT	1.00	-999.	0.000E+00	-999.
Length scale of facility	m	CONSTANT	150.	-999.	0.100E-08	0.100E+11
Width scale of facility	m	CONSTANT	20.0	-999.	0.100E-08	0.100E+11
Near field dilution		DERIVED	1.00	0.000E+00	0.000E+00	1.00

1

AQUIFER SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Particle diameter	cm	CONSTANT	0.235E-02	-999.	0.100E-08	100.
Aquifer porosity	--	NORMAL	0.150	0.140	0.100E-01	0.390
Bulk density	g/cc	NORMAL	1.54	0.120	1.33	1.81
Aquifer thickness	m	UNIFORM	10.8	-999.	7.90	13.7
Source thickness (mixing zone depth)	m	DERIVED	-999.	-999.	0.100E-08	0.100E+06
Conductivity (hydraulic)	m/yr	LOG NORMAL	21.1	31.2	0.390	94.7
Gradient (hydraulic)		UNIFORM	0.110E-01	-999.	0.710E-02	0.150E-01
Groundwater seepage velocity	m/yr	DERIVED	-999.	-999.	0.100E-09	0.100E+09
Retardation coefficient	--	DERIVED	-999.	-999.	1.00	0.100E+09
Longitudinal dispersivity	m	CONSTANT	5.50	15.0	0.100E-02	0.100E+05
Transverse dispersivity	m	CONSTANT	1.83	-999.	0.100E-02	0.100E+05
Vertical dispersivity	m	CONSTANT	0.308	-999.	0.100E-02	0.100E+05
Temperature of aquifer	C	CONSTANT	19.0	-999.	0.000E+00	100.
pH	--	UNIFORM	-999.	-999.	6.70	7.05
Organic carbon content (fraction)		CONSTANT	0.464E-02	-999.	0.100E-05	1.00
Well distance from site	m	CONSTANT	55.0	-999.	1.00	-999.
Angle off center	degree	CONSTANT	0.000E+00	-999.	0.000E+00	360.
Well vertical distance	m	CONSTANT	0.000E+00	-999.	0.000E+00	1.00

1 1355 Values generated which exceeded the specified bounds.

1

----- RESULTS -----

SATURATED ZONE TRANSPORT

SLAPS Site Suitability Study - Case 2

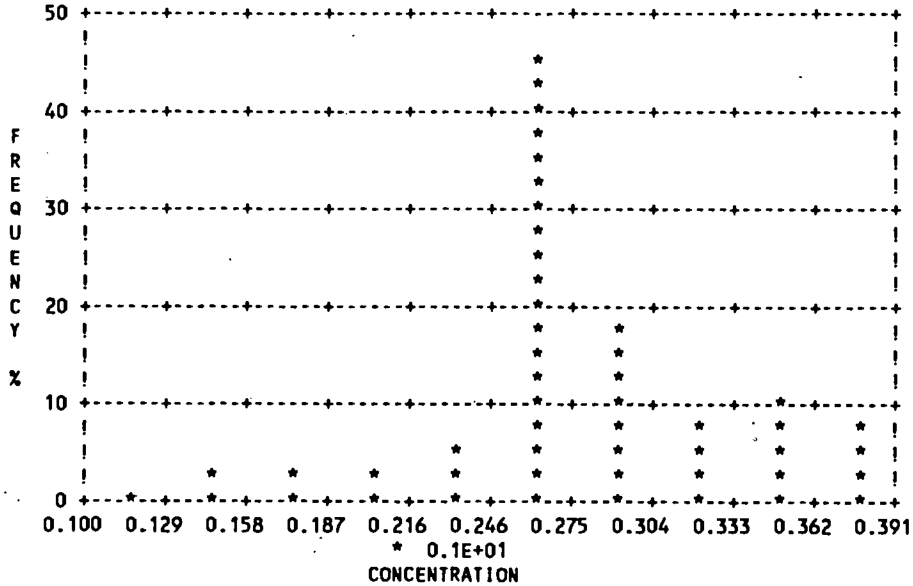
Monte Carlo simulation.

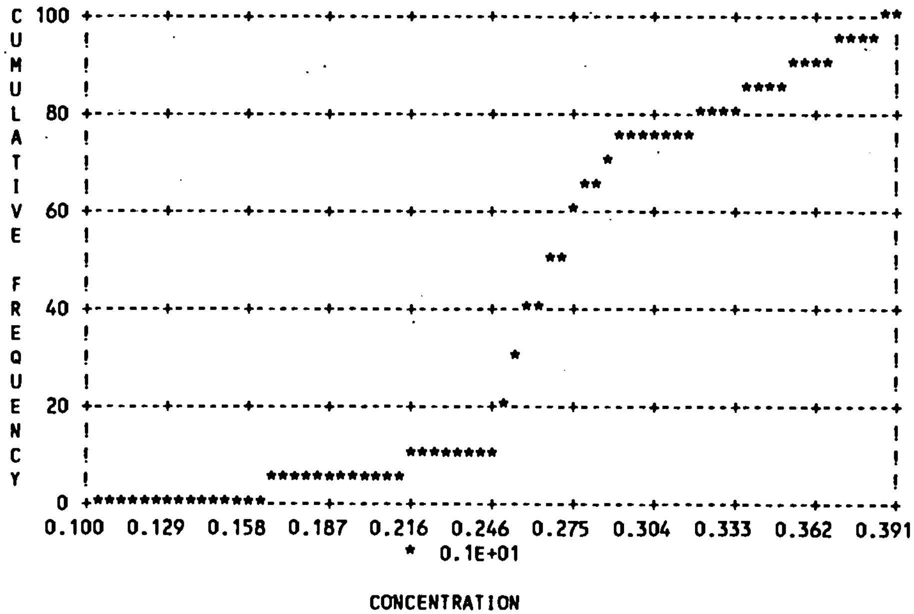
N	= 500		
MEAN	= 0.278		
STANDARD DEVIATION	= 0.509E-01		
COEFFICIENT OF VARIATION	= 0.183		
MINIMUM VALUE	= 0.129		
MAXIMUM VALUE	= 0.391		
50th PERCENTILE	= 0.268	0.265	0.271
80th PERCENTILE	= 0.327	0.313	0.334
85th PERCENTILE	= 0.341	0.333	0.351
90th PERCENTILE	= 0.357	0.351	0.368
95th PERCENTILE	= 0.378	0.370	0.382

-999 UNABLE TO COMPUTE CONFIDENCE BOUND DUE TO INSUFFICIENT DATA

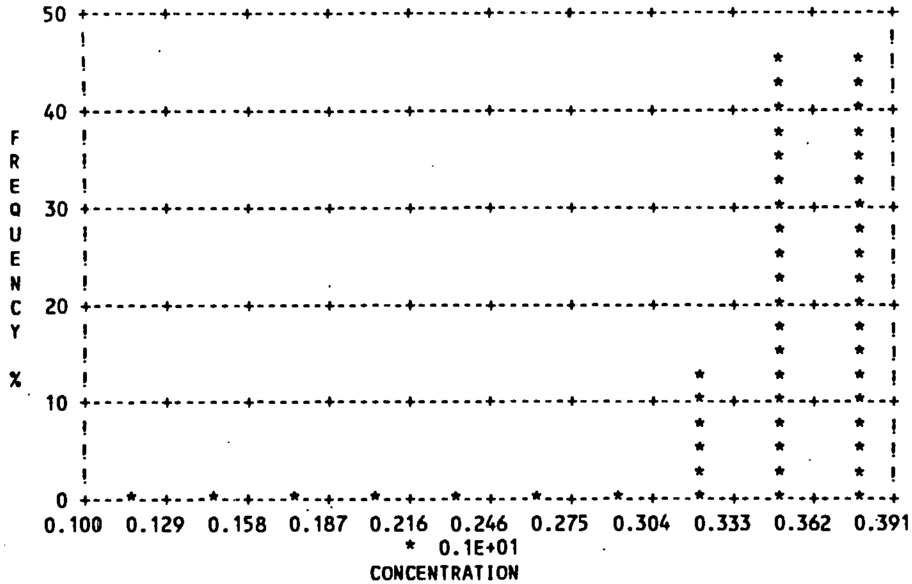
VALUE	% OF TIME EQUALLED OR EXCEEDED	% OF TIME IN INTERVAL
0.100	100.000	
		0.200
0.129	99.800	
		1.600
0.158	98.200	
		2.600
0.187	95.600	
		3.600
0.216	92.000	
		4.400
0.246	87.600	
		45.600
0.275	42.000	
		17.800
0.304	24.200	
		6.600
0.333	17.600	
		8.800
0.362	8.800	
		8.600
0.391	0.200	

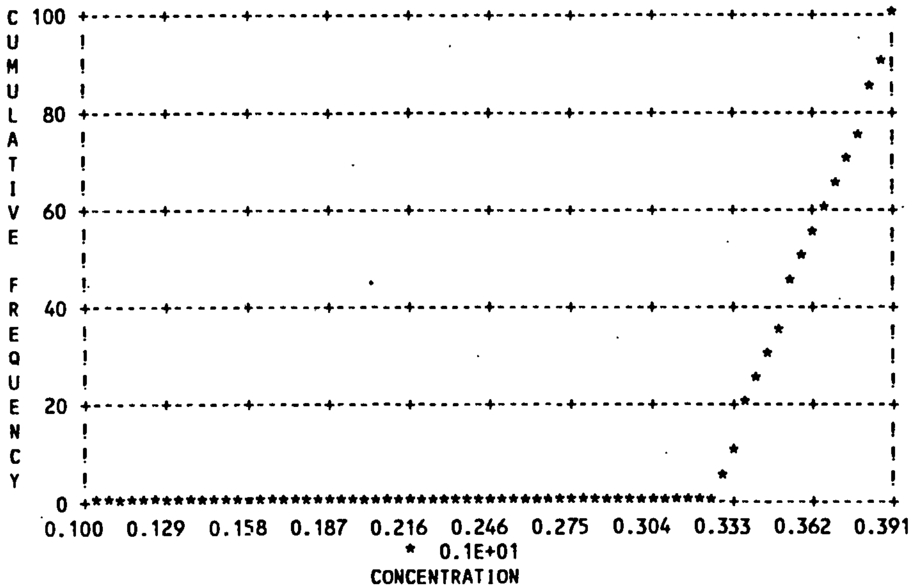
1


FREQUENCY %
50
40
30
20
10
0
0.100 0.129 0.158 0.187 0.216 0.246 0.275 0.304 0.333 0.362 0.391
* 0.1E+01
CONCENTRATION


CUMULATIVE FREQUENCY
100
80
60
40
20
0
0.100 0.129 0.158 0.187 0.216 0.246 0.275 0.304 0.333 0.362 0.391
* 0.1E+01
CONCENTRATION

FOLLOWING GRAPHS ARE FOR THE TOP 20% OF THERESULTS





1

U.S. ENVIRONMENTAL PROTECTION AGENCY

EXPOSURE ASSESSMENT

MULTIMEDIA MODEL

MULTIMED (Version 1.D1, June 1991)

1

Run options
--- -------

SLAPS Site Suitability Study - Case 3

Monte Carlo simulation.
Chemical simulated is Thorium

Option Chosen	Saturated and unsaturated zone models
Run was	MONTE
Infiltration input by user	
Number of monte carlo simulations	500
Run was steady-state	
Reject runs if Y coordinate outside plume	
Reject runs if Z coordinate outside plume	
Patch source used in saturated zone model	

1
1

UNSATURATED ZONE FLOW MODEL PARAMETERS
(input parameter description and value)

NP	- Total number of nodal points	240
NMAT	- Number of different porous materials	1
KPROP	- Van Genuchten or Brooks and Corey	1
IMSHGN	- Spatial discretization option	1
NVFLAYR	- Number of layers in flow model	1

OPTIONS CHOSEN
------- ------
Van Genuchten functional coefficients
User defined coordinate system

1

Layer information

LAYER NO.	LAYER THICKNESS	MATERIAL PROPERTY
1	1.00	1

DATA FOR MATERIAL 1

VADOSE ZONE MATERIAL VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Saturated hydraulic conductivity	cm/hr	LOG NORMAL	0.107	0.230	0.500E-04	0.720
Unsaturated zone porosity	--	NORMAL	0.150	0.140	0.100E-01	0.390
Air entry pressure head	m	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Depth of the unsaturated zone	m	CONSTANT	1.00	-999.	0.100E-08	-999.

DATA FOR MATERIAL 1

VADOSE ZONE FUNCTION VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Residual water content	--	UNIFORM	0.920E-01	-999.	0.834E-01	0.966E-01
Brook and Corey exponent,EN	--	CONSTANT	0.500	-999.	0.000E+00	10.0
ALFA coefficient	1/cm	UNIFORM	0.123E-01	-999.	0.987E-02	0.152E-01
Van Genuchten exponent, ENN	--	UNIFORM	1.25	-999.	1.21	1.29

1

UNSATURATED ZONE TRANSPORT MODEL PARAMETERS

NLAY	- Number of different layers used		1
NTSTPS	- Number of time values concentration calc		40
DUMMY	- Not presently used		1
ISOL	- Type of scheme used in unsaturated zone		1
N	- Stehfest terms or number of increments		18
NTEL	- Points in Lagrangian interpolation		3
NGPTS	- Number of Gauss points		104
NIT	- Convolution integral segments		2
IBOUND	- Type of boundary condition		1
ITSGEN	- Time values generated or input		1
TMAX	- Max simulation time	--	0.0
WTFUN	- Weighting factor	--	1.2

OPTIONS CHOSEN

Stehfest numerical inversion algorithm
Nondecaying continuous source
Computer generated times for computing concentrations
1

DATA FOR LAYER 1

VADOSE TRANSPORT VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Thickness of layer	m	CONSTANT	1.00	-999.	0.100E-08	-999.
Longitudinal dispersivity of layer	m	CONSTANT	0.420E-01	-999.	0.100E-02	0.100E+05
Percent organic matter	--	CONSTANT	0.800	-999.	0.000E+00	100.
Bulk density of soil for layer	g/cc	NORMAL	1.53	0.100	1.33	1.81
Biological decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.

1

CHEMICAL SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Solid phase decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Dissolved phase decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Overall chemical decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Acid catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Neutral hydrolysis rate constant	1/yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Base catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Reference temperature	C	CONSTANT	25.0	0.000E+00	0.000E+00	100.
Normalized distribution coefficient	ml/g	LOG NORMAL	0.401E+08	0.224E+06	0.646E+06	0.862E+08
Distribution coefficient	--	LOG NORMAL	0.186E+06	0.104E+04	0.300E+04	0.400E+06
Biodegradation coefficient (sat. zone)	1/yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Air diffusion coefficient	cm2/s	CONSTANT	0.000E+00	0.645E-02	0.000E+00	10.0
Reference temperature for air diffusion	C	CONSTANT	0.000E+00	0.000E+00	0.000E+00	100.
Molecular weight	g/M	CONSTANT	-999.	0.000E+00	0.000E+00	-999.
Mole fraction of solute	--	CONSTANT	-999.	0.100E-01	0.100E-08	1.00
Vapor pressure of solute	mm Hg	CONSTANT	-999.	0.230E-01	0.000E+00	100.
Henry's law constant	atm-m^3/M	CONSTANT	-999.	0.000E+00	0.100E-09	1.00
Overall 1st order decay sat. zone	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	1.00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	1.00	0.000E+00	0.000E+00	1.00

1

SOURCE SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Infiltration rate	m/yr	CONSTANT	0.276E-01	-999.	0.100E-09	0.100E+11
Area of waste disposal unit	m^2	CONSTANT	0.300E+04	-999.	0.100E-01	-999.
Duration of pulse	yr	CONSTANT	-999.	-999.	0.100E-08	-999.
Spread of contaminant source	m	DERIVED	-999.	-999.	0.100E-08	0.100E+11
Recharge rate	m/yr	CONSTANT	0.276E-01	-999.	0.000E+00	0.100E+11
Source decay constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Initial concentration at landfill	mg/l	CONSTANT	1.00	-999.	0.000E+00	-999.
Length scale of facility	m	CONSTANT	150.	-999.	0.100E-08	0.100E+11
Width scale of facility	m	CONSTANT	20.0	-999.	0.100E-08	0.100E+11
Near field dilution		DERIVED	1.00	0.000E+00	0.000E+00	1.00

1

AQUIFER SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Particle diameter	cm	CONSTANT	0.235E-02	-999.	0.100E-08	100.
Aquifer porosity	--	NORMAL	0.150	0.140	0.100E-01	0.390
Bulk density	g/cc	NORMAL	1.54	0.120	1.33	1.81
Aquifer thickness	m	UNIFORM	10.8	-999.	7.90	13.7
Source thickness (mixing zone depth)	m	DERIVED	-999.	-999.	0.100E-08	0.100E+06
Conductivity (hydraulic)	m/yr	LOG NORMAL	21.1	31.2	0.390	94.7
Gradient (hydraulic)		UNIFORM	0.110E-01	-999.	0.710E-02	0.150E-01
Groundwater seepage velocity	m/yr	DERIVED	-999.	-999.	0.100E-09	0.100E+09
Retardation coefficient	--	DERIVED	-999.	-999.	1.00	0.100E+09
Longitudinal dispersivity	m	CONSTANT	5.50	15.0	0.100E-02	0.100E+05
Transverse dispersivity	m	CONSTANT	1.83	-999.	0.100E-02	0.100E+05
Vertical dispersivity	m	CONSTANT	0.308	-999.	0.100E-02	0.100E+05
Temperature of aquifer	C	CONSTANT	19.0	-999.	0.000E+00	100.
pH	--	UNIFORM	-999.	-999.	6.70	7.05
Organic carbon content (fraction)		CONSTANT	0.464E-02	-999.	0.100E-05	1.00
Well distance from site	m	CONSTANT	55.0	-999.	1.00	-999.
Angle off center	degree	CONSTANT	0.000E+00	-999.	0.000E+00	360.
Well vertical distance	m	CONSTANT	0.000E+00	-999.	0.000E+00	1.00

1 1378 Values generated which exceeded the specified bounds.

1

----- RESULTS -----

SATURATED ZONE TRANSPORT

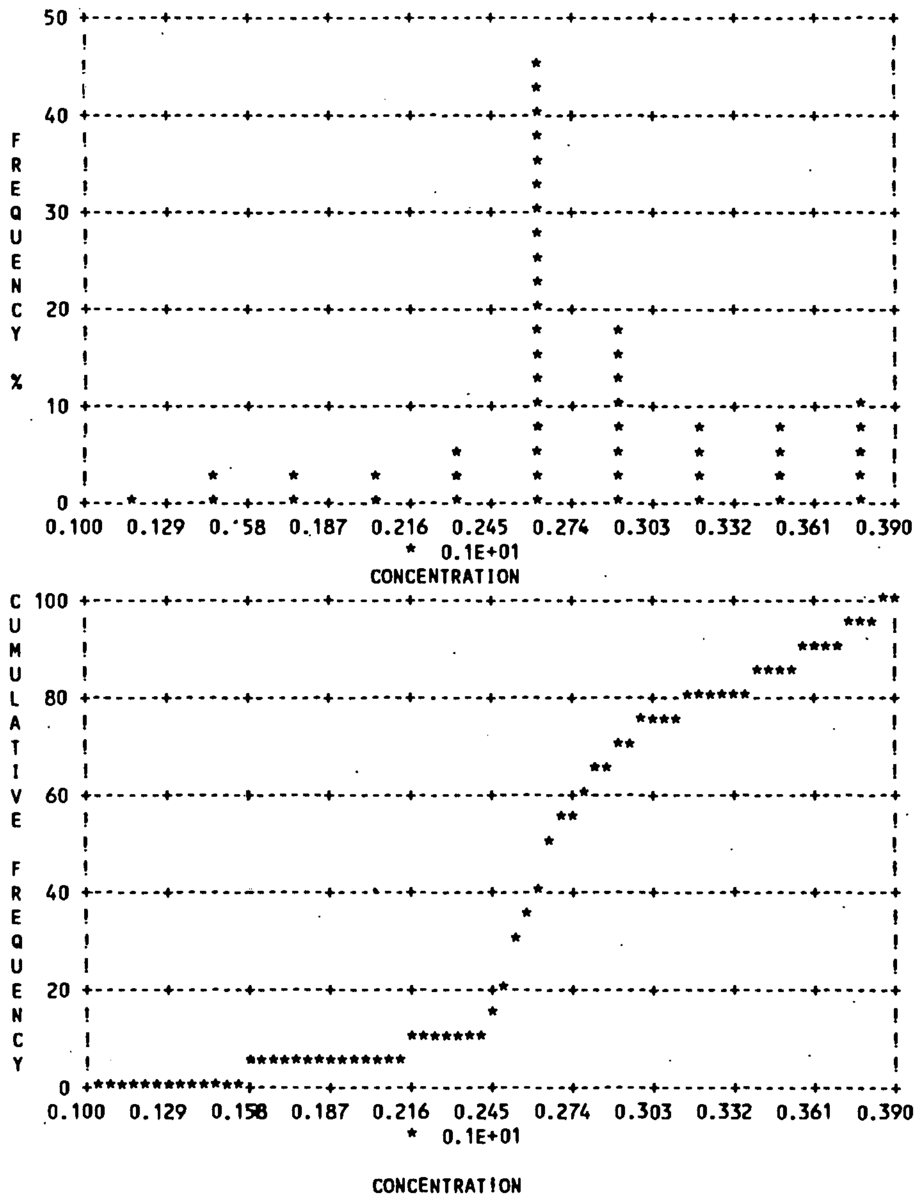
SLAPS Site Suitability Study - Case 3

Monte Carlo simulation.

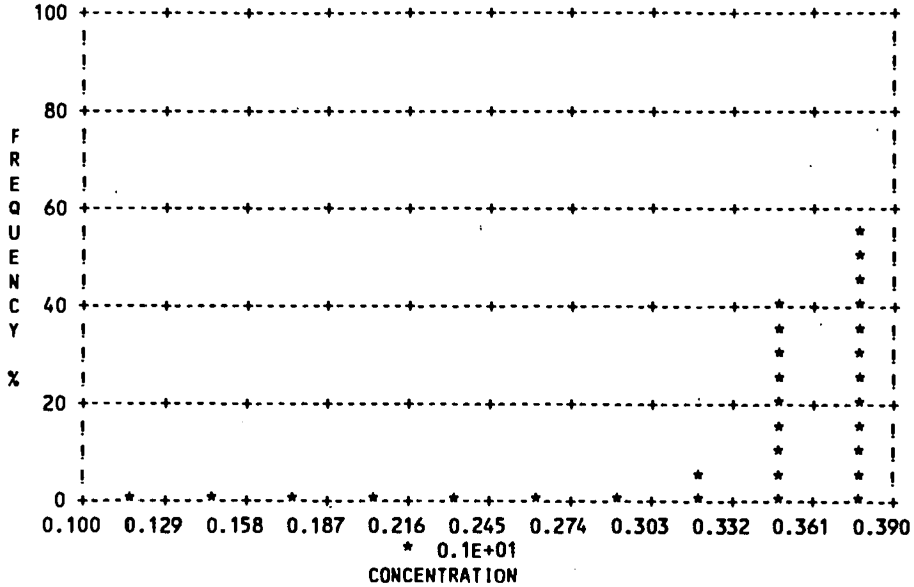
			90. PERCENT CONFIDENCE INTERVAL	
N	=	500		
MEAN	=	0.279		
STANDARD DEVIATION	=	0.524E-01		
COEFFICIENT OF VARIATION	=	0.183		
MINIMUM VALUE	=	0.121		
MAXIMUM VALUE	=	0.390		
50th PERCENTILE	=	0.267	0.265	0.270
80th PERCENTILE	=	0.327	0.313	0.339
85th PERCENTILE	=	0.344	0.338	0.354
90th PERCENTILE	=	0.362	0.354	0.370
95th PERCENTILE	=	0.378	0.374	0.382

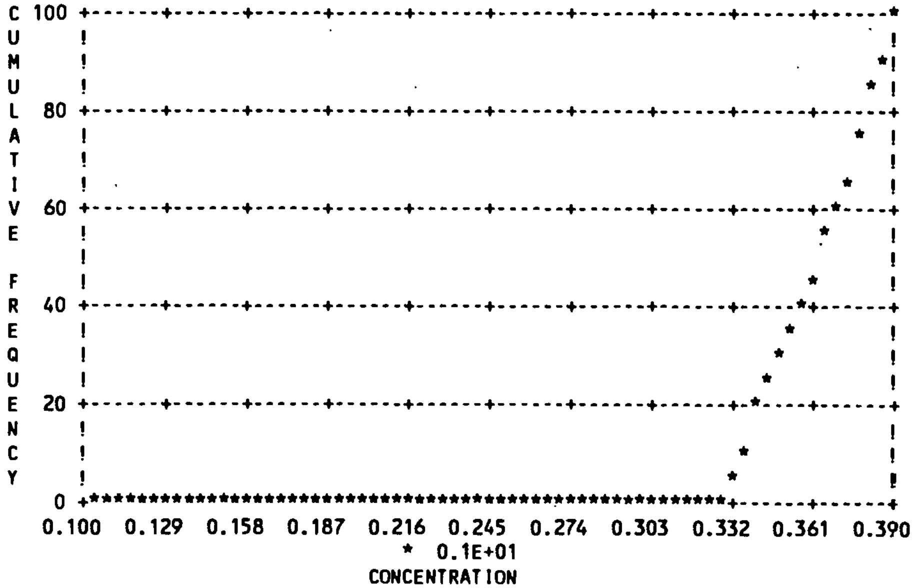
-999 UNABLE TO COMPUTE CONFIDENCE BOUND DUE TO INSUFFICIENT DATA

VALUE	% OF TIME EQUALLED OR EXCEEDED	% OF TIME IN INTERVAL
0.100	100.000	
		0.200
0.129	99.800	
		2.400
0.158	97.400	
		2.200
0.187	95.200	
		3.200
0.216	92.000	
		4.600
0.245	87.400	
		44.600
0.274	42.800	
		17.000
0.303	25.800	
		6.800
0.332	19.000	
		8.400
0.361	10.600	
		10.400
0.390	0.200	


FREQUENCY %
50
40
30
20
10
0
0.100 0.129 0.158 0.187 0.216 0.245 0.274 0.303 0.332 0.361 0.390
* 0.1E+01
CONCENTRATION
CUMULATIVE FREQUENCY
100
80
60
40
20
0
0.100 0.129 0.158 0.187 0.216 0.245 0.274 0.303 0.332 0.361 0.390
* 0.1E+01
CONCENTRATION

FOLLOWING GRAPHS ARE FOR THE TOP 20% OF THERESULTS





ATTACHMENT D-2

TRANSIENT SIMULATION RESULTS

1

U. S. ENVIRONMENTAL PROTECTION AGENCY

EXPOSURE ASSESSMENT

MULTIMEDIA MODEL

MULTIMED (Version 1.01, June 1991)

1

Run options
--- -------

SLAPS Site Suitability Study - Case 1 Transient

Deterministic Simulation
Chemical simulated is Uranium

Option Chosen	Saturated and unsaturated zone models
Run was	DETERMIN

Infiltration input by user
Run was transient
Reject runs if Y coordinate outside plume
Reject runs if Z coordinate outside plume
Gaussian source used in saturated zone model
1
1
UNSATURATED ZONE FLOW MODEL PARAMETERS
(input parameter description and value)

NP	- Total number of nodal points	240
NMAT	- Number of different porous materials	1
KPROP	- Van Genuchten or Brooks and Corey	1
IMSHGN	- Spatial discretization option	1
NVFLAYR	- Number of layers in flow model	1

OPTIONS CHOSEN
------- ------
Van Genuchten functional coefficients
User defined coordinate system
1

Layer information

LAYER NO.	LAYER THICKNESS	MATERIAL PROPERTY
1	1.00	1

DATA FOR MATERIAL 1

VADOSE ZONE MATERIAL VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Saturated hydraulic conductivity	cm/hr	CONSTANT	0.720	0.230	0.100E-10	0.100E+05
Unsaturated zone porosity	--	CONSTANT	0.150	0.140	0.100E-08	0.990
Air entry pressure head	m	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Depth of the unsaturated zone	m	CONSTANT	1.00	-999.	0.100E-08	-999.

DATA FOR MATERIAL 1

VADOSE ZONE FUNCTION VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Residual water content	--	CONSTANT	0.920E-01	-999.	0.100E-08	1.00
Brook and Corey exponent,EN	--	CONSTANT	0.500	-999.	0.000E+00	10.0
ALFA coefficient	1/cm	CONSTANT	0.123E-01	-999.	0.000E+00	1.00
Van Genuchten exponent, ENN	--	CONSTANT	1.25	-999.	1.00	5.00

1

UNSATURATED ZONE TRANSPORT MODEL PARAMETERS

NLAY	- Number of different layers used		1
NTSTPS	- Number of time values concentration calc		40
DUMMY	- Not presently used		1
ISOL	- Type of scheme used in unsaturated zone		1
N	- Stehfest terms or number of increments		18
NTEL	- Points in Lagrangian interpolation		3
NGPTS	- Number of Gauss points		104
NIT	- Convolution integral segments		2
IBOUND	- Type of boundary condition		2
ITSGEN	- Time values generated or input		1
TMAX	- Max simulation time	--	0.0
WTFUN	- Weighting factor	--	1.2

OPTIONS CHOSEN

Stehfest numerical inversion algorithm
Nondecaying pulse source
Computer generated times for computing concentrations

1

DATA FOR LAYER 1

VADOSE TRANSPORT VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Thickness of layer	m	CONSTANT	1.00	-999.	0.100E-08	-999.
Longitudinal dispersivity of layer	m	CONSTANT	0.420E-01	-999.	0.100E-02	0.100E+05
Percent organic matter	--	CONSTANT	0.800	-999.	0.000E+00	100.
Bulk density of soil for layer	g/cc	CONSTANT	1.53	0.100	0.100E-01	5.00
Biological decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.

1

CHEMICAL SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Solid phase decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Dissolved phase decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Overall chemical decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Acid catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Neutral hydrolysis rate constant	1/yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Base catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Reference temperature	C	CONSTANT	25.0	0.000E+00	0.000E+00	100.
Normalized distribution coefficient	ml/g	CONSTANT	0.237E+04	0.250E+06	0.000E+00	-999.
Distribution coefficient	--	CONSTANT	11.0	0.116	0.000E+00	0.100E+11
Biodegradation coefficient (sat. zone)	1/yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Air diffusion coefficient	cm2/s	CONSTANT	0.000E+00	0.645E-02	0.000E+00	10.0
Reference temperature for air diffusion	C	CONSTANT	0.000E+00	0.000E+00	0.000E+00	100.
Molecular weight	g/M	CONSTANT	-999.	0.000E+00	0.000E+00	-999.
Mole fraction of solute	--	CONSTANT	-999.	0.100E-01	0.100E-08	1.00
Vapor pressure of solute	mm Hg	CONSTANT	-999.	0.230E-01	0.000E+00	100.
Henry's law constant	atm-m^3/M	CONSTANT	-999.	0.000E+00	0.100E-09	1.00
Overall 1st order decay sat. zone	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	1.00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	1.00	0.000E+00	0.000E+00	1.00

1

SOURCE SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Infiltration rate	m/yr	CONSTANT	0.276E-01	-999.	0.100E-09	0.100E+11
Area of waste disposal unit	m^2	CONSTANT	0.300E+04	-999.	0.100E-01	-999.
Duration of pulse	yr	CONSTANT	0.100E+05	-999.	0.100E-08	-999.
Spread of contaminant source	m	DERIVED	-999.	-999.	0.100E-08	0.100E+11
Recharge rate	m/yr	CONSTANT	0.276E-01	-999.	0.000E+00	0.100E+11
Source decay constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Initial concentration at landfill	mg/l	CONSTANT	1.00	-999.	0.000E+00	-999.
Length scale of facility	m	CONSTANT	150.	-999.	0.100E-08	0.100E+11
Width scale of facility	m	CONSTANT	20.0	-999.	0.100E-08	0.100E+11
Near field dilution		DERIVED	1.00	0.000E+00	0.000E+00	1.00

1

AQUIFER SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Particle diameter	cm	CONSTANT	0.235E-02	-999.	0.100E-08	100.
Aquifer porosity	--	CONSTANT	0.150	0.140	0.100E-08	0.990
Bulk density	g/cc	CONSTANT	1.54	0.120	0.100E-01	5.00
Aquifer thickness	m	CONSTANT	10.8	-999.	0.100E-08	0.100E+06
Source thickness (mixing zone depth)	m	DERIVED	-999.	-999.	0.100E-08	0.100E+06
Conductivity (hydraulic)	m/yr	CONSTANT	94.7	31.2	0.100E-06	0.100E+09
Gradient (hydraulic)		CONSTANT	0.150E-01	-999.	0.100E-07	-999.
Groundwater seepage velocity	m/yr	DERIVED	-999.	-999.	0.100E-09	0.100E+09
Retardation coefficient	--	CONSTANT	114.	-999.	1.00	0.100E+09
Longitudinal dispersivity	m	CONSTANT	5.50	15.0	0.100E-02	0.100E+05
Transverse dispersivity	m	CONSTANT	1.83	-999.	0.100E-02	0.100E+05
Vertical dispersivity	m	CONSTANT	0.308	-999.	0.100E-02	0.100E+05
Temperature of aquifer	C	CONSTANT	19.0	-999.	0.000E+00	100.
pH	--	CONSTANT	6.90	-999.	0.300	14.0
Organic carbon content (fraction)		CONSTANT	0.464E-02	-999.	0.100E-05	1.00
Well distance from site	m	CONSTANT	55.0	-999.	1.00	-999.
Angle off center	degree	CONSTANT	0.000E+00	-999.	0.000E+00	360.
Well vertical distance	m	CONSTANT	0.000E+00	-999.	0.000E+00	1.00

1

TIME	CONCENTRATION
0.500E+02	0.00000E+00
0.100E+03	0.00000E+00
0.500E+03	0.39422E-04
0.100E+04	0.35042E-01
0.150E+04	0.11346E+00
0.200E+04	0.13950E+00
0.250E+04	0.14297E+00
0.300E+04	0.14344E+00
0.350E+04	0.14352E+00
0.400E+04	0.14351E+00
0.450E+04	0.14349E+00
0.500E+04	0.14347E+00
0.600E+04	0.14347E+00
0.700E+04	0.14347E+00
0.800E+04	0.14347E+00

1

U.S. ENVIRONMENTAL PROTECTION AGENCY

EXPOSURE ASSESSMENT

MULTIMEDIA MODEL

MULTIMED (Version 1.01, June 1991)

1

Run options
--- -------

SLAPS Site Suitability Study - Case 2 Transient

Deterministic Simulation
Chemical simulated is Radium

Option Chosen	Saturated and unsaturated zone models
Run was	DETERMIN

Infiltration input by user
Run was transient
Reject runs if Y coordinate outside plume
Reject runs if Z coordinate outside plume
Gaussian source used in saturated zone model
1
1

UNSATURATED ZONE FLOW MODEL PARAMETERS
(input parameter description and value)

NP	- Total number of nodal points	240
NMAT	- Number of different porous materials	1
KPROP	- Van Genuchten or Brooks and Corey	1
IMSHGN	- Spatial discretization option	1
NVFLAYR	- Number of layers in flow model	1

OPTIONS CHOSEN
------- ------

Van Genuchten functional coefficients
User defined coordinate system
1

Layer information

LAYER NO.	LAYER THICKNESS	MATERIAL PROPERTY
1	1.00	1

DATA FOR MATERIAL 1

VADOSE ZONE MATERIAL VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Saturatec hydraulic conductivity	cm/hr	CONSTANT	0.720	0.230	0.100E-10	0.100E+05
Unsaturated zone porosity	--	CONSTANT	0.150	0.140	0.100E-08	0.990
Air entry pressure head	m	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Depth of the unsaturated zone	m	CONSTANT	1.00	-999.	0.100E-08	-999.

DATA FOR MATERIAL 1

VADOSE ZONE FUNCTION VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Residual water content	--	CONSTANT	0.920E-01	-999.	0.100E-08	1.00
Brook and Corey exponent,EN	--	CONSTANT	0.500	-999.	0.000E+00	10.0
ALFA coefficient	1/cm	CONSTANT	0.123E-01	-999.	0.000E+00	1.00
Van Genuchten exponent, ENN	--	CONSTANT	1.25	-999.	1.00	5.00

1

UNSATURATED ZONE TRANSPORT MODEL PARAMETERS

NLAY	- Number of different layers used		1
NTSTPS	- Number of time values concentration calc		40
DUMMY	- Not presently used		1
ISOL	- Type of scheme used in unsaturated zone		1
N	- Stehfest terms or number of increments		18
NTEL	- Points in Lagrangian interpolation		3
NGPTS	- Number of Gauss points		104
NIT	- Convolution integral segments		2
IBOUND	- Type of boundary condition		2
ITSGEN	- Time values generated or input		1
TMAX	- Max simulation time	--	0.0
WTFUN	- Weighting factor	--	1.2

OPTIONS CHOSEN

Stehfest numerical irversion algorithm
Nondecaying pulse source
Computer generated times for computing concentrations

1

DATA FOR LAYER 1

VADOSE TRANSPORT VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Thickness of layer	m	CONSTANT	1.00	-999.	0.100E-08	-999.
Longitudinal dispersivity of layer	m	CONSTANT	0.420E-01	-999.	0.100E-02	0.100E+05
Percent organic matter	--	CONSTANT	0.800	-999.	0.000E+00	100.
Bulk density of soil for layer	g/cc	CONSTANT	1.53	0.100	0.100E-01	5.00
Biological decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.

1

CHEMICAL SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Solid phase decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Dissolved phase decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Overall chemical decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Acid catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Neutral hydrolysis rate constant	1/yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Base catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Reference temperature	C	CONSTANT	25.0	0.000E+00	0.000E+00	100.
Normalized distribution coefficient	ml/g	CONSTANT	0.129E+05	0.250E+06	0.000E+00	-999.
Distribution coefficient	--	CONSTANT	60.0	0.116	0.000E+00	0.100E+11
Biodegradation coefficient (sat. zone)	1/yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Air diffusion coefficient	cm2/s	CONSTANT	0.000E+00	0.645E-02	0.000E+00	10.0
Reference temperature for air diffusion	C	CONSTANT	0.000E+00	0.000E+00	0.000E+00	100.
Molecular weight	g/M	CONSTANT	-999.	0.000E+00	0.000E+00	-999.
Mole fraction of solute	--	CONSTANT	-999.	0.100E-01	0.100E-08	1.00
Vapor pressure of solute	mm Hg	CONSTANT	-999.	0.230E-01	0.000E+00	100.
Henry's law constant	atm-m^3/M	CONSTANT	-999.	0.000E+00	0.100E-09	1.00
Overall 1st order decay sat. zone	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	1.00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	1.00	0.000E+00	0.000E+00	1.00

1

SOURCE SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Infiltration rate	m/yr	CONSTANT	0.276E-01	-999.	0.100E-09	0.100E+11
Area of waste disposal unit	m^2	CONSTANT	0.300E+04	-999.	0.100E-01	-999.
Duration of pulse	yr	CONSTANT	0.200E+05	-999.	0.100E-08	-999.
Spread of contaminant source	m	DERIVED	-999.	-999.	0.100E-08	0.100E+11
Recharge rate	m/yr	CONSTANT	0.276E-01	-999.	0.000E+00	0.100E+11
Source decay constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Initial concentration at landfill	mg/l	CONSTANT	1.00	-999.	0.000E+00	-999.
Length scale of facility	m	CONSTANT	150.	-999.	0.100E-08	0.100E+11
Width scale of facility	m	CONSTANT	20.0	-999.	0.100E-08	0.100E+11
Near field dilution		DERIVED	1.00	0.000E+00	0.000E+00	1.00

1

AQUIFER SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Particle diameter	cm	CONSTANT	0.235E-02	-999.	0.100E-08	100.
Aquifer porosity	--	CONSTANT	0.150	0.140	0.100E-08	0.990
Bulk density	g/cc	CONSTANT	1.54	0.120	0.100E-01	5.00
Aquifer thickness	m	CONSTANT	10.8	-999.	0.100E-08	0.100E+06
Source thickness (mixing zone depth)	m	DERIVED	-999.	-999.	0.100E-08	0.100E+06
Conductivity (hydraulic)	m/yr	CONSTANT	94.7	31.2	0.100E-06	0.100E+09
Gradient (hydraulic)		CONSTANT	0.150E-01	-999.	0.100E-07	-999.
Groundwater seepage velocity	m/yr	DERIVED	-999.	-999.	0.100E-09	0.100E+09
Retardation coefficient	--	CONSTANT	617.	-999.	1.00	0.100E+09
Longitudinal dispersivity	m	CONSTANT	5.50	15.0	0.100E-02	0.100E+05
Transverse dispersivity	m	CONSTANT	1.83	-999.	0.100E-02	0.100E+05
Vertical dispersivity	m	CONSTANT	0.308	-999.	0.100E-02	0.100E+05
Temperature of aquifer	C	CONSTANT	19.0	-999.	0.000E+00	100.
pH	--	CONSTANT	6.90	-999.	0.300	14.0
Organic carbon content (fraction)		CONSTANT	0.464E-02	-999.	0.100E-05	1.00
Well distance from site	m	CONSTANT	55.0	-999.	1.00	-999.
Angle off center	degree	CONSTANT	0.000E+00	-999.	0.000E+00	360.
Well vertical distance	m	CONSTANT	0.000E+00	-999.	0.000E+00	1.00

1

TIME	CONCENTRATION
0.500E+02	0.00000E+00
0.100E+03	0.00000E+00
0.500E+03	0.00000E+00
0.100E+04	0.22216E-18
0.500E+04	0.24801E-01
0.100E+05	0.13755E+00
0.110E+05	0.14075E+00
0.120E+05	0.14217E+00
0.130E+05	0.14280E+00
0.140E+05	0.14307E+00
0.150E+05	0.14319E+00
0.160E+05	0.14324E+00
0.170E+05	0.14326E+00
0.180E+05	0.14327E+00
0.190E+05	0.14327E+00
0.200E+05	0.14327E+00

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U. S. ENVIRONMENTAL PROTECTION AGENCY

EXPOSURE ASSESSMENT

MULTIMEDIA MODEL

MULTIMED (Version 1.01, June 1991)

1

Run options

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SLAPS Site Suitability Study - Case 3 Transient

Deterministic Simulation
Chemical simulated is Thorium

Option Chosen	Saturated and unsaturated zone models
Run was	DETERMIN

Infiltration input by user
Run was transient
Reject runs if Y coordinate outside plume
Reject runs if Z coordinate outside plume
Gaussian source used in saturated zone model

1

1

UNSATURATED ZONE FLOW MODEL PARAMETERS
(input parameter description and value)

NP	- Total number of nodal points	240
NMAT	- Number of different porous materials	1
KPROP	- Van Genuchten or Brooks and Corey	1
IMSHGN	- Spatial discretization option	1
NVFLAYR	- Number of layers in flow model	1

OPTIONS CHOSEN

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Van Genuchten functional coefficients
User defined coordinate system

1

Layer information

LAYER NO.	LAYER THICKNESS	MATERIAL PROPERTY
1	1.00	1

DATA FOR MATERIAL 1

VADOSE ZONE MATERIAL VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Saturated hydraulic conductivity	cm/hr	CONSTANT	0.720	0.230	0.100E-10	0.100E+05
Unsaturated zone porosity	--	CONSTANT	0.150	0.140	0.100E-08	0.990
Air entry pressure head	m	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Depth of the unsaturated zone	m	CONSTANT	1.00	-999.	0.100E-08	-999.

DATA FOR MATERIAL 1

VADOSE ZONE FUNCTION VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Residual water content	--	CONSTANT	0.920E-01	-999.	0.100E-08	1.00
Brook and Corey exponent,EN	--	CONSTANT	0.500	-999.	0.000E+00	10.0
ALFA coefficient	1/cm	CONSTANT	0.123E-01	-999.	0.000E+00	1.00
Van Genuchten exponent, ENN	--	CONSTANT	1.25	-999.	1.00	5.00

1

UNSATURATED ZONE TRANSPORT MODEL PARAMETERS

NLAY	- Number of different layers used		1
NTSTPS	- Number of time values concentration calc		40
DUMMY	- Not presently used		1
ISOL	- Type of scheme used in unsaturated zone		1
N	- Stehfest terms or number of increments		18
NTEL	- Points in Lagrangian interpolation		3
NGPTS	- Number of Gauss points		104
NIT	- Convolution integral segments		2
IBOUND	- Type of boundary condition		2
ITSGEN	- Time values generated or input		1
TMAX	- Max simulation time	--	0.0
WTFUN	- Weighting factor	--	1.2

OPTIONS CHOSEN

Stehfest numerical inversion algorithm
Nondecaying pulse source
Computer generated times for computing concentrations

1

DATA FOR LAYER 1

VADOSE TRANSPORT VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	STD DEV	LIMITS MIN	MAX
Thickness of layer	m	CONSTANT	1.00	-999.	0.100E-08	-999.
Longitudinal dispersivity of layer	m	CONSTANT	0.420E-01	-999.	0.100E-02	0.100E+05
Percent organic matter	--	CONSTANT	0.800	-999.	0.000E+00	100.
Bulk density of soil for layer	g/cc	CONSTANT	1.53	0.100	0.100E-01	5.00
Biological decay coefficient	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.

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CHEMICAL SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	STD DEV	LIMITS MIN	MAX
Solid phase decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Dissolved phase decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Overall chemical decay coefficient	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	0.100E+11
Acid catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Neutral hydrolysis rate constant	1/yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Base catalyzed hydrolysis rate	l/M-yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Reference temperature	C	CONSTANT	25.0	0.000E+00	0.000E+00	100.
Normalized distribution coefficient	ml/g	CONSTANT	0.646E+06	0.250E+06	0.000E+00	-999.
Distribution coefficient	--	CONSTANT	0.300E+04	0.116	0.000E+00	0.100E+11
Biodegradation coefficient (sat. zone)	1/yr	CONSTANT	0.000E+00	0.000E+00	0.000E+00	-999.
Air diffusion coefficient	cm2/s	CONSTANT	0.000E+00	0.645E-02	0.000E+00	10.0
Reference temperature for air diffusion	C	CONSTANT	0.000E+00	0.000E+00	0.000E+00	100.
Molecular weight	g/M	CONSTANT	-999.	0.000E+00	0.000E+00	-999.
Mole fraction of solute	--	CONSTANT	-999.	0.100E-01	0.100E-08	1.00
Vapor pressure of solute	mm Hg	CONSTANT	-999.	0.230E-01	0.000E+00	100.
Henry's law constant	atm-m^3/M	CONSTANT	-999.	0.000E+00	0.100E-09	1.00
Overall 1st order decay sat. zone	1/yr	DERIVED	0.000E+00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	1.00	0.000E+00	0.000E+00	1.00
Not currently used		CONSTANT	1.00	0.000E+00	0.000E+00	1.00

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SOURCE SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Infiltration rate	m/yr	CONSTANT	0.276E-01	-999.	0.100E-09	0.100E+11
Area of waste disposal unit	m^2	CONSTANT	0.300E+04	-999.	0.100E-01	-999.
Duration of pulse	yr	CONSTANT	0.100E+07	-999.	0.100E-08	-999.
Spread of contaminant source	m	DERIVED	-999.	-999.	0.100E-08	0.100E+11
Recharge rate	m/yr	CONSTANT	0.276E-01	-999.	0.000E+00	0.100E+11
Source decay constant	1/yr	CONSTANT	0.000E+00	-999.	0.000E+00	-999.
Initial concentration at landfill	mg/l	CONSTANT	1.00	-999.	0.000E+00	-999.
Length scale of facility	m	CONSTANT	150.	-999.	0.100E-08	0.100E+11
Width scale of facility	m	CONSTANT	20.0	-999.	0.100E-08	0.100E+11
Near field dilution		DERIVED	1.00	0.000E+00	0.000E+00	1.00

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AQUIFER SPECIFIC VARIABLES

VARIABLE NAME	UNITS	DISTRIBUTION	PARAMETERS MEAN	PARAMETERS STD DEV	LIMITS MIN	LIMITS MAX
Particle diameter	cm	CONSTANT	0.235E-02	-999.	0.100E-08	100.
Aquifer porosity	--	CONSTANT	0.150	0.140	0.100E-08	0.990
Bulk density	g/cc	CONSTANT	1.54	0.120	0.100E-01	5.00
Aquifer thickness	m	CONSTANT	10.8	-999.	0.100E-08	0.100E+06
Source thickness (mixing zone depth)	m	DERIVED	-999.	-999.	0.100E-08	0.100E+06
Conductivity (hydraulic)	m/yr	CONSTANT	94.7	31.2	0.100E-06	0.100E+09
Gradient (hydraulic)		CONSTANT	0.150E-01	-999.	0.100E-07	-999.
Groundwater seepage velocity	m/yr	DERIVED	-999.	-999.	0.100E-09	0.100E+09
Retardation coefficient	--	CONSTANT	0.308E+05	-999.	1.00	0.100E+09
Longitudinal dispersivity	m	CONSTANT	5.50	15.0	0.100E-02	0.100E+05
Transverse dispersivity	m	CONSTANT	1.83	-999.	0.100E-02	0.100E+05
Vertical dispersivity	m	CONSTANT	0.308	-999.	0.100E-02	0.100E+05
Temperature of aquifer	C	CONSTANT	19.0	-999.	0.000E+00	100.
pH	--	CONSTANT	6.90	-999.	0.300	14.0
Organic carbon content (fraction)		CONSTANT	0.464E-02	-999.	0.100E-05	1.00
Well distance from site	m	CONSTANT	55.0	-999.	1.00	-999.
Angle off center	degree	CONSTANT	0.000E+00	-999.	0.000E+00	360.
Well vertical distance	m	CONSTANT	0.000E+00	-999.	0.000E+00	1.00

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TIME	CONCENTRATION
0.500E+02	0.00000E+00
0.100E+03	0.00000E+00
0.500E+03	0.00000E+00
0.100E+04	0.00000E+00
0.500E+04	0.00000E+00
0.100E+05	0.00000E+00
0.500E+05	0.22216E-18
0.100E+06	0.59142E-06
0.500E+06	0.13759E+00
0.600E+06	0.14219E+00
0.700E+06	0.14308E+00
0.800E+06	0.14324E+00
0.850E+06	0.14326E+00
0.900E+06	0.14327E+00
0.950E+06	0.14327E+00