JOHN ASHCROFT
Governor

G. TRACY MEHAN III
Director

Division of Energy
Division of Environmental Quality
Division of Geology and Land Survey
Division of Management Services
Division of Parks, Recreation, and Historic Preservation

STATE OF MISSOURI

DEPARTMENT OF NATURAL RESOURCES

OFFICE OF THE DIRECTOR
P.O. Box 176
Jefferson City, MO 65102
314-751-4422

October 17, 1989

Mr. Kenneth M. Carr, Chairman
U.S. Nuclear Regulatory Commission
One White Flint North Building
11555 Rockville Pike
Rockville, MD 20852

Dear Chairman Carr:

I understand, that during your visit to Missouri last year, you were briefed on the radioactive wastes at the Westlake Landfill Site in St. Louis County. The state has been urging the federal government to remedy this situation for over ten years and I continue to be concerned about the lack of action at this site.

The state believes that since the waste was transported to the site while under federal license, it is a federal responsibility to insure that a cleanup is initiated. I was encouraged recently to learn that the U.S. Nuclear Regulatory Commission is initiating an enforcement action against the Cotter Corporation regarding the Westlake waste.

I also understand that the U.S. Environmental Protection Agency (EPA) intends to propose the site for the Superfund National Priority List (NPL). I believe that listing the site on the NPL should not interfere with your enforcement action. However, I urge you to coordinate your actions with the EPA as soon as possible. Also, while the state does not want to take the lead at this site, we do want to be involved in the decision-making process and to assist in any way that we can.

I hope that you can proceed with your enforcement action as soon as possible so that this situation can be quickly resolved. Please keep me informed about your activities at the Westlake Site.

Very truly yours,

DEPARTMENT OF NATURAL RESOURCES

G. Tracy Mehan, III
Director

GTM/dbc

cc: Mr. Morris Kay, Regional Administrator
U.S. EPA, Region VII

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NUREG-1308
Rev. 1

Radioactive Material in the West Lake Landfill

Summary Report

U.S. Nuclear Regulatory Commission

Office of Nuclear Material Safety and Safeguards

8808050227

Enclosure 1

ABSTRACT

The West Lake Landfill is located near the city of St. Louis in Bridgeton, St. Louis County, Missouri. The site has been used since 1962 for disposing of municipal refuse, industrial solid and liquid wastes, and construction demolition debris.

This report summarizes the circumstances of the radioactive material in the West Lake Landfill. The radioactive material resulted from the processing of uranium ores and the subsequent sale by the AEC of processing residues. Primary emphasis is on the radiological environmental aspects as they relate to potential disposition of the material. It is concluded that remedial action is called for.

CONTENTS

1 INTRODUCTION AND BACKGROUND

This report summarizes the circumstances of the radioactive material in the West Lake Landfill (Figure 1), in particular, the radiological environmental aspects as they relate to potential disposition of the material.

The West Lake Landfill, Inc. property is a 200 acre tract in Bridgeton, St. Louis County, Missouri, on the outskirts of the city of St. Louis. It is about 4 miles west of St. Louis' Lambert Field International Airport, near the intersection of interstate highways I-70 and I-270. Limestone was quarried there from 1939 to 1987. Also on the property is an industrial complex where concrete ingredients are measured and combined, and where asphalt aggregate is prepared. Since 1962, portions of the property have been used as landfills for disposing of municipal refuse, industrial solid and liquid wastes, and construction demolition debris. In 1973, soil contaminated with radioactive material was placed in a landfill there.

The radioactive material originated with uranium-ore-processing residues which had been stored at Lambert Airport by the U.S. Atomic Energy Commission (AEC), and which were sold in early 1966 to the Continental Mining and Milling Company, of Chicago, Illinois. The AEC's invitation to bid listed the following residues for purchase: 74,000 tons of Belgian Congo pitchblende raffinate containing about 113 tons of uranium; 32,500 tons of Colorado raffinate containing about 48 tons of uranium; and 8700 tons of leached barium sulfate containing about 7 tons of uranium. The material was moved from the airport during 1966 to nearby 9200 Latty Avenue, Hazelwood, Missouri. In January 1967, the Commercial Discount Corporation of Chicago took possession of the residues to remove moisture and to ship the residues to the Cotter Corporation facilities in Canon City, Colorado. In December 1969, the remaining material was sold to the Cotter Corporation. In the following four years, the residues, with the principal exception of the 8700 tons of leached barium sulfate, were shipped to Canon City.[1]

In April 1974, Region III representatives of NRC's Office of Inspection and Enforcement visited the Cotter Corporation's Latty Avenue site to check on the progress of the decommissioning activities being performed there. This inspection disclosed that in 1973 Cotter Corporation had disposed of approximately 8700 tons of leached barium sulfate residues mixed with 39,000 tons of top soil at a local landfill.[1]

By letter dated June 2, 1976, the Missouri Department of Natural Resources (MDNR) forwarded to the NRC's Region III office newspaper articles which alleged that only 9000 tons of waste had been moved from the Latty Avenue site rather than 40,000 tons and that it was moved to the West Lake Landfill rather than to the St. Louis Landfill No. 1. Region III personnel investigated the allegations and found that 43,000 tons of waste and soil had been removed from the Latty Avenue site and had been dumped at the West Lake Landfill in Bridgeton, and that the waste was covered with only about 3 feet of soil.[1]

Discussion with the West Lake Landfill operators indicated that all of the material from Latty Avenue had been disposed of in one area; however, an aerial

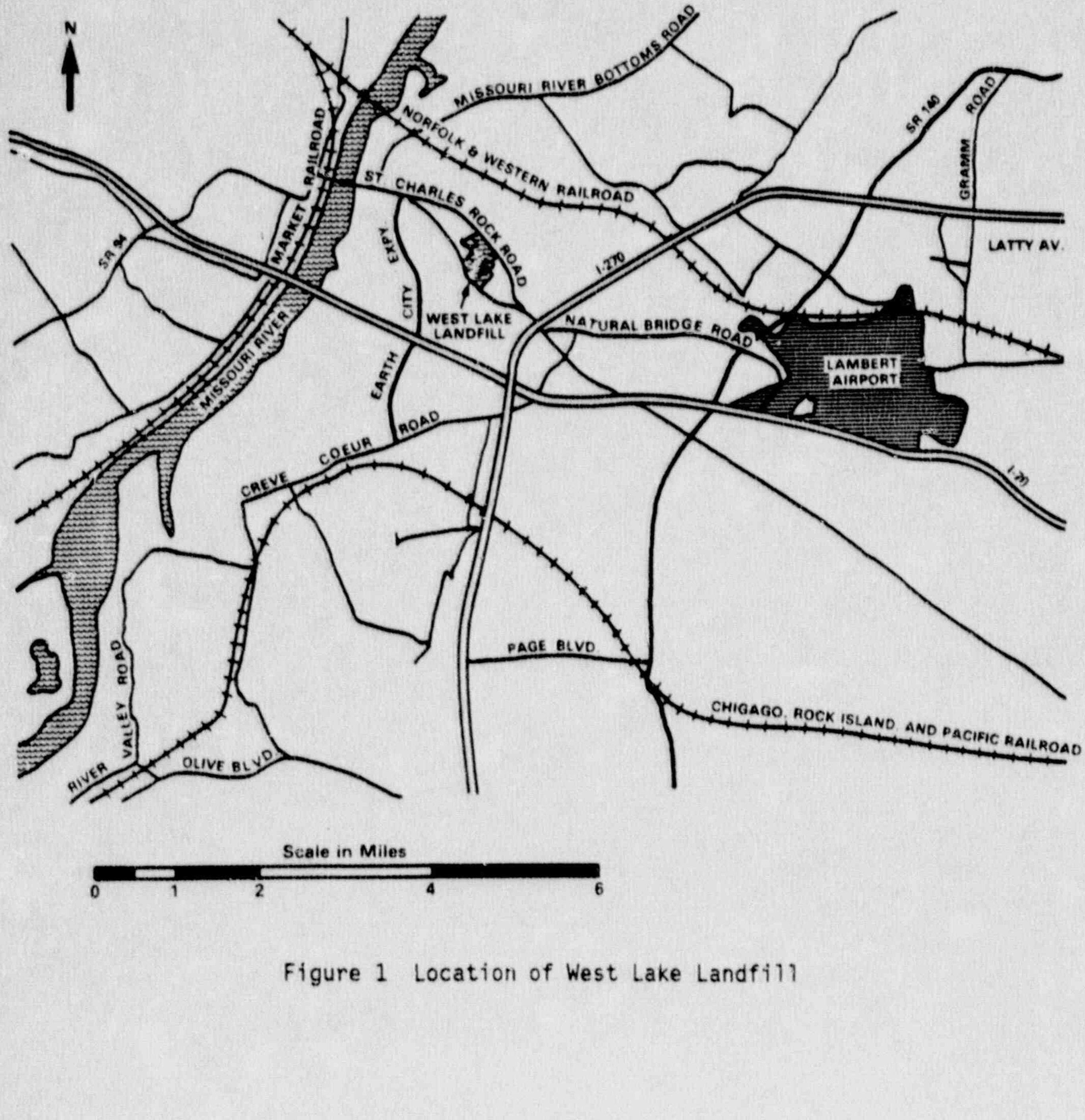

Figure 1 Location of West Lake Landfill

survey of the site identified two areas of contamination. The second contaminated area is identified as Area 1 in Figure 2.[2] Subsequently, the NRC sponsored other studies that were directed at determining the radiological status of the landfill. An extensive survey was initiated in November 1980 by the Radiation Management Corporation (RMC) under contract to the NRC. The findings were published in May 1982 in NUREG/CR-2722, "Radiological Survey of the West Lake Landfill, St. Louis County, Missouri."[3] In March 1983, the NRC through Oak Ridge Associated Universities (ORAU) contracted with the University of Missouri-Columbia (UMC), Department of Civil Engineering, to describe the environmental characteristics of the site, conduct an engineering evaluation, and propose possible remedial measures for dealing with the radioactive waste at the West Lake Landfill. In May 1986, ORAU sampled water from wells on and close to the landfill to determine if the radioactive material had migrated into the groundwater. A report is being prepared detailing the results of the investigations conducted by UMC and ORAU.[2]

Information from all these sources and from NRC site visits forms the basis for this report.

2 DESCRIPTION OF THE SITE

Location

The 200-acre West Lake Landfill site is situated on the southwest side of St. Charles Rock Road in Bridgeton, St. Louis County, Missouri (Figure 1).[2] It is about 16 miles northwest of the downtown area of the city of St. Louis, and about 4 miles west of Lambert Field International Airport (Figure 1). It is approximately 1.2 miles from the Missouri River.

History

The West Lake Landfill has been used since 1962 for the disposal of municipal refuse, industrial solid and liquid wastes, and construction demolition debris. Between 1939 and the spring of 1987, limestone was quarried there. Landfill operations filled in some of the excavated pits from the quarry operations. Also on the property is an active industrial complex in which concrete ingredients are measured and combined before mixing ("batching"), and asphalt aggregate is prepared.

The unregulated landfill, in which the radioactive material was placed in 1973, was closed in 1974 by the Missouri Department of Natural Resources (MDNR). Also in 1974, under an MDNR permit, a newer sanitary landfill was opened and now operates in an adjacent area on the West Lake Landfill property. The newer landfill is protected from groundwater contact. The bottom of the new landfill is lined with clay, and a leachate collection system has been installed. Leachate is pumped to a treatment system consisting of a lime precipitation unit followed in series by an aerated lagoon and two unaerated lagoons. The final lagoon effluent is discharged into St. Louis Metropolitan Sewer District sewers.[2]

Ownership

Since 1939, the West Lake Landfill has been owned by West Lake Landfill, Inc., of 13570 St. Charles Rock Road, Bridgeton, Missouri.

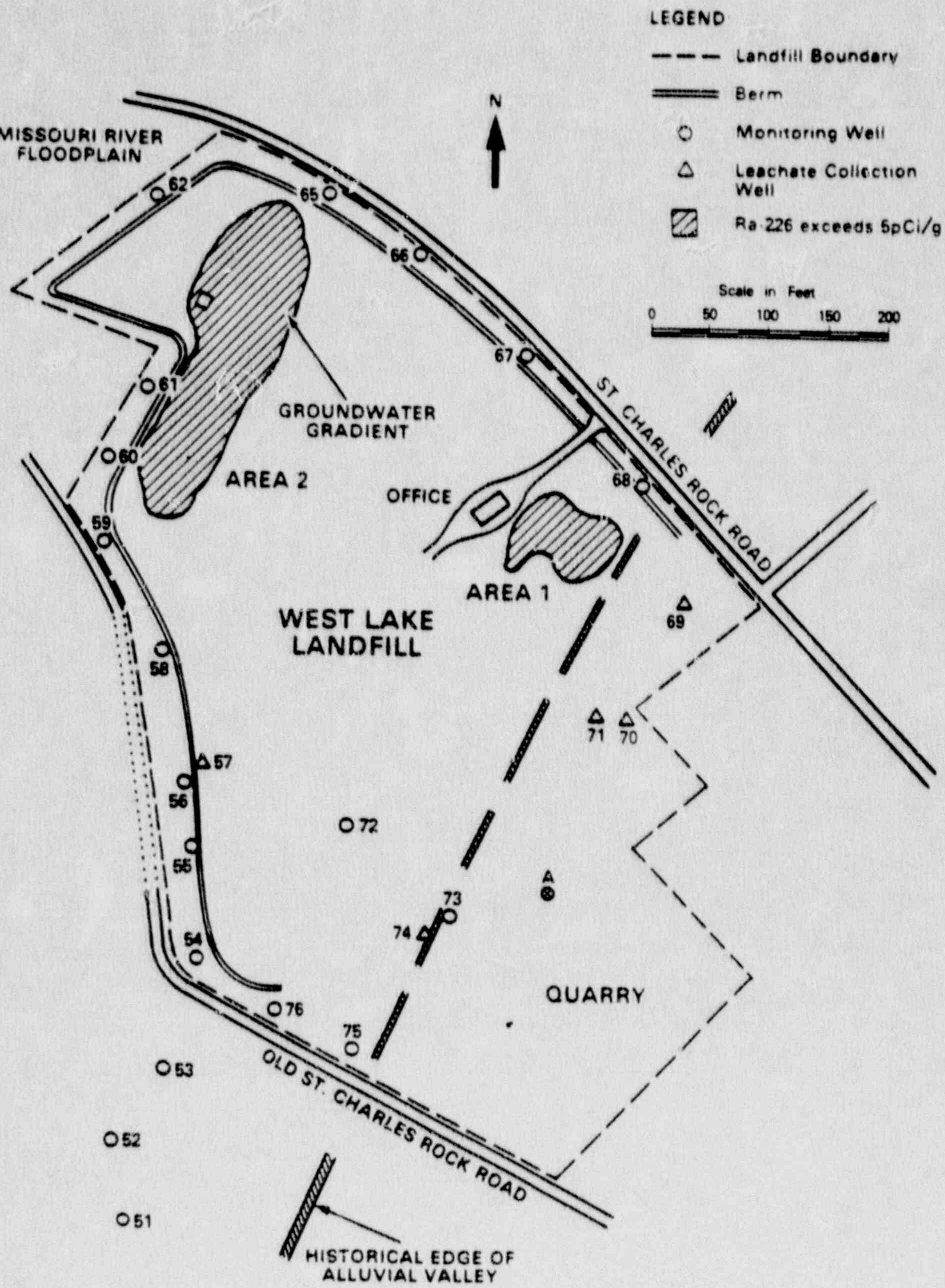

Figure 2 Site Details

Contaminated Areas

Radioactive contamination at the West Lake Landfill has been identified in two separate soil bodies (Figure 2).

The northern area (referred to as Area 2) covers about 13 acres[3] and lies above 16 to 20 feet of landfill debris. The contaminated soil forms a more or less continuous layer from 2 to 15 feet in thickness and consists of approximately 130,000 cubic yards of soil. Some of this contaminated soil is near or at the surface, particularly along the face of the northwestern berm. Beneath the landfill debris, the soil profile consists of 3 to 7 feet of floodplain top soil overlying 30 to 50 feet of sand and gravel alluvium.

The southern area of contamination (Area 1) covers about 3 acres[3] and contains roughly 20,000 cubic yards of contaminated soil. This body of soil is located east of the landfill's main office at a depth of about 3 to 5 feet and is located over a former quarry pit which was filled in with debris. The depth of debris beneath the contaminated soil is unknown but is estimated to be 50 to 65 feet. Limestone bedrock underlies the landfill debris.[2]

Topography

About 75 percent of the landfill site is located on the floodplain of the Missouri River (Figure 2) at about 440 feet above mean sea level (msl). The site topography is subject to change because of the types of activities (e.g., landfilling and quarrying) performed there. However, the areas containing the radioactive waste have their surface at about 470 feet (msl). The surface runoff in the area around the landfill follows several surface drains and ditches that run in a northwest direction and drain into the Missouri River.[2]

Geology

Bedrock beneath the West Lake Landfill consists of limestone that extends downward to an elevation of 190 feet msl. The limestone is dense, bedded, and except for intermittent layers that consist of abundant chert nodules, fairly pure. The Warsaw Formation, which lies directly beneath the limestone, is made up of approximately 40 feet of slightly calcareous, dense shale; this grades into shaley limestone toward the middle of the formation. Bedrock beneath the site dips at an angle of 0.5° to the northeast. Five miles east of the site, the attitude of the bedrock is reversed by the Florissant Dome.[2]

Since groundwater moving through carbonate rocks often creates channels for rapid water flow, the possibility of this occurring in the West Lake Landfill area was considered. Brief observation of the quarry walls at the landfill suggests that some of the limestone has dissolved. In a letter to West Lake Landfill, Inc., the Missouri Department of Natural Resources stated that the fact that grouting was necessary in the quarry area to block water inflow suggests that the limestone is at least somewhat solution weathered.[4] However, in the draft UMC report, the opinion is expressed that the solution activity has apparently been limited to minor widening of joints and bedding planes near the bedrock surface, and that, at depth and when undisturbed, the limestone is fairly impervious.[2] It is not clear whether the views represented by these statements are in conflict.

Soil material in the area may be divided into two categories: Missouri River alluvium and upland loessal soil. This demarcation is shown as the historical edge of the alluvial valley in Figure 2. The division is made on the basis of soil composition, depositional history, and physical properties. The West Lake Landfill lies over this transition zone.[2]

Hydrology

Groundwater flows in the area surrounding the West Lake site through two aquifers: the Missouri River alluvium and the shallow limestone bedrock. Although the limestone is fairly impervious and groundwater flows in most areas from the bedrock into the alluvium, contamination of water in the bedrock aquifer is possible. The base of the limestone aquifer is formed by the relatively impermeable Warsaw shale at an elevation of about 190 feet (msl). This shale layer has been reached, but not disturbed, by quarrying operations. Therefore, the Warsaw shale acts as an aquiclude, making contamination of the deeper limestone unlikely.

The deep Missouri River alluvium, which is under about 10 feet of more-recent alluvium, acts as a single aquifer of very high permeability. This aquifer is relatively homogeneous in a downstream direction and decreases in permeability near the valley walls.

The water table of the Missouri River floodplain is generally within 10 feet of the ground surface, but at many points it is even shallower. At any one time, the water levels and flow directions are influenced by both the river stage and the amount of water entering the floodplain from adjacent upland areas.

Water levels recorded between November 1983 and March 1984 in monitoring wells at the landfill, indicate a groundwater gradient of 0.005 flowing in a N 30°W direction beneath the northern portion of the landfill. This represents the likely direction of leachate migration from the landfill.

Since no other recharge sources exist above the level of the floodplain, the only water available to leach the landfill debris is that resulting from rainfall infiltrating the landfill surface. Because the underlying alluvial aquifer is highly permeable, there will be little "mounding" of water beneath the landfill. Also, the northern portion of the landfill has a level surface, and thus it is likely that at least half of the rainfall infiltrates the surface. The remaining rainfall is lost to evapotranspiration and (to a lesser degree) surface runoff.[2]

No public water supplies are drawn from the alluvial aquifer near the West Lake Landfill. It is believed that only one private well in the vicinity of the landfill is used as a drinking-water supply. This well is 1.4 miles N 35°W of the Butler-type building on the West Lake Landfill.

Because of the extremely low slope of the Missouri River floodplain surface, rain falling on the plain itself generally infiltrates the soil rather than running off the surface. The only streams present on the floodplain are those that originate in upland areas. Drainage patterns on the plain have been radically altered by flood control measures taken to protect Earth City and by drainage of swamps and marshes. Because of the relationship that exists between river level and groundwater level in portions of the floodplain near the river, streams may either lose flow (at low stage) or gain flow (at high stage).

The present channel of the Missouri River lies just under 2 miles west and northwest of the landfill. The Missouri River stage at St. Charles (mile 28) is zero for a water level of 413.7 feet (msl). Average discharge of the Missouri River is 77,338 cubic feet per second.

Water supplies are drawn from the Missouri River at mile 29 for the city of St. Charles, and the intake is located on the north bank of the river. Another intake at mile 20.5 is for the St. Louis Water Company's North County plant. The city of St. Louis takes water from the Mississippi River, which is joined by the Missouri River downstream from the landfill. The intake structures for St. Louis are on the east bank of the river, so that the water drawn is derived from the upper Mississippi.[2]

Demography

Two small residential communities are present near the West Lake Landfill: Spanish Lake Village consists of about 90 homes and is located 0.9 mile south of the landfill, and a small trailer court lies across St. Charles Rock Road, 0.9 mile southeast of the site. Subdivisions are presently being developed 1 to 2 miles east and southeast of the landfill in the hills above the floodplain. Ten or more houses lie east of the landfill, scattered along Taussig Road. The city of St. Charles is located north of the Missouri River, more than 2 miles from the landfill.[2]

Population density on the floodplain is generally less than 26 persons per square mile, but the daytime population (including factory workers) is much greater than the number of full-time residents. Earth City Industrial Park is located on the floodplain 0.9 to 1.2 miles northwest of the landfill. The Ralston-Purina facilities are located 0.2 mile northeast of the Butler-type building at the landfill. Considering that land in this area is relatively inexpensive and that much of it is zoned for manufacturing, industrial development on the floodplain will likely increase.[2]

3 RADIOLOGICAL SURVEYS

From August 1980 through the summer of 1981, the Radiation Management Corporation (RMC), under contract to the NRC, performed an onsite evaluation of the West Lake Landfill[3] to define the radiological conditions at the landfill. The results were utilized in performing this determination regarding whether or not remedial actions should be taken.

The area to be surveyed was divided into 33-foot grid blocks and included the following measurements:

(1) external gamma exposure rates 3.3 feet above the ground surface and beta-gamma count rates 0.4 inch above the surface;

(2) radionuclide concentrations in surface soils;

(3) radionuclide concentrations in subsurface deposits;

(4) total ("gross") activity and radionuclide concentrations in surface and subsurface water samples;

(5) radon flux emanating from surfaces;

(6) airborne radioactivity; and

(7) total activity in vegetation.

External Gamma

The two areas of elevated external (gamma) radiation levels, as they existed in November 1980 at the time of the preliminary RMC site survey, both contained places where levels exceeded 100 μR per hour at 3.3 feet. In Area 2, gamma levels as high as 3000 to 4000 μR per hour were detected. The total areas exceeding 20 μR per hour were about 2 acres in Area 1 and 9 acres in Area 2.[3] (The criterion of 20 μR per hour is derived from the NRC's Branch Technical Position, 46 FR 52061, October 23, 1981, which aims at exposure rates less than 10 μR per hour above background levels; background radiation was taken to be 10 μR per hour also.)

External gamma levels were measured in May and July of 1981. These levels were significantly smaller than the November 1980 values, especially in Area 1, because approximately 4 feet of sanitary fill had been added to the entire area, and an equal amount of construction fill was added to most of Area 2. As a result, only a few thousand square feet in Area 1 exceed 20 μR per hour. In Area 2, the total area exceeding 20 μR per hour decreased by about 10 percent, and the highest levels were about 1600 μR per hour near the Butler-type building.[3]

Surface Soil Analysis

A total of 61 surface soil samples were gathered and analyzed on site for gamma activity. Concentrations of U-238, Ra-226, Ra-223, Pb-211, and Pb-212 were determined for each sample. In all soil samples, only uranium and/or thorium decay chain nuclides and K-40 were detected. Offsite background samples were on the order of 2 pCi per gram for Ra-226. Onsite samples ranged from about 1 to 21,000 pCi Ra-226 per gram and from less than 10 to 2100 pCi U-238 per gram. In samples in which elevated levels of Ra-226 were detected, the concentrations of U-238 were generally one-half to one-tenth of those of Ra-226. In cases of elevated sample activity, daughter products of both U-238 and U-235 were found.[3]

In general, surface activity was limited to Area 2, as indicated by the surface beta-gamma measurements. Only two small regions in Area 1 showed surface contamination; both were near the access road across from the site offices.

In addition to onsite gamma analyses, 12 samples were submitted to RMC's radiochemical laboratories for thorium and uranium radiochemical determinations. The results of these measurements (Table 4 of NUREG/CR-2722) show that all samples contained high levels of Th-230. The ratio of Th-230 to Ra-226 (inferred from Bi-214) generally ranges from 4:1 to 40:1.

Subsurface Soil Analysis

Subsurface contamination was assessed by extensive "logging" of holes drilled through the landfill. Several holes were drilled in areas known to contain contamination, then additional holes were drilled at intervals in all directions until no further contamination was detected. A total of 43 holes were drilled (11 in Area 1 and 32 in Area 2), including 2 offsite wells for monitoring water. All holes were drilled with a 6-inch auger and were lined with 4-inch PVC (polyvinyl chloride) casing.[3]

Each hole was scanned with a 2-inch NaI(Tl) detector and rate meter system for an initial indication of the location of subsurface contamination. On the basis of the initial scans, 19 holes were selected for detailed gamma logging using the intrinsic germanium (IG) detector and multiple channel analyzer. Concentrations of Ra-226, as determined by the IG system, ranged from less than 1 pCi per gram to 22,000 pCi per gram.[3]

It was determined that the subsurface deposits extended beyond areas in which surface radiation measurements exceeded the reference level of 20 μR per hour. The lateral extent of material exceeding 5 pCi Ra-226 per gram, including both surface and buried materials, is shown on Figure 2. The total difference in areas is about 5 acres.

The surface elevations vary by about 20 feet, and the highest elevations occur at locations of more recent fill. Contaminated soil (>5 pCi Ra-226 per gram) is found from the surface to depths as great as 20 feet below the surface. In general, the contamination appears to be a continuous single layer ranging from 2 to 15 feet thick and covering 16 acres.[3]

Nonradiological Analysis

Six composite samples were submitted to RMC's Environmental Chemistry Laboratory for priority pollutant analysis. Five samples were taken from auger holes (one from Area 1 and four from Area 2) and the sixth was taken from sludge from the West Lake Landfill leachate treatment plant. The analysis shows organic solvents present in the Area 2 samples. Positive results were reported for 25 listed organic compounds. Chromium, copper, lead, nickel, and zinc were the predominant elemental priority pollutants detected. The analysis of the sample from the leachate treatment sludge showed that it had smaller pollutant concentrations than the samples from the auger holes.[3]

Chemical analyses of material from the radioactive layer from both areas were also performed by RMC's laboratory. In most cases, elevated levels of barium and lead were found.

Background Radioactivity Measurement

Several offsite locations (within a few miles of the West Lake Landfill) were selected for reference background measurements. Background values were all within the normal range. The gamma exposure rates were 8 and 10.6 μR per hour. Radium-226 concentrations in soil were 2.5 and 2.6 pCi per gram. Radon flux from the ground surface was 0.50 and 0.58 pCi per square meter-second; working level values were 0.0011, 0.0017, and 0.005 WL.[3]

Airborne Radioactivity Analysis

Both gaseous and particulate airborne radioactivity were sampled and analyzed during this study. Since it was known that the buried material consisted partially or totally of uranium ore residues, the sampling program concentrated on measuring radon and its daughters in the air. Two methods were used: the first was a scintillation flask (accumulator) method for radon gas, and the second was analysis of filter paper activity for particulate daughters. A series of grab samples using the accumulator method were taken between May and August of 1981. A total of 111 samples from 32 locations were collected. Measurable radon flux levels ranged from 0.2 pCi per square meter-second in low background areas to 865 pCi per square meter-second in areas of surface contamination.[3]

At three locations, measurements were repeated over a period of 2 months. Significant fluctuations were observed at two locations. The fact that these fluctuations were real and not measurement artifacts was later confirmed by duplicate charcoal canister samples.

A set of 10-minute, high-volume, particulate, air samples was taken to determine both short-lived radon daughter concentrations and long-lived gross alpha activity. The highest levels (0.031 WL) were detected in November 1980, near and inside the Butler-type building. These two samples approximately equal NRC's 10 CFR Part 20, Appendix B, alternate concentration limit of one-thirtieth WL for unrestricted areas. In addition to the routine 10-minute samples, five 20-minute, high-volume, air samples were taken and counted immediately on the IG gamma spectroscopy system to detect the presence of Rn-219 daughters. All samples were taken near surface contamination. Concentrations of Rn-219 daughters ranged from 6×10^{-11} to 9×10^{-10} µCi per cubic centimeter.[3]

Vegetation Analysis

Vegetation samples collected by RMC included weed samples from onsite locations and farm crop samples (winter wheat) near the northwest boundary of the landfill. This location was chosen because water could run off from the fill onto the farm field. No elevated activities were found in these samples.[3]

Water Analysis

A total of 37 water samples were taken by RMC and analyzed for gross alpha and beta activity. Four samples were taken in the fall of 1980 and the remainder in the spring and summer of 1981. One sample was equal to the U.S. Environmental Protection Agency (EPA) gross-alpha-activity standard for drinking water of 15 pCi per liter and that was a sample of standing water near the Butler-type building. Several samples, including all the leachate treatment plant samples, exceeded the EPA drinking water action level for gross beta activity. Subsequent isotopic analyses indicated that the beta activity could be attributed to K-40. None of the offsite samples exceeded either EPA standard.[3]

In 1981, the Missouri Department of Natural Resources collected 41 water samples that RMC analyzed for radioactivity. Of these samples, 5 were background, 10 were onsite surface water, 10 were shallow groundwater standing in boreholes, and 16 were landfill leachate. From these data, background activity is estimated as 1.5 pCi gross alpha activity per liter and 30 pCi gross beta activity per liter. One groundwater sample was at 15 pCi gross alpha per liter, and one surface water sample was 45 pCi per liter. Most of the leachate samples were above 50 pCi beta per liter.[3]

In addition, groundwater samples in 11 perimeter monitoring wells at the West Lake Landfill were taken by the Reitz and Jens Engineering firm on November 15, 1983, and by University of Missouri at Columbia (UMC) personnel on March 21, 1984. In both sampling times, one well, but not the same one, exceeded the EPA's drinking water standard of 15 pCi per liter (18.2 pCi per liter in 1983 and 20.5 pCi per liter in 1984). On May 7 and 8, 1986, Oak Ridge Associated Universities (ORAU) personnel took water samples from 44 perimeter wells; only one (by Old St. Charles Rock Road) with 17 pCi alpha activity per liter exceeded the drinking water standard.[2]

The operators of the landfill, West Lake Landfill, Inc., have an ongoing hydrogeologic investigation of the site, which also involves analyses of monitoring well samples for radioactivity and for priority pollutants.[4]

4 ESTIMATION OF RADIOACTIVITY INVENTORY

Soil sample analyses have shown that the radioactive material in Areas 1 and 2 of the landfill consists almost entirely of natural uranium and its radioactive decay products.

The analyses of soil samples indicate that the naturally occurring U-238 to Th-230 to Ra-226 equilibrium has been altered and that the ratio of Ra-226 to U-238 is on the order of 2:1 to 10:1; the ratio of Th-230 to Ra-226 generally ranges from 4:1 to about 40:1. These ratios are in accord with the history of the radionuclide deposits in the West Lake Landfill, i.e., that they came from the processing of uranium ores. The indicator radionuclides for assessment of the radiological impacts of the material are therefore U-238, Th-230, and Ra-226.

Using the RMC data and averaging the auger hole measurements over the volumes of radioactive material found in Areas 1 and 2, a mean concentration of 90 pCi per gram was calculated for Ra-226.[2] For the ratio of Th-230 to Ra-226, the RMC data[3] range from 4:1 to 40:1; data from samples taken in 1984 along the berm range up to almost 70:1.[5] A further consideration is that the material came from Cotter Corporation's Latty Avenue site (later sold to Futura Coatings, Inc.). Measurements at the Latty Avenue site are variously reported as up to 180:1[6] and about 300:1.[7] Some material of that nature might have been transferred along with the barium sulfate residues. To ensure conservatism in estimating the long-term in-growth of Ra-226, the NRC staff used a ratio of 100:1 to estimate the Th-230 activity. Similarly, the Ra-226:U-238 ratio ranges from 2:1 to 10:1. This ratio is less critical to the radiological aspect of the site and has been estimated to be 5:1 for purposes of calculation.

Using the Th-230:Ra-226 ratio of 100:1, the Th-230 activity is 9000 pCi per gram. If the U-238 concentration (as well as U-234 which would be similarly separated from the ore) is a factor of 5 less than Ra-226, this implies about 18 pCi U-238 per gram. The total mass of radioactive material in the landfill was estimated by visually integrating the volume of radioactive material from graphs and multiplying by an average soil density, resulting in 1.5×10^{11} grams (150,000 metric tons) of contaminated soil.

These numbers indicate that there are about 14 Ci of Ra-226 contained with its decay products in the radioactive material in the landfill. The material also contains about 3 Ci each of U-238 and U-234, and about 1400 Ci of Th-230. These estimates indicate the order of magnitude of the quantities to be dealt with, although the estimate for Th-230 is regarded as conservatively large.

5 APPLICABILITY OF THE BRANCH TECHNICAL POSITION

The NRC has established a Branch Technical Position (BTP) which identifies five acceptable options for disposal or onsite storage of wastes containing low levels of uranium and thorium (46 FR 52061, October 23, 1981).[8]

The concentrations permitted under each disposal option are shown in Table 1.

Table 1 Summary of maximum soil concentrations permitted under disposal options

Source: 46 Federal Register 52061

Kind of material	Disposal options 1[a]	2[b]	3[c]	4[d]
Natural thorium (Th-232 + Th-228) with daughters present and in equilibrium. (pCi/g)	10	50	-	500
Natural uranium (U-238 + U-234) with daughters present and in equilibrium. (pCi/g)	10	-	40	200

[a]Based on EPA uranium mill tailings cleanup standards.

[b]Concentrations based on limiting individual doses to 170 mrem per year.

[c]Concentration based on limiting equivalent exposure to 0.02 WL or less.

[d]Concentrations based on limiting individual intruder doses to 500 mrem per year and, in cases of natural uranium, limiting exposure to Rn-222 and other airborne alpha emitters to 0.02 WL or less.

Options 1-4 provide methods under 10 CFR 20.302, for onsite disposal of slightly contaminated materials, e.g., soil, if the concentrations of radioactivity are small enough and other circumstances are satisfactory. The fifth option consists of onsite storage pending availability of an appropriate disposal method.

The material present in the West Lake Landfill is a form of natural uranium with daughters, although the daughters are not now in equilibrium. As mentioned in

Section 4, the average concentration of Ra-226 in the West Lake Landfill wastes is about 90 pCi per gram, which (considered by itself) falls into Option 4 of the BTP since Option 4 criteria are controlled by the Ra-226 content in the wastes (i.e., 200 pCi of U-238 plus U-234 per gram would be accompanied by 100 pCi of Ra-226 per gram). However, because of the large ratio of Th-230 radioactivity to that of Ra-226, the radioactive decay of the Th-230 will increase the concentration of its decay product Ra-226 until these two radionuclides are again in equilibrium. Assuming the ratio of activities of 100:1 used above, the Ra-226 activity will increase by a factor of five over the next 100 years, by a factor of nine 200 years from now, and by a factor of thirty-five 1000 years from now. All radionuclides in the decay chain after Ra-226 (and thus the Rn-222 gas flux) will also be increased by similar multiples. Therefore, the long-term Ra-226 concentration will exceed the Option 4 criteria. Under these conditions, onsite disposal, if possible, will likely require moving the material to a carefully designed and constructed "disposal cell."

6 REMEDIAL ACTION ALTERNATIVES EXAMINED

The evaluation performed by staff of the University of Missouri at Columbia addresses six potential remedial action alternatives, including that of leaving the radioactive material as it is, designated Option A.[2] Option D is the option of excavating the material and shipping it to another site for disposal. Options B, C, E, and F address different approaches to stabilizing the material on the West Lake Landfill site, primarily as temporary remedial actions. Options B, C, and F leave most of the radioactive material where it is but include a variety of measures to contain it and its radon releases and gamma emissions. Option E addresses the approach of constructing an onsite earthen cell, similar to a disposal cell, and moving the radioactive material into it. Under Option F, the radioactive material would be left in place and separate slurry walls would be built downgradient of Areas 1 and 2 to constrain groundwater motion. The estimated costs of Options B through F range from about \$370,000 (Option B) to about \$5,500,000 (Option F) in 1984 dollars. The estimate for Option D is about \$2,500,000, but this does not include the cost of transporting the material to another site and disposing of it there; in the staff's judgment, this could increase the cost by as much as a factor of ten.

Further studies are necessary to determine the most practical approach to disposal of this material.

7 FACTORS CONTRIBUTING UNCERTAINTY

The presence in the landfill of other substances listed as hazardous by the U.S. Environmental Protection Agency raises issues of whether the waste is mixed waste (i.e., both radioactive and chemically hazardous), and whether the landfill must also be disturbed to provide for proper containment of the chemical wastes.

The manner of placing the 43,000 tons of contaminated soil in the landfill caused it to be mixed with additional soil and other material, so that now an appreciably larger amount is involved. If it must be moved, it is not certain whether the amount requiring disposal elsewhere is as little as 60,000 tons or even more than 150,000 tons.

Because the controlling radionuclide (Th-230) has no characteristics that make it easy to measure quantitatively in place, as can be done for the Ra-226 with its decay products, the large but variable ratio of Th-230 to Ra-226 and its decay products makes the delineation of cleanup more difficult. When the ratio is so large (20:1 or more), even a small concentration of Ra-226 in 1988 implies such a large concentration later that it will be necessary to employ more difficult measurement techniques to confirm that the cleanup has been satisfactory.

Any possibility of disposal on site will depend on adequate isolation of the waste from the environment, especially for protection of the groundwater. It is unclear whether the area's groundwater can be protected from onsite disposal at a reasonable cost. This matter will require additional investigation.

8 SUMMARY

In 1973, radioactively contaminated soil amounting to approximately 43,000 tons was deposited in the West Lake Landfill near St. Louis, Missouri. The material originated with decontamination efforts at the Cotter Corporation's Latty Avenue plant. Disposal in the West Lake Landfill was not authorized by the NRC. State officials were not notified of this disposal in 1973 because the landfill was not regulated by the State at the time.

In the period 1980-1981, Radiation Management Corporation (RMC) of Chicago, Illinois, under contract to the NRC, performed a detailed radiological survey of the West Lake Landfill. This survey showed that the radioactive contaminants are in two areas. The northern area (Area 2) covers about 13 acres. The radioactive debris forms a layer 2 to 15 feet thick, exposed in only a small area on the landfill surface and along the berm on the northwest face of the landfill. The southern area (Area 1) contains a relatively minor fraction of the debris covering approximately 3 acres with most of the contaminated soil buried with about 3 feet of clean soil and sanitary fill.

The RMC survey showed that the radioactivity is from the naturally occurring U-238 and U-235 series with Th-230 and Ra-226 as the radionuclides that dominate radiological impact. The survey data indicate that the average Ra-226 concentration in the radioactive wastes is about 90 pCi per gram; the staff estimates the average Th-230 concentration to be about 9000 pCi per gram. Since Ra-226 has been depleted with respect to its parent Th-230, Ra-226 activity will increase in time (for example, over the next 200 years, Ra-226 activity will increase ninefold over the present level). This increase in Ra-226 must be considered in evaluating the long-term hazard posed by this radioactive material.

In addition to RMC's radiological survey, soil and water samples were collected and analyzed by others, including ORAU, UMC, and MDNR. Occasionally a sample of water from a monitoring well exceeds slightly the EPA drinking water standard of 15 pCi gross alpha per liter. Sample analyses for priority pollutants (non-radioactive hazardous substances) show a number of listed pollutants are present. The landfill operators are also conducting a hydrogeological investigation.

From the RMC, UMC, and ORAU surveys conducted at the West Lake Landfill site the staff has made the following findings:

(1) There is a large quantity (on the order of 150,000 tons) of soil contaminated with long-lived radioactive material in the West Lake Landfill. Almost all the radioactivity consists of natural uranium and its radioactive decay products.[3]

(2) Based on the radiological surveys, the radioactive wastes as presently stored at the West Lake Landfill do not satisfy the conditions for Options 1-4 of the NRC's Branch Technical Position (BTP) regarding the disposal of radioactive wastes containing uranium or thorium residues.[8]

(3) A dominant factor for the future is that the average activity concentration of Th-230 is much larger than that of its decay product Ra-226, indicating a significant increase in the radiological hazards in the years and centuries to come.

(4) Some of the radioactive material on the northwestern face of the berm has no protective cover of soil to prevent the spread of contamination and attenuate radiation.

(5) Slightly more than 8 acres of the site exceed 20 μR per hour; the highest reading of 1600 μR per hour occurs near the Butler-type building.

(6) Radon and daughters were measured at 0.031 WL in and around the Butler-type building. This exceeds the BTP value of 0.02 WL.

(7) Based on monitoring-well sample analyses, some low-level contamination of the groundwater is occurring, indicating that the groundwater in the vicinity is not adequately protected by the present disposition of the wastes.

(8) Although these radiological conditions indicate that remedial action is needed, it is unlikely that anyone has received significant radiation exposures from the existing situation.

(9) Sampling results show that chemically hazardous materials have been disposed of adjacent to or possibly mixed with the radioactive material.[3] It is possible that part of the radioactive material has become "mixed" waste.

From these findings and the information developed to date, the NRC staff concludes: (1) measures must be taken to establish adequate permanent control of the radioactive waste and to mitigate the potential long-term adverse impacts from its existing temporary storage conditions and (2) the information developed to date is inadequate for a technological determination of several important issues, i.e., whether mixed wastes are involved, and whether onsite disposal is practical technologically, and, if so, under what alternative methods.

As indicated by the estimates developed by UMC, remedial action will be costly. Further, the investigations to develop the necessary information to resolve major questions and to provide a sound basis for evaluation of the feasibility of disposal alternatives may also be costly. Therefore, it is necessary to determine the way to accomplish the further studies and remedial actions that are needed.

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The West Lake Landfill is located near the city of St. Louis in Bridgeton, St. Louis County, Missouri. The site has been used since 1962 for disposing of municipal refuse, industrial solid and liquid wastes, and construction demolition debris. This report summarizes the circumstances of the radioactive material in the West Lake Landfill. The radioactive material resulted from the processing of uranium ores and the subsequent sale by the Atomic Energy Commission of the processing residues. Primary emphasis is on the radiological environmental aspects as they relate to potential disposition of the material. It is concluded that remedial action is called for.

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REMEDIAL ACTION CONCEPTS FOR
THE WEST LAKE LANDFILL

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Enclosure 2

PREFACE

This report has as its basis a characterization of the West Lake Landfill site and evaluation of some potential remedial measures performed primarily by S. K. Banerji, W. H. Miller, J. T. O'Connor and L. S. Uhazy of the University of Missouri-Columbia. The Nuclear Regulatory Commission received the first and second drafts, then titled "Engineering Evaluation of Options for Disposition of Radioactively Contaminated Residues Presently in the West Lake Landfill, St. Louis County, Missouri," in 1984; thus most of the information in this report dates from 1983-1984. However, some more recent data, principally water sampling results, have been added. Waste disposal and other industrial activities have continued on the 200 acre site, as have activities in the vicinity, resulting in changes in details of topography, roads, etc. To provide a more complete view of the radioactive material in the landfill, use has been made of figures from the report titled "Radiological Survey of the West Lake Landfill, St. Louis County, Missouri," NUREG/CR-2722, May 1982.

The remedial action concepts in this report are those proposed by the contractor. Judgments expressed in this report about these concepts are in general those of the contractor, and do not necessarily represent the views of the Nuclear Regulatory Commission. For example, the cost estimates for these concepts are based on radium-226 concentrations whereas the long-term issue is dependent upon the thorium-230 concentrations.

Although some of its information has not been updated since 1984, this report is being released so as to make its collected information available to interested parties.

ABSTRACT

The West Lake Landfill is near the city of St. Louis in Bridgeton, St. Louis County, Missouri. In addition to municipal refuse, industrial wastes and demolition debris, about 43,000 tons of soil contaminated with uranium and its radioactive decay products were placed there in 1973. After learning of the radioactive material in the landfill, the U.S. Nuclear Regulatory Commission (NRC) had a survey of the site's radioactivity performed and, in 1983, contracted, through Oak Ridge Associated Universities (ORAU), with the University of Missouri-Columbia (UMC) to characterize the environment of the site, conduct an engineering evaluation, and propose remedial measures. This report presents a description of the results of the UMC work, providing the environmental characteristics of the site, the extent and characteristics of the radioactive material there, some considerations with regard to potential disposal of the material, and some concepts for remedial measures.

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CONTENTS (Continued)

TABLES (Continued)

SUMMARY

In 1973, approximately 7900 metric tons (mt) (8700 short tons) of radioactively contaminated barium sulfate ($BaSO_4$) residues were mixed with about 35,000 mt (39,000 t) of soil, and the entire volume was placed in the West Lake Landfill in St. Louis County, Missouri. This material resulted from decontamination efforts at the Cotter Corporation's Latty Avenue plant where the material had been stored. Disposal in the West Lake Landfill was not authorized by the Nuclear Regulatory Commission (NRC) and was contrary to the disposal location indicated in the NRC records. State officials were not notified of this disposal since the landfill was not regulated by the State at the time. Although the contamination does not present an immediate health hazard, authorities have been concerned about whether this material poses a long-term health hazard to workers and residents of the area and what, if any, remedial action is necessary.

In 1980-81, Radiation Management Corporation (RMC) of Chicago, Illinois, performed a detailed radiological survey of the West Lake Landfill under contract to the NRC (NUREG/CR-2722). This survey was performed to determine the extent of radiological contamination. Before this survey, little was known about the location or activity of radionuclide-bearing soils in the landfill. This survey showed that the radioactive contaminants are in two areas. The northern area (Area 2) covers about 13 acres. The radioactive debris forms a layer 2 to 15 feet thick, exposed in only a small area on the landfill surface and along the berm on the northwest face of the landfill. The southern area (Area 1) contains a relatively minor fraction of the debris covering approximately 3 acres with most of the contaminated soil buried with about 3 feet of clean soil and sanitary fill.

The RMC survey showed that the radioactivity is from the naturally occurring U-238 and U-235 series with Th-230 and Ra-226 as the radionuclides that dominate radiological impact. The survey data indicate that the average Ra-226 concentration in the radioactive wastes is about 90 pCi per gram; the average Th-230

concentration is estimated to be about 9000 pCi per gram. Since Ra-226 has been depleted with respect to its parent Th-230, Ra-226 activity will increase in time (for example, over the next 200 years, Ra-226 activity will increase ninefold over the present level). This increase in Ra-226 must be considered in evaluating the long-term hazard posed by this radioactive material.

In addition to RMC's radiological survey, soil and water samples were collected and analyzed by others, including Oak Ridge Associated Universities (ORAU), and the University of Missouri-Columbia (UMC). Occasionally a sample of water from a monitoring well exceeds slightly the EPA drinking water standard of 15 pCi gross alpha per liter. Sample analyses for priority pollutants (non-radioactive hazardous substances) show a number of listed pollutants are present.

On the basis of radiological surveillance conducted by RMC, UMC, and ORAU, the following areas of concern have been identified:

(1) Radioactive soil is eroding from the northwestern face of the berm, and is being transported off site.

(2) Radon gas had been observed to accumulate to an unacceptable level in the Butler-type building on site. This building has since been removed.

(3) Some degree of radiological contamination has been found in the wells that monitor the perimeter.

(4) Surface exposure rates over much of the contaminated areas are greater than 20 μR/hr.

In March 1983, the NRC through ORAU, contracted with UMC to conduct an engineering evaluation of the site and propose possible remedial measures for NRC's consideration for dealing with the radioactive waste at the West Lake Landfill. The following six remedial options were proposed and evaluated in this study.

- Option A - No remedial action
- Option B - Stabilization onsite with restricted land use

- Option C - Extending the landfill offsite with restricted land use
- Option D - Removal and relocation of the contaminated material to an authorized disposal site
- Option E - Excavation and temporary onsite storage in a trench
- Option F - Construction of a slurry wall to prevent leachate from migrating off site

It is noted that some of the above alternatives for remedial action were initially evaluated with the objective of permanent disposal of the waste at the site.

1 INTRODUCTION

The West Lake Landfill is located in St. Louis County, Missouri, 6 km (3.7 miles) west of Lambert Field International Airport (Figure 1.1) and southwest of St. Charles Rock Road in Bridgeton, Missouri. The site has been used since 1962 for disposing of municipal refuse, industrial solid and liquid wastes, and construction demolition debris. In addition, the landfill is an active industrial complex on which concrete ingredients are measured and combined before mixing ("batching"), and asphalt aggregate is prepared. Limestone ceased to be quarried in the spring of 1987.

In 1973, 7900 metric tons [(mt) (8700 short tons)] of radioactively contaminated barium sulfate ($BaSO_4$) residues from uranium and radium processing were mixed with an estimated 35,000 mt (39,000 tons) of soil and deposited in the West Lake Landfill. Previously, this material was located at the Cotter Corporation's Latty Avenue facility in Hazelwood, Missouri, and was removed during decontamination work. It is not known what levels of contamination were already in the soil before the barium sulfate residues were mixed into it. Disposal in the West Lake Landfill was unauthorized and contrary to the disposal location indicated in the U.S. Nuclear Regulatory Commission's (NRC's) records.

Subsequently, the NRC sponsored studies that were directed at determining the radiological status of the landfill. In 1978, an aerial radiological survey revealed two areas within the landfill where the gamma radiation levels indicated radioactive material had been deposited. A more extensive survey was initiated in November 1980 by the Radiation Management Corporation (RMC) under contract to the NRC.

In March 1983, the NRC through Oak Ridge Associated Universities (ORAU) contracted with the University of Missouri-Columbia Department of Civil Engineering to describe the environmental characteristics of the site, conduct an engineering evaluation, and propose possible remedial measures for dealing with the radioactive waste at the West Lake Landfill. In May 1986, ORAU sampled water from

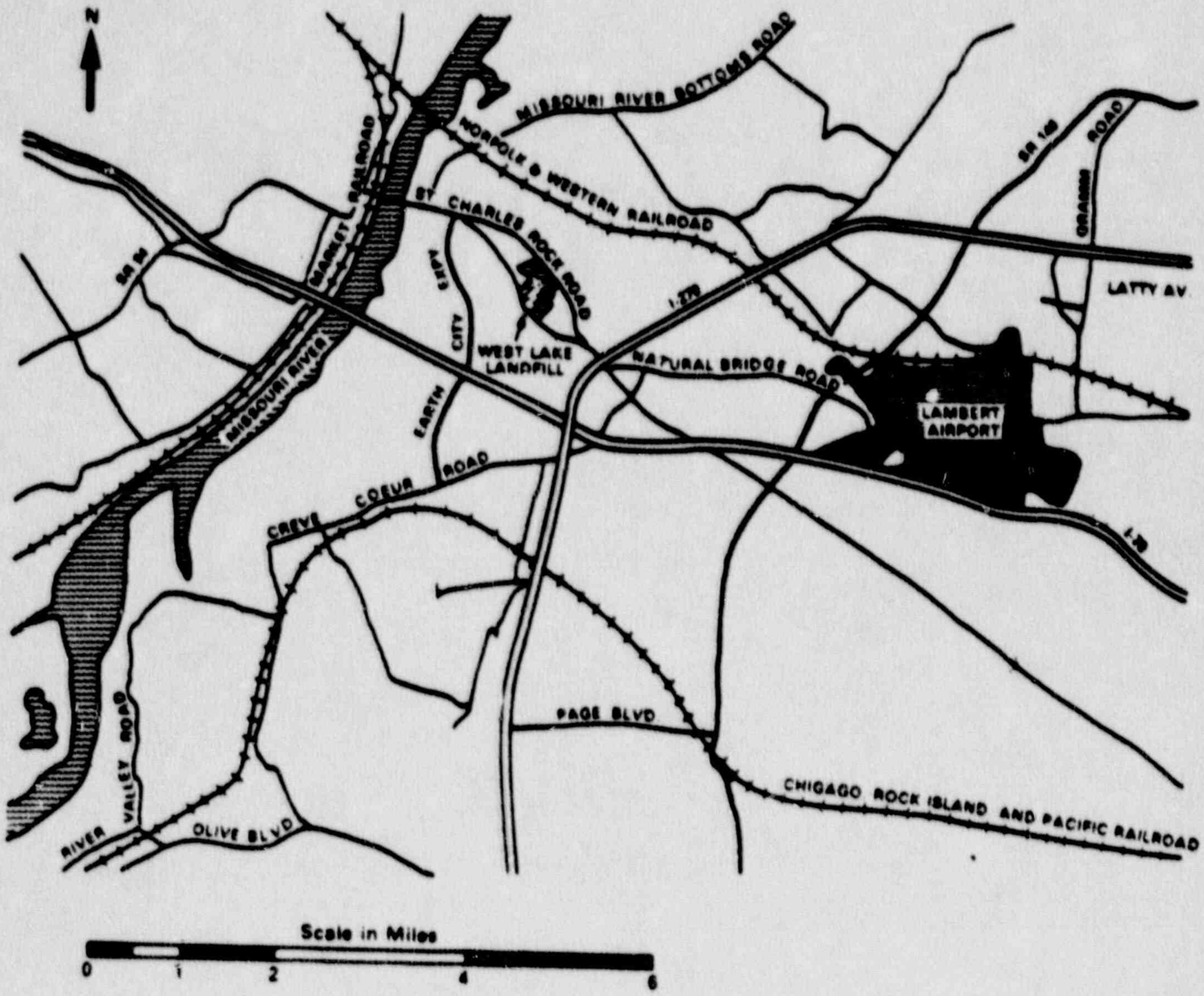

Figure 1.1 Location of West Lake Landfill

wells on and close to the landfill to determine if the radioactive material had migrated into the groundwater.

Information from all these sources forms the basis for this report.

2 SITE DESCRIPTION

This chapter presents a historical and environmental description of the West Lake Landfill site located in St. Louis County, Missouri.

2.1 Location

The 81-hectare (ha) (200-acre) West Lake Landfill property is situated between the St. Charles Rock Road and the Old St. Charles Rock Road in Bridgeton, Missouri. The southeastern and northwestern parts of the landfill abut farmland. Several commercial and industrial facilities are located near the landfill (Figure 2.1). The nearest residential area is a trailer park located approximately 1 km (0.6 mile) to the southeast. A major portion of the landfill (roughly the northern three-fourths of the site) is located on the floodplain, approximately 2 km (1.2 miles) from the Missouri River.

2.2 Zoning

The zoning plan obtained from the Bridgeton Planning and Zoning Department for properties on and adjacent to the landfill is shown in Figure 2.2. A portion of the landfill, including site Area 1, is zoned M-1, which is designated for light manufacturing; the northwest part of the landfill, including Area 2, is zoned as single-family residential (R-1). This R-1 zoning indicates the use to which the land was originally intended. However, the landfill was extended over the land zoned R-1, and the zoning plan was simply not changed to reflect the new usage. Other discrepancies between land use and zoning are found in the nearby Earth City Industrial Park (William Canney, Safety Supervisor of West Lake Landfill, Inc., personal communication, March 1984). The land across St. Charles Rock Road is zoned for light and heavy manufacturing. The remainder of the property surrounding the landfill is zoned residential and business.

2.3 History

The West Lake Landfill was started in 1962 for the disposal of municipal and industrial solid wastes, and to fill in the excavated pits from the quarry operations that had been performed at the site since 1939 (Canney, personal communication, March 1984). In 1974, the landfill was closed by the Missouri Department of Natural Resources (MDNR) (Karch, 1976). A new sanitary landfill, in an area of the West Lake Landfill property which is protected from groundwater contact, now operates under an MDNR permit.

This new part of the landfill was opened in 1974. The bottom is lined with clay and a leachate collection system has been installed. Leachate is pumped to a treatment system consisting of a lime precipitation unit followed in series by an aerated lagoon and two unaerated lagoons. The final lagoon effluent is discharged into St. Louis Metropolitan Sewer District sewers.

The quarrying operation ceased in the spring of 1987 because not enough "good rock" was left at the site.

2.4 Ownership

The West Lake Landfill was owned from 1939 until 1988 by West Lake Landfill, Inc., of 13570 St. Charles Rock Road, Bridgeton, Missouri. Most of the landfill was sold in 1988 to Laidlaw Industries, Inc. The two areas which contain the radioactive material were retained by West Lake Properties as the principal properties of a subsidiary named Rock Road Industries, Inc.

2.5 Contaminated Areas

Radioactive contamination at the West Lake Landfill has been identified in two separate soil bodies (Figure 2.3). Comparisons of radionuclide quantities and of the activity ratios between radionuclides not in secular equilibrium, indicate that the radioactive contamination in the separate soil bodies was derived from the same source, i.e., the Cotter Corporation's former Latty Avenue facility in Hazelwood, Missouri (NRC, NUREG/CR-2722).

The northern area (referred to as Area 2) of contamination shown on Figure 2.3 covers an area of 5.2 ha (13 acres) and lies above 5 to 6 m (16-20 ft) of landfill debris. The contaminated soil forms a more or less continuous layer from 1 to 4 m (3 to 13 ft) in thickness, and amounts to approximately 100,000 m^3 (130,000 yd^3). Some of this contaminated soil is near or at the surface, particularly along the face of the northwestern berm. Beneath the landfill debris, the soil profile consists of 1 to 2 m (3 to 7 ft) of floodplain top soil overlying 10 to 15 m (33 to 50 ft) of sand and gravel alluvium.

The southern area of contamination (referred to as Area 1) shown on Figure 2.3 covers approximately 1.1 ha (3 acres) and contains roughly 15,000 m^3 (20,000 yd^3) of contaminated soil. This body of soil is located east of the landfill's main office at a depth of about 1 m (3 to 5 ft), and is located over a former quarry pit, which was filled in with debris. The depth of debris beneath the contaminated soil is unknown, but is estimated to be 15 to 20 m (50 to 65 ft). Limestone bedrock underlies the landfill debris.

2.6 Topography

About 75% of the landfill site is located on the floodplain of the Missouri River. The site topography is subject to change because of the types of activities (e.g., landfilling and quarrying) performed there. Figure 2.3 shows a contour map of the site as of July 1986. The surface runoff follows several surface drains and ditches which run in a northwest direction and drain into the Missouri River.

2.7 Geology

2.7.1 Bedrock

Bedrock beneath the West Lake Landfill consists of Mississippian age limestone of the Meramacean Series of the St. Louis and Salem formations, which extends downward to an elevation of 58 m (190 ft) mean sea level (msl) (Figure 2.4).*

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*Missouri Department of Natural Resources, Division of Geology and Land Survey, Rolla, Missouri, Well Log Files.

The limestone is dense, bedded, and fairly pure except for intermittent layers which consist of abundant chert nodules. The Warsaw Formation--also of Mississippian age--lies directly beneath the limestone. The Warsaw is made up of approximately 12 m (38 ft) of slightly calcareous, dense shale; this grades into shaley limestone toward the middle of the formation (Figure 2.4) (Spreng, 1961). Bedrock beneath the site dips at an angle of 0.5° to the northeast. Eight kilometers (5 miles) east of the site, the attitude of the bedrock is reversed by the Florissant Dome; the bedrock dips radially outward from the apex of this dome at a low angle (Martin, 1966).

Since karst (solution) activity often occurs in carbonate rocks, the possibility of its occurrence in the West Lake Landfill area was considered. Brief observation of the quarry walls at the landfill suggests that some solution of the limestone has occurred, but this solution activity has apparently been limited (see Section 2.8.1) to minor widening of joints and bedding planes near the bedrock surface. Although karst activity within the limestone is relatively minor, the upper surface of the bedrock is irregular and pitted as a result of solution (Lutzen and Rockaway, 1971). This alteration of the bedrock surface is greatest beneath the Missouri River floodplain.

2.7.2 Soils

Soil material in this area may be divided into two categories: Missouri River alluvium and upland loessal soil. This demarcation is shown as the historical edge of the alluvial valley in Figure 2.5. The division is made on the basis of soil composition, depositional history, and physical properties. Because the West Lake Landfill lies over this transition zone, the surface material at the site varies considerably from southeast to northwest.

The Missouri River alluvium (Figure 2.6) ranges in thickness from 12 m (40 ft) beneath the landfill site to more than 30 m (100 ft) at mid-valley (Figure 2.7). The upper 3 m (10 ft) of the soil profile consists of organic silts and clays, that have been deposited by the Missouri River during floods.* Below this

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*Missouri Department of Natural Resources, Division of Geology and Land Survey, Rolla, Missouri, Well Log Files.

surface layer, the soil becomes sandy and grades to gravel at depths greater than 5 to 10 m (16 to 33 ft). Because of the effects of channel scour, which continues to grade the sediment after its initial deposition, the alluvium is fairly homogeneous in a horizontal direction and becomes progressively coarser with depth (Goodfield, 1965). At the edges of the floodplain, the alluvium is not as well graded, and a large amount of fine material is present in the deeper sand and gravel.

The upland loessal soil (Figure 2.8) is generally thinner than the floodplain soil, being usually less than 12 m (39 ft) thick, and was deposited during the age of Pleistocene glaciation. The loess consists of silt-sized particles that were transported by wind and deposited as a blanket over much of Missouri and Illinois. On the hills near the West Lake Landfill, the loess layer may be as much as 24 m (79 ft) thick. It consists of 6 to 9 m (20 to 30 ft) of fairly pure silt (Peoria loess) overlying 6 to 15 m (20 to 49 ft) of clay silt (Roxana loess) (Lutzen and Rockaway, 1971). This loess forms the hills to the southeast of the landfill, but it has long ago been removed from the landfill site and most of the surrounding valleys by erosion. The upper 1 m (3 ft) of the loess has been altered to form a thin soil profile. It should be noted that loess has a vertical permeability which is far greater than its horizontal permeability (Freeze and Cherry, 1979). The total permeability of loess is greatly increased by disturbance. The individual silt grains are generally quite angular, and therefore may not be effectively compacted by the methods commonly used to consolidate clay. The technique most effective in the compaction of loess would employ vibration beneath a surcharge. A relict soil profile from 5 to 10 m (16 to 33 ft) thick lies beneath the loess and directly on top of the bedrock. This soil was formed as a residuum before Pleistocene glaciation and was subsequently covered by the loess blanket. This soil is a highly consolidated clay containing abundant chert fragments (Lutzen and Rockaway, 1971). In addition to the natural geologic properties of the landfill, human disturbance of the soil must also be considered since material within the landfill itself can either limit or facilitate migration of leachate to the Missouri River alluvial aquifer.

In order to prevent downward movement of leachate, it is now a common practice to place a layer of compacted clay beneath sanitary landfills. Newer portions of the landfill (constructed since 1974) have 2 to 3 m (7 to 10 ft) of clay at the base and around the sides. Waste is covered every day with 15 cm (6 in.) of compacted soil; the cover soil presently used is loess (of soil classifications CL and A4) taken from southeast of the landfill (Reitz and Jens, 1983a). If not properly compacted, this material may have a permeability of 0.0001 cm/sec (0.00004 in./sec) or more. It is not known what procedures for compaction, if any, were used at the landfill before 1974 since the site was unregulated in design as well as in materials which were accepted for disposal. It is believed, however, that there is no liner present beneath the northwestern portion of the landfill, and that sanitary (and, possibly, some hazardous) material was placed directly on the original ground surface. Since waste was periodically covered with soil to minimize rodent and odor problems, the landfill probably consists of discrete layers of waste separated by thin soil layers. Both areas containing radioactive material are in these presumably unlined above-ground portions of the landfill.

2.8 Hydrology

2.8.1 Subsurface Hydrology

Groundwater flow in the area surrounding the West Lake site is through two aquifers: the Missouri River alluvium and the shallow limestone bedrock. The base of the limestone aquifer is formed by the relatively impermeable Warsaw shale at an elevation of about 58 m (190 ft) msl (Figure 2.4). This shale layer has been reached, but not disturbed, by quarrying operations. Therefore, the Warsaw shale acts as an aquiclude, making contamination of the deeper limestone very unlikely. The Mississippian limestone beds have very low intergranular permeability in an undisturbed state (Miller, 1977). However, a strong leachate enters the quarry pit at an elevation of about 67 m (220 ft) msl (pt. A on Figure 2.5). This leachate is migrating vertically through more than 30 m (98 ft) of limestone. Explosive detonations associated with quarrying operations will tend to cause fractures to propagate in the quarry wall. These fractures have probably extended less than 10 m (33 ft) into the rock from the quarry face. Beyond this, the rock probably remains undisturbed. These fractures will tend to increase inflow to the quarry pit and allow leachate to percolate downward through the fractured zone. Thus, leachate inflow to the quarry pit is not evidence of large-scale contamination of the limestone aquifer. The only other mechanism by which leachate could travel rapidly through the limestone is by transport through solution channels. Landfill consultants and quarry operators maintain that the limestone is fairly intact (Canney, personal communication, September 1983), and superficial observation of the quarry walls seems to support this conclusion. Since the limestone is fairly impervious, and groundwater flows in most areas from the bedrock into the alluvium, contamination of water in the bedrock aquifer does not appear likely.

The water table of the Missouri River floodplain is generally within 3 m (10 ft) of the ground surface, but at many points it is even shallower. At any one time, the water levels and flow directions are influenced by both the river stage and the amount of water entering the floodplain from adjacent upland areas. A high river stage tends to shift the groundwater gradient to the north, in a direction that more closely parallels the Missouri River. Local rainfall will shift the groundwater gradient to the west, toward the river and along the fall of the ground surface. This is inferred from water levels measured in monitoring wells at the West Lake site. The fact that groundwater levels commonly fluctuate more than does the Missouri River level, indicates that upland-derived recharge exerts a great deal of influence over groundwater flow at the West Lake site. This influence decreases toward the river.

The [illegible] Missouri River alluvium acts as a single aquifer of very high permeability. This aquifer is relatively homogeneous in a downstream direction, and decreases in permeability near the valley walls. The deeper alluvium is covered by 2 to 4 m (7 to 13 ft) of organic silts and clays that may locally contain a large fraction of sand-sized particles. Water levels recorded between November 1983 and March 1984 in monitoring wells at West Lake* indicate a groundwater gradient of 0.005 flowing in a N 30°W direction beneath the northern portion of the landfill. This represents the likely direction of any possible leachate migration from the landfill (Figure 2.5).

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*Data supplied by Reitz and Jens engineering firm, St. Louis, 1984.

The alluvial aquifer recharges from upland areas from three sources: seepage from loess and bedrock bordering the valley, channel underflow of upland streams entering the valley, and seepage losses from streams as they cross the floodplain. Of these sources, streams and their underflow represent the main source of upland recharge to the alluvial aquifer. Streams entering the floodplain raise the water table in a fan-shaped pattern radiating outward from their point of entrance to the plain. In areas where streams are not present, the water slopes downward from the hills, steeply at first and then gently to the level of the free water surface in the Missouri River channel. The situations described above do not take into account the effect of variations in permeability of the shallow soil layer. Aerial photography of the site indicates that a filled backchannel (oxbow lake) type of soil deposit is present along the southwest boundary of the landfill (USDA, 1953). This deposit is probably composed of fine-grained material to the depth of the former channel (6 to 10 m) (20 to 33 ft). This deposit may tend to hamper communication between shallow groundwater on opposite sides of the deposit.

Since no other recharge sources exist above the level of the floodplain, the only water available to leach the landfill debris is that resulting from rainfall infiltrating the landfill surface. Because the underlying alluvial aquifer is highly permeable, there will be little "mounding" of water beneath the landfill. Because the northern portion of the landfill has a level surface it is likely that at least half of the rainfall infiltrates the surface. The remaining rainfall is lost to evapotranspiration and (to a lesser degree) surface runoff. Due to the height of the berm, temporary impoundment of surface runoff is a common occurrence.

No public water supplies are drawn from the alluvial aquifer near the West Lake Landfill. It is believed that only one private well (Figure 2.9) in the vicinity of the landfill is used as a drinking water supply. This well is 2.2 km (1.4 miles) N 35°W of the former Butler-type Building location on the West Lake Landfill. In 1981, analysis showed water in this well to be fairly hard (natural origins) but otherwise of good quality (Long, 1981).

Water in the Missouri River alluvium is hard and usually contains a high concentration of iron and manganese (Miller, 1977). The amount of dissolved solids present in the water of the alluvial aquifer varies greatly; purity increases toward mid-valley where groundwater velocity is greatest. A water sample from a well in the alluvium 3 km (1.9 miles) north of the landfill had a total dissolved solids content of 510 mg/liter and total hardness as $CaCO_3$ of 415 mg/liter. Water in the limestone bedrock generally has a hardness greater than 180 mg/liter as $CaCO_3$ equivalent (Emmett and Jeffery, 1968). Total dissolved solids range from 311 to 970 mg/liter. Water in the limestone aquifer may contain a large amount of sulfate of natural origin (Miller, 1977).

2.8.2 Surface Hydrology

Because of the extremely low slope of the Missouri River flood plain surface, precipitation falling on the plain itself generally infiltrates the soil rather than running off the surface. The only streams present on the floodplain are those that originate in upland areas. Drainage patterns on the plain (Figure 2.9) have been radically altered by flood control measures taken to protect Earth City (Figure 2.1) and by drainage of swamps and marshes. Before these alterations, Creve Coeur Creek passed just south of the landfill, and drained a fairly large area. It has since been redirected to discharge into the Missouri River upstream (south) of St. Charles (Figure 2.9). The old channel still carries some water, and empties into the Missouri River 45.2 km (28 miles) upstream from the confluence with the Mississippi River. Near the landfill, this stream is usually dry. As it crosses the flood plain, the creek passes through shallow lakes which provide a more or less continuous flow to the Missouri River throughout the year. A second stream, Cowmire Creek, crosses the floodplain east of the site. This stream flows northward and joins a backwater portion of the Missouri River at kilometer 35.4 (22 miles). Because of the relationship which exists between river level and groundwater level in portions of the floodplain near the river, these streams may either lose flow (at low stage) or gain flow (at high stage).

The present channel of the Missouri River lies about 3 km (2 miles) west and northwest of the landfill. Early land surveys of this area indicate that 200 years ago the channel was located several hundred meters to the east (toward the landfill) of its present course (Reitz and Jens, 1983b). The Missouri River has a surface slope of about 0.00018 (Long, 1981). River stage at St. Charles [kilometer 45.2 (mile 28)] is zero for a water level of 126.1 m (413.7 ft) msl (Reitz and Jens, 1983a). Average discharge of the Missouri River is 2190 m^3/s (77,300 ft^3/s), with a maximum flow of 2850 m^3/s (101,000 ft^3/s) for the period of April through July, and a minimum flow of 1140 m^3/s (40,300 ft^3/s) in January and December (Miller, 1977). Some average properties of Missouri River water for the period 1951-1970 were: alkalinity = 150 mg/liter as $CaCO_3$ equivalent; hardness = 209 mg/liter as $CaCO_3$ equivalent; pH = 8.1; and turbidity = 694 JTU (Jackson turbidity unit).

Water supplies are drawn from the Missouri River at kilometer 46.6 (mile 29) for the city of St. Charles, and the intake is located on the north bank of the river. Another intake at kilometer 33 (mile 20.5) is for the St. Louis Water Company's North County plant (Reitz and Jens, 1983a).

The city of St. Louis takes water from the Mississippi River, which joins the Missouri River downstream from the landfill. In this segment of the river, the two flow-streams have not completely mixed and the water derived from the Missouri River is still flowing as a stream along the west bank of the Mississippi River channel*. The intake structures for St. Louis are on the east bank of the river so that the water drawn is derived from the upper Mississippi.

2.9 Meteorology

The climate of the West Lake area is typical of the midwestern United States, in that there are four distinct seasons. Winters are generally not too severe and summers are hot with high humidity. First frosts usually occur in October; and freezing temperatures generally do not persist past March. Rainfall is greatest in the warmer months, (about one-quarter of the annual precipitation occurs in May and June) (Figure 2.10) (NRC, 1981). In July and August, thunderstorms are common, and are often accompanied by short periods of heavy rainfall. Average annual precipitation is 897 mm (35.3 in.), which includes the average annual snowfall of 437 mm (17.2 inches snow). Average relative humidity is 68%,

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*Ned Harvey, hydrologist with the USGS, telephone communication, August 1983.

and humidities over 80% are common during the summer. Wind during the period of December through April is generally from the northwest; winds blow mainly from the south throughout the remainder of the year. A compilation of hourly wind observations shows that although the wind resultant is fairly consistent on a monthly basis, the wind actually shifts a good deal and is very well distributed in all directions (Figure 2.11) (NRC, 1981; U.S. Department of Commerce, 1960).

Meteorological data used is from Lambert Field International Airport which is 6 km (3.7 miles) east of the West Lake site. Temperature and precipitation data are also representative of West Lake. However, because of differences in topography between Lambert Field and the site, the actual wind directions at West Lake may be slightly skewed in a NE-SW direction parallel to the Missouri River valley.

2.10 Ecology

The West Lake Landfill is biologically and ecologically diverse. Rather than a single ecological system (e.g., a prairie), it is a mosaic of small habitats associated with

(1) moist bottomland and farmland adjacent to the perimeter berm

(2) poor quality drier soils on the upper exterior and interior slopes of the berm

(3) an irregular waste ground surface associated with the inactive portion of the landfill

(4) aquatic ecosystems present in low spots on the waste ground surface

Generally, the natural systems which are present are limited by operations in the active portion of the landfill and form a corridor along the perimeter berm from near well site 75 (Figure 2.5), on the Old St. Charles Rock Road, clockwise to the main entrance to the landfill near well site 68, along St. Charles Rock

Road. The following observation and descriptions demonstrate the biological variety of these sites.

The flora of the perimeter berm extending from the southwest clockwise to the area of the main entrance to the landfill present a series of contrasts. Along the Old St. Charles Rock Road, the bottom and lower slope of the berm is heavily influenced by the nearby mature silver maple (Acer saccharinum), boxelder (Acer negundo), oak (Quercus), sycamore (Platanus), green ash (Fraximus pennsylvanica), and eastern cottonwood (Populus deltoides) trees associated with the old channel of Creve Coeur Creek. At the corner, between wells 59 and 60 (Figure 2.5), large silver maple and boxelder trees form a dense stand in the moist soils at the base of the berm. The density of these trees declines on this slope extending toward the north (well 61) and the Butler-type Building corner. The extension of this slope toward the northwest is dominated by a dense willow-like thicket in which a few eastern cottonwoods and a hawthorn tree have established. From this northwest corner of the landfill to the eastern limit of the trees between the landfill and St. Charles Rock Road (well 65), the exterior slope of the berm is dominated by dense stands of small and large eastern cottonwoods. This latter occurrence reflects the influence of the well-established eastern cottonwoods and sycamores associated with the permanent pond just north of this site (Figure 2.9). The ground cover along these exterior slopes consists of grasses, forbs, plants common to disturbed areas, seedling cottonwoods, and shrubs. A well-manicured grass groundcover continues from the limit of the trees to the area around the main entrance of the landfill and well 68. This vegetation contributes to the partial stabilization of the steep exterior slopes.

The somewhat drier top and the short, interior slope of the berm, colonized by prairie grasses such as bluestem (Andropogon), blends into the irregular surface of the inactive portion of the landfill. Depressions in this surface allow water to collect and tall grasses, foxtail, and plants characteristic of disturbed areas [e.g., ragweed (Ambrosia), mullein (Verbascum), pokeweed (Phytolacca), cinquefoil (Potentilla), sunflower (Helianthus), and plantain (Plantago)] are replaced by characteristic wetland species [e.g., algae (Spirogyra), cattails (Typha), sedges (Carex), and smartweed (Polygonium)]. Young eastern cottonwoods are established at several of these wet sites.

Generally, the surface vegetation of the inactive landfill gives way to barren waste ground around the Butler-type Building location and the barren terrain associated with recent landfill activities.

Animals were observed associated with these habitats. Cottontail rabbits (Sylvilagus) were encountered most frequently and their fecal pellets were observed on the landfill. Density of fecal material was particularly heavy in the thickets on the exterior slopes of the perimeter berm. In this regard, coyote (Canis latrans) feces containing rabbit fur were observed. Small mammals (rodents) were not seen but could certainly be present in these areas. Large ungulates also were not sighted, but tracks and feces of white-tailed deer indicate that they utilize the landfill.

The only birds observed were a crow (Corvus), several robins (Turdus), and white-crowned sparrows (Zonotrichia leucophrys). This certainly does not reflect the extent to which birds utilize these habitats, for observations were made early in the spring. It is readily apparent that returning migratory passerines would utilize the surface vegetation and berm thickets for nesting, cover, and feed later in the season. It is also possible that waterfowl could utilize the permanent ponds on the landfill and adjacent to St. Charles Rock Road. Twelve scaup (Aythya) and mallards (Anas) were observed on the lagoon which serves as part of the landfill waste water treatment facility.

Small puddles contained characteristic aquatic invertebrates and at least two species of amphibians. Casual examination of these shallow waters revealed three genera of snails (Physa, Lymnaea, Helisoma), an isopod (Asnellus), cyclopoid copepods, and cladocerans. Aquatic insect larvae were not observed; however, this does not rule out their presence. The sighting of a bullfrog tadpole (Rana catesbeiana) and audition of spring peepers (Hyla), indicates these ponds are utilized as breeding sites. No fish were observed in these puddles on the landfill surface; however, a dead gizzard shad (Dorsoma cepedianum) was seen in the pond adjacent to St. Charles Rock Road. The only reptiles seen were the water snake (Nerodia) and the garter snake (Thamnophis).

Although the northwest inactive portion of the landfill is posted with "No Trespassing" signs, it was evident that humans do encroach on these habitats.

Fishing tackle was found tangled in power lines and trees, and spent small-gauge shotgun shells were found on the landfill surface and berms.

2.11 Demographics

The West Lake Landfill is located in the northwestern portion of the city of Bridgeton, in St. Louis County, Missouri. Earth City Industrial Park is located on the floodplain 1.5 to 2 km (0.9 to 1.2 miles) northwest of the landfill. Population density on the floodplain is generally less than 10 persons per square kilometer (26 persons per square mile); and the daytime population (including factory workers) is much greater than the number of full-time residents.

Major highways in the area include Interstate 70 (I-70) and Interstate 270 (I-270), which meet south of the landfill at Natural Bridge Junction (Figure 1.1). The Earth City Expressway and St. Charles Rock Road lie, respectively, west and east of the landfill. The Norfolk and Western Railroad passes about 1 km (0.6 mile) from the northern portion of the landfill (Figure 1.1). Lambert Field International Airport is located 6 km (3.7 miles) east of the West Lake Landfill.

In addition to factories at Earth City, plants are operated by Ralston-Purina and Hussman Refrigeration across St. Charles Rock Road. The employees of these two plants probably comprise the largest group of individuals in close proximity to the contaminated areas for significant periods of time. The Ralston-Purina facilities are located 0.4 km (0.2 mile) northeast of the Butler-type Building location at the landfill. Considering that land in this area is relatively inexpensive and that much of it is zoned for manufacturing, industrial development on the floodplain will likely increase in the future.

Two small residential communities are present near the West Lake Landfill. Spanish Lake Village consists of about 90 homes and is located 1.5 km (0.9 mile) south of the landfill, and a small trailer court lies across St. Charles Rock Road, 1.5 km (0.9 mile) southeast of th· site (Figure 2.1). Subdivisions are presently being developed 2 to 3 km (1.2 to 1.9 miles) east and southeast of the landfill in the hills above the floodplain. Ten or more houses lie east of the landfill scattered along Taussig Road. The city of St. Charles is located north of the Missouri River at a distance greater than 3 km (1.9 miles) from the landfill.

Areas south of the West Lake Landfill are zoned residential; areas on the other sides are zoned for manufacturing and business (Figure 2.2). Most of the landfill is zoned for light manufacturing (M-1). However, approximately 0.3 km^2 (0.12 mi^2) of the northern portion of the landfill is zoned for residential use; this includes the contaminated area around the Butler-type Building site. The field northwest of the landfill between Old St. Charles Rock Road and St. Charles Rock Road is under cultivation. Trends indicate that the population of this area will increase, but the land will probably be used primarily for industrial facilities.

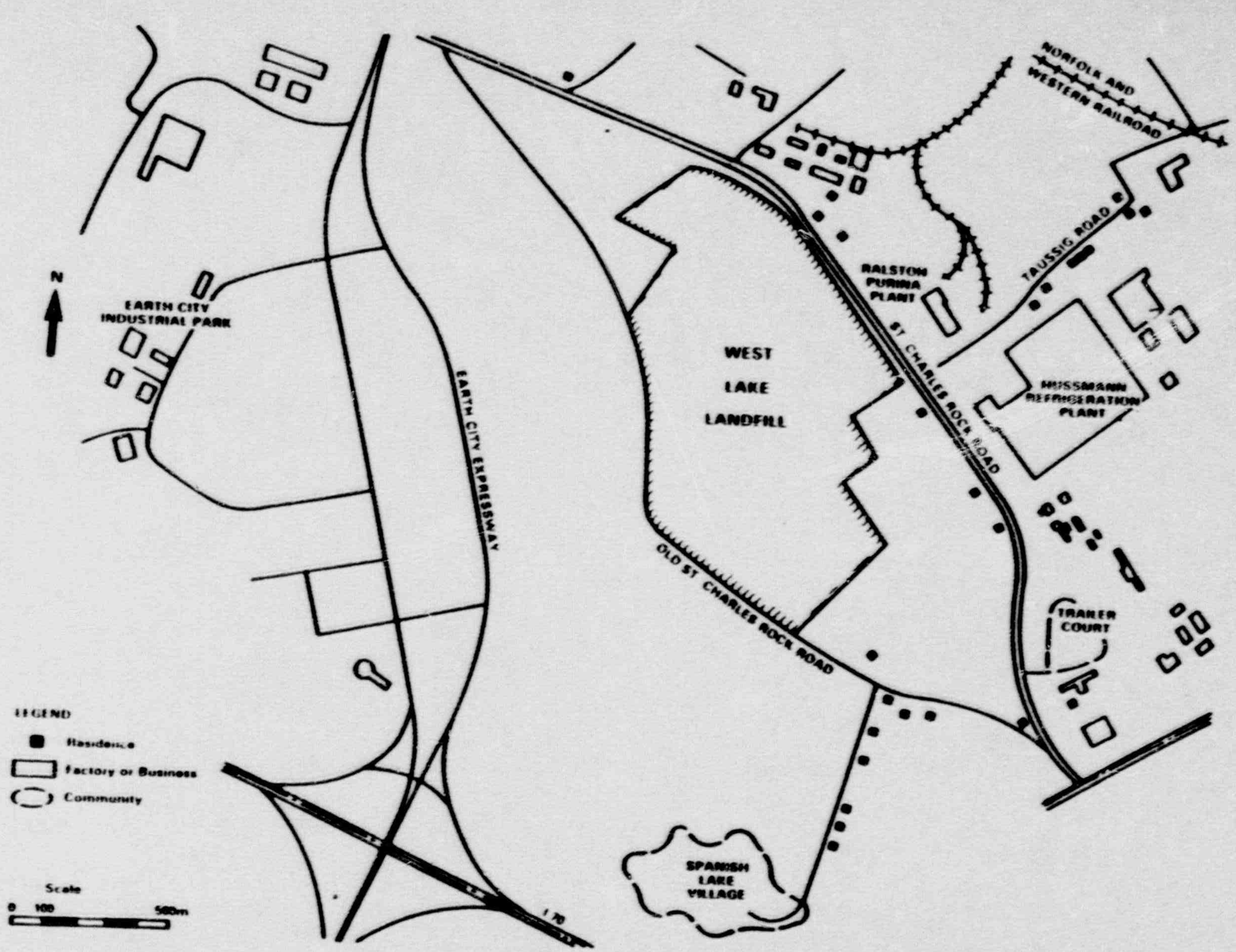


Figure 2.1 Land use around West Lake Landfill site

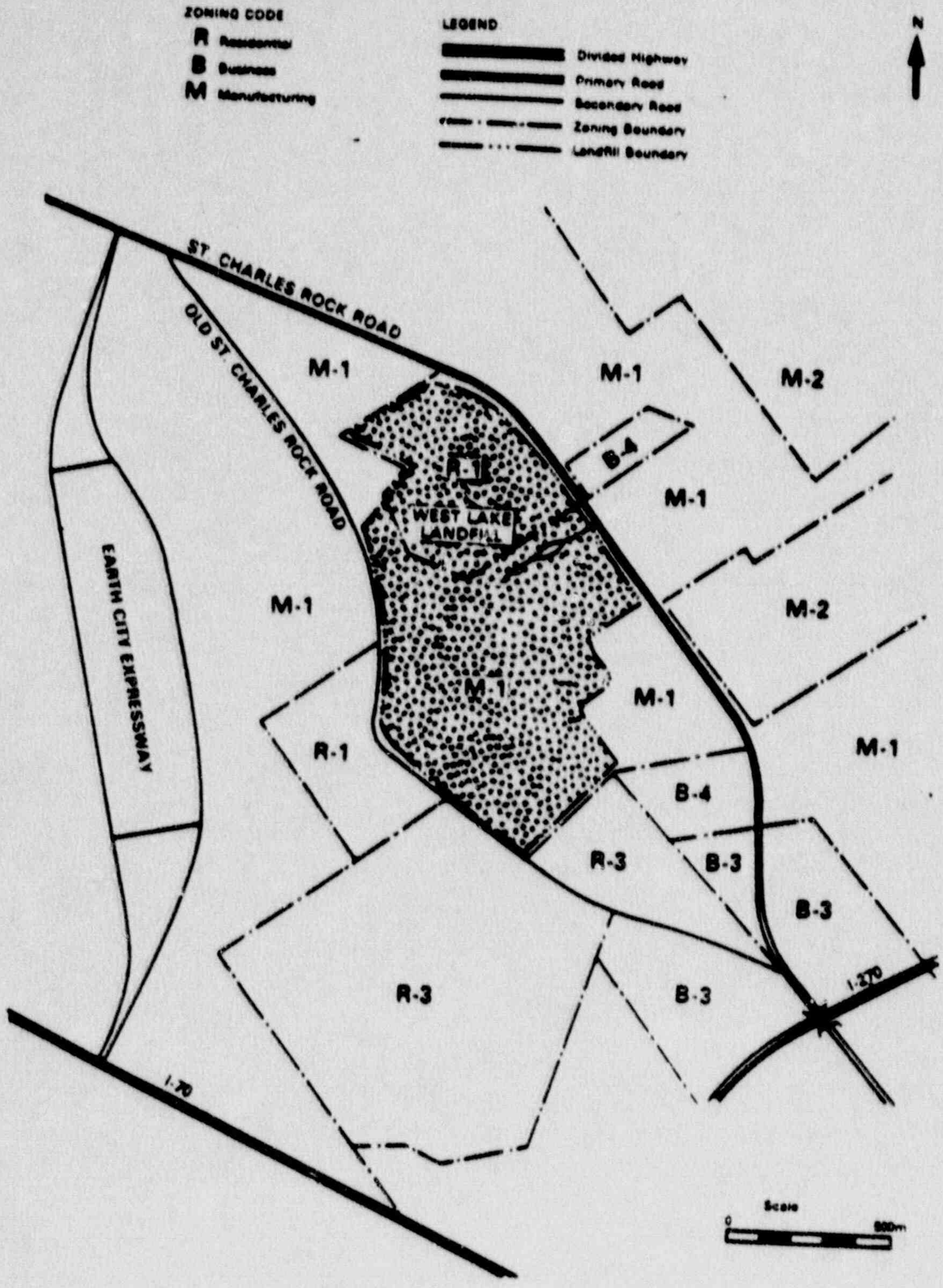


Figure 2.2 Zoning plan of West Lake area (June 1984)

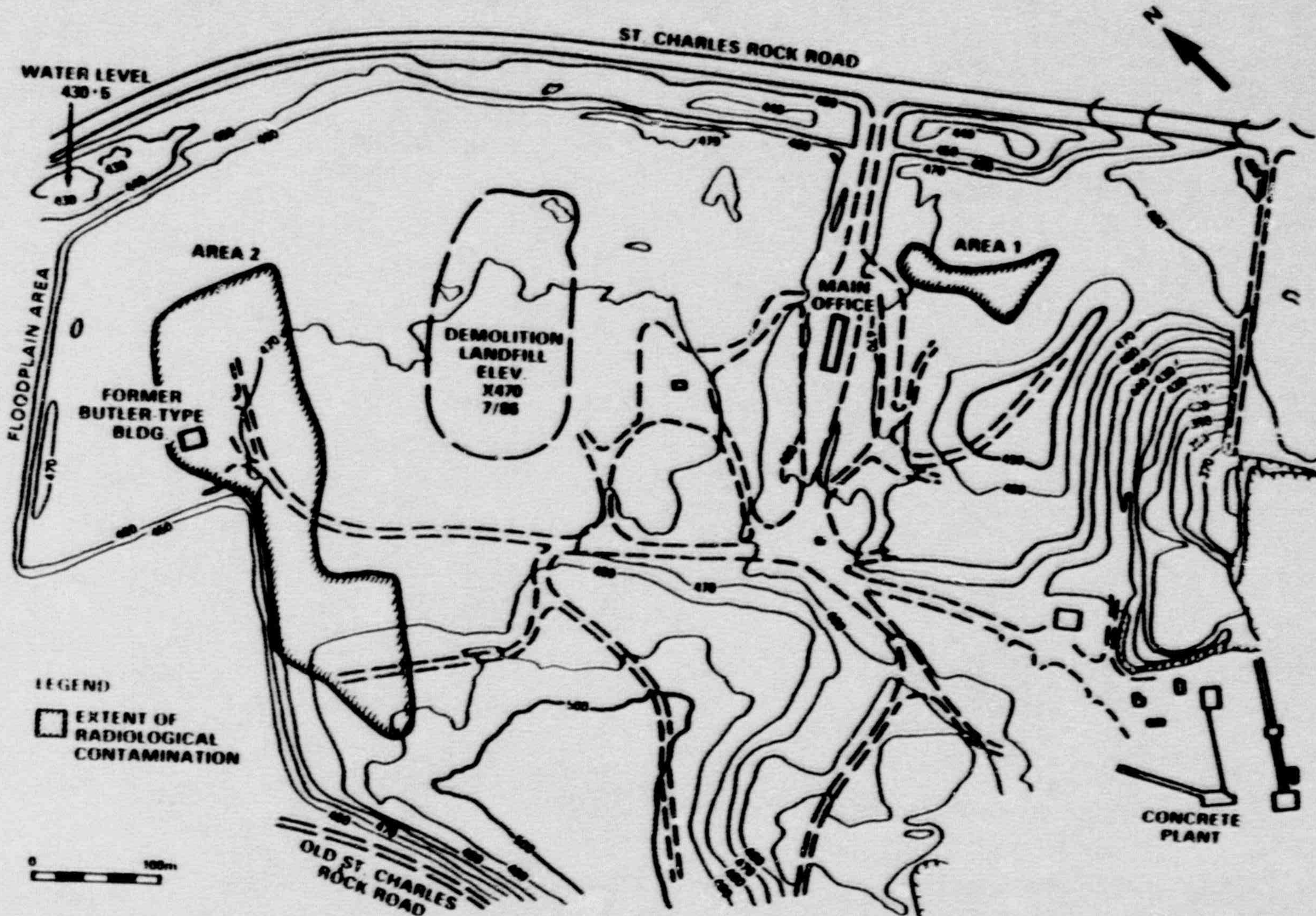


Figure 2.3 Site topography and extent of contamination.

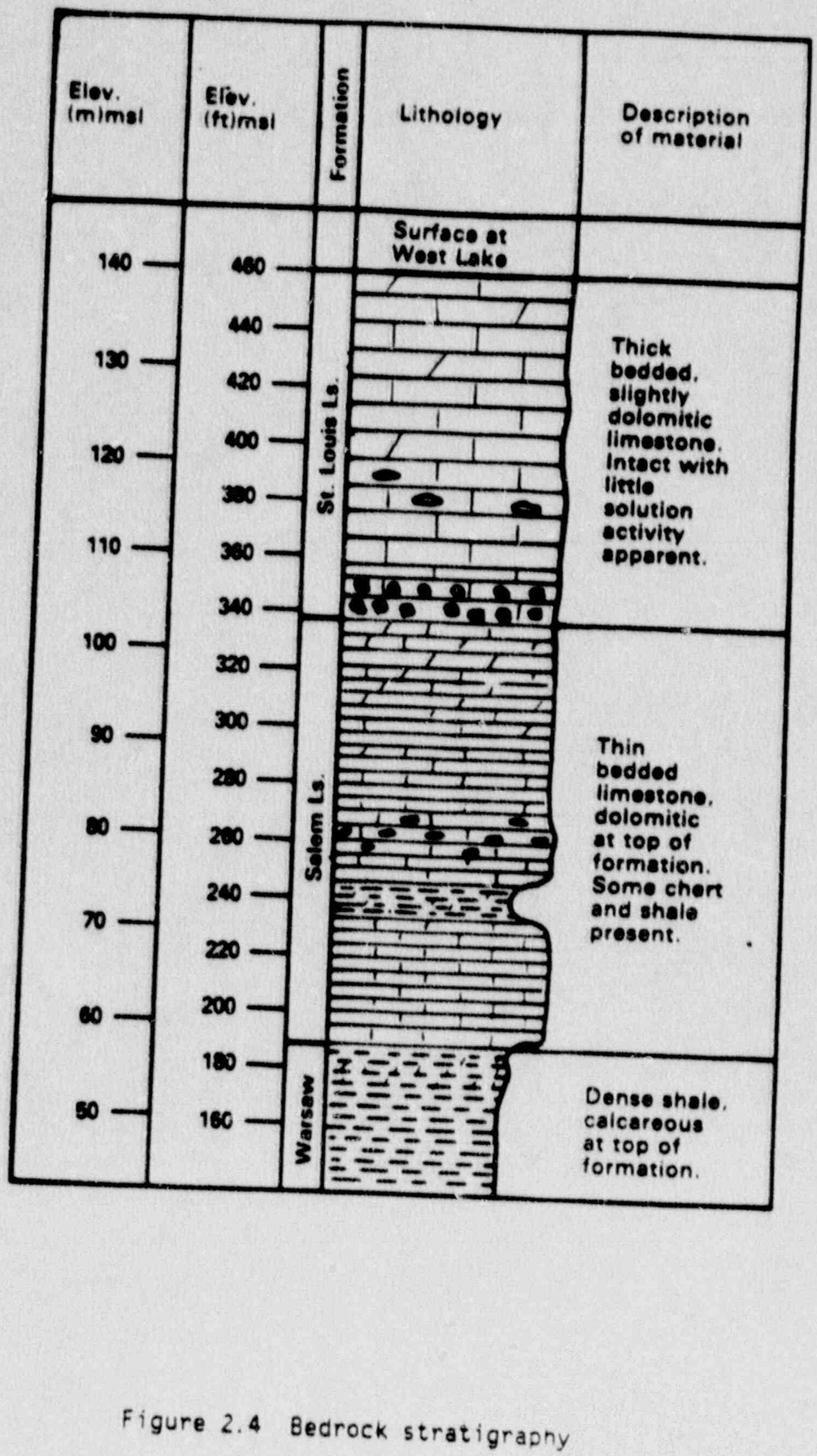


Figure 2.4 Bedrock stratigraphy

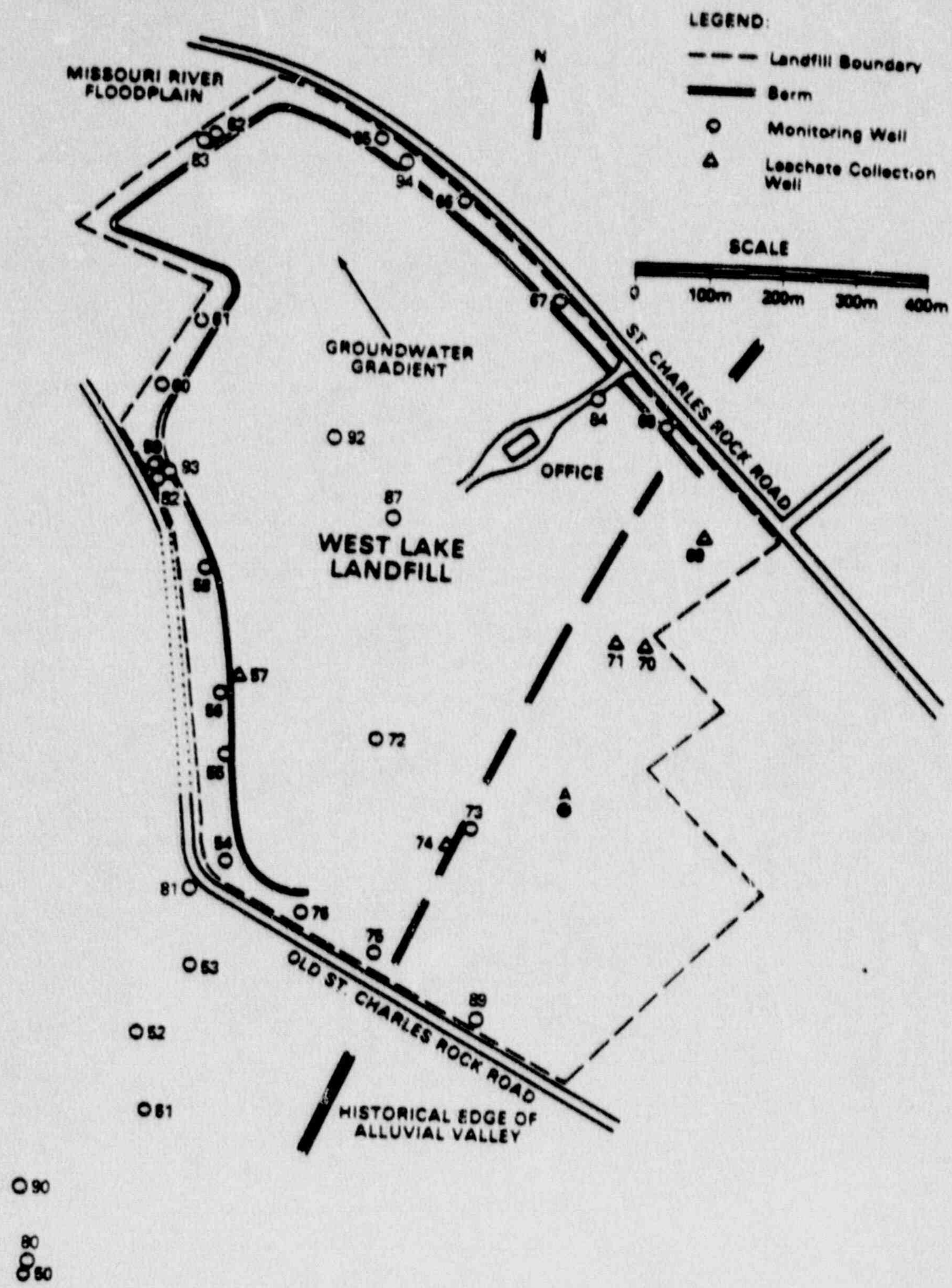


Figure 2.5 Location of monitoring wells

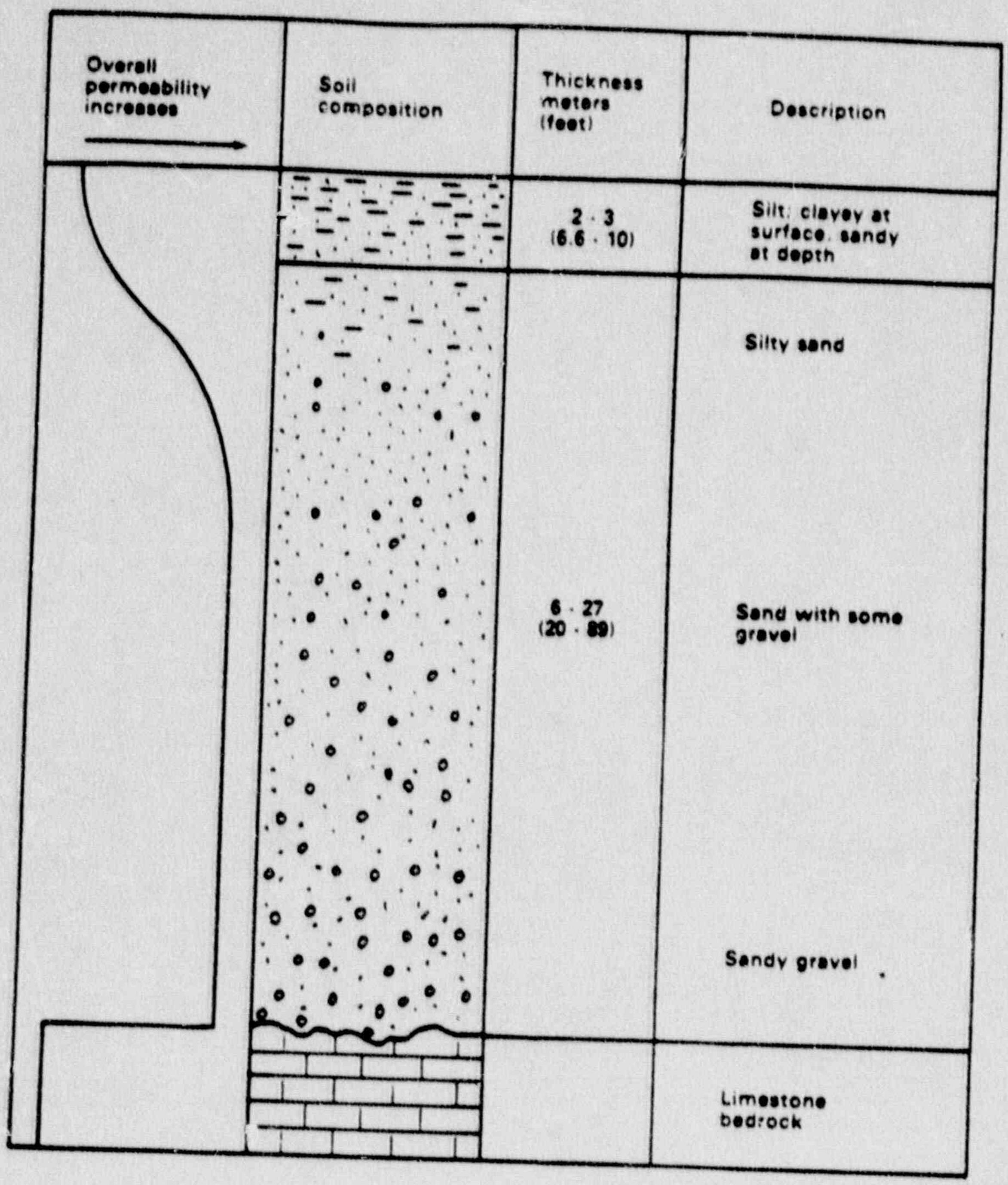


Figure 2.6 Soil profile of river alluvium

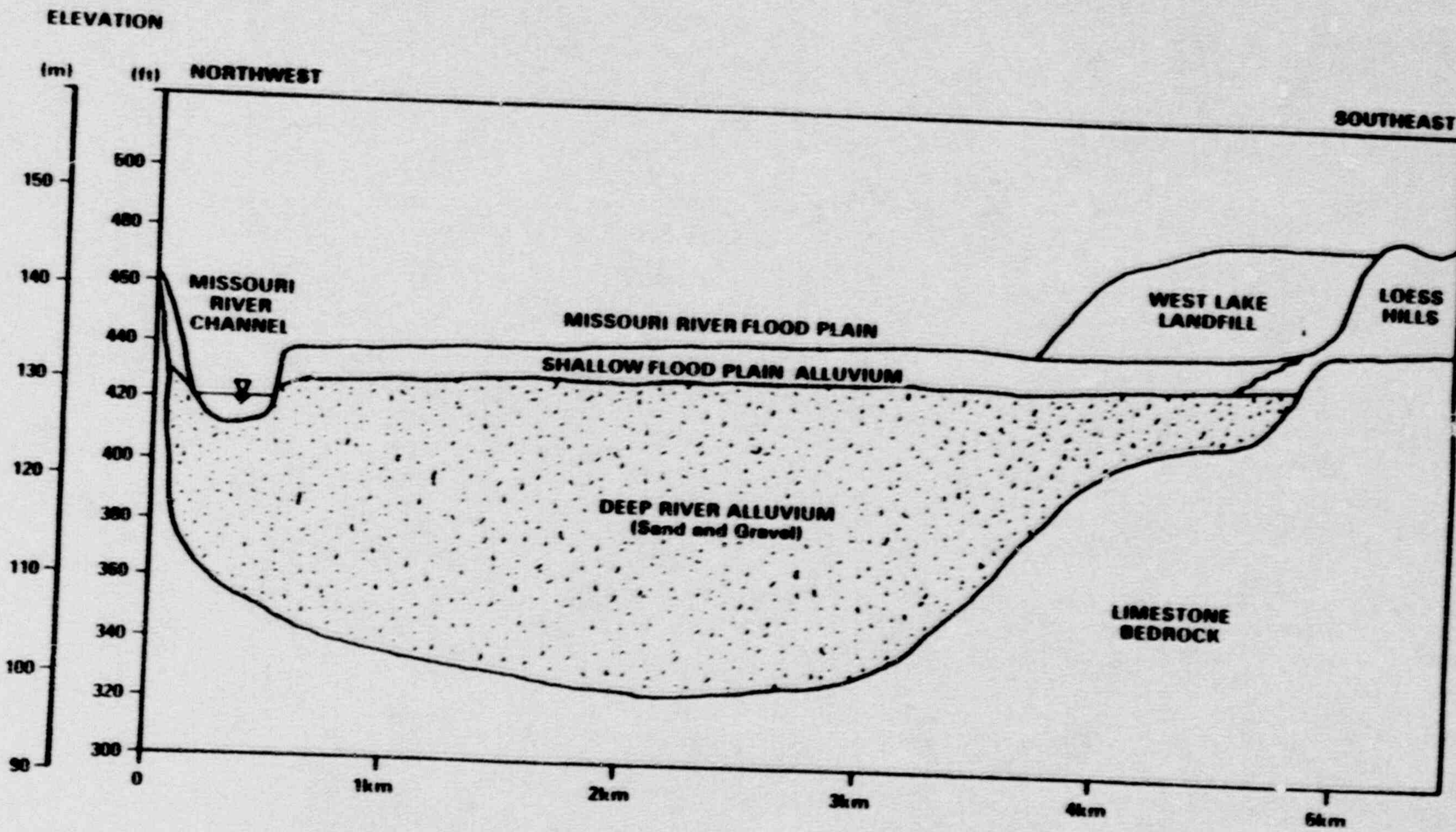


Figure 2.7 Cross-section of Missouri River alluvial valley

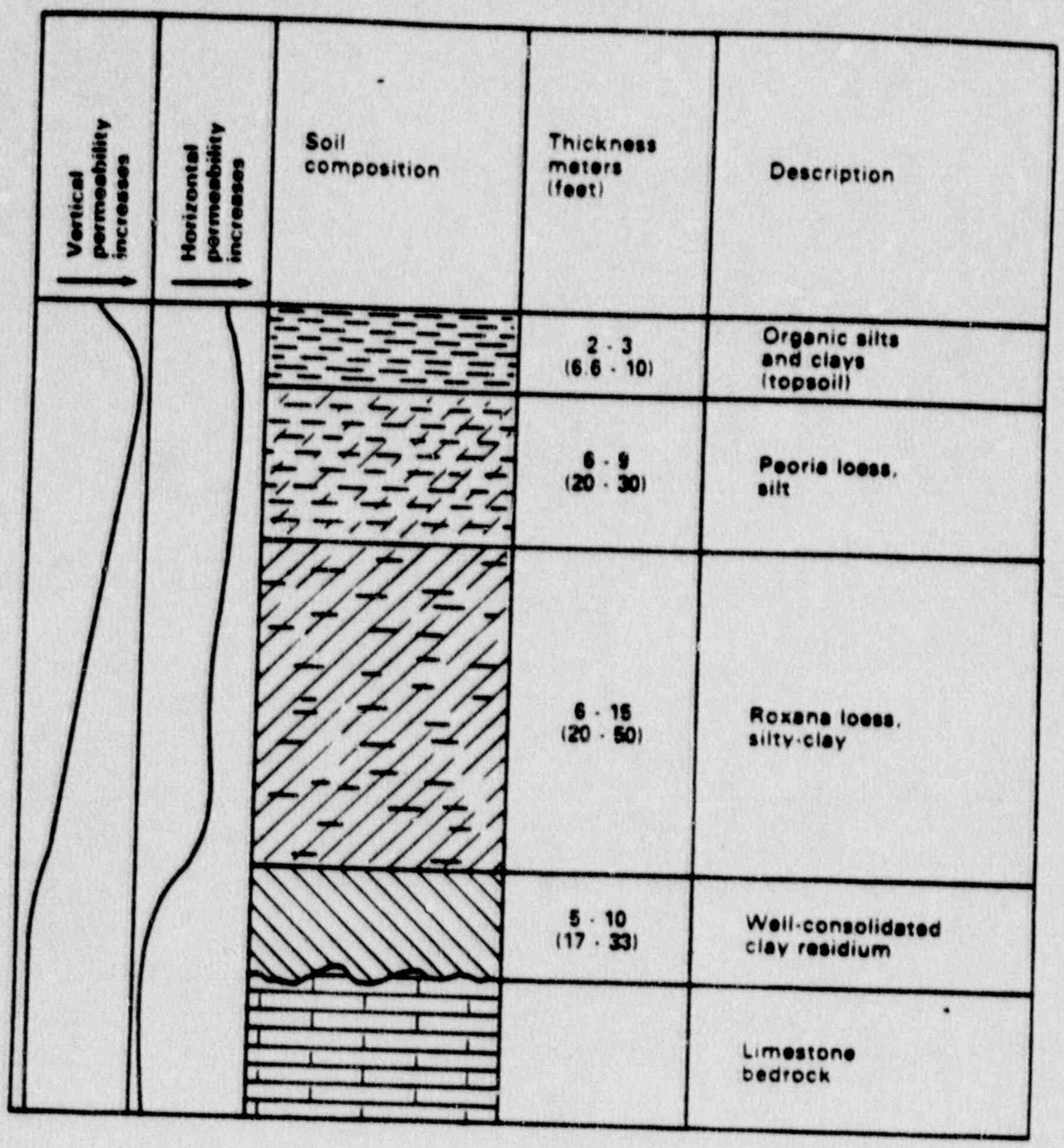


Figure 2.8 Soil profile of upland loessal soil

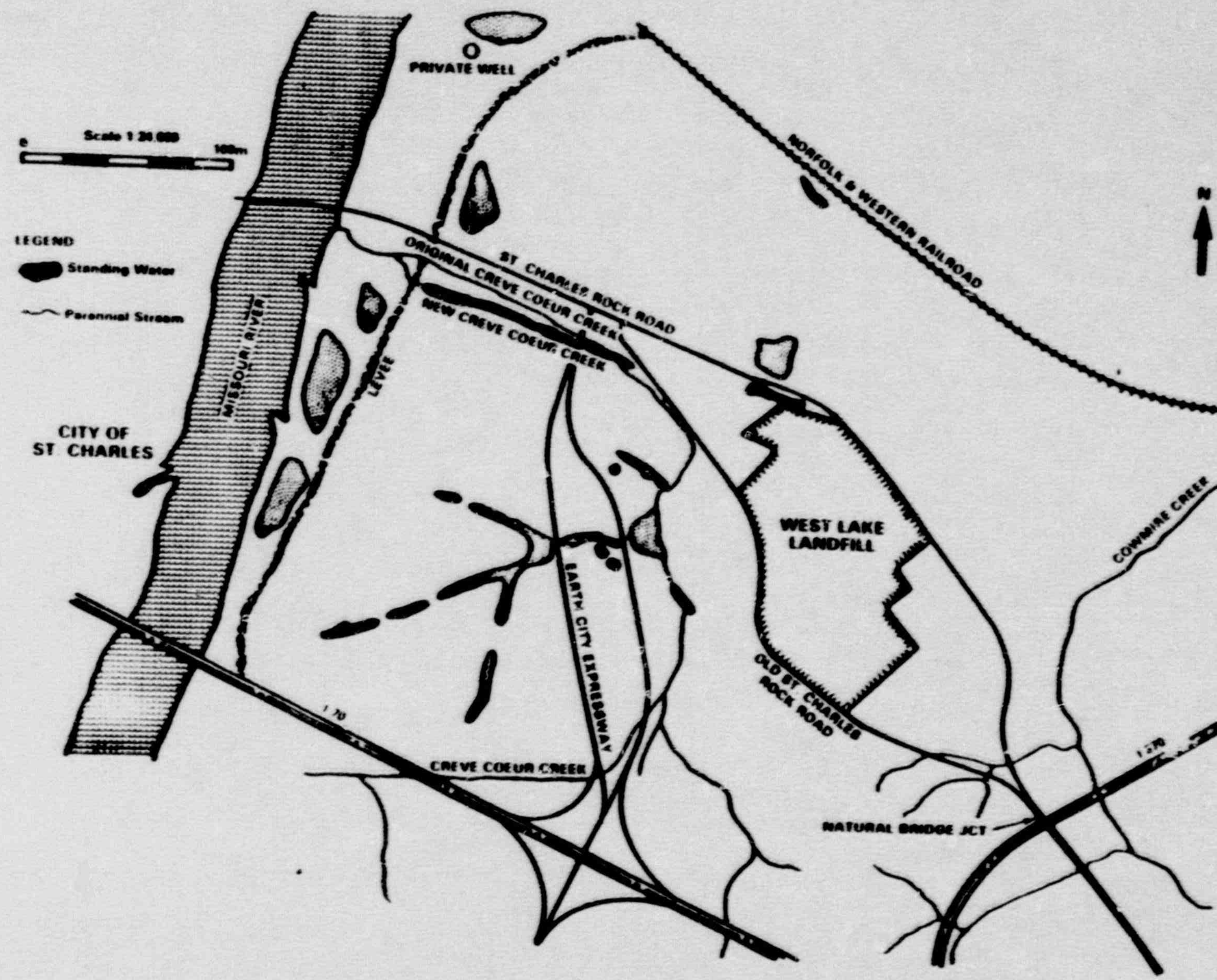


Figure 2.9 Surface hydrology of West Lake area

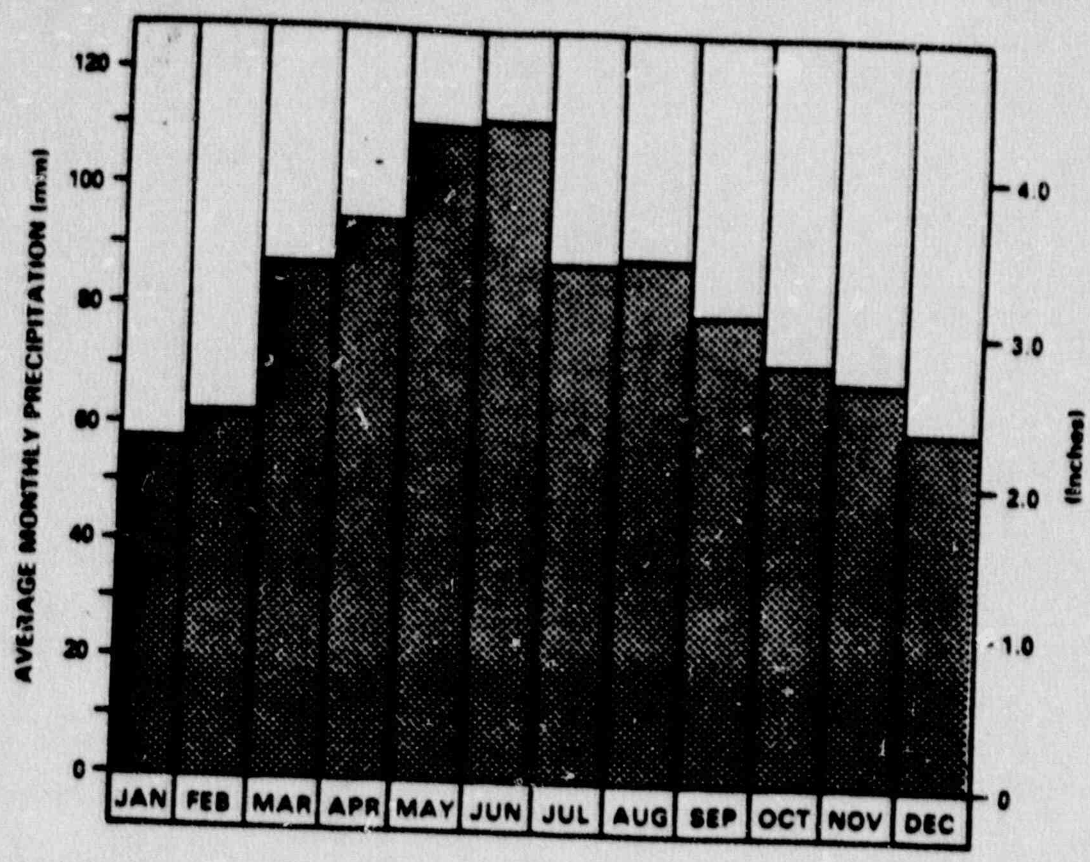
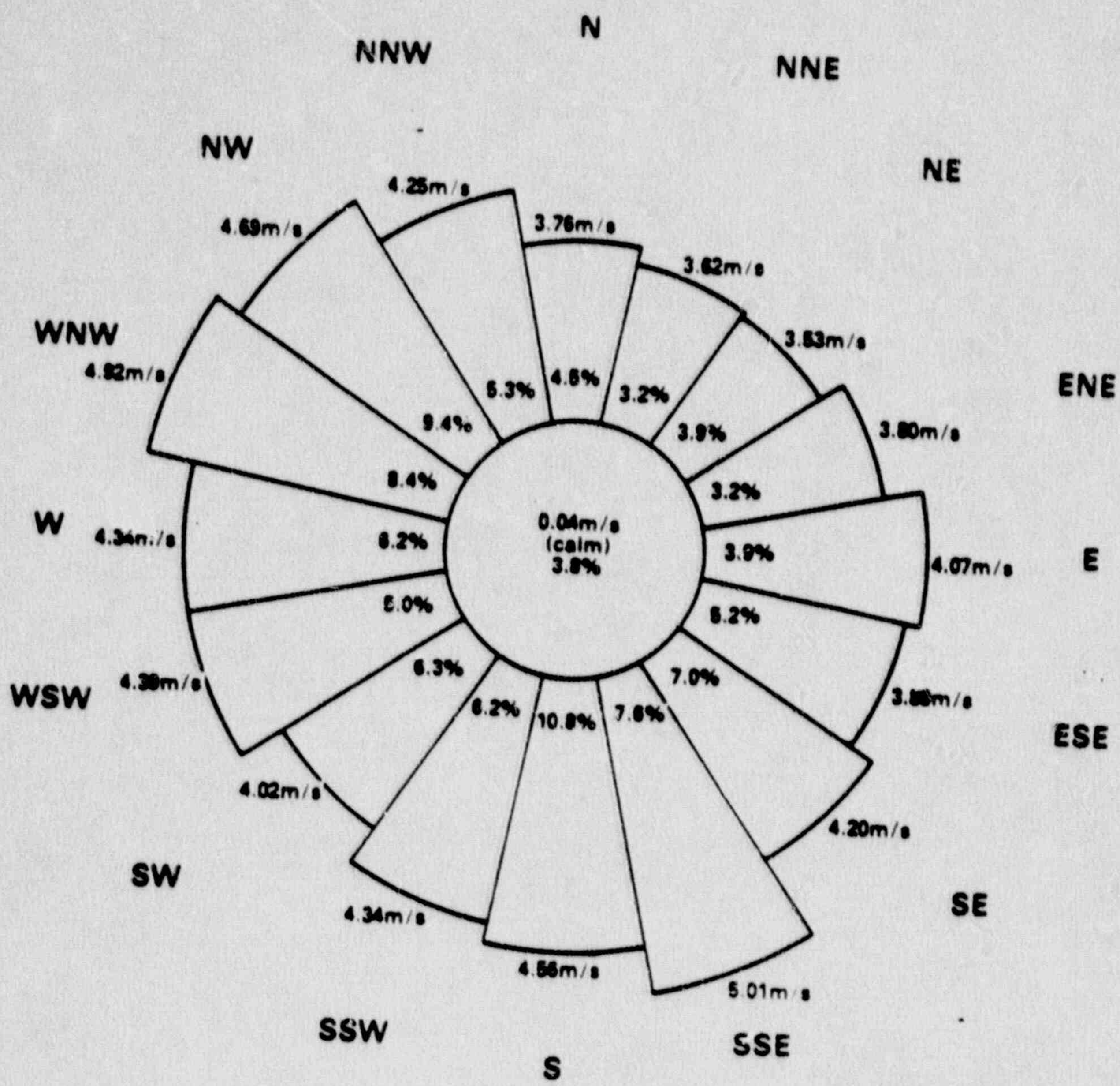


Figure 2.10 Average monthly precipitation at Lambert Field International Airport



Wind rose is for Lambert Field International Airport, Hazelwood, Missouri, and shows the percentage of hourly observations in each direction along with the average speed in that direction; for example: wind blew from the north 4.5% of the time at an average speed of 3.76 m/s.

Figure 2.11 Wind distribution for West Lake area

3 RADIOLOGICAL CHARACTERIZATION OF THE SITE

3.1 Radiological Surveillance

Approximately 43,000 mt (47,000 tons) of contaminated soil were reported to have been disposed of in the landfill. A fly-over radiological survey performed for the NRC in 1978 identified two areas of contamination at the West Lake Landfill.

Subsequently, from August 1980 through the summer of 1981, the Radiation Management Corporation (RMC), under contract to the NRC, performed an onsite evaluation of the West Lake Landfill (NRC, NUREG/CR-2722). The purpose of this survey was to clearly define the radiological conditions at the landfill. The results were to be utilized in performing an engineering evaluation to determine if remedial actions should and could be taken.

The area to be surveyed was divided into 10-m (33-ft) grid blocks and included the following measurements:

(1) external gamma exposure rates 1 m (3.3 ft) above the surfaces and beta-gamma count rates 1 cm (0.4 in.) above surfaces

(2) radionuclide concentrations in surface soils

(3) radionuclide concentrations in subsurface deposits

(4) gross activity and radionuclide concentrations in surface and subsurface water samples

(5) radon flux emanating from surfaces

(6) airborne radioactivity

(7) gross activity in vegetation

3.2 Survey Results

External Gamma

Figure 3.1 shows the two areas of elevated external radiation levels as they existed in November 1980, at the time of the preliminary RMC site survey. As can be seen, both areas contained locations where levels exceeded 100 μR/hr at 1 m (3.3 ft). In Area 2, gamma levels as high as 3000 to 4000 μR/hr were detected. The total areas exceeding 20 μR/hr were about 1.2 ha (3 acres) in Area 1 and 3.6 ha (9 acres) in Area 2.

External gamma levels measured in May and July of 1981 decreased significantly, especially in Area 1, because approximately 1.2 m (4 ft) of sanitary fill was added to the entire area and an equal amount of construction fill was added to most of Area 2. As a result, only a few hundred square meters (a few thousand square feet) in Area 1 exceed 20 μR/hr. In Area 2, the total area exceeding 20 μR/hr decreased by about 10%, and the highest levels were about 1600 μR/hr, near the location of the Butler-type building.

Surface Soil Analyses

A total of 61 surface soil samples were gathered and analyzed on site for gamma activity. Samples were normally stored 10 to 14 days to allow ingrowth of radium daughters. Concentrations of U-238, Ra-226 (from Pb-214 and Bi-214), Ra-223, Pb-211, and Pb-212 were determined for each sample. Surface soil samples are located in Figures 3.2 and 3.3.

In all soil samples, only uranium and/or thorium decay chain nuclides and K-40 were detected. Offsite background samples were on the order of 2 pCi/g Ra-226. Onsite samples ranged from about 1 to 21,000 pCi/g Ra-226, and from less than 10 to 2100 pCi/g U-238. In those cases where elevated levels of Ra-226 were detected, the concentrations of U-238 were generally anywhere from a factor of 2 to 10 lower. In cases of elevated sample activity, daughter products of both U-238 and U-235 were found.

In general, surface activity was limited to Area 2, as indicated by surface beta-gamma measurements. Only two small regions in Area 1 showed contamination; both were near the access road across from the site offices.

In addition to onsite gamma analyses, 12 samples were submitted to RMC's radiochemical laboratories for thorium and uranium radiochemical determinations. The results show all samples contain high levels of Th-230. The ratio of Th-230 to Ra-226 (Bi-214) is about 20 to 1.

Subsurface Soil Analysis

Subsurface contamination was assessed by extensively "logging" holes drilled through the landfill. Several holes were drilled in areas known to contain contamination, then additional holes were drilled at intervals in all directions until no further contamination was encountered. A total of 43 holes were drilled, 11 in Area 1 and, in Area 2, 32 including 2 nearby offsite wells for monitoring water. All holes were drilled with a 6-in. auger and lined with 4-in. PVC (polyvinyl chloride) casing. The location of these auger holes is shown in Figures 3.4 and 3.5.

Each hole was scanned with an NaI(Tl) detector and rate meter system for an initial indication of the location of subsurface contamination. On the basis of the initial scans, 19 holes were selected for detailed gamma logging using the intrinsic germanium (IG) detector and multiple channel analyzer.

The results of the NaI(Tl) counts and IG analyses show concentrations of Bi-214, as determined by the IG system, ranged from less than 1 to 19,000 pCi/g. For those holes where both NaI(Tl) counts and IG counts were made, a good correlation between gross NaI(Tl) counts and Ra-226 concentrations, as determined by in situ analysis of the daughter Bi-214 by the IG system, was found.

It was determined that the subsurface deposits extended beyond areas where surface radiation measurements exceeded 5 pCi/g. The approximate area of subsurface contamination compared to the area of elevated surface radiation levels shows a total difference in areas of 2 ha (5 acres).

The variations of contamination with depth for Areas 1 and 2 are shown in Figure 3.6. As can be seen, the surface elevations vary by about 6 m (20 ft), and the highest elevations occur at locations of fresh fill. Contamination (>5 pCi/g Ra-226) in several areas is found to extend from the surface to appreciable depths, about 6 m (20 ft) below the surface in two cases. In general, the subsurface contamination appears to be a continuous single layer, ranging from 0.6 to 4.6 m (2 to 15 ft) thick, located between elevations of 139 to 144 m (455 to 480 ft) and covering 6.5 ha (16 acres) total area.

In Figures 3.7 and 3.8, representations of the subsurface deposits are provided on the basis of auger hole measurements. These representations are consistent with the operating history of the site, which suggests that the contaminated material was moved onto the site and spread as cover over fill material. Thus, one would expect a fairly continuous, thin layer of contamination, as indicated by survey results.

Nonradiological Analysis

Six composite samples were submitted to RMC's Environmental Chemistry Laboratory for priority pollutant analysis. Five samples were taken from auger holes (one from Area 1 and four from Area 2) and the sixth from the West Lake leachate treatment plant sludge. The results indicate a significant presence of organic solvents in Area 2 samples. The results of the leachate sludge analysis were not as high as any of the soil samples.

A chemical analysis of radioactive material from both areas was also performed by RMC's laboratory. Results show elevated levels of barium and lead in most cases.

Background Radioactivity Measurement

Various offsite locations were selected for reference background measurements. The results of these measurements were within the normal range.

Airborne Radioactivity Analyses

Both gaseous and particulate airborne radioactivity were sampled and analyzed during this study. Since it was known that the buried material consisted partially or totally of uranium ore residues, the sampling program concentrated on measuring radon and its daughters in the air. Two methods were used: the first was a scintillation flask method for radon gas and the second was analysis of filter paper activity for particulate daughters.

A series of grab samples using the accumulator method were taken between May and August of 1981. A total of 111 samples from 32 locations was collected. Measurable radon flux levels ranged from 0.2 pCi/m^2s in low background areas to 865 pCi/m^2s in areas of surface contamination.

At three locations, repetitive measurements were made over a period of 2 months. These results are plotted in Figure 3.9. As can be seen, significant fluctuations were observed at two locations. The fact that these fluctuations were real and not measurement artifacts was later confirmed by duplicate charcoal canister samples, as described below.

A total of 35 charcoal canister samples was gathered at 19 locations over a 3-month period. The results show levels ranging from 0.3 pCi/m^2s to 613 pCi/m^2s. On 24 different occasions, the charcoal canisters and accumulator were placed in essentially the same locations, at the same time, for duplicate sampling. The results of this side-by-side study show generally good correlation between the two methods.

A set of 10-minute high-volume particulate air samples was taken to determine both short-lived radon daughter concentrations and long-lived gross alpha activity. The highest levels were detected in November 1980, near and inside the Butler-type building which has since been removed. These two samples approximately equal NRC's 10 CFR Part 20, Appendix B. alternate concentration limit of one-thirtieth WL for unrestricted areas.

In addition to the routine 10-minute samples, five 20-minute high-volume air samples were taken and counted immediately on the IG gamma spectroscopy system to detect the presence of Rn-219 daughters. All samples were taken near surface contamination. In addition to Rn-222 daughter gamma activities, Rn-219 daughters were detected by measuring the low-abundance gamma rays of Pb-211. Concentrations of Rn-219 daughters ranged from 6×10^{-11} to 9×10^{-10} μCi/cc.

Vegetation Analysis

Vegetation samples included weed samples from onsite locations and farm crop samples (winter wheat) near the northwest boundary of the landfill. This location was chosen because runoff from the fill onto the farm field was possible. No elevated activities were found in these samples.

Water Analyses

A total of 37 water samples was taken: 4 in the fall of 1980, and the remainder in the spring and summer of 1981. One sample was equal to the U.S. Environmental Protection Agency (EPA) gross alpha activity standard for drinking water of 15 pCi/liter and that was a sample of standing water near the Butler-type building. Several samples, including all the leachate treatment plant samples, exceeded the EPA drinking water screening level for gross beta which would require isotopic analyses. Subsequent isotopic analyses indicated that the beta activity could be attributed to K-40. None of the offsite samples exceeded either EPA standard or screening level.

In 1981, MDNR collected 41 water samples which RMC analyzed for radioactivity (Table 3.1). Of these samples, 5 were background, 10 were onsite surface water, 10 were shallow groundwater standing in boreholes, and 16 were landfill leachate. From these data, background activity is estimated as 1.2 pCi/liter gross alpha and 27 pCi/liter gross beta. Results in Table 3.1 show the gross alpha in two water samples exceeded or equaled 15 pCi/l; the gross beta in ten water samples exceeded 50 pCi/l. Most of the gross beta activity comes from naturally occurring K-40 as determined from subsequent isotopic analysis.

In addition, groundwater samples in perimeter monitoring wells at the West Lake Landfill were taken by UMC personnel and ORAU in 1983, 1984, and 1986. The well locations are shown in Figure 2.5 and the results are presented in

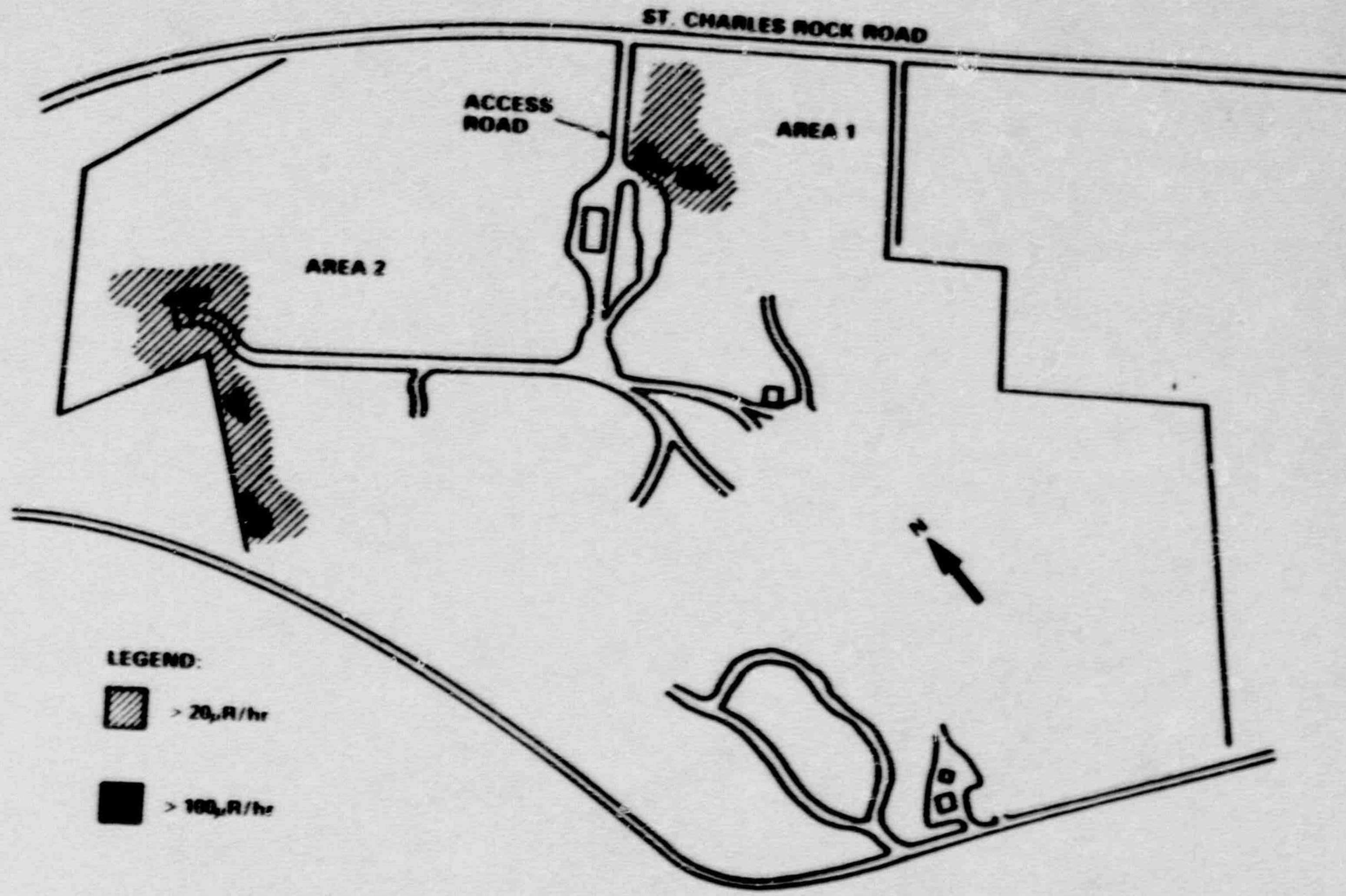
Tables 3.2 and 3.3. Results in Table 3.2 show the gross alpha in two water samples slightly exceeded 15 pCi/l; the gross beta were all below 50 pCi/l in all water samples. Table 3.3 shows analyses were below 15 pCi/l for gross alpha and 50 pCi/l for gross beta for all the wells.

3.3 Estimation of Radioactivity Inventory

In examining the RMC report for bore hole samples (Table 3.3), it is noted that the naturally occurring U-238 to Th-230 to Ra-226 equilibrium has been disturbed. The RMC report (NRC, NUREG/CR-2722) indicates that the ratio of Ra-226 to U-238 is on the order of 2:1 to 10:1. This observation is consistent with the history of the radionuclide deposits in the West Lake Landfill, i.e., that they came from the processing of uranium ores to extract the uranium content and that the radioactive material at West Lake came from the former Cotter Corporation facility on Latty Avenue (presently occupied by Futura Coatings Company) in Hazelwood, Missouri. This location contains contamination from ore processing residues from which uranium had been previously separated, leaving the daughters behind at relatively higher concentrations. Additionally, it is noted in the RMC report that the ratio of Th-230 to Ra-226 is on the order of 5:1 to 50:1. This indicates that radium has also been removed. Other data are available in the Latty Avenue site study (Cole, 1981). Table 3.4 presents the radionuclide concentrations in Latty Avenue composite samples.

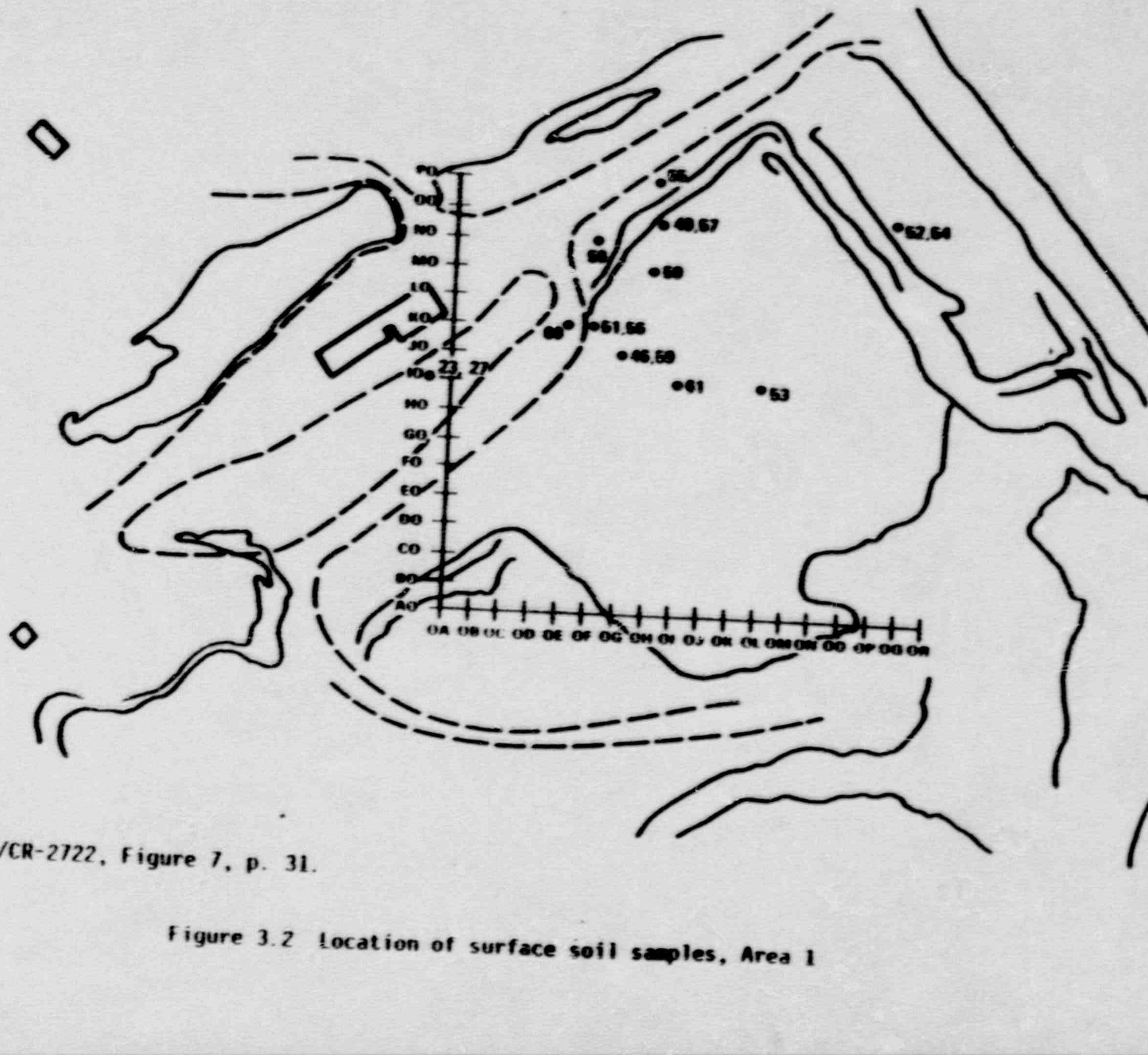
Using the RMC data and averaging the auger hole measurements over the two volumes of radioactive material found in Areas 1 and 2, a mean concentration of 90 pCi/g was calculated for Ra-226. Also, the ratios of Th-230 to Ra-226 were established since the level of Th-230 will determine the increase of Ra-226 with time. Although the ratio of Th-230 to Ra-226 ranged from 5:1 to 150:1, most of the data were in the 30:1 to 50:1 range. To ensure conservatism in estimating the long-term effects of Ra-226, a ratio of 100:1 was used for all further calculations.

Using the Th-230:Ra-226 ratio of 100:1, the Th-230 activity is 9000 pCi per gram. If the U-238 concentration (as well as U-234 which would be similarly separated from the ore) is a factor of 5 less than Ra-226, this implies about 18 pCi U-238 per gram. The total mass of radioactive material (having Ra-226 concentrations of 5 pCi/g or more) in the landfill was estimated by visually integrating the volume of radioactive material from graphs and multiplying by an average soil density, resulting in 1.5×10^{11} grams (150,000 metric tons) of contaminated soil. These numbers indicate that there are about 14 Ci of Ra-226 contained with its decay products in the radioactive material in the landfill. The material also contains about 3 Ci each of U-238 and U-234, and about 1400 Ci of Th-230. These estimates indicate the order of magnitude of the quantities to be dealt with, although the estimate for Th-230 is regarded as conservatively large.



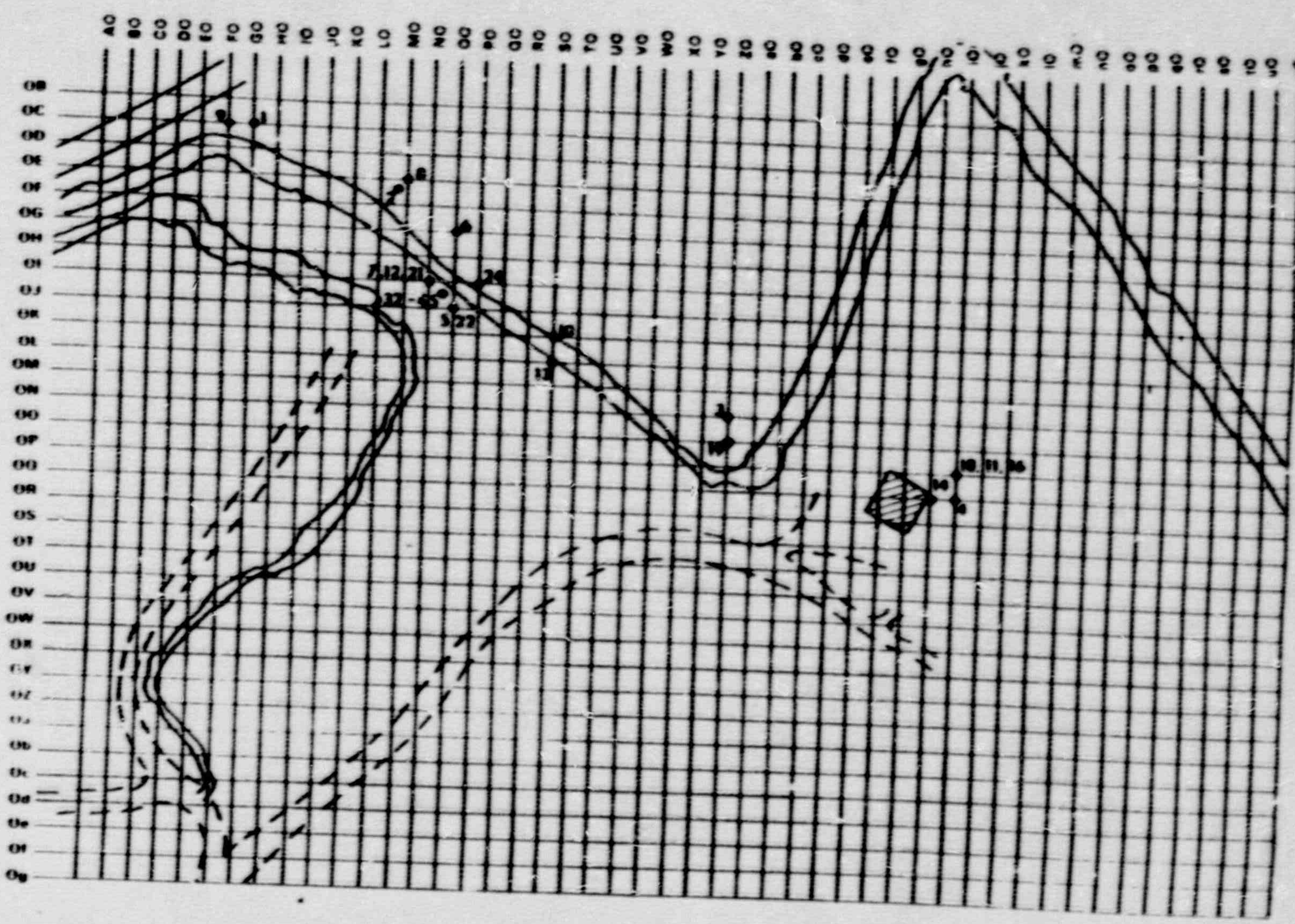
Source: NUREG/CR-2722, Figure 3, p. 27.

Figure 3.1 External gamma radiation levels (November 1980)



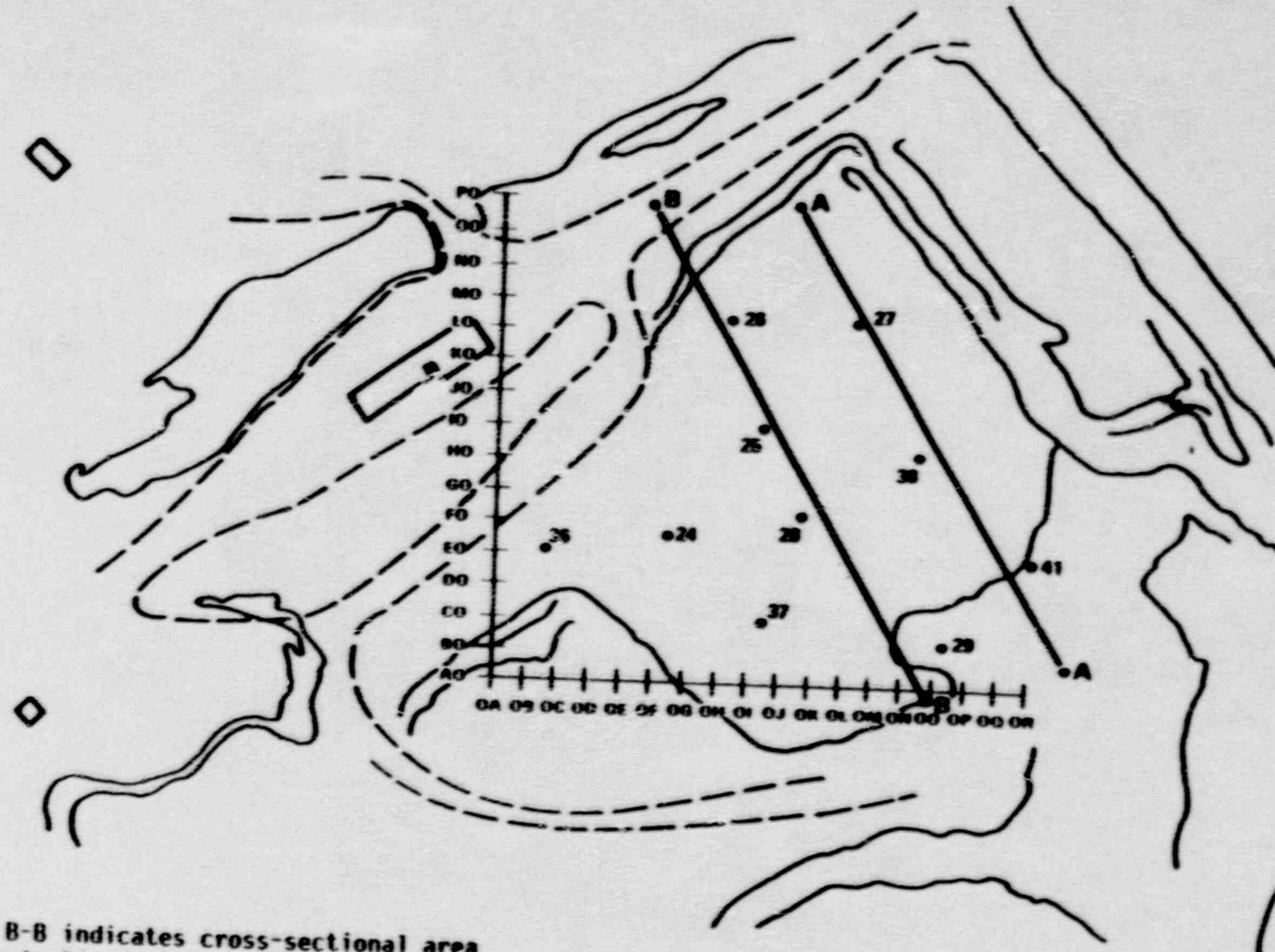
Source: NUREG/CR-2722, Figure 7, p. 31.

Figure 3.2 Location of surface soil samples, Area 1



Source: NUREG/CR-2722, Figure 8, p. 32.

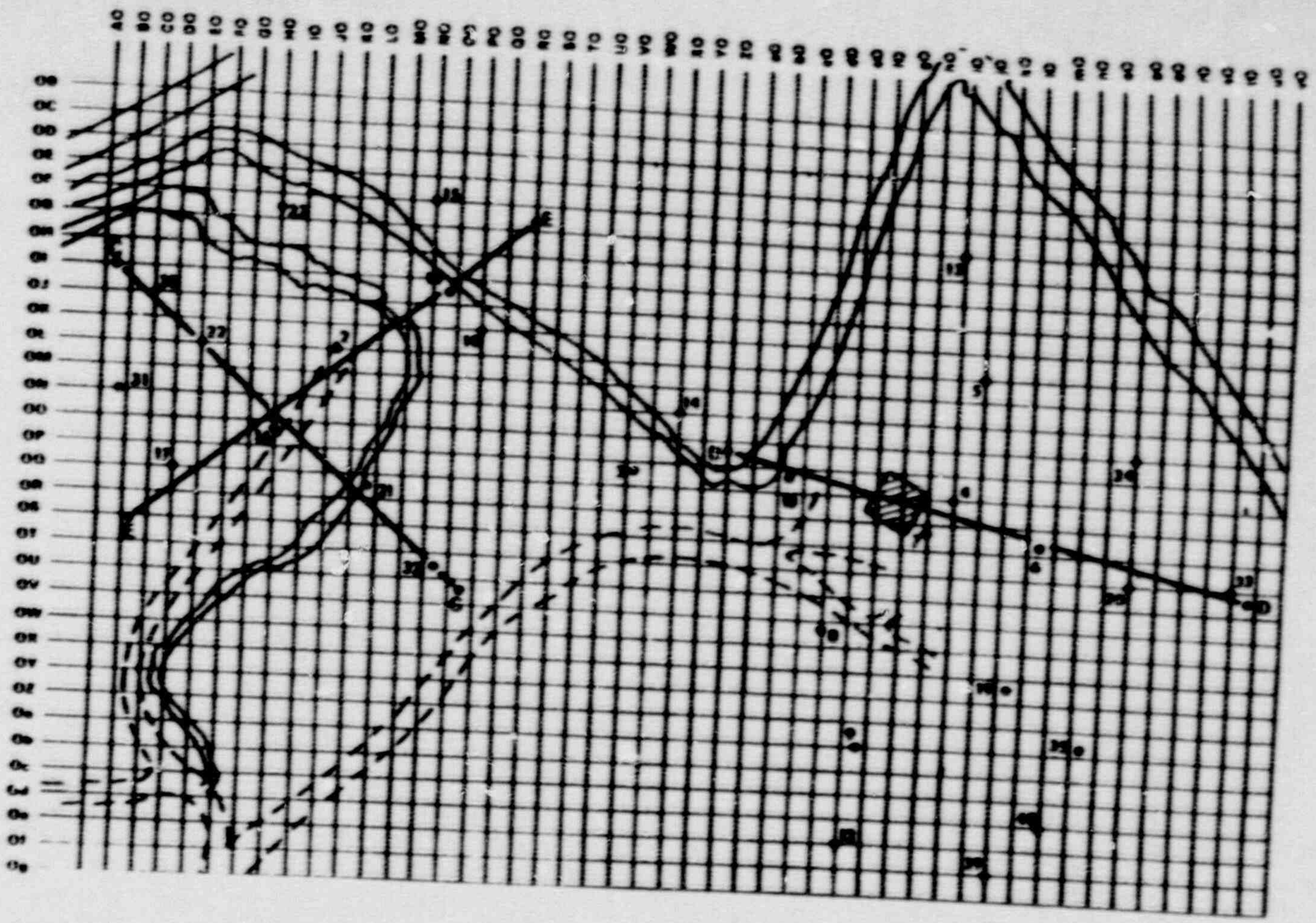
Figure 3.3 Location of surface soil samples, Area 2



Note: Line B-B indicates cross-sectional area shown in Figure 3.7.

Source: NUREG/CR-2722, Figure 9, p. 33.

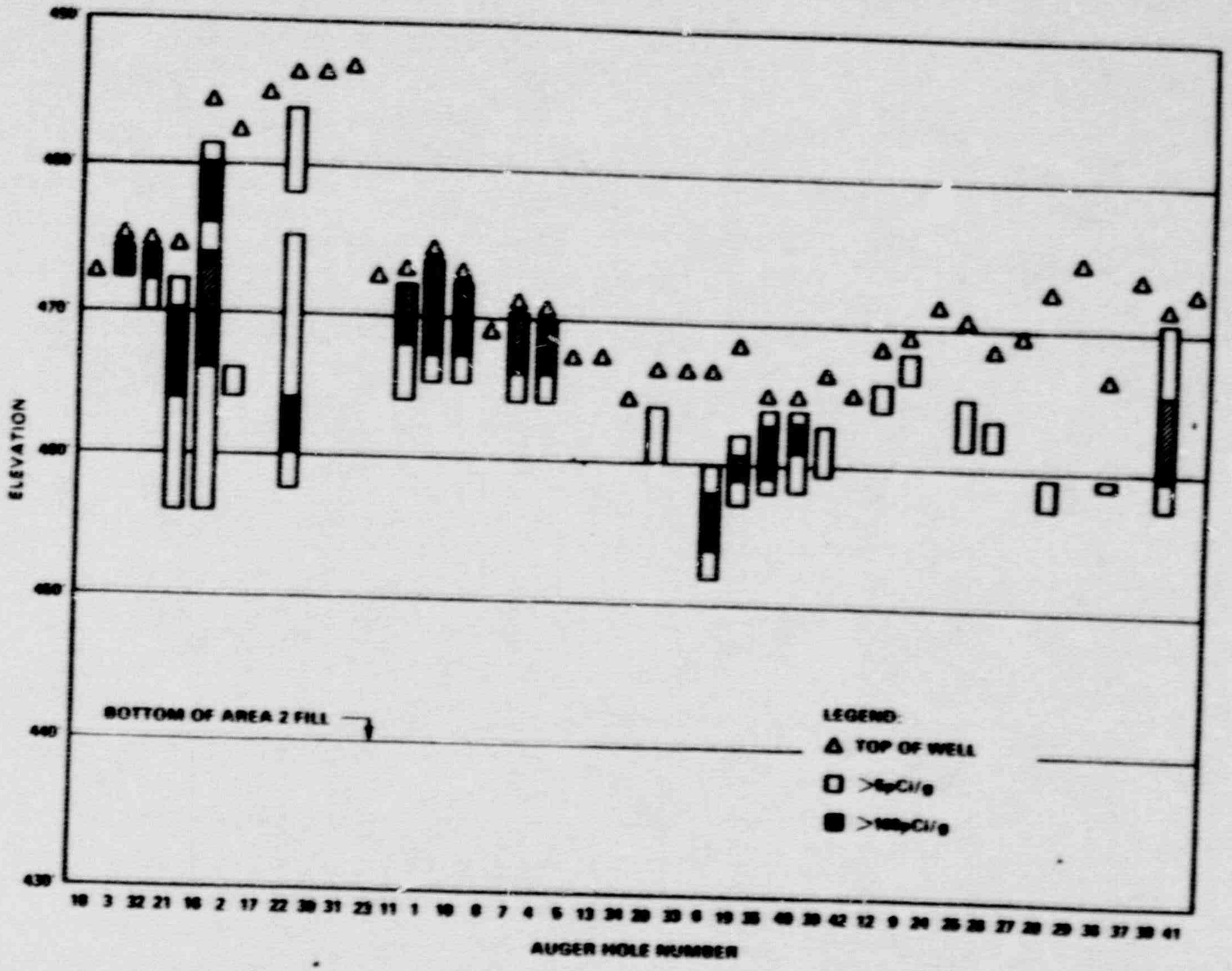
Figure 3.4 Location of auger holes, Area 1



Note: Line E-E indicates cross-sectional area shown in Figure 3.8.

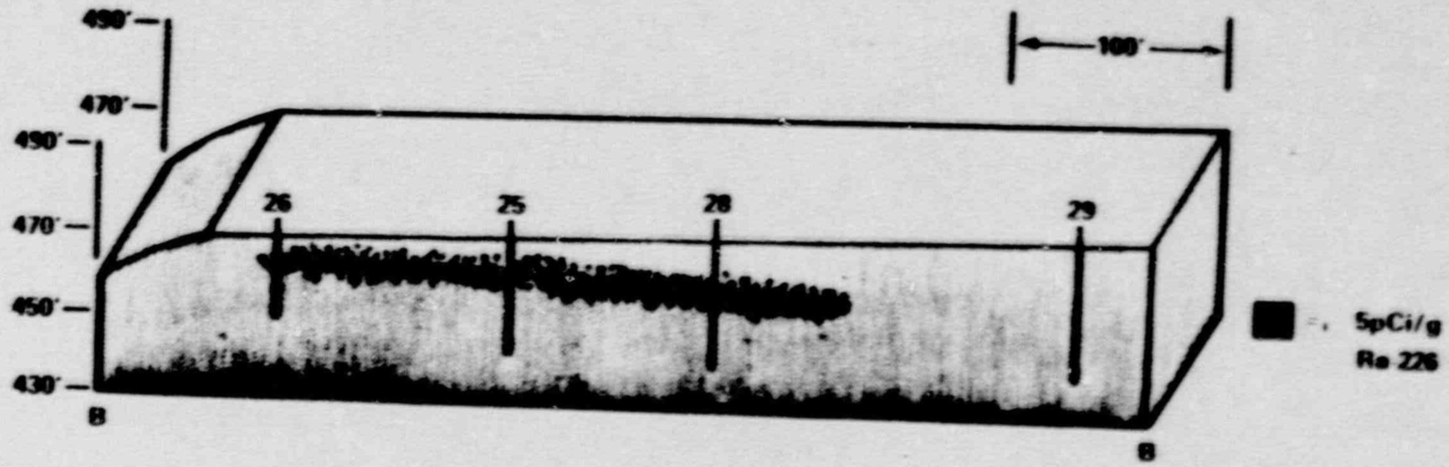
Source: NUREG/CR-2722, Figure 10, p. 34.

Figure 3.5 Location of auger holes, Area 2



Source: NUREG/CR-2722, Figure 14, p. 38.

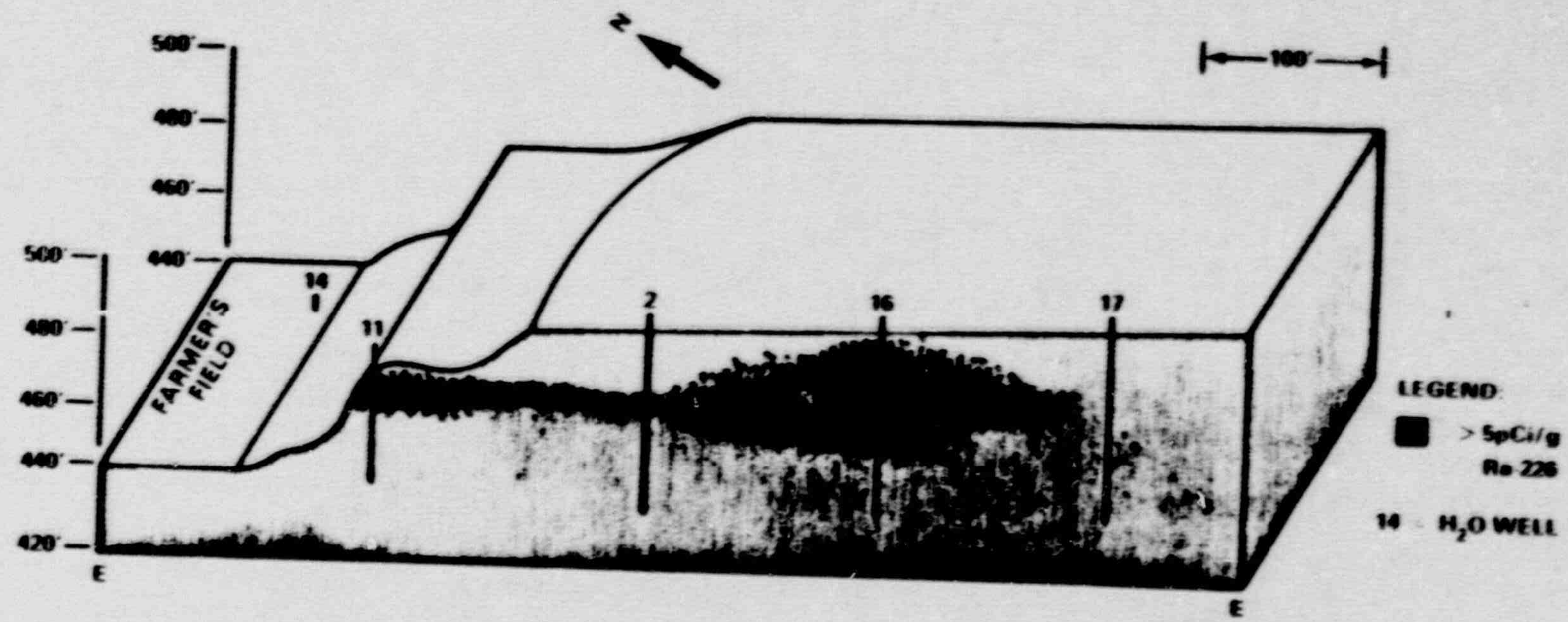
Figure 3.6 Auger hole elevations and location of contamination within each hole



Notes: (1) B-B is defined in Figure 3.4.
(2) The blackened areas indicate the estimated extent of contamination exceeding 5 pCi/g Ra-226, based on surface and auger hole measurements.

Source: NUREG/CR-2722, Figure 16, p. 39.

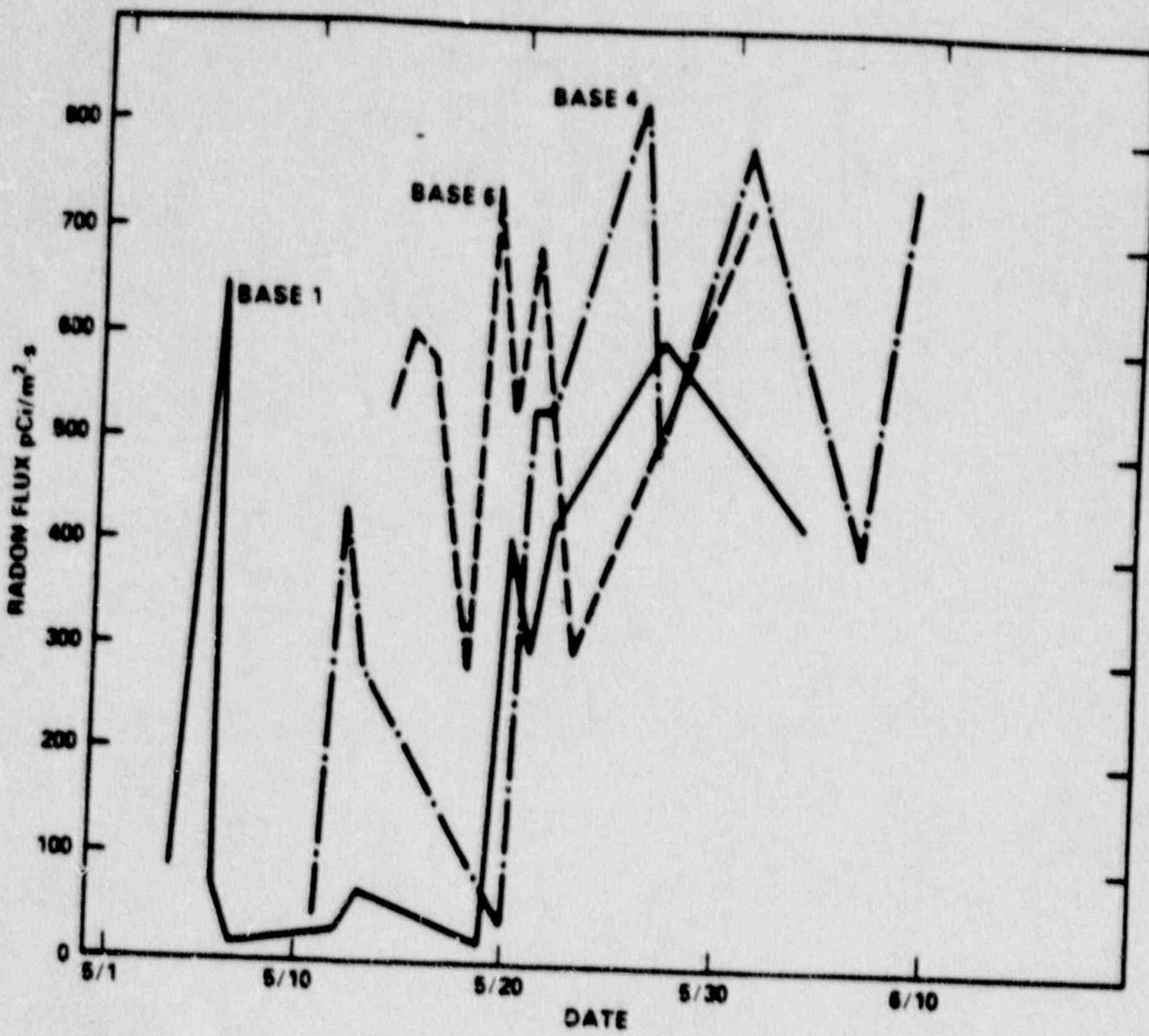
Figure 3.7 Cross-section B-B showing subsurface deposits in Area 1



Notes: (1) E-E is defined in Figure 3.5.
(2) The blackened areas indicate the estimated extent of contamination exceeding 5 pCi/g Ra-226, based on surface and auger hole measurements.

Source: NUREG/CR-2722, Figure 19, p. 42.

Figure 3.8 Cross-section E-E showing subsurface deposits in Area 2



Source: NUREG/CR-2722, Figure 20, p. 43.

Figure 3.9 Rn-222 flux measurements at three locations in Area 2 (1981)

Table 3.1 RMC radionuclide analyses of water samples from the West Lake site taken by MDNR in 1981

Sample #	Type of sample*	Gross alpha (pCi/l)	Gross beta (pCi/l)
7001	S	3.11	22.5
7002	S	8.00	23.4
7003	S	1.56	9.88
7019	S	1.91	30.0
7025	S	1.56	36.5
7028	S	45.2	87.8
7029	S	<0.64	<1.34
7030	S	0.52	35.1
7031	S	1.43	26.3
7004	B	1.04	19.7
7021	B	1.56	29.1
7027	B	1.04	32.5
7032	B	<0.05	26.3
7033	B	1.04	29.0
7009	G	4.50	22.3
7010	G	2.60	15.2
7011	G	3.12	10.6
7012	G	7.10	16.6
7017	G	0.52	33.6
7018	G	6.76	36.1
7020	G	8.84	30.1
7026	G	<2.0	38.9
2	G	15.0	41.0
3	G	2.9	7.6

See footnote at end of table.

Table 3.1 (Continued)

Sample #	Type of sample*	Gross alpha (pCi/l)	Gross beta (pCi/l)
7013	L	<3.0	1.30
7014	L	<3.0	130
7015	L	<3.0	103
7016	L	<3.0	98.9
7022	L	3.45	107
7023	L	<3.0	122
7024	L	<3.0	86.7
7034	L	<3.0	10.3
7035	L	<3.0	84.5
7036	L	<3.0	69.6
1	L	7.3	80
4	L	<3.0	26

Sample #	Type of sample*	Ra-226 (pCi/l)	K-40 (pCi/l)
7014	L	<1.6	138
7015	L	3.9	136
7016	L	<1.6	98.9
7022	L	2.4	104
7028	S	1.6	124

*S = surface sample
B = offsite, background
G = groundwater from boreholes
L = leachate

Table 3.2 Radiological quality of water in perimeter monitoring wells of West Lake Landfill (concentrations reported in pCi/l)

Well #	Ra-226	Gross-alpha*	Gross beta*	Gross alpha**	Gross beta**
18	-	-	-	12.5	12.5
59	<3	3.2	9.9	-	-
60	-	-	-	20.5	20.8
61	-	-	-	2.7	13.9
62	<3	2.8	7.4	3.5	8.5
63	-	-	-	2.2	7.0
65	<3	12.4	33.1	5.7	6.3
66	<3	4.3	6.9	-	-
67	<3	5	5.3	-	-
68	<3	18.2	18.8	-	-
50***	<3	5	7.7	1.3	8.1

*Samples taken November 15, 1983.
**Samples taken March 21, 1984, by UMC personnel, analyzed by Environmental Health Lab of St. Louis County Health Department, Clayton, Missouri.
***Well #50 used as background.

Table 3.3 Radionuclide concentrations in well water samples: May 7-8, 1986

Radionuclide	Concentrations (pCi/l)						
	Well 50[a]	Well 51	Well 52	Well 53	Well 54	Well 55	Well 56
Gross alpha	2.2	2.2	1.9	11	4.4	4.8	5.7
Gross beta	7.5	4.4	7.5	16	14	14	12
Ra-226	--[b]	--	--	0.4	--	--	0.2
Ra-228	--	--	--	1.7	--	--	0.3
U-total	--	--	--	22	--	--	8.9
Th-228	--	--	--	0.5	--	--	0.3
Th-230	--	--	--	0.9	--	--	0.9
Th-232	--	--	--	0.3	--	--	0.8
Depth to water (m)	5.0	3.8	3.2	3.3	15.5	11.5	11.5

Table 3.3 (Continued)

Radionuclide	Concentrations (pCi/l)						
	Well 58	Well 59	Well 60	Well 61	Well 62	Well 65	Well 66
Gross alpha	5.8	11	14	3.3	5.6	3.5	1.8
Gross beta	15	46	19	14	10	7.4	9.9
Ra-226	0.3	0.3	2.5	--	0.8	--	--
Ra-228	2.9	0.5	1.6	--	0.6	--	--
U-total	13	25	19	--	2.3	--	--
Th-228	0.6	0.5	0.5	--	0.8	--	--
Th-230	1.5	0.2	4.4	--	1.2	--	--
Th-232	0.7	0.1	0.1	--	0.6	--	--
Depth to water (m)	14.0	Not determined	3.5	4.5	4.2	1.9	1.9

Table 3.3 (Continued)

Radionuclide	Concentrations (pCi/l)						
	Well 67	Well 68	Well 72	Well 73	Well 75	Well 76	Well 80
Gross alpha	8.4	0.9	1.4	6.5	11	3.6	0.4
Gross beta	7.1	1.9	4.6	7.7	22	6.9	3.2
Ra-226	0.7			0.3	--	--	--
Ra-228	0.3			0.9	--	--	--
U-total	7.4			3.1	16	--	2.2
Th-228	0.9			1.7	0.6	--	0.3
Th-230	9.9			6.7	12	--	0.0
Th-232	0.2			0.2	0.2	--	0.1
Depth to water (m)	1.5	4.4	10.0	8.4	7.6	13.8	5.3

Table 3.3 (Continued)

Radionuclide	Concentrations (pCi/l)						
	Well 81	Well 82	Well 83	Well 84	Well 87	Well 88	Well 89
Gross alpha	7.9	17	9.0	13	1.5	11	3.7
Gross beta	16	47	18	27	7.2	18	9.1
Ra-226	0.8	9.3	3.4	1.7	--	2.3	--
Ra-228	0.4	0.4	4.6	5.8	--	0.2	--
U-total	4.9	13	1.6	9.0	--	3.0	--
Th-228	0.9	0.4	0.2	0.6	--	1.1	--
Th-230	0.9	1.8	0.4	1.3	--	1.5	--
Th-232	0.3	0.3	1.0	1.1	--	4.0	--
Depth to water (m)	4.8	5.1	3.9	7.0	9.4	8.6	7.5

Table 3.3 (Continued)

	Concentrations (pCi/l)			
Radionuclide	Well 90	Well 92	Well 93	Well 94
Gross alpha	2.2	7.3	7.4	1.6
Gross beta	6.8	11	22	9.9
Ra-226	--	1.0	1.6	
Ra-228	--	0.8	1.4	
U-total	--	17	6.0	
Th-228	--	0.5	0.8	
Th-230	--	0.1	0.7	
Th-232	--	0.4	1.6	
Depth to water (m)	4.1	13.1	4.7	2.1

[a]Refer to Figure 2.5 for well location.

[b]Dash indicates analysis not performed.

Table 3.4 Radionuclide concentrations in Latty Avenue composite samples

Sample	Concentrations (pCi/gm)								
Sample	U-235	U-238	Th-232*	Th-230	Th-228	Ra-226	Ra-228	Pa-231	Ac-227
Composite 1	3.6 ± 0.3**	82 ± 8	2.3 ± 0.6	8770 ± 100	2.1 ± 0.5	64 ± 1	2.3 ± 0.6	114 ± 2	205 ± 2
Composite 2	4.4 ± 0.3	62 ± 15	1.5 ± 0.5	8950 ± 370	2.0 ± 0.5	50 ± 1	1.5 ± 0.5	117 ± 8	Not Performed
Average	4.0 ± 0.2	72 ± 9	1.9 ± 0.4	8860 ± 190	2.1 ± 0.3	57 ± 1	1.9 ± 0.4	116 ± 4	205 ± 2

*Based on Ra-228 and assumption of secular equilibrium of thorium decay series.
**Errors are 2σ based only on counting statistics.

Source: Table 2 (Cole, 1981).

4 APPLICABILITY OF THE BRANCH TECHNICAL POSITION

The NRC has established a Branch Technical Position (BTP) which identifies five acceptable options for disposal or onsite storage of wastes containing low levels of uranium and thorium (46 FR 52061, October 23, 1981). Options 1-4 provide methods under 10 CFR 20.302, for onsite disposal of slightly contaminated materials, e.g., soil, if the concentrations of radioactivity are small enough and other circumstances are satisfactory. The fifth option consists of onsite storage pending availability of an appropriate disposal method. Table 4.1 shows the radionuclide concentrations specified for the disposal options.

The material present in the West Lake Landfill is a form of natural uranium with daughters, although the daughters are not now in equilibrium. As mentioned above, the average concentration of Ra-226 in the West Lake Landfill wastes is about 90 pCi per gram, which (considered by itself) falls into Option 4 of the BTP since Option 4 criteria are controlled by the Ra-226 content in the wastes (i.e., 200 pCi of U-238 plus U-234 per gram would be accompanied by 100 pCi of Ra-226 per gram). However, because of the large ratio of Th-230 radioactivity to that of Ra-226, the radioactive decay of the Th-230 will increase the concentration of its decay product Ra-226 until these two radionuclides are again in equilibrium. Assuming the ratio of activities of 100:1 used above, the Ra-226 activity will increase by a factor of five over the next 100 years, by a factor of nine 200 years from now, and by a factor of thirty-five 1000 years from now. All radionuclides in the decay chain after Ra-226 (and thus the Rn-222 gas flux) will also be increased by similar multiples. Therefore, the long-term Ra-226 concentration will exceed the Option 4 criteria.

Table 4.1 Summary of maximum soil concentrations permitted under disposal options

Source: 46 Federal Register 52061

Kind of material	Disposal options			
	1[a]	2[b]	3[c]	4[d]
Natural thorium (Th-232 + Th-228) with daughters present and in equilibrium. (pCi/g)	10	50	-	500
Natural uranium (U-238 + U-234) with daughters present and in equilibrium. (pCi/g)	10	-	40	200

[a]Based on EPA uranium mill tailings cleanup standards.

[b]Concentrations based on limiting individual intruder doses to 170 mrem per year.

[c]Concentration based on limiting equivalent exposure to 0.02 WL or less.

[d]Concentrations based on limiting individual intruder doses to 500 mrem per year and, in cases of natural uranium, limiting exposure to Rn-222 and its decay product airborne alpha emitters to 0.02 WL or less.

5 REMEDIAL ACTION ALTERNATIVE CONSIDERATIONS

The radioactive material as it presently exists does not pose an immediate health hazard for individuals living or working in the area of the landfill. However, there is a long-term potential for the radioactive material to pose a health problem. Therefore, this section discusses six (A-F) possible courses of action, of which all but A and D are considered temporary. Option A, in which no remedial action is proposed, is unacceptable because the concentrations of radionuclides in the landfill will become too high; Option A is described for comparison purposes only. Costs are based on the Dodge Guide to Public Works and Heavy Construction, 1984.

5.1 Option A: No Remedial Action

Under Option A, no remedial work would be done on the West Lake site. The landfill and the radioactive soil would be left in their present condition. The contaminated areas would be available for demolition fill emplacement and final closure. It is not certain how much additional fill would be emplaced. Filling would be followed by normal landfill closure operations.

Normal closure procedures consist of applying at least 0.61 m (2 ft) of compacted final cover. A 0.3-m (1 ft) layer of topsoil would be placed over the cover and upgraded to support vegetation. Establishment of a vegetative cover would require seeding, liming, and fertilization. Surface seeps of leachate would be eliminated. Maintenance of the monitoring wells would be required to allow continued sampling by MDNR, should MDNR require such action. The public would be discouraged from entering the site. After closure, a detailed description of the site would be filed with the County Recorder of Deeds. This description would include: a legal description of the site, types and location of wastes present, depth of fill, and description of any environmental control or monitoring systems requiring future maintenance (MDNR, January 1983). MDNR regulations also specifically prohibit excavation or disruption of the closed landfill without written approval of MDNR; no time frame is stated with this regulation (MDNR, 1975).

There would be no further cost under this option since no remedial actions would be taken; i.e., costs are normal landfill costs.

5.2 Option B: Stabilization on Site With Restricted Land Use

Two areas in the landfill contain radioactive material. Therefore, the work required for this option is described separately for each area. Nevertheless, restrictions would be imposed on the use of land within each area. This would discourage future activities on these areas which might expose individuals to radioactivity. No additional landfill would be permitted to be deposited on either area.

Area 1

It is believed that a total of 2 to 3 m (7 to 10 ft) of soil has been added to most of Area 1 since the 1981 land survey by RMC. This cover has altered the radiation environment of the site. Measurements by Oak Ridge Associated Universities (ORAU) personnel in March 1984 (Berger) showed that only a very small area exceeded the exposure rate of 20 μR/hr at 1 m. By extending the cover 20 m (66 ft) outward in all directions from the area showing an unacceptable surface exposure rate, the shallow wastes likely to give high rates of radon emanation will also be covered. The amount of radioactive debris in Area 1 is relatively minor compared with that present in Area 2. Therefore, a soil cover of 1.5 m (5 ft) is considered adequate to reduce surface exposure rates and radon emanation. After the soil cover is in place, a layer of topsoil 0.3 m (1 ft) thick would be emplaced, seeded, and mulched.

Area 2

Vegetation over Area 2 as well as on the slope of the berm would be cleared and placed in the demolition portion of the landfill or disposed of as is convenient. Brush should not be left in place and covered since this may reduce the integrity of the soil cap. Grass should be mowed, and may be left in place.

The berm on the northwest portion of the landfill which contains an estimated 7,500 m^3 (9,800 yd^3) of contaminated soil would be excavated and redeposited in layers in a secure portion of the landfill. The actual amount can be determined by survey during implementation of the work.

All equipment and materials now stored over Area 2 would be removed to other portions of the site or disposed of as is convenient to the owners. Gravel piles found on Area 2 should be removed to other portions of the site after having been surveyed to ensure that contaminants have not been mixed with the gravel. However, the lower 10 to 15 cm (4 to 6 in.) of rock should be left in place and covered with the soil cap, since this gravel may have become mixed with contaminated soil.

Such stabilization would place the contaminated soil well below the surface and would prevent radioactive materials from eroding as can now occur along sections of the berm. Stabilization would require emplacement of a soil cover of 48,000 m^3 (63,000 yd^3) to give a final slope of 3:1 with 1.5 m (5 ft) of soil at the top of the berm. At least 1.5 m (5 ft) of soil cover would be used, as this much soil will be required to reduce radon gas exhalation. The final slope of 3:1 on the berm would be shallow enough to prevent failure and, after the cover is emplaced, it should be further covered with at least 0.3 m (1 ft) of topsoil and seeded with native grasses to prevent erosion. The slope would be directed radially outward from the center of the cap. An interceptor ditch would be provided around the cap to channel runoff and prevent gullies from being cut into the stabilized cover The cover soil presently used in the landfilling operations may be used to stabilize the berm. This soil is a clay silt (loess) excavated near the West Lake Landfill site.

The portion of Area 2 to be covered by the soil cap includes that portion of the landfill identified in the RMC survey as having surface exposure rates greater than 20 μR/hr at 1 m (3.3 ft) above ground level, along with those areas in which auger holes revealed radium-bearing soil within 1 m of the surface. The shallow contaminants may be sufficiently shielded to produce low surface exposure rates; however, these shallow deposits will still produce radon emanations greater than the desired level of 20 pCi/m^2s. Therefore, the soil cover must be extended over these areas of shallow contamination.

The cover soil used should be capable of compaction to a permeability of less than 10^{-7} cm/s in order to keep radon release and soil leaching as low as possible. This value is based on common practices used for sealing of hazardous waste landfills. Because accurately measuring permeability of this magnitude is difficult, the value of 10^{-7} cm/s should be used only as a target criterion which should, if possible, be bettered. If laboratory testing of the cover soil presently used at the West Lake Landfill indicates that this permeability can be achieved, this soil would be acceptable for use as the soil cap. Otherwise, clay soil would have to be imported from off the site to be used in constructing the soil cap.

The overall estimated cost for the required work under Option B is approximately $360,000 (Table 5.1) and would require about 2 months to complete. Costs of this option may be higher if the total quantity of contaminated material to be moved is higher than the estimated quantity.

5.3 Option C: Extending the Landfill Off Site

Soil eroding on the northwest berm of Area 2 is carrying contaminated soil off the landfill property onto an adjacent cultivated field. A contributing factor to the erosion is the steepness of the berm. It would, therefore, be desirable to lessen the slope's steepness by extending the berm onto the adjacent field. This option would require the acquisition of approximately 2 ha (5 acres) of land not owned by the landfill company.

In this option, Area 1 would be treated the same as in Option B. The contaminated portion of the northwestern berm of Area 2 would not be disturbed. Instead the existing berm would be extended 13 to 16 m (42 to 52 ft) onto the adjacent field. This would require an additional solid volume of approximately 20,200 m^3 (26,400 yd^3) to give a final slope of 3:1 with 1.5 m (5 ft) of soil on top of the berm. As in Option B, this cover should receive an additional 0.3 m (1 ft) of topsoil and be seeded with native grasses to prevent erosion.

This option will require the relocation of three transmission poles. All other necessary work for Option C is as described for Option B.

The overall estimated cost for required work under Option C is approximately $470,000 (Table 5.2) and would require about 2 months to complete. The extent of work required under this option is well defined.

5.4 Option D: Removing Radioactive Soil and Relocating It

This option would involve excavating and removing all contaminated soil and debris from the West Lake Landfill and relocating it to an authorized disposal facility.

Vegetation over Areas 1 and 2 would be cleared and placed in the demolition portion of the West Lake Landfill.

All equipment stored on the two contaminated areas would be removed to another portion of the site. Gravel piles in Area 2 should be removed. The lower 10 to 15 cm (4 to 6 in.) of rock should be left in place to be disposed of with other contaminated materials, since this gravel may have become mixed with contaminated soil at the surface.

The areas known to contain radioactive contamination at levels above the action criteria (20 μR/hr at 1 m) would be excavated initially. Next, the excavated area would be surveyed to determine the extent of contamination remaining. Excavation would continue until unacceptable levels of contamination have been removed. Immediately after excavation, the soil would be placed in 208-liter (55 gal) approved drums (or other approved containers) for transport. Containment in the drums will prevent the spread of dust and loose soil during transport.

Some of the nonradiological hazardous material known to be present in the landfill could present a serious danger to workers should they excavate into this material. Proper precautions should, therefore, be taken as the work is being performed.

Estimated costs under Option D would be $2,500,000 (Table 5.3). Transporting the contaminated soil to another site and emplacing the material there would significantly add to the cost. This option could be completed in about

3 months, providing that a suitable disposal facility were available to receive the contaminated waste.

5.5 Option E: Excavation and Temporary Onsite Storage in a Trench

Under this option, as much radioactive soil would be excavated as in Option D and would be placed in a specially prepared trench on the West Lake site but would not be placed in drums. This trench would become a temporary repository for the radioactive soil. The trench would be surrounded by an impervious clay liner to minimize leachate production and transport into the groundwater system. The cap should give acceptable rates of surface exposure and acceptable rates of radon gas release.

As under Option D, surface vegetation, machinery, and piles of crushed rock would be removed from the surface of areas to be excavated. Design of the trench is based upon the "secure landfill concept" (Shuster and Wagner, 1980) with three primary functions: eliminate direct gamma-ray exposure at the ground surface, reduce radon emanation, and prevent leaching of radionuclides to the groundwater system.

The excavated area would be cut to a maximum elevation of 140 m (460 ft) msl over the area to be covered by the trench. The base of the trench would cover an area 120 x 120 m (394 x 394 ft) and would have a negligible slope. Low spots would be filled with borrow soil* compacted to at least 90% of its standard Proctor density (SPD). Once the base for the trench has been leveled to a final elevation of about 140 m (460 ft) msl, a blanket of borrow soil at least 1.5 m (5 ft) thick compacted to at least 90% SPD would be emplaced. Specification of compaction of this underlayer is based on the requirement of avoiding subsidence which could cause the clay liner to crack and fail. A clay liner would be placed above the underlayer. The liner would be 0.5 m (1.6 ft) thick and would have a permeability less than 10^{-8} cm/s (4×10^{-9} in./s). An impermeable plastic liner could also be used.

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*Borrow soil refers to a clayey-silt loess (Soil Conservation Service type CL) excavated southeast of the site for use as daily cover in the landfilling operation.

Sides of the trench would be built at a 3:1 slope up to the level of the surrounding undisturbed landfill surface, about 143 m (470 ft) msl. The walls would consist of an underlayer and liner as described for the base. A layer of crusher-run limestone 0.5 m (1.6 ft) thick would be placed on top of the liner to allow leachate buildup in the trench to be monitored and to facilitate pumping should leachate buildup become a problem.

After the base and walls of the trench have been built, the previously excavated debris would be placed in the trench. Then the remaining radioactive debris would be excavated and placed in the trench. As excavation proceeds, it will become apparent how much volume the trench must have to contain all the contaminated soil. At this point, the walls of the trench would be raised to an appropriate level. Excavation and filling can then proceed until the work is complete. The final thickness of debris is expected to be from 4 to 6 m (13 to 20 ft).

A cover, as described below, would be placed over the debris. A 1 m (3 ft) layer of borrow soil compacted to 90% SPD will be placed over the debris. A clay liner 0.5 m (1.6 ft) thick of permeability less than 10^{-8} cm/s (4×10^{-9} in./s) would be placed over the borrow soil blanket. A 0.5-m (1.6-ft) layer of crusher-run limestone would be placed over the clay layer to prevent infiltration water from building up over the liner. A cover soil layer of average thickness about 2 m (7 ft) would be placed over the rock layer.

The cover soil would be compacted and built with a surface slope of from 2% to 4% to minimize erosion. Three-tenths of a meter (1 ft) of top soil would be placed over the cover layer and would be seeded and mulched to establish a vegetative cover.

Once the trench has been prepared to accept the soil, workers may begin to excavate contaminated soil. As under Option C, an initial excavation would remove the area of known contamination, and a cleanup phase would remove all soil containing radionuclide concentrations above an action level of 15 pCi/g Ra-226. As soon as the soil has been excavated, it would be hauled to the trench and emplaced. The contaminated soil should be sufficiently compacted to prevent settling, to maintain the integrity of the soil cap. As fill is being emplaced, the pipe for a monitoring well would be extended upward from the base of the gravel underdrain. This well should be designed in a manner that would allow future installation of a pump for drawing off leachate should this become necessary.

Costs for Option E would be approximately $2,150,000 (Table 5.4). The estimated costs vary somewhat, since the exact limits of excavation cannot be defined until work begins. This work would require approximately 4 months to complete.

5.6 Option F: Construction of a Slurry Wall to Prevent Offsite Leachate Migration

Under Option F, radioactive soil would be left in place at the West Lake site. The wastes would be stabilized by means of a soil cover (as under Option B) and a downgradient slurry wall would be built around the contaminated soil. The slurry wall would be intended to keep leachate from migrating off site. This remedial action would be somewhat more effective than Option B in reducing the potential for groundwater contamination. However, costs incurred would be substantially higher than those for Option B or C. Benefits would be nearly identical to those derived by the soil cover and berm stabilization alone; the sole advantage of Option F over Option B or C would be greater protection to groundwater in the Missouri River alluvium.

Vegetation, machinery, and piles of crushed rock would have to be removed as described for Option B. A slurry wall would be constructed by excavating a trench [approximately 1 m (3.3 ft) wide] to the depth of bedrock. This trench would be bored out in the presence of a mud weighted with bentonite (clay) to keep the walls from collapsing and to keep groundwater from intruding into the trench. The trench would be excavated in sections 6 to 8 m (20 to 26 ft) long. Once a section of trench has been excavated, concrete would be poured by tremie into the trench to displace the slurry. The final slurry walls would each consist of a concrete slab about 1 m (3.3 ft) thick extending to bedrock and partially encircling the bodies of radioactive soil in both Areas 1 and 2. A total of approximately 1300 linear meters (4,300 ft) of wall would be constructed to depths varying from 5 to 15 m (16 to 50 ft).

After each of the slurry walls had been emplaced, fill would be added along the face of the berm to stabilize the slope. Finally, a soil cover would be placed over the contaminated areas. The berm would be stabilized and the soil cover would be placed as outlined for Option B.

Costs of work required for Option F would be approximately $5,600,000 (Table 5.5). The exact amount of slurry wall cannot be determined until work is begun; therefore, this cost will be highly variable. Since the walls should extend to bedrock, the depth of soil and landfill debris will govern the depth of the required wall. Slight errors in estimating the depth of alluvium could result in large errors in the cost estimate. It is estimated that it would take 6 to 8 months to complete this option.

Table 5.1 Itemized cost of remedial action, Option B

Item	Quantity	Unit price	Cost	Reference
Clearing and grubbing	2.9 ha	$1850/ha	$ 5,365	*
Remove Shuman Building	--	--	$ 6,200	**
Excavate contaminated soil and redeposit it at a secure site	7500 m^3	$10/$m^3$	$ 75,000	†
Emplace soil cover	48,000 m^3	$4.64/$m^3$	$222,720	†
Bury clean rubble	225 m^3	$12.50/$m^3$	$ 2,812	†
Seed and mulch cover	3.3 ha	$2165/ha	$ 7,145	*
Subtotal			$319,242	
Contingency @ 10%			31,924	
Engineering and legal fees @ 5%			15,962	
Estimated total cost			$360,000††	

*Dodge Guide to Public Works and Heavy Construction, 1984.

**Ford, Bacon and Davis Utah, Inc., "Engineering Evaluation of the Latty Avenue Site, Hazelwood, Missouri," NRC Contract No. NRC-02-77-197, 1978. (This Butler-type building has already been removed.)

†Based on best estimated cost.

††Adjusted for deletion of building removal.

Table 5.2 Itemized cost of remedial action, Option C

Item	Quantity	Unit price	Cost	Reference
Clearing and grubbing	2.9 ha	$1850/ha	$ 5,365	*
Remove Shuman Building	--	--	$ 6,200	**
Relocate power transmission poles	3	$2060	$ 6,180	†
Stablize berm (fill)	20,200 m³	$6.70/m³	$135,340	†
Emplace soil cover	48,000 m³	$4.64/m³	$222,720	†
Bury clean rubble	225 m³	$12.50/m³	$ 2,812	†
Seed and mulch cover	3.3 ha	$2165/ha	$ 7,145	*
Subtotal			$385,762	
Contingency @ 10%			38,576	
Engineering and legal fees @ 5%			19,290	
Land acquisition	2 ha	$15,500/ha	31,000	
Estimated total cost			$470,000	

*Dodge Guide to Public Works and Heavy Construction, 1984.

**Ford, Bacon and Davis Utah, Inc., "Engineering Evaluation of the Latty Avenue Site, Hazelwood, Missouri," NRC Contract No. NRC-02-77-197, 1978. (This Butler-type building has already been removed.)

†Based on best estimated cost.

Table 5.3 Itemized cost of remedial action, Option D

Item	Quantity	Unit price	Cost	Reference
Clearing and grubbing	2.9 ha	$1850/ha	$ 5,365	*
Remove Shuman Building	--	--	$ 6,200	**
Bury clean rubble	230 m^3	$12.5/$m^3$	$ 2,875	†
Excavate contaminated soil	70,000 m^3	$5.25/$m^3$	$ 367,500	†,††
Site decontamination	27,600 m^3	$1.4/$m^2$	$ 38,640	***
Packing waste for transportation	70,000 m^3	$25/$m^3$	$1,750,000	†
Subtotal			$2,170,580	
Contingency @ 10%			217,058	
Engineering and legal fees @ 5%			108,529	
Estimated total cost			$2,500,000***	

*Dodge Guide to Public Works and Heavy Construction, 1984.

**Ford, Bacon and Davis Utah, Inc., "Engineering Evaluation of the Latty Avenue Site, Hazelwood, Missouri," NRC Contract No. NRC-02-77-197, 1978. (This Butler-type building has already been removed.)

***No costs have been included here for moving the waste, for emplacing it and for disposal facility users fees.

†Based upon best estimate.

††Estimated quantity of soil having Ra-226 concentrations of 15 pCi/g or more.

Table 5.4 Itemized cost of remedial action, Option E

Item	Quantity	Unit price	Cost	Reference
Prepare secure trench	80,000 m^3	$9/$m^3$	$ 720,000	*
Clearing and grubbing	2.9 ha	$1,850/ha	$ 5,365	*
Remove Shuman building			$ 6,200	**
Bury clean rubble	230 m^3	$12.5/$m^3$	$ 2,875	*
Excavate contaminated soil	70,000 m^3	$5.25/$m^3$	$ 367,500	*
Site decontamination	27,600 m^3	$1.40/$m^3$	$ 38,640	†
Emplace contaminated soil	70,000 m^3	$10.3/$m^3$	$ 722,200	*
Monitoring well	---	---	$ 6,000	*
Seed and mulch cover	0.08 ha	$2,165/ha	$ 200	†
Subtotal			$1,868,980	
Contingency @ 10%			186,900	
Engineering and legal fees @ 5%			93,450	
Estimated total cost			$2,150,000	

* Dodge Guide to Public Works and Heavy Construction, 1984.

**Ford, Bacon and Davis Utah, Inc., "Engineering Evaluation of the Latty Avenue Site, Hazelwood, Missouri," NRC Contract No. NRC-02-77-197, 1978. (This Butler-type building has already been removed.)

† Based on best estimate.

Table 5.5 Itemized cost of remedial action, Option F

Item	Quantity	Unit price	Cost	Reference
Clearing and grubbing	2.9 ha	$1,850/ha	$ 5,365	*
Remove Shuman building			$ 6,200	**
Relocate power transmission poles	7 poles	$2,060/@	$ 14,420	†
Construct slurry wall	11,000 m^2	$402/$m^2$	$4,422,000	*
Stabilize berm	20,200 m^3	$6.70/$m^3$	$ 135,340	†
Emplace soil cap	48,000 m^3	$4.64/$m^3$	$ 222,720	†
Bury clean rubble	225 m^3	$12.5/$m^3$	$ 2,812	†
Seed and mulch cover	3.3 ha	$2,165/ha	$ 7,145	*
Subtotal			$4,816,002	
Contingency @ 10%			481,600	
Engineering and legal fees @ 5%			240,800	
Land acquisition	2 ha	$15,500/ha	31,000	
Estimated total cost			$5,600,000	

*Dodge Guide to Public Works and Heavy Construction, 1984.

**Ford, Bacon and Davis Utah, Inc., "Engineering Evaluation of the Latty Avenue Site, Hazelwood, Missouri," NRC Contract No. NRC-02-77-197, 1978. (This Butler-type building has already been removed.)

†Based on best estimate.

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UNITED STATES
NUCLEAR REGULATORY COMMISSION
WASHINGTON, D. C. 20555

OCT 25 1989

Docket Nos. 40-8035
40-8801

Cotter Corporation
ATTN: Mr. George Rifakes
President
P.O. Box 767
Chicago, Illinois 60690

Gentlemen:

I am writing this letter to follow through on our discussion of September 13, 1989, and your discussion with Mr. Rouse on October 16, concerning the radioactive material in the West Lake Landfill. In view of the record, I have concluded that the Cotter Corporation is responsible for the presence of this material in the landfill, and the consequent environmental and radiation health problems that may result from the radioactive material.

The situation of this radioactivity is summarized in the Nuclear Regulatory Commission's report titled "Radioactive Material in the West Lake Landfill, Summary Report," NUREG-1308, Revision 1, June 1988. This radioactive material, if neglected, has the potential of becoming a threat to the public health and safety because its concentrations of radium-226 and other radioactive decay products will be continually increased by the radioactive decay of the thorium-230 present. The increasing concentrations will mean proportionally increasing gamma radiation emissions, radon-222 generation, and potential for leaching into the groundwater.

The record shows that Cotter Corporation purchased the radioactive material and used it under an Atomic Energy Commission license at its processing site on Latty Avenue in Hazelwood, Missouri, and that later, in the process of decontaminating the site prior to termination of the license, the contractor for Cotter Corporation had the material trucked to the West Lake Landfill in Bridgeton, Missouri. Incorrect information was reported to the Commission with regard to which landfill the material was trucked to and with regard to how deeply it was buried. The dilution of the material with soil prior to transport to the landfill was noted as a violation of regulations. The record establishes the traceability of the material to Cotter Corporation activities under license.

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Enclosure 3

We have concluded that remediation is called for, and we see nothing in the circumstances of the radioactive material in the West Lake Landfill which argues for delay in this matter. Please advise us within 30 days of the date of this letter what your plans are for further site characterization and evaluation of what remediation is appropriate.

Sincerely,

Robert M. Bernero, Director
Office of Nuclear Material Safety
and Safeguards

cc: Edward J. McGrath, Esq.
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Denver, Colorado 80203