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INVESTIGATION OF DAMAGE TO STRUCTURES IN THE M^cCUTCHANVILLE-DAYLIGHT AREA OF SOUTHWESTERN INDIANA

Volume 3 of 3

Part VII: Experimental and Analytical Studies of the Vibration Response of Residential Structures Due to Surface Mine Blasting.

Part VIII: Dynamic Soil Property Testing and Analysis of Soil Properties, Daylight and McCutchanville, Indiana.

Part IX: Environmental Conditions Related to Geology, Soils, and Precipitation, McCutchanville and Daylight, Vanderburgh County, Indiana.

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Part IX

Environmental Conditions Related to Geology, Soils, and Precipitation, McCutchanville and Daylight, Vanderburgh County, Indiana.

INVESTIGATION OF DAMAGE TO STRUCTURES IN THE McCUTCHANVILLE-DAYLIGHT AREA OF SOUTHWESTERN INDIANA

A FINAL REPORT

PART IX: ENVIRONMENTAL CONDITIONS RELATED TO GEOLOGY, SOILS, AND PRECIPITATION McCUTCHANVILLE AND DAYLIGHT, VANDERBURGH COUNTY, IN

(Appendices for Part IX are separate)

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Appendix I. Tables 11 and 12 of the USGS Investigation of Building Damage in the McCutchanville and Daylight, IN Area (USGS, 1993). Site descriptions of the study area Category 1 (complainant) and Category 2 (non-complainant companion structures), and Control area Category 3 structures.

Tables 11 and 12 list: (1) Site Category, name/address, USGS ID/OSM ID; (2) Description of building; (3) Damage; and (4) Site conditions. Column 4 results from a 1992, Inter-Agency Meeting to: Establish complainant and non-complainant foundation and subsurface summaries from borehole data, gamma logs, shear wave tests, etc. The findings include interpretations by: N. Bleuer and D. Eggert (IDNR-GS); P. Hadala (COE-WES); K. King (GS-BGRA); and B. Maynard (OSM-ESC), Indiana University (IU), Bloomington, IN, October 13 through 16.

Environmental Conditions
Related to Geology, Soils, and Precipitation
McCutchanville and Daylight, Vanderburgh County, Indiana

INTRODUCTION

Background

In 1989 the Office of Surface Mining Reclamation and Enforcement (OSM) interviewed some 100 residents regarding structural damage that had been attributed to vibrations from surface coal mine blasting activities at the Ayrshire Mine which is located north of Evansville, and east northeast of McCutchanville and Daylight, Vanderburgh County, IN. In addition to the interview responses, OSM video taped and photographed reported damage to residential structures.

In late 1989 the Indiana Department of Natural Resources (IDNR), Indiana Geological Survey (IGS) core and auger drilled, gamma logged, and sampled soils within the "study area" defined as the McCutchanville and Daylight area (IGS, 1990). Soil samples were analyzed by the IGS (1990); United States Corps of Engineers, South Atlantic Division Laboratory (USCOE-SADL, 1990) and Waterways Experimental Station, Geotechnical Laboratories (USCOE-WES-GL, 1992). AmTech Engineering, Indianapolis, IN collected and analyzed soil samples for the USGS (1992). The United States Geological Survey (USGS), Branch of Geologic Risk Assessment completed seismic soil to bedrock profiling (1992). Field data by Federal and State agencies and their sub-contractors enabled the study area surface, soil profile, and subsurface to be described and characterized. Precipitation is discussed as an external factor capable of activating or altering surface, soil, and geologic conditions.

In 1989 the United States Bureau of Mines (USBOM) studied the vibrational environment and damage characteristics of houses in the study area (USBOM, 1990). In 1992 the USGS investigated building damage in the study area, and an area of about two miles around Kasson, IN termed the "control area" (USGS, 1993). The control area has environmental similarities to the study area but is distant enough not to be effected by blasting vibrations from the Ayrshire surface coal mine.

The data available and the data sources identified are in the "Synopsis of Appendices" following the List of Figures and Tables. The Appendices include: Auger Hole Boring Data; Soil Descriptions, Gamma-Ray Logs and Data Plots for OSM Auger Holes; Soil Sample Analysis; X-ray Diffraction of Clay and Non-clay Minerals; Estimated Degree of Limitation for Residential and

Light Industrial Development and Use of Septic Tank Absorption Fields Relative to Soil Series and Increasing Slope; Composite Site Specific Complainant and Non-complainant Structure Data from Appendices, OSM Interviews, Maps, and related Information; Precipitation and drought information for 1987 and 1988; and USGS Table 11 and 12 (1993) containing structural evaluation characteristics in the study and control areas.

The primary sculptor of the earth's surface is water and moisture is the most influential factor affecting soil properties. The U.S. Bureau of Reclamation states moisture is the principal factor subject to change either from natural causes or at the discretion of man (USBOR, 1985). The study area including the McCutchanville ridge and Daylight, IN area is a remnant outlier of an ancient eastern landmass of the Illinois basin shaped by fluviation processes.

Purpose and Objectives

The purpose of this part of the report is to determine if natural and man-induced environmental conditions, other than blasting vibrations, are potential contributors to observed structural damage.

Several physical environmental conditions have the potential to contribute to and cause structure damage. These include natural and man-induced water related conditions; the distribution and intensity of seasonal precipitation and temperature; soil water absorption and drainage; soil physical and chemical conditions; geologic stratigraphy, structure, seismicity and geomorphology; and man-induced disruption of natural conditions, such as, man-made lakes and ponds, and excavations for residential construction.

The tabulation of field data identified existing natural and man-induced environmental conditions and problems (attached appendices). Site specific complainant and non-complainant companion structure locations were cross-checked against identified environmental conditions and problems. A non-complainant companion structure is a structure paired with a complainant structure for comparing structure and subsurface conditions.

Preliminary observations of structural problems and environmental conditions suggest the following objectives need to be addressed: (1) determine whether potential relationships exist between environmental conditions and damage at site specific locations, and (2) determine if potential relationships are significant enough to contribute to or cause observed structural damage.

STUDY AREA CHARACTERISTICS
Geology and Surface Features

The structural geology of McCutchanville and Daylight, IN is shown on Figure 1. Structure contours are drawn on the top of the West Franklin limestone. Contours are solid where this rock unit has been located and dashed where inferred. The strike of the strata is north-northeast and the dip is west northwest at a rate of about 25 to 30 feet per mile. Cross-section C-C′ shows the strata dipping, flattening near Darmstadt, IN and continuing to dip westward (Indiana Department of Conservation-Geologic Survey IDOC-GS, 1954).

The study area on Figure 1 is bounded by Base Line Road to the north; the intersection of U.S. 41 and State Route 57 and Millersburg Road to the south; U.S. Route 41 to the west; and County Line Road on the east. The primary complaint area is the shaded McCutchanville ridge area.

The McCutchanville ridge is a remnant outlier of a cratonic (continental platform) upland located east and southeast of the Illinois basin (Mintz, 1977; INDR-IGS, 1970). Cratonic uplifts along the eastern flanks of a rapidly subsiding Illinois basin spread sedimentary deposits over gentle dipping western slopes of the present McCutchanville ridge. The regression of the shallow sea resulted in emergence of the land. This landscape and the erosional surface that developed occurred over millions of years and was terminated by loess deposition during Pleistocene and post-Pleistocene time.

Stratigraphic correlation was established by a rock cored hole (OSM #26) drilled at the McCutchanville Fire Station, McCutchanville, IN (IDNR-GS, 1990). Figure 2 shows that the uppermost bedrock of the McCutchanville ridge is sandy shale. The West Franklin limestone member of the Shelburn Formation can be toprock along a narrow outcrop zone covered by recent loess deposits. Down-section of the West Franklin limestone member shale prevails (IDNR-GS, 1990; IDOC-GS, 1954).

The McCutchanville ridge is considered preserved by the West Franklin limestone member. Eight feet of the West Franklin Member was recovered at the Fire Station (509 ft. surface elevation) at an elevation between 476 and 466 feet. A void was encountered between 472 and 470 feet (IDNR-GS, 1990). This void may represent a solution zone capable of water transport.

Common along the McCutchanville ridge are soil piping holes formed by water moving down or along vertical posts, foundation walls, tree roots, and buried pipe. Individual holes may originate by dripping water while other may form and merge into larger surface holes. Piping depth and channelization depend on soil profile conditions.

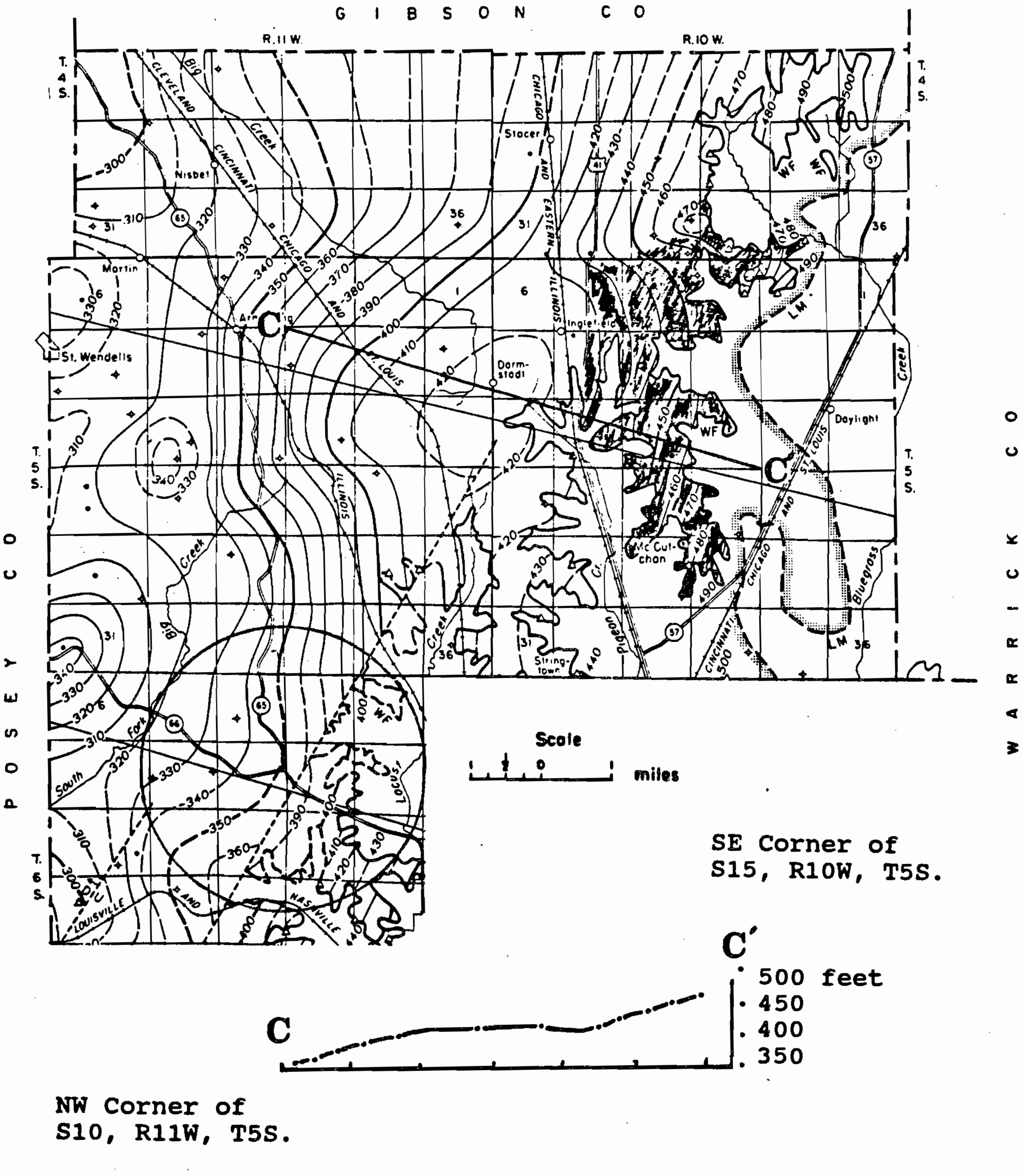
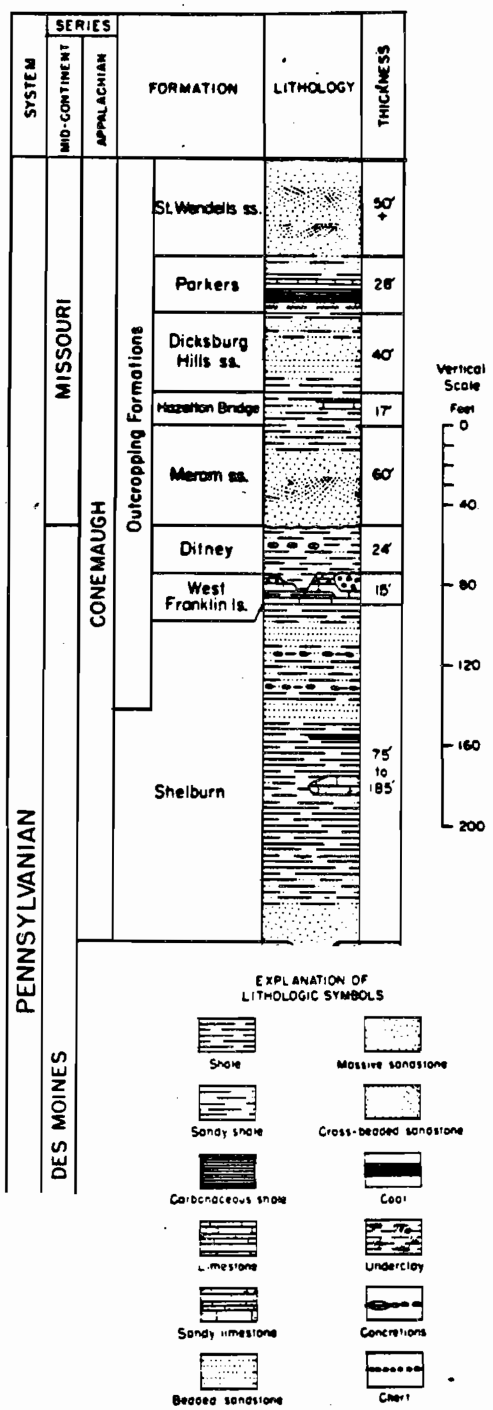


Figure 1. Geologic Structure map of Evansville North and Daylight, (R.10 W., T.5 S.), IN, 7.5 minute topographic map area. Cross-section C-C′is drawn along the general dip of the shaded McCutchanville ridge. Structure contours are drawn on the top of the West Franklin limestone (1954, INDOC-GS).



<u>Upper most bedrock unit:</u>

<u>Control Area</u>
Merom sandstone

<u>Study Area</u>
West Franklin limestone member
sandy shale or limestone

Figure 2. Generalized stratigraphic column of Vanderburgh County, IN. The upper most bedrock unit in the Study area is sandy shale or the West Franklin limestone/West Franklin limestone member, while in the Control area it is the Merom sandstone (1954, INDOC-GS).

Piping holes have been identified beneath structures, along patched driveways, along fences and in valley sides of tributary re-entrants along the McCutchanville Ridge. Surface runoff encountering vertical and linear obstructions (fence posts, buried pipes, tree roots and impervious strata) will slow, infiltrate and drain in subsurface streamlets that may emerge from valley slopes, flow as a surface stream, and again disappear beneath the valley bottom (photo documentation, 1991). Stream emergence may occur at colluvial boundaries, clay layers, limestone, or clayey paleosols. Water seepage from downspout drains, field tile, perforated PVC, field and septic tile, and water lines can also initiate or accelerate piping and cause structure damage.

Karst related surface features, not previously documented, characterize the McCutchanville ridge. Blocks of West Franklin limestone which are displayed as decoration in the front yards of homes along the ridge show rounded edges and solution features. Displays of sculptured bedrock are usually not far from their origin. These blocks, according to residents, are from foundation levels encountered during construction, other earthmoving activities and outcrop exposures. Also common along the ridge are shallow elongated depressions and open-ended cup-like depressions suggesting internal drainage.

Precipitation and waste water from residential septic systems reach bedrock along the western slopes of the McCutchanville ridge by infiltrating the loess profile and colluvial zone. Water reaching bedrock moves across weathered (clay) and competent shale. All ground water movement follows the buried erosion surface and bedrock dip-slope. These conditions suggest structures on the western slope have more water around basement walls and foundations than structures along the eastern slopes of the ridge. Most of the complainant structures are on the regional dip-slope. Shale with colluvium mantles the down-dip side of the ridge axis. Groundwater conditions on the dip slope, if not properly controlled, will contribute to basement wall and foundation wetness and foundation damage (Appendix G).

Along the eastern slopes of the ridge precipitation and waste water infiltrate, and if a permeable strata is encountered, drains northwest along the regional dip, or the water infiltrates and follows the buried landscape and surface drainage to the valleys. Ground water movement may fill depressions, form springs, ponds, or streams; or emerge at locations where man has disrupted ground water flow from ridge crest to valley floor.

Small Lakes and Ponds

Related to low permeable soils, shallow bedrock depth, and available groundwater are small local lakes and ponds along the McCutchanville ridge. The Evansville North topographic map (7.5 minute series) shows the McCutchanville ridge residential area contains more than 50 natural and man-made water bodies. Natural and man-made water bodies impede natural drainage by forming temporary water levels. There are isolated natural and man-made water bodies, and interconnected natural and man-made water bodies along stream courses. A temporary water table forms around each water body that drains or "spills over" to the next lower body of water along the stream course. Fluctuations of ground water levels around water bodies are controlled by the soil column, surface run-off, bedrock permeability, size of the up-dip water catchment area, storage capacity of the water body, precipitation, residential waste water, and evapo-transpiration. In general, structures with basements affected by proximate lakes or ponds should be subject to greater ground water quantities and water-related damage than other structures.

Natural Gamma Logging

The goal of natural gamma logging is to determine the textural variation of unconsolidated units in the vertical soil profile (IDNR-GS, 1990). A gamma ray probe detector measures natural gamma radiation emitted by unconsolidated material around the borehole. Gamma ray sources are weathered igneous and metamorphic rock fragments containing radioactive minerals. Sand, silt and clay are the weathered rock byproducts that retain radioactive decay products. A descending gamma probe, in a borehole, traces or logs the radioactive decay products encountered. This trace or log shows textural change. The texture becomes finer (clayey) as the trace moves right (increased gamma radiation) and coarser (sandy) as the trace moves left (decreased gamma radiation).

Natural gamma logging was used to supply subsurface information at depths not covered by soil and bedrock sampling. Not all auger holes were natural gamma logged and sampled, while others were gamma logged only. Natural gamma logging was used as an alternative to soil sampling and to reduce field cost.

Natural gamma logging showed a fining of particle size in the two to three foot depth level in the majority of the holes augered. This depth level corresponds to the Hosmer and Zanesville fragipan (Appendix 9B). Gamma logs provided the means to develop soil to bedrock stratigraphy. Natural gamma logs were used to identify soil horizons, loess, colluvium, weathered shale, competent shale, and the vertical thickness of each unit (Inter-Agency meeting (IAM), 1992; IGS, 1990).

Loess, Colluvium, and Depth to Top of Bedrock

Soil analysis, gamma logging, and residential construction provide data for assessing soil profile, bedrock, and exterior basement wall and foundation water conditions. Table 1, columns A through E list; loess, colluvium, weathered shale (clay) thickness, and depth to the upper (top) surface of bedrock. Columns F lists structure foundation type. Column G includes knowledge of past and present interior basement wall wetness reflective of hydrologic conditions along the exterior of basement walls and foundation.

Table 1 includes 13 structures extending about five miles along the McCutchanville ridge. Loess thickness at these structures range from 3 to 9 feet and average 6.1 feet in depth. Below the loess colluvial deposits range up to 3 feet and average 1.6 feet in thickness. Weathered shale (clay) varies in thickness from 0 to 7.5 feet and averages 2.9 feet. The depth to competent bedrock varies from 8 to 14 feet and averages 10.7 feet.

The colluvial zone or stone-line material identified by IGS (1990) is defined as fragmented angular or sub-angular rock debris along or at the foot of a slope transported by water and gravity. The permeability (capacity for transmitting a fluid) of the colluvium was not determined. Data from drill hole locations along the McCutchanville ridge infer the erosional surface of the westward dipping regional slope is mantled with colluvium (Appendix A and G). Other locations of colluvium on eastern and southeastern facing slopes and at depth in stream valleys suggest a wider distribution than the McCutchanville ridge alone. This is believed related to regional structure and subsequent degradation of the outer rim of the Illinois basin. The colluvial zone is contiguous with the weathered and competent shale. No intermediate strata was identified.

Surface water infiltrates the loess and saturates the colluvium. Groundwater flow occurs along the upper surface and through the colluvium and above the clay and shale aquatards. Although the specific permeability of the colluvium is unknown, it is expected to be greater than the underlying clay and shale. The colluvium may function only to elevate ground water levels above the clay and shale.

The shallow depth to bedrock (Table 1) suggests all basement excavation depths extend into the colluvial zone and most residential basement excavations intersect clay of low to high swell potential and/or competent shale (Appendix A, C, E, G.1, and G.2). These circumstances infer that structures without a properly functioning drainage system along the ridge are susceptible to basement water intrusion from available groundwater sources.

Table 1

LOESS, COLLUVIUM, WEATHERED SHALE THICKNESS, AND DEPTH TO TOP OF COMPETENT BEDROCK (shale/limestone), FOUNDATION TYPE AND WETNESS (data from auger boring and gamma logging, IGS, 1990; Amtech,1992; and USGS, 1993)						
A	B	C	D	E	F	G
Location: IGS or OSM borehole/ structure number and resident name	Thickness of Loess in feet	Thickness of Colluvium in feet	Thickness of clay (weathered shale)	Top of competent shale (sh) or limestone (ls)	Foundation Type	Foundat-ion or Basement Wetness
--/107 Harris	7	1	0	>8	Basement	Yes
10/108 McCutchan,R.	4	1	5	>10	Basement	Yes
--/108A Zinn	7	1	2	>10	Concrete pad/pt.crawl	No
1/111 Brinker	3	2	5	>10	Basement	* Not known
33/113 Boettcher	5	3	2	>10	Basement	Yes
01/118 Hoover	7	0	0	>8	Basement	No
32/201 Effinger	9	2	3	>14	Basement	Yes
35/202 Richey	5	1	3	>10 (sh/ls)	Basement	Yes
04/209 Gore	6	2	2	>10	Basement	Yes
--/301 Fink	8.5	2.5	3	>14	Basement	Yes
--/302 Greenfield	4	0	7.5	>11.5	Basement	Yes
34/403 McCutchan,W.	7	3	1-2	>12	Not known	* Not known
29/421 Osborn	7	2	3	>12	Basement	Yes

* Structures not included in basement wetness/dryness percentage.

The circumstances involving water intrusion are many, such as: chemical interaction of ground water and mortar, drainage system techniques at the time of construction, maintenance of drainage systems, and other drainage problems left uncorrected. It may take several years before water damage reaches the extent of observable intrusion on interior basement surfaces. Photographic prints and video footage of some complainant structures infer water deterioration has been a problem of ongoing historic significance (1989 and 1990 OSM interviews).

Residential Construction

Freeze and Cherry (1979) discuss groundwater movement into excavations when flow is disrupted. The rates of groundwater inflow will depend on the size and depth of the excavation and on the hydrogeological properties of the soils and rocks being excavated. Where soil or rock have low hydraulic conductivities, small inflows occur, and these can usually be handled by a sump pump or collector trench.

In silts and sands dewatering of excavations can become a significant aspect of engineering construction and design. Drainage systems lower water tables, intercept seepage, reduce uplift pressures and uplift gradients on the bottom of an excavation, and provide protection against bottom heave and piping. Dewatered excavations also lead to reduced pore pressure on its slopes so that slope stability is improved (Freeze and Cherry, 1979).

Table 1 presents the complete data sets that are available on soil thickness and depth to bedrock; basement depth; and evidence of hydrologic conditions as evidenced by interior basement wetness. Only 2 of 11 basements are dry. The partial crawl and concrete slab foundation of Zinn (108A) is dry. The water table below 108A was at a depth of approximately 12 feet below the surface on May 15, 1992. Foundation dryness is believed related to lack of foundation contact with existing groundwater conditions. Hoover (118) is located on the crest of a small knoll and contacts bedrock at less than 10 feet. Basement dryness is considered related to the small size of the water catchment area which limits groundwater contact with the partial basement (/crawl space). The OSM damage level for structure 118 is minor. Damage levels are based on complainant interviews and structure descriptions. Damage Levels include: Minor; Minor/Moderate; Moderate; Moderate/Severe; and Severe.

Nine of the 11 structures in Table 1 have wet basements. These structures have basement depths sufficient to intercept available up slope ground water, which could contribute to foundation damage. The OSM damage levels of the nine structures with wet basements are: 5 severe (#: 108, 113, 201, 202, and 421), 2 moderate/severe (#: 107, and 301), and 2 moderate (#: 209 and 302).

The data based on 11 structures show: (A) residents in the study area with partial and full basement foundation types ought to be aware that geologic and hydrologic conditions exist, that unless controlled, will contribute to water intrusion and foundation compromise; (B) structures with full crawl spaces appear less vulnerable to water intrusion; and (C) topographic position relative to geologic structure and hydrologic conditions affect the presence and degree of structure damage.

West Franklin limestone

The 450 foot contour above sea level marks a break in slope possibly formed by the West Franklin limestone member of the Shelburn Formation along the McCutchanville ridge (IGS, 1990). Loess, colluvium and sandy shale may overlie and conceal the West Franklin limestone along the ridge and slopes. Houses on the ridge slope can be close to limestone, span limestone and unconsolidated material, or be down slope of the outcrop.

The West Franklin limestone member of the Shelburn Formation underlies the McCuchanville ridge in those areas where topographic elevation exceeds geologic structure contour elevation (Figure 1; INDOC-GS, 1954). West Franklin limestone strikes northeast-southwest, and includes a tongue-like extension into the Blue Grass area. The West Franklin crops out along re-entrant valleys of the McCutchanville ridge and the Blue Grass Cemetery area, and dips in a northwest direction (Figure 1).

A generalized geologic cross-section includes a soil profile above two eolian loess formations named Peoria and Roxana. Below the loess, sandy shale lies on the top of the West Franklin limestone member which, in turn, overlies shale (IGS, 1990).

Varying degrees of karst development are associated with the West Franklin limestone in southwestern Indiana. May (1990) first documents the occurrence of karst development in Pennsylvanian-host rock west of Evansville in southwestern Indiana. Plant and animal fossils are encased in travertine deposits associated with a collapsed cavern system. The deposits are in the Desmoinesian West Franklin limestone member of the Shelburn Formation (Geological Society of America (GSA).

Case Studies Along the West Franklin Limestone Outcrop Zone

Two complainant structures, Fink (301) and Richey (202), are located close to the stratigraphic position of the West Franklin limestone. Structure 301 is located on the western dip-slope at the elevation of 460 feet. This is approximately 10 feet above the outcrop of the West Franklin limestone. Structure 202 is located west of the Blue Grass Cemetery by less than 1,000 feet and is also about 10 feet above the West Franklin limestone. The site characteristics of each structure are discussed below.

Structure 301

Six West Franklin limestone exposures were located along the McCutchanville Ridge. One exposure is along the south side of a tributary valley about 1,300 feet east and within plus/minus one foot of the void elevation in the core hole at the McCutchanville Fire Station. Solution pits and vertical fluted zones mark the top limestone surface exposed in a ravine and within 250 to 300 feet of complainant structure 301. These surface characteristics should have formed when the limestone was either at or near the surface. This exposure may represent a paleo-karst contact between the buried erosion surface and recent loess deposition.

During the initial visit to structure 301, it was observed that ceramic field drains with flush ends extended from both ends of the house. The drain from the front left, facing the house, contained loess but was still open. The second, from the right rear of the house (garage end), was clogged. The concrete floor of the garage end rests against the basement wall of the main structure. Sufficient loess has piped from beneath the garage slab abutting the structure end that the concrete has cracked and sagged about two feet. The ground at the exterior end of the garage continues to settle, e.g. a separation between the bottom of the exterior garage door and the concrete floor on the down-slope side continues to widen.

Holes in the roof gutters allowed water to drain outside the down-spouts and infiltrate the ground. A depression more than five feet deep was found along the outside rear basement wall. A subsequent crawl space inspection identified a hole in the footer that allowed loess to pipe into the crawl space. A flower pot found inside the crawl space was identified by the home owner as having been outside in the area where the hole formed. A piping hole near the breached footer in the crawl space allowed water to further transport material to lower levels.

Structure 301 was augered at three locations in May 1992. One hole which was 20 feet off the rear corner of the garage on the down slope side, encountered limestone associated "terra rossa" soil. In-situ limestone was not found. Two holes were augered in front of the structure, front center and front right facing the house. Both holes were drilled 5 foot deeper than the estimated limestone depth. The front center hole showed no evidence of limestone or terra rossa. The auger in the front right hole, closest to the garage, struck solid strata, chattered and vibrated at the estimated depth of the West Franklin limestone (12 to 15 feet) and augered deeper. The auger either rode the edge of a solution hole or the edge of a limestone block. The three holes were augered 10 feet below the estimated depth of the West Franklin limestone without encountering firm strata. Limestone fragments did not surface in the cuttings.

Loess at this site extends to a depth of 8.5 feet. Medium swell potential clay was identified between 5.0 and 6.5 feet and colluvium contacts the basement wall between 8.5 and 11.0 feet. The up-dip water catchment area is large and the basement has water problems. Weathered shale was found between 11.0 and 14.0 feet. Shale and siltstone were found below 14.0 feet.

The closeness of structure 301 to the West Franklin exposure suggests that if the limestone extended beneath the structure, loess could have piped via solution conduits. The three auger holes place doubt on the continuity and competence of the West Franklin beneath structure 301. This finding corresponds with the previously suggested source of "yard art" limestone blocks with solution features and rounded block edges. Alternatively, failure to encounter the West Franklin limestone may indicate the structure is down-slope of the outcrop. In addition to limestone solution holes, avenues of piping may involve clay horizons, tree roots, the outside of clogged drains, property line posts, and gaps in foundation footers.

Structure 202

The Richey (202) property contains in situ surface exposures and loose blocks of West Franklin limestone showing solution related features. In 1985 OSM investigated a complaint at this location near the Blue Grass Cemetery on the possibility that abandoned underground mining caused structural damage.

The report of this investigation describes a concrete floor slab that had settled unevenly with a displacement of up to 3.5 inches. The rear basement wall had a horizontal crack with some inward displacement near the top. These cracks were said to have become noticeable in the summer of 1984 with further development during the summer of 1985. The above damages and an exterior veneer failure of Indiana Limestone were photo documented (OSM, 1985).

A core hole drilled during the 1985 investigation recorded the depth to bedrock at 11 feet. At one foot into the top of the West Franklin limestone the drilling water was lost (water pumped down the borehole did not return to the surface for recirculation). The water loss is interpreted as entering open fractures widened and interconnected by limestone solution. The investigation in 1985 determined no apparent relationship existed between the structural damage of the residence and past underground mining (Engineers International, 1985).

Structure 202 is also a OSM complainant in the present AMAX cast-blasting study (OSM, 1989). The structural damages described and photographed in 1989 are the same damages described and photographed by Engineers International in 1985.

Little Ditney Hill area

Limestone blocks 10 feet across and about two feet thick were removed from the Ayrshire surface mine permit area during mining. These blocks were placed adjacent to Young Cemetery on West Run Road (off Base Line Road). Their characteristics include pits, open channels and conduits formed by solution. The limestone should be West Franklin although stratigraphic position is not verified. A limestone unit (thinner than the blocks described) can be seen on the east side of the road just south of Young Cemetery. A late 1800/early 1900 reference mentions a "double limestone" in this area (photocopies of text pages are held by complainant 103).

The West Franklin limestone of the McCutchanville ridge shows variable strata conditions. Limestone blocks in residential yards show strata separation by solution. Auger holes did not encounter solid limestone. These features suggest in situ West Franklin limestone is not continuous and competent.

Precipitation in McCutchanville and Daylight, IN

Table 2A lists the historical record of annual precipitation for Evansville, IN Regional Airport from 1949 through 1992. The record shows that annual precipitation exceeded 50 inches (in bold) 10 times during this 44 year period. The years of interest in precipitation distribution are 1982 through 1990 and the intervening drought years of 1986 through 1988 (Table 2B shaded).

Following the 1982 precipitation high, the years 1983 through 1987 show a general precipitation decrease. Vanderburgh County experienced incipient to mild drought conditions in 1986. Drought conditions in 1987 increased from mild to moderate, and remained moderate during 1988. Yearly precipitation marked the

A. **Annual Precipitation 1949 through 1992**
Evansville, IN Regional Airport: Weather Service Office (WSO)

Year	Inches	Year	Inches	Year	Inches
1949	**53.54**	1964	38.37	**1979**	**52.21**
1950	**60.13**	1965	35.03	1980	35.76
1951	**51.37**	1966	36.53	1981	43.35
1952	33.93	1967	43.19	* **1982**	**52.68**
1953	**53.66**	1968	43.21	1983	48.48
1954	33.83	1969	49.23	1984	49.75
1955	40.52	1970	45.93	1985	45.89
1956	33.93	1971	40.25	* 1986	37.68
1957	**53.66**	1972	42.27	* 1987	34.51
1958	42.22	1973	46.18	* 1988	38.43
1959	45.12	1974	43.27	1989	47.34
1960	34.48	**1975**	**51.01**	* **1990**	**52.52**
1961	47.38	1976	32.09	1991	32.68
1962	40.91	**1977**	**50.08**	1992	35.81
1963	27.88	1978	42.96		

B. FREQUENCY AND DURATION OF WEEKS WITH 0.20 IN. AND LESS OF PRECIPITATION PER YEAR. (# = FREQUENCY EACH DURATION OCCURRED)

YEAR	ANNUAL PRCP (ins.)	ONE WEEK	TWO WEEKS	THREE WEEKS	FOUR WEEKS	FIVE WEEKS	TOTAL - WEEKS (DAYS)	PERCENT OF YEAR
1982	52.68	10	2	--	--	--	14 (98)	26.8
1983	48.48	6	3	2	--	--	18 (126)	34.5
1984	49.75	6	--	2	--	1	17 (119)	32.6
1985	45.89	9	2	1	--	--	16 (112)	30.7
1986	37.68	11	4	1	--	--	22 (154)	42.2
1987	34.51	7	4	2	--	--	21 (147)	40.2
1988	38.43	9	4	1	--	--	20 (140)	38.3
1989	47.34	4	1	--	1	1	15 (105)	28.7
1990	52.52	5	3	--	--	--	11 (77)	21.1

Table 2. A. Annual precipitation (Prcp) in inches for 1949 through 1992 (Evansville, IN Regional Airport Weather Service Office (WSO) Vanderburgh County, IN), and B. Frequency and duration summary of weeks with 0.20 in. and less of prcp 1982 through 1990 (1992, USDOC, NOAA, NCDC).

end of a six year low in 1988, increased in 1989, and in 1990 exceeded 50 in. (Table 2) (DOC, NOAA, WWCB, 1986, 1987 and 1988).

Figure 3 bar graphs show weekly precipitation distribution for 1987 and 1988. Visual inspection shows there are numerous single and multiple weeks of 0.20 in. or less.

(1) In 1987 the annual precipitation was 34.51 inches. There were 23 weeks (161 days) when precipitation was 0.2 inches or less. These included: five intervals, each of one week duration; three intervals of two weeks duration; and four intervals of three weeks duration. These low intervals of precipitation totaled to 44.1 % of 1987 (Appendix G).

(2) In 1988 the annual precipitation was 38.43 inches. There were 22 weeks (154 days) when precipitation was 0.2 inches or less. This included: six intervals, each of one week duration; three intervals of two weeks duration; two intervals of three weeks duration; and one interval of four week duration. These low intervals of precipitation totaled to 42.2 % of 1988 (Appendix G).

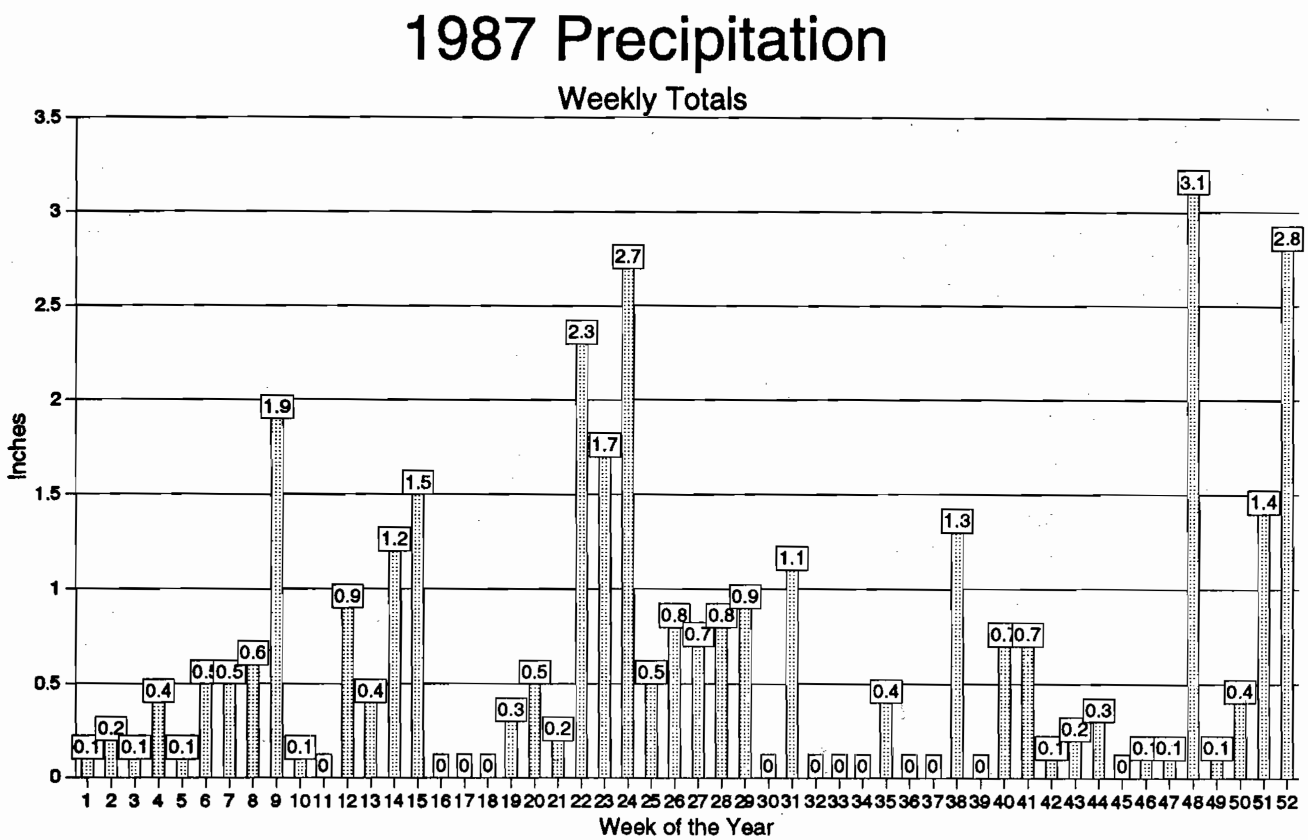
In contrast, the weekly distribution of precipitation during 1982 and 1990 exceeded 50 in. The record shows:

(1) In 1982 annual precipitation was 52.68 inches. There were 14 weeks (98 days) when precipitation was 0.2 inches or less. These included: ten intervals, each of one week in duration; and two intervals of two week duration. Low intervals of precipitation totaled to 26.8 % of 1990 (USDOC, NOAA, 1992).

(2) In 1990 annual precipitation was 52.52 inches. There were 11 weeks (77 days) when precipitation was 0.2 inches or less. These included: seven intervals, each of one week in duration, and three intervals of two week duration. Low intervals of precipitation totaled to 21.1 % of 1990 (USDOC, NOAA, 1992).

Table 2B shows frequency and duration of weekly low level precipitation (0.20 in. or less) for both high and low level precipitation years. The frequency of weekly intervals of low level precipitation peaked during 1986 through 1988. Intervals of low level precipitation during 1986 through 1988 are 15 to 21 percent greater than low level precipitation intervals during 1982 and 1990 (Table 2B).

The interval of structural damage escalation in the study area was identified in a May 1989 McCutchanville, IN public meeting that reviewed AMAX's mining permit. The USBOM states that "A



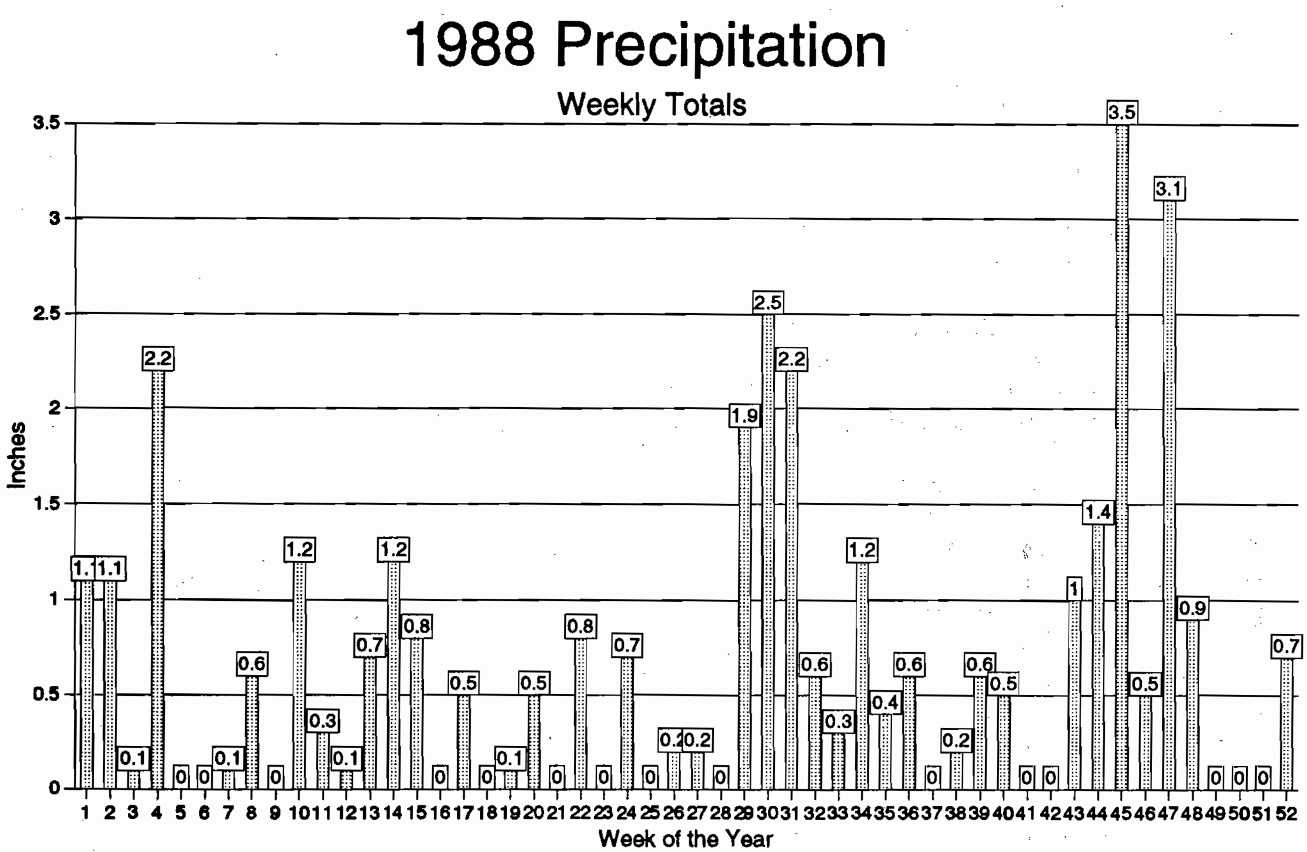


Figure 3. Weekly precipitation in inches for 1987 and 1988 (1992, USDOC, NOAA, NCDC).

point of general agreement was the relatively recent time frame for the escalation of these problems.

A number of speakers noted that they had either been lifelong residents or had been in the neighborhood for more than 10 to 15 years and that serious problems have only been noted since 1987-1988" (1990).

The identified interval of escalation coincides with decreasing precipitation that began in 1982 and culminated during the years 1986 through 1988 (Table 2B). Table 2A shows the 34.51 ins. of precipitation for 1987 was the lowest of six deceasing years and 1988 totaled 38.43 ins. The June 1988 precipitation was an 11 year low for that month.

The precipitation pattern in the 12 months preceding the drought of June 1988 included the following (Figure 3) (1) July through November 1987 received 10.23 inches. This is a 42.43% drop in precipitation from an 11 year average of 17.77 inches; (2) December 1987 through February 1988 received 12.93 inches of precipitation. This is a surplus of 3.48 inches above the 11-year average of 9.45 inches for these months; and (3) March through June 1988 received 7.1 inches. This is a 58.11% drop in precipitation from an 11-year average of 16.95 inches for these months. In July 1988 precipitation jumped 2.39 inches above the 11-year average to 6.63 inches (USDOC, NOAA, NCDC, 1992).

Decreased Precipitation and Drying Soils

As precipitation decreased, the frequency of soil drying should have increased. Several authors have discussed the effects of drying soil clays. The USBOM (1990) report on damage to the houses in McCutchanville and Daylight, IN state certain houses in these areas developed cracks in a way that follows a mechanism outlined by Bauer (1982) and the Small Homes Council, Building Research Council, University of Illinois, Illinois State Geological Survey (SHC-BRC-UI-ISGS, 1988).

Bauer (1982) described the mechanism as follows;

> "Compression forces against foundation walls are commonly developed by an increase of soil moisture after an extended dry period. During long, extremely dry weather, the soil shrinks and pulls away from the foundation, and soil particles fall into the resulting gap. Wind, animals, and rain may also push material into this gap. The return of soil moisture causes clay particles in the gap and in adjacent soil to expand, exerting horizontal pressure on the foundation walls. Horizontal pressures push the foundation walls inward, forming a bow shape with the mid-span of the wall pushed farthest inward. The foundation walls usually

have horizontal cracks within 2 feet of the ground surface. We conclude that horizontal pressures are generally built up by a combination of wetting/drying and swelling/shrinkage cycles. It may take several such cycles to exert enough pressure to damage the foundation, although the process can be accelerated by drought."

The SHC-BRC-UI-ISGS states that during a drought, soil containing clay minerals around house foundations shrinks away from the walls, creating vertical separations which may be 1/2-inch wide at the top and 2-feet deep (1988).

> "This separation of the soil from the wall is not detrimental as long as it stays open and free of any debris which may be deposited by the wind, water (initial rainfalls or watering) or animals traveling next to the foundation."

The separation is detrimental only if soil is repeatedly allowed to accumulate in the open crack. When rain occurs the soil will try to swell back to its original dimension but is hindered by the collected debris in the crack.

> "This increases the pressure on the walls after each dry period. Years of accumulation and pressure buildup can cause walls to bulge inward and in extreme cases, cause the basement walls to collapse (SHC-BRC-UI-ISGS, 1988 in USBOM, Appendix H, 1990)."

According to Chen (1988), expansive soils are not subject to volume change unless there is an increase in moisture content. A dryer soil swells more than a wet soil. Chen also states that watering of lawns, especially after a heavy drought period, has caused the swelling of expansive soils (1988).

The precipitation patterns shown on Table 2 and Figure 3 appear complementary to the concepts described by Bauer (1982), Chen (1988), and SHC-BRC-UI-ISGS (1988). The opportunity for cyclic soil wetting/drying and swelling/shrinkage increased as the number of single and multiple week intervals of low precipitation increased between the years of 1982 and 1990.

Study Area Soils

The 1976 Soil Survey of Vanderburgh County, IN includes the McCutchanville, IN ridge and Daylight, IN (study area) and Kasson, IN (control area) (United States Department of Agriculture (USDA), Soil Conservation Service (SCS), 1976). The published survey provides a general soil map, soil descriptions, and recommendations on the use, limitations, and management of the county soils. The soil series that occur in the study area are listed in Appendix F.

Residential or light development limitations (without considering disposal of septic-tank effluent) are severe when soils are subject to flooding and steep slopes, and moderate when subjected to poor drainage, seasonal high water table, low strength, and increasing slope. Only Hosmer soils with 0 to 6 percent slopes have slight soil limitations (USDA, 1967; Appendix F).

The soil survey showed that 75 percent of all soil series slope categories identified in the study area had severe limitation due to moderate to very slow soil permeability (the relative ease of fluid flow under unequal pressure) (USDA, 1976). The OSM damage inventory of 1990 showed that 90 of 104 complainant structures (86%) had established septic sewage systems in these soils.

Soil Permeability

Permeability depends on the size and shape of pore voids, the size and shape of their interconnections, and the extent of interconnections. The soils of the study area are mostly silt loams that change downward to silty clay loams within two to three feet of the surface (USDA, 1976).

The Hosmer and Zanesville soil series have a slow to very slow water absorption zone ranging from 25 to 36 inches below the surface called a fragipan. The dominant particle size is silt or very fine sand. Soils of medium swell potential were identified within the fragipan zone at three structures (105, 118, and 215). Sample depth and soil analysis was not designed to identify swelling clays within the fragipan zone. These three sites have Hosmer soils with two to six percent slopes (IGS, 1990; USCOE-SADL, 1990). These low-permeable soil horizons act as aquitards to limit water infiltration.

Where a claypan is present, drainage is poor. Where loess deposits are thick and no claypan is present septic tanks may be more practicable, but fields that are concentrated in grouped lots of subdivision size, can still lead to a raised water table, increasingly poor drainage conditions, and consequent failure of the absorption fields (Straw, Gray, and Powell, 1977).

Residential development in the last 10 years may have increased water related problems. The Evansville Water and Sewer Utility (EWSU) is expanding city water lines into the McCutchanville area. However, less than 20 percent of the 60 square mile study area is serviced by public sewage facilities (EWSU, 1991). Eighty-five percent (90 of 104 structures) of the homes in the OSM damage inventory of 1990 were on septic sewage systems. Eleven percent (12 of 104 structures) were on EWSU. Waste water disposal systems for the two remaining structures are not known.

The EWSU sewage lines extend along state highways and major secondary roads of the study area. Public sewage services are found in 24 to 30 quarter mile sections (6 to 7.5 square miles) in the study area (EWSU, 1991).

The Indiana State Board of Health (ISBH) and the Board of Commissioners of Vanderburgh County (BCVC), stipulate sewer disposal system standards and design specifications (1990). Study area soil characteristics dictate that septic tank absorption fields be carefully designed (ISBH, 1990; and BCVC, 1990). The Vanderburgh County Soil Survey indicates severe limitations on septic fields in the study area due to slow permeability, seasonally high water tables, flooding or steep slopes that hinder construction of the fields (Appendix F).

The complaint survey by OSM in 1989 is estimated to have covered 5.6 percent of the 1850 structures on the 1961 USGS, 7.5 minute topographic maps of Evansville North and Daylight, IN. If the ratio of OSM complainant families on septic systems and EWSU are representative of the study area, the quantity of waste water discharge into low permeability soils is considerable.

The average water use in the State of Indiana for a self supplied septic system is 78 gallons per day per person (gpdpp) (USGS, 1985). A family of four uses 312 gallons per day (gpd). The yearly water use for a family of four would be 113,958 gallons per year (gpy). The water used by the 90 families on septic systems in the OSM survey (assuming four member families) would total 10,256,220 gpy.

An up-dated estimate of the number of structures in the study area approaches 3000. If 75% of 3000 families were on private sewage systems and all were four member families, the yearly water use would be 256,405,500 gpy.

The significance of waste water in equivalent inches of rainfall is a function of septic system absorption field size. For example, a 200 foot square absorption field, 114,000 gallons is equivalent to 4.5 inches of precipitation. Waste water contributions to already available ground water may effect a structure down-dip or down-slope of the source if the structure is without adequate foundation drainage. Increases in available water around basement walls and foundations are known to cause foundation damage.

Clay Content

The OSM/USBOM cooperative agreement (1988) included a task that stated "if the blasting is not found to be responsible for the observed damage, researchers will try to determine the likely causes."

The relatively low levels of vibration measured by the USBOM during their investigation prompted a search for alternative causes. The USBOM suggested that expansive clay-containing soils activated by weather extremes may be the primary cause of major cracking in area homes. This hypothesis was based on a soil sample collected from complainant structure 108 (1990).

The University of Minnesota (UM) analysis for the USBOM, dated February 9, 1990, states the sample had a moderate shrink-swell hazard and the clay fraction was dominated by smectite and inter-layered smectite/illite clays. These are both expansible clays and contribute to the shrink-swell hazard. Probably the only factor that prevents these soils from having severe shrink-swell is their low (approximate 20%) clay fraction (USBOM, 1990; Appendix I).

The expansive clay hypothesis prompted an OSM request to IDNR-GS (1990) and USCOE-SADL (1990) to identify the clay mineralogy in soil profiles using x-ray diffraction (XRD). Appendix D, Table 1 estimates clay mineral percentages in seven auger holes at specified depths for the 2 micron (0.002 mm) and smaller particle sizes (USCOE-SADL, 1990). Table 2 estimates the clay mineral percentages (same auger holes) based on the total sample. The USCOE-SADL (1990) petrographic report of X-ray diffraction results is also provided in Appendix D. The USCOE-SADL XRD summary in Appendix D shows: (1) the clay mineralogy of the eight soil samples from seven drill holes analyzed by X-ray diffraction appear similar, (2) vermiculite is the most abundant clay mineral present, (3) kaolinite, illite/mica and chlorite are much less abundant, and (3) one sample identified smectite (montmorillonite).

Appendix B, Table B.1 shows the clay type and percentage estimates of the 2 micron (0.002 mm) and smaller particle sizes (IDNR-GS, 1990). The term "mixed layer" in Table B.1 refers to smectite as the dominant clay group. Smectite was identified in all 38 samples from 12 boreholes (IDNR-GS, 1990).

Soil Moisture Content and Dry Density

The natural field density of loess is an important factor for the amount of compaction that will occur during wetting. Natural density is the weight of the solid particles and moisture expressed in pounds per cubic foot (lbs./cu.ft.). Dry density is the unit weight per cubic foot of a dry sample excluding the water content. The water content is expressed as a percentage of the dry density.

Moisture Content

Moisture content is the most influential factor affecting the properties of a soil. Lofgren (1966) states that when water is added to primary loess deposits the strength of the soil decreases and consolidation increases until full natural consolidation (compaction) results. Where the moisture content of loess is more than 15 percent, full natural consolidation (compaction) under load generally will have occurred. Moisture contents between 10 and 15 percent are intermediate with relatively high strength. Moisture contents below 10 percent have a high susceptibility to hydrocompaction.

The IGS boring data (1990) included 118 moisture values expressed as a percentage of the dry density (Appendix B). The moisture content in 108 of the samples exceeded 15 percent. Nine of the remaining 10 moisture values ranged between 10 and 14 percent.

Applying the Lofgren (1966) criteria to the soil moisture values in the study area soils infers full natural consolidation (compaction) has occurred in 91.5% of the soil samples. Intermediate compaction with relatively high strength has occurred in 7.6% of the soil samples. Less than one percent of the soil samples showed a high susceptibility to hydrocompaction.

Soil Density

Soil density is also related to soil compaction. A loess natural density of less than 80 pounds per cubic foot (lbs./cu. ft.) is considered loose and highly susceptible to settlement on saturation with little or no surface loading. Natural densities of 80 to 90 lbs./cu. ft are considered medium-dense, and is moderately susceptible to settlement on saturation when loaded. Deposits with natural densities above 90 lbs./cu. ft. is quite dense and capable of supporting ordinary structures without serious settlement, even on saturation (USDOI, BOR, 1985; Lofgren, 1966; Gibbs and Holland, 1960).

The dry density and moisture content of 106 soil samples from 12 of 22 study area auger holes exceed 90 lbs./cu. ft. (Appendix B). The soils sampled are capable of supporting ordinary structures without serious settlement, even on saturation.

Structure Settlement

USBOM checked structural settlement as a contributory problem to structural damage (1990). Two USBOM figures (30 and 31) show a concrete patio poured in contact with a basement wall. The side of the patio against the house has settled and tilts inward toward the structure. Seven homes were level-loop surveyed by USBOM in October 1989 and January 1990. Three structures were in Daylight and four in McCutchanville, IN (USBOM, 1990).

The four structures (Numbers 107, 108, 209, and 303) level-loop surveyed in McCutchanville show settlement on the down slope side (USBOM, 1990). All four McCutchanville structures are on hillside slopes. Three structures are located above colluvial deposits, and three depend on septic systems. The septic system at structure 107 was replaced with EWSU service. USBOM states some damage is consistent with slope failure and level-loop surveys can reveal gross differential settlement of the structures to a resolution of about 0.01 feet (1990). USBOM suggests water, slope movement or both are contributing factor(s) to the damages (1990).

Case Studies of Structure Settlement

The slope, soil conditions and underlying stratigraphy for level-looped structures of Gore (209) and Harris (107), are evaluated below. Structure 209 is up-slope of 107. Hawles (107B) a non-complainant companion located down-slope of 107 is also discussed in comparison with the Harris residence.

Structure 209

Structure 209 is about 400 feet from and up slope of structure 107 by about 10 feet. The roof of 209 is visible from outside the basement entrance of structure 107. Structure 209 is a 43 year old dwelling with no additions, located near the surface divide and nose of the ridge. The surface area around the structure and driveway to Whetstone Road has been landscaped from the county soil survey slope of 0 to 6 percent (USDA, 1976). Whetstone Road is mid-way between the two structures. Borehole data for structure 209 at a depth of 6.6 to 8.3 feet shows a colluvial stone-line as evidence of an erosional surface atop weathered shale (IGS, 1990). The weathered shale at a depth of 8.25 to 10.7 feet is a clay of high swell potential. Many steeply dipping joints with slickensided faces were identified in shale at a depth of 10.2 to 12.5 feet (IGS, 1990).

Basement photos of structure 209 show a full length basement floor crack. Water stains follow a wall crack and run to the floor and soil has been transported through the basement wall and deposited on the floor. Bricks support boxes off the basement floor. These observations infer a long term water problem.

Basement water intrusion suggests saturation on exterior basement walls and foundation. Loess, colluvium, and weathered (clay) to shale contact basement walls and foundation. The steeply dipping slickensided joints in expansive clay suggest down slope extension. Structure 209 has four residents and uses a septic sewage system. The depth of the waste water absorption field is, most likely, similar to the present depth requirement of 10 to 36 inches (ISBH, 1990; BCVC, 1990). Waste water flows above the fragipan surface or infiltrates and moves along the colluvium and bedrock surface. Structure 209 is close to the surface divide with basement construction in colluvium (stone-line) and high swell potential clay on the western dip-slope.

Structure 107

Structure 107 is 41 years old and has several additions. It sits down slope of structure 209 and is on a county soil survey slope of 6 to 12 percent. Bedrock strata dips westward at a rate of 25 to 30 feet/mile (INDC-GS, 1954). This places bedrock at structure 107 about 2 feet deeper than at structure 209.

The ground up-slope and to the right of the house (facing front); front yard; and driveway is changed slightly from the original surface slope. The present residents have owned the structure since April, 1988. The USBOM determined that the house structure had settled (1990). An OSM inspection file (1989) states that the southwest (down-slope) corner of an unattached garage, built in 1981, appears to have settled. The front exterior door of the house structure would not close easily at the time of the OSM inspection and the owner stated it had been sticking since they moved in. Also, an exterior door to a sun room on the opposite side of the house would not open (noticed by the home owner in December 1988). The sun room also had an outward bowing storm window (deck side) (OSM, 1989).

A painted crack on a basement wall in the laundry room was traced to a cabinet purchased with the house. The crack continued behind the cabinet and was not painted. The present owners thought the house had been painted in 1985-1986 (OSM, 1989). By relative age dating, this shows that some process has caused cracking during or prior to the mid-1980's. (USGS, 1993).

Structure 107 was built in 1953. The annual precipitation exceeded 50.0 in. during this year. The annual precipitation exceeded 50.0 in. in three of the four years (1949 to 1951) preceding construction (Table 2A). A sump pump located in the laundry room is assumed to have been installed at the time of construction (1953). Sump pumps are installed to prevent or reduce water around foundation and subsurface exterior walls from seeping into a basement.

In 1982 the annual precipitation again exceeded 50.0 ins. In 1983 a second sump pump was installed beneath the first story rooms on the up-slope side of the structure. The area has been excavated below the original footer and backfilled with gravel. A plastic conduit is placed vertically to a depth of about 5 or 6 feet. A drain near the bottom of the sump allows excess water to collect and be removed. A second story was added (following sump pump installation) in 1984.

Settlement can occur as a result of water extraction and consequent soil consolidation. When water is pumped from the soil, the pore pressure is reduced; consolidation transfers the load carried by the pore water to the soil solids, and a reduction in soil mass volume is caused by adjustment and rearrangement of soil particles under stress (Costa and Baker, 1981).

The second sump pump added in 1983 may have decreased pore water pressure and initiated soil particle rearrangement. The second story was added in 1984 and increased soil loading. These two actions, in combination, may have contributed to the structural settlement identified by the USBOM (1990). Alternatively, this settlement and other kinds of structural distress may have been effected by significant drainage problems prior to the installation of the second pump.

Structure 107B

The Hawles structure (107B) is a non-complainant companion located about 5 feet lower in elevation and 200 feet horizontally from complainant 107. It is within the same up-slope drainage area as 107 and 209. Structure 107B has a full crawl space. There is no water problem and the damage level is minor. The surface foundation of the house does not come in contact with the deeper parts of the soil profile, bedrock and available up-slope water that 209 and 107 encounter. Structure 107B was not level-loop surveyed or augered.

Structures 209, 107, and 107B describe physical environmental conditions along the western dip-slope. These conditions include: (1) similarity of soil; (2) colluvium or stone-line deposits above bedrock; (3) weathered and/or competent shale bedrock; (4) inferred down-slope ground water increase based on geological conditions; (5) down-slope structural settlement; (6) structure foundations in bedrock with moderate and moderate/severe OSM damage levels; and (7) structure foundations on shallow footings with minor damage.

CONTROL AREA
Selection Criteria

The control area was selected by interagency representatives for comparison to the McCutchanville and Daylight study area. The control area lies within two miles of the merging of Indiana Routes 65 and 66 (circled on Figure 1). This area includes the southeast and northeast corners of the Kasson, and West Franklin, IN 7.5 minute quadrangles. The maximum distance between the control and study area is about 10 miles.

Four essential control area selection criteria were developed: (1) the area should not be influenced by blasting vibrations or other extraordinary sources of vibration; (2) the soil should be primarily Hosmer; (3) topography (ridge to valley) should be comparable to the study area; and (4) structure evaluation should include a mix of houses similar in construction, age and slope position to houses sampled in the study area. Secondary criteria included: similar bedrock geology; structural densities comparable to the McCutchanville and Daylight areas; presence of septic systems; and vegetation. All "essential" elements had to be met while "secondary" criteria were applied to enhance site similarity.

The selection of specific structures by USGS and OSM for evaluation was based on their similarity to structures in the McCutchanville and Daylight area. Another controlling criterion for the building evaluation was the willingness of residents to sign a right-of-entry for structural inspection, drilling and disclosure of data.

Geology

The structural geology of the control and study area is shown on Figure 8.1. An inferred fault strikes North 30 degrees East in the direction of Darmstadt, IN. The southeastern block of the fault is upthrown relative to the opposing block. Bedrock dip on the upthrown block is about 30 to 35 feet per mile to the northwest. On the downthrown side the bedrock dip is less than the study area and generally westward (IDOC-GS, 1954).

About twelve exposures of the West Franklin limestone were located in the control area. An American Pauline aneroid altimeter with a plus/minus two foot accuracy was used to establish elevation control at a USGS bench mark.

The uppermost strata in the control area is the Merom sandstone which is younger in age and higher in topographic elevation than the uppermost West Franklin limestone member, Shelburn Formation of the McCutchanville ridge in the study area (IDNR-GS, 1990).

Apparent thickness of the Merom sandstone was determined by locating the furthest upstream and downstream exposures along a stream bed on Cochise Road off Schaefer Road. Elevation difference identified a bed thickness of 58 to 60 feet. Below this sandstone, gullies and streams contained coarse sand stained by iron oxide with limonitic nodules and concretions. Below the iron oxidized sandy zone is the West Franklin limestone of the Shelburn formation.

The stratigraphic column (Figure 2) consists of the Merom sandstone (65 feet), Ditney sandy shale with concretions (24 feet), and West Franklin limestone (15 feet). The three uppermost units form a thickness of about 104 feet (INDOC-GS, 1954).

Merom sandstone is a thick competent ridge former in the Kasson area. Rising out of the valleys eroded into the Merom sandstone the stratigraphic top of the Merom forms an accordant level that appears topped only by loess deposits. This appears related to the period when the Ohio River eroded the Bayou Creek bluffs (West Franklin, IN-KY and Kasson, IN 7.5 minute topographic map series). Only weathered evidence of the Ditney unit was found in the control area. The Merom sandstone and Ditney unit were not found in the McCutchanville and Daylight area.

The West Franklin limestone exposures in the control area are thicker and more competent than those in the study area. Valley-side and bottom exposures of the West Franklin in the control area show a dense grey fossiliferous limestone with varying degrees of solution.

The rock sequence in the control area consists of a 60 foot thick sandstone that is absent in the study area. The West Franklin limestone is thicker and more competent than its counterpart underlying the McCutchanville ridge. The rest of the Shelburn formation below the West Franklin member was not observed in the control area.

Loessial piping is common throughout the control area along tributary valleys. For example, a well developed system of piping in the control area is found 2000 ft. north of Mt. Vernon Road on Red Bank at Tupman Cemetery. Inside the entrance off Red Bank Road, a bowl-shaped headland valley opens to the south in the direction of Mt. Vernon Road. The valley head is characterized by subsurface drainage. Along the valley bottom, vertical piping holes as deep as four feet connect to subsurface drainage. Openings occur along tree trunks and follow root systems. The stream flows in a subsurface network, emerges along a mid-valley section, then disappears as the small valley merges with a larger valley. Slopes along the valley sides show evidence of soil creep by leaning trees and bent tree trunks near ground surface.

Soils

The USCOE-WES collected five undisturbed (fixed piston) soil samples from the north side of Dieffenbach Road, about 0.4 miles south of Koring Road in May 1992. The soils are classified as silty clay (CL) with iron oxide nodules (Appendix A, Figure A.1, Unified Soil Classification).

Control area soil sampling depths in three holes ranged from 3.5 to 6.0 feet. Dry density sample weights were 102.4 to 112.2 lb./cu.ft. Moisture content ranged from of 16.8 to 20.6 percent. Maximum soil saturation percent in holes OSM-UD10 and UD7 were 84.4 (3.5 ft.) and 85.0 (4.7 ft.) respectively. Dry density and soil moisture show the soil is dense and full natural consolidation or compaction has occurred.

A comparative upland study area location exists along Kansas Road. The soil sampling depths at three holes ranged from 5.0 to 10.7 feet. The maximum percent saturation in holes OSM-UD4, UD5, and UD6 were 91.6 (at 6.3 ft.), 95.7 (at 9.7 ft.) and 96.8 (at 10.7 ft.) respectively.

The maximum percent saturation at the control area is 7.2 to 11.8 percent less than the Kansas Road site. The control area site is located in an open grassed field with a minimum of three intermittent streams that direct ground water away from the up-land surface, has less than 20 feet of relief, and is situated on the dip slope. The study area location is on the scarp slope of the McCutchanville ridge, has some 70 feet of up-slope relief, is adjacent to Kansas Road, and occurs within the road side drainage ditch. These two locations provide site specific moisture values, but can not be assumed to be representative of the entire control and study areas. It is possible that these are differences in average soil saturation percent between the two areas due to: (1) a greater permeability in the Merom sandstone in the control area relative to the uppermost shale in the study area; and (2) the greater depths of the West Franklin limestone in the control area than in the study area. However, this cannot be verified with the existing data.

Road cuts and valley-side exposures were used to confirm depth to firm bedrock. One USCOE-WES-GL test hole confirmed bedrock at 9 feet. Foundation depths at four new construction sites did not encounter bedrock at 10.0 and 11.0 feet. Field observations of bedrock depths range between 9 and 12 feet.

Foundation Damage Distribution
Study Area

Structural evaluations of 33 study area residential structures by the USGS (1993) included separate exterior, foundation, and interior damage assessments (Appendix I). The foundation types evaluated included: full crawl; (FC) and partial crawl/slab (PC/S); 10 partial basement/crawl (PB/CS); and 16 full basement (FB) foundation types. Twenty-three structures were inspected along the McCutchanville ridge and north to the Blue Grass area; and 10 structures along Baseline Road, Green River Road, and in Daylight (USGS, 1992). Damage information relative to foundation type provides a basis for further consideration of site specific soil and geology conditions as potential causes of structural damage.

The following analysis is based on data in the USGS (1993) Table 11 and other site specific conditions (Appendix G). For each complainant and non-complainant structure the table lists the resident name; foundation type; year of construction; and a short description of foundation damage. Complainant structures are identified by three digit numbers (example: 202, Richey). Non-complainant structures proximate to specific complainant structures are identified by a three digit number and capital letter (example: 202A, Stevens). In this example, the Stevens structure (202A, a non-complainant) was paired with the Richey structure (202, a complainant) for comparison. An assessment of foundation damage and site conditions is presented below:

A. Six full crawl (FC) and one partial crawl/slab (PC/S) foundation types:

1. Three of seven structures (FC and PC/S) are located on the regional dip slope on the McCutchanville ridge and north. These structures include: (1) Hawles (107B); Stevens (202A); and (3) Zinn (108A). Foundation damage was not observed. Zinn (108A) has medium and Stevens low swell potential clays below their structures. Full crawl (FC) and PC/S do not contact the deeper soil profile and ground water conditions. Surface positions of FC and PC/S appear less susceptible to foundation damage.

2. Four of seven FC structures are located on Baseline Road, and Green River Road in Daylight. Foundation damage was not observed. The structures include: Miller (105A); Board (115B); Klausmeir (115A); and Shelton (103A). Klausmeir (115A) and Shelton (103A) have clays of low swell potential below their foundations. The damage to Klausmeir (115A) is believed none (USGS Table 11, oversight error). The FC foundations do not intersect ground water.

B. Ten (10) partial basement/crawl space (PB/CS) foundation types:

1. Four of 10 structures are PB/CS located on the McCutchanville ridge regional dip-slope. Foundation damage was not identified. Topographic position is considered contributory to lack of foundation damage.

Hoover (118) and Arnold (114B) are positioned on topographic highs with less than 10 feet of up-slope relief. The small up-slope water catchment areas suggest adequate natural drainage e.g. water accumulation around the foundations should be relatively small.

Ogg (113A) is on the eastern slope of the McCutchanville ridge with strata that dips westward into the hillside. There is less than 20 feet of up-slope relief. Ogg has medium swell potential clays beneath the structure. The small soil water catchment area suggest adequate natural drainage.

Deutch (107A) is positioned adjacent to a drainage basin that diverts ground water away from the structure. Expansive weathered shale is 8 to 12 feet deep which is probably below the foundation level.

2. Five of the 10 PB/CS structures on the McCutchanville ridge regional dip slope have various levels of cracking in foundations. The soils around or below these structures have high to low clay swell potentials: High (Greenfield (302) and Richey (202); Medium (Boettcher (113) and Fink (301) and Low Harris (107). All five structures have evidence of basement wetness (Table 1; Appendix G).

The Boettcher (113) foundation is known to have started cracking in 1955. The clay swell potential below this structure is medium. Damage includes wall and slab cracks.

Fink (301A) has a drainage problem involving soil piping beneath the PC and attached garage floor slab. The clay swell potential below this structure is medium. Damage includes cracks in all walls and step footer area was discontinuous at the step.

Harris (107) has a drainage problem controlled by sump pumps (discussed earlier) that may be related to structural settlement (USBOM, 1990). The clay swell potential below this structure is low. Damage includes cracks in walls and slab.

Greenfield (302) is of particular interest because damage is confined to the PB part of the foundation while no cracks were observed in the crawl space foundation. The clay swell potential below this structure is medium.

The Richey (202) foundation is on limestone and clay with a high and medium swell potential. Damage was described by Engineers International, Inc. in 1986. Damage includes large basement cracks.

3. One of 10 PB/CS is located on Baseline road. Topographic position is believed contributory to foundation damage.

The Christensen (115) foundation is in weathered shale of low swell potential. The NW corner of the lot, west side of house is wet due to drainage from surrounding agricultural fields. Structural damage include cracks and signs of movement of upper story floor beam supports.

C. Sixteen (16) full basement (FB) foundation types:

1. Eight of 16 FB structures are located on the McCutchanville ridge and have foundation damage. Topographic position is believed to affect foundation damage level.

Condict (301A) is positioned on the regional dip-slope. Damage includes numerous cracks in the basement walls with evidence of moisture penetration from the outside.

Lavallo (113B) is positioned on the regional dip slope. Basement walls have numerous cracks in the older part of the house.

Palmer (302A) is positioned on the crest (east) side of the McCutchanville ridge with strata that dips into the hillside. There is no up slope drainage. The foundation exhibits minor cracking.

McCutchan (108) has several drainage problems. Soil of high swell potential has been found at four and seven feet in depth. The up-slope basement wall against the garage has a subsurface void in the soil (COE, 1990; USBOM, 1990).

Kinney (114) has downspout pipes (left and right corners facing the house) that have separated from in-ground drainage pipes. The interior basement wall opposite the front right corner has evidence of water penetration.

Damage includes a large North-South crack in the basement slab, and horizontal and stairstep cracks in the block walls. This location was not augered.

The Wolff (114A) foundation has a few hairline cracks. This location was not augered.

Effinger (201) has an up-slope collapsing foundation wall that is 8 ft. high and completely below ground level. The wall span (about 60 ft.) contains no intersecting walls except at the two ends and also no visible reinforcing pilasters (USBOM, 1990). The external pressure on this wall was estimated at 2.1 T/sq. ft. (USCOE-WES-GL, 1993). Damage also includes northwest corner stairstep cracks, cracked slab, and moisture evidence.

Gorbett (316) is on the regional dip slope. However, the rear of the structure (east) is on the side of a drainage basin that drains ground water movement from the structure. Damage includes a minor crack in the foundation slab.

3. Three of 16 FB structures are located on Schlensker (421, 421A) and Cemetery (202A) roads. Topographic position is believed to affect the level of foundation damage.

The Rozanski (421A) foundation is on an interfluvial divide. The drainage area behind the structure is relatively small and suggest good drainage. Damage includes a few cracks around the basement windows.

The Osborne (421) foundation is in a cut slope position with colluvium at a depth of 7.0 to 8.0 feet and clays of high and medium swell potential below the colluvium. Up-slope relief approaches 50 feet. During construction a section of the basement wall collapsed because of water pressure. Damage includes a few cracks in the basement wall.

Heil (202B) is located at the headwaters of an intermittent stream that directs ground water away from the structure. Damage includes a few hairline cracks.

4. Five of 16 FB structures are located along the eastern boundary of the study area. Four structures are on Green River Road. Structure 105 is on the Booneville New Harmony Road. Topographic position is believed to affect foundation damage.

The Norton (104) structure has hairline cracks. The basement windows in the residence are flush with the ground level with interior hairline cracks beneath the windows. The bulk of the damage is in an out building that has a cracked concrete slab without expansion joints. A downspout discharges water within about two feet of the front left corner of the building. A large slab crack occurs on the inside corner from the downspout discharge. Saturated ground exists around the exterior of the out building.

LeCocq (104A) believes the hairline wall and slab cracks are associated with the water system lines. There is evidence of moisture penetration. The area outside appeared well drained. This structure was not augered for soil analysis and bedrock depth.

Bohrer (105) is located on a near level area 2.5 to 5.0 feet above and within 400 feet of a man-made open drainage ditch. The ditch collects primary groundwater from Daylight and directs it to the Schlensker Ditch that controls and maintains ground water levels in the lacustrine lowlands. Structure 105 has a french drain. Damage includes a horizontal crack along one wall of the basement. USGS states this may be where the block size changes since it was about at the ground line (1993).

Daugherty (103A) is positioned on a minor drainage divide along the old lake shore of the lacustrine lowland. The foundation has a few hairline cracks. The structure was not augered for soil analysis and bedrock depth.

Zimmerman (103) is located on the down-slope side of Green River Road. The slopes of a hill (510 ft. elevation) drains ground water southwest and west toward the structure (395 ft. elevation) and ends at an open ditch (380 ft. elevation). The ditch drains into the Schlensker Ditch which controls the water level of the lacustrine lowland area for agricultural purposes and more recently residential and industrial construction.

The foundation depth is in loess (exact depth is not known). Auger drilling identified about 7 feet of dry fill material at the southeast corner of the structure. The depth of fill from the road to the front of the structure is not known. A septic tank was installed at the northwest corner (front left) of the structure on the up-slope drainage side.

According to Mrs. Zimmerman some of the basement cracks are old and worsening and some are more recent. One of the old (pre-1984) cracks in the northwest corner of the basement (up-slope drainage side and opposite the septic tank) is 17 feet long and up to 1/8 inch wide. Topographic position indicates ground water drainage from the southwest and west, and septic effluent contributed to the northwest basement corner damage.

There is approximately 115 feet of relief between the top of the hill and the structure and 15 feet between the structure and the drainage ditch. Topographic crenulations show structure 103 is positioned on the near shore of a Pleistocene lake along a natural ground water drainage path that terminates at the same open ditch described above. Six undisturbed soil samples were collected, two each from three holes about 60 feet behind the southeast corner of the structure. Maximum soil saturation percent in UD1 was 98.5% (at 6.8 ft.); UD2 was 92.0% at 6.0 ft.; and UD3 was 94.3% at 13.2 ft. respectively (USCOE-WES-GL). These values appear to confirm that structure 301 is constructed along a natural ground water drainage path which merges with man-made ditches that control ground water level within the lacustrine lowland. The location of the structure between the hill and the ditch suggest ground water is a contributor to structure damage.

Table 3 tallies foundation damage distribution of the study area structures in three divisions: (1) McCutchanville ridge regional dip slope; (2) northern tier along Schlensker and Cemetery roads; and (3) eastern boundary along Baseline and Green River roads, and Daylight. The sample size includes 33 study area structures. The categories of damage level are limited to "Damage" and "No Damage" and are based on the USGS inspection results. The findings of analysis and Table 3 show:

1. Foundation damage was not found in 7 of 7 FC and FC/S foundation types.

2. Foundation damage was found in 16 of 16 FB foundation types.

3. Foundation damage was found in six (6) of 10 PB/PC foundation types. The remaining four foundations were not damaged. The occurrence or non-occurrence of damage is attributable to topographic positioning.

4. Foundations with no foundation damage (FC, FC/S, PB/PC) tend to be positioned: (A) completely or partially on the surface; (B) on topographic highs, (C) with strata that dips into the slope and limits up-slope ground water accumulation and movement to the loess zone; (D) adjacent to small drainage networks that drain ground water away from the structure, or (E) a combination of the above.

Table 3

STUDY AREA FOUNDATION DAMAGE DISTRIBUTION Data: USGS Table 11, (1993), (App. I)					
Study Area Location	Foundation Damage *	Full Crawl and Full Crawl/slab	Partial Basement/ Partial/ Crawl	Full Basement	Total Structures
McCut-chanville Ridge	No Damage	3	4	--	7 (21.2%)
	Damage	--	5	8	13 (39.4%)
Northern Boundary	No Damage	--	--	--	--
	Damage	--	1	3	4 (12.1%)
Eastern Boundary	No Damage	4	--	--	4 (12.1%)
	Damage	--	--	5	5 (15.2%)
	No Dam.	7	4	--	11 (33.3%)
	Damage	--	6	16	22 (66.6%)
Totals		7	10	16	33 (99.9%)

5. Structures with damaged foundations (PB/PC; FB) tend to be positioned: (A) on the regional dip-slope; (B) have larger up-slope drainage areas; (C) are affected by loessial piping; and (D) are affected by swelling soils; or (E) a combination of the above.

6. Structures with damaged foundations to the north and east tend to be positioned: (A) at varying elevations, on long erosional slopes, in cut and fill locations, receiving up-slope ground water from areas of relief close to 100 feet; (B) along ancient lake shores with structures located along ground water drainage ways leading to the ancient lacustrine lowlands; and (D) on ancient lacustrine shore deposits with minimal relief above man-made drainage ditches that control ground water level and prevent conditions of saturation. Topographic positions that tend to limit or minimize damage appear to include interfluvial and fan-like deposits, and interstream divides along ground water drainage paths leading to lacustrine lowlands.

7. Table 3 shows that foundation damage was found in 22 of the 33 structures. The remaining 11 structures were not damaged. Foundation damage distribution in the study area show there are 2 damaged structures for every structure not damaged.

The 33 structures evaluated indicate that: (A) site specific environmental conditions exist that are capable of contributing to or causing structure damage; and (B) structure position relative to geologic structure, topographic and local hydrologic conditions is a major factor in determining foundation damage.

Foundation Damage Distribution
Control Area

The USGS (1993) completed damage evaluations for 19 structures located between New Harmony Road (north), Hogue Road (south), Eickhoff Road (west) and Red Bank Road (east) (Appendix I). Table 4 tallies foundation damage distribution in the control area. The findings show:

1. Foundation damage was not found in 3 of 3 FC and FC/S foundation types.

2. Foundation damage was found in 9 of 11 FB foundation types.

3. Foundation damage was found in two (2) of four (4) PB/PC foundation types.

Table 4

CONTROL AREA FOUNDATION DAMAGE DISTRIBUTION (Data: USGS Table 12, (1993), (App. I)						
Study Area Locat-ion	Found-ation Damage *	Full Crawl and Full Crawl/ slab	Partial Basement/ Partial/ Crawl	Full Base-ment	Un-known Found-ation type	Total Structures
Kasson area	No Damage	3	2	2		7 (36.8%)
	Damage	--	2	9	1	12 (63.2%)
	Totals	3	4	11	1	19 (100 %)

* Damage levels vary depending on topographic position. * Kasson: One FB had finished inside walls and was not evaluated (Not included above). * One foundation type is unknown and has a full-length horizontal crack (placed in damaged column).

4. Foundation damage distribution in the control area show there are 1.71 damaged structures for every structure not damaged.

Foundation Damage Distribution
Combined Study/Control Areas

Table 5 compares foundation damage in the study and control areas. The number of foundation inspections in both areas totaled 52. Foundation damage was identified at 34 (65.38%) of the 52 structures. The remaining 18 (34.61%) showed no foundation damage. The findings show:

1. The combined number of structures inspected shows that the distribution of foundation damage is 1.88 damaged structures for every structure not damaged.

2. Separately, the number of damaged to non-damaged structures in the study area (2:1) and control area (1.7:1) are comparable to the combined area number of damaged to non-damaged structures (1.88:1).

3. The damage distribution in the study and control area and, combined (study/control) areas, show little difference in number of damaged to non-damaged structures inspected.

Site Specific Characteristics
Site Variables

Appendices A through F and H contain background information, raw data, test data analyses, and interpretations from participating agencies and sub-contractors covering a time period from 1989 to 1992. Table 6 is a synoptic form of Appendix G.1 through G.3. Site identification and variables for 28 complainant and non-complainant companion structures include:

* Structure identification: For example, Row 2, Column 1 represents auger hole and structure number (all hole in this table were augered by IGS in 1989. Number 118, the OSM complainant number, is followed by the complainants name. Dashes in place of a auger hole number indicate the structure was not augered by IGS in 1989. A number followed by a capital letter (such as 202A in Row 1, Column 1) identifies the structure as an OSM non-complainant companion to a complainant structure (which would be 202).

Table 5

STUDY VS. CONTROL AREA FOUNDATION DAMAGE DISTRIBUTION (Data: USGS Tables 11 and 12, (1993), (App. I).			
Foundation Damage	Study Area	Control Area	Total Structures
No Damage	11 (21.15%)	7 (13.46%)	18 (34.61%)
Damage	22 (42.30%)	12 (23.07%)	34 (65.38%)
Total Structures	33 (63.46%)	19 (36.53%)	52 (99.99%)

Table 6
Natural and Man-Induced Conditions at Complainant and Non-complainant Locations
McCutchan Ridge North to the Blue Grass Area

	1	2	3	4	5	6	7	8
	Structure Ident-ification	Colluv-ium	Swell Potential of Clay: High, Medium, Low	Relative Up-slope Area: Small, Medium, Large	Base-ment Water Prob-lem: Yes, No,	Foundat-ion Type: Full, Part, Slab, Crawl	Damage Level:	Other Site Conditions
1	--/202A Stevens	No	Low	Medium	No	FC	Minor	Non-complainant companion to Richey 202; Limestone pebbles returned between 10 and 14; Located on crest of hill
2	01/118 Hoover	No	Medium	Small	No	PB/C	Minor	Up-slope on dip-slope; Ground water drainage is away from structure.
3	--/113a Ogg	No	Medium	Small	No	PB/C	Minor	Non-complainant companion to Boettcher 113; Ground water drains away from house; scarp-slope location; Down-slope on scarp-slope; Strata dips into hillside.
4	34/403 McCutchan William	Yes	Low	Small	--	--	Minor	Location is on an inter-stream divide (down-slope) on toe-slope of fan-deposit; Ground water flow is away from house.
5	--/108A Zinn	Yes	Medium	Medium	No	PC/S	Minor	Non-complainant companion to McCutchan 108; Located in major drainage valley; On valley fill with dip-slope below structure; Down-section of W.F. ls.; Water filled auger hole to within 15 feet of surface.

	1	2	3	4	5	6	7	8
6	--/421A Rozanski	Yes	Low	Medium	No	FB	Minor	Non-complainant companion to Osborn 421; Structure is located on flat interfluve area not in direct path of primary ground water flow.
7	--/301A Condict	--	Low	Medium	Yes	FB	Minor/ Moderate	Non-complainant companion to Fink 301; Sampling method was not designed to identify colluvium; Up-section of the W.F. ls.; Mid-slope on dip-slope; An up-slope tributary intercepts drainage and limits ground water reaching structure.
8	--/302A Palmer	--	Low	Small	--	FB	Minor/ Moderate	Non-complainant companion to Greenfield 302; Up-slope (ridge crest) on dip-slope; Slope position and close proximity to lake may contribute to damage.
9	31/111 Brinker	Yes	Low	Small	--	FB	Moderate	Slope position and close proximity to lake may contribute to damage; Up-slope on dip-slope; Ground water saturated loess from auger hole.
10	--/107a Deutch	--	High	Large	Yes	PB/C	Moderate	Non-complainant companion to Harris 107; Sampling method was not designed to identify colluvium; Down-slope on dip-slope; Up-Section of W.F. ls.
11	04/209 Gore	Yes	High	Medium	Yes	PB/C	Moderate	Located down-slope of ridge crest; Up-slope on dip-slope; House settlement (1990, BOM).
12	--/302 Greenfield	No	High	Large	Yes	PB/C	Moderate	Down-slope on dip-slope;
13	--/301 Fink	Yes	Medium	Large	Yes	PB/C	Moderate/ Severe	Down-slope on dip-slope; Soil piping problem, garage and foundation.

	1	2	3	4	5	6	7	8
14	--/107 Harris	Yes	Low	Large	Yes	PB/C	Moderate/ Severe	Down-slope on dip-slope; Down-section of W.F. ls. on shale; House settlement (1990, BOM); Sump pumps control ground water level;
15	35/202 Richey	Yes	High	Medium	Yes	PB/C	Severe	Crest of hill with limestone exposures.
16	33/113 Boettcher	Yes	Medium	Medium	Yes	PB/C	Severe	Down-slope on dip-slope; Up-section of W.F. ls.
17	32/201 Effinger	Yes	Medium	Medium	Yes	FB	Severe	Down-slope on dip-slope; Down-section of W.F. ls.
18	29/421 Osborn	Yes	High	Large	Yes	FB	Severe	Down-slope location with 50' of relief behind structure; Ground water from relief passes structure on way to Schlensker ditch.
19	10/108 McCutchan	Yes	High	Large	Yes	FB	Severe	Down-slope with 65-70' of relief behind structure; Driveway is ditched on up-slope side with drainage terminating along back right side of house; Piping void on up-slope garage end; House settlement (1990, BOM).

	1	2	3	4	5	6	7	8
20	--/107B Hawles	Not Aug-ered	--	Large	No	FC	Minor	Non-complainant companion to Harris 107; Down-slope on dip-slope.
21	36/411 Carter	--	--	Small	No	FC	Minor	Blue Grass Area; Soil samples were not collected for analysis; OSM information incomplete.
22	--/108B Arnold	Not Aug-ered	--	Small	--	PB/C	Minor	Located on the crest of a knoll.
23	--/202B Heil	Not Aug-ered	--	Small	--	FB	Minor	Blue Grass Area; Non-Complainant companion to Richey 202.
24	--/114A Wolff	Not Aug-ered	--	Small	--	FB	Minor	Non-complainant companion to Kinney 114;
25	--/316 Gorbett	Not Aug-ered	--	Small	--	FB	Minor	
26	--/113B Lavallo	Not Aug-ered	--	Medium	--	FB	Minor/ Moderate	Non-complainant companion to Boettcher 113; Down-slope on dip-slope; Up-section of the W.F. ls.
27	30/401 Poston	--	--	Small	--	PB/C	Minor/ Moderate	Soil samples were not collected for analysis; OSM information incomplete; Down-slope on down-dip strata; Blue Grass Area.
28	--/114 Kinney	Not Aug-ered	--	Small	Yes	FB	Moderate	Structure estimated to be on shale below W.F.ls.; Soil to bedrock not augered.

* Column 2; Colluvium: An erosional deposit of mixed angular rock fragments on bedrock that may differ from loess in permeability. Colluvium at a site is identified as either "yes" or "no." Identification is based on soil profile data and Natural Gamma Logs (Inter-Agency Meeting, Bloomington, IN, 1992).

* Column 3; Potential clay swell: This variable is based on Atterberg Liquid Limit and Plasticity Index values. Potential swell is listed as: 1. Low; 2. Medium; and 3. High (USCOE, 1965).

* Column 4; Up-slope water catchment area: The drainage area up-slope of a structure determines the quantity of water that will collect, drain down slope, down-dip (in case of a dip-slope), and encounter structures. Catchment area size was determined from its topographic map area. Other factors influencing this variable are contour crenulation, stream divides, and structural dip. Up-dip catchment areas are: 1. small; 2. medium; and 3. large.

* Column 5; Basement wetness. Basement moisture conditions are designated as: 1. evidence of wetness "No" (not identified); or 2. evidence of wetness "Yes" (identified). Dashes indicate information is not available.

* Column 6; Basement type: This includes: 1. full crawl and partial crawl/slab; 2. partial crawl/partial basement; 3. and full basement.

* Column 7; Damage level: OSM damage levels are based on complainant interviews and structure descriptions during the summer of 1989; and subsequent structure evaluations. Damage Levels include: 1. Minor; 2. Minor/Moderate; 3. Moderate; 4. Moderate/Severe; and 5. Severe.

* Column 8; Site Conditions: Information includes site conditions not listed in Columns one through eight.

Statistical Tests
Correlation Analysis

Correlation analysis provides a preliminary view of the relationships among variables. A correlation coefficient is a quantitative measure of association between two variables. Statements regarding variable pair associations are provided for each listed significant relationship.

Correlation analysis uses "Pairwise and Listwise methods" by Statgraphics, Statistical Graphics System by Statistical Graphics Corporation (STSC, Version 4.0, 1989). The database is shown in Table 6.

The Listwise method represented in Table 7 includes 14 structures that have all values for all variables (STSC, 1989). The sample sizes for all the coefficients are the same, since all structures with missing values are omitted from the computations in the Listwise method. The structures in Table 7 are "Core Structures" consisting of 10 complainant and four non-complainant structures listed at the table bottom.

The Pairwise method represented in Table 8 includes structures with incomplete sets of values. The available values are used under certain statistical requirements (STSC, 1989). Sample size for each coefficient varies between 15 and 28 and depends on the number of missing values. Table 8 includes "Overall Structures" distributed along the McCutchanville ridge and north to the Blue Grass area.

Tables 7 and 8 show Pearson Product-Moment (PPM) correlation coefficients. Significant correlation coefficients are shown as shaded blocks and are based on the Student's t distribution. Each block in Tables 7 and 8 contains, from top to bottom, a strength of correlation description, correlation coefficient, sample size (in parenthesis), and significance level. Each shaded block shows a significance level of at least 0.05 (95.0% confidence level) (STSC, 1989).

Table 7
Correlation Coefficient Matrix
Core Structures:
McCutchanville Ridge and North to the Blue Grass Area

Shaded Correlation Coefficients (Pearson product-moment) showing relationship using a t-Test at the significance level, 0.05 (1986, STSC; 1980, Chao)
Each block contains: Coefficient, (sample size), significance level

	Y |	1	2	3	4	5	6
X --	**VARIABLES**	Colluvium	Potential Clay Swell	Up-slope Water Catchment Area	Foundation Moisture or Wetness	Foundation Type	Damage Level
1	Colluvium		Chance .1217 (14) .6785	Fair .4358 (14) .1194	Fair .5185 (14) .0575	Slight .3889 (14) .1693	Moderate to Marked .6019 (14) .0228
2	Potential Clay Swell			Slight .2244 (14) .4406	Fair .5451 (14) .0438	Slight .2582 (14) .3728	Fair .4858 (14) .0782
3	Up-slope Water Catchment Area				Moderate to Marked .6795 (14) .0075	Slight .2607 (14) .3680	Fair .5878 (14) .0271
4	Foundation Moisture or Wetness					Fair .4000 (14) .1564	Highly Dependable .9253 (14) .0000
5	Foundation Type						Fair .4997 (14) .0689

Matrix is based Table 6 information for:
Non-complainant companion structures: Ogg, Rozanski, Stevens, Zinn;
Complainant structures: Boettcher, Effinger, Fink, Gore, Greenfield, Harris, Hoover, McCutchan, Osborn, and Richey.

Table 8
Correlation Coefficient Matrix
Overall Structures:
McCutchanville Ridge and North to the Blue Grass Area

Shaded Correlation Coefficients (Pearson product-moment) showing relationship using a t-Test at the significance level, 0.05 (1986, STSC, Inc.; 1980, Chao)
Each block top to bottom: Coefficient, (sample size), significance level

	Y |	1	2	3	4	5	6
X --	VARIABLES	Colluvium	Potential Clay Swell	Up-dip Water Catchment Area	Foundation Moisture or Wetness	Foundation Type	Damage Level
1	Colluvium		Negligable .0000 (16) 1.0000	Slight .2691 (17) .2963	Fair .4308 (15) .1089	Slight .3111 (16) .2409	Fair .4482 (17) .0712
2	Potential Clay Swell			Fair .5084 (19) .0262	Fair .4534 (16) .0777	Chance .1046 (18) .6795	Fair .5184 (19) .0230
3	Up-dip Water Catchment Area				Fair .4552 (19) .0502	Chance .1827 (27) .3616	Fair .5586 (28) .0020
4	Foundation Moisture or Wetness					Fair .5680 (19) .0112	Highly Dependable .8628 (19) .0000
5	Foundation type						Fair .2444 (27) .2191

Matrix is based on Table 6 information.

The following descriptions of Koenker (1961) are used to describe correlation intervals (A) and correlation strength (B):

(A)	(B)
.80 to 1.00	highly dependable relationship
.60 to .79	moderate to marked relationship
.40 to .59	fair degree of relationship
.20 to .39	slight relationship
.00 to .19	negligible or chance relationship

Core Structures

Core Structures (Table 7) show five significance levels of at least 0.05. Each of these relationships are commented upon as follows:

1. Foundation Wetness and Potential Clay Swell;

   This "Fair" relationship suggests that when clay swell potential increases, foundation wetness tends to increase.

2. Foundation Wetness and Up-slope water catchment area;

   This "moderate to marked" relationship suggests that when up-slope water catchment area increases, foundation wetness tends to increase.

3. Damage Level and Colluvium;

   This "moderate to marked" relationship suggests that when foundation excavations encounter colluvium, damage level tends to increase. This may only be a statistical relationship. Alternatively, the presence of colluvium may elevate the ground water level against basement walls. This could increase lateral pressure on the walls.

4. Damage Level and Up-slope water catchment area;

   This "fair" relationship suggests that as up-slope water catchment area increases, basement wetness tends to increase.

5. Damage Level and Foundation wetness;

   This "highly dependable" relationship suggests that as wetness occurs, damage level tends to increase.

Overall Structures

The overall Structures (Table 8) show six significance levels of at least 0.05. The first three Overall Structure relationships are the same as those discussed under core structures. The relationships include:

1. Foundation wetness and Up-dip water catchment area;

2. Damage Level and Up-dip water catchment area;

3. Damage Level and Foundation wetness;

4. Foundation type and Foundation wetness;

   This "fair" relationship suggests that certain foundation types are more susceptible to foundation wetness.

5. Up-dip water catchment area and Potential clay swell;

   This "fair" relationship suggests that with increased water catchment area, potential clay swell tends to increase. This may only be a statistical relationship. However, the soils tested at 19 structures (Table 6) show weathered shale (clay) swell potentials of; low at 7 structures, medium at 6 structures, and high at 6 structures. These locations include the more severely damaged structures along the regional dip-slope. Practically all chemical weathering processes depend on the presence of water. The development of these in situ clays are, most likely, aided by water and the process of hydrolysis. Available groundwater flowing down-slope aids hydrolysis by removing soluble material through leaching, complexing, adsorption, or precipitation, and the continued introduction of H+ ions. Other more complex chemical reactions may also contribute to clay swell potential (Mitchell, 1976).

6. Damage Level and Potential Clay Swell;

   This "fair" relationship suggests that as clay swell potential increases, damage level tends to increase.

Further statistical testing using such methods as categorical data analysis are needed to establish multi-variable relationships.

Summary of Findings

The purpose of this report (part IX) is to identify environmental conditions, other than blasting vibrations, that can contribute to and cause observed structural damage.

The study areas are characterized by residual geological structure and a buried erosional landscape which many might simplistically call "pancake" geology. These two areas are located on an outlier of the eastern rim of the Illinois basin. The Merom sandstone, some 60 feet thick, is the uppermost rock in the western (control) area and eroded from the eastern study area. The uppermost bedrock in the study area is sandy shale weathered to clay of low to high swell potential. Above the shale, a colluvial deposit appears to mantle the study area from ridge crest to valley bottom. Modern soils and loess overlie colluvium and shale (study area) and sandstone in the control area. Bedrock dips gently westward in both areas. Loess of recent origin deposited across the study areas terminated an erosional interval lasting millions of years.

Below the blanket of recent loess is a buried landscape. The surface features include: stream channels; stream divides; undulating low ridges; depressions; interfluve areas; fan-like deposits; lake shorelines and lake beds; exhumed outcrops and exhumed exposures of limestone; and surface debris of weathered rock byproducts including sandstone (control area), and colluvium, clay and shale (study area); karst features that infer internal drainage capable of water transport; and loessial piping channels that presently act as avenues of water transport from ridge crest to valley bottom. Through several intervals of loess deposition, precipitation sculpted the "new" surface through weathering and erosional processes. The Pleistocene issued in a new interval of interaction between the surface and the buried landscape.

Man altered the natural landscape for agriculture and building purposes, artificially lowered lake levels in the lacustrine lowlands, and altered drainage patterns. Private sewage systems and water collecting cisterns are in common use in both study and control areas. Public water and sewage is being extended into the areas, but is not fully available throughout either study area. Millions of gallons of waste water are discharged from septic systems each year and the affect is not known. Ground water flows around structure foundations and maintains small man-made lakes and ponds by the same process.

The primary difference between the study and control areas is the lithology of the uppermost bedrock. This suggests that any ground water flow differences along a sandy shale and sandstone surface is related to permeability and hydraulic conductivity. The shale is of slow permeability and an aquatard.
The permeability and hydraulic conductivity of the sandstone, although not known, is expected to be more than that of the shale. The amount of ground water flow (from hydrologic events) along this sandstone surface would, most likely, be proportionately less than the shale. The number of damaged and non-damaged foundations in the study and control areas are nearly equal. However, the level of structural damage identified by the USGS in the control area is relatively less than in the study area. The difference in level of structural damage between the two areas, although documented, may be attributable to lithologic permeability and hydraulic conductivity.

Site conditions at complainant and non-complainant structures suggest that ground water is a contributing cause affecting levels of foundation damage. Other contributing factors include: loess; weathered shale (clay) swell potential; gently dipping strata; and annual precipitation. Topographic position (site location) and foundation type are factors affecting structural foundation damage. A topographic position that places the foundation of a structure above local ground water conditions is less susceptible to damage, other contributing factors considered.

The above findings are based on complainant and non-complainant structures in the study and control areas. Site-specific conditions show:

(1) Full/Crawl (FC) and Full Crawl/Slab (FC/S) foundation types were not damaged. The surface position of FC and FC/S foundations appear less susceptible to damage because their foundations do not contact ground water.

(2) Some of the partial basement/crawl space (PB/CS) foundations were not damaged. Non-damaged foundations were located: on topographic highs; scarp-slope positions; small up-slope water catchment areas; and adjacent to stream valleys that drain ground water away from the structure.

(3) Some PB/CS and all full basement (FB) foundations were damaged. Variable levels of foundation damage were associated with: slope position; interfluvial areas; clays of variable swell potential; wet basements, piping voids, up-slope water problems, control and maintenance of down-spout waste water; and level saturated areas around structures. The partial basement of one PB/CS foundation had cracked walls, visible moisture, and expansive clays at or below the PB foundation. The crawl space had no observable cracks. Locations along lacustrine lowlands were close to open ditch drainage that maintains lowland water levels for agricultural use, and more recently residential and business construction.

(4) At two structures, foundation damages were documented as occurring in 1955 and 1986.

The above site conditions identify natural and man-induced environmental conditions in the study area that contribute to and cause structural damage. Comparable information for control area site locations was not available.

The findings suggest that site selection conditions should consider topographic location relative to ground water quantity and flow patterns. Basement foundations (full or partial) should consider the: soil column; loess-bedrock interface with regard to foundation contact; and up-slope ground water. Random site selection over unknown subsurface drainage obscured by the soil column is precarious. Soil core analysis and an evaluation of local ground water conditions is recommended for prospective construction sites.

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INVESTIGATION OF DAMAGE TO STRUCTURES IN THE McCUTCHANVILLE-DAYLIGHT AREA OF SOUTHWESTERN INDIANA

A FINAL REPORT

APPENDICIES

PART IX: ENVIRONMENTAL CONDITIONS RELATED TO GEOLOGY, SOILS, AND PRECIPITATION McCUTCHANVILLE AND DAYLIGHT, VANDERBURGH COUNTY, IN

U.S. Department of Interior
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May, 1993

Synopsis of Appendices

Between 1989 and 1992 site specific and area conditions involving hydrology, climate, meteorology, geology, soils, and man-induced disruption of natural conditions have been determined by State and Federal Agencies. The data and some discussion are provided in the following:

Page

Auger Hole Boring Data: Indiana Geological Survey (IDNR-GS) 1990.

Appendix 8A lists IGS soil boring data for holes augered during the fall of 1989 (IGS, 1990). The data includes soil particle size analysis, shrinkage limit, lineal shrinkage, soil classification, Atterberg limits, and soil core descriptions. Soil samples were analyzed every six inches in depth. Interval spacing for Atterberg Limit analysis varied. Included in Appendix A is Figure 8A.1 showing the Unified Soil Classification System (USCS) chart. The USCS chart provides Major Division characteristics, group symbols, and typical names (Liu and Evett, 1981).

Soil Descriptions, Gamma-Ray Logs and Data Plots for OSM Auger Holes 1 to 25, 27 to 37. Unified Soil Classification Chart from American Society for Testing and Materials (ASTM) D2487-85.

Appendix B includes soil core and boring data collected during the fall of 1989 (IGS, 1990). Data includes pocket penetrometer values, percent moisture, dry density in pounds/cubic feet, soil profile descriptions and natural gamma logs. Included in Appendix B is Table B.1 showing x-ray diffraction estimates of clay mineral type and percentages for 2 micron (0.002 mm) and below sieve size fractions only (IGS, 1990).

Soil Sample Analysis, Corps of Engineers, South Atlantic Division Laboratory (COE-SADL), Marietta, Georgia.

Appendix C contains soil sample test results from 13 bore holes augered by IGS (1989). The USCOE-SADL, Marietta, GA did the analysis (1990). Data includes particle size gradation curves, soil classification, consolidation tests with time curves, Atterberg Limits, unconfined compression and direct shear tests. The full analysis from bore hole OSM-10 is included as an example. The analyses for the remaining soil samples are available from OSM, Eastern Service Center (ESC), Pittsburgh, PA 15220.

Petrographic report of X-ray diffraction (XRD) analysis of 2-micron and less particle size minerals from seven bore holes, Corps of Engineers, South Atlantic Division Laboratory (COE-SADL), Marietta, Georgia. Appendix D includes clay and non-clay mineral identification (USCOE-SADL, 1990).

Atterberg Limit and Moisture Content for Soil Samples from 10 complainant and 9 non-complainant companion structures; and, one ridge top and one valley bottom site. Data was prepared for the USGS and COE by AmTech Engineering (1992).

Atterberg limits define the consistency (firmness) for cohesive soils and include Liquid Limit (L.L.), Plastic Limit (P.L.), Plasticity Index (P.I.), and Shrinkage Limit (S.L.). If a soil in the liquid state is gradually dried out, it will pass through the L.L., plastic state, P.L., semisolid state, and shrinkage limit, and will reach the solid state. The liquid, plastic, and shrinkage limits are quantified therefore in terms of water content. The difference between L.L. and P.L. is the P.I. (Liu and Evett, 1981). Potential clay swell is based on L.L. and P.I. values: Potential clay swell is classified as Low (L.L. <50, P.I. <25); Medium (L.L. 50-60, P.I. 25-35), and High (L.L. >60, P.I. >35) (DOA-HQ, TM 5-818-7, 1983).

Soil samples were collected with a split-tube sampler at 2.5 foot intervals to a depth of 2.5 feet below the foundation of each structure. Sample depths were: (#1) 2.5 to 4.0'; (#2) 5.0 to 6.5'; (#3) 7.5 to 9.0'; (#4) 10.0 to 11.5'; and (#5) 12.5 to 14.0'. All soil samples were classified using the USCS system according to ASTM D2487-85 (Appendix 8A). Grain size distribution curves and Atterberg Limit laboratory sheets are available from OSM, ESC, Pittsburgh, PA. Data were prepared for the USGS (1993) and USCOE-WES-GL (1993) by AmTech Engineering, Indianapolis, IN (1992). Atterberg limit analyses are included in Appendices A through C, plus E, and G.

Estimated Degree of Limitation for Residential and Light Industrial Development and the Use of Septic Tank Absorption Fields Relative to Soil Series and Increasing Slope (1976, USDA, Table 9).

Appendix F is Table 9 of the Soil Survey of Vanderburgh County, IN. The estimated degree of limitation for residential and light industrial development and use of septic tank absorption fields for soil series and increasing slope are listed. Soil associations and series descriptions are found on pages 1 through 38 of the soil survey (USDA, 1976).

Accumulative Site Specific Data from Appendices, OSM Interviews, Maps, and related Information:

Tables G.1 through G.5 contain site specific information from the appendices for bore holes augered during the McCutchanville and Daylight, IN Blasting Study. Table entries contain location identifiers, surface elevation, geomorphic slope, and depth of augered hole. Refusal depth (RD) is based primarily on drill rig capability (IGS, 1990). Total depth (TD) is used to identify bedrock or the deepest sample collected (AmTech, 1992).

Table G.1 contains natural and man-induced site conditions for complainant and non-complainant companion locations with clays of high and medium swell potential. Included are Atterberg Limits, colluvium, relative ground water movement, and other related site conditions.

Table G.2 includes complainant and non-complainant companion locations with designated sampling depths to 2.5 feet below the foundation of each structure. Natural and man-induced site conditions are given for those locations with clays of low swell potential. Atterberg Limits, colluvium, relative ground water movement, and other related site conditions are included.

Table G.3 includes complainant and non-complainant companion locations inspected for damage comparison by the USGS. These locations were not augered or gamma logged, and soil samples were not collected for analysis.

Table G.4 includes complainant locations augered and natural gamma logged (IGS, 1989). Soil cores were not collected for analysis.

Table G.5 lists auger locations used to characterize the study area (IGS, 1989). Locations are without structures.

Precipitation during 1987 and 1988 for Evansville, IN, Southwestern District 7, National Oceanic and Atmospheric Administration (NOAA) and National Weather Service (NWS). Precipitation data is from the Weekly Weather and Crop Bulletin (WWCB) a joint venture of the USDOC and USDA. Explanations are included.

Appendix H lists weekly precipitation and drought conditions for 1987 and 1988 for Evansville, IN. An explanation of the Palmer Drought Severity Index (PSD) and Crop Moisture Index (CMI) is included from the Weekly Weather and Crop Bulletin (DOC-WWCB, NOAA, NWS; USDOA-NASS, WAOB 1987 through 1993). Weekly precipitation data shows the drought conditions of 1988 were preceded by drought conditions during 1986 and 1987.

USGS Site descriptions of the structures evaluated in the Study and Control areas (1993).

Table 11. Category 1 (complainant) and Category 2 (non-complainant companion structures) .

Table 12. Structure inspection and damage evaluation of Category 3 buildings (Control area). Category 3 buildings were not augered.

Structure characteristics listed by column include: (1) Site Category, name/address, USGS ID/OSM ID; (2) Description of building; (3) Damage; and (4) Site conditions. Column 4 shows soil to bedrock stratigraphy. Interpretations in Column 4 result from an Inter-Agency meeting to establish foundation and subsurface summaries from borehole data, gamma logs, shear wave tests, etc. Agency members included: N. Bleuer and D. Eggert (IGS); P. Hadala (COE-WES); K. King (GS-BGRA); and B. Maynard (OSM-ESC), Indiana University (IU), Bloomington, IN, October 13 through 16, 1992.

APPENDIX A

Auger Hole Boring Data: Indiana Geological Survey (IDNR-GS, 1990).

OSM EVANSVILLE PROJECT

LAB ID	BORING	DEPTH inches	% GR	% SA	% SI	% CL	L.L.	P.L.	P.I.	SHRINK. LIMIT %	LINEAL SHRINK. %	CLASS.
891161	OSM1	13-18	0.0	0.5	74.6	24.8	51.4	23.2	28.2	7.2	19.0	CH,Fat Clay
891162	OSM1	30-36	0.0	0.4	85.0	14.6						CL,lean Clay
891163	OSM1	42-48	0.0	8.3	82.4	9.3						ML,Silt
891164	OSM1	66-72	0.0	10.2	85.3	4.5						ML,Silt
891165	OSM1	72-78	0.0	93.2	4.8	1.9						SW-SM,Wel Grad Sa w Si
891166	OSM1	96-102	3.5	1.0	93.5	2.0	NONPLASTIC					ML,Silt
891167	OSM2	2-8	0.8	50.0	48.8	0.4						SM,Silty Sand
891168	OSM2	8-16	0.4	5.0	92.1	2.5	32.1	21.2	10.9	21.3	4.9	CL,Lean Clay
891169	OSM2	16-22	0.0	6.8	86.5	6.6						CL,Lean Clay
891170	OSM2	23-29	0.0	3.2	77.9	18.9						CL,Lean Clay
891171	OSM2	39-45	0.1	2.8	78.8	18.3						CL,Lean Clay
891172	OSM2	54-60	0.0	2.3	84.9	12.9	36.0	20.6	15.4	23.7	5.8	CL,Lean Clay
891173	OSM2	93-96	0.2	3.0	84.8	12.0						CL,Lean Clay
891174	OSM2	98-104	0.1	1.9	82.0	16.0						CL,Lean Clay
891175	OSM2	114-120	0.5	2.5	82.6	14.4						CL,Lean Clay
891176	OSM2	120-126	1.5	2.2	74.8	21.5	37.8	18.9	18.9	33.0	2.3	CL,Lean Clay
891177	OSM2	144-150	0.6	1.8	70.9	26.7						CL,Lean Clay
891178	OSM2	150-156	0.7	3.7	75.7	19.9						CL,Lean Clay
891179	OSM2	162-168	0.3	3.6	67.7	28.4						CL,Lean Clay
891180	OSM2	168-172	0.3	3.8	60.0	35.9	50.5	26.7	23.8	9.3	18.8	CH,Fat Clay
891181	OSM2	?	0.1	2.0	63.2	34.7						CH,Fat Clay
891324	OSM3	12-18	0.0	1.7	72.0	26.3						CL,Lean Clay
891325	OSM3	24-30	0.0	1.0	78.0	21.0	41.6	24.6	17.0	21.4	8.9	CL,Lean Clay
891326	OSM3	37-43	0.0	1.1	81.1	17.8						CL,Lean Clay
891327	OSM3	54-60	0.0	0.9	82.9	16.1						CL,Lean Clay
891328	OSM3	79-85	15.2	9.1	63.1	12.6						ML,Silt with Gravel
891329	OSM3	94-100	5.2	11.1	66.9	16.8	30.0	19.2	10.8	16.5	6.7	CL,Lean Clay
891330	OSM3	110-116	4.6	5.6	52.1	37.8						CH,Fat Clay
891331	OSM3	128-134	0.0	1.1	64.7	34.2						CL,Lean Clay
891332	OSM3	144-150	0.0	4.6	68.3	27.1	39.8	21.8	18.0	18.4	9.8	CL,Lean Clay
891263	OSM4	12-18	0.0	1.0	75.6	23.4						CL,Lean Clay
891273	OSM4	14-20	0.0	2.0	80.4	17.6						CL,Lean Clay
891264	OSM4	22-28	0.0	2.0	80.6	17.4	43.8	25.0	18.8	20.0	10.7	CL,Lean Clay

OSM EVANSVILLE PROJECT

LAB ID	BORING	DEPTH inches	% GR	% SA	% SI	% CL	L.L.	P.L.	P.I.	SHRINK. LIMIT %	LINEAL SHRINK. %	CLASS.
891274	OSM4	24-30	0.0	1.8	73.1	25.2						CL,Lean Clay
891265	OSM4	30-36	0.0	1.9	79.5	18.5						CL,Lean Clay
891275	OSM4	35-41	0.0	1.0	74.0	25.0						CL,Lean Clay
891276	OSM4	44-50	0.0	1.1	78.1	20.8						CL,Lean Clay
891277	OSM4	54-60	0.0	1.0	81.4	17.7						CL,Lean Clay
891266	OSM4	54-60	0.0	3.0	82.1	14.9						CL,Lean Clay
891278	OSM4	60-66	0.0	2.1	82.3	15.5						CL,Lean Clay
891267	OSM4	69-75	0.0	18.5	62.2	19.3						CL,Lean Clay with Sand
891279	OSM4	72-78	0.0	6.7	79.7	13.6						ML,Silt
891280	OSM4	78-83	0.0	8.7	77.7	13.6						ML,Silt
891268	OSM4	79-85	0.0	22.7	51.9	25.4						CL,Lean Clay with Sand
891281	OSM4	84-90	0.0	12.3	72.8	14.9						CL,Lean Clay
891269	OSM4	90-96	6.9	30.0	38.4	24.7	45.8	22.1	23.7	17.0	13.1	CL,Lean Clay with Sand
891282	OSM4	98-104	6.0	20.5	57.3	16.2						CL,Lean Clay with Sand
891270	OSM4	99-105	0.0	22.2	29.8	48.1						CH,Fat Clay with Sand
891271	OSM4	114-120	0.0	11.6	32.4	56.0						CH,Fat Clay
891272	OSM4	122-128	0.0	0.2	44.6	55.1	63.1	25.5	37.6	13.8	19.2	CH,Fat Clay
891283	OSM5	38-44	0.6	27.2	54.7	17.5						CL,Lean Clay with Sand
891284	OSM5	50-56	0.1	29.8	51.2	18.9	30.8	16.0	14.8	11.4	10.1	CL,Lean Clay with Sand
891285	OSM5	70-76	6.1	29.1	37.9	27.0						CL,Sandy Lean Clay
891286	OSM5	79-85	0.9	31.9	37.4	29.8						CL,Sandy Lean Clay
891287	OSM5	90-96	0.0	31.5	41.9	26.6						CL,Sandy Lean Clay
891288	OSM5	101-107	1.0	38.6	36.4	24.1						CL,Sandy Lean Clay
891289	OSM5	114-120	0.0	29.4	45.7	25.0	33.6	17.3	16.3	12.8	10.2	CL,Lean Clay with Sand
891290	OSM5	128-134	0.0	37.1	41.4	21.5						CL,Sandy Lean Clay
891291	OSM5	137-146	0.5	18.4	46.0	35.0						CL,Lean Clay with Sand
891292	OSM5	145-150	0.0	13.0	52.3	34.7						CL,Lean Clay
891293	OSM5	151-157	3.8	20.9	48.4	26.9	44.0	23.0	21.0	17.5	11.9	CL,Lean Clay with Sand
891237	OSM8	10-16	0.0	2.2	72.6	25.2						CL,Lean Clay
891238	OSM8	20-26	0.0	2.3	70.3	27.4	51.0	21.0	30.0	6.4	19.8	CH,Fat Clay
891239	OSM8	30-36	0.0	1.7	81.0	17.3						CL,Lean Clay
891240	OSM8	54-60	0.0	1.1	86.1	12.8						ML,Silt
891241	OSM8	60-66	0.0	7.2	79.6	13.2						ML,Silt
891242	OSM8	84-90	0.0	4.9	78.3	16.7	30.9	19.1	11.8	16.7	7.3	CL,Lean Clay

OSM EVANSVILLE PROJECT

LAB ID	BORING	DEPTH inches	% GR	% SA	% SI	% CL	L.L.	P.L.	P.I.	SHRINK. LIMIT %	LINEAL SHRINK. %	CLASS.
891243	OSM8	120-126	0.0	6.0	71.4	22.6						CL,Lean Clay
891244	OSM8	138-144	0.0	6.7	72.6	20.7	34.3	18.4	15.9	13.9	10.4	CL,Lean Clay
891313	OSM9	24-30	0.0	1.7	44.8	53.4						CH,Fat Clay
891314	OSM9	38-44	0.0	1.2	52.3	46.4	54.3	23.6	30.7	12.3	17.9	CH,Fat Clay
891315	OSM9	49-55	0.0	1.9	57.6	40.5						CH,Fat Clay
891316	OSM9	120-125	0.0	0.9	61.4	37.7	40.1	23.2	16.9	14.6	12.0	CL,Lean Clay
891317	OSM9	125-130	0.0	0.5	61.1	38.4						CL,Lean Clay
891318	OSM9	130-135	1.3	3.7	52.0	43.1						CH,Fat Clay
891319	OSM9	135-140	0.0	0.9	49.1	50.0						CH,Fat Clay
891320	OSM9	140-145	1.1	1.5	43.5	53.9						CH,Fat Clay
891321	OSM9	145-150	0.0	2.4	42.4	55.2						CH,Fat Clay
891322	OSM9	150-155	0.2	1.4	53.8	44.6						CH,Fat Clay
891323	OSM9	155-158	0.0	0.5	62.0	37.5	36.9	22.0	14.9	NA	NA	CL,Lean Clay
891294	OSM10	9-15	0.0	2.5	78.1	19.4						CL,Lean Clay
891295	OSM10	22-28	0.0	4.4	75.0	20.6	38.4	21.4	17.0	20.5	8.2	CL,Lean Clay
891296	OSM10	30-36	0.0	8.0	69.9	22.1						CL,Lean Clay
891297	OSM10	42-48	0.0	28.2	41.8	30.1						CL,Lean Clay with Sand
891298	OSM10	54-60	0.4	34.0	40.1	25.5						CL,Sandy Lean Clay
891299	OSM10	64-70	0.0	10.9	39.0	50.1						CH,Fat Clay
891300	OSM10	84-90	0.0	5.1	49.2	45.7	66.3	28.0	38.3	12.6	20.5	CH,Fat Clay
891301	OSM10	93-98	0.0	3.8	58.7	37.5						CH,Fat Clay
891302	OSM10	114-120	0.0	0.6	78.1	21.4						CL,Lean Clay
891303	OSM10	130-138	0.0	13.9	67.8	18.3	39.3	24.0	15.3	17.4	10.0	CL,Lean Clay
891304	OSM12	11-17	0.0	4.4	81.4	14.2						CL,Lean Clay
891305	OSM12	30-36	0.2	4.3	80.3	15.2	30.6	21.7	8.9	16.1	7.3	CL,Lean Clay
891306	OSM12	48-54	0.0	5.8	67.1	27.1						CL,Lean Clay
891307	OSM12	57-73	0.0	8.9	68.3	22.8						CL,Lean Clay
891308	OSM12	84-90	0.0	6.4	74.4	19.1	35.7	21.5	14.2	16.6	9.3	CL,Lean Clay
891309	OSM12	102-108	0.0	2.0	76.8	21.2						CL,Lean Clay
891310	OSM12	120-126	0.0	3.6	65.9	30.5						CL,Lean Clay
891311	OSM12	137-143	0.0	3.8	70.4	25.9						CL,Lean Clay
891312	OSM12	150-156	0.7	4.2	73.7	21.5	32.3	19.3	13.0	13.9	9.3	CL,Lean Clay

OSM EVANSVILLE PROJECT

LAB ID	BORING	DEPTH inches	% GR	% SA	% SI	% CL	L.L.	P.L.	P.I.	SHRINK. LIMIT %	LINEAL SHRINK. %	CLASS.
891255	OSM13	23-29	0.0	3.4	74.8	21.8						CL,Lean Clay
891256	OSM13	42-48	0.0	2.2	77.6	20.3	37.0	19.7	17.3	19.4	3.2	CL,Lean Clay
891257	OSM13	62-68	0.0	2.9	78.8	18.4						CL,Lean Clay
891258	OSM13	84-90	0.0	3.2	76.2	20.5						CL,Lean Clay
891259	OSM13	100-106	0.0	7.3	66.8	25.9	39.0	19.1	19.9	14.4	11.9	CL,Lean Clay
891260	OSM13	114-120	0.0	5.5	66.6	27.9						CL,Lean Clay
891261	OSM13	120-126	0.0	6.4	70.7	23.0						CL,Lean Clay
891262	OSM13	144-150	0.0	7.4	70.6	22.0	31.4	18.0	13.4	18.2	18.0	CL,Lean Clay
891223	OSM17	18-24	0.3	0.9	82.2	16.6						CL,Lean Clay
891224	OSM17	31-37	0.0	1.3	67.3	31.4	43.9	21.6	22.3	18.9	18.9	CL,Lean Clay
891225	OSM17	45-50	0.0	1.8	66.0	32.2						CL,Lean Clay
891226	OSM17	64-70	0.0	2.2	61.2	36.6						CL,Lean Clay
891227	OSM17	84-90	0.0	5.0	66.5	28.6	40.9	20.4	20.5	17.3	10.6	CL,Lean Clay
891228	OSM17	97-102	0.2	2.7	71.3	25.8						CL,Lean Clay
891229	OSM17	123-129	0.1	2.7	52.8	44.4						CH,Fat Clay
891230	OSM17	150-156	0.0	1.8	66.7	31.5						CL,Lean Clay
891231	OSM17	170-176	0.3	2.4	72.3	25.0	31.7	17.4	14.3	20.9	5.4	CL,Lean Clay
891333	OSM19	16-20	0.0	2.1	51.0	46.9						CH,Fat Clay
891334	OSM19	22-28	0.0	2.1	56.0	41.9	49.7	20.6	29.1	16.4	14.3	CH,Fat Clay
891335	OSM19	36-42	0.0	1.5	58.7	39.8						CH,Fat Clay
891336	OSM19	67-73	5.3	4.1	58.1	32.5						CL,Lean Clay
891337	OSM19	84-90	0.0	1.0	56.1	43.0	40.8	24.1	16.7	14.8	12.3	CL,Lean Clay
891338	OSM19	48-54	0.0	1.9	54.8	43.3						CL,Lean Clay
891339	OSM19	108-113	0.0	5.9	52.1	42.0						CL,Lean Clay
891340	OSM19	168-173	0.0	1.1	54.2	44.7						CL,Lean Clay
891341	OSM19	113-118	0.0	0.5	54.1	45.4						CH,Fat Clay
891342	OSM19	121-126	0.0	0.1	42.9	57.0						CH,Fat Clay
891343	OSM19	173-178	0.0	0.9	62.2	36.9						CH,Fat Clay
891344	OSM19	178-183	0.0	1.1	65.1	33.8						CL,Lean Clay
891345	OSM19	233-238	0.0	2.6	75.0	22.4						CL,Lean Clay
891346	OSM19	228-233	0.0	2.5	77.3	20.2						CL,Lean Clay
891347	OSM19	238-243	0.0	2.6	75.9	21.5						CL,Lean Clay
891348	OSM19	243-245	0.0	3.8	76.0	20.2						CL,Lean Clay

OSM EVANSVILLE PROJECT

LAB ID	BORING	DEPTH inches	% GR	% SA	% SI	% CL	L.L.	P.L.	P.I.	SHRINK. LIMIT %	LINEAL SHRINK. %	CLASS.
891245	OSM20	13-19	0.0	2.4	75.1	22.5						CL,Lean Clay
891246	OSM20	21-26	0.0	1.7	74.6	23.8	47.7	24.2	23.5	12.8	15.0	CL,Lean Clay
891247	OSM20	36-42	0.0	1.3	79.7	19.0						CL,Lean Clay
891248	OSM20	52-58	0.0	4.1	81.1	14.8						CL,Lean Clay
891249	OSM20	72-78	0.0	13.0	72.6	14.4						CL,Lean Clay
891250	OSM20	90-96	0.0	18.1	59.9	22.0	31.8	16.0	15.8	12.9	9.7	CL,Lean Clay With Sand
891251	OSM20	106-112	0.0	10.1	54.0	35.9						CL,Lean Clay
891252	OSM20	123-129	0.0	6.4	61.5	32.1						CL,Lean Clay
891253	OSM20	144-150	0.0	14.2	60.1	25.7						CL,Lean Clay
891254	OSM20	172-178	0.0	10.0	49.4	40.6	52.5	20.0	32.5	11.6	17.4	CH,Fat Clay
891232	OSM21	12-18	0.1	1.3	61.2	37.4						CL,Lean Clay
891233	OSM21	30-36	0.0	1.1	47.8	51.1	62.9	26.8	36.1	8.4	22.5	CH,Fat Clay
891234	OSM21	54-59	0.0	1.0	52.0	46.9						CH,Fat Clay
891235	OSM21	65-71	0.2	4.3	58.3	37.3						CL,Lean Clay
891236	OSM21	84-90	0.0	2.7	66.9	30.4	41.7	21.2	20.5	13.3	13.4	CL,Lean Clay
891350	OSM21	108-113	0.0	4.6	73.1	22.2						CL,Lean Clay
891351	OSM21	168-173	0.8	3.9	73.7	21.5						CL,Lean Clay
891352	OSM21	178-183	1.1	3.1	76.1	19.7	30.1	20.5	9.6	NA	NA	CL,Lean Clay
891353	OSM22	48-53	0.0	1.1	46.6	52.3						CH,Fat Clay
891354	OSM22	53-58	0.0	0.7	51.5	47.8	57.3	24.7	32.6	20.1	14.9	CH,Fat Clay
891355	OSM22	108-113	0.0	1.1	45.6	53.3						CH,Fat Clay
891356	OSM22	113-116	0.0	1.4	50.7	47.9						CH,Fat Clay
891357	OSM22	168-173	0.0	2.0	60.5	37.5						CH,Fat Clay
891358	OSM22	173-178	0.0	2.0	63.5	34.5						CH,Fat Clay
891359	OSM22	183-186	0.0	2.4	81.1	16.4						CL,Lean Clay
891360	OSM22	228-233	0.0	2.9	69.4	27.7						CL,Lean Clay
891361	OSM22	233-238	4.3	5.0	72.5	18.2						CL,Lean Clay
891362	OSM22	238-243	0.0	3.8	71.9	24.3						CL,Lean Clay
891363	OSM22	288-293	0.0	14.8	70.6	14.6						CL,Lean Clay
891364	OSM22	293-298	0.0	15.1	72.4	12.5						ML,Silt with Sand
891365	OSM22	298-303	0.0	15.3	73.3	11.4						ML,Silt with Sand
891366	OSM22	303-306	0.0	18.6	67.8	13.6						ML,Silt with Sand
891210	OSM29	6-12	0.0	1.8	83.1	15.1						CL,Lean Clay

OSM EVANSVILLE PROJECT

LAB ID	BORING	DEPTH inches	% GR	% SA	% SI	% CL	L.L.	P.L.	P.I.	SHRINK. LIMIT %	LINEAL SHRINK. %	CLASS.
891211	OSM29	12-18	0.0	1.5	82.2	16.3	46.7	23.2	23.5	18.7	12.2	CL,Lean Clay
891212	OSM29	24-30	0.0	0.7	81.2	18.1						CL,Lean Clay
891213	OSM29	30-36	0.0	0.8	79.3	19.9						CL,Lean Clay
891214	OSM29	36-42	0.0	1.1	84.1	14.9						CL,Lean Clay
891215	OSM29	42-48	0.0	1.4	84.7	13.9						CL,Lean Clay
891216	OSM29	48-60	0.0	3.8	79.5	16.7						CL,Lean Clay
891217	OSM29	60-66	0.0	8.7	69.4	21.9						CL,Lean Clay
891218	OSM29	70-78	1.1	9.1	56.5	33.3						CL,Lean Clay
891219	OSM29	78-82	4.7	10.3	42.0	43.0						CL,lean Cl with Sa
891220	OSM29	85-90	0.0	6.1	32.6	61.3						CH,Fat Clay
891221	OSM29	90-96	1.5	8.3	38.1	52.1						CH,Fat Clay
891222	OSM29	110-115	0.1	8.2	39.6	52.1	74.6	26.0	48.6	6.5	24.9	CH,Fat Clay
891208	OSM31	24-30	0.3	32.7	58.2	8.7	21.7	14.9	6.8	9.1	7.2	CL-ML,Sandy Silty Cl
891209	OSM31	62-67	0.0	4.4	52.0	43.5						CH,Fat Clay
891202	OSM32	12-16	0.0	0.6	86.6	12.8	39.1	25.4	13.7	20.4	8.8	ML,Silt
891203	OSM32	24-30	0.0	1.0	86.8	12.2						ML,Silt
891204	OSM32	30-36	0.0	1.5	87.5	10.9						ML,Silt
891205	OSM32	54-60	0.0	5.3	82.4	12.3						ML,Silt
891206	OSM32	80-86	3.2	10.8	57.1	28.9						CL,Lean Clay
891207	OSM32	100-104	0.0	1.4	79.1	19.6	47.0	26.7	20.3	8.4	18.0	CL,Lean Clay
891196	OSM33	10-16	0.0	0.5	85.8	13.6						CL,Lean Clay
891197	OSM33	24-30	0.0	1.3	90.2	8.6	36.4	25.4	11.0	24.3	17.0	ML,Silt
891198	OSM33	36-42	0.0	10.7	79.8	9.5						ML,Silt
891199	OSM33	54-60	0.0	32.4	58.8	8.8						ML,Sandy Silt
891200	OSM33	67-73	0.0	40.7	48.8	10.5						ML,Sandy Silt
891201	OSM33	84-90	0.9	42.2	37.2	19.6	38.4	18.1	20.3	15.8	10.3	CL,Sandy Lean Clay
891187	OSM34	6-10	0.0	0.7	85.7	13.6						CL,Lean Clay
891188	OSM34	24-30	0.0	2.9	71.0	26.1	44.2	22.4	21.8	9.8	16.0	CL,Lean Clay
891189	OSM34	42-48	0.0	1.1	83.6	15.3						CL,Lean Clay
891190	OSM34	52-58	0.0	1.5	82.6	15.8						CL,Lean Clay
891191	OSM34	60-66	0.2	3.3	81.2	15.3						CL,Lean Clay
891192	OSM34	72-78	1.7	6.9	76.8	14.6						CL,Lean Clay

OSM EVANSVILLE PROJECT

LAB ID	BORING	DEPTH inches	% GR	% SA	% SI	% CL	L.L.	P.L.	P.I.	SHRINK. LIMIT %	LINEAL SHRINK. %	CLASS.
891193	OSM34	84-90	1.4	6.6	80.9	11.1	30.7	18.1	12.6	21.2	14.3	CL,Lean Clay
891194	OSM34	96-102	1.0	7.2	73.0	18.8						CL,Lean Clay
891195	OSM34	114-120	1.2	6.1	73.6	19.1						CL,Lean Clay
891182	OSM37	2-7	0.2	3.0	72.4	24.3						CL,Lean Clay
891183	OSM37	16-22	0.0	2.0	60.2	37.8	55.8	22.5	33.3	7.5	20.8	CH,Fat Clay
891184	OSM37	33-39	0.2	2.0	71.4	26.4						CL,Lean Clay
891185	OSM37	47-53	0.2	2.5	77.4	19.9						CL,Lean Clay
891186	OSM37	73-77	0.1	2.5	74.8	22.7	30.9	20.7	10.2	24.0	11.8	CL,Lean Clay

Major Divisions			Group Symbols	Typical Names
Coarse-Grained Soils More than 50% retained on No. 200 sieve	Gravels 50% or more of coarse fraction retained on No. 4 sieve	Clean Gravels	GW	Well-graded gravels and gravel-sand mixtures, little or no fines
			GP	Poorly graded gravels and gravel-sand mixtures, little or no fines
		Gravel with Fines	GM	Silty gravels, gravel-sand-silt mixtures
			GC	Clayey gravels, gravel-sand-clay mixtures
	Sands More than 50% of coarse fraction passes No. 4 sieve	Clean sands	SW	Well-graded sands and gravelly sands, little or no fines
			SP	Poorly graded sands and gravelly sands, little or no fines
		Sands with Fines	SM	Silty sands, sand-silt mixtures
			SC	Clayey sands, sand-clay mixtures
Fine-Grained Soils 50% or more passes No. 200 sieve	Silts and Clays Liquid limit 50% or less		ML	Inorganic silts, very fine sands, rock flour, silty or clayey fine sands
			CL	Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
			OL	Organic silts and organic silty clays of low plasticity
	Silts and Clays Liquid limit greater than 50%		MH	Inorganic silts, micaceous or diatomaceous fine sands or silts, elastic silts
			CH	Inorganic clays of high plasticity, fat clays
			OH	Organic clays of medium to high plasticity
Highly organic soils			PT	Peat, muck, and other highly organic soils

Figure A.1. Unified Soil Classification Chart, American Society for Testing and Materials (ASTM), D 2487-85 (Liu and Evett, 1981).

APPENDIX B

Soil Descriptions, Gamma-Ray Logs and Data Plots for OSM Auger Holes 1 to 25, 27 to 37 (IDNR-GS, 1990).

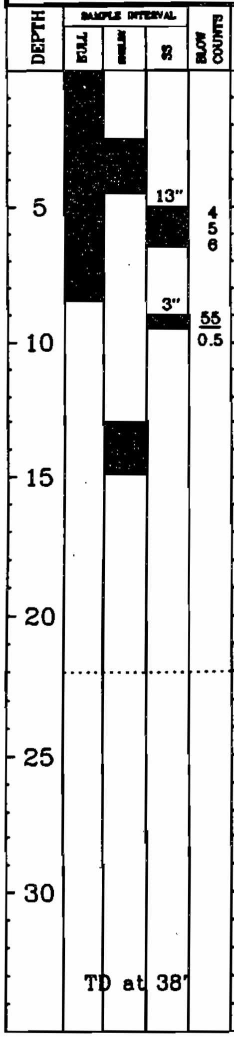
Unified Soil Classification Chart from American Society for Testing and Materials (ASTM) D2487-85.

INDIANA GEOLOGICAL SURVEY — Dept. of Natural Resources, State of Indiana

OSM–EVANSVILLE PROJECT

BORING# 1
Page 1 of 1

LOCATION: 1/4 NE 1/4 NE 1/4 NE 1/4 SEC 27 T. 5 S. R. 10 W. ELEVATION: 500'
DATE: METHOD: 4 IN. RIG: B-34 DRILLED BY: ARNOLD/RIDDLE
GAMMA LOGGED BY: CHITWOOD DESCRIBED BY: BLEUER



DESCRIPTION

B21 - 0-2" silty clay loam; moderate medium subangular blocky; 7.5YR 4/4, with 10YR 4/4 ped stains and 5YR 4/3 continuous, thin, clay films; many fine roots

B22 - 2-13" silty clay loam; strong medium subangular blocky; 7.5YR 4/4 with 5YR 4/6 continuous clay films; many fine roots

B23 - 13-28" silty clay loam to silt loam; moderate coarse to medium subangular blocky; 7.5YR 5/4 with 5YR 4/4 continuous, thin, clay films; few fine roots

B31 - 28-42" silt loam; weak, coarse, subangular blocky; 7.5 YR 5/4 with 7.5YR 4/4 discontinuous, thin, clay films; some streaked (tubes and blotches) silt coatings; common, fine 3/2-3 manganese coatings

B32 - 42-60" silt loam; massive to weak, coarse subangular blocky; breaks along thick, continuous 10YR 6/3 silt coated joint; common root tubules

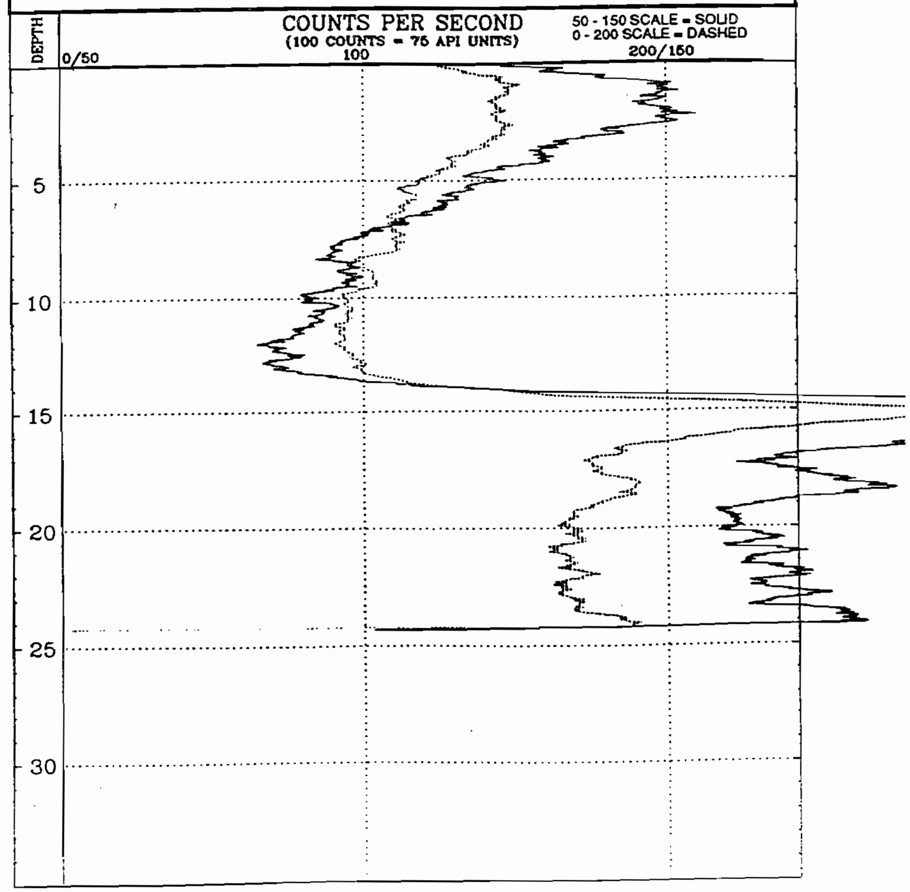
IIB3 - 60-78" loam; weak, coarse, subangular blocky; 10-7.5YR with thin, discontinuous 10YR 6/3 clay films and many diffuse darker stains on very fine structures; many small voids and tubules; few coarse manganese concretions

IIC - 78-85" silt loam; weak to moderate, coarse platy; 7.5YR 4/4, few small, diffuse iron and manganese stains and root tubule coats

IIIC - 85-102" loamy sand; massive; 5YR 3/4, small diffuse splotches to 6/6, varicolored concretionary masses at 95" and varicolored splotches and joint surfaces, 10YR 5/6 - 6/4 in lower half

NATURAL GAMMA–RAY LOG

TC = 5 RATE = 5 FT/MIN OSM– 1 LOG # 89–306



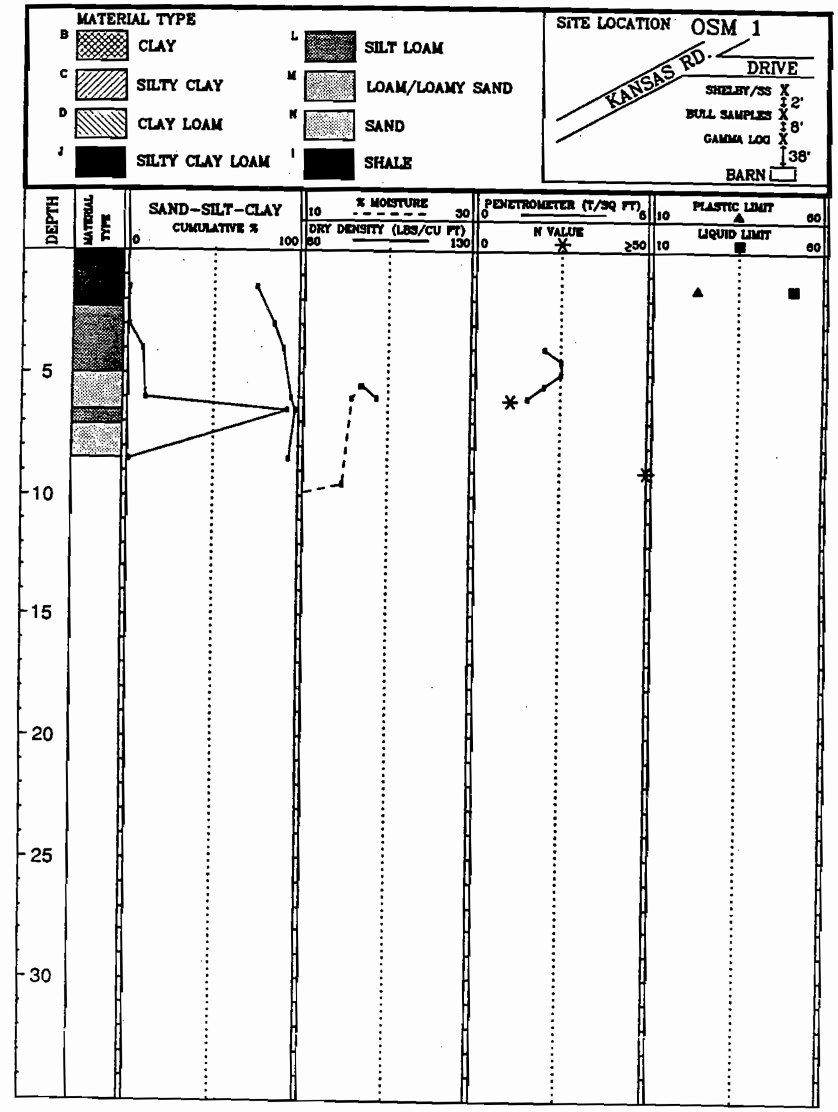
INDIANA GEOLOGICAL SURVEY	Dept. of Natural Resources State of Indiana
OSM-EVANSVILLE PROJECT	BORING# 1

BORING DATA

LAB ID	BORING	DEPTH inches	% GR	% SA	% SI	% CL	L.L.	P.L.	P.I.	SHRINK. LIMIT %	LINEAL SHRINK. %	CLASS.
891161	OSM1	13-18	0.0	0.5	74.6	24.8	51.4	23.2	28.2	7.2	19.0	CH,Fat Clay
891162	OSM1	30-36	0.0	0.4	85.0	14.6						CL,lean Clay
891163	OSM1	42-48	0.0	8.3	82.4	9.3						ML,Silt
891164	OSM1	66-72	0.0	10.2	85.3	4.5						ML,Silt
891165	OSM1	72-78	0.0	93.2	4.8	1.9						SW-SM,Wel Grad Sa w Si
891166	OSM1	96-102	3.5	1.0	93.5	2.0	NONPLASTIC					ML,Silt

BORING	DEPTH in.	P.P. t/sq ft	N VAL
OSM-1	48	2.00	
OSM-1	54	2.50	
OSM-1	60	2.50	
OSM-1	66	2.00	
OSM-1	72	1.50	11
OSM-1	108		55

LAB ID	BORING	SAMP DEPTH inches	% MOIS	DRY DENS lbs/cu ft
890881	OSM-1	66	16.9	97.7
890882	OSM-1	72	15.9	102.0
890883	OSM-1	114	14.8	na
890884	OSM-1	120	8.2	na



INDIANA GEOLOGICAL SURVEY

Dept. of Natural Resources
State of Indiana

OSM-EVANSVILLE PROJECT

BORING# 2
Page 1 of 1

LOCATION: 1/4 NE 1/4 NE 1/4 NE 1/4 SEC 26 T. 5 S. R. 10 W. ELEVATION: 410'
DATE: METHOD: 4 IN. RIG: B-34 DRILLED BY: ARNOLD/RIDDLE
GAMMA LOGGED BY: CHITWOOD DESCRIBED BY: BLEUER

DEPTH | SAMPLE INTERVAL (BULL, SHELBY, SS) | BLOW COUNTS | DESCRIPTION

TD
REFUSAL

AP - 0-8" silt loam, granular; 10YR 5/6; abundant roots

B21 - 8-16" silt loam; very weak, medium subangular blocky; 10YR 5/6 with thin, fine 5/4 clay films; few, fine manganese concretions

Eb - 16-23" silt loam; weak, coarse subangular blocky; 10YR 6/2, many, faint, coarse 5/4 mottles; 5% small elongate voids; few small iron concretions (7.5YR 5/4)

B21b - 23-34" silty clay loam; moderate medium subangular blocky with medium prismatic parting; 10YR 6/3 with common, faint, coarse 6/2 mottles, some 4/2 fine, distinct mottles, and few 7.5YR 4/4 fine concretions; thick, continuous

10YR 4/3 clay films; subhorizontal 7/2 silt coats outline silt loam and silty loam stratification in basal 3"

B22b - 34-45" silty clay loam; weak, medium to fine subangular blocky; mottled 10YR 6/2 and 6/8 with many 3/4 medium manganese concretions and streaks of 6/1 staining; few thin 6/1 clay films; basal 2" apparently finely laminated 7/1 to various oxidized values in silty clay loam to silt loam

B3 - 45-54" silty clay loam; massive to diffusely stratified; 10YR 6/2 with many medium, distinct 6/8 to 4/6 mottles and many 2/1 diffuse splotches and concretions

C - 54-60" silt loam, massive, 10YR 6/6 with some 6/6, coarse, distinct mottles and some fine to medium 5/1 concretions

- 60-117" silt loam, massive, 10YR 5/6-6/8 with faint, medium, diffuse 6/1 mottles and streaks, few fine 3/3-4 concretions

- (98-116" krotovina chamber fill of 10YR 6/1 silt with thick, 4/1 clay-film edges)

- 117-120 silt loam; massive, 10YR 6/6 with common medium, distinct mottles of 5/4 to 6/2 and many, distinct, 2/1 manganese splotches

IIB3b - 120-150" silt loam to silty clay loam in lower 1/3; weak fine to medium subangular blocky (blocky structure blends into distinct concretionary masses, fine bottroidal structure); 10YR 5/4 with many distinct 2/1 stains, 3/4 root-tubule fills and clay-lined, silt-filled krotovina fill at 144-150"

IIIBxb (A') - 150-154" silt loam; irregular fragmental structure with abundant tubule fills; 10YR 5/8 with varishaped 3/4 clay fills and 2/1 manganese stains on voids

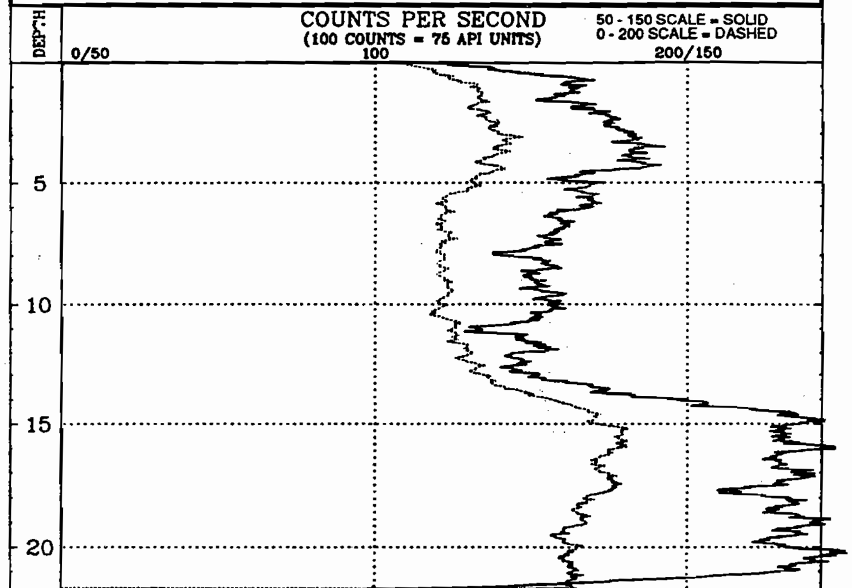
CONTINUED NEXT PAGE

NATURAL GAMMA-RAY LOG

TC = 5 RATE = 5 FT/MIN OSM-2 LOG # 89-308

COUNTS PER SECOND
(100 COUNTS = 75 API UNITS)

50 - 150 SCALE = SOLID
0 - 200 SCALE = DASHED



DESCRIPTION, CONTINUED

IIIB31b - 154-168 silt loam (heavy); massive but with trace discrete fine clay (shale) fragments in basal half; 10YR 6/6-5/8 with distinct, thick, 6/1 clayey vertical streaks prominent, some 3/4 root-channel clay linings and common 2/1 manganese splotches and fenestrate streaks

IIIB32b - 168-192" alternating layered, soft SHALE; 2.5Y 5-6/4; cut with sub-vertical joints, stained 10YR 6/6-8 with heavy, darker iron staining on immediate joint surfaces and on most bedding surfaces; also cut by irregular joints filled with medium to thick, gleyed 5-6/1 clay films

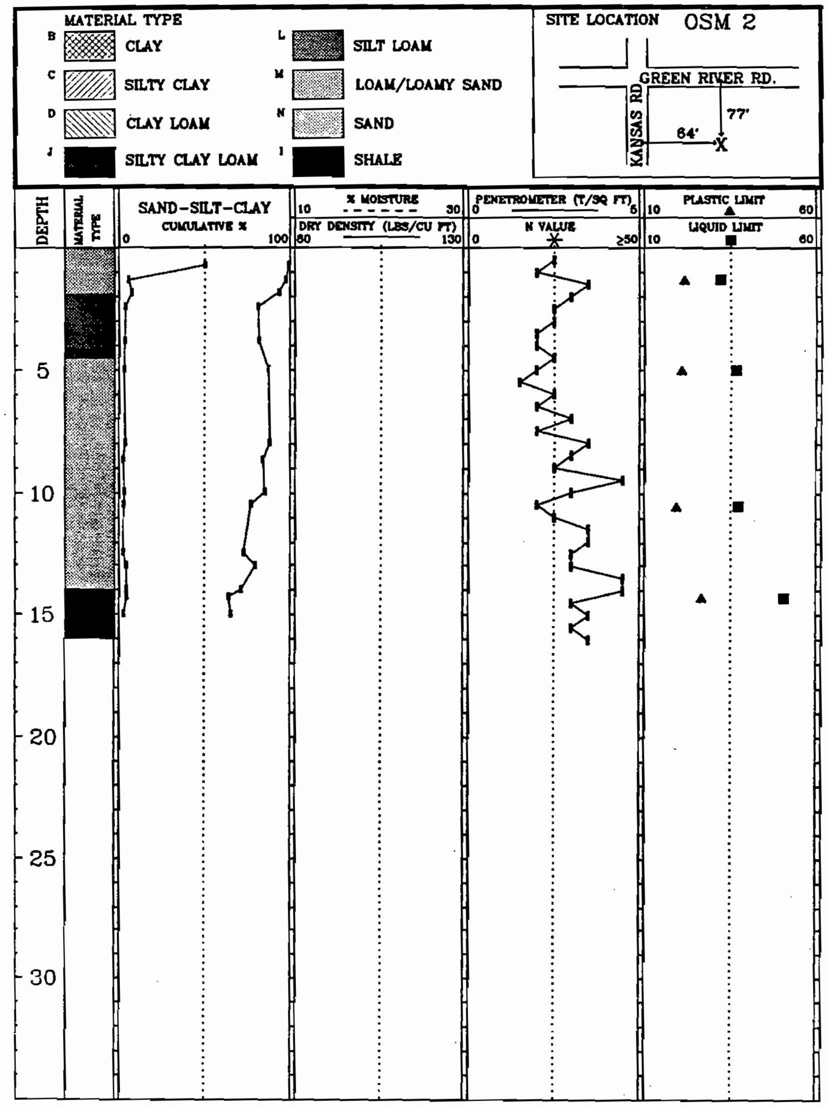
Comments: upper A-B is a poorly developed alluvial profile (entisol) defined mostly by a color B. IIB3b is a structure and root-tubule defined B. Bxb is possibly a paleo A horizon, is essentially a buried fragipan. IIB3b begins the transition to physically weathered shale

INDIANA GEOLOGICAL SURVEY	Dept. of Natural Resources State of Indiana
OSM-EVANSVILLE PROJECT	BORING# 2

BORING DATA

LAB ID	BORING	DEPTH inches	% GR	% SA	% SI	% CL	L.L.	P.L.	P.I.	SHRINK. LIMIT %	LINEAL SHRINK. %	CLASS.
891167	OSM2	2-8	0.8	50.0	48.8	0.4						SM,Silty Sand
891168	OSM2	8-16	0.4	5.0	92.1	2.5	32.1	21.2	10.9	21.3	4.9	CL,Lean Clay
891169	OSM2	16-22	0.0	6.8	86.5	6.6						CL,Lean Clay
891170	OSM2	23-29	0.0	3.2	77.9	18.9						CL,Lean Clay
891171	OSM2	39-45	0.1	2.8	78.8	18.3						CL,Lean Clay
891172	OSM2	54-60	0.0	2.3	84.9	12.9	36.0	20.6	15.4	23.7	5.8	CL,Lean Clay
891173	OSM2	93-96	0.2	3.0	84.8	12.0						CL,Lean Clay
891174	OSM2	98-104	0.1	1.9	82.0	16.0						CL,Lean Clay
891175	OSM2	114-120	0.5	2.5	82.6	14.4						CL,Lean Clay
891176	OSM2	120-126	1.5	2.2	74.8	21.5	37.8	18.9	18.9	33.0	2.3	CL,Lean Clay
891177	OSM2	144-150	0.6	1.8	70.9	26.7						CL,Lean Clay
891178	OSM2	150-156	0.7	3.7	75.7	19.9						CL,Lean Clay
891179	OSM2	162-168	0.3	3.6	67.7	28.4						CL,Lean Clay
891180	OSM2	168-172	0.3	3.8	60.0	35.9	50.5	26.7	23.8	9.3	18.8	CH,Fat Clay
891181	OSM2	?	0.1	2.0	63.2	34.7						CH,Fat Clay

BORING	DEPTH in.	P.P. t/sq ft	N VAL
OSM-2	6	2.50	
OSM-2	12	2.00	
OSM-2	18	3.50	
OSM-2	24	3.00	
OSM-2	30	2.50	
OSM-2	36	2.50	
OSM-2	42	2.00	
OSM-2	48	2.00	
OSM-2	54	2.50	
OSM-2	60	2.00	
OSM-2	66	1.50	
OSM-2	72	2.50	
OSM-2	78	2.00	
OSM-2	84	3.00	
OSM-2	90	2.00	
OSM-2	96	3.50	
OSM-2	102	3.00	
OSM-2	108	2.50	
OSM-2	114	4.50	
OSM-2	120	3.00	
OSM-2	126	2.00	
OSM-2	132	2.50	
OSM-2	138	3.50	
OSM-2	144	3.50	
OSM-2	150	3.00	
OSM-2	156	3.00	
OSM-2	162	4.50	
OSM-2	168	4.50	
OSM-2	174	3.00	
OSM-2	180	3.50	
OSM-2	186	3.00	
OSM-2	192	3.50	

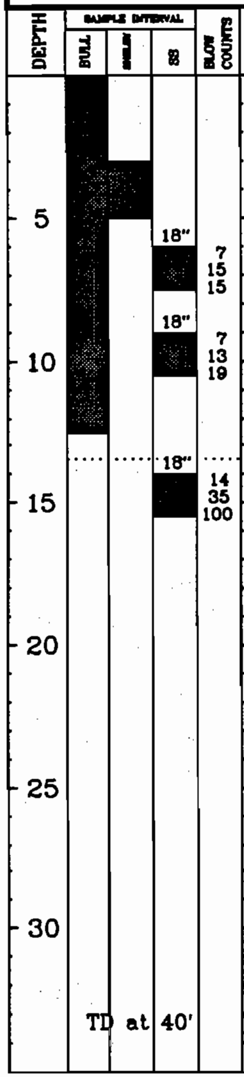


INDIANA GEOLOGICAL SURVEY — Dept. of Natural Resources, State of Indiana

OSM-EVANSVILLE PROJECT

BORING# 3
Page 1 of 1

LOCATION: 1/4 NW1/4 NW1/4 NE1/4 SEC 34 T. 5 S. R. 10 W. ELEVATION: 390'
DATE: METHOD: 4 IN. RIG: B-34 DRILLED BY: ARNOLD/RIDDLE
GAMMA LOGGED BY: CHITWOOD DESCRIBED BY: BLEUER



DESCRIPTION

AP - 0-7" silt loam; massive; 10YR 4.5/4

B1 - 7-18" silt loam; massive to weak medium subangular blocky; 10YR 5/6 with thin discontinuous 4.5/6 clay films; common live roots

B2 - 18-30" silt loam; strong, medium subangular blocky; 10YR 5/6 with common, continuous 4-5/6 clay films and common, thin to medium, 7/4 silt coatings

B3x - 30-63" silt loam; massive to very weak, coarse subangular blocky, locally weak fine subangular blocky; 7.5YR 4/6 with distinct, medium mottles 10YR 5/4-7/3; cut by continuious vertical joint planes with thin 5/4 clay films and few, thin, discontinuous, 8/2 silt coats, locally (as in base of interval) very thick to continuous or making up bulk of core as possibly a krotovina chamber

IIB3xb(?) - 63-78" silt loam; massive to very fine subangular blocky; 10YR 6/6, diffuse, fine stains to 4/3, 40% surfaces manganese stained in upper 4" (coarse,diffuse blotches); possible thin, discontinuous clay films with distinct ped stains ranging from 3/2 to 5/6

IICb - 78-94" silt loam; as above, massive and unstained

IIIB1b - 94-107" silt loam, weak, medium subangular blocky; 10YR 5/5 with diffuse, fine stains to 5/8; general loamy appearnce, with scattered fine clay (shale?) clasts and concretions, shale fragments reach 3/4" in bottom 6" (STONE LINE)

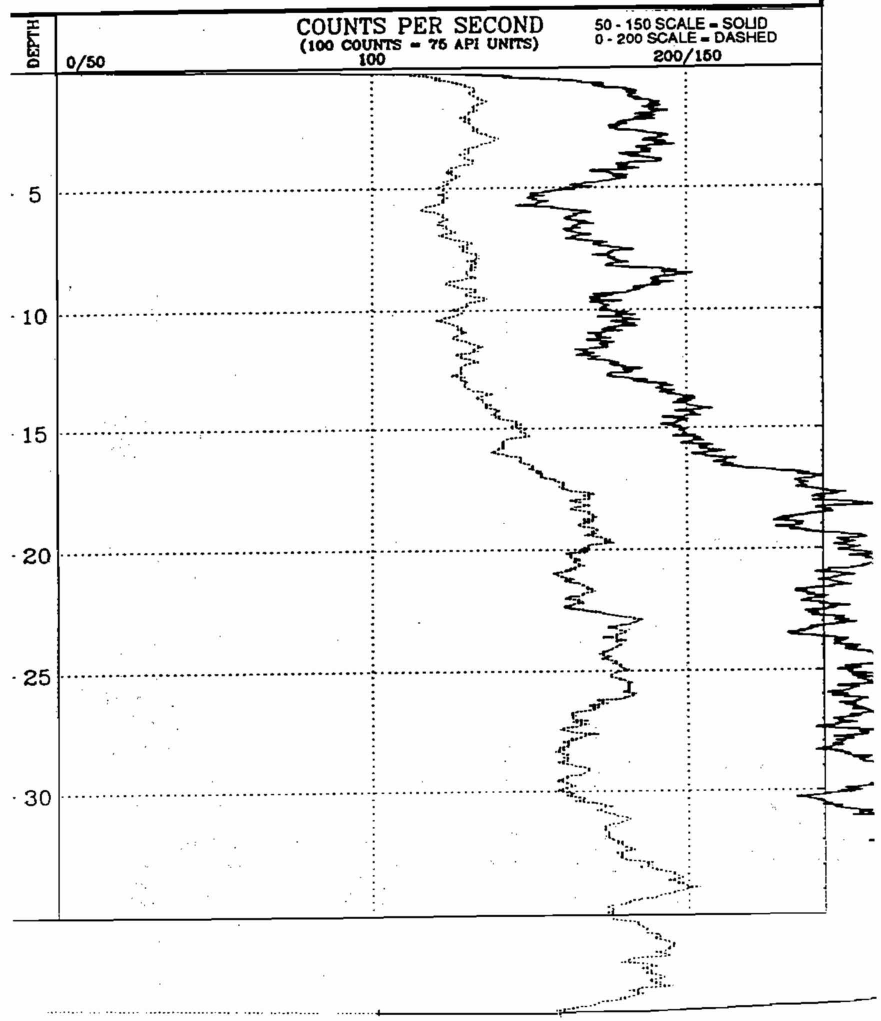
IVB2b - 107-120" silty clay; diffuse, weak mottles 7.5YR 4/6 to 2.5Y 6/5; matrix is fine fragments of angular to rounded, soft to firm shale with common to continuous, very fine clay films anastomosing between fragments; trace of anastomosing root tubules with thick, continuous 2.5Y 4/2 clay films

IVB3b - 120-150" as above, discontinuous clay films, local thin silt coats on continuous vertical joints

Comments: Thick (5'+) IVB developed in shale apparently represents thicknesses of physically weathered material expected on absolute, non-eroded spur crests of the middle surface, although the stone line does represent some erosional interval and slope processes, possibly related to initial pediment formation. An upper and lower loess parent material are present, the lower containing evidence of soil formation (IIIB).

NATURAL GAMMA-RAY LOG

TC = 5 RATE = 5 FT/MIN OSM-3 LOG # 89-310



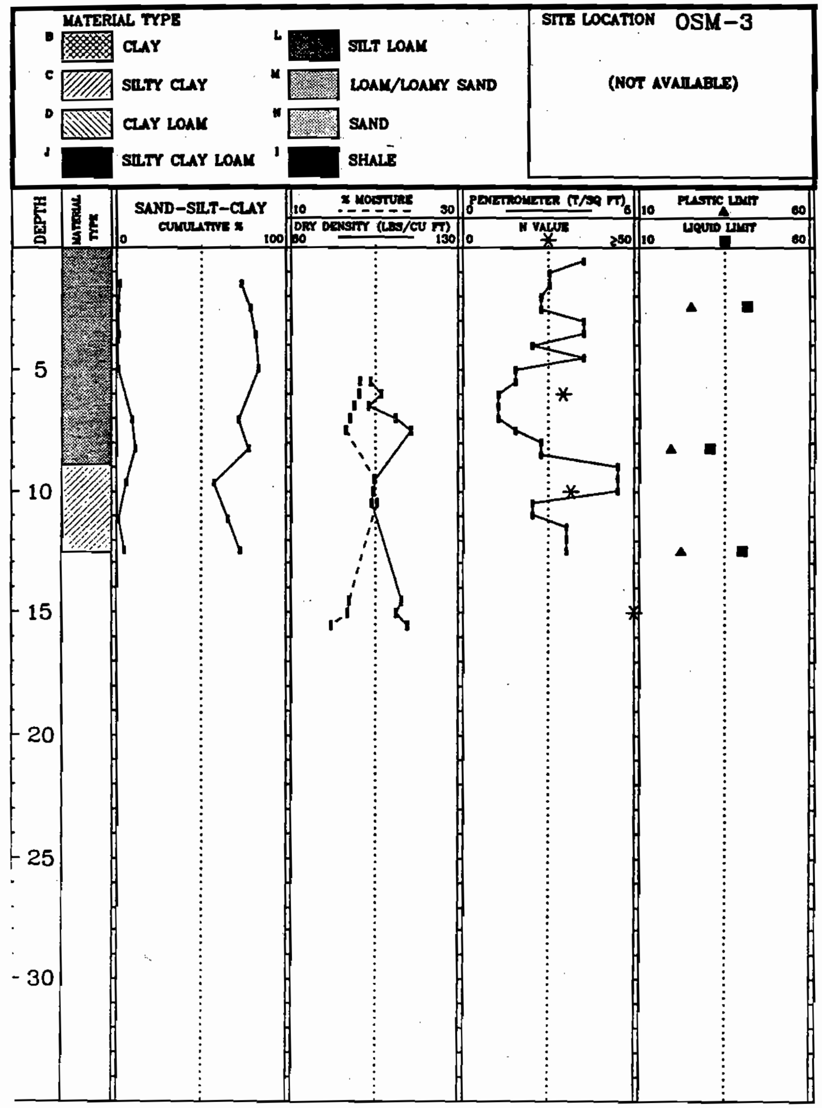
INDIANA GEOLOGICAL SURVEY	Dept. of Natural Resources State of Indiana
OSM–EVANSVILLE PROJECT	BORING# 3

BORING DATA

LAB ID	BORING	DEPTH inches	% GR	% SA	% SI	% CL	L.L.	P.L.	P.I.	SHRINK. LIMIT %	LINEAL SHRINK. %	CLASS.
891324	OSM3	12-18	0.0	1.7	72.0	26.3						CL,Lean Clay
891325	OSM3	24-30	0.0	1.0	78.0	21.0	41.6	24.6	17.0	21.4	8.9	CL,Lean Clay
891326	OSM3	37-43	0.0	1.1	81.1	17.8						CL,Lean Clay
891327	OSM3	54-60	0.0	0.9	82.9	16.1						CL,Lean Clay
891328	OSM3	79-85	15.2	9.1	63.1	12.6						ML,Silt with Gravel
891329	OSM3	94-100	5.2	11.1	66.9	16.8	30.0	19.2	10.8	16.5	6.7	CL,Lean Clay
891330	OSM3	110-116	4.6	5.6	52.1	37.8						CH,Fat Clay
891331	OSM3	128-134	0.0	1.1	64.7	34.2						CL,Lean Clay
891332	OSM3	144-150	0.0	4.6	68.3	27.1	39.8	21.8	18.0	18.4	9.8	CL,Lean Clay

BORING	DEPTH in.	P.P. t/sq ft	N VAL
OSM-3	6	3.50	
OSM-3	12	2.50	
OSM-3	18	2.50	
OSM-3	24	2.25	
OSM-3	30	2.25	
OSM-3	36	3.50	
OSM-3	42	3.50	
OSM-3	48	2.00	
OSM-3	54	3.50	
OSM-3	60	1.50	
OSM-3	66	1.50	
OSM-3	72	1.00	30
OSM-3	78	1.00	
OSM-3	84	1.00	
OSM-3	90	1.50	
OSM-3	96	2.25	
OSM-3	102	2.25	
OSM-3	108	4.50	
OSM-3	114	4.50	
OSM-3	120	4.50	32
OSM-3	126	2.00	
OSM-3	132	2.00	
OSM-3	138	3.00	
OSM-3	144	3.00	
OSM-3	150	3.00	
OSM-3	180		135

LAB ID	BORING	SAMP DEPTH inches	% MOIS	DRY DENS lbs/cu ft
890885	OSM-3	66	18.1	103.7
890886	OSM-3	72	18.0	106.9
890887	OSM-3	78	17.4	103.1
890888	OSM-3	84	16.9	111.1
890889	OSM-3	90	16.4	115.7
890890	OSM-3	114	19.8	105.1
890891	OSM-3	120	19.7	104.4
890892	OSM-3	126	20.1	104.0
890893	OSM-3	174	16.8	112.8
890894	OSM-3	180	16.6	111.2
890895	OSM-3	186	14.6	114.6

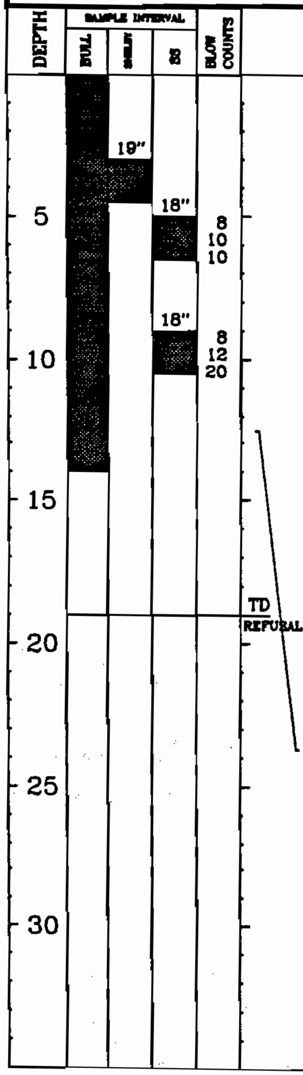


INDIANA GEOLOGICAL SURVEY — Dept. of Natural Resources, State of Indiana

OSM–EVANSVILLE PROJECT

BORING# 4
Page 1 of 1

LOCATION: 1/4 SE1/4 SE1/4 SW1/4 SEC 27 T. 5 S. R. 10 W. ELEVATION: 470'
DATE: METHOD: 4 IN. RIG: B-34 DRILLED BY: ARNOLD/RIDDLE
GAMMA LOGGED BY: CHITWOOD DESCRIBED BY: BLEUER



DESCRIPTION (GORE STRUCTURE)

AP - 0-8" silt loam; massive; 10YR 4/4; corn stalk near base

B1 - 8-20" silt loam; massive; weak, coarse subangular blocky; 10YR 6/6 with discontinuous, thin, 5/6 clay films

B1x - 20-42" silt loam; massive to fine subangular blocky; 10YR 5/6-8, diffusely stained 4/6, common 4/4-6, thin to medium clay films; cut (50% surfaces) by continuous joints, films, stringers coated with 10YR 7/2 silt; common root tubules; brittle

B2x - (as above), medium to coarse subangular blocky; 20% 10YR 6/4 silt coats, 70% 4/4-6, thin to medium clay films; brittle

B3 - 49-68" silt loam; weak, medium subangular blocky; 10YR 6/5 with discontinuous, thin 5/6 clay films; few root tubules and few gleyed joints with modern, fine roots

IIC - 68-79" loam; massive to coarse platy; 10YR 5/6, fine, diffuse, 4/4 splotches and veins; few root tubules and modern, fine roots

IIIB2 - 79-100" silt loam (heavy); massive to compacted granular to strong, fine to medium subangular blocky; 10YR 5/6 with common (30%) 2/2 manganese coats and stains on peds and joints, and sub-horizontal bands; discontinuous, medium, 4/4 clay films; sub-horizontally layered with loamy sand, composed of fine to medium concretionary masses or subrounded clasts (STONE LINE)

IVB31b - 100-106" clay; fine subangular blocky (most "peds" are clay, disaggregated, angular to subrounded shale); 10YR 6/6, diffuse, 5/6, medium mottles (20%)

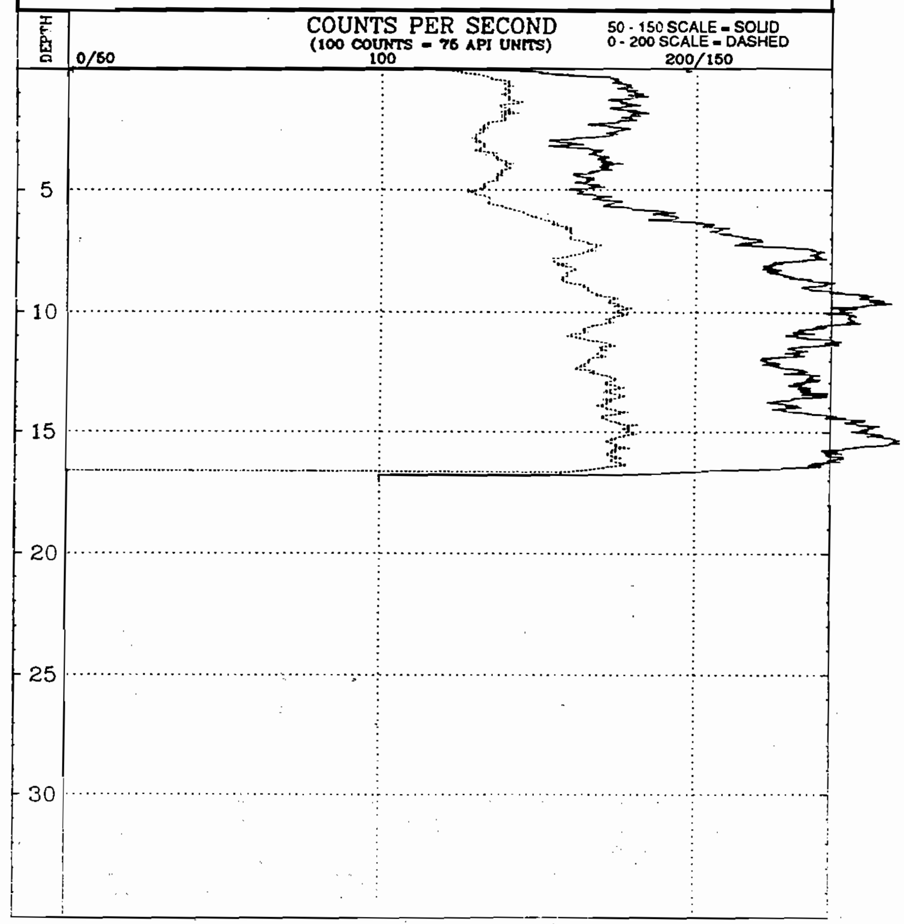
IVB32b - 106-122" clay; massive in top 10", below is even mix of varicolored shale fragments, varishaped manganese concretionary masses; 10YR 5/6-8, diffusely mottled 2.5Y 6/2 (lower 6") matrix; 60% surfaces are 10YR 2/2, fine, round to oval manganese pellets and continuous joint coats

IVC - 122-150" shale; massive but cut by many steeply dipping joints with slickensided faces; varicolored 2/5Y 7/1, diffuse stains to 10YR 6/6, thin, subhorizontal 5R banding below top 1'

Comments: Profile is basic Hosmer series, with fragipan. The complex IIIB2 appears to be a granular mix of various fragments, i.e., not simply formed-in-place concretionary masses. It is interpreted as a stone line, as evidence of an erosional surface atop the physically disaggregated shale of the IVB3 horizons which are relatively thin (100-122")

NATURAL GAMMA–RAY LOG

TC = 5 RATE = 5 FT/MIN OSM–4 LOG # 89–312



INDIANA GEOLOGICAL SURVEY

Dept. of Natural Resources
State of Indiana

OSM-EVANSVILLE PROJECT

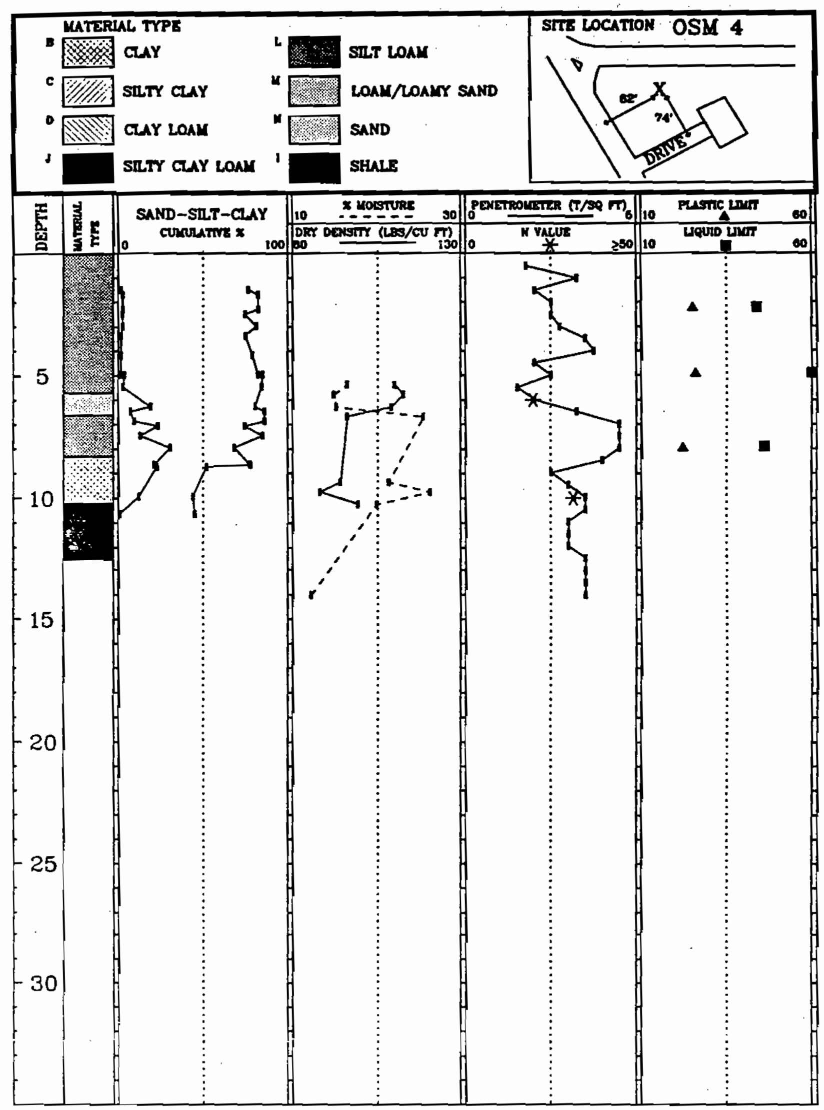
BORING# 4

BORING DATA

LAB ID	BORING	DEPTH inches	% GR	% SA	% SI	% CL	L.L.	P.L.	P.I.	SHRINK. LIMIT %	LINEAL SHRINK. %	CLASS.
891263	OSM4	12-18	0.0	1.0	75.6	23.4						CL,Lean Clay
891273	OSM4	14-20	0.0	2.0	80.4	17.6						CL,Lean Clay
891264	OSM4	22-28	0.0	2.0	80.6	17.4	43.8	25.0	18.8	20.0	10.7	CL,Lean Clay
891274	OSM4	24-30	0.0	1.8	73.1	25.2						CL,Lean Clay
891265	OSM4	30-36	0.0	1.9	79.5	18.5						CL,Lean Clay
891275	OSM4	35-41	0.0	1.0	74.0	25.0						CL,Lean Clay
891276	OSM4	44-50	0.0	1.1	78.1	20.8						CL,Lean Clay
891277	OSM4	54-60	0.0	1.0	81.4	17.7						CL,Lean Clay
891266	OSM4	54-60	0.0	3.0	82.1	14.9						CL,Lean Clay
891278	OSM4	60-66	0.0	2.1	82.3	15.5						CL,Lean Clay
891267	OSM4	69-75	0.0	18.5	62.2	19.3						CL,Lean Clay with Sand
891279	OSM4	72-78	0.0	6.7	79.7	13.6						ML,Silt
891280	OSM4	78-83	0.0	8.7	77.7	13.6						ML,Silt
891268	OSM4	79-85	0.0	22.7	51.9	25.4						CL,Lean Clay with Sand
891281	OSM4	84-90	0.0	12.3	72.8	14.9						CL,Lean Clay
891269	OSM4	90-96	6.9	30.0	38.4	24.7	45.8	22.1	23.7	17.0	13.1	CL,Lean Clay with Sand
891282	OSM4	98-104	6.0	20.5	57.3	16.2						CL,Lean Clay with Sand
891270	OSM4	99-105	0.0	22.2	29.8	48.1						CH,Fat Clay with Sand
891271	OSM4	114-120	0.0	11.6	32.4	56.0						CH,Fat Clay
891272	OSM4	122-128	0.0	0.2	44.6	55.1	63.1	25.5	37.6	13.8	19.2	CH,Fat Clay

BORING	DEPTH in.	P.P. t/sq ft	N VAL
OSM-4	6	1.75	
OSM-4	12	3.25	
OSM-4	18	2.00	
OSM-4	24	2.50	
OSM-4	30	2.50	
OSM-4	36	2.75	
OSM-4	42	3.50	
OSM-4	48	3.75	
OSM-4	54	2.00	
OSM-4	60	2.50	
OSM-4	66	1.50	
OSM-4	72	2.00	20
OSM-4	78	3.25	
OSM-4	84	4.50	
OSM-4	90	4.50	
OSM-4	96	4.50	
OSM-4	102	4.00	
OSM-4	108	2.50	
OSM-4	114	3.00	
OSM-4	120	3.50	32
OSM-4	126	3.50	
OSM-4	132	3.00	
OSM-4	138	3.00	
OSM-4	144	3.00	
OSM-4	150	3.50	
OSM-4	156	3.50	
OSM-4	162	3.50	
OSM-4	168	3.50	

LAB ID	BORING	SAMP DEPTH inches	% MOIS	DRY DENS lbs/cu ft
891015	OSM-4	65	16.6	110.3
891016	OSM-4	70	15.0	112.9
891017	OSM-4	76	15.3	109.3
891018	OSM-4	80	25.6	96.2
891019	OSM-4	113	21.5	94.2
891020	OSM-4	118	26.4	88.1
891021	OSM-4	124	20.1	99.5
890896	OSM-4	168	12.3	na



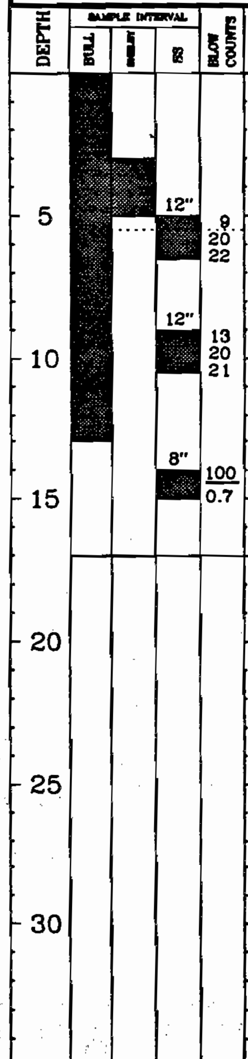
INDIANA GEOLOGICAL SURVEY

Dept. of Natural Resources
State of Indiana

OSM–EVANSVILLE PROJECT

BORING# 5
Page 1 of 1

LOCATION: 1/4 SE1/4 SW1/4 SE1/4 SEC 22 T. 5 S. R. 10 W. ELEVATION: 400'
DATE: METHOD: 4 IN. RIG: B-34 DRILLED BY: ARNOLD/RIDDLE
GAMMA LOGGED BY: CHITWOOD DESCRIBED BY: BLEUER



DESCRIPTION

Fill - 0-8" fine, rounded Ohio River gravel (0-6") over silt loam, 10YR 5/4, massive to weak horizontal lamination

C1 - 8-11" silt loam; massive; 10YR 4/4, irregularly spotted 6/4, with fine disseminated carbonaceous splotches and organic root debris

C2 - 11-30 silt loam, silty clay loam, silty clay, with disseminated carbonaceous splotches; interlaminated silt and clay, trace of ripple drift lamination in silt zones, dominantly silt in lower 6"

IIC - 30-44" silt loam; massive; 10YR 6/6, fine, distinct, 4/6 stains and discontinuous clay films along tubules

IIIB3b - 44-60" silt loam to loam; massive to weak medium subangular blocky, overall suggestion of horizontal textural stratification; 10YR 6/4, faint, diffuse, medium mottles to 6/6, few, discontinuous, thin, 5/6 clay films, some 2/2 manganese joint stains and small diffuse pellets

IVB31b - 60-120 loam, silt loam to silty clay loam matrix; overall suggestion of strong coarse platy to medium to coarse subangular blocky; highly fragmental with angular clasts of sandstone and shale (60-64", 80-86"); 10YR 6/8 background, with 75% of exposed surfaces on fragments and peds are thick, continuous, 5/5 clay films with common 3/4 iron stains, common 2/2 hairline joint coats and some thick, 5/2 joint fills of continuous clay, common 2/1 vug fills and coarse concretions; highly fragmental zone 99-104", heavily penetrated with varicolored manganese and iron staining and cement

IVB32b - 120-134" loam; massive with suggestion of coarse subangular blocky;

10YR 5/6 with diffuse, fine splotchy stains to 4/6, common thick, continuous 2/2 manganese stains on joint surfaces, some small concretions; common thick, clay films on irregular jointed surfaces; bottom marked by thin fragmental zone at 132", basal 2" includes interbedded loamy mateials, coarse sand to fine, rounded gravel siltstone clasts;

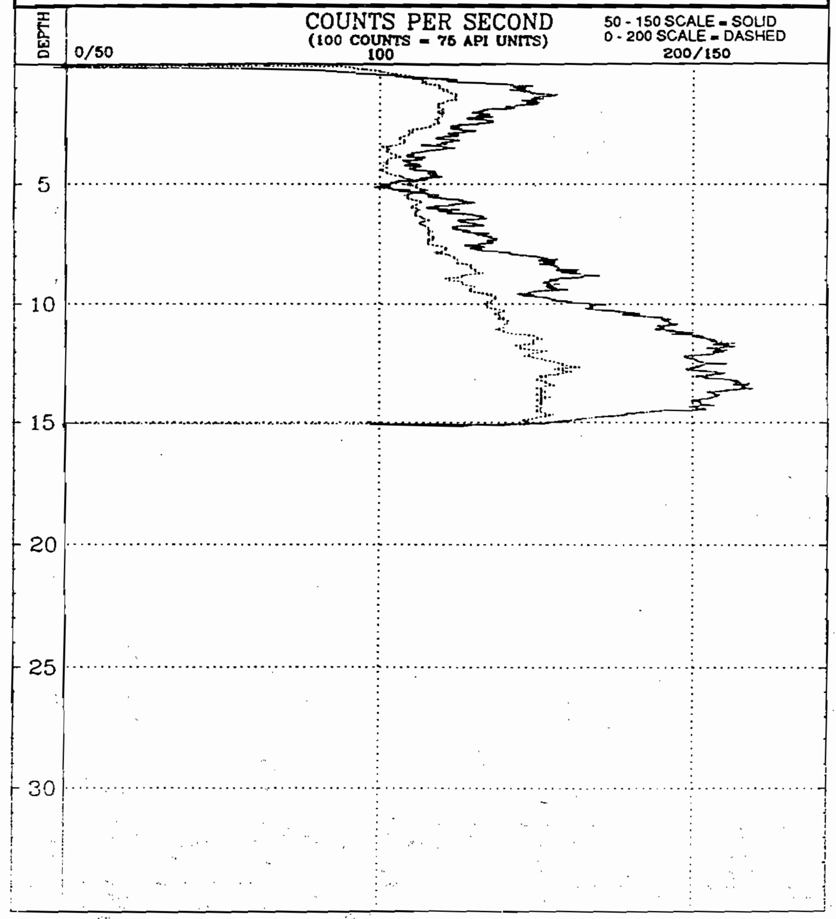
VB3 - 134-150" clay; massive to fine subangular blocky in top 3" grades to angular and subangular fine to medium jumbled fragments of clay (soft shale) below; anastamosing thin to medium clay films penetrate entire matrix; 2.5y 5/6 with common diffuse stains to 5-6/6, common gleyed 7/0 subvertical joint faces or thick clay films lining tubules; common 2/2, irregular manganese veins and fine pellets

VC - 150-157" clay (shale); breaks into fragmental, subhorizontal bedding surfaces; 2.5y 7/0

Comments: Upper C is post-settlement slopewash sediment deposited atop eroded loess (IIC.) IIIB3 is similar to loamy lower loess of numerous other holes. All IVB materials are stratified colluvial material, fan sheetwash material derived from upland slopes, deposited at this head of the middle surface. No obvious B occurs in the shale, suggesting that this colluvial material reflects depositional/erosional events equivalent to stone lines or fragmental zones in other holes.

NATURAL GAMMA–RAY LOG

TC = 5 RATE = 5 FT/MIN OSM–5 LOG # 89–314



INDIANA GEOLOGICAL SURVEY

Dept. of Natural Resources
State of Indiana

OSM–EVANSVILLE PROJECT

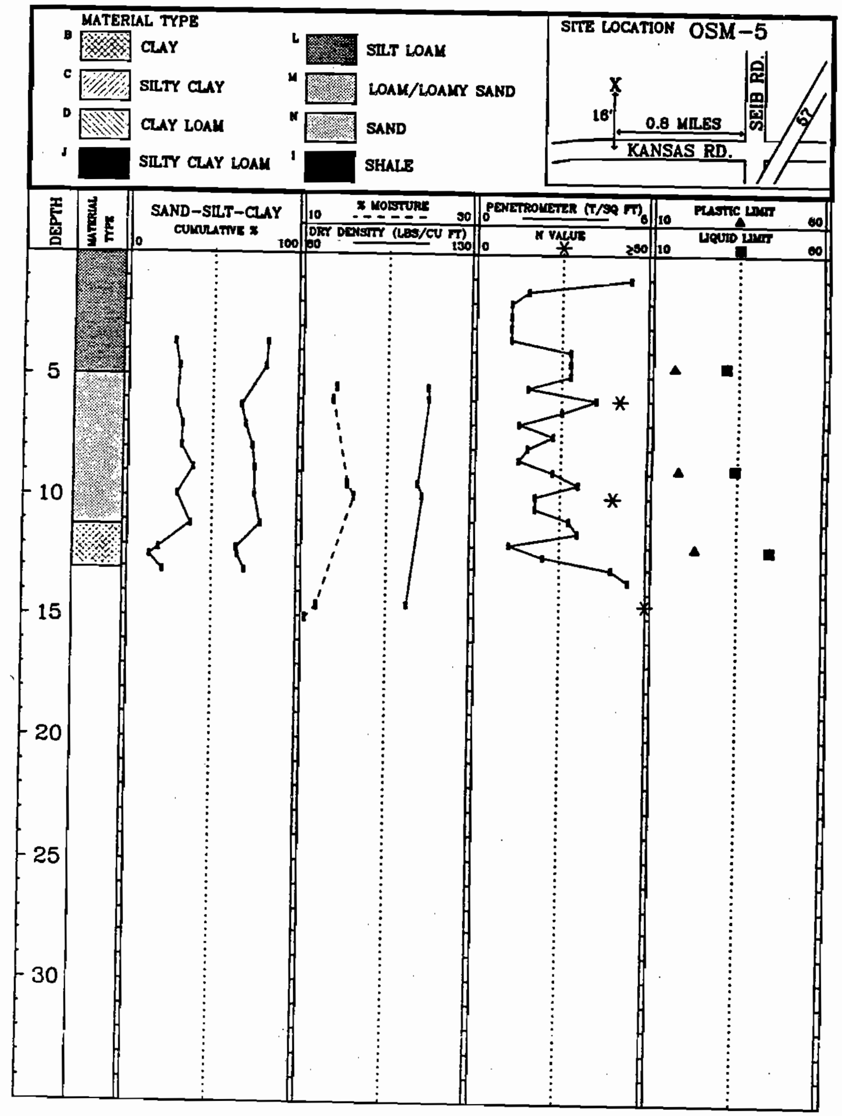
BORING# 5

BORING DATA

LAB ID	BORING	DEPTH inches	% GR	% SA	% SI	% CL	L.L.	P.L.	P.I.	SHRINK. LIMIT %	LINEAL SHRINK. %	CLASS.
891283	OSM5	38-44	0.6	27.2	54.7	17.5						CL,Lean Clay with Sand
891284	OSM5	50-56	0.1	29.8	51.2	18.9	30.8	16.0	14.8	11.4	10.1	CL,Lean Clay with Sand
891285	OSM5	70-76	6.1	29.1	37.9	27.0						CL,Sandy Lean Clay
891286	OSM5	79-85	0.9	31.9	37.4	29.8						CL,Sandy Lean Clay
891287	OSM5	90-96	0.0	31.5	41.9	26.6						CL,Sandy Lean Clay
891288	OSM5	101-107	1.0	38.6	36.4	24.1						CL,Sandy Lean Clay
891289	OSM5	114-120	0.0	29.4	45.7	25.0	33.6	17.3	16.3	12.8	10.2	CL,Lean Clay with Sand
891290	OSM5	128-134	0.0	37.1	41.4	21.5						CL,Sandy Lean Clay
891291	OSM5	137-146	0.5	18.4	46.0	35.0						CL,Lean Clay with Sand
891292	OSM5	145-150	0.0	13.0	52.3	34.7						CL,Lean Clay
891293	OSM5	151-157	3.8	20.9	48.4	26.9	44.0	23.0	21.0	17.5	11.9	CL,Lean Clay with Sand

BORING	DEPTH in.	P.P. t/sq ft	N VAL
OSM-5	12	4.50	
OSM-5	18	1.50	
OSM-5	24	1.00	
OSM-5	30	1.00	
OSM-5	36	1.00	
OSM-5	42	1.00	
OSM-5	48	2.75	
OSM-5	54	2.75	
OSM-5	60	2.75	
OSM-5	66	1.50	
OSM-5	72	3.50	42
OSM-5	78	2.50	
OSM-5	84	1.25	
OSM-5	90	2.25	
OSM-5	96	1.50	
OSM-5	102	1.25	
OSM-5	108	2.25	
OSM-5	114	3.00	
OSM-5	120	1.75	41
OSM-5	126	1.75	
OSM-5	132	2.75	
OSM-5	138	3.00	
OSM-5	144	1.00	
OSM-5	150	2.00	
OSM-5	156	4.00	
OSM-5	162	4.50	
OSM-5	174		100

LAB ID	BORING	SAMP DEPTH inches	% MOIS	DRY DENS lbs/cu ft
890897	OSM-5	66	14.1	117.4
890898	OSM-5	72	13.7	117.5
890899	OSM-5	114	15.5	114.4
890900	OSM-5	120	16.3	115.8
890901	OSM-5	174	11.9	111.5
890902	OSM-5	180	10.6	na

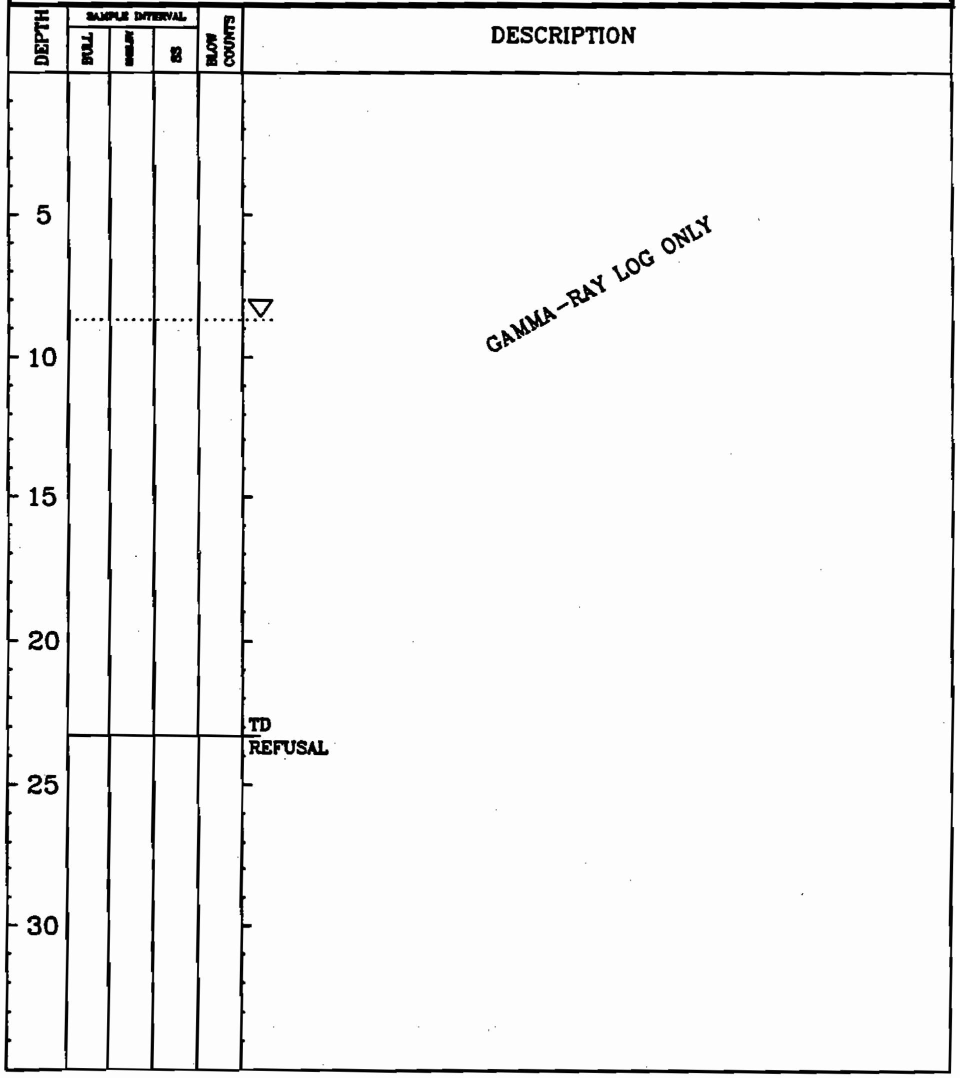


INDIANA GEOLOGICAL SURVEY — Dept. of Natural Resources, State of Indiana

OSM–EVANSVILLE PROJECT

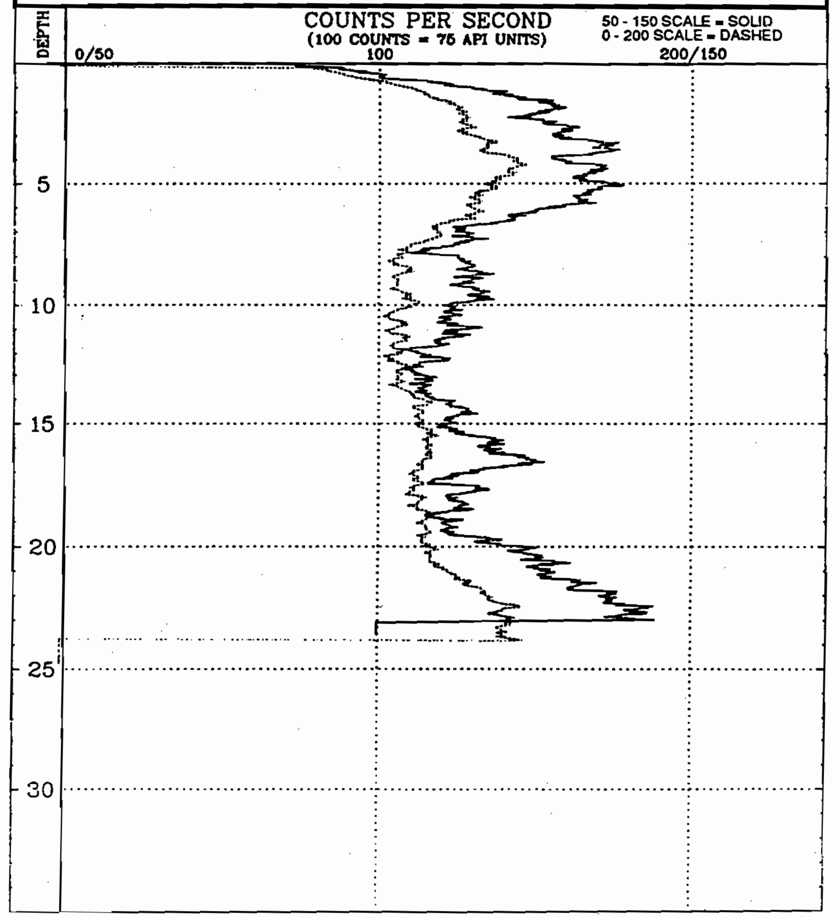
BORING# 6
Page 1 of 1

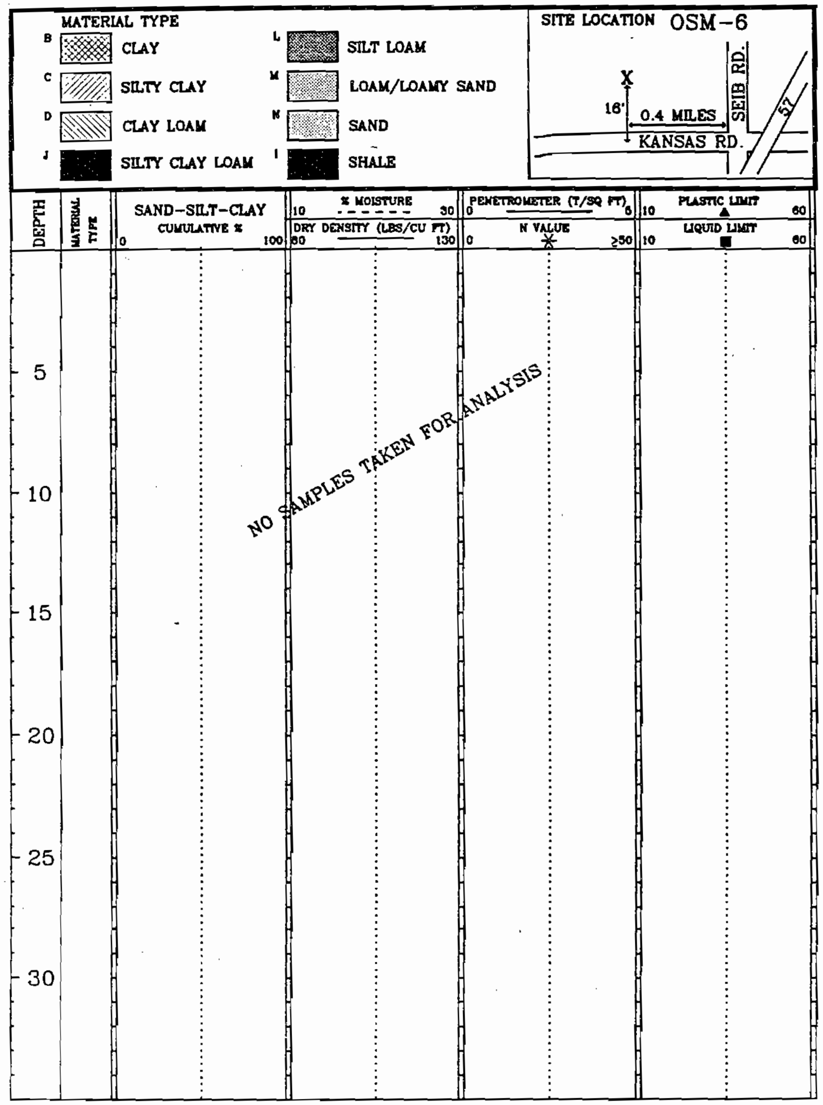
LOCATION: 1/4 SW 1/4 SE 1/4 SE 1/4 SEC 22 T. 5 S. R.10 W. ELEVATION: 400'
DATE: METHOD: 4 IN. RIG: B-34 DRILLED BY: ARNOLD/RIDDLE
GAMMA LOGGED BY: CHITWOOD DESCRIBED BY: BLEUER



NATURAL GAMMA–RAY LOG

TC = 5 RATE = 5 FT/MIN OSM–6 LOG # 89–316




MATERIAL TYPE
B CLAY
C SILTY CLAY
D CLAY LOAM
J SILTY CLAY LOAM
L SILT LOAM
M LOAM/LOAMY SAND
N SAND
I SHALE
SITE LOCATION OSM-6
X
16'
0.4 MILES
SEIB RD.
KANSAS RD.
57
DEPTH
MATERIAL TYPE
SAND-SILT-CLAY
CUMULATIVE %
0
100
10
% MOISTURE
30
DRY DENSITY (LBS/CU FT)
60
130
PENETROMETER (T/SQ FT)
0
6
N VALUE
0
≥50
PLASTIC LIMIT
10
60
LIQUID LIMIT
10
60
5
10
15
20
25
30
NO SAMPLES TAKEN FOR ANALYSIS

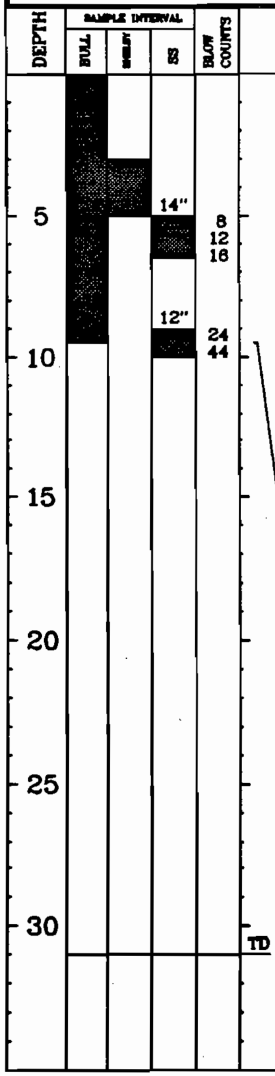
INDIANA GEOLOGICAL SURVEY

Dept. of Natural Resources
State of Indiana

OSM–EVANSVILLE PROJECT

BORING# 7
Page 1 of 1

LOCATION: 1/4 SE 1/4 SW 1/4 SE 1/4 SEC 36 T. 4 S. R. 10 W. ELEVATION: 420'
DATE: METHOD: 4 IN. RIG: B-34 DRILLED BY: ARNOLD/RIDDLE
GAMMA LOGGED BY: CHITWOOD DESCRIBED BY: BLEUER



DESCRIPTION

AP - 0-9" silt loam; massive; 10YR 6/3, slightly gleyed in top 3"; gradational contact under grass and thatch; common living roots

B1 - 9-19" silt loam; moderate, coarse subangular blocky; 10YR 6/5, common, continuous, thin 5-6/6 clay films

Bx - 19-34" silt loam; strong, fine to medium subangular blocky with suggestion of intersecting vertical joints; 10YR 6/4 with continuous, medium to thick 5/8-4/6 clay films, peds and joints coated by common, diffuse, thin splotches of 7/3 silt; common root tubules and live roots

B3 - 34-53" silt loam; weak, fine subangular blocky to massive; fine, distinct mottling 10YR 6/2-5/6, with common root tubules defined by thin, 2/2 clay-film lining, some 7/2-3 clay films on surfaces and in cavities

C - 53-78" silt loam; massive to weak, coarse platy; 10YR 6/4 diffusely stained 4.5/4

IIC - 78-92" silt loam (heavy); massive, 10YR 5/8, cut by joints with thick, 7/3 silt fill, common fine 2/2 manganese stains and streaks in bottom 3"

IIIB31b - 92-102" silty clay loam; strong, fine subangular blocky grading to medium platy; 10YR 5/8 with common, thin, discontinuous 4/6 clay films and common 3/4-2/2 stains on vertical fractures and platy surfaces

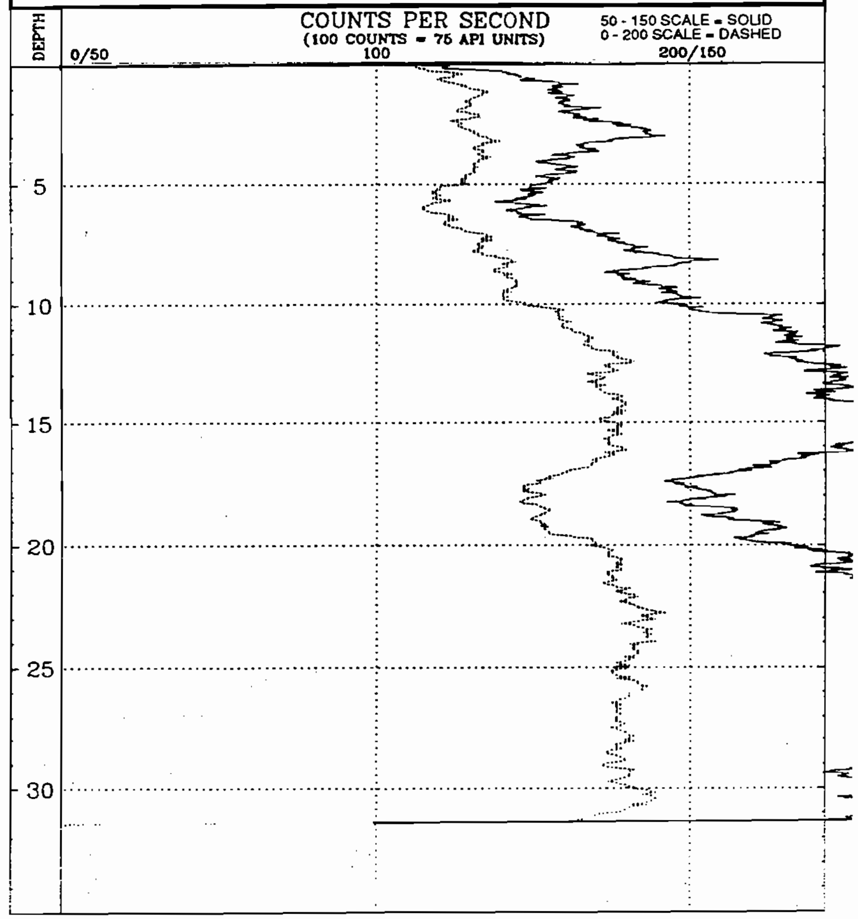
IIIB32b - 102-110" clay; massive but with appearance of a mass of 1/8" fragments of clay; 10YR 5-6/8, cemented by continuous, subhorizontal, 2/2 masses of manganese concretion

IVB3b - 110-114" loamy sand; massive; 10YR 6/8, partly cemented with subhorizontal 2/2 banding

Comments: Physically weathered IIIB and IV B occur in interstratified zone of shale and sandstone. The sharp log shoulder at 120" is original bedding. The weathered (fragmental) shale transition begins at 92". Bx logs high here, apparently heavy textured B. Other holes log lower in Bx, reflecting silt.

NATURAL GAMMA–RAY LOG

TC = 5 RATE = 5 FT/MIN OSM–7 LOG # 89–318



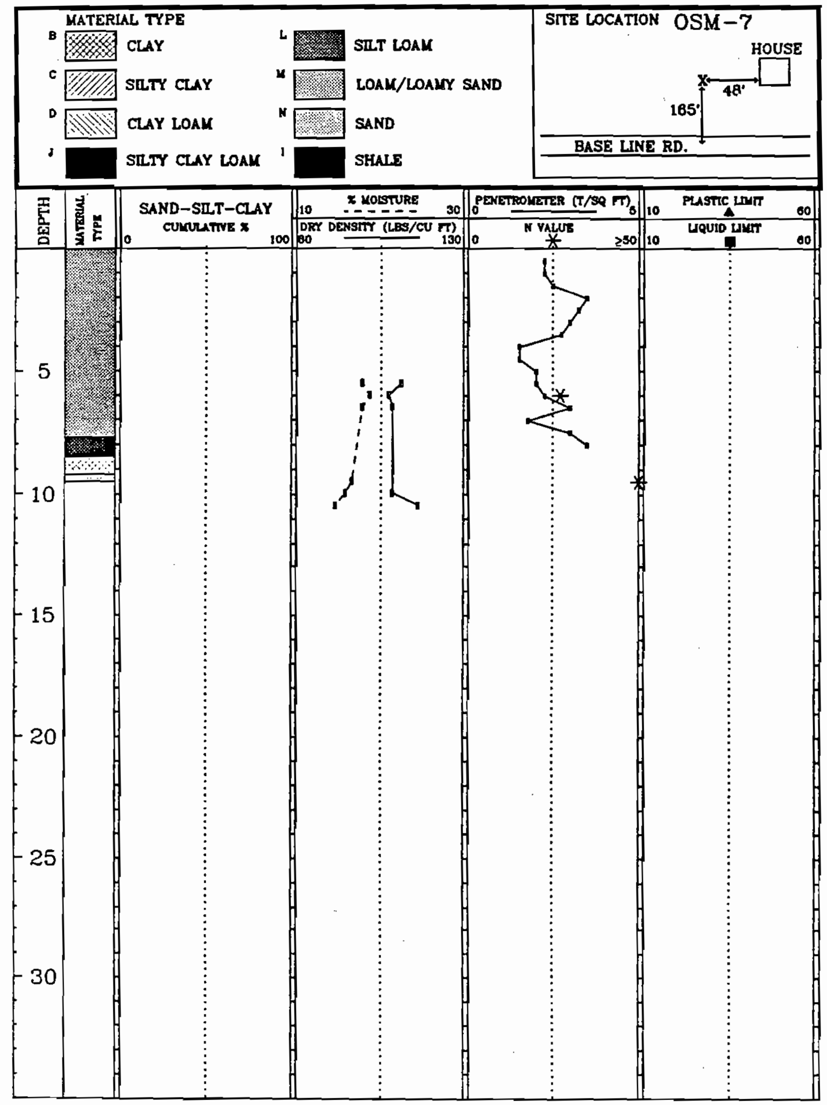
INDIANA GEOLOGICAL SURVEY — Dept. of Natural Resources, State of Indiana

OSM-EVANSVILLE PROJECT — BORING# 7

BORING DATA

BORING	DEPTH in.	P.P. t/sq ft	N VAL
OSM-7	6	2.25	
OSM-7	12	2.25	
OSM-7	18	2.50	
OSM-7	24	3.50	
OSM-7	30	3.25	
OSM-7	36	3.00	
OSM-7	42	2.75	
OSM-7	48	1.50	
OSM-7	54	1.50	
OSM-7	60	2.00	
OSM-7	66	2.00	
OSM-7	72	2.25	28
OSM-7	78	3.00	
OSM-7	84	1.75	
OSM-7	90	3.00	
OSM-7	96	3.50	
OSM-7	114		68

LAB ID	BORING	SAMP DEPTH inches	% MOIS	DRY DENS lbs/cu ft
890903	OSM-7	66	17.9	111.6
890904	OSM-7	72	18.8	107.7
890905	OSM-7	78	17.9	108.9
890906	OSM-7	114	16.7	na
890907	OSM-7	120	15.9	108.9
890908	OSM-7	126	14.7	116.5

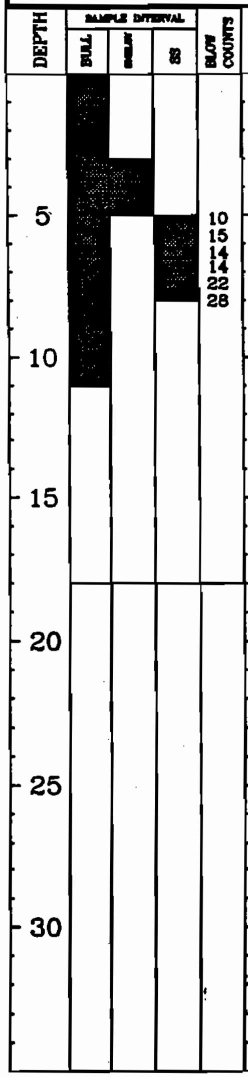


INDIANA GEOLOGICAL SURVEY — Dept. of Natural Resources, State of Indiana

OSM-EVANSVILLE PROJECT

BORING# 8
Page 1 of 1

LOCATION: 1/4 NW1/4 SW1/4 NW1/4 SEC 13 T. 5 S. R.10 W. ELEVATION: 387'
DATE: METHOD: 4 IN. RIG: B-34 DRILLED BY: ARNOLD/RIDDLE
GAMMA LOGGED BY: CHITWOOD DESCRIBED BY: BLEUER



DESCRIPTION

(O) - 0-1" mucky silt loam; 50% rooted matter

A1 - 1-3" silt loam; massive to granular; 10YR 3/2; common root tubules and fecal pellets

B1 - 3-10" silt loam; weak, medium subangular blocky; 10YR 6/6 with common, thin, 5/6-6/8 stains on joints

B21 - 10-18" silt loam; strong fine subangular blocky, possibly prismatic; 10YR 5/5, common 5/3 silt coats on surfaces

B22 - 18-30" silt loam; medium subangular blocky; mottled 10YR 6/8-6 with diffuse, medium 3/4-4 staining and pellets; common roots and voids

B3 - 30-56" silt loam; strong, medium platy in top 6", massive below; 10YR 6/6-8 (90%) to 5/6 to 6/2; common dark, soft incipient concretionary pellets in lower 10"

C - 56-82" silt loam; massive; 10YR 6/4; few, fine iron-manganese pellets;

IIB2b - 82-88" silt loam to silty clay loam; massive to welded, fine, subangular blocky; 6.5/4 matrix with common, penetrating 5/4 clay films

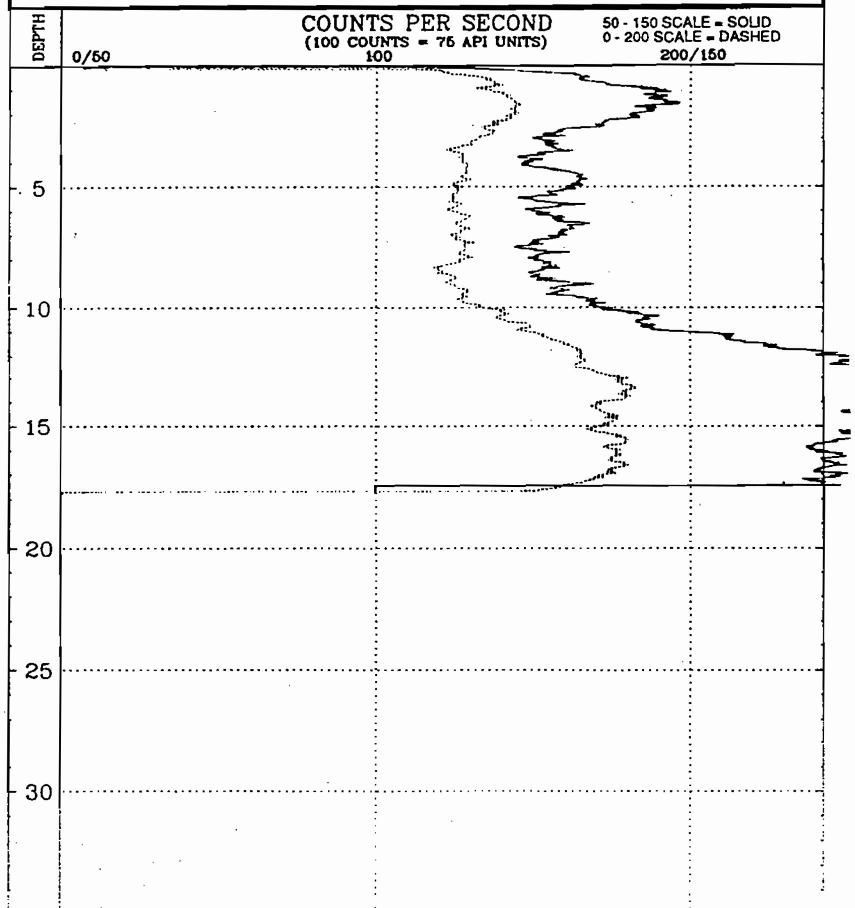
IIIB3b - 88-114" silty clay; massive to slightly platy, superimposed upon fine subangular blocky, traces of shale fragments; 19YR 6/4 with continuous 7/3 silt coats and streaks, 4/3 thick clay films on root tubules and cavities

IIIBxb - 114-132" silty clay; as above; highly fragmental appearance (clay, assumed soft shale); with locally greater 10YR 8/2, discontinuous, fine to medium silt coatings; thick (1/2") 10YR 6/1 clay fills within mottled 10YR 6/8-4/6 matrix

Comments: The B is severely eroded. The IIB is the top of physically weathered, fragmental shale.

NATURAL GAMMA-RAY LOG

TC = 5 RATE = 5 FT/MIN OSM-8 LOG # 89-320



INDIANA GEOLOGICAL SURVEY

Dept. of Natural Resources
State of Indiana

OSM–EVANSVILLE PROJECT

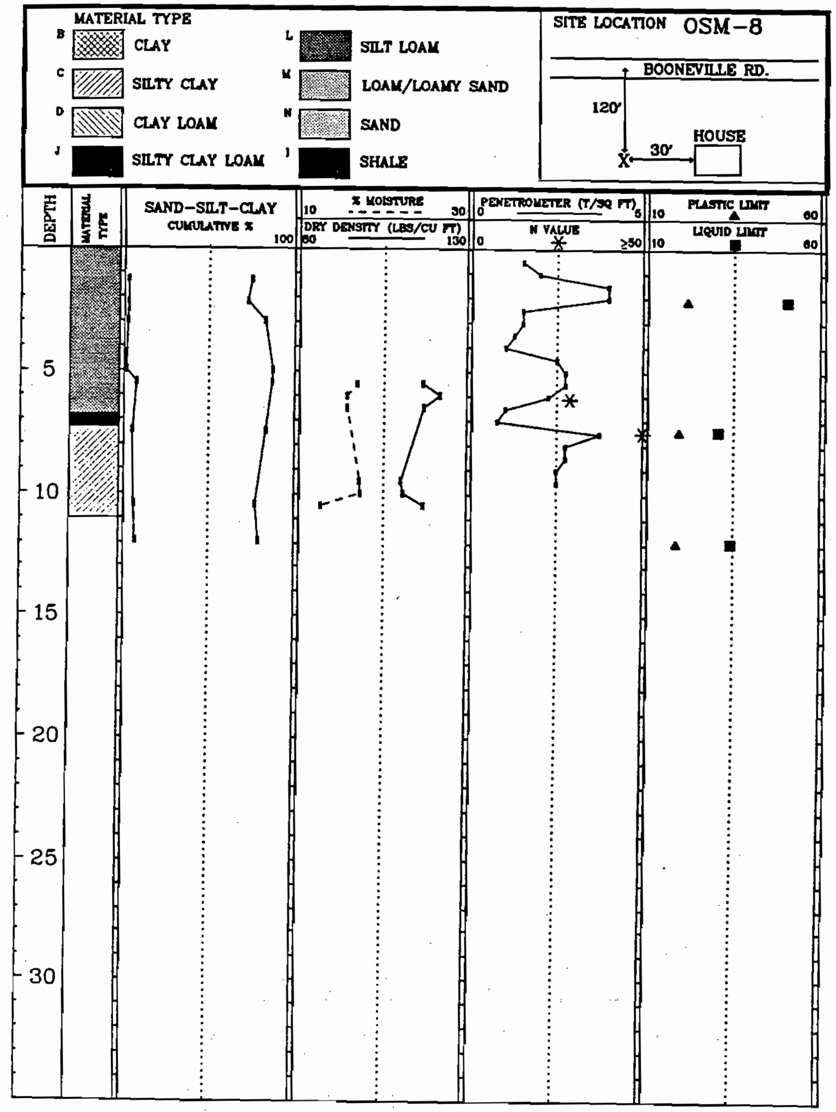
BORING# 8

BORING DATA

LAB ID	BORING	DEPTH inches	% GR	% SA	% SI	% CL	L.L.	P.L.	P.I.	SHRINK. LIMIT %	LINEAL SHRINK. %	CLASS.
891237	OSM8	10-16	0.0	2.2	72.6	25.2						CL,Lean Clay
891238	OSM8	20-26	0.0	2.3	70.3	27.4	51.0	21.0	30.0	6.4	19.8	CH,Fat Clay
891239	OSM8	30-36	0.0	1.7	81.0	17.3						CL,Lean Clay
891240	OSM8	54-60	0.0	1.1	86.1	12.8						ML,Silt
891241	OSM8	60-66	0.0	7.2	79.6	13.2						ML,Silt
891242	OSM8	84-90	0.0	4.9	78.3	16.7	30.9	19.1	11.8	16.7	7.3	CL,Lean Clay
891243	OSM8	120-126	0.0	6.0	71.4	22.6						CL,Lean Clay
891244	OSM8	138-144	0.0	6.7	72.6	20.7	34.3	18.4	15.9	13.9	10.4	CL,Lean Clay

BORING	DEPTH in.	P.P. t/sq ft	N VAL
OSM-8	6	1.50	
OSM-8	12	2.00	
OSM-8	18	4.00	
OSM-8	24	4.00	
OSM-8	30	1.50	
OSM-8	36	1.50	
OSM-8	42	1.25	
OSM-8	48	1.00	
OSM-8	54	2.50	
OSM-8	60	2.75	
OSM-8	66	2.75	
OSM-8	72	2.25	29
OSM-8	78	1.00	
OSM-8	84	0.75	
OSM-8	90	3.75	50
OSM-8	96	2.75	
OSM-8	102	2.75	
OSM-8	108	2.50	
OSM-8	114	2.50	

LAB ID	BORING	SAMP DEPTH inches	% MOIS	DRY DENS lbs/cu ft
890909	OSM-8	66	17.0	116.9
890910	OSM-8	72	15.8	121.9
890911	OSM-8	78	15.8	117.1
890912	OSM-8	114	17.3	110.4
890913	OSM-8	120	17.4	111.1
890914	OSM-8	126	12.7	117.1

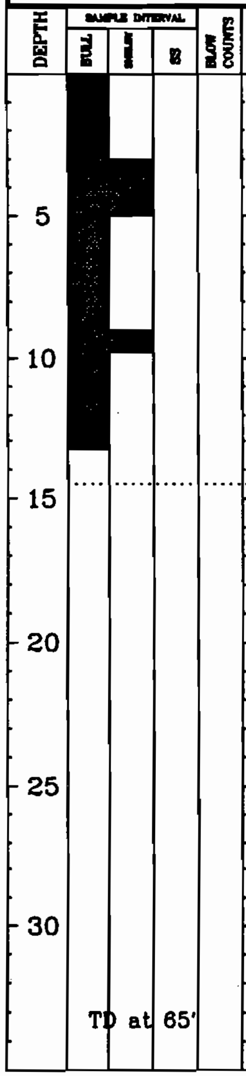


INDIANA GEOLOGICAL SURVEY — Dept. of Natural Resources, State of Indiana

OSM–EVANSVILLE PROJECT

BORING# 9
Page 1 of 1

LOCATION: 1/4 SE 1/4 SE 1/4 SE 1/4 SEC 24 T. 5 S. R.10 W. ELEVATION: 380'
DATE: METHOD: 4 IN. RIG: B–34 DRILLED BY: ARNOLD/RIDDLE
GAMMA LOGGED BY: CHITWOOD DESCRIBED BY: BLEUER



DESCRIPTION

FILL - 0-6" silty clay loam, compacted

6-12" mixed medium gravel and macadam

B1 - 12-30" silty clay loam; massive to weak subangular blocky; 2.5Y 6/4, few, fine diffuse 6/2 mottles; some discontinuous clay films; common roots and tubules

B21g - 30-48" silty clay loam; strong, fine subangular blocky; 2/5Y 6/2 with thin, discontinuous clay films, common very fine 2/2 manganese splotches and tubule stains

B22g - 48-55" silty clay loam; strong medium subangular blocky; 2.5YR 5/2, with some discontinuous thin, 2.5Y 6/2-6/6 clay films and diffuse, fine 5/6 mottles; scattered carbonate nodules at base

no samples, 55-120"

B3g - 120-145" silty clay loam; massive; 10YR 5/4-6, with few, fine to medium, distinct 6/1 mottled surfaces and tubule gleying, medium, discontinuous 5/2 clay films and abundant carbonate nodules on joint surfaces (130"+)

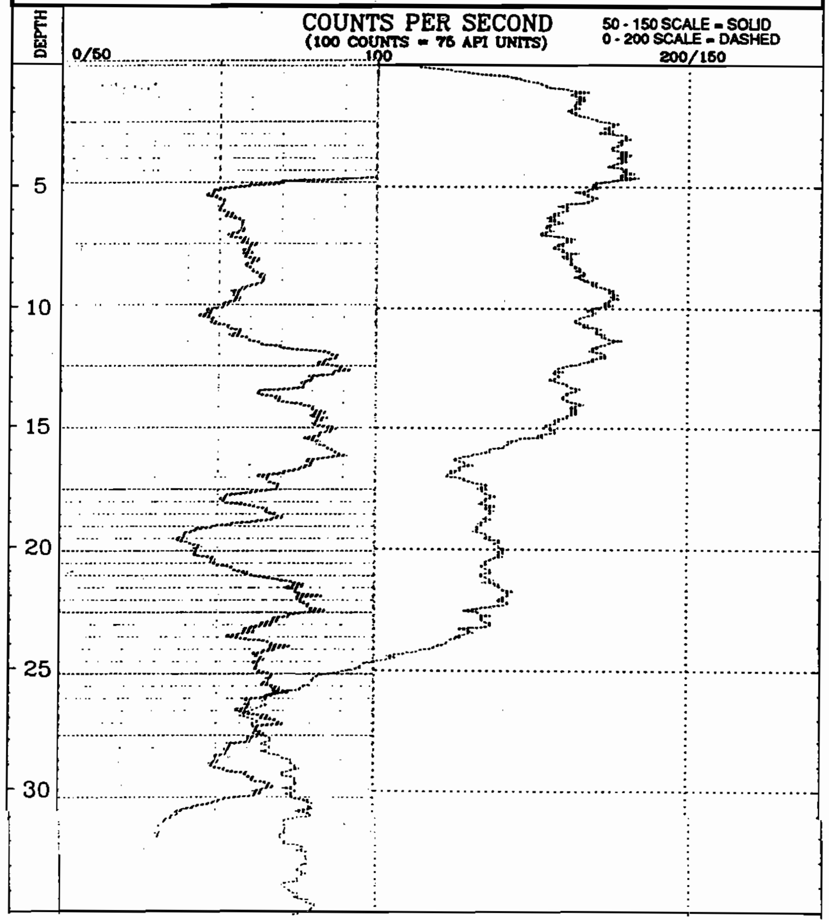
C - 155-160" clayey silt; massive; 2.5Y 6/4 (bull sample; 0-160" from hole 9A)

no samples, 160" to 39'

39'-43.5' laminated clay and fine silt, massive silt below 42.5'

NATURAL GAMMA–RAY LOG

TC = 5 RATE = 5 FT/MIN OSM–9 LOG # 89–322



INDIANA GEOLOGICAL SURVEY — Dept. of Natural Resources, State of Indiana

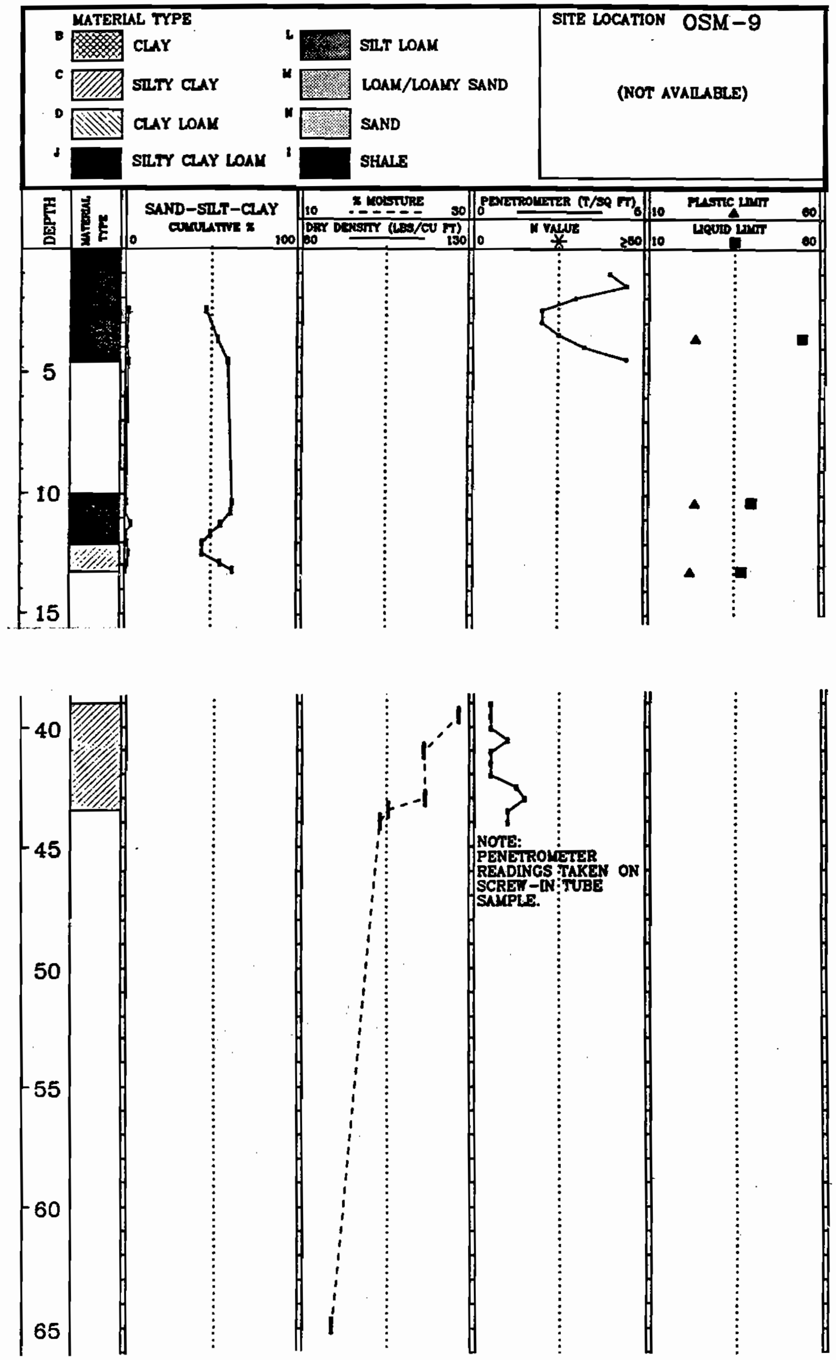
OSM–EVANSVILLE PROJECT — BORING# 9

BORING DATA

LAB ID	BORING	DEPTH inches	% GR	% SA	% SI	% CL	L.L.	P.L.	P.I.	SHRINK. LIMIT %	LINEAL SHRINK. %	CLASS.
891313	OSM9	24-30	0.0	1.7	44.8	53.4						CH,Fat Clay
891314	OSM9	38-44	0.0	1.2	52.3	46.4	54.3	23.6	30.7	12.3	17.9	CH,Fat Clay
891315	OSM9	49-55	0.0	1.9	57.6	40.5						CH,Fat Clay
891316	OSM9	120-125	0.0	0.9	61.4	37.7	40.1	23.2	16.9	14.6	12.0	CL,Lean Clay
891317	OSM9	125-130	0.0	0.5	61.1	38.4						CL,Lean Clay
891318	OSM9	130-135	1.3	3.7	52.0	43.1						CH,Fat Clay
891319	OSM9	135-140	0.0	0.9	49.1	50.0						CH,Fat Clay
891320	OSM9	140-145	1.1	1.5	43.5	53.9						CH,Fat Clay
891321	OSM9	145-150	0.0	2.4	42.4	55.2						CH,Fat Clay
891322	OSM9	150-155	0.2	1.4	53.8	44.6						CH,Fat Clay
891323	OSM9	155-158	0.0	0.5	62.0	37.5	36.9	22.0	14.9	NA	NA	CL,Lean Clay

BORING	DEPTH in.	P.P. t/sq ft	N VAL
OSM-9	12	4.00	
OSM-9	18	4.50	
OSM-9	24	3.00	
OSM-9	30	2.00	
OSM-9	36	2.00	
OSM-9	42	2.50	
OSM-9	48	3.25	
OSM-9	54	4.50	
OSM-9	468	0.50	
OSM-9	474	0.50	
OSM-9	480	0.50	
OSM-9	486	1.00	
OSM-9	492	0.50	
OSM-9	498	0.50	
OSM-9	504	0.50	
OSM-9	510	1.25	
OSM-9	516	1.50	
OSM-9	522	1.00	
OSM-9	528	1.00	

LAB ID	BORING	SAMP DEPTH inches	% MOIS	DRY DENS lbs/cu ft
891022	OSM-9	474	28.8	na
891023	OSM-9	492	24.6	na
891024	OSM-9	516	24.8	na
891025	OSM-9	522	20.4	na
891026	OSM-9	528	19.4	na
891122	OSM-9	780	13.6	na



INDIANA GEOLOGICAL SURVEY — Dept. of Natural Resources, State of Indiana

OSM–EVANSVILLE PROJECT

BORING# 10
Page 1 of 1

LOCATION: 1/4 NE 1/4 NE 1/4 NW 1/4 SEC 28 T. 5 S. R. 10 W. ELEVATION: 430'
DATE: METHOD: 4 IN. RIG: B-34 DRILLED BY: ARNOLD/RIDDLE
GAMMA LOGGED BY: CHITWOOD DESCRIBED BY: BLEUER

DEPTH | SAMPLE INTERVAL (BULL, SHELBY, SS) | BLOW COUNTS | DESCRIPTION

AP - 0-5" silt loam; massive to weak, fine subangular blocky, medium platy in bottom half; 10YR 5/6

B1 - 5-13" silt loam; massive; 10Y/4 5/6, diffusely stained 5/6; trace fine roots

B21x - 13-27" silt loam; strong, welded, fine subangular blocky; 10YR 5-6/6, with 5/6, thin to thick clay films, with continuous, medium 7/2 joint fills and some small splotches of fine silt; few root tubules, modern roots

B22x - 27-36 silt loam; fine to medium subangular blocky; 10YR 5/4 with 7/2 silt coats on 70% of ped exteriors

IIB2b - 36-60" silt loam to silty clay loam; strong, fine subangular blocky, individual peds appear eroded along some open joits; 10YR 5/6 with common heavy, continuous 4/6 clay films, discontinuous, heavy 2/2 manganese staining on primary joints, lower half contains continuous joint coats and pelletoid masses of manganese medium; continuous 7/2 silt films along major joints; lower 10"is open framework of coarse sand composed of manganese and clay pellets separated by open voids or thick clay films, discrete clasts (?) of clay (shale) in lower 5"; base marked by iron cemented sandstone clasts

IIIB3b - 60-90" clay; massive to moderate, medium subangular blocky; 2.5Y6/6, 50% diffusely stained 7.5YR 5/6-6/8 with common,m thin to medium, continuous 6/6 clay films on peds, slickensides, and highly inclined joint surfaces; below 10" composed of 1/16-1/4" irregular, tabular clasts, generally horizontally oriented, broken by continuous, anastamosing 2.5Y 6/2 clay fill, individual clasts totally surrounded

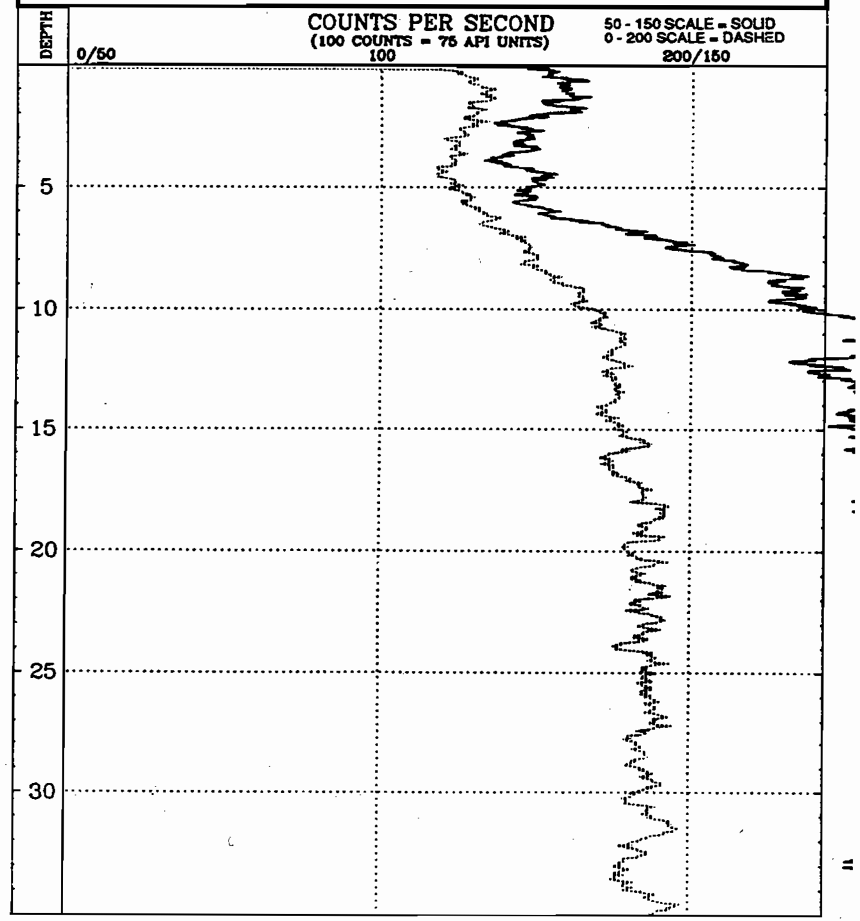
IIICc - 90-136" shale, firm to hard; some incline joints with slickensides cross core

Commments: Entire IIB2b is colluvial debris.

Water at 37'
TD at 39'

NATURAL GAMMA–RAY LOG

TC = 5 RATE = 5 FT/MIN OSM–10 LOG # 89–334



INDIANA GEOLOGICAL SURVEY — Dept. of Natural Resources, State of Indiana

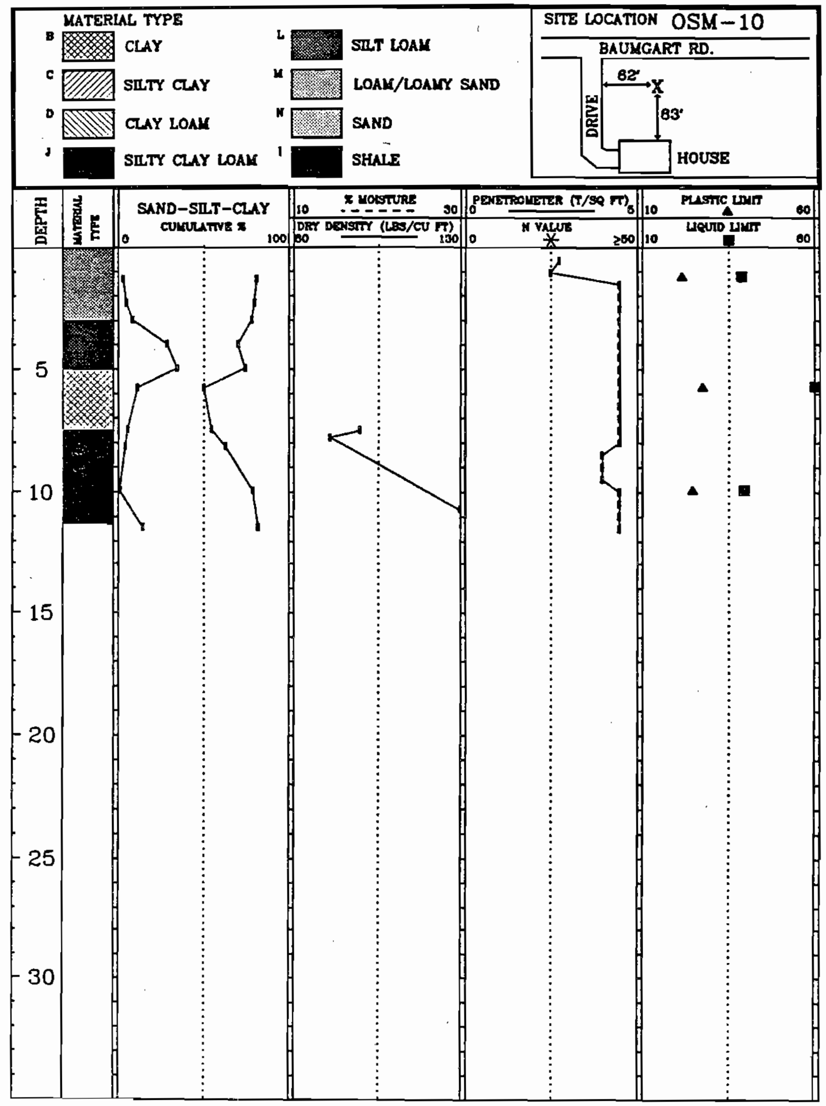
OSM–EVANSVILLE PROJECT — BORING# 10

BORING DATA

LAB ID	BORING	DEPTH inches	% GR	% SA	% SI	% CL	L.L.	P.L.	P.I.	SHRINK. LIMIT %	LINEAL SHRINK. %	CLASS.
891294	OSM10	9-15	0.0	2.5	78.1	19.4						CL,Lean Clay
891295	OSM10	22-28	0.0	4.4	75.0	20.6	38.4	21.4	17.0	20.5	8.2	CL,Lean Clay
891296	OSM10	30-36	0.0	8.0	69.9	22.1						CL,Lean Clay
891297	OSM10	42-48	0.0	28.2	41.8	30.1						CL,Lean Clay with Sand
891298	OSM10	54-60	0.4	34.0	40.1	25.5						CL,Sandy Lean Clay
891299	OSM10	64-70	0.0	10.9	39.0	50.1						CH,Fat Clay
891300	OSM10	84-90	0.0	5.1	49.2	45.7	66.3	28.0	38.3	12.6	20.5	CH,Fat Clay
891301	OSM10	93-98	0.0	3.8	58.7	37.5						CH,Fat Clay
891302	OSM10	114-120	0.0	0.6	78.1	21.4						CL,Lean Clay
891303	OSM10	130-138	0.0	13.9	67.8	18.3	39.3	24.0	15.3	17.4	10.0	CL,Lean Clay

BORING	DEPTH in.	P.P. t/sq ft	N VAL
OSM-10	6	2.75	
OSM-10	12	2.50	
OSM-10	18	4.50	
OSM-10	24	4.50	
OSM-10	30	4.50	
OSM-10	36	4.50	
OSM-10	42	4.50	
OSM-10	48	4.50	
OSM-10	54	4.50	
OSM-10	60	4.50	
OSM-10	66	4.50	
OSM-10	72	4.50	
OSM-10	78	4.50	
OSM-10	84	4.50	
OSM-10	90	4.50	
OSM-10	96	4.50	
OSM-10	102	4.00	
OSM-10	108	4.00	
OSM-10	114	4.00	
OSM-10	120	4.50	
OSM-10	126	4.50	
OSM-10	132	4.50	
OSM-10	138	4.50	

LAB ID	BORING	SAMP DEPTH inches	% MOIS	DRY DENS lbs/cu ft
	OSM-10	90	na	99.8
	OSM-10	94	na	90.9
	OSM-10	130	na	130.3

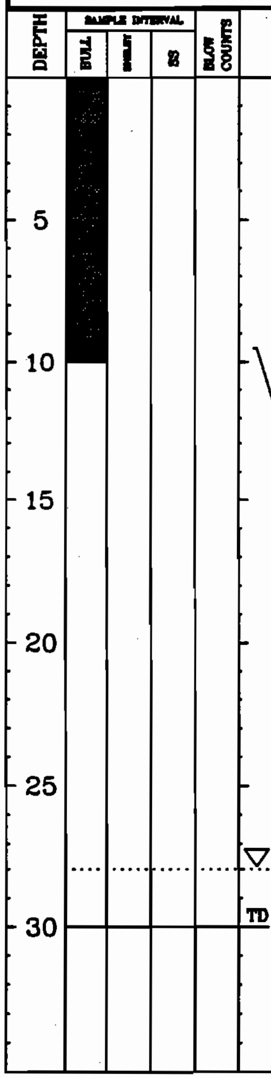


INDIANA GEOLOGICAL SURVEY — Dept. of Natural Resources, State of Indiana

OSM–EVANSVILLE PROJECT

BORING# 11
Page 1 of 1

LOCATION: 1/4 NE 1/4 NE 1/4 NW 1/4 SEC 26 T. 5 S. R. 10 W. ELEVATION: 415'
DATE: METHOD: 4 IN. RIG: B-34 DRILLED BY: ARNOLD/RIDDLE
GAMMA LOGGED BY: CHITWOOD DESCRIBED BY: BLEUER



DESCRIPTION

AP - 0-8" silt loam; massive; 10YR 5/4

B1 - 8-10" silt loam; weak, medium subangular blocky; 10YR 6/6, with thin, discontinuous 5/6 clay films

B2 - silt loam; moderate medium to coarse subangular blocky; 10YR 5/4 with continous, thin 4-5/6 clay films, common diffuse 5/6 staining and darker tubules

B3 - 32-45" silt loam; coarse platy; 10YR 6/6; common vertical joints with thin to medium 6/2 silt coats

C1 - 45-80" silt loam; massive; 10YR 5/6

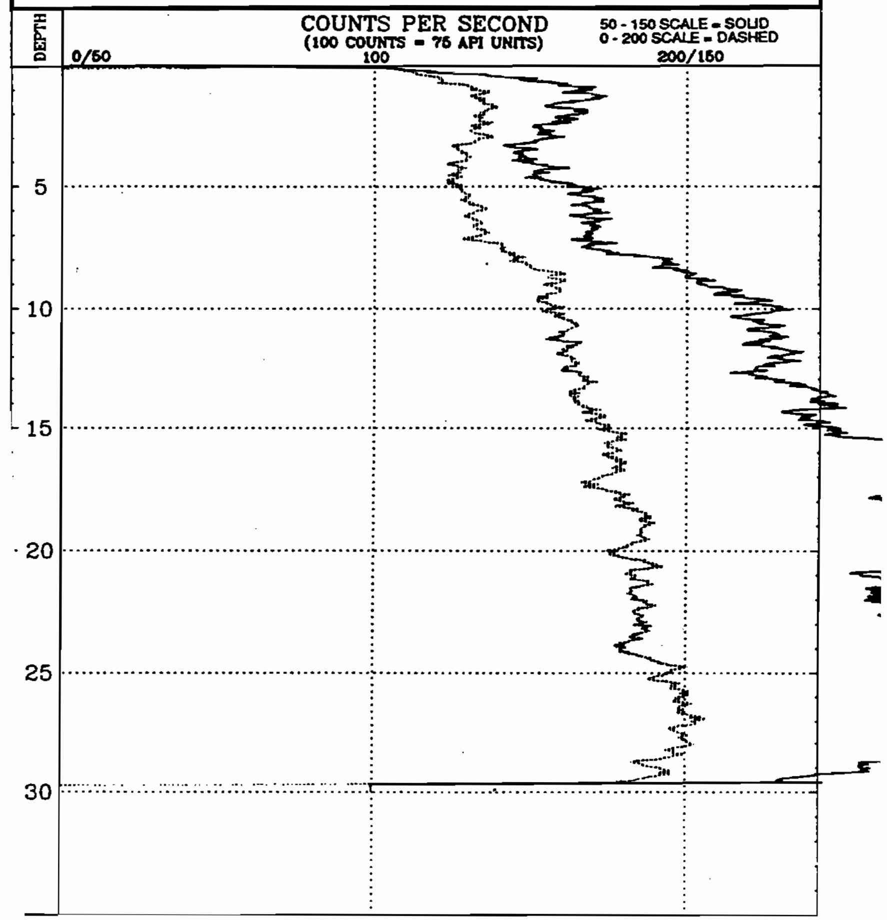
C2 - 80-90" as above, diffuse, coarse mottling, 10YR 5/4-6/8, many small 2/2 manganese concretions

IIC - silt loam; massive; distinct, fine mottling 10YR 6/2-7/6

IIIB3 - 94-114" as above, grades to coarse/fragmental gray sale; tradce of thick, 10YR 5/2, medium clay films in joints and anastamosing fill between fragments

NATURAL GAMMA–RAY LOG

TC = 5 RATE = 5 FT/MIN OSM–11 LOG # 89–338



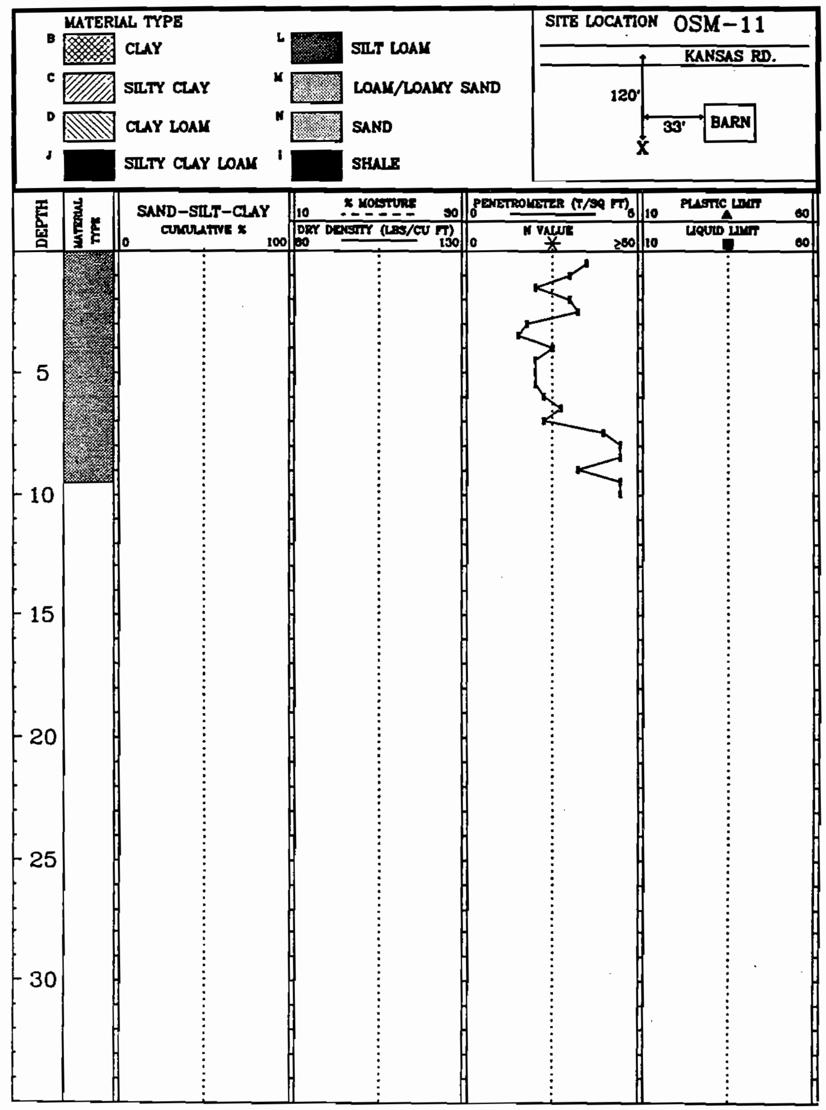
INDIANA GEOLOGICAL SURVEY — Dept. of Natural Resources, State of Indiana

OSM-EVANSVILLE PROJECT

BORING# 11

BORING DATA

BORING	DEPTH in.	P.P. t/sq ft	N VAL
OSM-11	6	3.50	
OSM-11	12	3.00	
OSM-11	18	2.00	
OSM-11	24	3.00	
OSM-11	30	3.25	
OSM-11	36	1.75	
OSM-11	42	1.50	
OSM-11	48	2.50	
OSM-11	54	2.00	
OSM-11	60	2.00	
OSM-11	66	2.00	
OSM-11	72	2.25	
OSM-11	78	2.75	
OSM-11	84	2.25	
OSM-11	90	4.00	
OSM-11	96	4.50	
OSM-11	102	4.50	
OSM-11	108	3.25	
OSM-11	114	4.50	
OSM-11	120	4.50	



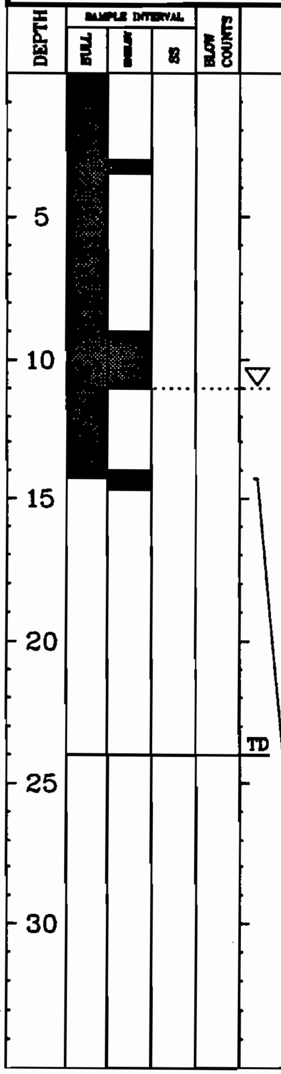
INDIANA GEOLOGICAL SURVEY

Dept. of Natural Resources
State of Indiana

OSM–EVANSVILLE PROJECT

BORING# 12
Page 1 of 1

LOCATION: 1/4 SW 1/4 NE 1/4 NW 1/4 SEC 26 T. 5 S. R.10 W. ELEVATION: 390'
DATE: METHOD: 4 IN. RIG: B–34 DRILLED BY: ARNOLD/RIDDLE
GAMMA LOGGED BY: CHITWOOD DESCRIBED BY: BLEUER



DESCRIPTION

AP1 - 0-7" silt loam; medium platy; 10YR 5/3; common live roots

AP2 - 7-11" silt loam; massive; some evidence of disrupted fine blocky structure; 10YR 6/2, streaks to 4/2

B21g - 11-18" silt loam; massive; 2.5Y 5.5/2, with common 7/2 streaking, small splotches and tubule staining

B22g - 18-32" silt loam; massive; 2.5Y 5/2, with common 5/2-8/2 fine streaks and splotches of fine silt, 30% fine, distinct mottles to 7.5Y 5/8

B3g - 22-48" silt loam; massive; cut locally by zones of intense fine, blocky to granular structure with high porosity, with scattered root traces and thin to medium clay films

IIB3 - 48-66" clay; massive; fine, distinct mottling 2.5Y 7/0 and 10YR 5/6; krotovina chamber 50-55" of massive 7/2 clay, with irregular, compacted, granular mixture of coarse clay clasts

IIIB2b - 66-96" clay loam to silty clay loam; fine to medium subangular blocky; 7.5YR 6-7/8, cut by 2.5Y 7/2-4, continuous, medium to thick clay films on anastomosing root traces and ped surfaces; common fine root tubules with 2/2 coats, including several root-filled joints that penetrate top 12" of unit, few below; lower 9" massive, 7.5 YR 6/8, with 20" gleying on tubules and curvilinear joints

IVC - 96-122" silt loam; massive; 10YR 6/8, with 10YR 5-6/1 gleying and medium clay films on root tubules in lower 2/3

IVB1b - 122-127" silt loam (heavy); massive to very weak, fine subangular blocky; 10YR 6/6-8, diffusely 2.5Y 6/4, common 6-7/1 gleying and thin films on irregular joint surfaces

IVB2b - 127-137" silt loam (heavy); moderate, fine subangular blocky; vari-colored 10YR 5-7/6, common 4-6/1 gleying and thin films on joints

IVB31b - 137-150" silt loam; massive to fine subangular blocky, grading to irregular coarse platy in lower part, defined by darker iron staining; 10YR 6-7/1, some fine to medium, diffuse 5-6/8 mottles

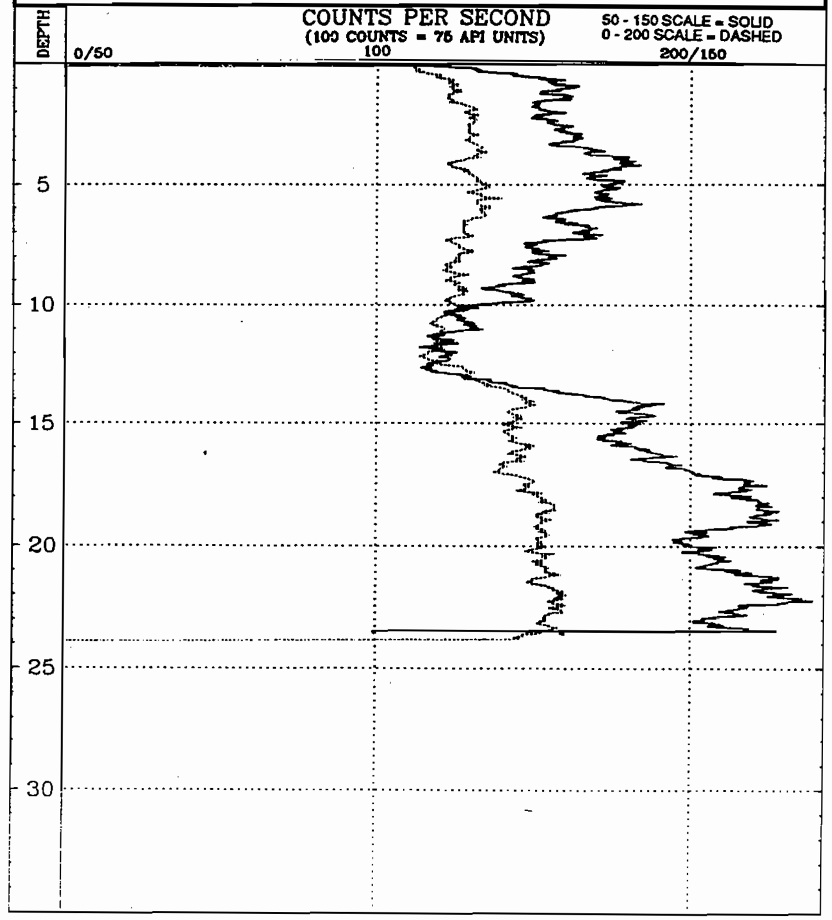
VB32b - 150-156" silt loam; massive to medium platy (apparently derived from underlying bedding structure); 2.5Y 6/6 with 40% fine, distinct mottles to 7/2, with some 2/2 manganese stains on fine hairline joints and blotches

VC - 156-172" silty clay loam; preserves subhorizontal original bedding planes; 10YR 6/6 with 2/2 manganese concretions and blebs in top 6"

Comments: IVB -VB/C profile, though silt loam, is assumed to be derived loess mixture overlying shale. This lower profile lacks the gradation of finely disaggregated clay pellets common to many other holes. The clay/silt sequences separated by the overlying IIIB may represent a mix of loess, lake, and/or slopewash events.

NATURAL GAMMA–RAY LOG

TC = 5 RATE = 5 FT/MIN OSM–12 LOG # 89–340



INDIANA GEOLOGICAL SURVEY

Dept. of Natural Resources
State of Indiana

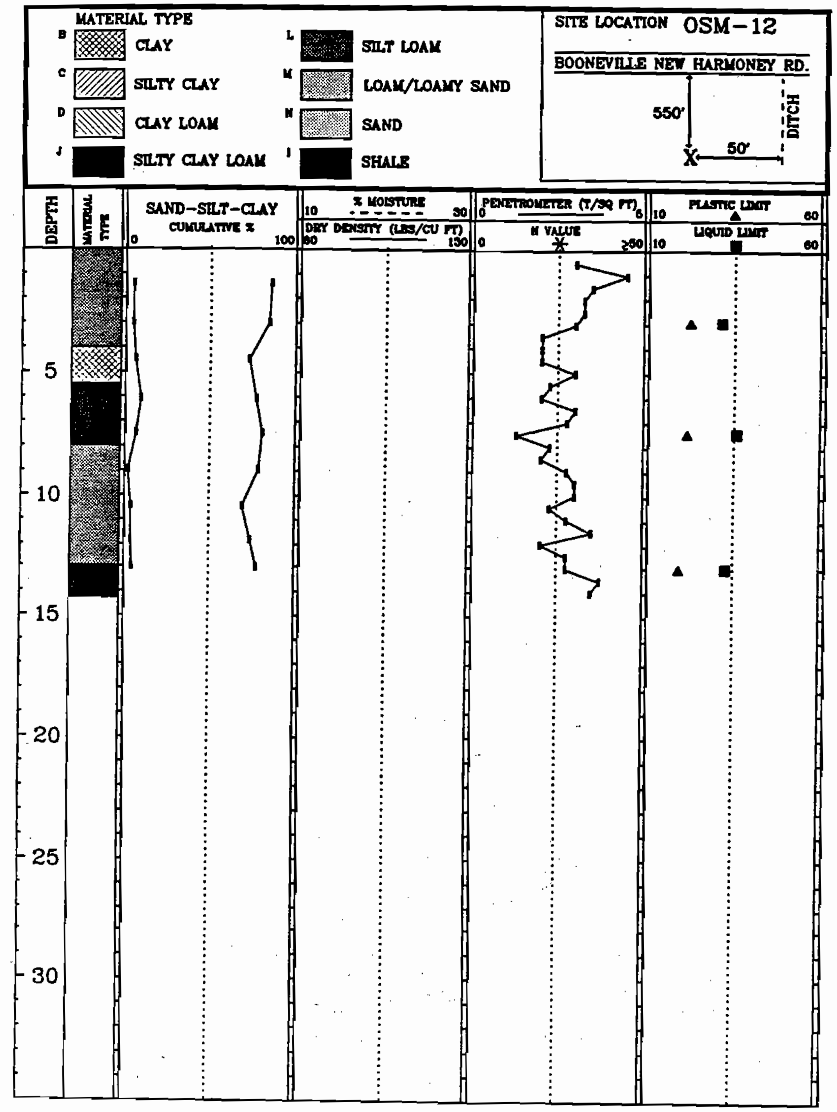
OSM–EVANSVILLE PROJECT

BORING# 12

BORING DATA

LAB ID	BORING	DEPTH inches	% GR	% SA	% SI	% CL	L.L.	P.L.	P.I.	SHRINK. LIMIT %	LINEAL SHRINK. %	CLASS.
891304	OSM12	11-17	0.0	4.4	81.4	14.2						CL,Lean Clay
891305	OSM12	30-36	0.2	4.3	80.3	15.2	30.6	21.7	8.9	16.1	7.3	CL,Lean Clay
891306	OSM12	48-54	0.0	5.8	67.1	27.1						CL,Lean Clay
891307	OSM12	57-73	0.0	8.9	68.3	22.8						CL,Lean Clay
891308	OSM12	84-90	0.0	6.4	74.4	19.1	35.7	21.5	14.2	16.6	9.3	CL,Lean Clay
891309	OSM12	102-108	0.0	2.0	76.8	21.2						CL,Lean Clay
891310	OSM12	120-126	0.0	3.6	65.9	30.5						CL,Lean Clay
891311	OSM12	137-143	0.0	3.8	70.4	25.9						CL,Lean Clay
891312	OSM12	150-156	0.7	4.2	73.7	21.5	32.3	19.3	13.0	13.9	9.3	CL,Lean Clay

BORING	DEPTH in.	P.P. t/sq ft	N VAL
OSM-12	6	3.00	
OSM-12	12	4.50	
OSM-12	18	3.50	
OSM-12	24	3.25	
OSM-12	30	3.25	
OSM-12	36	3.00	
OSM-12	42	2.00	
OSM-12	48	2.00	
OSM-12	54	2.00	
OSM-12	60	3.00	
OSM-12	66	2.25	
OSM-12	72	2.00	
OSM-12	78	3.00	
OSM-12	84	2.75	
OSM-12	90	1.25	
OSM-12	96	2.25	
OSM-12	102	2.00	
OSM-12	108	2.75	
OSM-12	114	3.00	
OSM-12	120	3.00	
OSM-12	126	2.25	
OSM-12	132	2.75	
OSM-12	138	3.50	
OSM-12	144	2.00	
OSM-12	150	2.75	
OSM-12	156	2.75	
OSM-12	162	3.75	
OSM-12	168	3.50	



INDIANA GEOLOGICAL SURVEY — Dept. of Natural Resources, State of Indiana

OSM–EVANSVILLE PROJECT

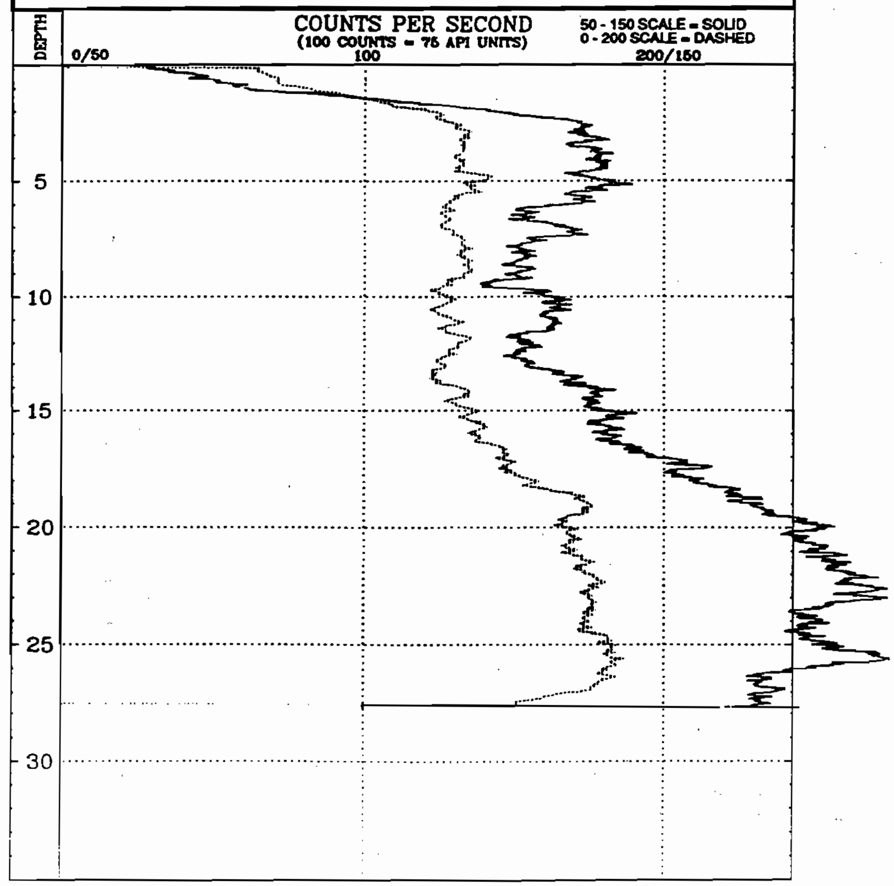
BORING# 13
Page 1 of 1

LOCATION: 1/4 NW1/4 NE 1/4 NE 1/4 SEC 26 T. 5 S. R.10 W. ELEVATION: 410'
DATE: METHOD: 4 IN. RIG: B-34 DRILLED BY: ARNOLD/RIDDLE
GAMMA LOGGED BY: CHITWOOD DESCRIBED BY: BLEUER

DEPTH	SAMPLE INTERVAL: FULL	SAMPLE INTERVAL: SPLIT	SAMPLE INTERVAL: SS	BLOW COUNTS	DESCRIPTION
					AP - 0-9" silt loam; massive; 10YR 5.5/3-8
					B1 - 9-21" silt loam; moderate medium subangular blocky; 10YR 5/4 with continuous, thin 5/4 clay films on prominent joints, common 7/2 thin silt coats
5					B2 - 21-34" silt loam; strong, medium subangular blocky (overall fragmental appearance; 10YR 6/4, with abundant, thick 6/4-7/3 silt coats, few 2/2 manganese veins and fine splotches in lower 4"
					B3 - 34-60" silt loam; massive; diffuse, medium 10YR 6/8-6/2 mottling; few scattered concretions and gleyed krotovina
					60-94" - C silt loam; massive; 10YR 6/5, with few silt coats on joints or tubule walls, few small 2/2 manganese concretions
10					IIB1b - 94-106" silt loam; strong, fine subagular blocky; diffuse, fine to medium, 2.5Y 6/2-6 mottles, with common clay films to 10YR 6/8; common root tubules
					IIB2b - 106-120" silt loam; massive to moderate, medium subangular blocky; 10YR 6/8, with common 2/2 manganese staining and cementation in top part, varicolored darker and gleyed clay films interwoven with 2/2 veins interwoven to base giving overall fragmental appearnce; some root tubules
15					IIIB31 - 120-136" silt loam (heavy); strong, fine to medium subangular blocky, largely welded to massive; 10YR 6/7-8, common 5/6 medium, discontinuous clay films, common, some thick 10YR 6/1 clay films , common 2/6 manganese splotches and pet coats in lower 5"
20				▽	IIIB31 - 136-150" silt loam; massive to weak, fine subangular blocky; 10YR 6/7 with some 7/1 tubule rims
25				TD	
30					

NATURAL GAMMA–RAY LOG

TC = 5 RATE = 5 FT/MIN OSM–13 LOG # 89–342



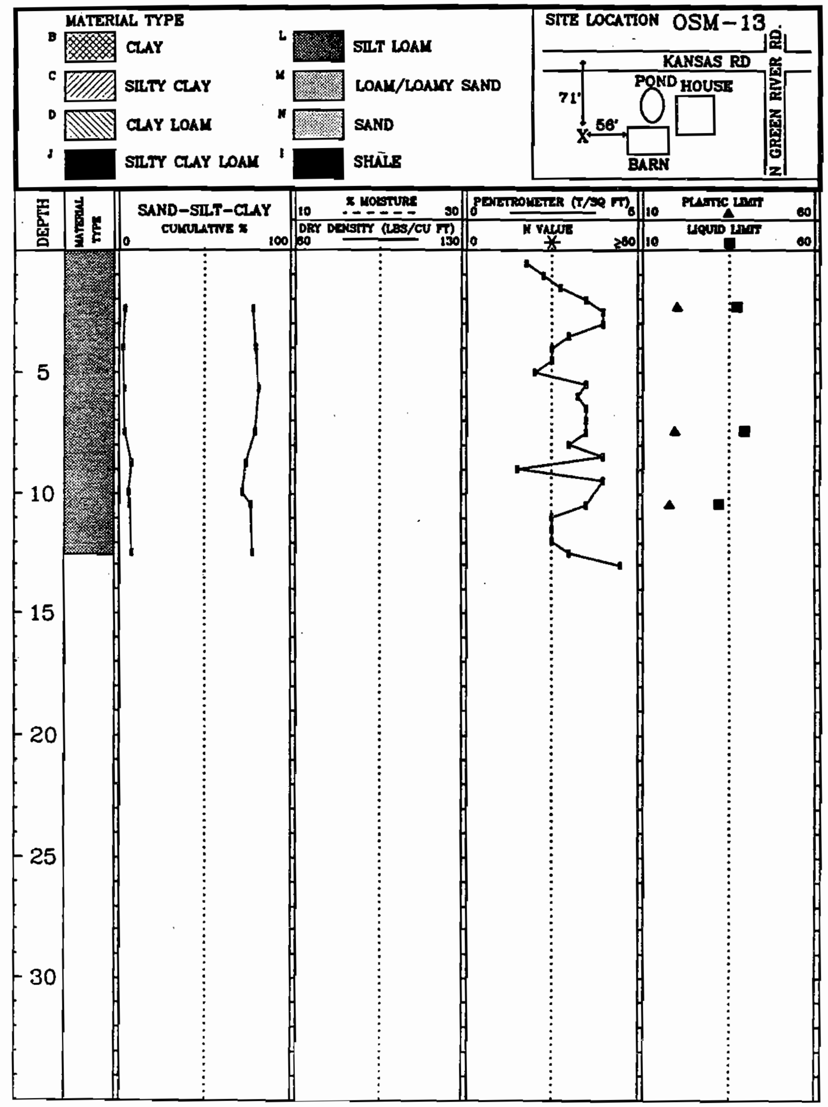
INDIANA GEOLOGICAL SURVEY — Dept. of Natural Resources, State of Indiana

OSM-EVANSVILLE PROJECT — BORING# 13

BORING DATA

LAB ID	BORING	DEPTH inches	% GR	% SA	% SI	% CL	L.L.	P.L.	P.I.	SHRINK. LIMIT %	LINEAL SHRINK. %	CLASS.
891255	OSM13	23-29	0.0	3.4	74.8	21.8						CL,Lean Clay
891256	OSM13	42-48	0.0	2.2	77.6	20.3	37.0	19.7	17.3	19.4	3.2	CL,Lean Clay
891257	OSM13	62-68	0.0	2.9	78.8	18.4						CL,Lean Clay
891258	OSM13	84-90	0.0	3.2	76.2	20.5						CL,Lean Clay
891259	OSM13	100-106	0.0	7.3	66.8	25.9	39.0	19.1	19.9	14.4	11.9	CL,Lean Clay
891260	OSM13	114-120	0.0	5.5	66.6	27.9						CL,Lean Clay
891261	OSM13	120-126	0.0	6.4	70.7	23.0						CL,Lean Clay
891262	OSM13	144-150	0.0	7.4	70.6	22.0	31.4	18.0	13.4	18.2	18.0	CL,Lean Clay

BORING	DEPTH in.	P.P. t/sq ft	N VAL
OSM-13	6	1.75	
OSM-13	12	2.25	
OSM-13	18	2.75	
OSM-13	24	3.50	
OSM-13	30	4.00	
OSM-13	36	4.00	
OSM-13	42	3.00	
OSM-13	48	2.50	
OSM-13	54	2.50	
OSM-13	60	2.00	
OSM-13	66	3.50	
OSM-13	72	3.25	
OSM-13	78	3.50	
OSM-13	84	3.50	
OSM-13	90	3.50	
OSM-13	96	3.00	
OSM-13	102	4.00	
OSM-13	108	1.50	
OSM-13	114	4.00	
OSM-13	120		
OSM-13	126	3.50	
OSM-13	132	2.50	
OSM-13	138	2.50	
OSM-13	144	2.50	
OSM-13	150	3.00	
OSM-13	156	4.50	



INDIANA GEOLOGICAL SURVEY

Dept. of Natural Resources
State of Indiana

OSM–EVANSVILLE PROJECT

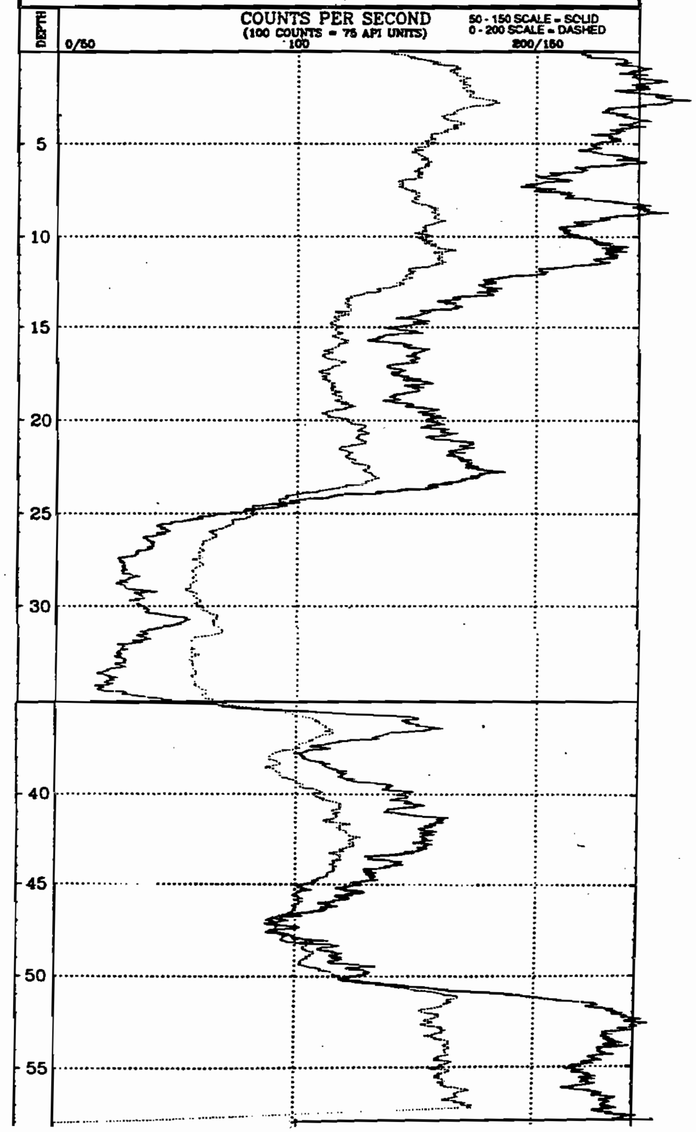
BORING# 14
Page 1 of 1

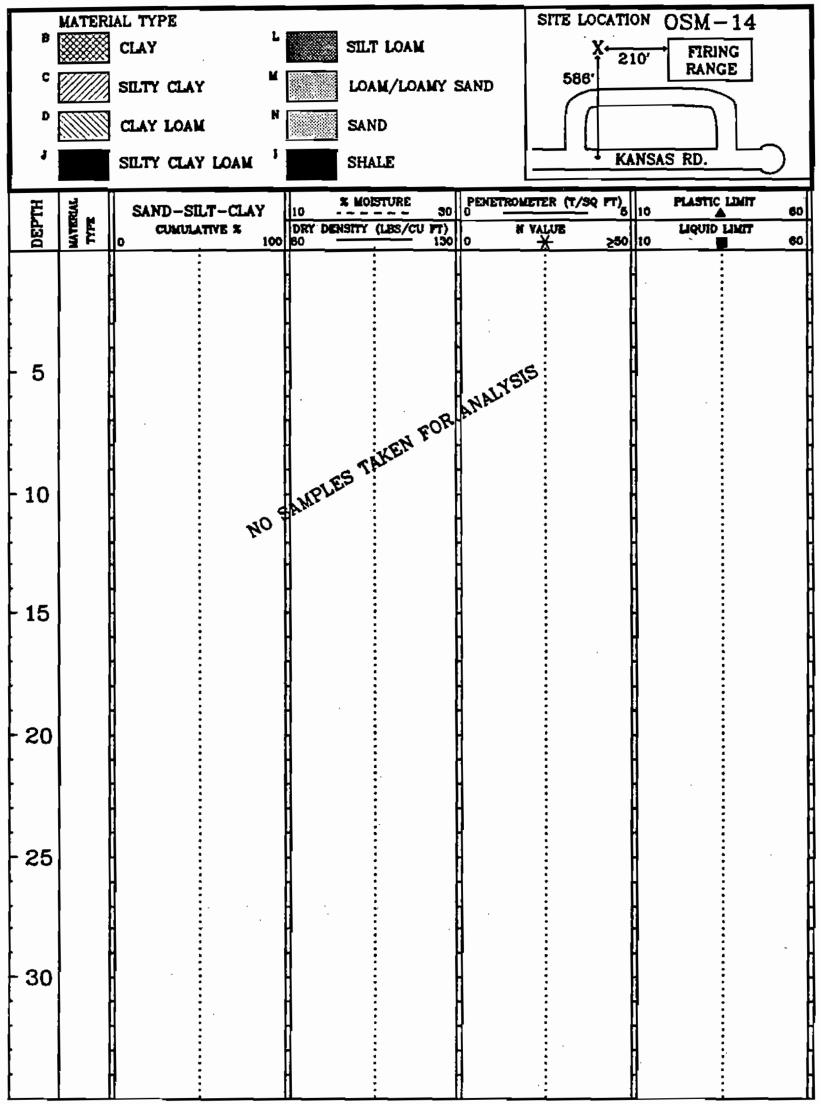
LOCATION: 1/4 SE 1/4 SW 1/4 SE 1/4 SEC 24 T. 5 S. R.10 W. ELEVATION: 380
DATE: METHOD: 4 IN. RIG: B-34 DRILLED BY: ARNOLD/RIDDLE
GAMMA LOGGED BY: CHITWOOD DESCRIBED BY: BLEUER

DEPTH	SAMPLE INTERVAL: BULL	SAMPLE INTERVAL: SHELBY	SAMPLE INTERVAL: SS	BLOW COUNTS	DESCRIPTION
5					GAMMA-RAY LOG ONLY
10					
15					
20					
					WATER (ON RODS)
25					
30					
	TD at 58'				

NATURAL GAMMA-RAY LOG

TC = 5 RATE = 5 FT/MIN OSM-14 LOG # 89-344



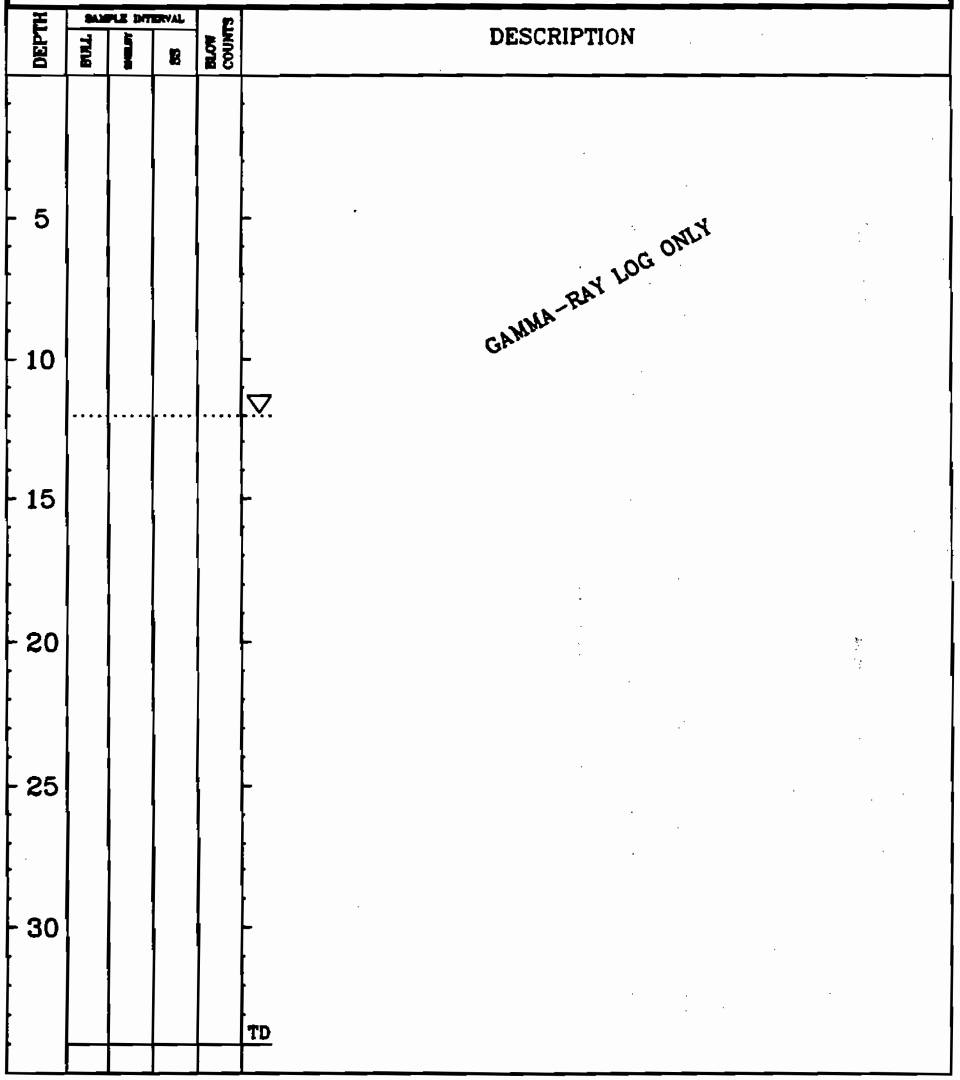

MATERIAL TYPE
B CLAY
C SILTY CLAY
D CLAY LOAM
J SILTY CLAY LOAM
L SILT LOAM
M LOAM/LOAMY SAND
N SAND
I SHALE
SITE LOCATION OSM-14
210'
586'
FIRING RANGE
KANSAS RD.
DEPTH
MATERIAL TYPE
SAND-SILT-CLAY
CUMULATIVE %
0
100
% MOISTURE
10
30
DRY DENSITY (LBS/CU FT)
80
130
PENETROMETER (T/SQ FT)
0
5
N VALUE
0
≥50
PLASTIC LIMIT
10
60
LIQUID LIMIT
10
60
5
10
15
20
25
30
NO SAMPLES TAKEN FOR ANALYSIS

INDIANA GEOLOGICAL SURVEY — Dept. of Natural Resources, State of Indiana

OSM–EVANSVILLE PROJECT

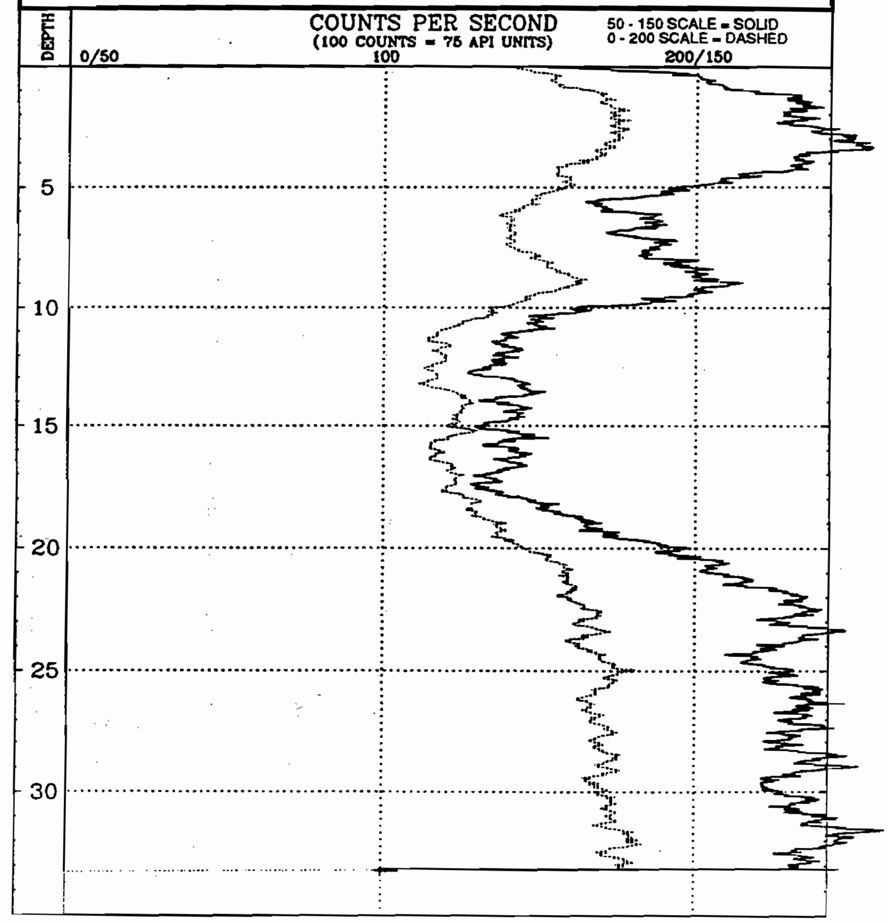
BORING# 15
Page 1 of 1

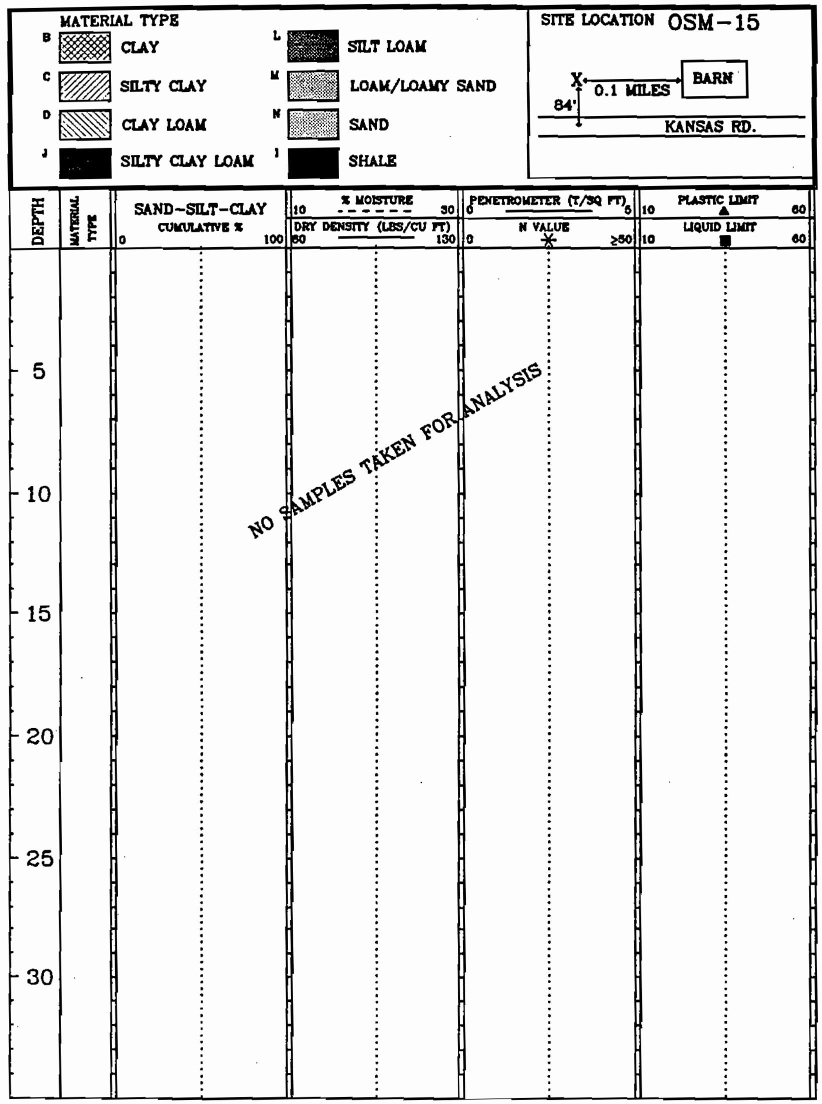
LOCATION: 1/4 SW 1/4 SE 1/4 SW 1/4 SEC 24 T. 5 S. R. 10 W. ELEVATION: 380'
DATE: METHOD: 4 IN. RIG: B-34 DRILLED BY: ARNOLD/RIDDLE
GAMMA LOGGED BY: CHITWOOD DESCRIBED BY: BLEUER



NATURAL GAMMA-RAY LOG

TC = 5 RATE = 5 FT/MIN OSM-15 LOG # 89-346




MATERIAL TYPE
B CLAY
C SILTY CLAY
D CLAY LOAM
J SILTY CLAY LOAM
L SILT LOAM
M LOAM/LOAMY SAND
N SAND
I SHALE
SITE LOCATION OSM-15
X
0.1 MILES
BARN
84'
KANSAS RD.
DEPTH
MATERIAL TYPE
SAND-SILT-CLAY
CUMULATIVE %
0
100
10
% MOISTURE
30
DRY DENSITY (LBS/CU FT)
80
130
0
PENETROMETER (T/SQ FT)
5
N VALUE
0
≥50
10
PLASTIC LIMIT
60
10
LIQUID LIMIT
60
5
10
15
20
25
30
NO SAMPLES TAKEN FOR ANALYSIS

INDIANA GEOLOGICAL SURVEY — Dept. of Natural Resources, State of Indiana

OSM–EVANSVILLE PROJECT

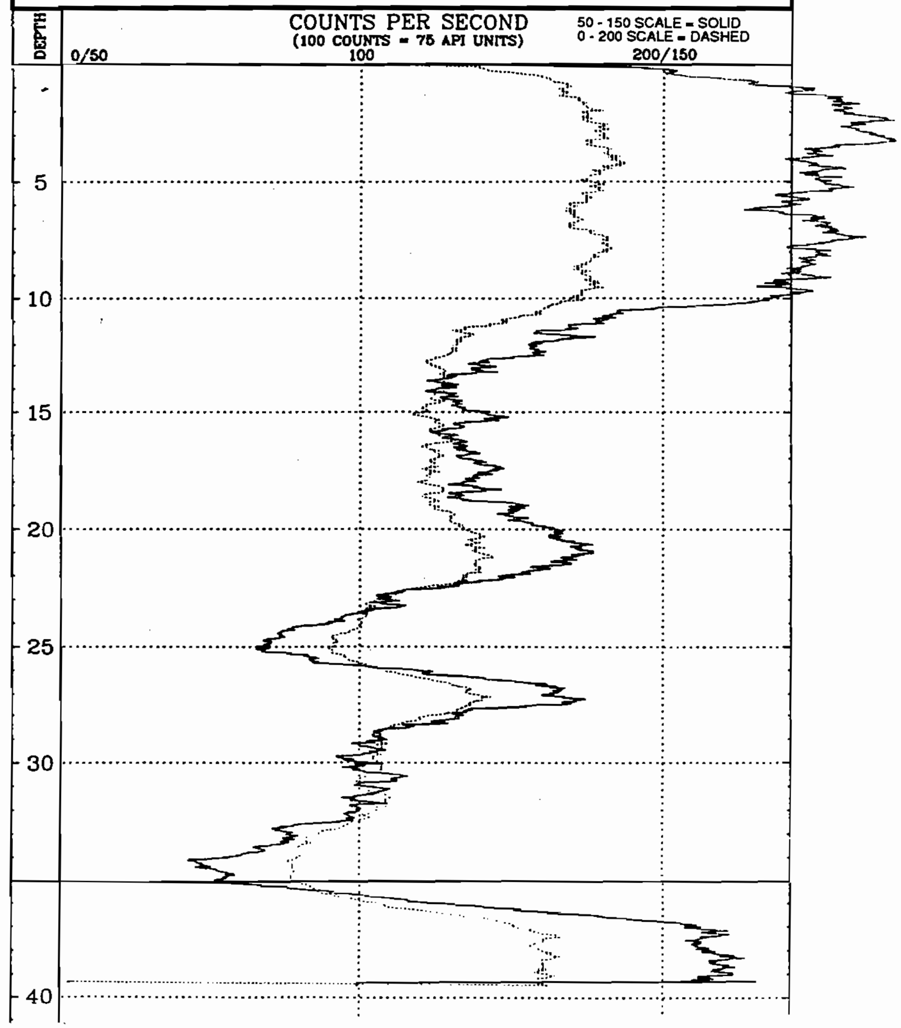
BORING# 16
Page 1 of 1

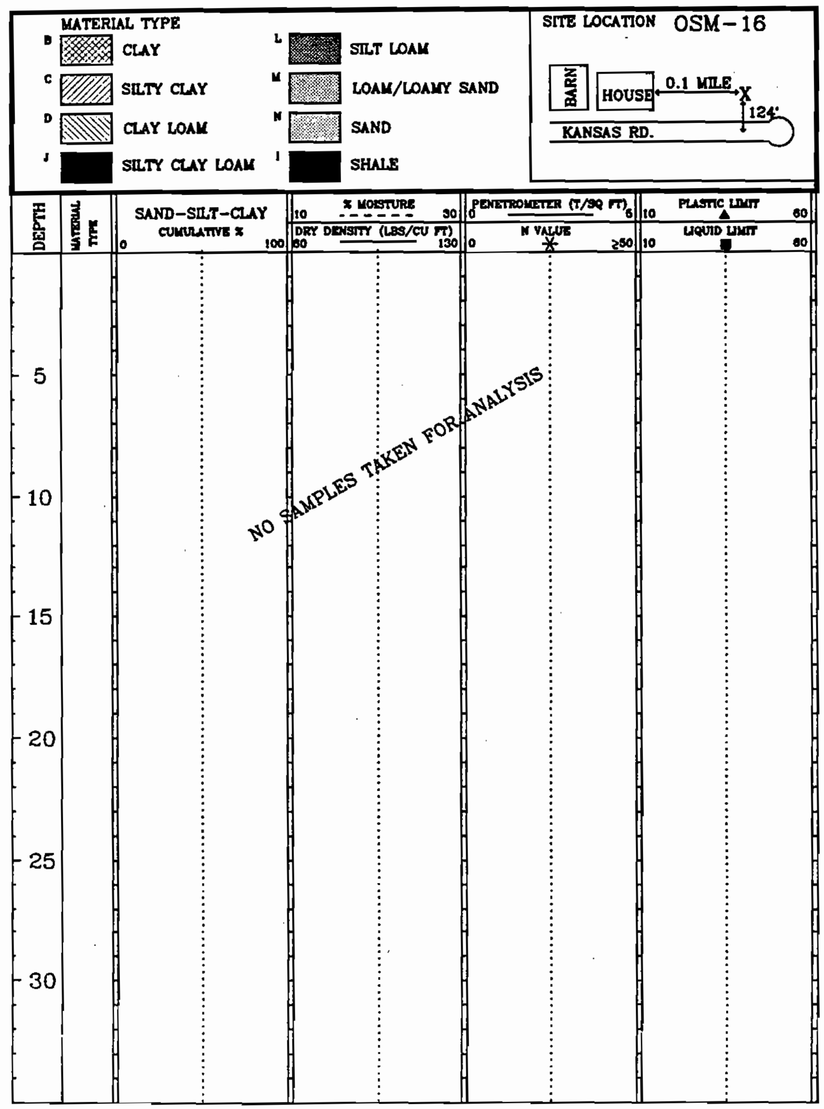
LOCATION: 1/4 SE 1/4 SE 1/4 SW 1/4 SEC 24 T. 5 S. R.10 W. ELEVATION: 380'
DATE: METHOD: 4 IN. RIG: B-34 DRILLED BY: ARNOLD/RIDDLE
GAMMA LOGGED BY: CHITWOOD DESCRIBED BY: BLEUER

DEPTH	SAMPLE INTERVAL: BULL	SAMPLE INTERVAL: SHELBY	SAMPLE INTERVAL: SS	BLOW COUNTS	DESCRIPTION
5					GAMMA-RAY LOG ONLY
10					
15					
20					
25					
30					
	TD at 40'				

NATURAL GAMMA-RAY LOG

TC = 5 RATE = 5 FT/MIN OSM-16 LOG # 89-348





MATERIAL TYPE
B CLAY
C SILTY CLAY
D CLAY LOAM
J SILTY CLAY LOAM
L SILT LOAM
M LOAM/LOAMY SAND
N SAND
I SHALE
SITE LOCATION OSM-16
BARN
HOUSE
0.1 MILE
X
124'
KANSAS RD.
DEPTH
MATERIAL TYPE
SAND-SILT-CLAY CUMULATIVE %
0
100
% MOISTURE
10
30
DRY DENSITY (LBS/CU FT)
60
130
PENETROMETER (T/SQ FT)
0
6
N VALUE
0
≥50
PLASTIC LIMIT
LIQUID LIMIT
10
60
5
10
15
20
25
30
NO SAMPLES TAKEN FOR ANALYSIS

INDIANA GEOLOGICAL SURVEY — Dept. of Natural Resources, State of Indiana

OSM–EVANSVILLE PROJECT

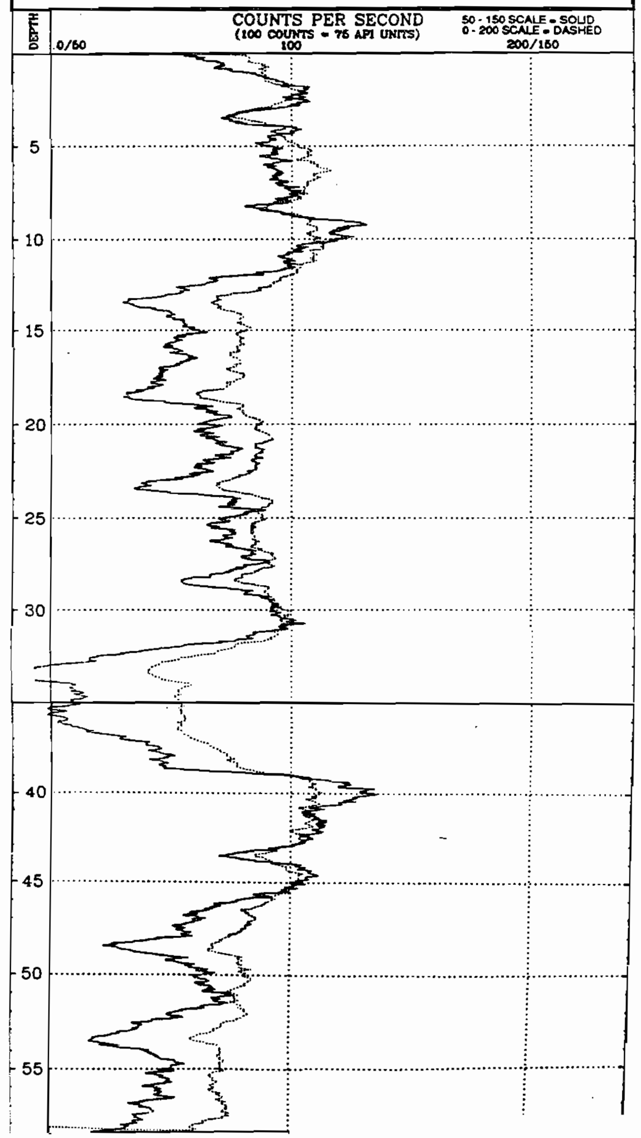
BORING# 17
Page 1 of 1

LOCATION: 1/4 SW 1/4 SW 1/4 SW 1/4 SEC 19 T. 5 S. R.10 W. ELEVATION: 380'
DATE: METHOD: 4 IN. RIG: B-34 DRILLED BY: ARNOLD/RIDDLE
GAMMA LOGGED BY: CHITWOOD DESCRIBED BY: BLEUER

DEPTH	SAMPLE INTERVAL: BULK / SHELBY / SS	BLOW COUNTS	DESCRIPTION
0–5			AP - 0-5" silt loam; massive; 10YR 5/3; sharp base
			C1 5-10 silt loam; massive to medium, coarse platy; 2.5 Y 5/3, plates outlined by 10YR 5/6 staining
			C2 - 10-22" silt loam; massive; diffuse, coarse mottling 2.5Y5/2 - 5/6; abundant live roots and root tubules
5			IIB2gb - 22-36" silty clay loam; moderate, small to medium subangular blocky; 10YR 5/2 with 80% 10YR 4/6 stains, and thick, continuous clay films, common, discontinuous 10YR 6/3 silt coats on joints and vugs in lower 3"; common live roots and tubules, fecal pelets; general open, fragmental appearance
10			IIB31gb - 38-60" silty clay; massive to weak subangular blocky; 2.5Y 4/2 with 40% 10YR-2.5Y 5-6/6 staining on joints and common root tubules
			IIB32gb - 60-90" silty clay; massive; 2.5Y 5/4 with 30% diffuse to distinct, medium mottles; 67-72" zone of distinct, fine 2/2 iron-manganese pelletoid concretions, grading downward to 50% of surfaces, similar zone at 86-90; 78-90" medium, diffuse 2.5Y 6/2 mottles; root tubules throughout
15			IIB33b - 90-150" silty clay; massive; 2.5Y5/4, diffusely stained 5/6, cut by mottled 5/2 gleying and carbonate films on intersecting joint faces; calcareous; common root tubules; 92-95" zone of interbedded 1/16-1/4" carbonate nodules and some 1/2-1" puppies (detrital interbedded?); some carbonate-lined tubules continue to base
			IIC - 150-180" silty clay; massive with suggetion of horizontal layering; 2.5Y 5/6; few root tubules with minor gleying; few snail shell fragments
20			
25			
30			
	TD at 58'		

NATURAL GAMMA-RAY LOG

TC = 5 RATE = 5 FT/MIN OSM-17 LOG # 89-350

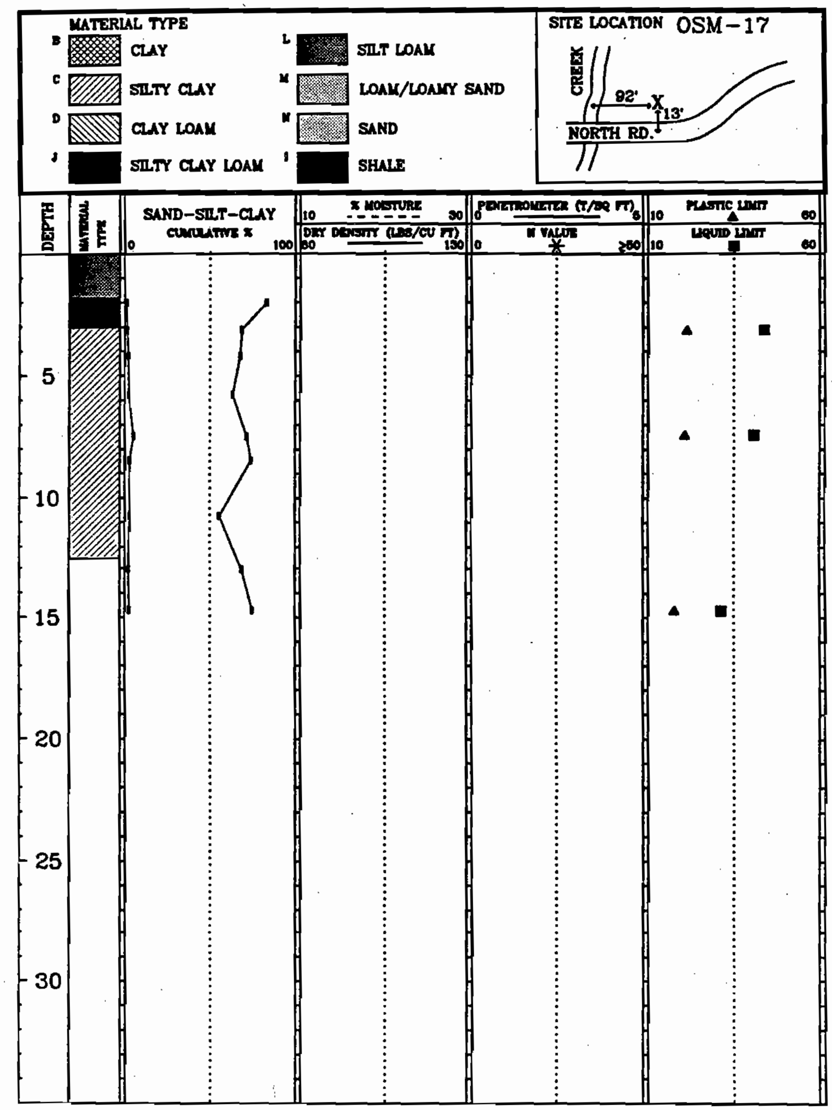


INDIANA GEOLOGICAL SURVEY	Dept. of Natural Resources State of Indiana
OSM-EVANSVILLE PROJECT	BORING# 17

BORING DATA

LAB ID	BORING	DEPTH inches	% GR	% SA	% SI	% CL	L.L.	P.L.	P.I.	SHRINK. LIMIT %	LINEAL SHRINK. %	CLASS.
891223	OSM17	18-24	0.3	0.9	82.2	16.6						CL,Lean Clay
891224	OSM17	31-37	0.0	1.3	67.3	31.4	43.9	21.6	22.3	18.9	18.9	CL,Lean Clay
891225	OSM17	45-50	0.0	1.8	66.0	32.2						CL,Lean Clay
891226	OSM17	64-70	0.0	2.2	61.2	36.6						CL,Lean Clay
891227	OSM17	84-90	0.0	5.0	66.5	28.6	40.9	20.4	20.5	17.3	10.6	CL,Lean Clay
891228	OSM17	97-102	0.2	2.7	71.3	25.8						CL,Lean Clay
891229	OSM17	123-129	0.1	2.7	52.8	44.4						CH,Fat Clay
891230	OSM17	150-156	0.0	1.8	66.7	31.5						CL,Lean Clay
891231	OSM17	170-176	0.3	2.4	72.3	25.0	31.7	17.4	14.3	20.9	5.4	CL,Lean Clay

BORING	DEPTH in.	P.P. t/sq ft	N VAL
OSM-17	6	3.50	
OSM-17	12	4.25	
OSM-17	18	2.75	
OSM-17	24	3.00	
OSM-17	30	3.00	
OSM-17	36	2.50	
OSM-17	42	2.50	
OSM-17	48	2.75	
OSM-17	54	2.50	
OSM-17	60	2.50	
OSM-17	66	2.50	
OSM-17	72	2.25	
OSM-17	78	1.75	
OSM-17	84	2.00	
OSM-17	90	2.50	
OSM-17	96	3.25	
OSM-17	102	4.50	
OSM-17	108	4.50	
OSM-17	114	4.50	
OSM-17	120	4.50	
OSM-17	126	4.50	
OSM-17	156	2.75	
OSM-17	162	2.50	
OSM-17	168	2.25	
OSM-17	174	1.50	
OSM-17	180	0.75	



INDIANA GEOLOGICAL SURVEY — Dept. of Natural Resources, State of Indiana

OSM-EVANSVILLE PROJECT — BORING# 18

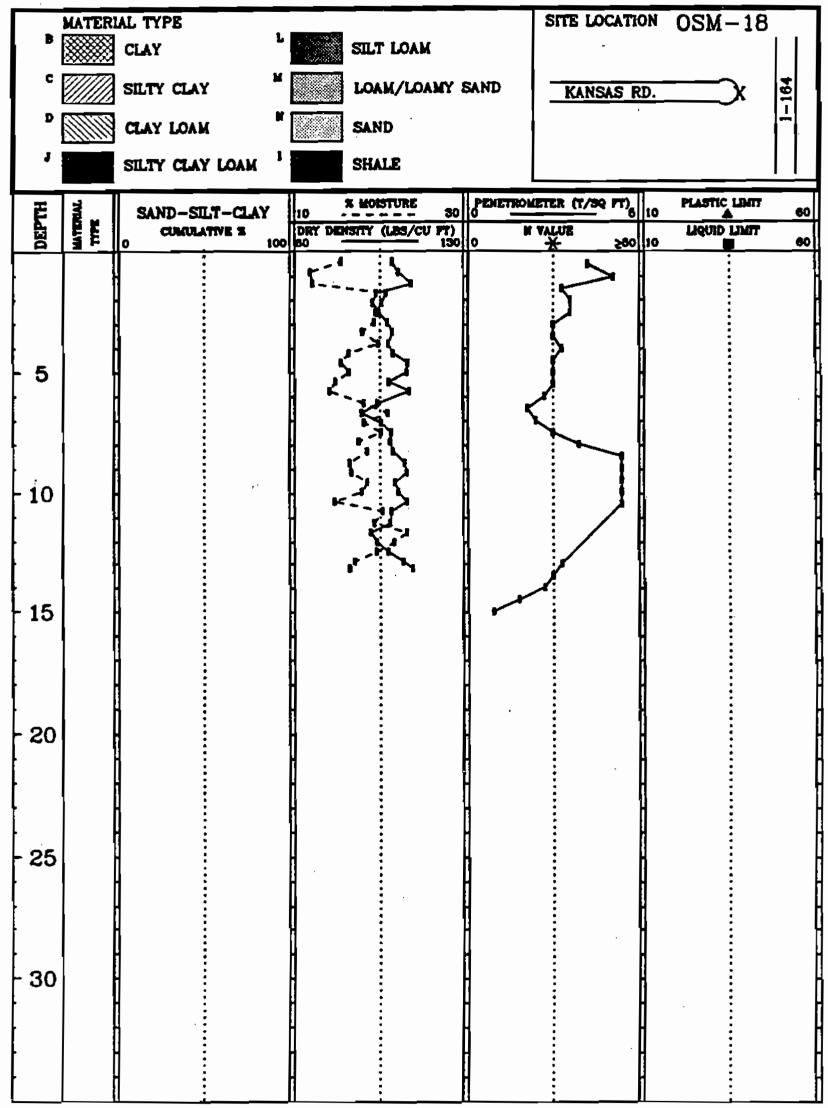
BORING DATA

SEE BORING # 9

FOR LOG

BORING	DEPTH in.	P.P. t/sq ft	N VAL
OSM-18	6	3.50	
OSM-18	12	4.25	
OSM-18	18	2.75	
OSM-18	24	3.00	
OSM-18	30	3.00	
OSM-18	36	2.50	
OSM-18	42	2.50	
OSM-18	48	2.75	
OSM-18	54	2.50	
OSM-18	60	2.50	
OSM-18	66	2.50	
OSM-18	72	2.25	
OSM-18	78	1.75	
OSM-18	84	2.00	
OSM-18	90	2.50	
OSM-18	96	3.25	
OSM-18	102	4.50	
OSM-18	108	4.50	
OSM-18	114	4.50	
OSM-18	120	4.50	
OSM-18	126	4.50	
OSM-18	132		
OSM-18	138		
OSM-18	144		
OSM-18	150		
OSM-18	156	2.75	
OSM-18	162	2.50	
OSM-18	168	2.25	
OSM-18	174	1.50	
OSM-18	180	0.75	

LAB ID	BORING	SAMP DEPTH inches	% MOIS	DRY DENS lbs/cu ft
891090	OSM-18	5	15.5	108.8
891091	OSM-18	10	11.8	110.7
891092	OSM-18	16	12.1	114.5
891093	OSM-18	20	20.8	104.1
891094	OSM-18	25	20.3	103.1
891095	OSM-18	30	19.6	105.0
891096	OSM-18	35	19.4	107.4
891097	OSM-18	40	18.0	108.9
891098	OSM-18	46	19.9	107.7
891099	OSM-18	50	16.4	109.1
891100	OSM-18	55	15.5	113.5
891101	OSM-18	60	16.4	113.2
891102	OSM-18	65	14.8	107.8
891103	OSM-18	70	14.1	113.9
891104	OSM-18	76	18.2	104.5
891105	OSM-18	80	21.0	99.8
891106	OSM-18	85	18.2	105.5
891107	OSM-18	90	20.2	108.6
891108	OSM-18	95	17.6	108.2
891109	OSM-18	100	18.6	109.0
891110	OSM-18	106	16.5	112.6
891111	OSM-18	110	16.7	113.2
891112	OSM-18	115	18.6	109.7
891113	OSM-18	120	17.9	110.7
891114	OSM-18	125	14.7	113.2
891115	OSM-18	130	20.4	108.6
891116	OSM-18	136	19.4	108.2
891117	OSM-18	140	23.3	102.5
891118	OSM-18	145	21.8	104.4
891119	OSM-18	150	19.7	107.6
891120	OSM-18	155	17.1	112.1
891121	OSM-18	158	16.5	114.9



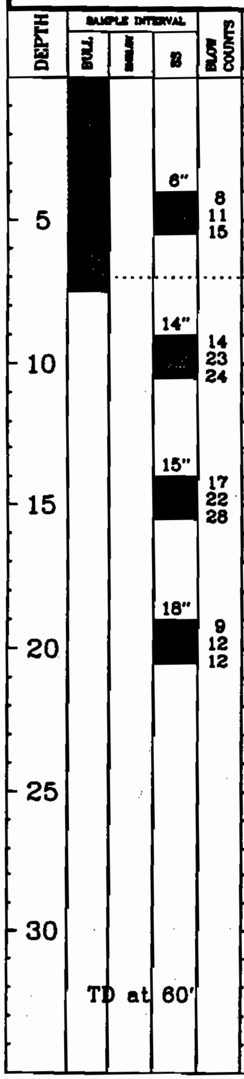
INDIANA GEOLOGICAL SURVEY

Dept. of Natural Resources
State of Indiana

OSM–EVANSVILLE PROJECT

BORING# 19
Page 1 of 1

LOCATION: 1/4 NE 1/4 SW 1/4 SW 1/4 SEC 19 T. 5 S. R. 9 W. ELEVATION: 380'
DATE: METHOD: 4 IN. RIG: B–34 DRILLED BY: ARNOLD/RIDDLE
GAMMA LOGGED BY: CHITWOOD DESCRIBED BY: BLEUER



DESCRIPTION

AP - 0-8" silt loam; massive; 10YR 4/2 with varicolored fine subangular blocky in lower 4"

C - 8-20" silty clay; massive; 2.5Y 5/4 with few, diffuse 4/4 films on root tubules; organic layer at 14" with woody detritus

IIB2gb - 20-32" silty clay; weak, medium subangular blocky; ; 2.5Y 5/2 with common, diffuse, fine mottles to 5/6, common fine 2/2 manganese splotches; few modern roots

IIB31gb - 32-44" silty clay; massive; 2.5Y 5/2 with 40% joint surfaces with discontinuous and splotchy 5/6 stains; common fine root tubules

IIB32b - 44-78" clay; massive; 10YR 5/6 with 50% surfaces gleyed 5/2; 15-20% fine carbonate vein-fills and splotches

IIC - 78-90" clay; massive; 10YR 5./6; few, discontinuous 7/2 silt lamellae
Individual tube samples:

4'-4'6" silty clay; weak, fine subangular blocky; distinct, fine mottled 10YR 5/6-5/2

9'-9'10" clay; trace of fine lamination; 10YR 5/8 with 15% diffuse, medium mottles to 6/1

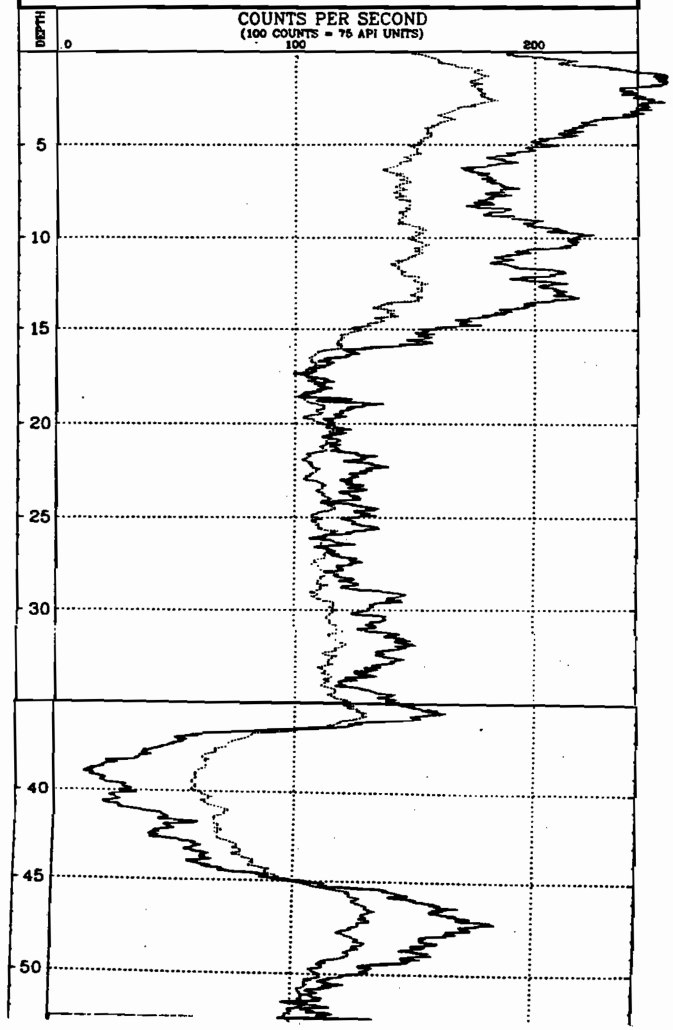
9'10"-10'1" clay; 10YR 4/5; massive to trace of fine lamination

14'-15'3" clay; massive; 2.5Y 4/4 with diffuse mottles to 6/1; grades coarser downward (all above generally firm...all below generally soft)

19'-20'5" silt loam; massive; diffuse, coarse mottled 2.5Y 6/6-7/2

NATURAL GAMMA–RAY LOG

TC = 5 RATE = 5 FT/MIN OSM–19 LOG # 89–358



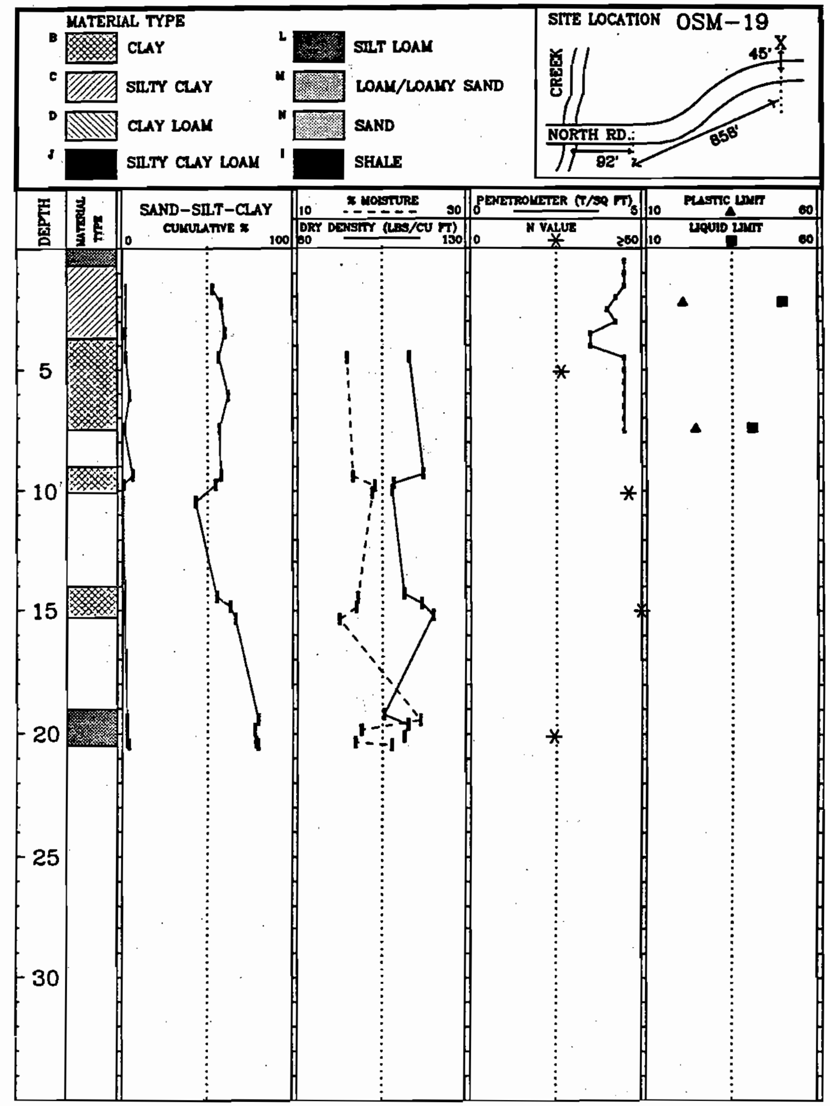
INDIANA GEOLOGICAL SURVEY	Dept. of Natural Resources State of Indiana
OSM–EVANSVILLE PROJECT	BORING# 19

BORING DATA

LAB ID	BORING	DEPTH inches	% GR	% SA	% SI	% CL	L.L.	P.L.	P.I.	SHRINK. LIMIT %	LINEAL SHRINK. %	CLASS.
891333	OSM19	16-20	0.0	2.1	51.0	46.9						CH,Fat Clay
891334	OSM19	22-28	0.0	2.1	56.0	41.9	49.7	20.6	29.1	16.4	14.3	CH,Fat Clay
891335	OSM19	36-42	0.0	1.5	58.7	39.8						CH,Fat Clay
891336	OSM19	67-73	5.3	4.1	58.1	32.5						CL,Lean Clay
891337	OSM19	84-90	0.0	1.0	56.1	43.0	40.8	24.1	16.7	14.8	12.3	CL,Lean Clay
891338	OSM19	48-54	0.0	1.9	54.8	43.3						CL,Lean Clay
891339	OSM19	108-113	0.0	5.9	52.1	42.0						CL,Lean Clay
891340	OSM19	168-173	0.0	1.1	54.2	44.7						CL,Lean Clay
891341	OSM19	113-118	0.0	0.5	54.1	45.4						CH,Fat Clay
891342	OSM19	121-126	0.0	0.1	42.9	57.0						CH,Fat Clay
891343	OSM19	173-178	0.0	0.9	62.2	36.9						CH,Fat Clay
891344	OSM19	178-183	0.0	1.1	65.1	33.8						CL,Lean Clay
891345	OSM19	233-238	0.0	2.6	75.0	22.4						CL,Lean Clay
891346	OSM19	228-233	0.0	2.5	77.3	20.2						CL,Lean Clay
891347	OSM19	238-243	0.0	2.6	75.9	21.5						CL,Lean Clay
891348	OSM19	243-245	0.0	3.8	76.0	20.2						CL,Lean Clay

BORING	DEPTH in.	P.P. t/sq ft	N VAL
OSM-19	6	4.50	
OSM-19	12	4.50	
OSM-19	18	4.50	
OSM-19	24	4.25	
OSM-19	30	4.00	
OSM-19	36	4.25	
OSM-19	42	3.50	
OSM-19	48	3.50	
OSM-19	54	4.50	
OSM-19	60	4.50	27
OSM-19	66	4.50	
OSM-19	72	4.50	
OSM-19	78	4.50	
OSM-19	84	4.50	
OSM-19	90	4.50	
OSM-19	120		47
OSM-19	180		50
OSM-19	240		24

LAB ID	BORING	SAMP DEPTH inches	% MOIS	DRY DENS lbs/cu ft
891123	OSM-19	54	16.0	113.4
891124	OSM-19	113	16.7	117.5
891125	OSM-19	118	19.3	108.7
891126	OSM-19	121	19.0	108.3
891127	OSM-19	173	17.3	111.8
891128	OSM-19	178	17.1	117.0
891129	OSM-19	184	15.1	120.4
891130	OSM-19	233	24.7	105.8
891131	OSM-19	238	17.7	113.0
891132	OSM-19	244	17.0	111.9
891133	OSM-19	245	21.3	na



INDIANA GEOLOGICAL SURVEY — Dept. of Natural Resources, State of Indiana

OSM–EVANSVILLE PROJECT

BORING# 20
Page 1 of 1

LOCATION: NW1/4 NE1/4 NE1/4 SW1/4 SEC 22 T. 5 S. R. 10 W. ELEVATION: 430'
DATE: METHOD: 4 IN. RIG: B–34 DRILLED BY: ARNOLD/RIDDLE
GAMMA LOGGED BY: CHITWOOD DESCRIBED BY: BLEUER

DEPTH	SAMPLE INTERVAL: FULL	SAMPLE INTERVAL: SHELBY	SAMPLE INTERVAL: SS	BLOW COUNTS
5				
10				
15				TD
20				
25				
30				

DESCRIPTION

AP - 0-7" silt loam; massive; 10YR5/5

B21 - 7-16" silt loam; well developed medium subangular blocky; 10YR 6/8, thin, discontiuous, 10YR 5/4 clay films; common fine root tubules

B2x - 16-35" silt loam; well devoloped, medium subangular blocky; 10YR-7.5YR 5/6, common 10YR 4/6 stains and thick, continous, 10YR 6-7/3 silt coats on joint surfaces; common medium to coarse, diffuse to distinct 10YR 6/2 mottles; possible columnar joint structures, brittle;

B3x - 35-63" silt loam; 10KYR 4/6 with many medium to coarse, diffuse, 10YR 6/2 mottles; slightly brittle medium subangular blocky grades to coarse platy; few thin discontinuous clay films; few fine root traces

C1 - 63-72" silt loam, weak, coarse subangular blocky grading to massive; 10YR 5/6, few, diffuse 10YR 6/4 mottles, trace of fine root tubules with some internal 10YR 6/3 clay films

C2 72-88" silt loam; massive; 10YR 6/5 grading to 7.5 YR in bottom 3", scattered blotches and streaks of 10YR 2/2 manganese stains and coats

IIB21b 88-98" silty clay loam; moderate, medium subangular blocky; 5YR 5/5 with medium to thick 10YR 4/4 clay films, common 2/2 fine blotches, streaks, small concretions, few 7.5 YR 6/4 fine silt coats and diffuse joint fills

IIB22b - 98-120" silty clay loam; strong (compacted) fine subangular blocky; 5YR 5/5-6, common 2/2 fine to medium manganese blotches, discontinuous joint coats and veins, few 7.5YR silt films; base marked by 3" of very strongly Mn streaking, giving layered appearance

IIB22b - 120-150" silty clay; weak, fine to medium subangular blocky; 7.5YR to 10YR 6/6-8, common 2/2 manganese joint coats, few, fine 3/4 concretions giving overall loamy apperance; bottom 6" massive

IIB23 - 150-180" clay; overall appears as well developed (welded) fine subangular blocky to to fragmental clay (shale), clasts bounded by well developed fine to medium clay films of oxidized and gleyed colors; 10YR 5/6 with common 2.5Y 6/1-2 veins and vug fills

Comments: The thick (98-180") paleosol at base, including the physically disaggregated basal unit, appears to be in situ development in what may be overthickened shale colluvium. The site is at the absolute head of the middle surface, or at the absolute toe of the slope of the upper surface where colluvial thickening (of granular shale) may have occurred. A stone line atop a thinner paleosol in other holes on middle surface suggests that paleosol thickness may have been determined by pre-loess slope processes.

INDIANA GEOLOGICAL SURVEY

Dept. of Natural Resources
State of Indiana

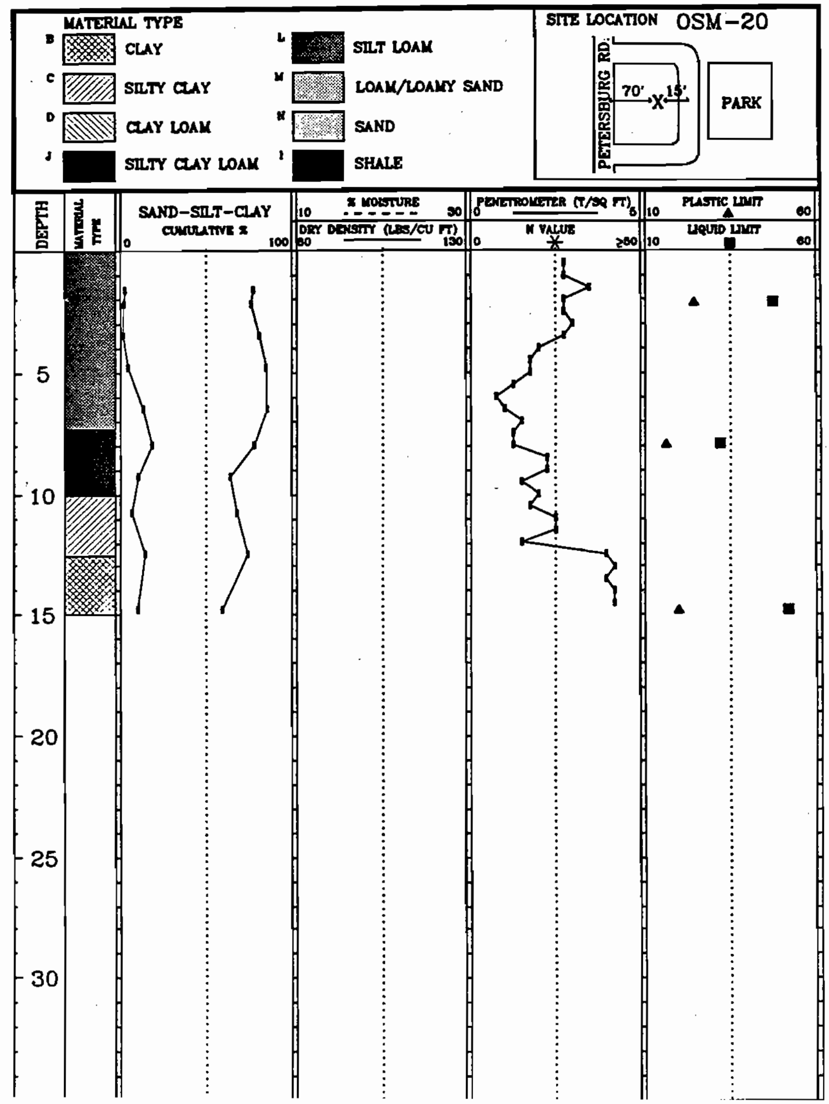
OSM–EVANSVILLE PROJECT

BORING# 20

BORING DATA

LAB ID	BORING	DEPTH inches	% GR	% SA	% SI	% CL	L.L.	P.L.	P.I.	SHRINK. LIMIT %	LINEAL SHRINK. %	CLASS.
891245	OSM20	13-19	0.0	2.4	75.1	22.5						CL,Lean Clay
891246	OSM20	21-26	0.0	1.7	74.6	23.8	47.7	24.2	23.5	12.8	15.0	CL,Lean Clay
891247	OSM20	36-42	0.0	1.3	79.7	19.0						CL,Lean Clay
891248	OSM20	52-58	0.0	4.1	81.1	14.8						CL,Lean Clay
891249	OSM20	72-78	0.0	13.0	72.6	14.4						CL,Lean Clay
891250	OSM20	90-96	0.0	18.1	59.9	22.0	31.8	16.0	15.8	12.9	9.7	CL,Lean Clay With
891251	OSM20	106-112	0.0	10.1	54.0	35.9						CL,Lean Clay
891252	OSM20	123-129	0.0	6.4	61.5	32.1						CL,Lean Clay
891253	OSM20	144-150	0.0	14.2	60.1	25.7						CL,Lean Clay
891254	OSM20	172-178	0.0	10.0	49.4	40.6	52.5	20.0	32.5	11.6	17.4	CH,Fat Clay

BORING	DEPTH in.	P.P. t/sq ft	N VAL
OSM-20	6	2.75	
OSM-20	12	2.75	
OSM-20	18	3.50	
OSM-20	24	2.75	
OSM-20	30	2.75	
OSM-20	36	3.00	
OSM-20	42	2.75	
OSM-20	48	2.00	
OSM-20	54	1.75	
OSM-20	60	1.75	
OSM-20	66	1.25	
OSM-20	72	0.75	
OSM-20	78	1.00	
OSM-20	84	1.50	
OSM-20	90	1.25	
OSM-20	96	1.25	
OSM-20	102	2.25	
OSM-20	108	2.25	
OSM-20	114	1.50	
OSM-20	120	2.00	
OSM-20	126	1.75	
OSM-20	132	2.50	
OSM-20	138	2.50	
OSM-20	144	1.50	
OSM-20	150	4.00	
OSM-20	156	4.25	
OSM-20	162	4.00	
OSM-20	168	4.25	
OSM-20	174	4.25	
OSM-20	180	4.25	

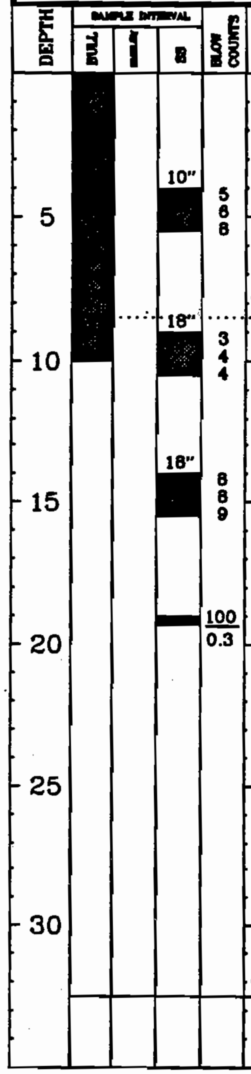


INDIANA GEOLOGICAL SURVEY — Dept. of Natural Resources, State of Indiana

OSM–EVANSVILLE PROJECT

BORING# 21
Page 1 of 1

LOCATION: 1/4 NE 1/4 NW 1/4 NW 1/4 SEC 25 T. 5 S. R.10 W. ELEVATION: 380'
DATE: METHOD: 4 IN. RIG: B–34 DRILLED BY: ARNOLD/RIDDLE
GAMMA LOGGED BY: CHITWOOD DESCRIBED BY: BLEUER



DESCRIPTION

AP - 0-7" silt loam; massive; 10YR 4/3

B1 - 7-14" silt loam; medium platy in top 4" (pan) to weak, fine subangular blocky; 2.5Y 5/4 with fine, distinct stains to 5/6

B2 - 14-30" silty clay; weak, coarse subangular blocky to prismatic; diffuse to distinct medium mottles 10YR 2-5/6

B31g - 30-68" silty clay; massive but cut by many joints with common slickensides on medium clay films; 2.5YR 4/2 to 10YR 5/1 (paper-wrapped bull sample vs. bottled split-tube sample)in top 10", remainder mottled 2.5Y 5/2-6; common root tubules

B32g - 68-90" silty clay; massive; 10YR 5/6 diffusely mottled 5GY6/1, common 1/16-1/4" iron-manganese splotches and pellets; some gleyed root tubules, some with medium to thick clay film; carbonate zone at 72" with fine, spherical masses (possibly detrital ?)
Individual tube samples:

4'-4'9" (above)

9'5"-10'3" silt loam; massive; 10YR 6/8; trace of 6/0 clay films on subhorizontal joins

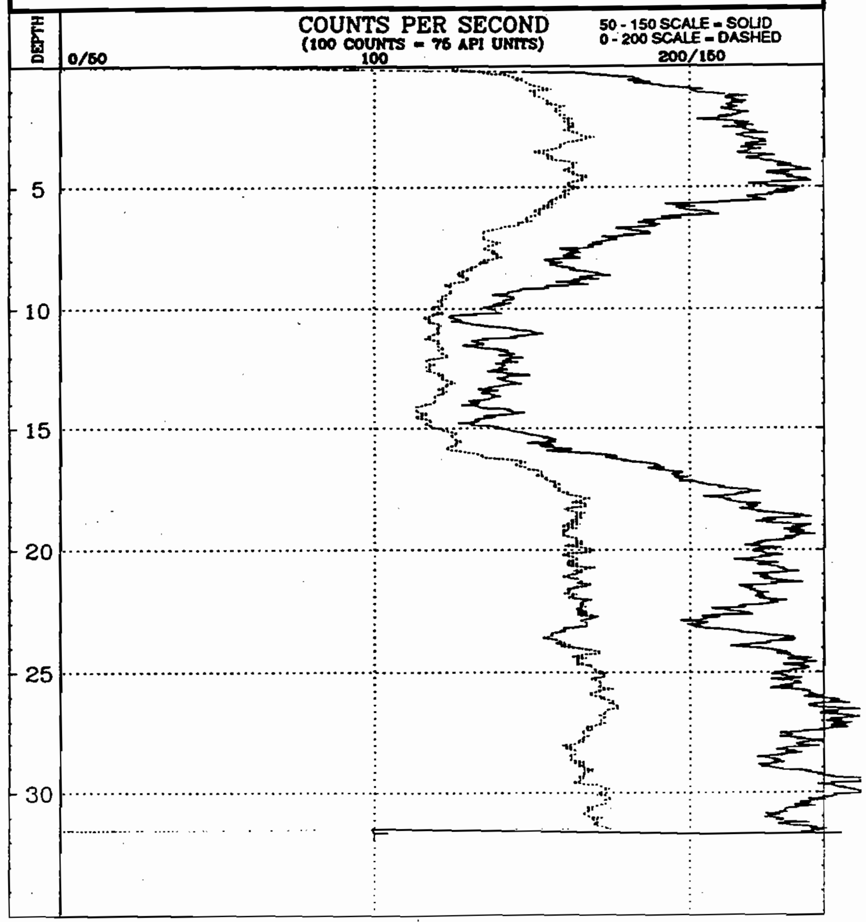
14'-15'6" as above,with disseminated shale fragments and 80% manganese staining below 14'8"; some root tubules with thin 6/1 clay films

19'-19'4" soft to firm silty shale; 2.Y 5/4

Comments: Upper B horizons appear to be developed in clayey parent material, overlying massive brown silt, parallel the sequence of eastern Kansas Road holes.

NATURAL GAMMA–RAY LOG

TC = 5 RATE = 5 FT/MIN OSM–21 LOG # 89–362



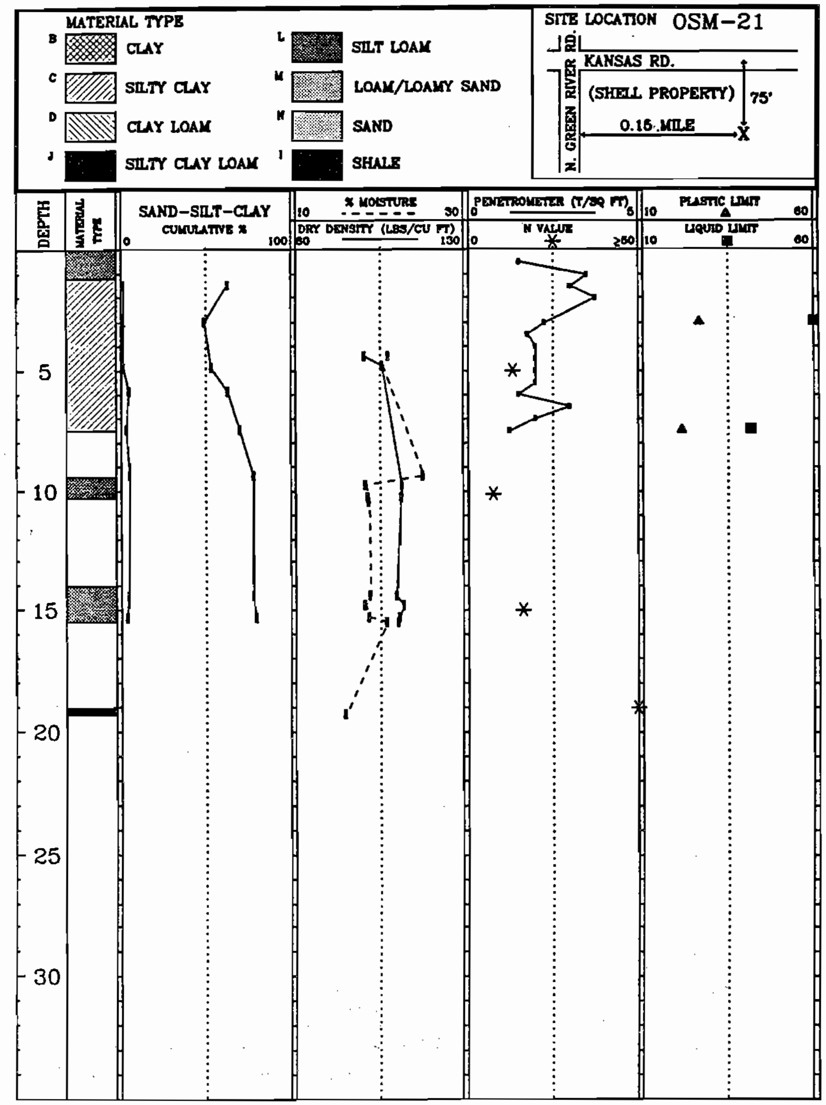
INDIANA GEOLOGICAL SURVEY	Dept. of Natural Resources State of Indiana
OSM-EVANSVILLE PROJECT	BORING# 21

BORING DATA

LAB ID	BORING	DEPTH inches	% GR	% SA	% SI	% CL	L.L.	P.L.	P.I.	SHRINK. LIMIT %	LINEAL SHRINK. %	CLASS.
891232	OSM21	12-18	0.1	1.3	61.2	37.4						CL,Lean Clay
891233	OSM21	30-36	0.0	1.1	47.8	51.1	62.9	26.8	36.1	8.4	22.5	CH,Fat Clay
891234	OSM21	54-59	0.0	1.0	52.0	46.9						CH,Fat Clay
891235	OSM21	65-71	0.2	4.3	58.3	37.3						CL,Lean Clay
891236	OSM21	84-90	0.0	2.7	66.9	30.4	41.7	21.2	20.5	13.3	13.4	CL,Lean Clay
891350	OSM21	108-113	0.0	4.6	73.1	22.2						CL,Lean Clay
891351	OSM21	168-173	0.8	3.9	73.7	21.5						CL,Lean Clay
891352	OSM21	178-183	1.1	3.1	76.1	19.7	30.1	20.5	9.6	NA	NA	CL,Lean Clay

BORING	DEPTH in.	P.P. t/sq ft	N VAL
OSM-21	6	1.50	
OSM-21	12	3.50	
OSM-21	18	3.00	
OSM-21	24	3.75	
OSM-21	30	na	
OSM-21	36	2.25	
OSM-21	42	1.75	
OSM-21	48	2.00	
OSM-21	54	2.00	
OSM-21	60	4.00	14
OSM-21	66	2.00	
OSM-21	72	1.50	
OSM-21	78	3.00	
OSM-21	84	2.00	
OSM-21	90	1.25	
OSM-21	120		8
OSM-21	180		17
OSM-21	228		100

LAB ID	BORING	SAMP DEPTH inches	% MOIS	DRY DENS lbs/cu ft
		0		
891134	OSM-21	53	21.2	100.5
891135	OSM-21	58	20.5	105.9
891136	OSM-21	113	25.3	na
891137	OSM-21	118	18.5	111.7
891138	OSM-21	124	18.8	111.5
891139	OSM-21	126	18.9	na
891140	OSM-21	173	19.0	110.0
891141	OSM-21	178	18.4	112.2
891142	OSM-21	184	18.9	110.9
891143	OSM-21	186	21.0	110.6
891144	OSM-21	232	16.1	na



INDIANA GEOLOGICAL SURVEY — Dept. of Natural Resources, State of Indiana

OSM–EVANSVILLE PROJECT

BORING# 22
Page 1 of 1

LOCATION: 1/4 SE 1/4 SW 1/4 SW 1/4 SEC 19 T. 5 S. R. 9 W. ELEVATION: 380'
DATE: METHOD: 4 IN. RIG: B-34 DRILLED BY: ARNOLD/RIDDLE
GAMMA LOGGED BY: CHITWOOD DESCRIBED BY: BLEUER

DEPTH	SAMPLE INTERVAL: SS	BLOW COUNTS
5	10"	9 10 12
10	8.5"	9 12 15
15	18"	12 12 11
20	15"	12 11 13
25	18"	15 19 15
30		

TD at 66'

DESCRIPTION

Split-tube samples only

4'-4'10" clay; firm to stiff; massive to fine subangular blocky with common, medium clay films; fine, distinct mottling 2.5Y 6/6-5/2; noncalcareous

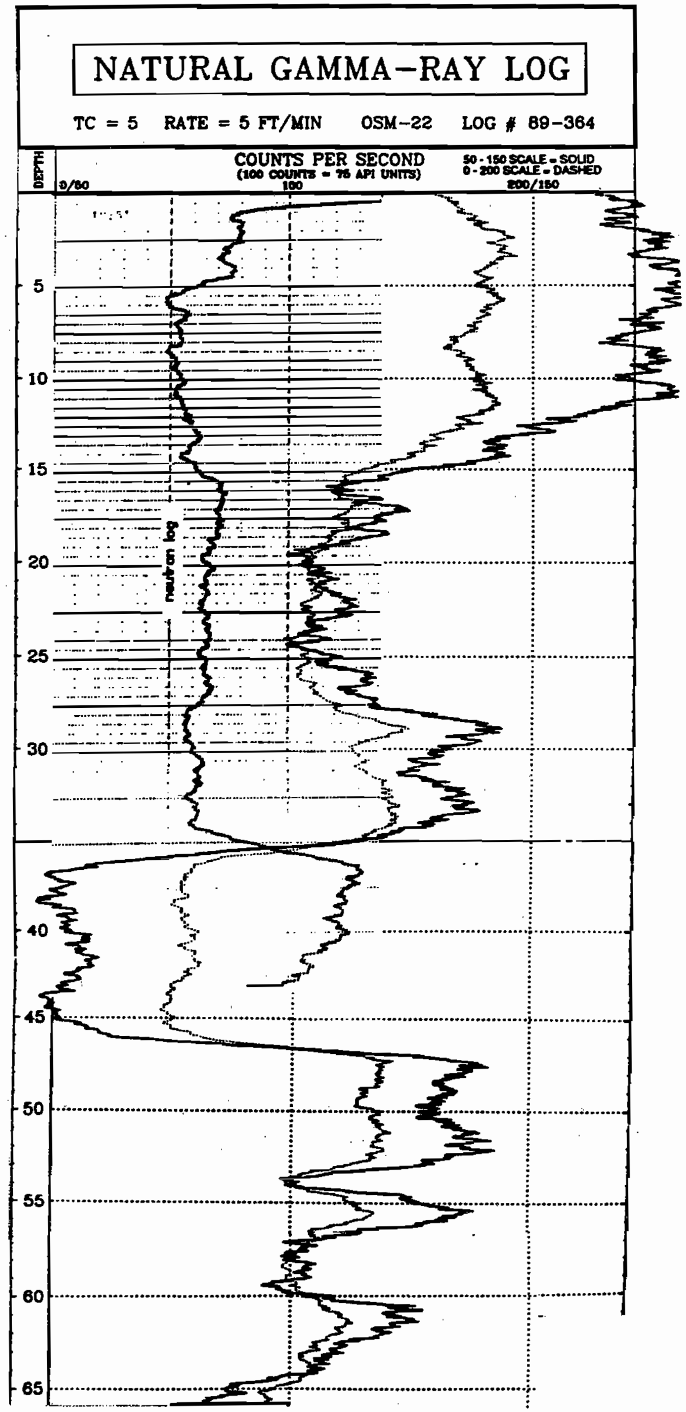
9'-9'8" clay; massive to finely laminated; 2.5Y 5/0, streaked 6/8, with trace of 8/1 silt coats on some bedding surfaces; layer of single grain (1/4") rounded shale (?) 1' over base; calcareous

14'-15'6" silty clay, massive silt below 14'9"; 2.5Y 4/2, diffusely stained 5/2; calcareous to 15'3", noncalcareous below; few snail shells (Succinea) at about 15'

19'-20'3" silt loam; massive; 5Y 6/2 - 4/2; trace of 4/2 organic clay

24'-25'6" silt; massive; coarse, distinct mottles 2.5Y 7/0 - 5/6

66' off bit varicolored, fine coal gravel in silt matrix



450

INDIANA GEOLOGICAL SURVEY — Dept. of Natural Resources, State of Indiana

OSM-EVANSVILLE PROJECT

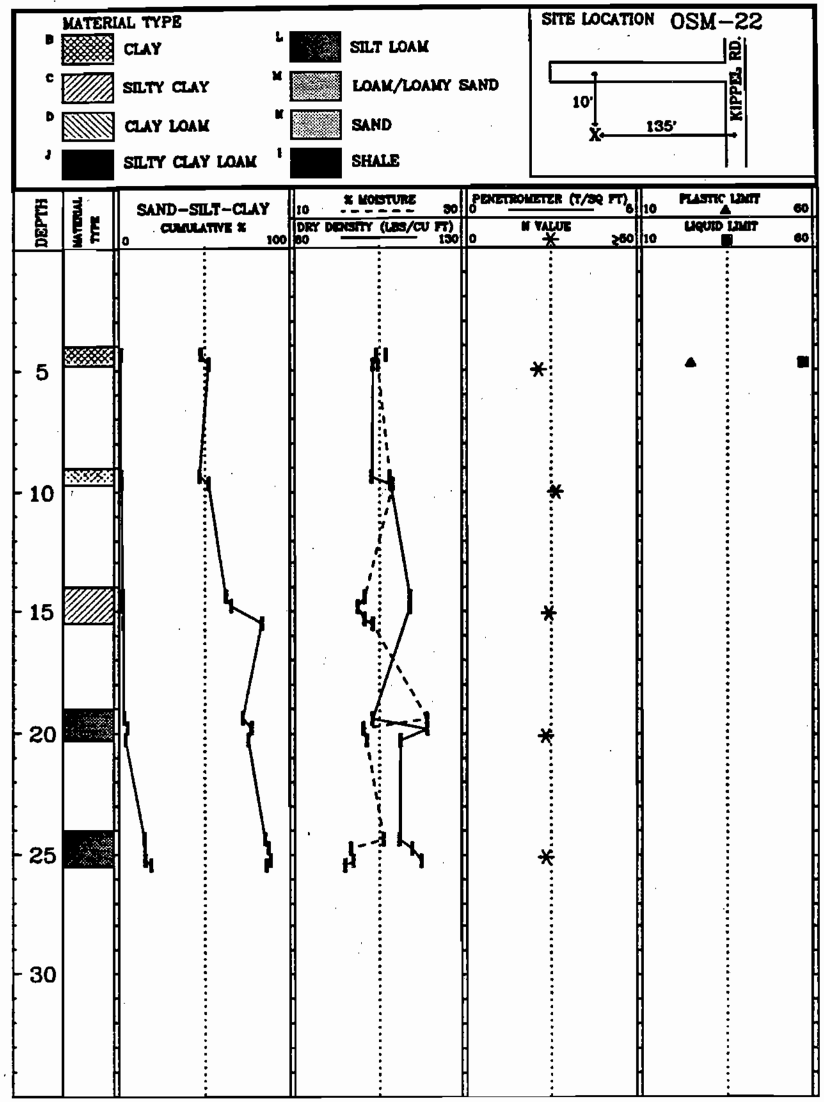
BORING# 22

BORING DATA

LAB ID	BORING	DEPTH inches	% GR	% SA	% SI	% CL	L.L.	P.L.	P.I.	SHRINK. LIMIT %	LINEAL SHRINK. %	CLASS.
891353	OSM22	48-53	0.0	1.1	46.6	52.3						CH,Fat Clay
891354	OSM22	53-58	0.0	0.7	51.5	47.8	57.3	24.7	32.6	20.1	14.9	CH,Fat Clay
891355	OSM22	108-113	0.0	1.1	45.6	53.3						CH,Fat Clay
891356	OSM22	113-116	0.0	1.4	50.7	47.9						CH,Fat Clay
891357	OSM22	168-173	0.0	2.0	60.5	37.5						CH,Fat Clay
891358	OSM22	173-178	0.0	2.0	63.5	34.5						CH,Fat Clay
891359	OSM22	183-186	0.0	2.4	81.1	16.4						CL,Lean Clay
891360	OSM22	228-233	0.0	2.9	69.4	27.7						CL,Lean Clay
891361	OSM22	233-238	4.3	5.0	72.5	18.2						CL,Lean Clay
891362	OSM22	238-243	0.0	3.8	71.9	24.3						CL,Lean Clay
891363	OSM22	288-293	0.0	14.8	70.6	14.6						CL,Lean Clay
891364	OSM22	293-298	0.0	15.1	72.4	12.5						ML,Silt with Sand
891365	OSM22	298-303	0.0	15.3	73.3	11.4						ML,Silt with Sand
891366	OSM22	303-306	0.0	18.6	67.8	13.6						ML,Silt with Sand

BORING	DEPTH in.	P.P. t/sq ft	N VAL
OSM-22	60		22
OSM-22	120		27
OSM-22	180		23
OSM-22	240		24
OSM-22	300		24

LAB ID	BORING	SAMP DEPTH inches	% MOIS	DRY DENS lbs/cu ft
891145	OSM-22	53	20.9	104.5
891146	OSM-22	58	19.9	103.5
891147	OSM-22	113	21.3	103.1
891148	OSM-22	116	21.7	108.7
891149	OSM-22	173	18.3	114.5
891150	OSM-22	178	17.5	114.5
891151	OSM-22	184	18.3	na
891152	OSM-22	186	19.3	na
891153	OSM-22	233	25.8	103.4
891154	OSM-22	238	18.2	119.8
891155	OSM-22	244	18.6	111.8
891156	OSM-22	293	20.6	111.4
891157	OSM-22	298	16.7	115.2
891158	OSM-22	304	17.0	118.0
891159	OSM-22	306	16.0	na
891160	OSM-22	792	19.3	na



INDIANA GEOLOGICAL SURVEY — Dept. of Natural Resources, State of Indiana

OSM–EVANSVILLE PROJECT

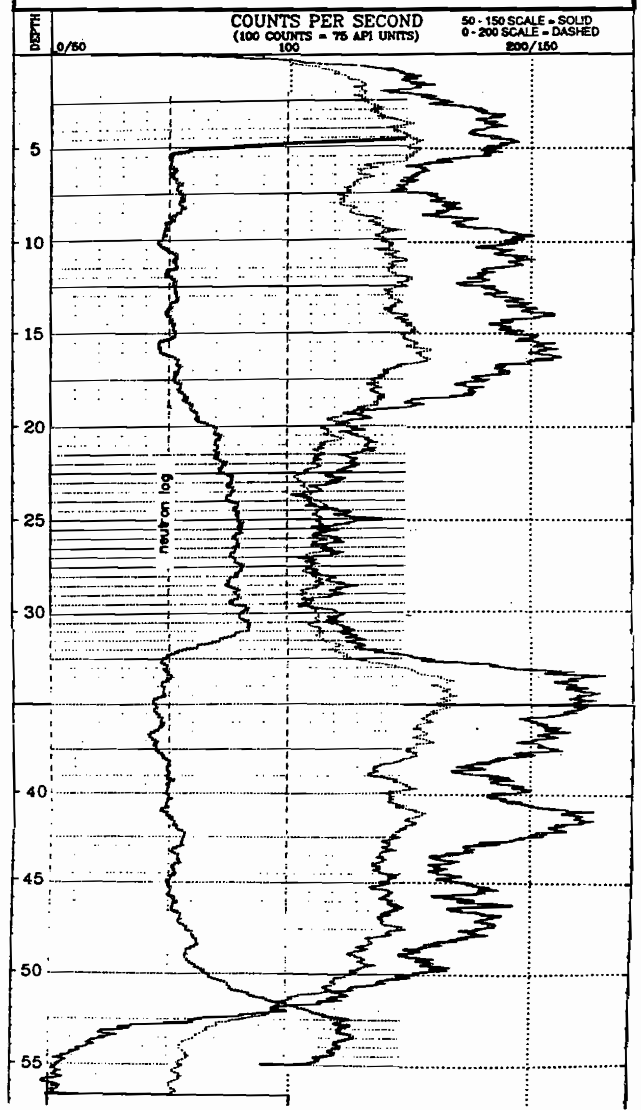
BORING# 23
Page 1 of 1

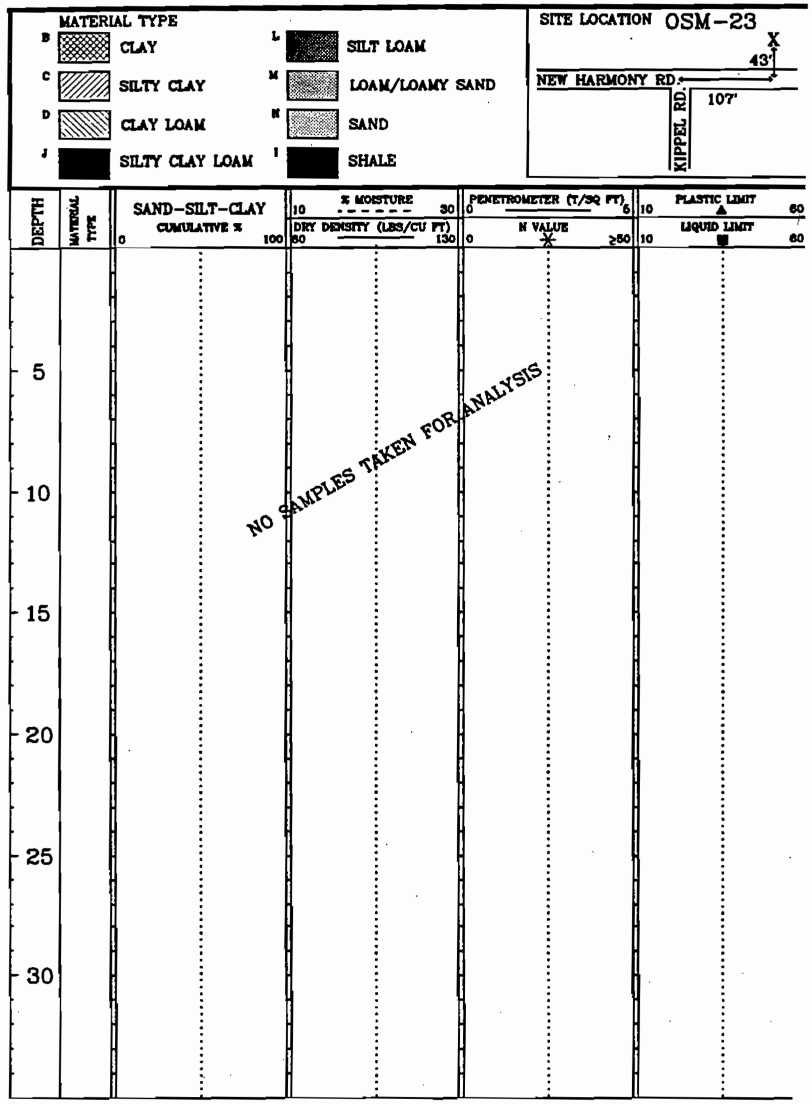
LOCATION: 1/4 NE 1/4 SW 1/4 NW 1/4 SEC 18 T. 5 S. R. 9 W. ELEVATION: 380'
DATE: METHOD: 4 IN. RIG: B-34 DRILLED BY: ARNOLD/RIDDLE
GAMMA LOGGED BY: CHITWOOD DESCRIBED BY: BLEUER

DEPTH	SAMPLE INTERVAL: BULL	SAMPLE INTERVAL: SHELBY	SAMPLE INTERVAL: SS	BLOW COUNTS	DESCRIPTION
5					
10					GAMMA-RAY LOG ONLY
15					
20					
25					
30					
	TD at 58'				

NATURAL GAMMA-RAY LOG

TC = 5 RATE = 5 FT/MIN OSM-23 LOG # 89-398





MATERIAL TYPE
B CLAY
C SILTY CLAY
D CLAY LOAM
J SILTY CLAY LOAM
L SILT LOAM
M LOAM/LOAMY SAND
N SAND
I SHALE
SITE LOCATION OSM-23
NEW HARMONY RD.
KIPPEL RD.
43'
107'
X
DEPTH
MATERIAL TYPE
SAND-SILT-CLAY
CUMULATIVE %
0
100
10
% MOISTURE
30
DRY DENSITY (LBS/CU FT)
80
130
PENETROMETER (T/SQ FT)
0
5
N VALUE
≥50
PLASTIC LIMIT
LIQUID LIMIT
10
60
5
10
15
20
25
30
NO SAMPLES TAKEN FOR ANALYSIS

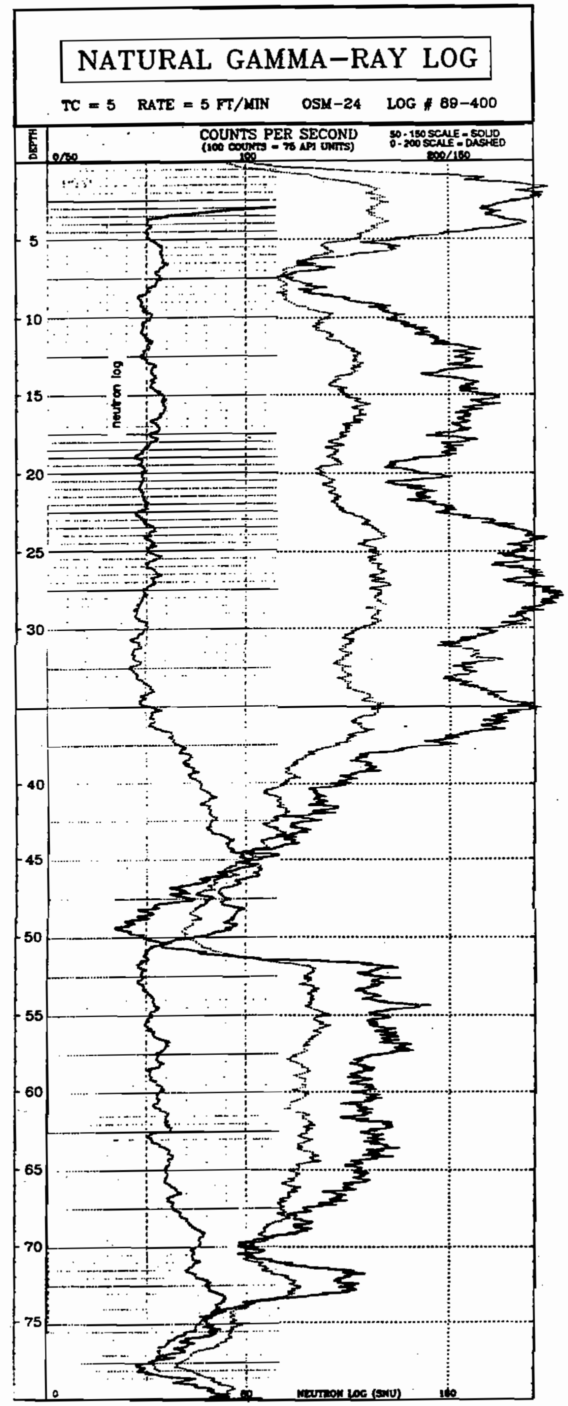
INDIANA GEOLOGICAL SURVEY — Dept. of Natural Resources, State of Indiana

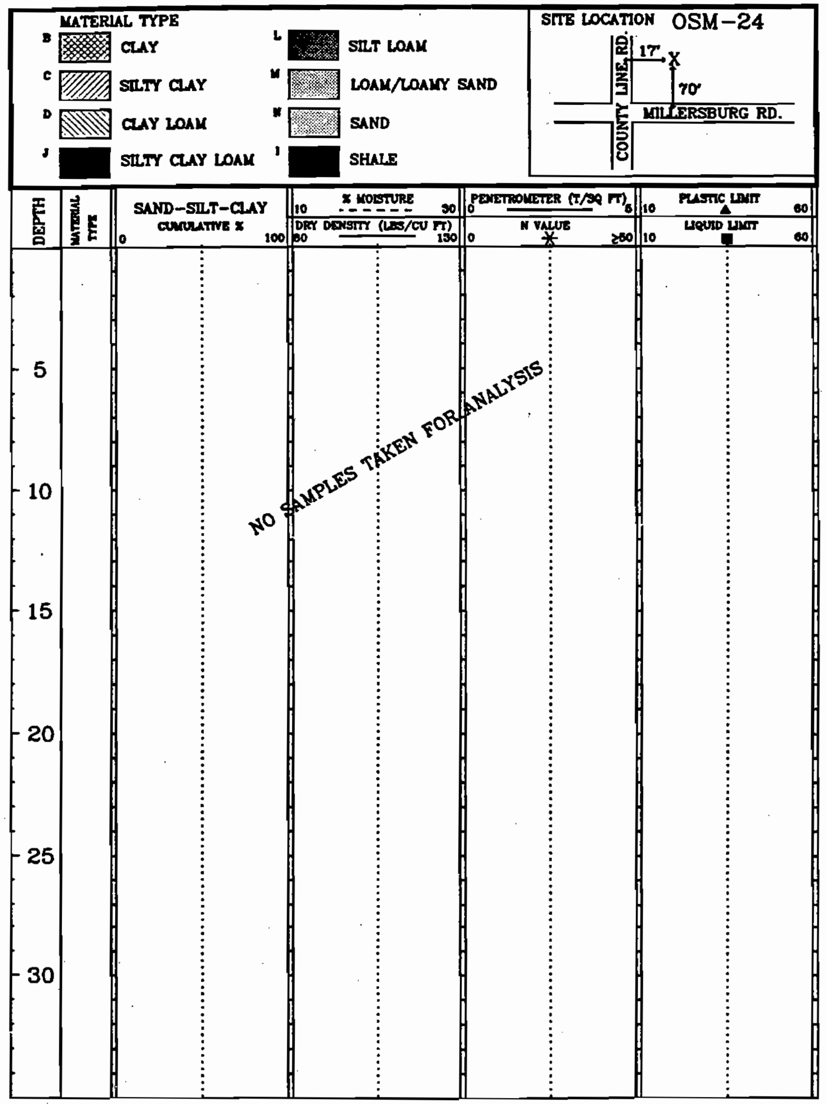
OSM–EVANSVILLE PROJECT

BORING# 24
Page 1 of 1

LOCATION: 1/4 SW 1/4 SW 1/4 SW 1/4 SEC 30 T. 5 S. R. 9 W. ELEVATION: 380'
DATE: METHOD: 4 IN. RIG: B-34 DRILLED BY: ARNOLD/RIDDLE
GAMMA LOGGED BY: CHITWOOD DESCRIBED BY: BLEUER

DEPTH	SAMPLE INTERVAL: BULL	SAMPLE INTERVAL: SHELBY	SAMPLE INTERVAL: SS	BLOW COUNTS	DESCRIPTION
5					▽
10					GAMMA-RAY LOG ONLY
15					
20					
25					
30	TD at 80'				




MATERIAL TYPE
B CLAY
C SILTY CLAY
D CLAY LOAM
J SILTY CLAY LOAM
L SILT LOAM
M LOAM/LOAMY SAND
N SAND
I SHALE
SITE LOCATION OSM-24
COUNTY LINE RD.
17'
X
70'
MILLERSBURG RD.
DEPTH
MATERIAL TYPE
SAND-SILT-CLAY
CUMULATIVE %
0
100
% MOISTURE
10
30
DRY DENSITY (LBS/CU FT)
80
130
PENETROMETER (T/SQ FT)
0
6
N VALUE
0
≥50
PLASTIC LIMIT
10
60
LIQUID LIMIT
10
60
5
10
15
20
25
30
NO SAMPLES TAKEN FOR ANALYSIS

INDIANA GEOLOGICAL SURVEY

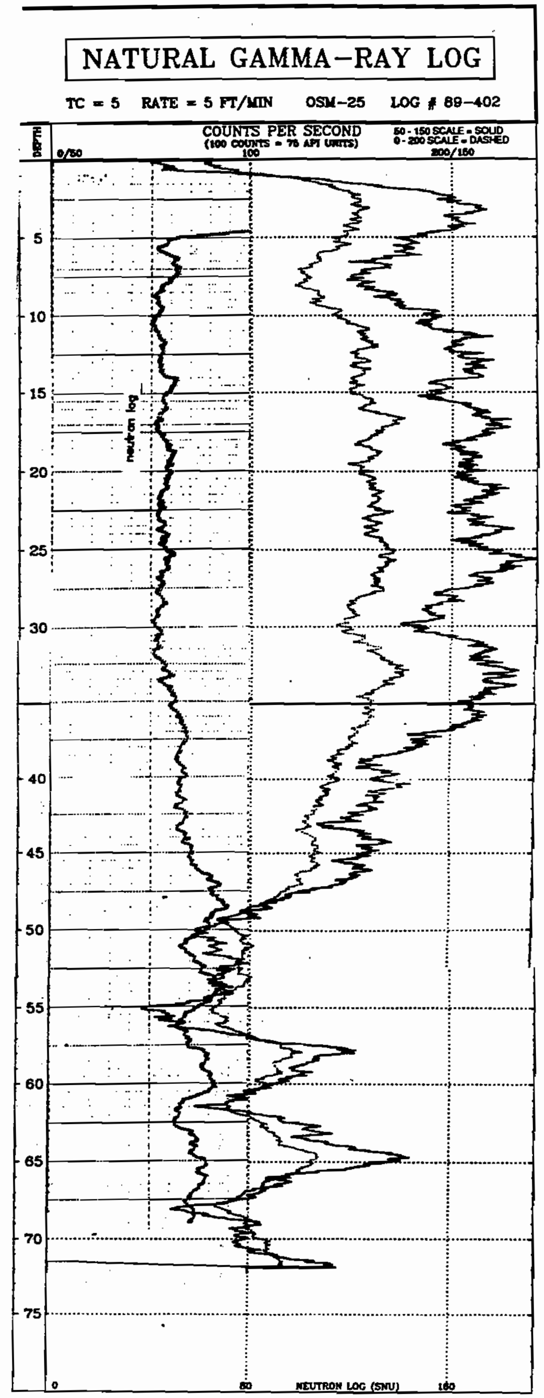
Dept. of Natural Resources
State of Indiana

OSM–EVANSVILLE PROJECT

BORING# 25
Page 1 of 1

LOCATION: 1/4 SW1/4 SW1/4 SW1/4 SEC 23 T. 5 S. R. 9 W. ELEVATION: 390'
DATE: METHOD: 4 IN. RIG: B-34 DRILLED BY: ARNOLD/RIDDLE
GAMMA LOGGED BY: CHITWOOD DESCRIBED BY: BLEUER

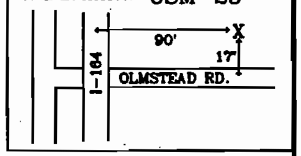
DEPTH	SAMPLE INTERVAL: BULL	SAMPLE INTERVAL: SHELBY	SAMPLE INTERVAL: SS	BLOW COUNTS	DESCRIPTION
5					GAMMA-RAY LOG ONLY
10					
15				▽	
20					
25					
30					
	TD at 89'				



MATERIAL TYPE

Code	Material	Code	Material
B	CLAY	L	SILT LOAM
C	SILTY CLAY	M	LOAM/LOAMY SAND
D	CLAY LOAM	N	SAND
J	SILTY CLAY LOAM	I	SHALE

SITE LOCATION OSM−25



DEPTH	MATERIAL TYPE	SAND−SILT−CLAY CUMULATIVE % (0–100)	% MOISTURE (10–30) / DRY DENSITY (LBS/CU FT) (60–130)	PENETROMETER (T/SQ FT) (0–6) / N VALUE (0–≥50)	PLASTIC LIMIT ▲ (10–60) / LIQUID LIMIT ■ (10–60)
5					
10					
15					
20					
25					
30					

NO SAMPLES TAKEN FOR ANALYSIS

INDIANA GEOLOGICAL SURVEY

Dept. of Natural Resources
State of Indiana

OSM–EVANSVILLE PROJECT

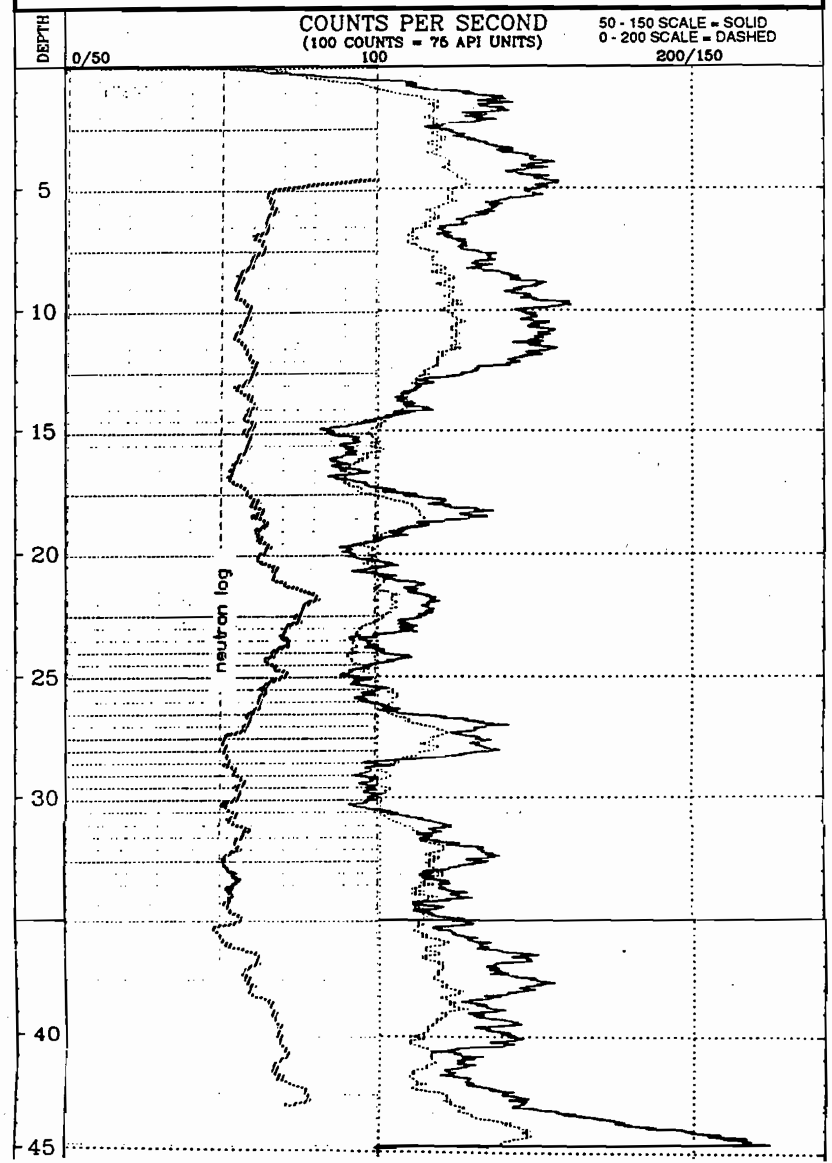
BORING# 27
Page 1 of 1

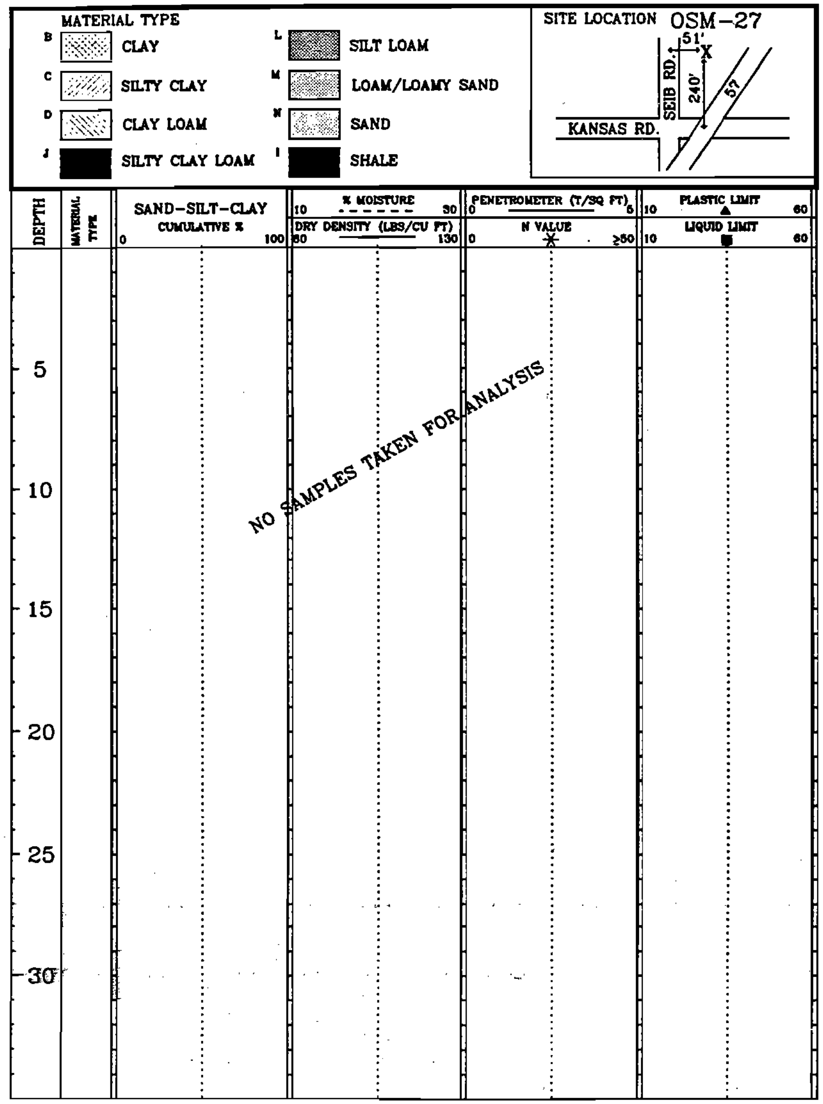
LOCATION: 1/4 SW1/4 SW1/4 SW1/4 SEC 23 T. 5 S. R.10 W. ELEVATION: 390'
DATE: METHOD: 4 IN. RIG: B-34 DRILLED BY: ARNOLD/RIDDLE
GAMMA LOGGED BY: CHITWOOD DESCRIBED BY: BLEUER

DEPTH	SAMPLE INTERVAL: BULL	SAMPLE INTERVAL: SHELBY	SAMPLE INTERVAL: SS	BLOW COUNTS	DESCRIPTION
5					GAMMA-RAY LOG ONLY
10					
15					
20					
25					
30					
	TD at 44'				

NATURAL GAMMA–RAY LOG

TC = 5 RATE = 5 FT/MIN OSM–27 LOG # 89–404




MATERIAL TYPE
B CLAY
C SILTY CLAY
D CLAY LOAM
J SILTY CLAY LOAM
L SILT LOAM
M LOAM/LOAMY SAND
N SAND
I SHALE
SITE LOCATION OSM-27
51'
X
240'
57
SEIB RD.
KANSAS RD.
DEPTH
MATERIAL TYPE
SAND-SILT-CLAY
CUMULATIVE %
0
100
% MOISTURE
10
30
DRY DENSITY (LBS/CU FT)
80
130
PENETROMETER (T/SQ FT)
0
5
N VALUE
0
≥50
PLASTIC LIMIT
10
60
LIQUID LIMIT
10
60
5
10
15
20
25
30
NO SAMPLES TAKEN FOR ANALYSIS

INDIANA GEOLOGICAL SURVEY — Dept. of Natural Resources, State of Indiana

OSM-EVANSVILLE PROJECT

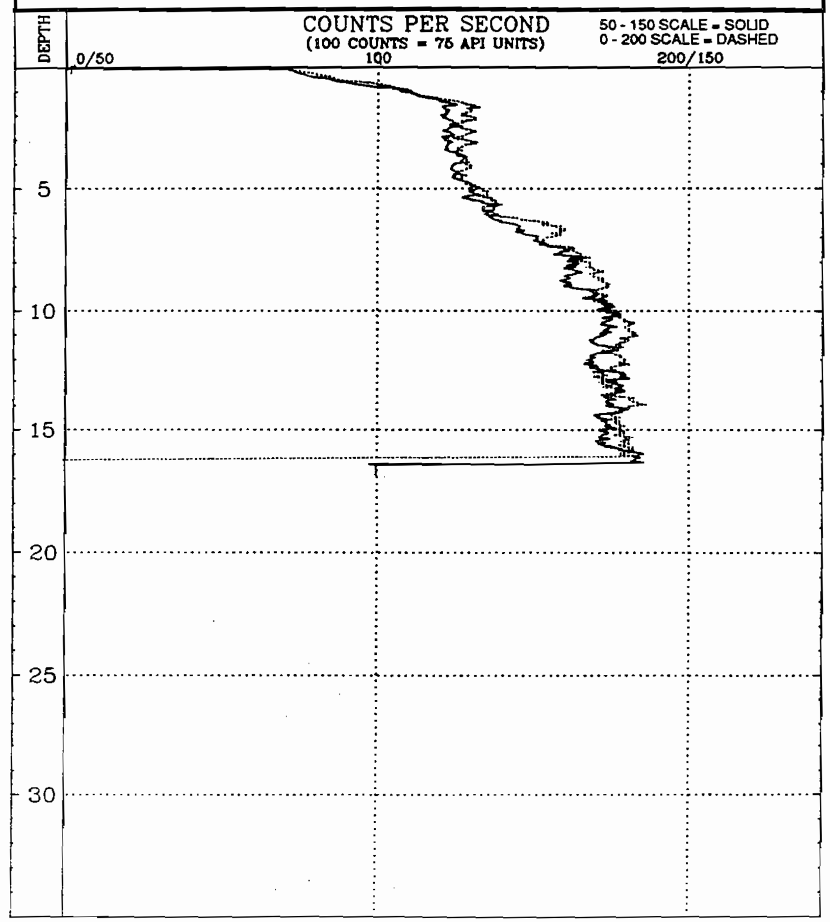
BORING# 28
Page 1 of 1

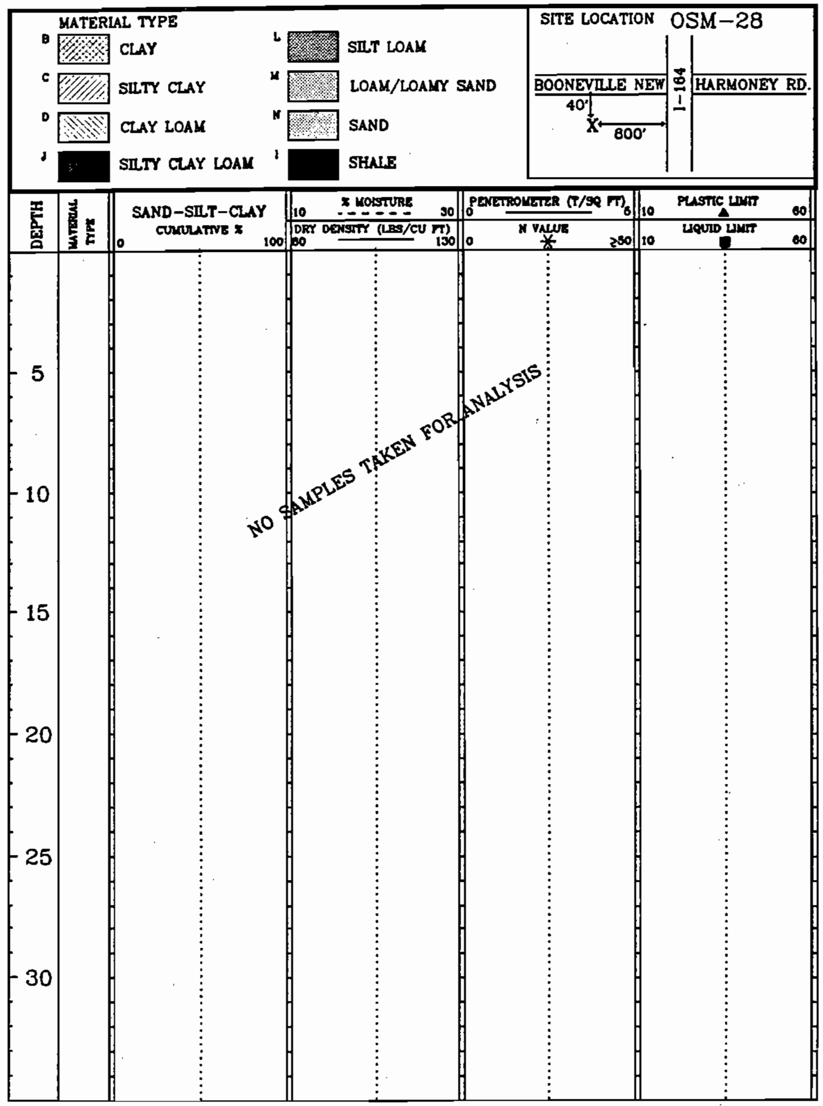
LOCATION: 1/4 SW 1/4 SE 1/4 NE 1/4 SEC 13 T. 5 S. R. 10 W. ELEVATION: 380'
DATE: METHOD: 4 IN. RIG: B-34 DRILLED BY: ARNOLD/RIDDLE
GAMMA LOGGED BY: CHITWOOD DESCRIBED BY: BLEUER

DEPTH	SAMPLE INTERVAL: BULL	SAMPLE INTERVAL: SHELBY	SAMPLE INTERVAL: SS	BLOW COUNTS	DESCRIPTION
5					GAMMA-RAY LOG ONLY
10					
15				TD	
20					
25					
30					

NATURAL GAMMA-RAY LOG

TC = 5 RATE = 5 FT/MIN OSM-28 LOG # 89-396



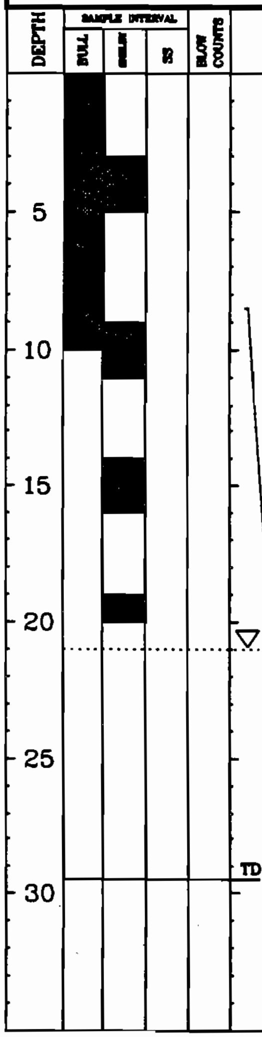

MATERIAL TYPE
B CLAY
C SILTY CLAY
D CLAY LOAM
J SILTY CLAY LOAM
L SILT LOAM
M LOAM/LOAMY SAND
N SAND
I SHALE
SITE LOCATION OSM-28
BOONEVILLE NEW
HARMONEY RD.
I-164
40'
800'
X
DEPTH
MATERIAL TYPE
SAND-SILT-CLAY
CUMULATIVE %
0
100
% MOISTURE
10
30
DRY DENSITY (LBS/CU FT)
80
130
PENETROMETER (T/SQ FT)
0
5
N VALUE
0
≥50
PLASTIC LIMIT
10
60
LIQUID LIMIT
10
60
5
10
15
20
25
30
NO SAMPLES TAKEN FOR ANALYSIS

INDIANA GEOLOGICAL SURVEY — Dept. of Natural Resources, State of Indiana

OSM–EVANSVILLE PROJECT

BORING# 29 Page 1 of 1

LOCATION: 1/4 SW 1/4 SW 1/4 SE 1/4 SEC 3 T. 5 S. R. 10 W. ELEVATION: 445'
DATE: METHOD: 4 IN. RIG: B-34 DRILLED BY: ARNOLD/RIDDLE
GAMMA LOGGED BY: CHITWOOD DESCRIBED BY: BLEUER



DESCRIPTION

AP - 0-6" silt loam; massive with common spherical, fine, broken 10YR 5/5

B1 - 6-14" silt loam; weak, medium subangular blocky; 10YR 5/6 with thin, continuous 5/5 clay films; common worm cavities and feces; common root tubules

B2 - 14-26" silt loam to silty clay loam; moderate, medium subangular blocky to weak prismatic; mottled 10YR 5/2-6, with thin, continuous 5/2 clay films; very dense 20-30 (incipient X)

B3 - 26-34" silt loam; moderate, coarse subangular blocky; diffuse to sharp, medium mottles 10YR 5/2-5/4-8; common root tubules; common 5/2 gleyed joints; common 7/1 silt coats

C - 34-60" silt loam; massive (top half) to coarse platy; 10YR 5/4-6, diffusely stained 3/6 and irregular gleyed 5/2-3 surfaces

IIB3b - 60-78" silty clay loam; massive to moderate, fine subangular blocky; 10YR 6/6-5/8, weak diffusely mottled, few 5/2 gleyed root traces and thick clay films; discontinuous, heavy 2/2 manganese coats

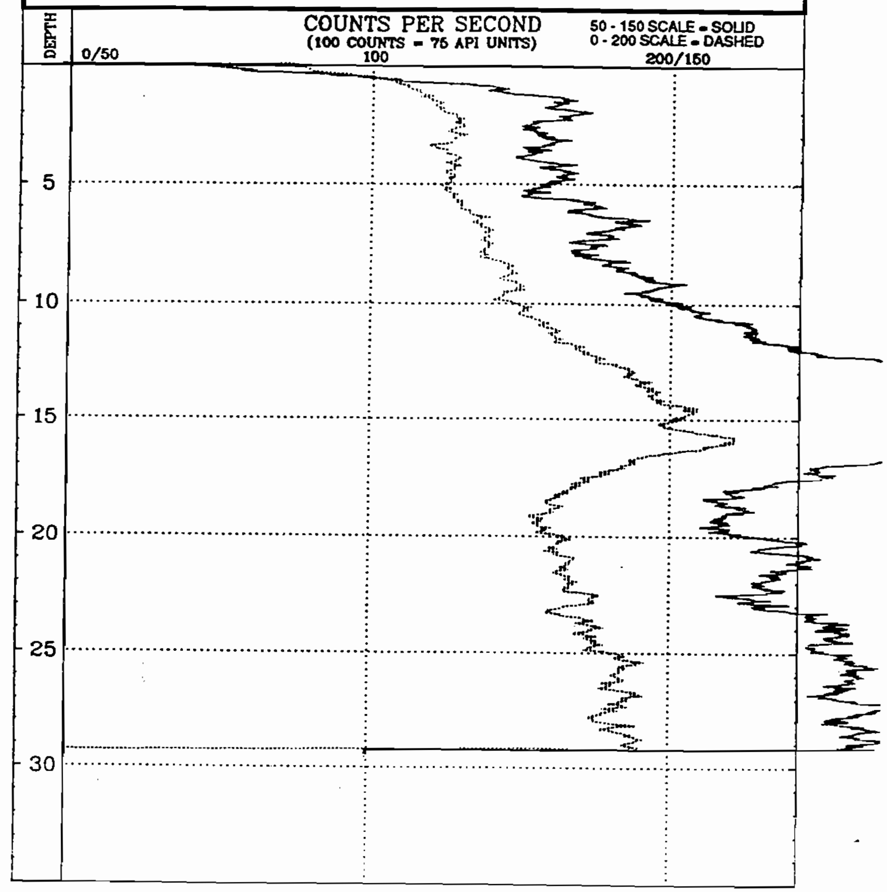
IIIB2b - 78-90" STONE LINE pisolitic granular, with dark pisolitic nodules, trace shale and chert clasts in top 4" grading downward to clay; strong, medium subangular blocky; 7.5YR 4/6-5/4, cut by 40% 2/2 manganese dendrites and continuous coats

IIIB3b - 90-102" clay loam; massive to very fine subangular blocky; diffusely 10YR 5/4-6 with trace of 5/2 clay films on through joints and few root tubules; common darker, very fine fragments of shale

Comments: Very weak surface B (see log) suggests erosion. Stone line and long log-slope to shale suggest aggredation on this head-of-middle surface (=toe of upper surface). IIB3 could represent lower loess.

NATURAL GAMMA–RAY LOG

TC = 5 RATE = 5 FT/MIN OSM–29 LOG # 89–406



INDIANA GEOLOGICAL SURVEY

Dept. of Natural Resources
State of Indiana

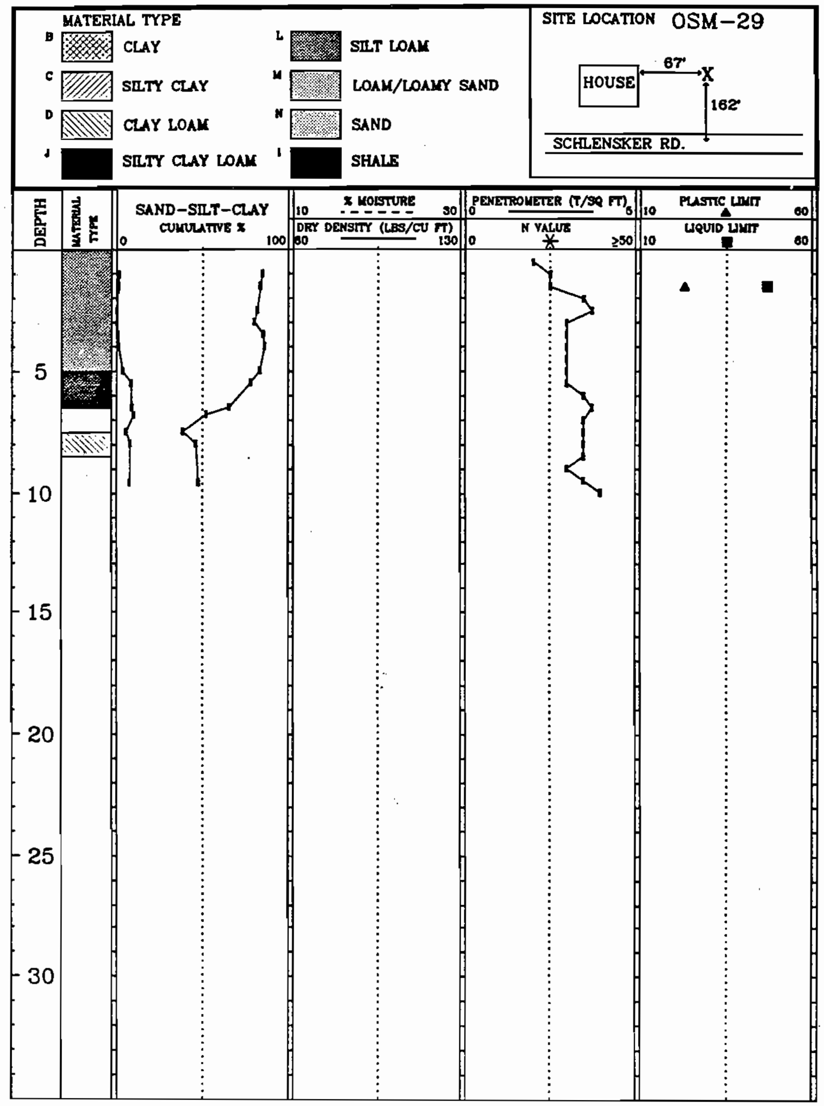
OSM-EVANSVILLE PROJECT

BORING# 29

BORING DATA

LAB ID	BORING	DEPTH inches	% Gk	% SA	% SI	% CL	L.L.	P.L.	P.I.	SHRINK. LIMIT %	LINEAL SHRINK. %	CLASS.
891210	OSM29	6-12	0.0	1.8	83.1	15.1						CL,Lean Clay
891211	OSM29	12-18	0.0	1.5	82.2	16.3	46.7	23.2	23.5	18.7	12.2	CL,Lean Clay
891212	OSM29	24-30	0.0	0.7	81.2	18.1						CL,Lean Clay
891213	OSM29	30-36	0.0	0.8	79.3	19.9						CL,Lean Clay
891214	OSM29	36-42	0.0	1.1	84.1	14.9						CL,Lean Clay
891215	OSM29	42-48	0.0	1.4	84.7	13.9						CL,Lean Clay
891216	OSM29	48-60	0.0	3.8	79.5	16.7						CL,Lean Clay
891217	OSM29	60-66	0.0	8.7	69.4	21.9						CL,Lean Clay
891218	OSM29	70-78	1.1	9.1	56.5	33.3						CL,Lean Clay
891219	OSM29	78-82	4.7	10.3	42.0	43.0						CL,lean Cl with Sa
891220	OSM29	85-90	0.0	6.1	32.6	61.3						CH,Fat Clay
891221	OSM29	90-96	1.5	8.3	38.1	52.1						CH,Fat Clay
891222	OSM29	110-115	0.1	8.2	39.6	52.1	74.6	26.0	48.6	6.5	24.9	CH,Fat Clay

BORING	DEPTH in.	P.P. t/sq ft	N VAL
OSM-29	6	2.00	
OSM-29	12	2.50	
OSM-29	18	2.50	
OSM-29	24	3.50	
OSM-29	30	3.75	
OSM-29	36	3.00	
OSM-29	42	3.00	
OSM-29	48	3.00	
OSM-29	54	3.00	
OSM-29	60	3.00	
OSM-29	66	3.00	
OSM-29	72	3.50	
OSM-29	78	3.75	
OSM-29	84	3.50	
OSM-29	90	3.50	
OSM-29	96	3.50	
OSM-29	102	3.50	
OSM-29	108	3.00	
OSM-29	114	3.50	
OSM-29	120	4.00	



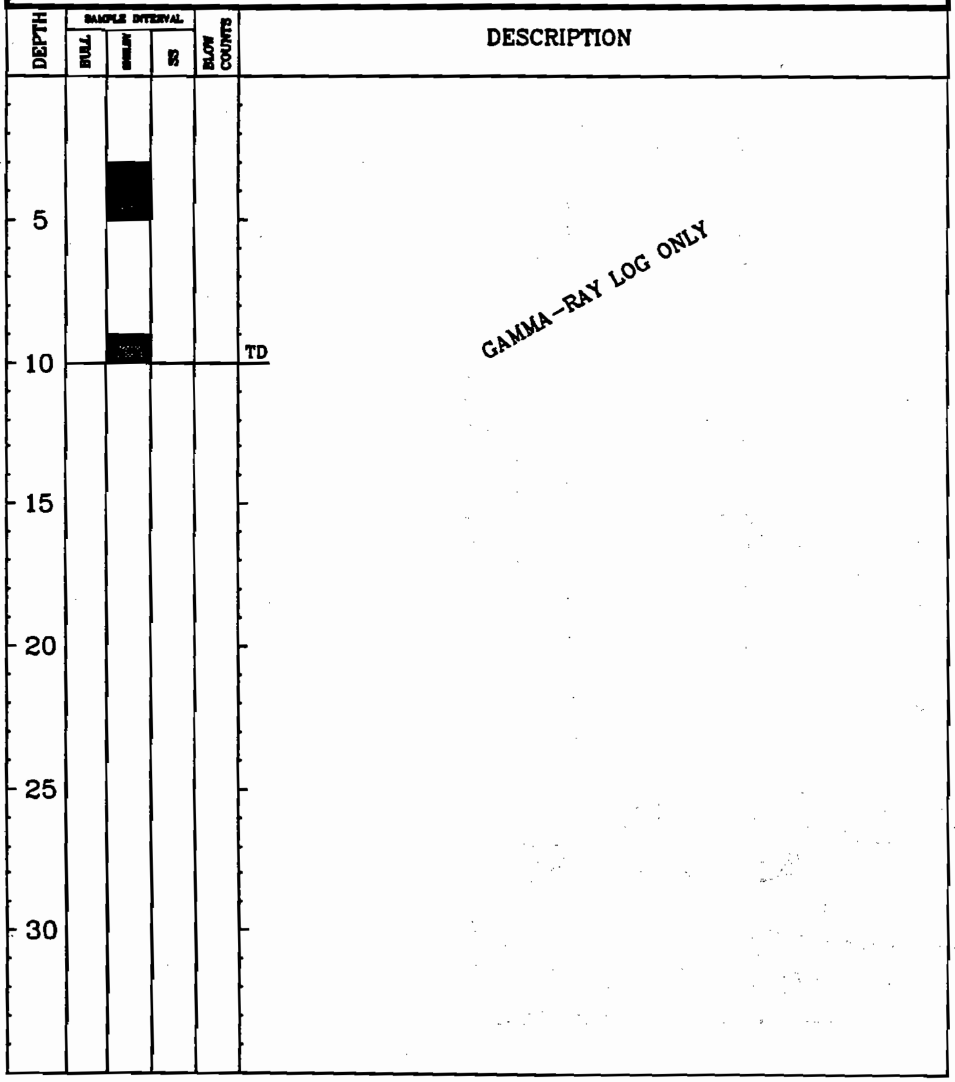
INDIANA GEOLOGICAL SURVEY

Dept. of Natural Resources
State of Indiana

OSM–EVANSVILLE PROJECT

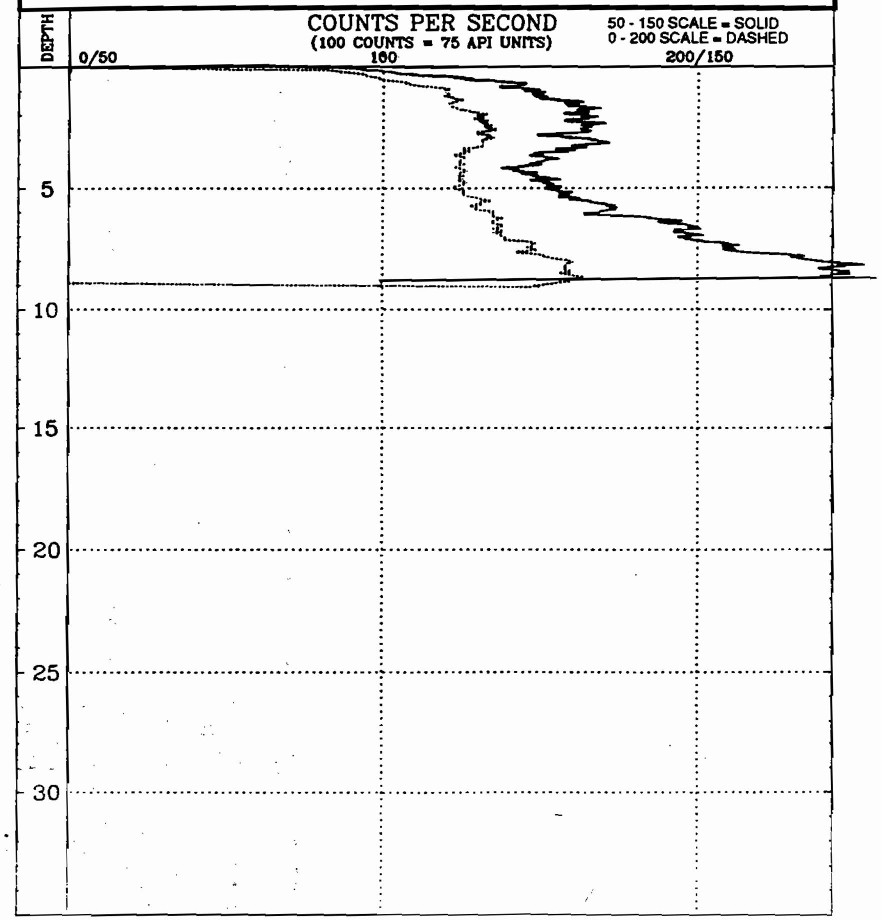
BORING# 30
Page 1 of 1

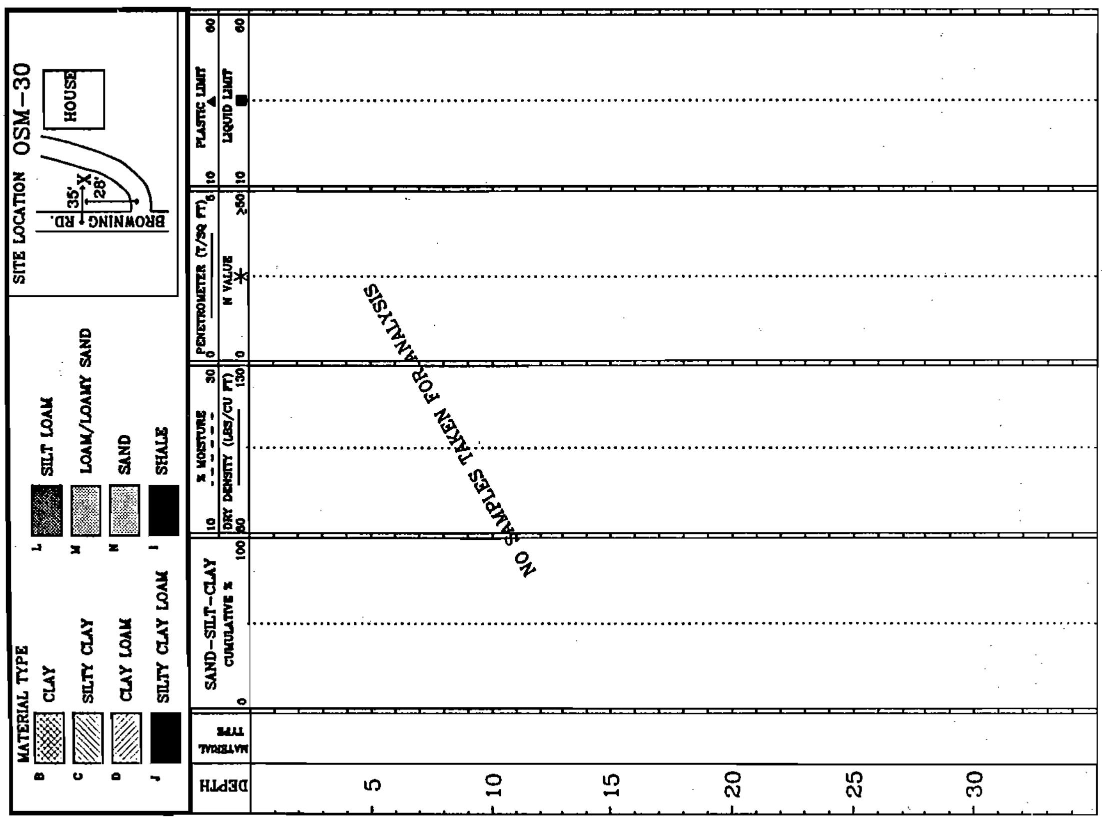
LOCATION: 1/4 NE1/4 SW1/4 SE1/4 SEC 9 T. 5 S. R. 10 W. ELEVATION: 465'
DATE: METHOD: 4 IN. RIG: B-34 DRILLED BY: ARNOLD/RIDDLE
GAMMA LOGGED BY: CHITWOOD DESCRIBED BY: BLEUER



NATURAL GAMMA–RAY LOG

TC = 5 RATE = 5 FT/MIN OSM–30 LOG # 89–408



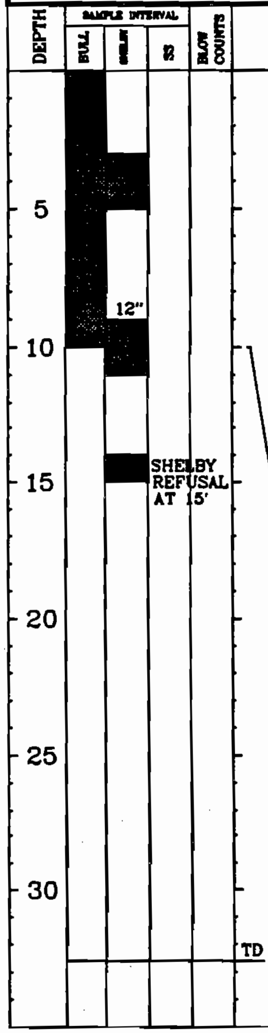

MATERIAL TYPE
B CLAY
C SILTY CLAY
D CLAY LOAM
J SILTY CLAY LOAM
L SILT LOAM
M LOAM/LOAMY SAND
N SAND
I SHALE
SITE LOCATION OSM-30
BROWNING RD.
35'
28'
X
HOUSE
DEPTH
MATERIAL TYPE
SAND-SILT-CLAY
CUMULATIVE %
0
100
% MOISTURE
10
30
DRY DENSITY (LBS/CU FT)
80
130
PENETROMETER (T/SQ FT)
0
5
N VALUE
0
≥50
PLASTIC LIMIT
10
60
LIQUID LIMIT
10
60
NO SAMPLES TAKEN FOR ANALYSIS
5
10
15
20
25
30

INDIANA GEOLOGICAL SURVEY — Dept. of Natural Resources, State of Indiana

OSM-EVANSVILLE PROJECT

BORING# 31
Page 1 of 1

LOCATION: 1/4 NW1/4 SW1/4 SW1/4 SEC 22 T. 5 S. R. 10 W. ELEVATION: 470'
DATE: METHOD: 4 IN. RIG: B-34 DRILLED BY: ARNOLD/RIDDLE
GAMMA LOGGED BY: CHITWOOD DESCRIBED BY: BLEUER



DESCRIPTION

A - 0-2" silt loam; massive to granular; 10YR 3/2; diffuse base (turf effects)

B21 - 2-6" silt loam to loam; moderate, coarse platy; 10YR 5/5-6 with few, diffuse to distinct, fine 5-6/1 mottles; common root tubules

B22 - 6-32" silt loam to loam; weak to moderate medium subangular blocky in top half, grades to massive below; 10YR 5/6 with thin 4/6 clay films; cut obliquely at 12-15" by silt-filled krotovina

B31 - 32-58" loam; massive to weak coarse platy; 10YR 4/6, 40% stained 5/6, common darker iron and manganese staining on joints and as 1/8" manganese pellets or as diffuse, connected masses (plinthite) in lower 5"; STRONG SOLVENT ODOR

IIB32 - 58-62" silty clay loam; strong, medium subangular blocky; 10YR 3/3 with thick 3/4-6 clay films on joints and ped surfaces and 40% 2/2 manganese staining

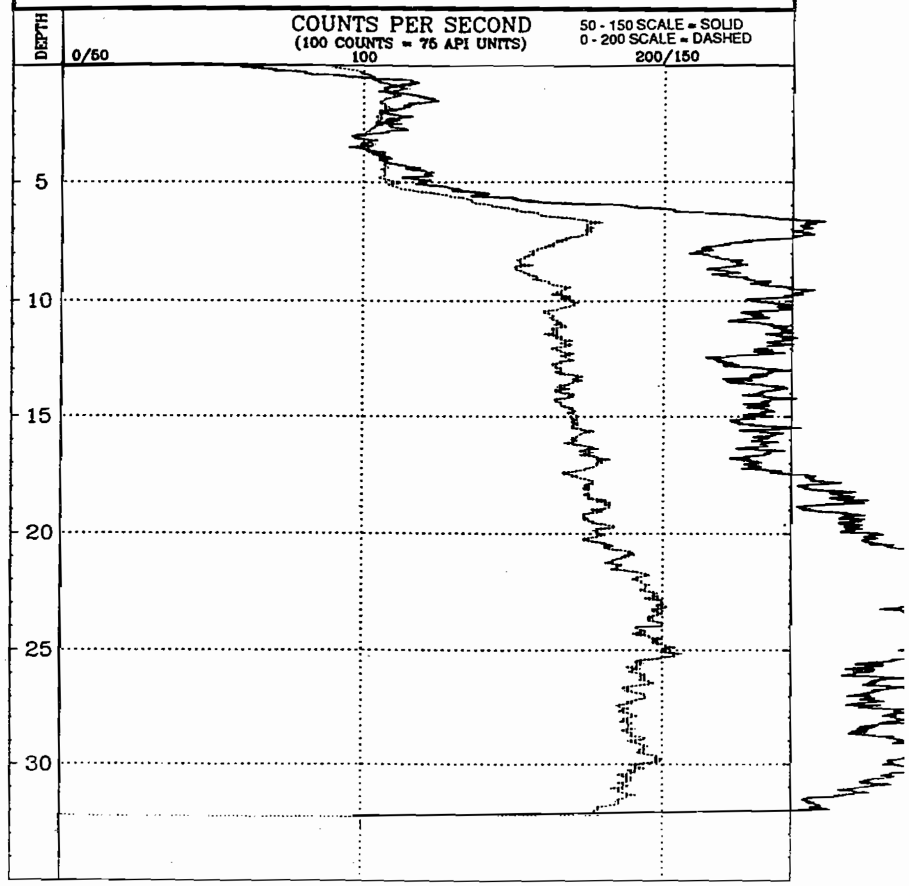
IIC1 - 60-67" clay; massive, cut by widely spaced joints; 10YR 6/6 (top 3" to 2.5Y 6/4 below

IIC2 - 67-120" clay 2.5Y 7/6

Comments: A and part of the B are missing. Upper plattiness due to equipment compaction. Generally loamy throughout, entire section is more like lower loess interval at sites on middle surface, or a result of sandstone stringers in bedrock. B31 is similar to "stone line" materials described at lower sites, i.e., ground-water effects are localized due to coarser texture over residual shale. Material below appears to grade directly to massive shale, without long sloping log through physically disaggregated shale. Solvent is perched atop the IIB32 clay.

NATURAL GAMMA-RAY LOG

TC = 5 RATE = 5 FT/MIN OSM-31 LOG #89-410

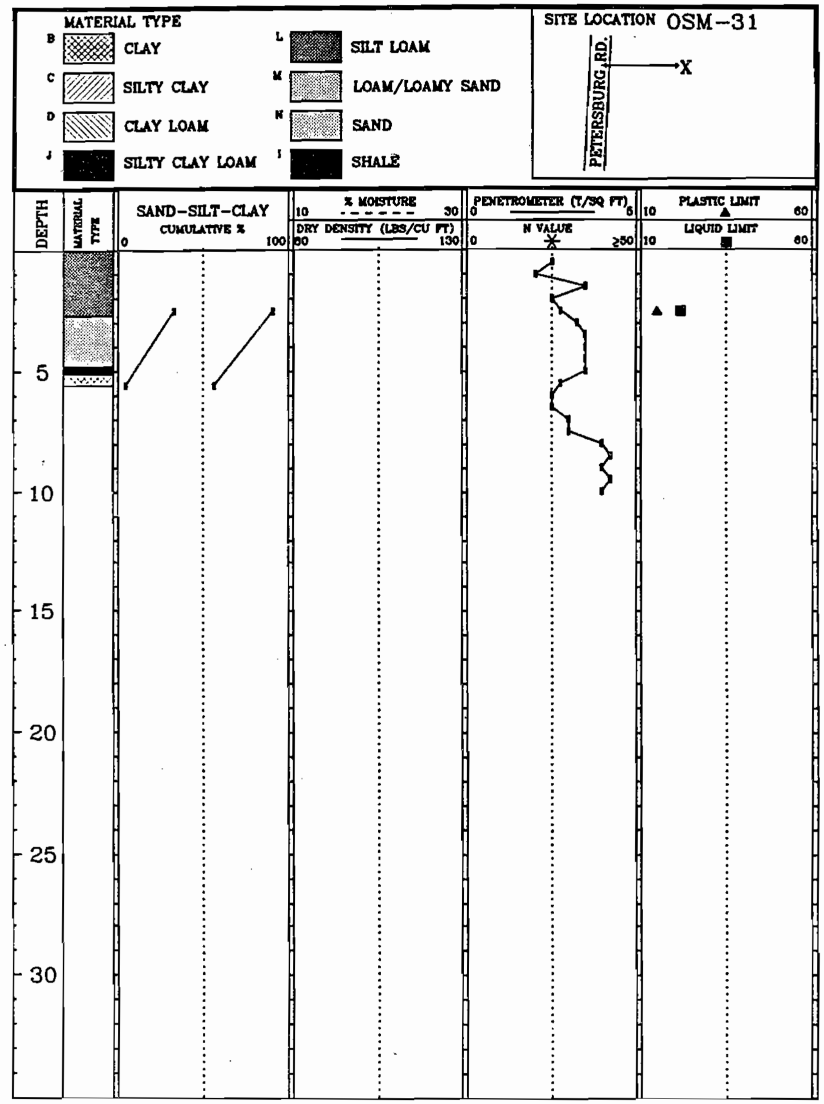


INDIANA GEOLOGICAL SURVEY	Dept. of Natural Resources State of Indiana
OSM–EVANSVILLE PROJECT	BORING# 31

BORING DATA

LAB ID	BORING	DEPTH inches	% GR	% SA	% SI	% CL	L.L.	P.L.	P.I.	SHRINK. LIMIT %	LINEAL SHRINK. %	CLASS.
891208	OSM31	24-30	0.3	32.7	58.2	8.7	21.7	14.9	6.8	9.1	7.2	CL-ML,Sandy Silty Cl
891209	OSM31	62-67	0.0	4.4	52.0	43.5						CH,Fat Clay

BORING	DEPTH in.	P.P. t/sq ft	N VAL
OSM-31	6	2.50	
OSM-31	12	2.00	
OSM-31	18	3.50	
OSM-31	24	2.50	
OSM-31	30	2.75	
OSM-31	36	3.25	
OSM-31	42	3.50	
OSM-31	48	3.50	
OSM-31	54	3.50	
OSM-31	60	3.50	
OSM-31	66	2.75	
OSM-31	72	2.50	
OSM-31	78	2.50	
OSM-31	84	3.00	
OSM-31	90	3.00	
OSM-31	96	4.00	
OSM-31	102	4.25	
OSM-31	108	4.00	
OSM-31	114	4.25	
OSM-31	120	4.00	



INDIANA GEOLOGICAL SURVEY — Dept. of Natural Resources, State of Indiana

OSM-EVANSVILLE PROJECT

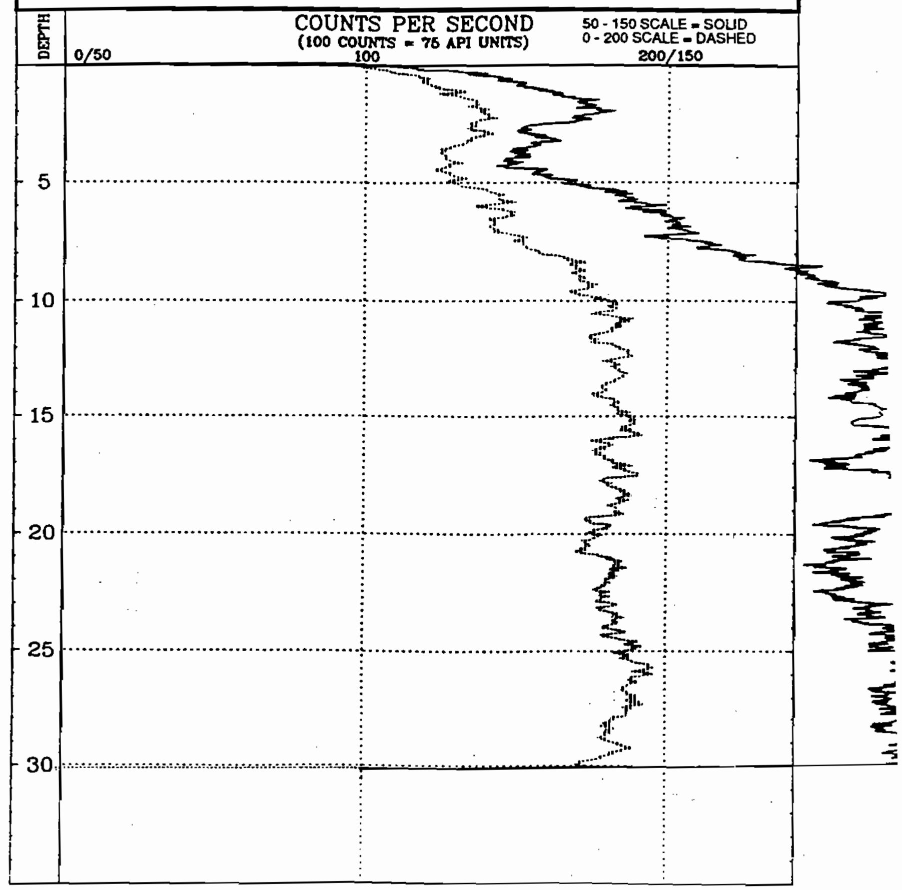
BORING# 32 — Page 1 of 1

LOCATION: 1/4 SE 1/4 SW 1/4 SE 1/4 SEC 28 T. 5 S. R. 10 W. ELEVATION: 430'
DATE: METHOD: 4 IN. RIG: B-34 DRILLED BY: ARNOLD/RIDDLE
GAMMA LOGGED BY: CHITWOOD DESCRIBED BY: BLEUER

DEPTH	SAMPLE INTERVAL: BULK	SAMPLE INTERVAL: SHELBY	SAMPLE INTERVAL: SS	BLOW COUNTS	DESCRIPTION
5					AP - 0-7" silt loam to loam; massive; 10 YR 3/6
					B21 - 7-16" silt loam; moderate, medium to coarse subangular blocky; 10YR 6/6, with thin, continuous 4/6 clay films, few 3/4 manganese blotches
					B22 - 16-30" silt loam; weak, coarse subangular blocky; 7.5YR 4/4, faintly stained 6/4, few 7/3 silt coats on scattered tubes and joints
10					Bx - 30-46" silt loam; massive to weak, coarse subangular blocky to primatic, to strong, fine subangular blocky in lower half; 7.5YR 4/4 with distinct, medium 2.5Y 5/4, 6/2, mottling; cut by 2.5Y 7/2 coats on prism joints; brittle
					B3 - 46-60" silt loam; weak, medium subangular blocky; 10YR 5/6-6/3, few fine diffuse mottles, cut by common 2/2 manganese joint stains; few, thin clay films
15					IIB2b - 60-72" silty clay loam; strong, fine subangular blocky; 10YR 5/6 with common 5/5 medium clay films, some 7/3 silt coats on vertical joints in top 4"
20					IIIB2b - 72-86" - silty clay loam; strong, medium subangular blocky; very irregular mottled appearance of 7.5YR 5-6/6, with medium to thick, continuous clay films anastamosing about peds and lining root tubules, few 5/3-4 slight gleying, few 7/2-3 silt coats on irregular joints
					IIIB3 - 86-94" clay; as above grading to massive, basal 6" a broken jumble of 1/16-1/4" fragments of soft shale; 2.5Y 6/2-6, with diffuse, fine 2/2 manganese blotches, diffusely mottled 7/6-6/8
25					IIIC - 94-108" clay (shale); coarsely jointed; 2.5Y 7/4; few weak joint stains
30				TD	

NATURAL GAMMA-RAY LOG

TC = 5 RATE = 5 FT/MIN OSM-32 LOG #89-412



INDIANA GEOLOGICAL SURVEY — Dept. of Natural Resources, State of Indiana

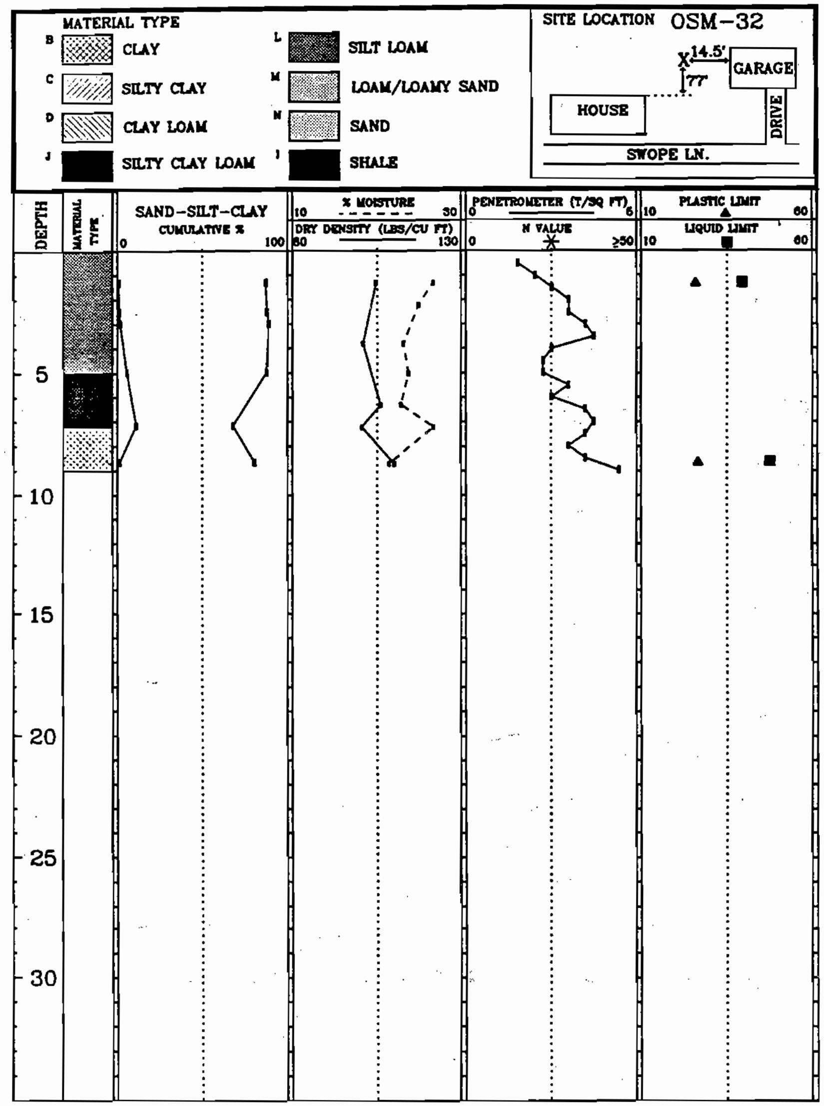
OSM–EVANSVILLE PROJECT — BORING# 32

BORING DATA

LAB ID	BORING	DEPTH inches	% GR	% SA	% SI	% CL	L.L.	P.L.	P.I.	SHRINK. LIMIT %	LINEAL SHRINK. %	CLASS.
891202	OSM32	12-16	0.0	0.6	86.6	12.8	39.1	25.4	13.7	20.4	8.8	ML,Silt
891203	OSM32	24-30	0.0	1.0	86.8	12.2						ML,Silt
891204	OSM32	30-36	0.0	1.5	87.5	10.9						ML,Silt
891205	OSM32	54-60	0.0	5.3	82.4	12.3						ML,Silt
891206	OSM32	80-86	3.2	10.8	57.1	28.9						CL,Lean Clay
891207	OSM32	100-104	0.0	1.4	79.1	19.6	47.0	26.7	20.3	8.4	18.0	CL,Lean Clay

BORING	DEPTH in.	P.P. t/sq ft	N VAL
OSM-32	6	1.50	
OSM-32	12	2.00	
OSM-32	18	2.50	
OSM-32	24	3.00	
OSM-32	30	3.00	
OSM-32	36	3.50	
OSM-32	42	3.75	
OSM-32	48	2.50	
OSM-32	54	2.25	
OSM-32	60	2.25	
OSM-32	66	3.00	
OSM-32	72	2.50	
OSM-32	78	3.50	
OSM-32	84	3.75	
OSM-32	90	3.50	
OSM-32	96	3.00	
OSM-32	102	3.50	
OSM-32	108	4.50	

LAB ID	BORING	SAMP DEPTH inches	% MOIS	DRY DENS lbs/cu ft
	OSM-32	16	25.1	105.0
	OSM-32	26	22.6	na
	OSM-32	46	19.9	101.2
	OSM-32	60	20.8	na
	OSM-32	76	19.5	106.4
	OSM-32	86	25.2	100.8
	OSM-32	104	17.4	110.4



INDIANA GEOLOGICAL SURVEY

Dept. of Natural Resources
State of Indiana

OSM–EVANSVILLE PROJECT

BORING# 33
Page 1 of 1

LOCATION: 1/4 NE1/4 SE1/4 SE1/4 SEC 28 T. 5 S. R.10 W. ELEVATION: 420'
DATE: METHOD: 4 IN. RIG: B-34 DRILLED BY: ARNOLD/RIDDLE
GAMMA LOGGED BY: CHITWOOD DESCRIBED BY: BLEUER

DEPTH | SAMPLE INTERVAL: BULL, SHELBY, SS | BLOW COUNTS | DESCRIPTION

O - 1+" silt loam, 50% rooted matter, top 1/2" thatch

AP - 1-2' silt loam; massive; massive; 10YR 3/2

B1 - 2-6" silt loam; massive to weak, medium platy to subangular blocky; 10YR 4/4; roots common to base

B2 - 6-18" silt loam; weak medium subangular blocky; 10YR 4/4 with common thin clay films and tubule fill, few diffuse 2/2 manganese stains on ped surfaces; common live roots

B3 - 18-30" silt loam; strong, fine to medium subangular blocky (highly jumbled appearance); 10YR 4/5-6, with common 7/4 silt coats and splotches, few 5YR 3/3 clay films in tubules and larger joints

Bx - 30-43" silt loam to silt; 10YR 2/3 (silt fills making up 50-70% of whole) to 4/5-6 (original matrix), well developed subhorizontal streaks in lower part, elsewhere as blebs and irregular veins

IIC - 43-66" loam; massive; 10YR 4/5, common root tubules with varicolored darker coats

IIIB1b - 66-73" loam; massive to weak (welded), fine subangular blocky; 10YR 6/4 with thin 4-5/6 clay films and stains

TD

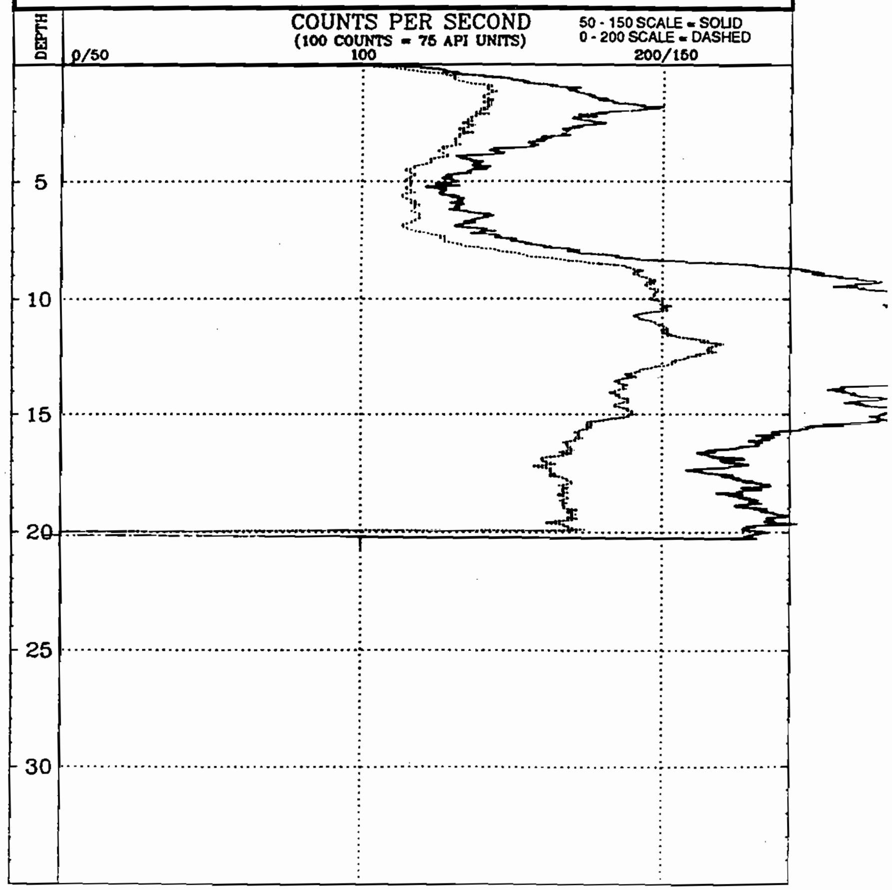
IIIB2b - 73-90" loam to silty clay loam; medium to coarse subangular blocky; diffusely mottled 7.5 to 5YR 4-5/4, with thick 5YR 4/6 clay coats on major joints and common thin coats and films, common 10-7.5YR silt coats on joints; heavy 2/2 manganese staining in basal 4'; basal 2" is iron cemented sandstone (plinthite)

Comments: No fragmental IIIB2 in shale found in this or #31, similar upland crest hole. Plinthite and sandstone are present in the "stoneline" position of lower holes.

Depth scale: 5, 10, 15, 20, 25, 30

NATURAL GAMMA–RAY LOG

TC = 5 RATE = 5 FT/MIN OSM–33 LOG # 89–414



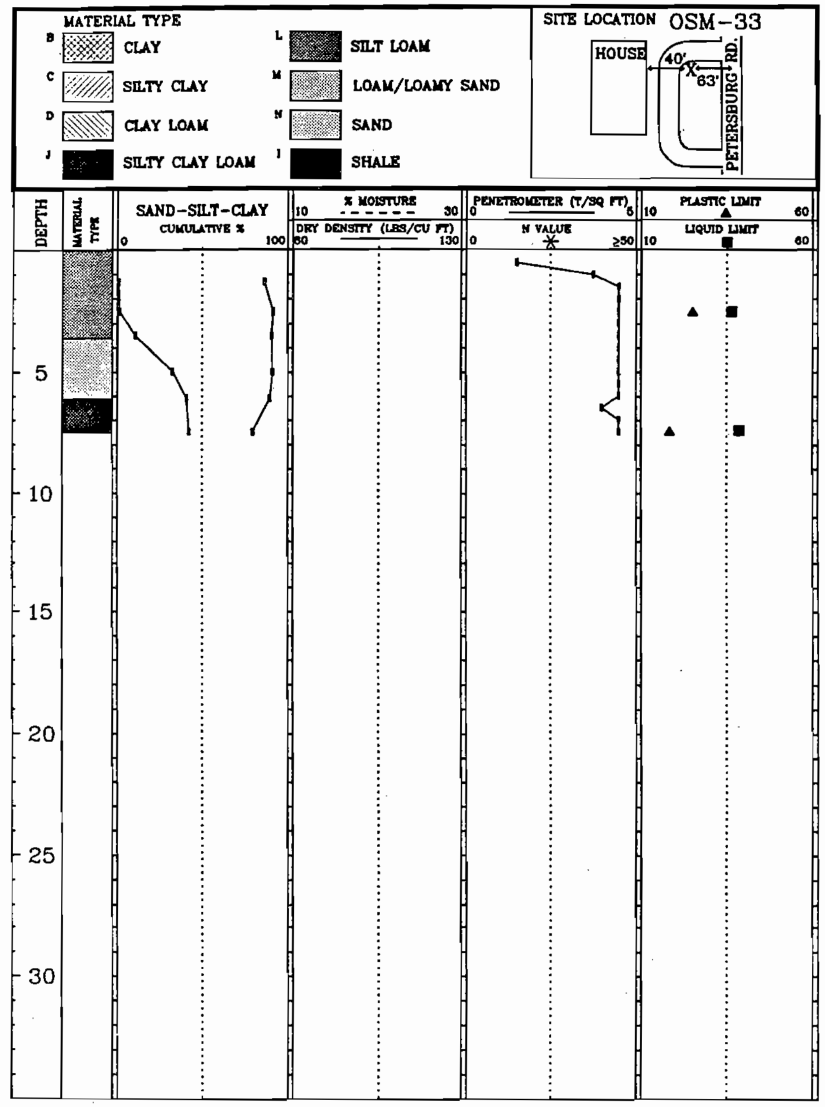
INDIANA GEOLOGICAL SURVEY Dept. of Natural Resources State of Indiana

OSM-EVANSVILLE PROJECT BORING# 33

BORING DATA

LAB ID	BORING	DEPTH inches	% GR	% SA	% SI	% CL	L.L.	P.L.	P.I.	SHRINK. LIMIT %	LINEAL SHRINK. %	CLASS.
891196	OSM33	10-16	0.0	0.5	85.8	13.6						CL,Lean Clay
891197	OSM33	24-30	0.0	1.3	90.2	8.6	36.4	25.4	11.0	24.3	17.0	ML,Silt
891198	OSM33	36-42	0.0	10.7	79.8	9.5						ML,Silt
891199	OSM33	54-60	0.0	32.4	58.8	8.8						ML,Sandy Silt
891200	OSM33	67-73	0.0	40.7	48.8	10.5						ML,Sandy Silt
891201	OSM33	84-90	0.9	42.2	37.2	19.6	38.4	18.1	20.3	15.8	10.3	CL,Sandy Lean Clay

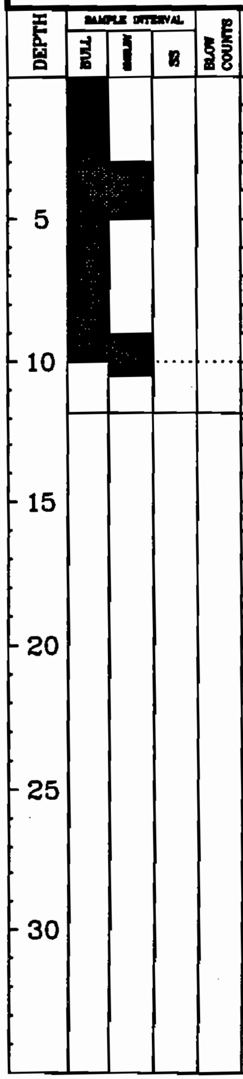
BORING	DEPTH in.	P.P. t/sq ft	N VAL
OSM-33	6	1.50	
OSM-33	12	3.75	
OSM-33	18	4.50	
OSM-33	24	4.50	
OSM-33	30	4.50	
OSM-33	36	4.50	
OSM-33	42	4.50	
OSM-33	48	4.50	
OSM-33	54	4.50	
OSM-33	60	4.50	
OSM-33	66	4.50	
OSM-33	72	4.50	
OSM-33	78	4.00	
OSM-33	84	4.50	
OSM-33	90	4.50	



INDIANA GEOLOGICAL SURVEY
Dept. of Natural Resources
State of Indiana

OSM–EVANSVILLE PROJECT
BORING# 34
Page 1 of 1

LOCATION: 1/4 SE 1/4 SW 1/4 SE 1/4 SEC 15 T. 5 S. R. 10 W. ELEVATION: 430'
DATE: METHOD: 4 IN. RIG: B-34 DRILLED BY: ARNOLD/RIDDLE
GAMMA LOGGED BY: CHITWOOD DESCRIBED BY: BLEUER



DESCRIPTION

AP - 0-6" silt loam; massive; 10YR 3/3-4

C - 6-10" silt loam; massive to very weak medium subangular blocky; 10YR 5/6; common root tubules

IIB2b - 10-15" silt loam to silty clay loam; strong, medium subangular blocky; 10YR 6/6, with medijm continuous 4-5/6 clay films, abundant splotches and dendrites of 2/2 manganese staining; common root tubules and other pores; very open, fragmental appearance

IIB22b - 15-60" silt loam to silty clay loam; massive to weak, fine to medium subangular blocky; distinct, highly contrasting medium mottles, 10YR 5-6/5-6, common 7/1 masses of silt in pods and as long, continuous tube fills, common, thick, discontinuous 4/2 clay coats ; evidence of lateral and pressure deformation in streaking and convolution of structures

IIC - 60-84 silt loam; massive; 10YR 6/4, diffusely stained 5/6; traces of root pores throughout, associated with weak 7/1 gleying; sandy loam and complex in basal 6" (similar to horizon above)

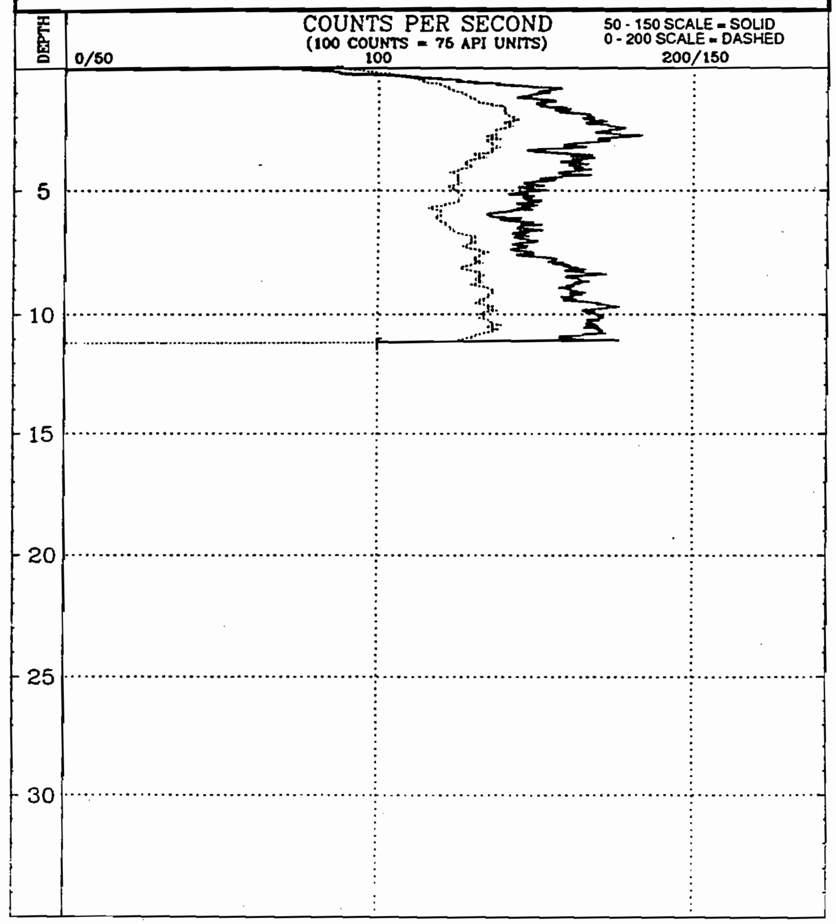
IIIEb (?) - 84-94" silt loam; 10YR 6/4, with common 4/3 splotches and tubule stains, cut by 7/3-4 silt loam to silt fills and common ped coats; basal 2" horizontally laminated, with contorted structure of fine welded peds, containing trace of fragmental shale

IIIB2b - 94-120" silt loam to silty clay loam; fine to medium subangular blocky OR welded blebs of ?; 10YR 5/6 with common 6/3-6/5 to 7.5YR 4/6 thick clay coats; common 2/0 manganese stains and stained clay coats (50% surface areas)

Comments: The top A-C profile is presumed to be either artificial fill or post-settlement sheetwash. IIB22b is a highly variable unit that is interpreted as a toe-slope colluvial fan. (Without evidence of through-tubules, it would be, and perhaps still should be interpreted as artificial fill). IIIE appears to be an eluvial top of another paleosol, but it too contains colluvial (?) debris. The profile does not reach disaggregated shale.

NATURAL GAMMA–RAY LOG

TC = 5 RATE = 5 FT/MIN OSM–34 LOG #89-416



INDIANA GEOLOGICAL SURVEY

Dept. of Natural Resources
State of Indiana

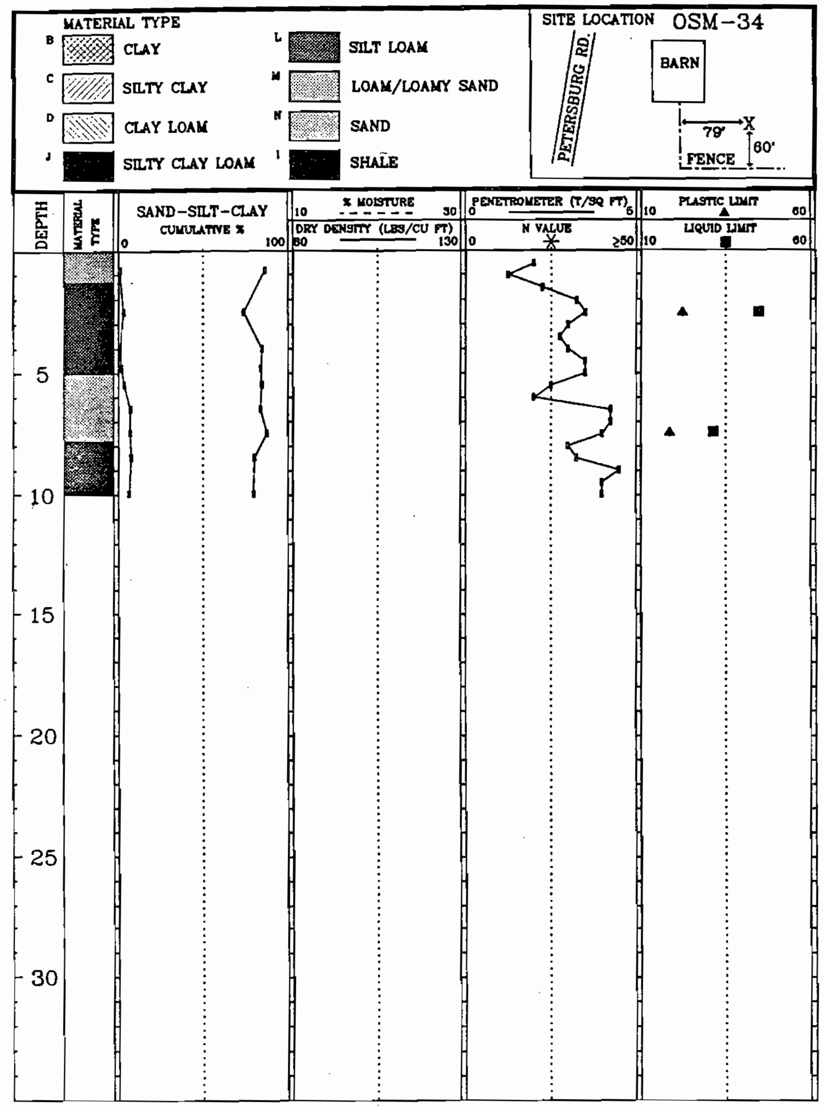
OSM-EVANSVILLE PROJECT

BORING# 34

BORING DATA

LAB ID	BORING	DEPTH inches	% GR	% SA	% SI	% CL	L.L.	P.L.	P.I.	SHRINK. LIMIT %	LINEAL SHRINK. %	CLASS.
891187	OSM34	6-10	0.0	0.7	85.7	13.6						CL,Lean Clay
891188	OSM34	24-30	0.0	2.9	71.0	26.1	44.2	22.4	21.8	9.8	16.0	CL,Lean Clay
891189	OSM34	42-48	0.0	1.1	83.6	15.3						CL,Lean Clay
891190	OSM34	52-58	0.0	1.5	82.6	15.8						CL,Lean Clay
891191	OSM34	60-66	0.2	3.3	81.2	15.3						CL,Lean Clay
891192	OSM34	72-78	1.7	6.9	76.8	14.6						CL,Lean Clay
891193	OSM34	84-90	1.4	6.6	80.9	11.1	30.7	18.1	12.6	21.2	14.3	CL,Lean Clay
891194	OSM34	96-102	1.0	7.2	73.0	18.8						CL,Lean Clay
891195	OSM34	114-120	1.2	6.1	73.6	19.1						CL,Lean Clay

BORING	DEPTH in.	P.P. t/sq ft	N VAL
OSM-34	6	2.00	
OSM-34	12	1.25	
OSM-34	18	2.25	
OSM-34	24	3.25	
OSM-34	30	3.50	
OSM-34	36	3.00	
OSM-34	42	2.75	
OSM-34	48	3.00	
OSM-34	54	3.50	
OSM-34	60	3.50	
OSM-34	66	2.50	
OSM-34	72	2.00	
OSM-34	78	4.25	
OSM-34	84	4.25	
OSM-34	90	4.00	
OSM-34	96	3.00	
OSM-34	102	3.25	
OSM-34	108	4.50	
OSM-34	114	4.00	
OSM-34	120	4.00	



INDIANA GEOLOGICAL SURVEY — Dept. of Natural Resources, State of Indiana

OSM–EVANSVILLE PROJECT

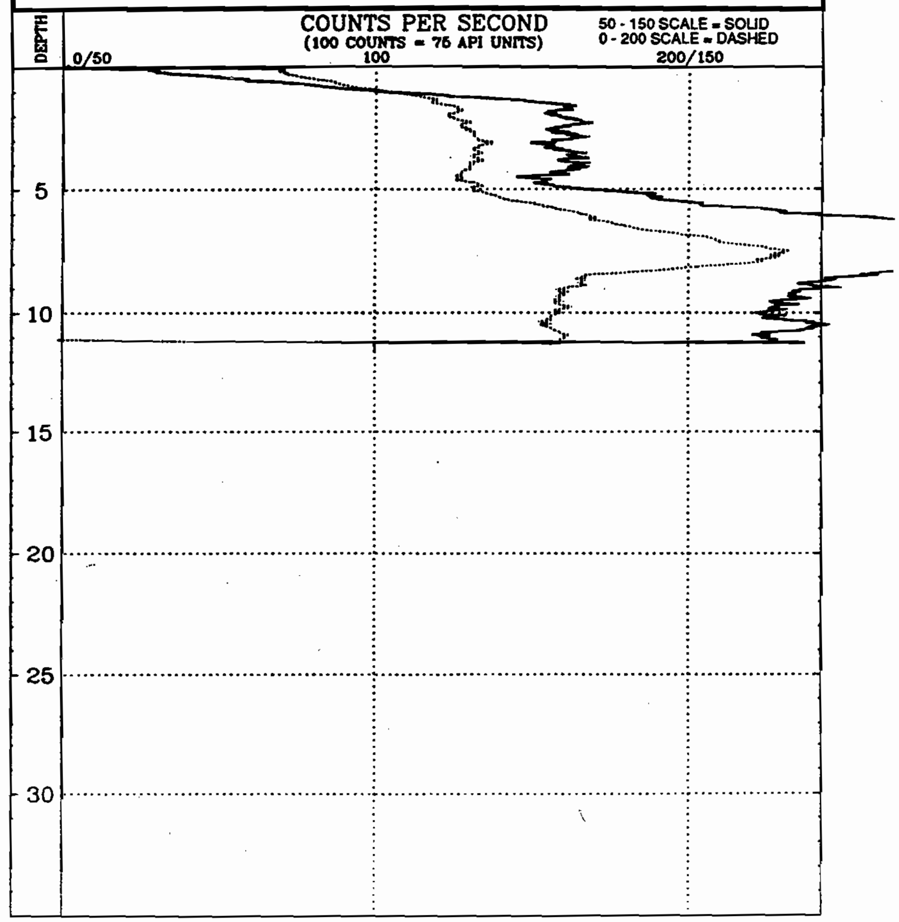
BORING# 35
Page 1 of 1

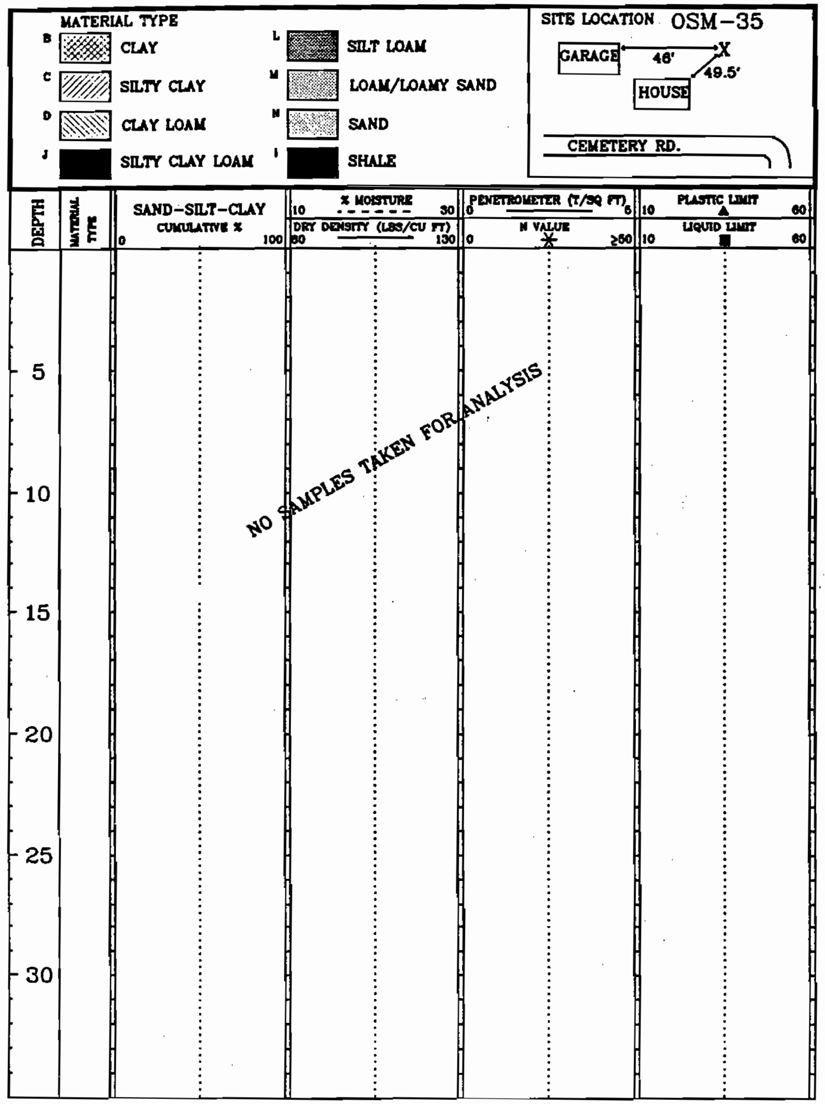
LOCATION: 1/4 SE1/4 SE1/4 NW1/4 SEC 2 T. 5 S. R. 10 W. ELEVATION: 480'
DATE: METHOD: 4 IN. RIG: B-34 DRILLED BY: ARNOLD/RIDDLE
GAMMA LOGGED BY: CHITWOOD DESCRIBED BY: BLEUER

DEPTH	SAMPLE INTERVAL: FULL	SHELBY	SS	BLOW COUNTS	DESCRIPTION
5					GAMMA-RAY LOG ONLY
10					▽ TD
15					
20					
25					
30					

NATURAL GAMMA–RAY LOG

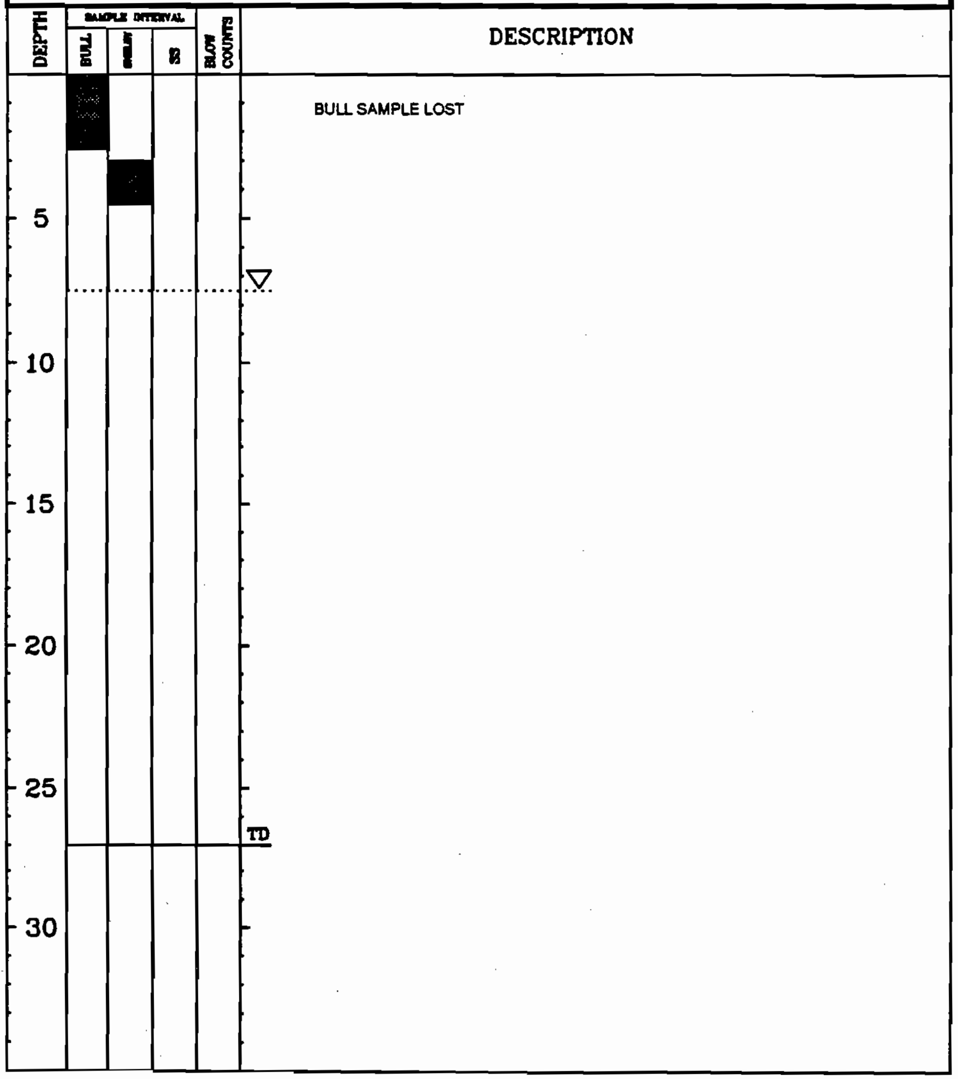
TC = 5 RATE = 5 FT/MIN OSM–35 LOG # 89–418




MATERIAL TYPE
B CLAY
C SILTY CLAY
D CLAY LOAM
J SILTY CLAY LOAM
L SILT LOAM
M LOAM/LOAMY SAND
N SAND
I SHALE
SITE LOCATION OSM-35
GARAGE
46'
X
49.5'
HOUSE
CEMETERY RD.
DEPTH
MATERIAL TYPE
SAND-SILT-CLAY
CUMULATIVE %
0
100
% MOISTURE
10
30
DRY DENSITY (LBS/CU FT)
80
130
PENETROMETER (T/SQ FT)
0
6
N VALUE
0
≥50
PLASTIC LIMIT
10
60
LIQUID LIMIT
10
60
5
10
15
20
25
30
NO SAMPLES TAKEN FOR ANALYSIS

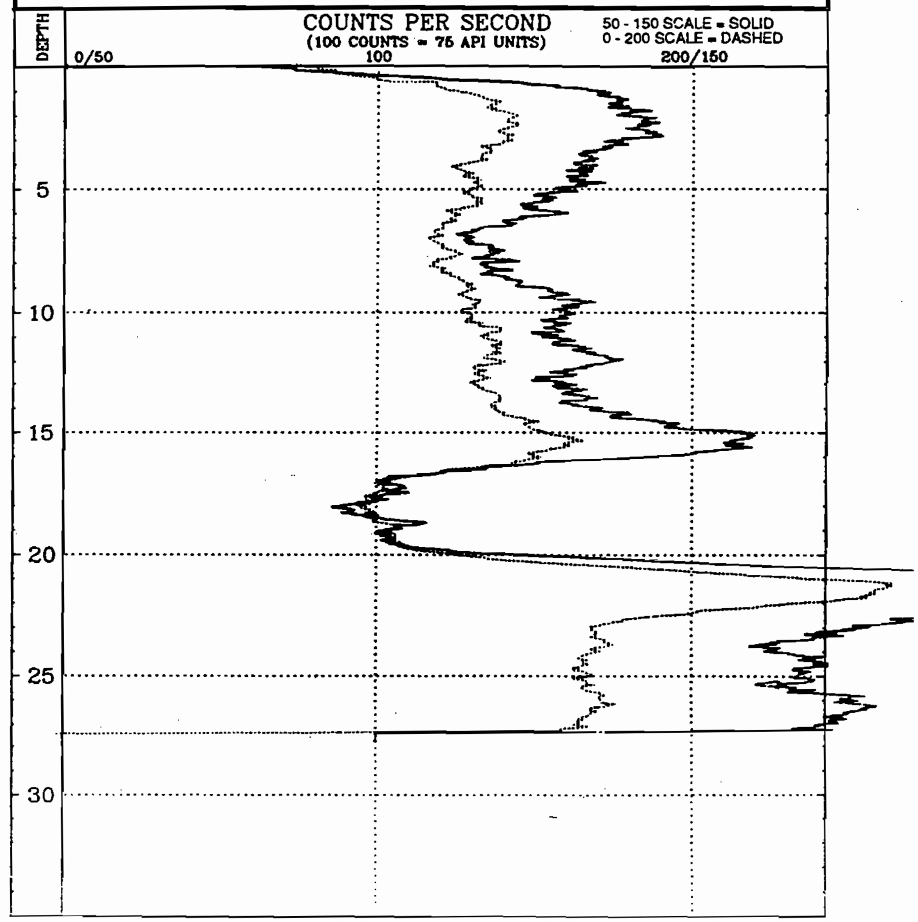
INDIANA GEOLOGICAL SURVEY	Dept. of Natural Resources State of Indiana
OSM–EVANSVILLE PROJECT	BORING# 36 Page 1 of 1

LOCATION: 1/4 NE1/4 SE1/4 NW1/4 SEC 2 T. 5 S. R.10 W. ELEVATION: 470'
DATE: METHOD: 4 IN. RIG: B-34 DRILLED BY: ARNOLD/RIDDLE
GAMMA LOGGED BY: CHITWOOD DESCRIBED BY: BLEUER



NATURAL GAMMA–RAY LOG

TC = 5 RATE = 5 FT/MIN OSM–36 LOG # 89–420

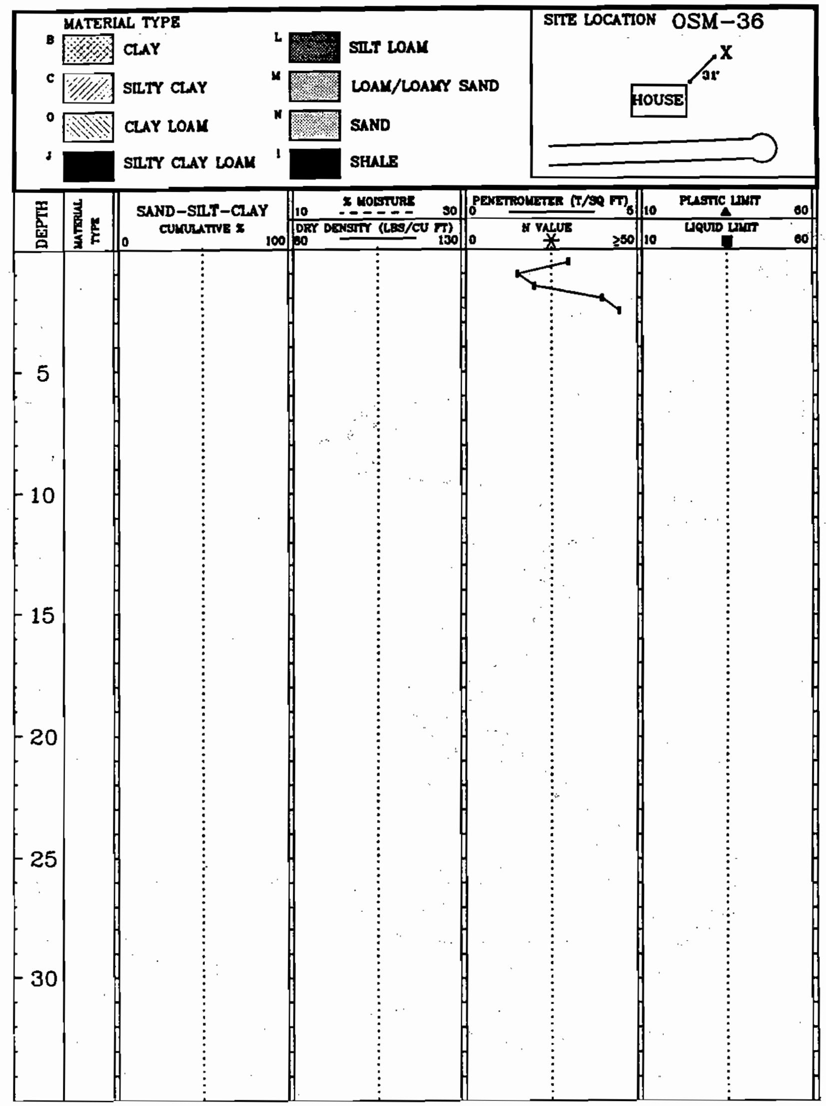


INDIANA GEOLOGICAL SURVEY — Dept. of Natural Resources, State of Indiana

OSM–EVANSVILLE PROJECT — BORING# 36

BORING DATA

BORING	DEPTH in.	P.P. t/sq ft	N VAL
OSM-36	6	3.00	
OSM-36	12	1.50	
OSM-36	18	2.00	
OSM-36	24	4.00	
OSM-36	30	4.50	



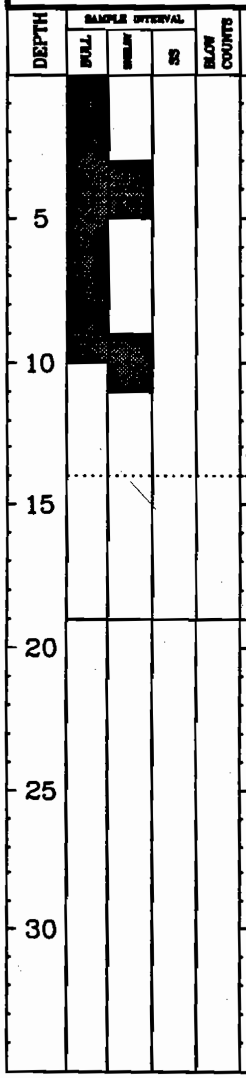
INDIANA GEOLOGICAL SURVEY

Dept. of Natural Resources
State of Indiana

OSM–EVANSVILLE PROJECT

BORING# 37
Page 1 of 1

LOCATION: 1/4 NE1/4 NE1/4 SE1/4 SEC 11 T. 5 S. R.10 W. ELEVATION: 420'
DATE: METHOD: 4 IN. RIG: B-34 DRILLED BY: ARNOLD/RIDDLE
GAMMA LOGGED BY: CHITWOOD DESCRIBED BY: BLEUER



DESCRIPTION

AP - 0-7" silt loam; massive to disorganized mix of organic matter, fecal pellets and peds; 10YR 3-4/4

B21 - 7-16" silt loam; weak to moderate fine subangular blocky; 10YR 5/4, few faint 6/3 mottles; common root tubules

B22 - 16-30" silt loam to silty clay loam; massive to weak,coarse subangular blocky; 10YR 6/6-8, diffusely mottled 6/3-4, common 5-6/1 gleyed joint s with thin, continuous clay films and 2/2 manganese splotches and discontinuous films

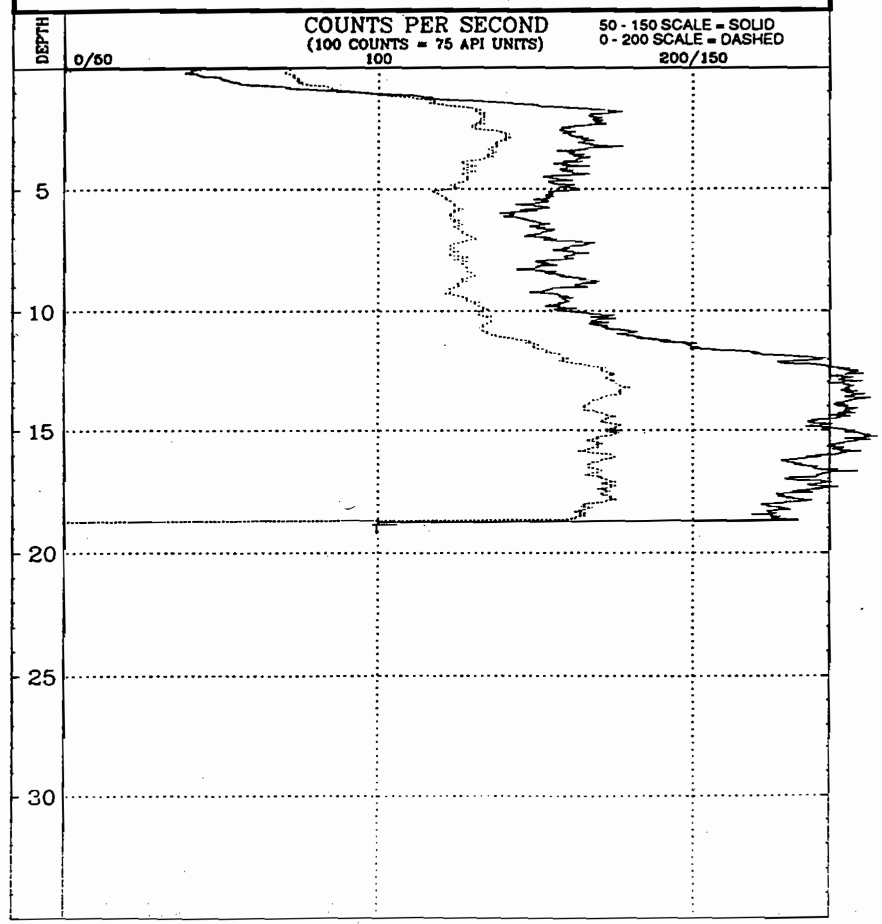
B3 - 30-33" silt loam; massive to very weak subangular blocky; common gleyed root tubules with thin clay film linings

C - 33-60" silt loam; massive; 10YR 5/6
60-120" as above (most of sample lost; log appearance similar to IIB2 horizon in lower loess

Comments: The 60-90" lost interval logs like lower loesses of other holes (as 12, 13, 32).

NATURAL GAMMA-RAY LOG

TC = 5 RATE = 5 FT/MIN OSM-37 LOG # 89-422



INDIANA GEOLOGICAL SURVEY — Dept. of Natural Resources, State of Indiana

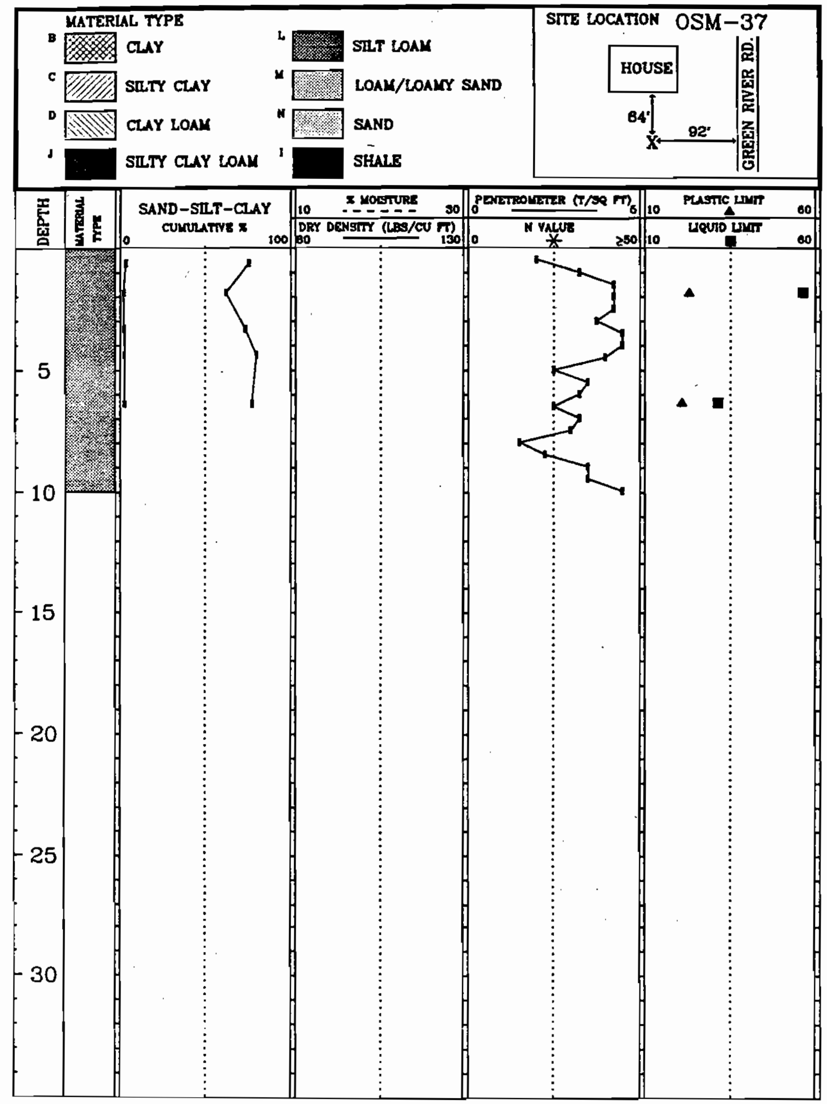
OSM-EVANSVILLE PROJECT

BORING# 37

BORING DATA

LAB ID	BORING	DEPTH inches	% GR	% SA	% SI	% CL	L.L.	P.L.	P.I.	SHRINK. LIMIT %	LINEAL SHRINK. %	CLASS.
891182	OSM37	2-7	0.2	3.0	72.4	24.3						CL,Lean Clay
891183	OSM37	16-22	0.0	2.0	60.2	37.8	55.8	22.5	33.3	7.5	20.8	CH,Fat Clay
891184	OSM37	33-39	0.2	2.0	71.4	26.4						CL,Lean Clay
891185	OSM37	47-53	0.2	2.5	77.4	19.9						CL,Lean Clay
891186	OSM37	73-77	0.1	2.5	74.8	22.7	30.9	20.7	10.2	24.0	11.8	CL,Lean Clay

BORING	DEPTH in.	P.P. t/sq ft	N VAL
OSM-37	6	2.00	
OSM-37	12	3.25	
OSM-37	18	4.25	
OSM-37	24	4.25	
OSM-37	30	4.25	
OSM-37	36	3.75	
OSM-37	42	4.50	
OSM-37	48	4.50	
OSM-37	54	4.00	
OSM-37	60	2.50	
OSM-37	66	3.50	
OSM-37	72	3.25	
OSM-37	78	2.50	
OSM-37	84	3.25	
OSM-37	90	3.00	
OSM-37	96	1.50	
OSM-37	102	2.25	
OSM-37	108	3.50	
OSM-37	114	3.50	
OSM-37	120	4.50	



APPENDIX C

Soil Sample Analysis, USDOA Corps of Engineers, South Atlantic Division Laboratory, Marietta, Georgia (COE-SADL, 1990).

CESAD-EN-FL 11 July 1990

W.O. No. 5988 Reqn. No. EC68-IA9-13260

SUMMARY OF TESTS PERFORMED
ON 3-INCH DIAMETER SHELBY TUBE SAMPLES
FOR OFFICE OF SURFACE MINING
INDIANA GEOLOGIC SURVEY, EVANSVILLE PROJECT, BLOOMINGTON, IN

Lab. No.	Sample Field ID Hole No.	Sample Field ID Depth (ft)	(a)* ATT. Lim.	(b)* Shr'k Lim.	(c)* Sp. Grav.	(d)* Grad. Anal.	(e)* Cons. w/TC	(f)* S-Dir Shear	(g)* Uncf. Comp.	(h)* X-Ray
211/53	OSM-1	30-52**	X	X	X	X	X	X	X	X
55	OSM-4	3-5	X	X	X	X	-	X	X	X
56	OSM-5	"	X	X	X	X	X	X	X	X
57	OSM-7	"	X	-	X	X	-	X	X	-
58	OSM-8	"	X	-	X	X	-	X	X	-
62	OSM-10	4-6	X	-	X	X	X	X	X	X
64	OSM-12	9-11	X	X	X	X	X	X	X	X
66	OSM-17	3-5	X	-	X	X	X	X	X	-
67	OSM-17	9-11	X	X	X	X	X	X	X	-
68	OSM-17	14-16.3	X	X	X	X	X	X	X	-
69	OSM-29	3-5	X	-	X	X	X	X	X	-
70	OSM-29	9-11	X	X	X	X	X	X	X	X
73	OSM-30	3-5	X	-	X	X	X	X	X	-

(Continued on page 2)

*See Page 2 For Legend for Tests Performed.

**Depth in inches; this sample only.

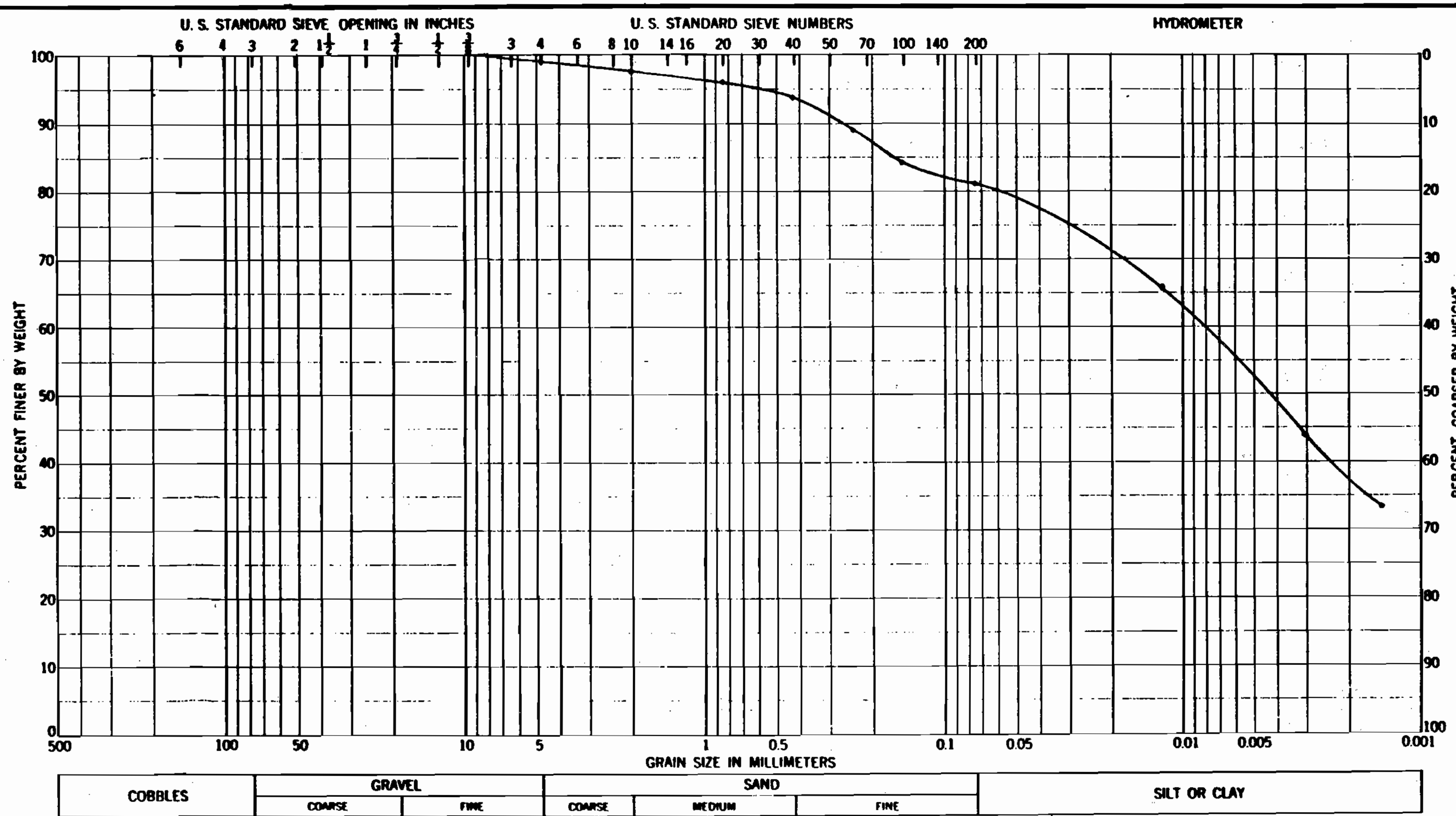
SUMMARY OF TESTS PERFORMED - continued

Lab. No.	Sample Field ID Hole No.	Depth (ft)	(a)* ATT. Lim.	(b)* Shr'k Lim.	(c)* Sp. Grav.	(d)* Grad. Anal.	(e)* Cons. w/TC	(f)* S-Dir Shear	(g)* Uncf. Comp.	(h)* X-Ray
78	OSM-32	"	X	X	X	X	X	X	X	-
79	OSM-32	9-10.5	X	X	X	X	X	X	X	-
80	OSM-33	3-4.5	X	-	X	X	X	X	X	-
83	OSM-35	3-5	X	X	X	X	X	X	X	X
84	OSM-35	9-10	X	X	X	X	-	-	X	X

*Legend for Tests Performed in Accordance with Appendices identified in EM-1110-2-1906, Engineer Manual, Engineering and Design Laboratory Soils Testing, 30 November 1970, U. S. Army Corps of Engineers:

(a) Atterberg Limits, Appendix III.
(b) Shrinkage Limits, Appendix IIIB.
(c) Specific Gravity, Appendix IV.
(d) Gradation Analysis, Appendix V.
(e) Consolidation Load w/ & wo TC, Appendix VIII.
(f) S-Direct Shear, Appendix IX.
(g) Unconfined Compression, Appendix XI.
(h) X-Ray Diffraction Analysis (see report of analysis).

W.O. NO. 5988
REQ. NO. EC6B-IA9-13260



Sample No.	Hole No. Depth	Classification	Nat w %	LL	PL	PI
-	4-6'	Lt. brown, fat clay (CH), w/ a little sand & a trace of gravel sizes.	21.0	98	25	73

Project O.S.M.-Indiana Geological Survey
Lab. No. 211/62*
Area Evansville Project
Boring No. OSM-10
Date 12 March 1990

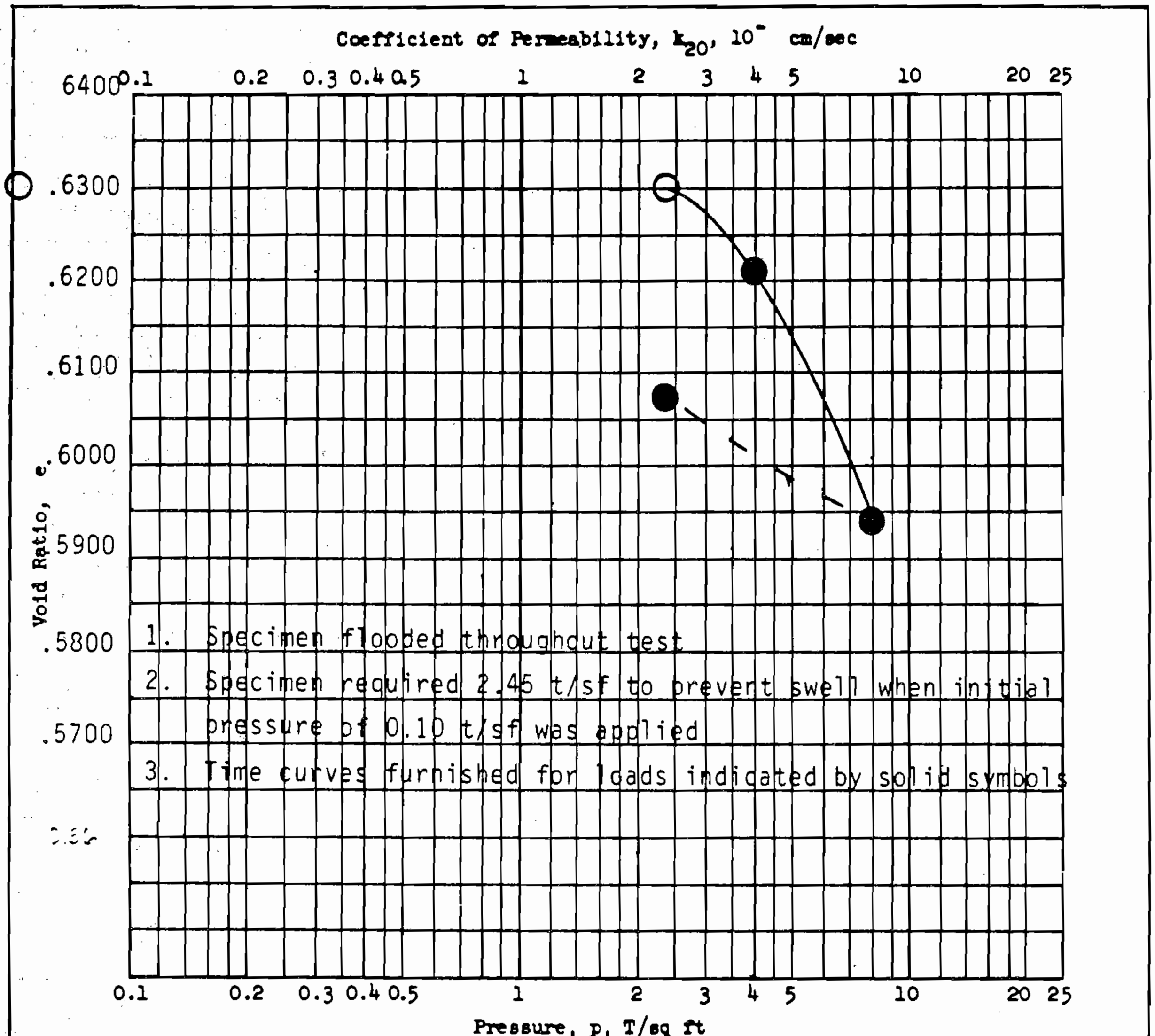
GRADATION CURVES

ENG FORM 1 MAY 63 2087

*unconfined compression, CDD & consolidation tests

DEPARTMENT OF THE ARMY, SOUTH ATLANTIC DIVISION LABORATORY
CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE, MARIETTA, GA. 30060

WORK ORDER NO. 5988
Req. No. EC6B-IA9-13260



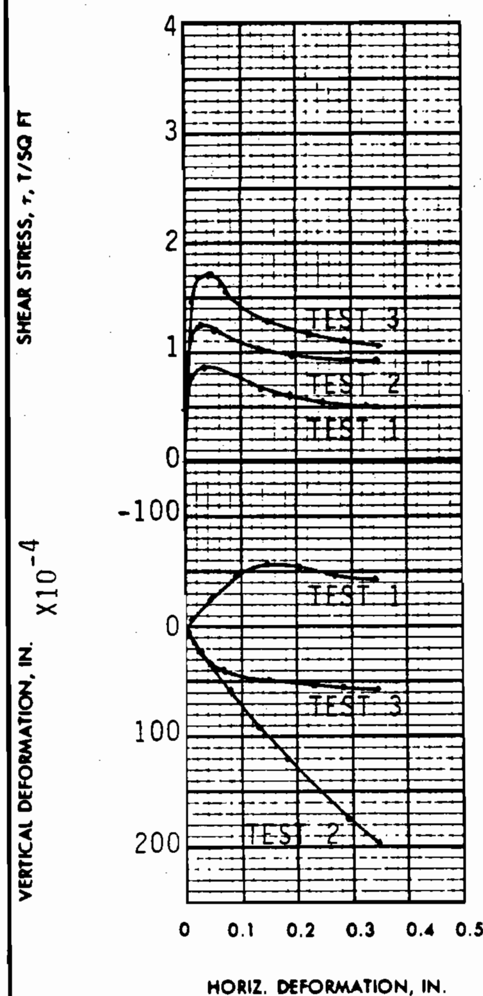
Type of Specimen undisturbed		**Before Test**		**After Test**
Diam 2.49 in.	Ht 1.00 in.	Water Content, w_o	19.5 %	w_f 21.9 %
Overburden Pressure, p_o T/sq ft		Void Ratio, e_o	.630	e_f .607
Preconsol. Pressure, p_c T/sq ft		Saturation, S_o	85.6 %	S_f 100.0 %
Compression Index, C_c = 0.086		Dry Density, γ_d	106.1 lb/ft³	
Classification Lt. brown, fat clay (CH), w/ a little sand&trace of gravel sizes		k_{20} at e_o = × 10⁻ cm/sec		
LL 98	G_s 2.77	Project O.S.M. Indiana Geological Survey Lab. No. 211/62		
PL 25	D_{10} < 0.002mm			
Remarks See gradation curve and additional information on ENG Form 2087.		Area Evansville Project		
		Boring No. OSM-10		Sample No. --
		Depth 4-6'		Date 12 March 1990

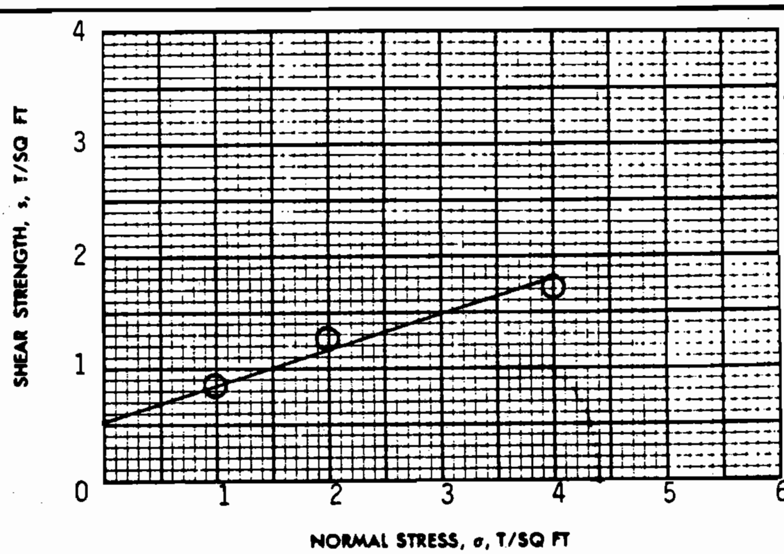
CONSOLIDATION TEST REPORT

ENG FORM 1 MAY 63 2090 PREVIOUS EDITIONS ARE OBSOLETE.

DEPARTMENT OF THE ARMY, SOUTH ATLANTIC DIVISION LABORATORY
CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE, MARIETTA, GA. 30060

WORK ORDER NO. 5988
Req. No. EC6B-IA9-13260





TEST NO.			1	2	3	
INITIAL	WATER CONTENT	w_o	18.9 %	20.3 %	24.4 %	%
	VOID RATIO	e_o	.664	.692	.796	
	SATURATION	S_o	78.9 %	81.4 %	84.8 %	%
	DRY DENSITY, LB/CU FT	γ_d	103.9	102.2	96.3	
VOID RATIO AFTER CONSOLIDATION		e_c	.666	.696	.727	
TIME FOR 50 PERCENT CONSOLIDATION, MIN		t_{50}	SPECIMENS SWELLED			
FINAL	WATER CONTENT	w_f	24.5 %	22.7 %	25.5 %	%
	VOID RATIO	e_f	.680	.696	.706	
	SATURATION	S_f	100.0 %	100.0 %	100.0 %	%
NORMAL STRESS, T/SQ FT		σ	1.0	2.0	4.0	
MAXIMUM SHEAR STRESS, T/SQ FT		τ_{max}	0.86	1.24	1.71	
ACTUAL TIME TO FAILURE, MIN		t_f	45	45	60	
RATE OF STRAIN, IN./MIN			.0007	.0007	.0007	
ULTIMATE SHEAR STRESS, T/SQ FT		τ_{ult}	0.50	.92	1.04	

SHEAR STRENGTH PARAMETERS

ϕ' = 18.0

TAN ϕ' = 0.325

c' = 0.52* T/SQ FT

*apparent cohesion is questionable for design computations

☐ CONTROLLED STRESS

☒ CONTROLLED STRAIN

TYPE OF SPECIMEN undisturbed		2.00 IN. SQUARE	0.50 IN. THICK

CLASSIFICATION Lt. brown, fat clay (CH), w/ a little sand & trace of gravel sizes

LL	PL	PI		G_s
98	25	73	---	2.77

REMARKS See gradation curve and additional information on ENG Form 2087.

PROJECT O.S.M. Indiana Geological Survey
Lab. No. 211/62

AREA ---

BORING NO. OSM-10 | SAMPLE NO. ----

DEPTH 4-6' | DATE 12 March 1990

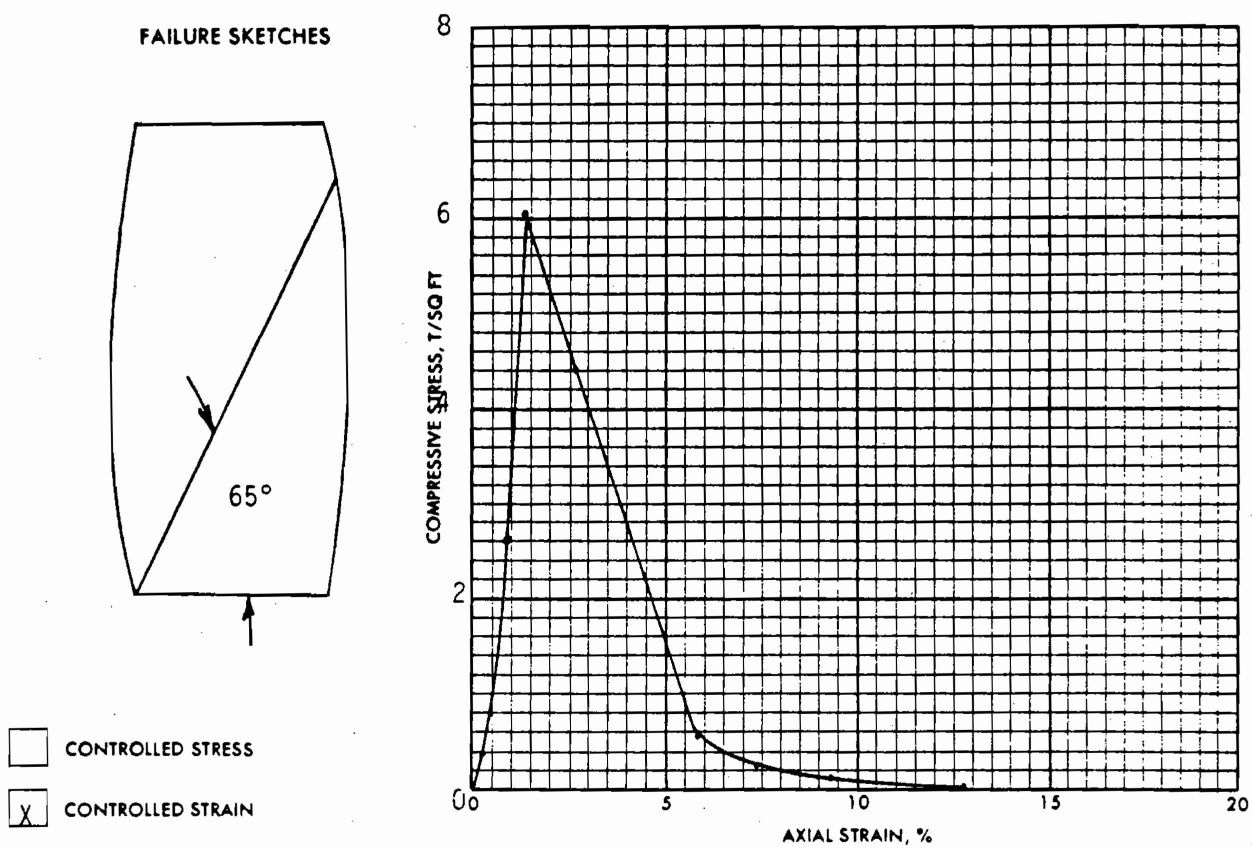
DIRECT SHEAR TEST REPORT

ENG FORM 1 JUN 65 2092 (EM 1110-2-1906) PREVIOUS EDITIONS ARE OBSOLETE

GPO : 1964 OF—214-945

PLATE IX-3

W.O. NO. 5983
REQ. NO. EC6B-IA9-13260



TEST NO.		1			
TYPE OF SPECIMEN		undisturbed			
INITIAL — WATER CONTENT	w_o	21.9 %	%	%	%
INITIAL — VOID RATIO	e_o	.693			
INITIAL — SATURATION	S_o	87.3 %	%	%	%
INITIAL — DRY DENSITY, LB/CU FT	γ_d	102.1			
TIME TO FAILURE, MIN	t_f	4.75			
UNCONFINED COMPRESSIVE STRENGTH, T/SQ FT	q_u	6.01			
UNDRAINED SHEAR STRENGTH, T/SQ FT	s_u	3.00			
~~SENSITIVITY RATIO~~ Rate of strain, %/min	S_t	0.75			
INITIAL SPECIMEN DIAMETER, IN	D_o	1.38			
INITIAL SPECIMEN HEIGHT, IN.	H_o	3.08			

CLASSIFICATION Lt. brown, fat clay (CH), w/ a little sand & trace of gravel sizes

LL 98 | PL 25 | PI 73 | G_s 2.77

REMARKS See gardation curve and additional information on ENG Form 2087.

PROJECT OSM-Indiana Geological Survey Lab. No. 211/62

AREA Evansville Project

BORING NO. OSM-10 | SAMPLE NO. --

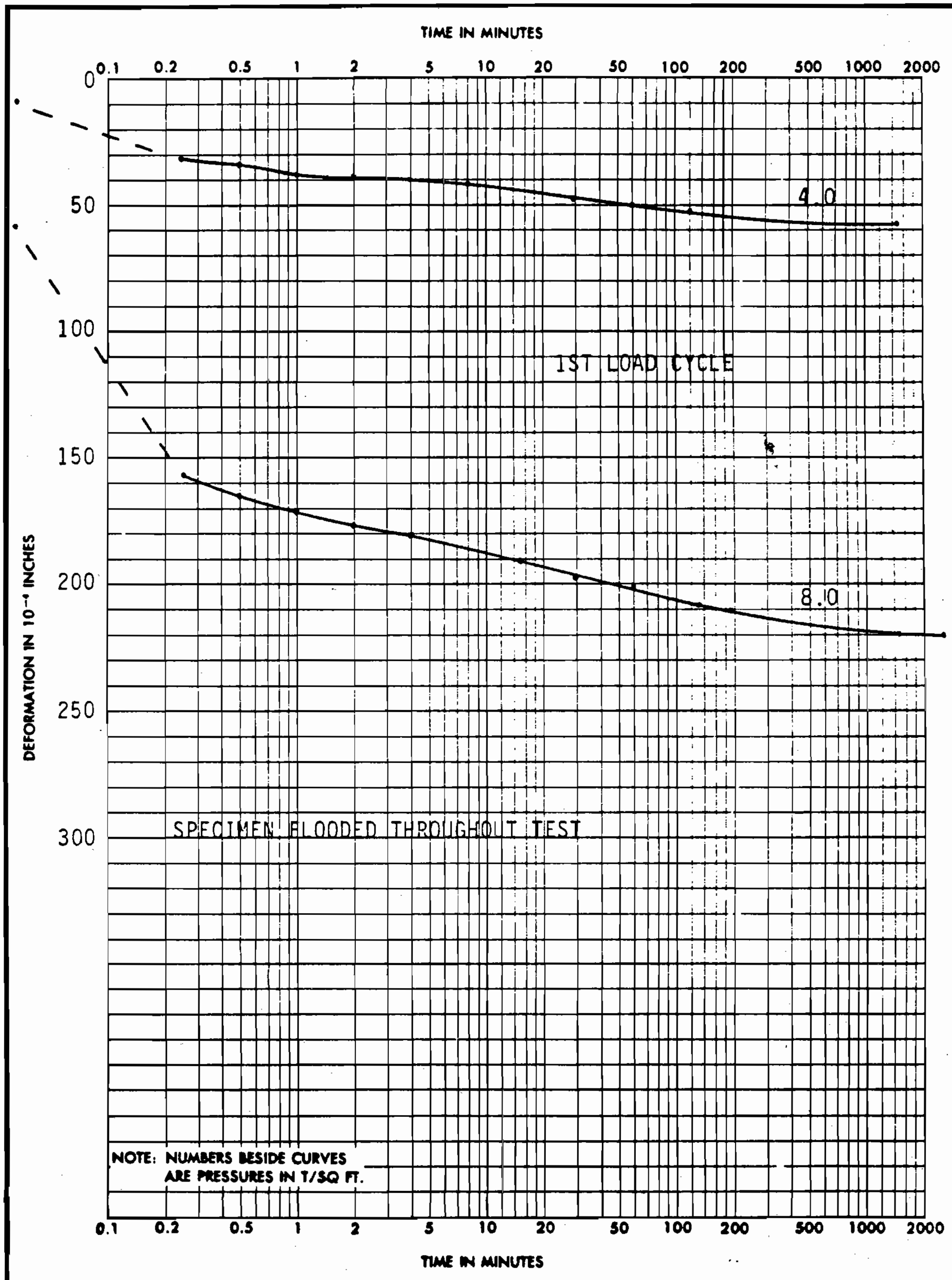
DEPTH ~~EL~~ 4-6' | DATE 12 March 1990

UNCONFINED COMPRESSION TEST REPORT

ENG FORM 1 JUN 65 **3659** (EM 1110-2-1906) (TRANSLUCENT) GPO 1966 OF—214-946 PLATE XI-2

DEPARTMENT OF THE ARMY, SOUTH ATLANTIC DIVISION LABORATORY
CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE, MARIETTA, GA. 30061

WORK ORDER NO. 5988
Req. No. EC6B-IA9-13260



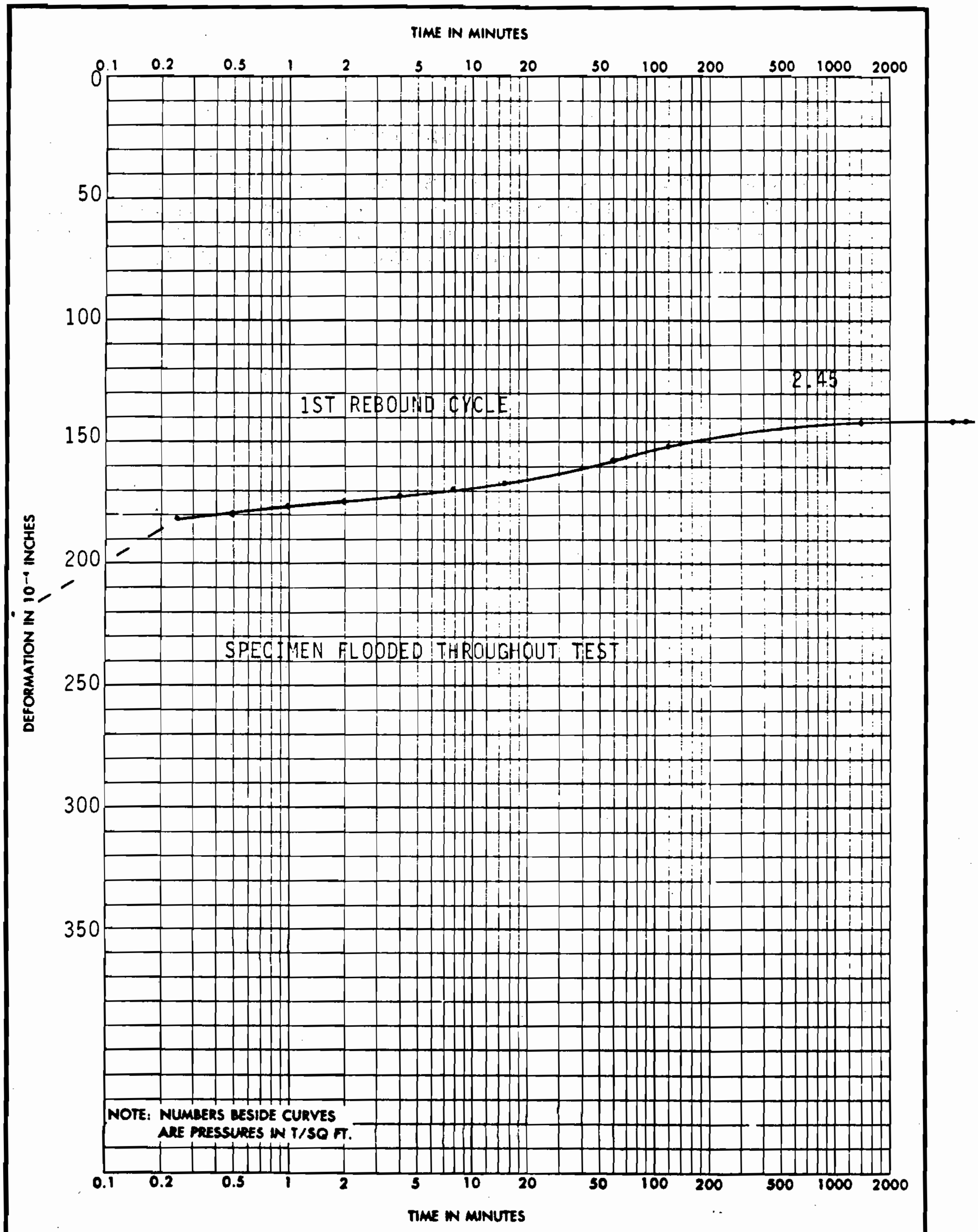
PROJECT	O.S.M. - Indiana Geological Survey					
AREA	Evansville Project Lab. No. 211/62					
BORING NO.	OSM-10	SAMPLE NO.	--	DEPTH	4-6'	DATE 12 March 1990

ENG FORM 2088 1 MAY 63 PREVIOUS EDITIONS ARE OBSOLETE. **CONSOLIDATION TEST—TIME CURVES** (TRANSLUCENT)

* GPO : 1964 OF—715-065

DEPARTMENT OF THE ARMY, SOUTH ATLANTIC DIVISION LABORATORY
CORPS OF ENGINEERS, 611 SOUTH COBB DRIVE, MARIETTA, GA. 30061

WORK ORDER NO. 5988
Req. No. EC6B-IA9-13260



PROJECT O.S.M. - Indiana Geological Survey

AREA Evansville Project Lab. No. 211/62

BORING NO. OSM-10 | SAMPLE NO. --- | DEPTH 4-6' | DATE 12 March 1990

ENG FORM 2088 1 MAY 63 PREVIOUS EDITIONS ARE OBSOLETE. **CONSOLIDATION TEST—TIME CURVES** (TRANSLUCENT)

★ GPO : 1964 OF—718-985

Appendix D

Petrographic report of X-ray diffraction (XRD) analysis of 2-micron and less particle size minerals from seven bore holes, Corps of Engineers, South Atlantic Division Laboratory, Marietta, Georgia (COE-SADL, 1990)

DEPARTMENT OF THE ARMY
SOUTH ATLANTIC DIVISION LABORATORY, CORPS OR ENGINEERS
611 SOUTH COBB DRIVE
MARIETTA, GEORGIA 30060-3112

PETROGRAPHIC REPORT

X-RAY DIFFRACTION RESULTS FOR EVANSVILLE PROJECT
OFFICE OF SURFACE MINING-INDIANA GEOLOGICAL SURVEY

Work Order No: 5988 Requisition No.: EC68-IA9-13260

Lab. No: 211/53,55,56,62,64.,70,83 84 Date Received: 6 Nov & Dec 89

Description of Sample: Eight Soil Samples (from Shelby Tubes)

Sampled by: Unknown (Samples to be analyzed were selected by OSM)

Analyzed for: Clay Mineralogy (0.002mm & smaller sizes)

Last Previous Testing: NA

SUMMARY

The clay mineralogy of the eight soil samples analyzed by x-ray diffraction for the Evansville Project appear very similar. X-ray diffraction analyses of the 2 μ fractions from these samples indicates that vermiculite is the most abundant clay mineral present. Kaolinite, illite/mica and chlorite are much less abundant. The exception was sample OSM-10 which appears to have smectite (montmorillonite) instead of vermiculite.

Vermiculite clays are very similar to smectite (swelling clays) in that they are capable of dehydrating and rehydrating depending on heat and moisture conditions.

The estimate of the clay mineral perdentages in the 2 μ fractions appears in TABLE 1 of this report. The clay mineral percentages, based on "total sample" appear in TABLE 2.

Prepared by: RW Reviewed by WT

PETROGRAPHIC REPORT
X-RAY DIFFRACTION RESULTS FOR EVANSVILLE PROJECT
For
OFFICE OF SURFACE MINING-INDIANA GEOLOGICAL SURVEY

INTRODUCTION

1. The clay size fractions (0.002 mm & below sizes) from eight soil samples received 6 Nov. and 11 Dec. 1989 were analyzed by X-ray diffraction (XRD) techniques for clay mineral constituents. The samples chosen were selected by Mr. Robert Welsh (OSM) from several shelby tube samples previously submitted to SAD Laboratory under Interagency Agreement No. EC68-IA9-13260. The original request for the XRD study was for the minus No. 200 sieve sizes of the eight samples to be analyzed. However, in later conversations with Mr. Welsh, it was agreed to analyze the 0.002 mm (2 μ) and below sizes to aid the clay mineral identification.

Sample Identification

2. The XRD analyses were performed on the following samples:

SAD Lab. No.	OSM NO.	Depth	Date Received
211/53	OSM-1	30-52 in.	6 Nov. '89
211/55	OSM-4	3-5 ft.	6 Nov. '89
211/56	OSM-5	3-5 ft.	6 Nov. '89
211/62	OSM-10	4-6 ft.	6 Nov. '89
211/64	OSM-12	9-11 ft.	6 Nov. '89
211/70	OSM-29	9-11 ft.	11 Dec.'89

211/83	OSM-35	3-5 ft.	11 Dec.'89
211/84	OSM-35	9-10 ft.	11 Dec.'89

Purpose of Study

3. The purpose of the XRD analyses was to determine the clay mineral species present in the 0.002 mm and below size fractions of the samples listed in paragraph 2. It was also requested that an estimate of the quantity of each clay mineral species in the 2 μ fractions be given.

X-RAY DIFFRACTION PROCEDURE

4. There is no one "standard" procedure for XRD analyses of clay minerals. This is true for both qualitative as well as quantitative XRD analyses. Procedures generally used do however take advantage of certain diagnostic properties exhibited by differing clay mineral species. XRD analytical techniques do vary considerably depending on the analysts' training, type equipment, experience in analyzing various types of clay mineral groups and knowledge of clay mineral reactions when subjected to various treatments (thermal, hydration etc.).

5. A brief description of the procedures used in this study appears below. These procedures are based on clay mineral data primarily from Brown* (1), and Grim (2). These references and several others routinely used by the writer appear at the end of this report. All XRD analyses were performed by the writer using a Philips XRG 3000 diffractometer.

* References are listed at end of report.

Sample Preparation

6. Representative portions of each of the eight samples were first analyzed by XRD in their "as received" condition to determine the presence of clay minerals like halloysite that may dehydrate and go unnoticed in succeeding XRD analyses. Other representative portions were saturated overnight followed by light stirring in a blender to disperse particles. The slurries were then placed in 1000 ml graduated cylinders to observe settling behavior. Several of the samples began to floccculate, therefore, several drops of sodium tripolyphosph-ate (a dispersing agent) was added to each sample. The contents in each cylinder was agitated and allowed to gravity settle for an appropiate time as determined by Stokes' law to remove particles greater than 0.002 mm (2 μ). The 2 μ and smaller sizes were siphoned off and centrifuged to remove excess water. X-ray diffraction analyses were performed on the remaining clay "cakes" (2 μ sizes).

XRD Techniques Used

7. Air dried portions of each sample were reground, sieved and prepared as powder press (unoriented mounts) mounts and x-rayed using identical diffrac-tometer (machine) settings for all samples. Powder press (PP) mounts are used in this study to determine mineral percentages and aid in identifying clay mineral species. The clay percentages or quantities assigned to the various mineral species are based on comparison to known clay mineral "standards". The quantities appearing in this report are estimates only. The quantitative procedure assumes there is a direct relationship between x-ray intensity (and

area) and quantity present although there are other factors (crystallinity, particle size, masking by other minerals etc.) that may influence peak height (intensity). No standard was available for clay vermiculite. Since both vermiculite and montmorillonite (smectite) occur in the same region, a montmorillonite standard was used to estimate the quantity of vermiculite present.

8. In addition to the powder mounts, sedimented slides (oriented mounts) were also prepared and analyzed by XRD. The sedimented slides (SS) allow small quantities to be detected because the strong "001" clay spacings are enhanced by this method. The SS mounts are the primary means of determining the clay mineral identities because of the enhanced sensitivity. The sedimented slides are also the mounts used in the glycolation (saturation with ethylene glycol, glycerin or other liquids) tests and thermal tests. Due to the clay minerals present, both ethylene glycol and glycerin were used to test for swelling clay minerals. Following the glycolation tests, the sedimented slides were heated at 350 and 550 degrees centigrade and X-rayed after each elevation in temperature. Because vermiculite was suspected, the heat treated sedimented slides were analyzed while hot in a nitrogen atmosphere. Close examination of the 3.5 Angstrom region of the diffractograms (the print of a x-ray scan or x-ray signature) as outlined by Biscaye (3) was necessary to differentiate between chlorite and kaolin clay minerals. Procedures outlined here are common techniques performed by most clay mineralogist. Certain clay minerals, however, require additional preparation and x-ray analyses.

DISCUSSION

XRD Summary Results

9. The results of the XRD analyses appear in TABLES 1 and 2. The clay mineral species and nonclay minerals (clay size minerals, e.g., quartz) are listed in TABLE 1 along with the estimated mineral percentages for the clay minerals comprising the 2 μ and below sizes. The clay mineral quantities appearing in TABLE 1 were recalulated to reflect the "total sample" percentage. The "total sample" percentages are shown in TABLE 2. The quantities appearing in TABLE 2 were computed using the amount (percentage) of the 2 μ and below sizes picked from the gradation curves (values appear in the 3rd column from the left in TABLE 2) for each sample and multiplying this value by the estimated mineral percentage for each identified clay mineral in TABLE 1.

10. This procedure assumes that all clay minerals appear in the 2 μ and smaller sizes, however, this is not always true. The 2 μ break between silt and clay sizes is an arbitrary one but is usually considered the best split for clay mineral and nonclay mineral natural components according to Grim (2).

11. The x-ray diffractograms for each sample appear as PLATES 1-8. The bottom diffractogram in each plate is of the powder sample from which the quantitative data was obtained. Selected portions of some of the other x-ray diffractograms (e.g., glycolated and thermal scans) also appear in the plates.

Mineralogy

12. With one exception, the mineralogies of the 2 μ fractions of the eight samples are similar. The most abundant clay mineral is vermiculite. Kaolinite and illite/mica were second in abundance. The exception was sample OSM-10 which had a predominance of smectite (swelling clays like montmorillonite) clay instead of vermiculite. Small amounts of chlorite were also detected in many of the samples. Nonclay minerals identified in the x-ray analyses are quartz (very common), and traces (<1%) of zeolites and feldspars. All of these are considered normal in clay size fractions.

13. The appearance of the 14 Angstrom regions on the x-ray diffractograms (far right-see PLATES 1-8) suggest that vermiculite is interlayed with illite which is common. There is also evidence that suggests some smectite may be present in small quantities, however, the amount is insufficient to make a positive identification.

14. Vermiculite clay is a mineral structurally similar to micas but it differs in having water as an interlayer (also very similar to smectites). Vermiculites occur in the 14 Angstrom region of the diffractogram (see PLATES 1-8) along with smectites and chlorites. Vermiculites are distinguished from the smectites by their ability to swell only to the 14+ Angstrom region when glycolated whereas smectites readily swell to the 17-18 Angstrom region. Except for very rare species, members of the chlorite family do not swell. Vermiculites differ from chlorites in that they dehydrate (loose water) at relatively low laboratory temperatures, chlorites do not. The subject samples

dehydrate to the 9-10 Angstrom region when heated, therefore all chlorite species (even swelling chlorites) are excluded as significant members of the 14 Angstrom region. Vermiculites do have the ability to rapidly rehydrate, therefore, additional precautions (controlled atmosphere in addition to analyzing while hot) were taken during the x-ray analyses.

SUMMARY

15. The clay mineralogy of the eight soil samples analyzed by X-ray diffraction for the Evansville Project appear very similar. X-ray diffraction analyses of the 2 μ fractions from these samples indicate that vermiculite is the most abundant clay mineral present. Kaolinite, illite/mica and chlotite are much less abundant. The exception was sample OSM-10 which appears to have smectite (montmorillonite) instead of vermiculite.

16. Vermiculite clays are very similar to smectite (swelling clays) in that they are capable of dehydrating and rehydrating depending on heat and moisture conditions.

17. The estimate of the clay mineral percentages in the 2 μ fractions appear in TABLE 1 of this report. The clay mineral percentages, based on "total sample" appear in TABLE 2.

Ray Willingham

Ray Willingham
Geologist

ENCL: TABLE 1 (clay mineral estimates, 2 micron fraction)
TABLE 2 (clay mineral estimates, whole sample)
References
PLATES 1-8 (X-ray Diffractograms)

TABLE 1

ESTIMATES OF CLAY MINERAL PERCENTAGES
FOR 2 MICRON (0.002 MM) AND BELOW SIEVE SIZE FRACTIONS ONLY

SAD LAB. NO.	OSM NO./DEPTH	SMECTITE	VERM.	MINERALOGY ILLITE	KAO.	QTZ.	CHL.	OTHER
211/53	OSM-1 (30-52 IN.)	--	31	27	15	18	5	4
211/55	OSM-4 (3-5 FT.)	--	42	23	10	18	TR	7
211/56	OSM-5 (3-5 FT.)	--	37	23	15	19	--	6
211/62	OSM-10 (4-6 FT.)	53	--	17	15	10	--	5
211/64	OSM-12 (9-11 FT.)	--	38	19	18	18	TR	7
211/70	OSM-29 (9-11 FT.)	--	57	17	11	10	TR	5
211/83	OSM-35 (3-5 FT.)	--	43	14	17	19	TR	7
211/84	OSM-35 (9-10 FT.)	--	48	22	17	13	--	TR

NOTES: SMECTITE= any member of the swelling 14 Angstrom clays; montmorillonite is common example

VERM. = Vermiculite, appears to be mixed-layered with illite/mica

ILLITE= Illite/mica, KAO.= kaolinite, QTZ.= quartz, CHL.= chlorite

OTHER= Possible Zeolites, Feldspar, etc. TR= Trace (<1%)

TABLE 2

ESTIMATES OF CLAY MINERAL PERCENTAGES BASED ON TOTAL SAMPLE

LAB. NO.	OSM NO./DEPTH	TOTAL SAMPLE % 2 μ & BELOW	SMECTITE	MINERALOGY VERM.	ILLITE	KAO.	CHL.	OTHER
211/53	OSM-1 (30-52 in.)	18	--	6	5	3	1	1
211/55	OSM-4 (3-5 ft.)	13	--	5	3	1	--	1
211/56	OSM-5 (3-5 ft.)	17	--	6	4	3	--	1
211/62	OSM-10 (4-6 ft.)	37	20	--	6	6	--	2
211/64	OSM-12 (9-11 ft.)	25	--	9	5	4	--	2
211/70	OSM-29 (9-11 ft.)	48	--	27	8	5	--	2
211/83	OSM-35 (3-5 ft.)	20	--	9	3	3	--	1
211/84	OSM-35 (9-10 ft.)	44	--	21	10	7	--	TR

NOTES: SMECTITE= any member of the swelling 14 Angstrom clays; montmorillonite is common example

VERM. = Vermiculite, appears to be mixed-layered with illite/mica

ILLITE= Illite/mica, KAO.= kaolinite, QTZ.= quartz, CHL.= chlorite

OTHER= Possible Zeolites, Feldspar, etc. TR= Trace (<1%)

REFERENCES

1. Brown, G. (editor), 1961, "The X-Ray Identification and Crystal Structures of Clay Minerals", Mineralogical Society (Clay Mineral Group) London, England

2. Grim, Ralph E., 1968, "Clay Mineralogy" 2nd Edition, McGraw Hill Book Co.

3. Biscage, P. E., 1964, "Distinction Between Kaolinite and Chlorite in Recent Sediments by X-Ray Diffraction", The Am. Mineralogist, Vol 49, Sept-Oct 1964

4. Carrol, Dorothy, 1970, "Clay Minerals: A Guide to Their X-Ray Identification. Special Paper 126, The Geol. Society of America.

5. Hutchinson, C.S., 1974, "Laboratory Handbook of Petrographic Techniques", John Wiley & Sons, N.Y. pages 225-231

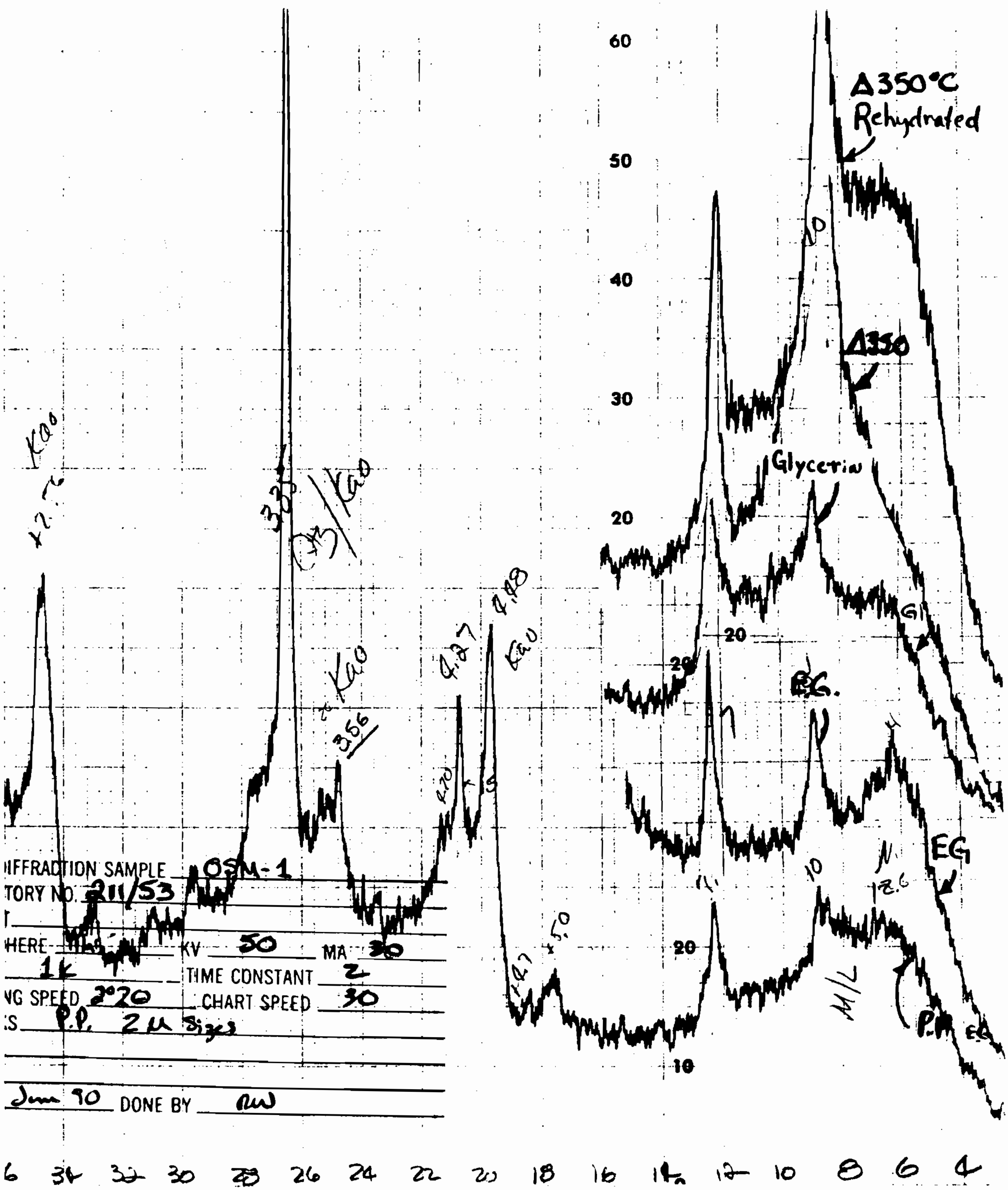


Plate 1. X-ray diffractograms for Sample OSM-1, d. 30-52 inches.

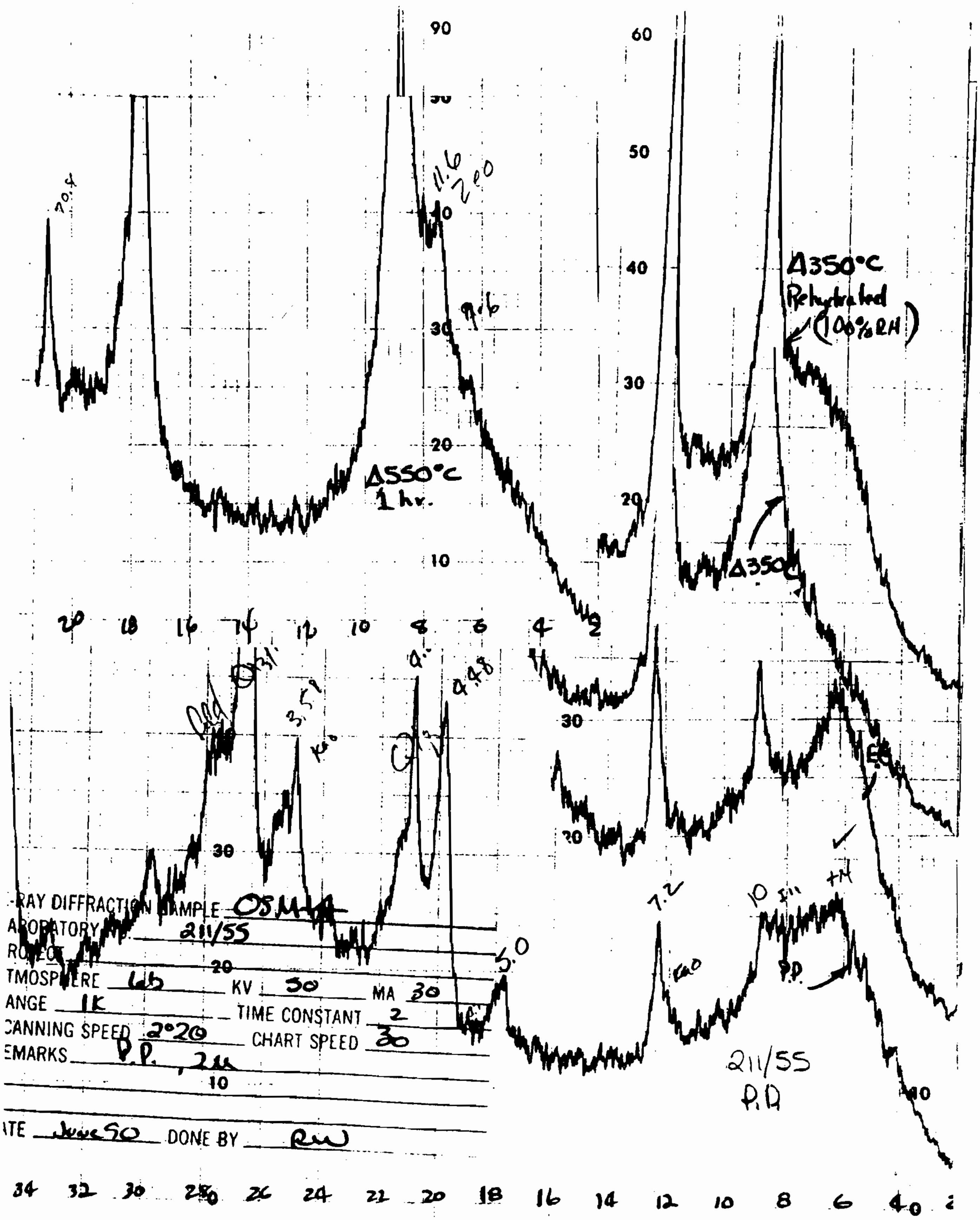


Plate 2. X-ray diffractograms for Sample OSM-4, d. 3-5 feet.

SAD Lab. No. 211/55

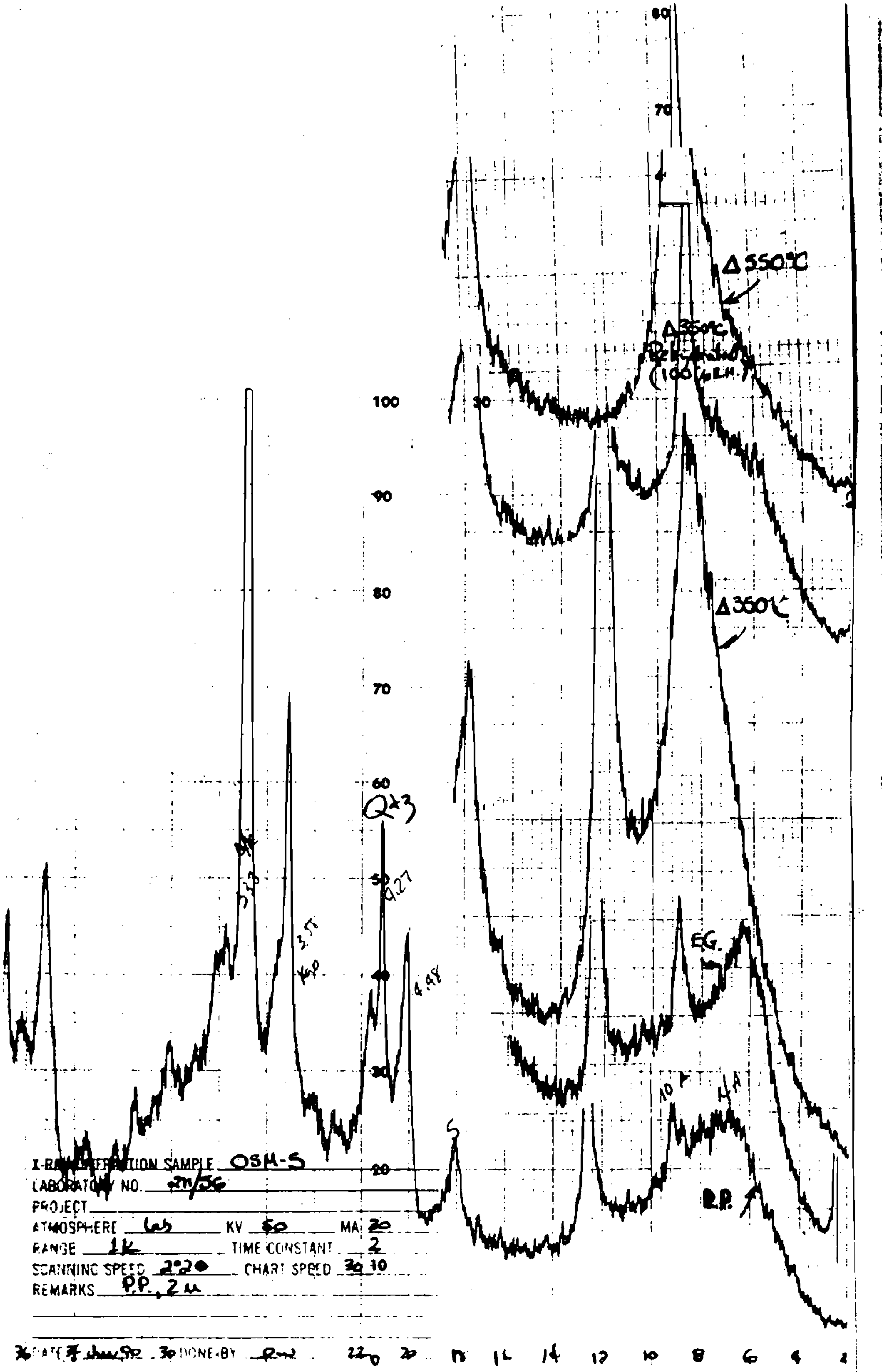


Plate 3. X-ray diffractograms for Sample OSM-5, d. 3-5 feet.

SAD Lab. No. 211/56

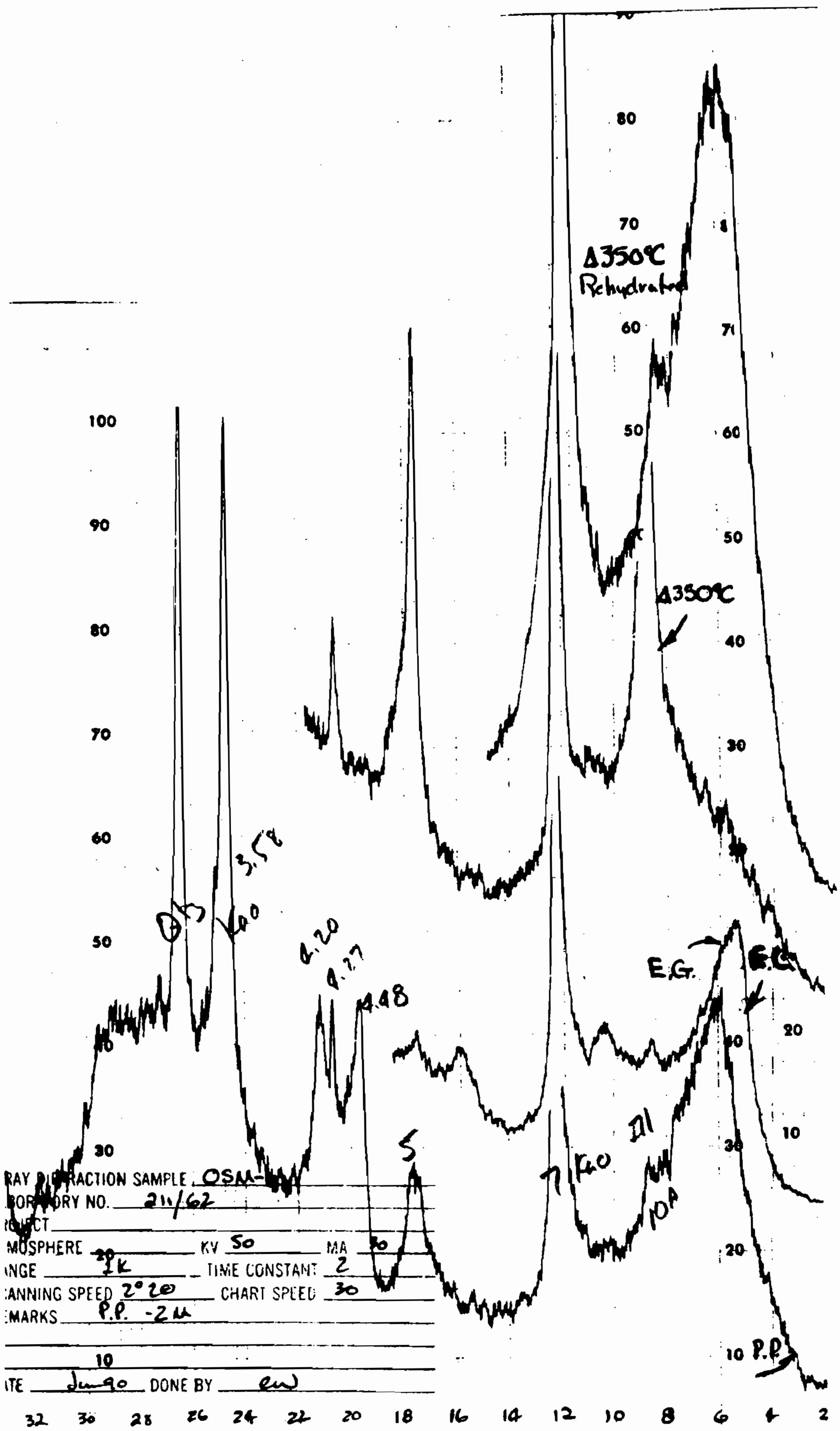


Plate 4. X-ray diffractograms for Sample OSM-10, d. 4-6 feet.

SAD Lab. No. 211/62

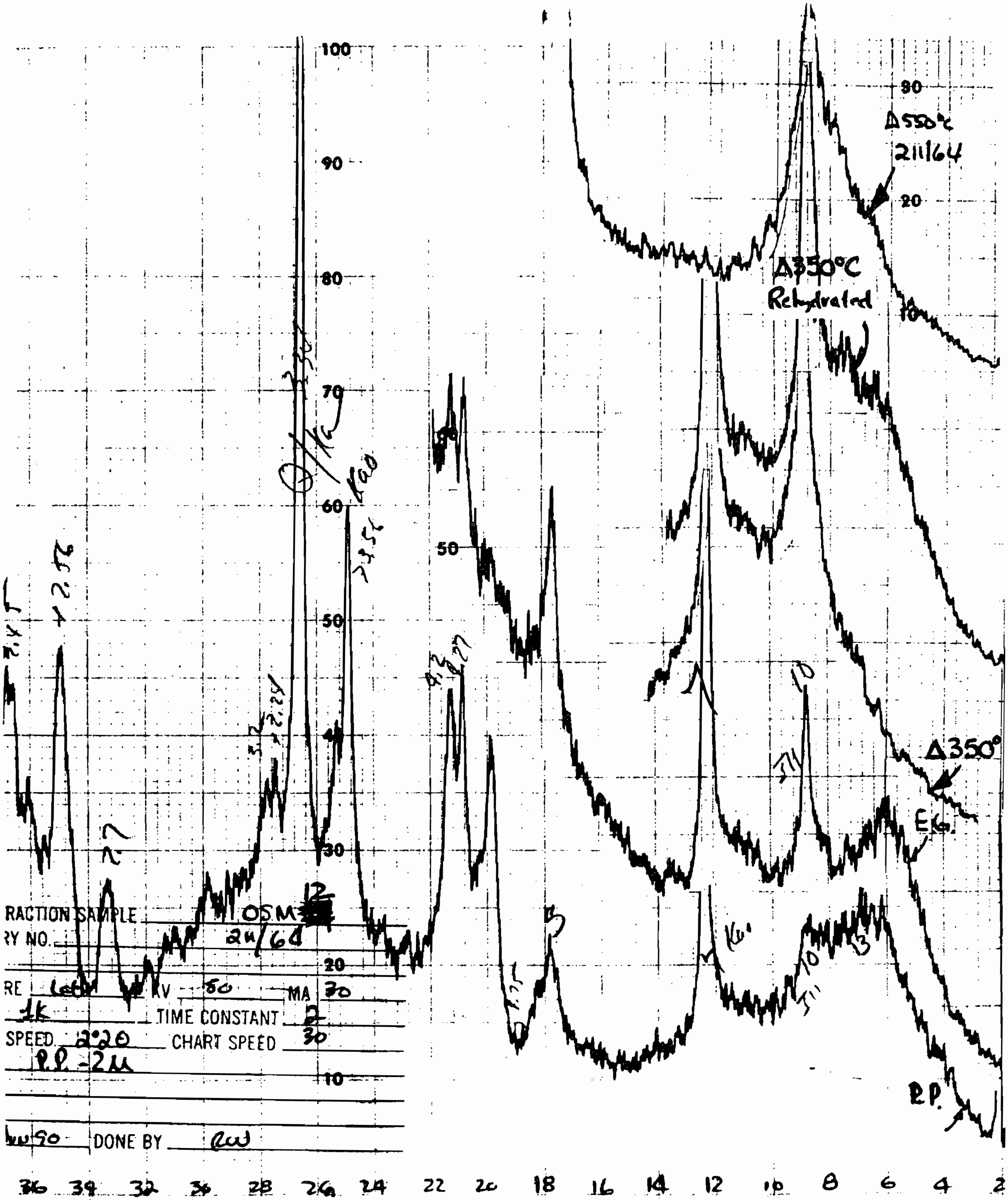


Plate 5. X-ray diffractograms for Sample OSM-12, d. 9-11 feet.

SAD Lab. No. 211/64

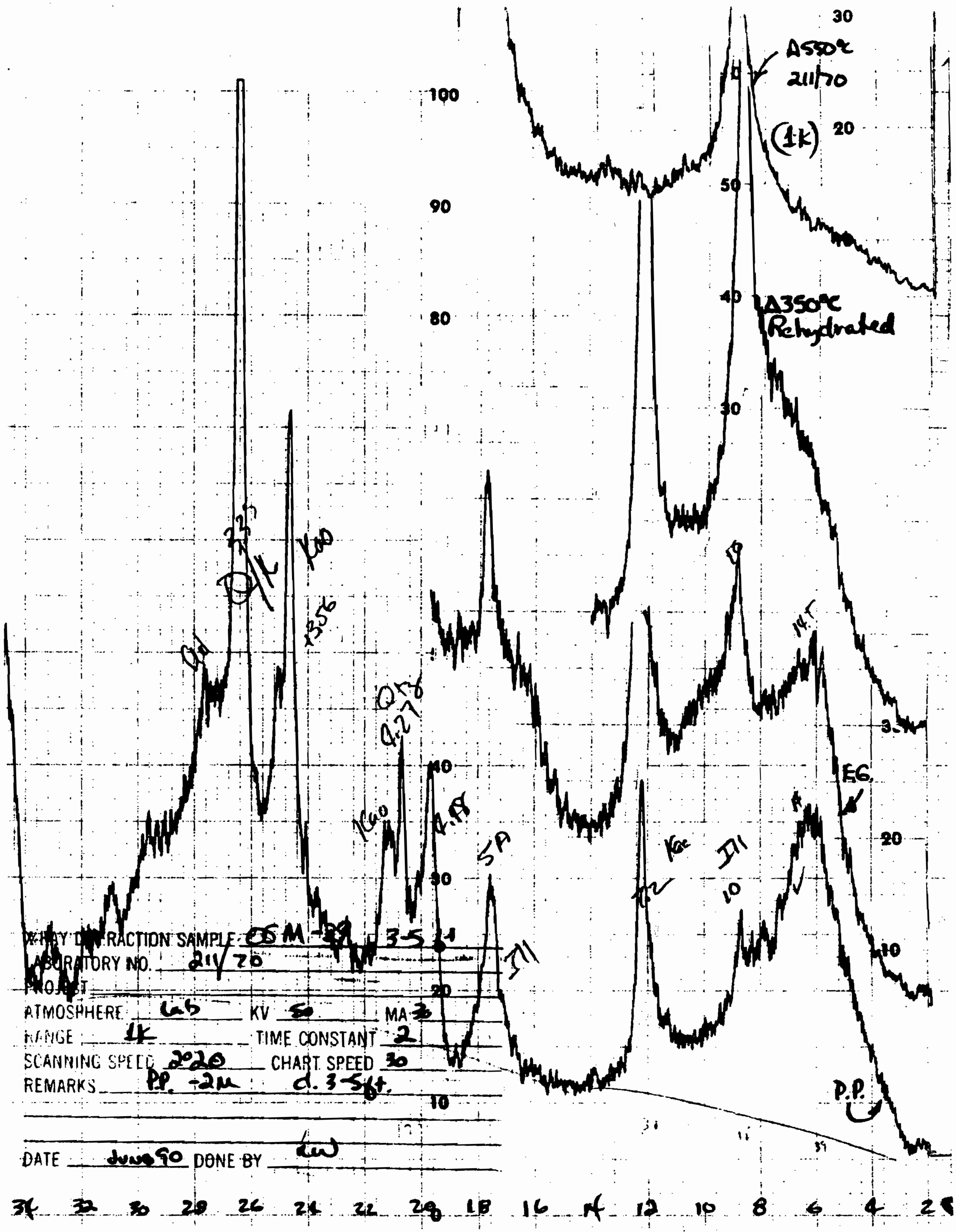


Plate 6. X-ray diffractograms for Sample OSM-29, d. 9-11 feet.

SAD Lab. No. 211/70

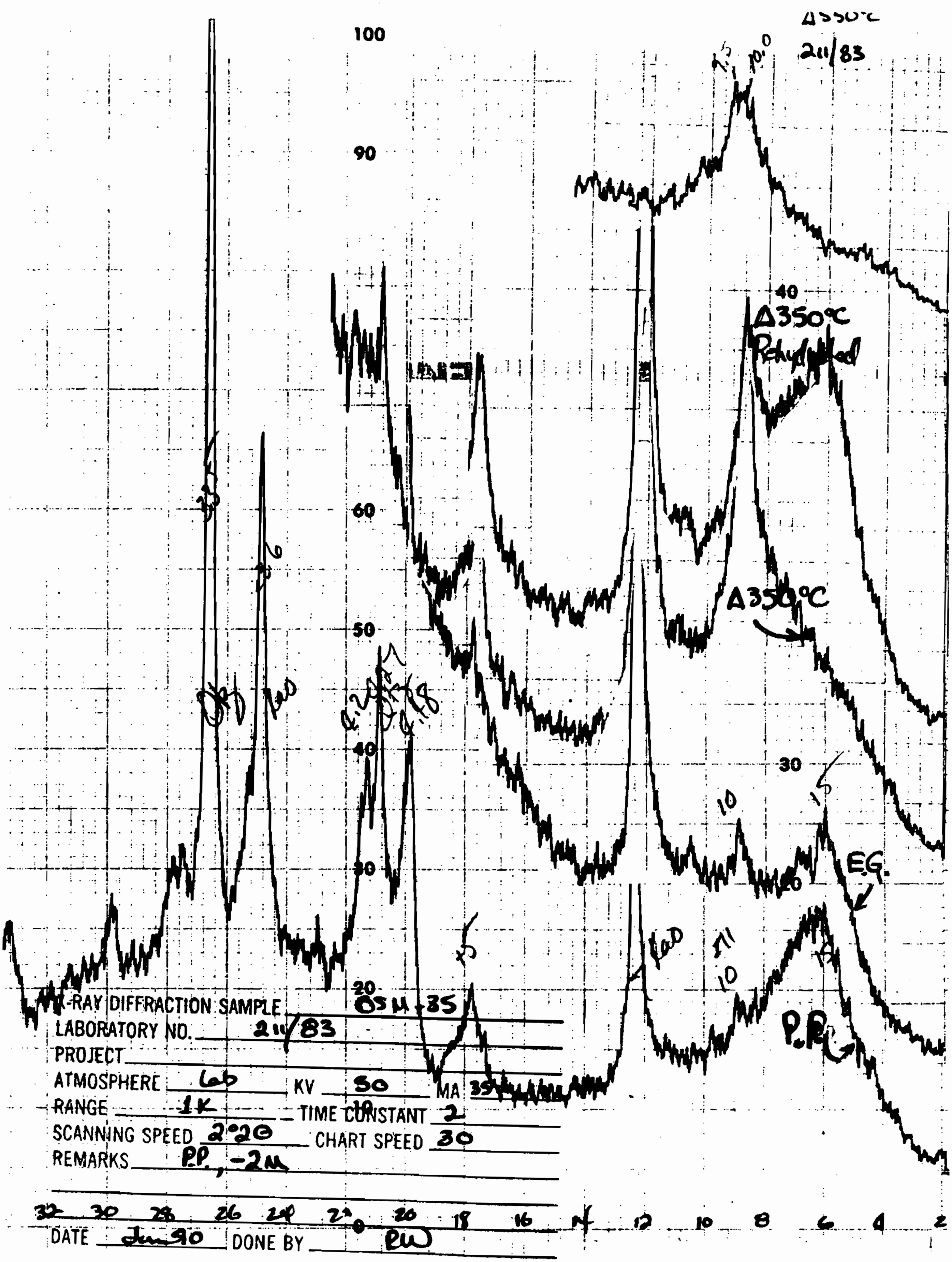


Plate 7. X-ray diffractogarms for Sample OSM-35, d. 3-5 feet

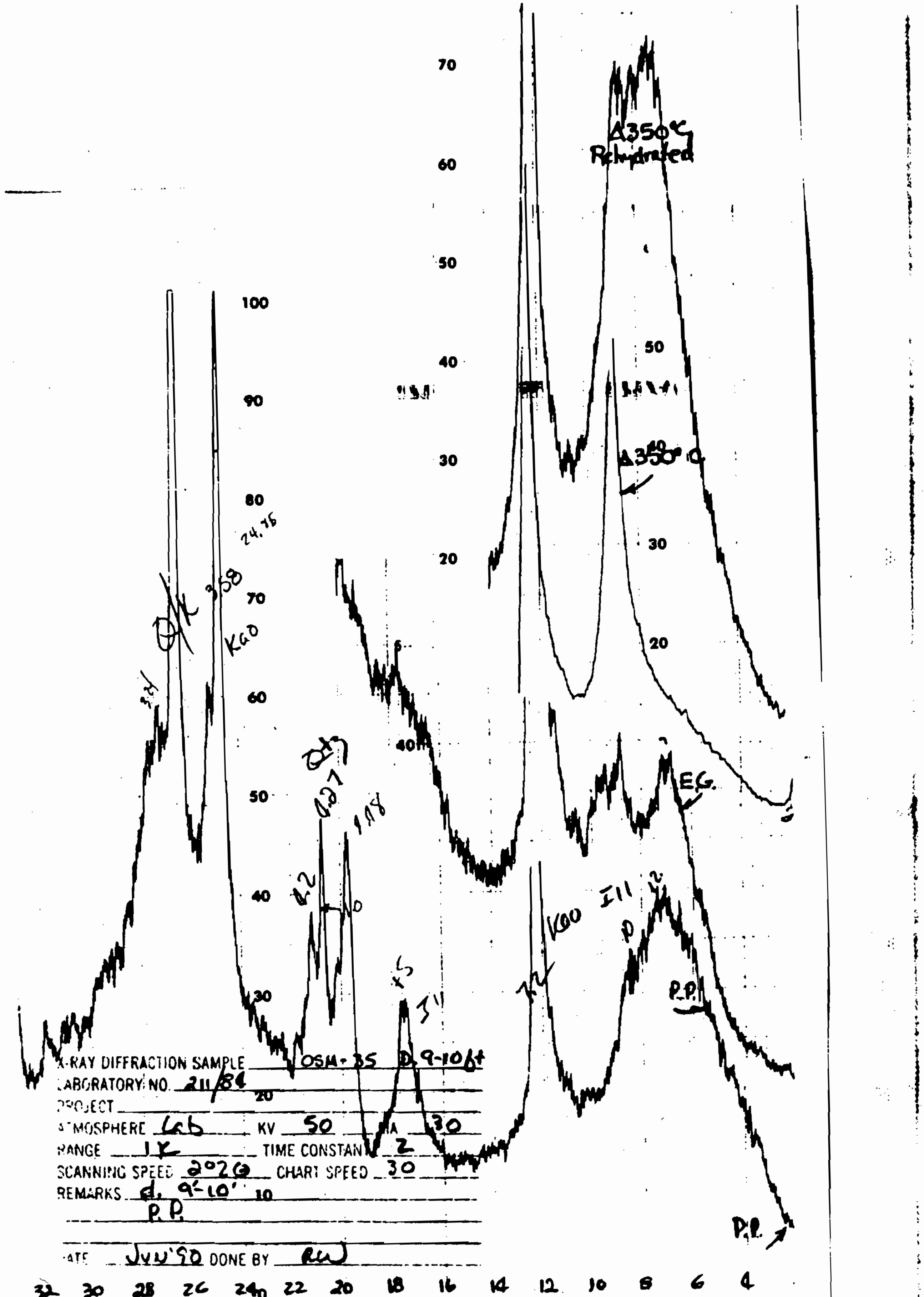


Plate 8. X-ray diffractograms for Sample OSM-35, d. 9-10 feet.

SAD Lab. No. 211/84

Appendix E

Atterberg limit and moisture content for soil samples from 10 complainant and 9 non-complainant companion structures, one ridge top and one valley bottom reference site. Data collected and prepared for the USGS and COE by AmTech Engineering, 1992.

Note: Boring number column references complainant (Number and non-complainant (Number with letter).

SUMMARY OF ATTERBERG LIMITS AND SOIL CLASSIFICATION

Boring No.	Sample No.	Laboratory No.	Natural M.C. %	Atterberg Limits LL	PL	PI	Unified Soil Class.
301	1	92106-3-1	16.8	45	29	16	ML
	2	-2	19.4	59	28	31	CH
	3	-3	16.7	28	22	6	CL-ML
	4	-4	18.5	30	25	5	CL-ML
	5	-5	13.3	39	33	6	ML
301 A	1	-6	21.2	41	24	17	CL
	2	-7	14.6	26	22	4	CL-ML
	3	-8	15.5	27	19	8	CL
	4	-9	16.2	29	21	8	SC
	5	-10	16.8	25	20	5	SC-SM
107	1	-11	17.8	39	24	15	CL
	2	-12	17.2	31	25	6	ML
	3	-13	9.6	26	18	8	CL
	4	-14	17.8	39	23	16	CL
107 A	1	-15	18.4	36	26	10	ML
	2	-16	19.6	38	22	16	CL
	3	-80	21.2	70	21	49	SC
	4	-81	17.1	55	18	37	SC
	5	-82	14.0	39	21	18	SC
108	1	-17	17.3	29	21	8	CL-ML
	2	-18	14.4	27	20	7	CL-ML
	3	-19	16.4	28	24	4	SM
	4	-20	14.7	25	22	3	SM
	5	-21	11.3	24	20	4	SM
108 A	1	-22	21.7	42	26	16	CL
	2	-23	19.2	27	15	12	CL
	3	-24	15.8	28	21	7	SC
	4	-25	15.3	52	27	25	CH
201	1	-26	20.6	28	23	5	ML
	2	-27	15.0	21	16	5	CL-ML
	3	-28	12.9	30	22	8	SC
	4	-29	14.7	39	18	21	SC
	5	-30	14.3	36	20	16	SC
302	1	-31	15.4	25	16	9	CL
	2	-32	14.1	32	21	11	CL
	3	-33	11.6	47	36	11	ML
	4	-34	29.3	76	51	25	CH

302 A	1	-35	14.0	26	18	8	CL
	2	-36	24.3	48	30	18	ML
	3	-37	14.8	46	29	17	ML
421	1	-38	19.8	35	17	18	CL
	2	-39	20.0	32	20	12	CL
	3	-86	8.8	50	24	26	CL/CH
	4	-40	19.9	61	27	34	CH
	5	-41	16.8	47	23	24	CL
421 A	1	-42	18.7	30	28	2	ML
	2	-43	19.4	32	25	7	ML
	3	-44	17.6	31	22	9	CL
	4	-45	11.0	30	27	3	ML
	5	-46	8.0	26	23	3	ML
202	1	-47	14.0	23	20	3	ML
	2	-48	14.1	28	20	8	CL
	3	-49	14.1	67	37	30	SM
	4	-50	14.9	60	33	27	SC-SM
202 A	1	-51	20.2	32	27	5	ML
	2	-52	15.3	27	20	7	CL-ML
	3	-53	9.6	42	33	9	SM
113	1	-54	19.1	36	25	11	ML
	2	-55	15.4	24	20	4	CL-ML
	3	-56	14.8	23	15	8	CL
	4	-57	13.1	23	16	7	SC-SM
	5	-58	21.5	58	35	23	SM
113 A	1	-59	14.8	30	21	9	ML
	2	-60	16.1	57	30	27	CH
	3	-61	16.5	53	24	29	CH
	4	-62	16.7	50	22	28	CH
	5	-63	19.0	51	22	29	CH
115	1	-64	16.1	39	24	15	CL
	2	-65	18.2	30	18	12	CL
	3	-66	15.6	34	19	15	CL
	4	-67	15.6	31	23	8	CL
	5	-68	9.7	29	20	9	CL
115 A	1	-69	20.2	37	26	11	ML
	2	-70	18.6	29	23	6	ML
	3	-71	17.9	37	30	7	ML
103	1	-72	16.1	34	22	12	CL
	2	-73	18.5	30	20	10	SM
	3	-74	19.0	32	29	3	ML
	4	-75	18.3	31	22	9	CL
KK-1	1	-76	23.0	35	19	16	SC
	2	-77	20.7	38	25	13	CL
KK-2	1	-78	18.4	25	20	5	ML
	2	-79	16.8	32	22	10	CL
103 A	1	-83	20.0	29	19	10	SC
	2	-84	19.8	39	20	19	SC
	3	-85	18.4	30	18	12	CL

Appendix F

Estimated degree of limitation for residential and light industrial development and use of septic tank absorption fields relative to soil series and increasing slope (1976, USDA Soil Survey of Vanderburgh County, IN, Table 9)

Appendix 8F

stimated degree of limitation for residential and light industrial development and use of septic tank absorption fields relative to soil series and increasing slope (1976, USDA Soil Survey of Vanderburgh County, IN, Table 9)

Estimated Degree of limitations for:

oil series and ap symbols	A. Residential or light development	B. Septic tank absorption fields
irds: Bd	Severe: subject to flooding.	Severe: subject to flooding.
enshaw: He	Moderate: somewhat poorly drained; seasonal high water table at a depth of 1 to 3 feet.	Severe: seasonal high water table at a depth of 1 to 3 feet; moderately slow permeability; estimated percolation rate slower than 60 minutes per inch.
losmer: HoA	Slight	Severe: very slow permeability depth to fragipan ranges from 25 to 36 inches.
IoB2	Slight	Severe: very slow permeability depth to fragipan ranges from 25 to 36 inches.
IoB3	Slight	Severe: very slow permeability depth to fragipan ranges from 25 to 36 inches.
IoC2	Moderate: moderately sloping; some excavation generally required.	Severe: very slow permeability depth to fragipan ranges from generally 25 to 36 inches.
IoC3	Moderate: moderately sloping; some excavation generally required.	Severe: very slow permeability depth to fragipan ranges from 25 to 36 inches.
HoD3	Severe: slope	Severe: slope severely hinders design of septic system; very slow permeability; estimated percolation rate slower than 60 minutes per inch.

Iona: IoA	Moderate: low strength	Severe: moderately slow permeability; estimated percolation rate slower than 60 minutes per inch.
IoB2	Moderate: low strength	Severe: moderately slow permeability; estimated percolation rate slower than 60 minutes per inch.
Iva: Iv	Moderate: somewhat poorly drained; seasonal high water table at a depth of 1 to 3 feet.	Severe: seasonal high water table at a depth of 1 to 3 feet; slow permeability; estimated percolation rate slower than 60 minutes per inch.
McGary: Mr	Moderate: somewhat poorly drained; seasonal high water table at a depth of 1 to 3 feet.	Severe: seasonal high water table at a depth of 1 to 3 feet; slow permeability; estimated percolation rate slower than 60 minutes per inch.
Reesville: Rs	Moderate: somewhat poorly drained; seasonal high water table at a depth of 1 to 3 feet.	Severe: seasonal high water table at a depth of 1 to 3 feet; moderately slow permeability; estimated percolation rate slower than 60 minutes per inch.
Stendal: St	Severe: subject to flooding.	Severe: subject to flooding.
Wakeland: Wa	Severe; subject to flooding.	Severe: subject to flooding.
Wellston: WeD2, WeD3, WeE2, WeF system.	Severe: steep slopes severely hinder	Severe: steep slopes severely hinder design of septic development of site.
Wilbur: Wm	Severe: subject to flooding.	Severe: subject to flooding.

Zanesville: ZaC2	Moderate: moderately sloping; some excavation generally required.	Severe: very slow permeability depth to fragipan ranges from 25 to 36 inches.
Zainesville: ZaC3	Moderate: moderately sloping; some excavation generally required.	Severe: very slow permeability depth to fragipan ranges from 25 to 36 inches.
ZaD2, ZaD3	Severe: slope	Severe: slope severely hinders design of septic system.
Zipp: Zp	Severe: subject to ponding and flooding; very poorly drained; seasonal high water table.	Severe: very poorly drained; subject to ponding and seasonal high water table; very slow permeability; estimated percolation rate slower than 75 minutes per inch.

Notes:

1. Soil Series limitations are listed in the Soil Survey of Vanderburgh County, Indiana, USDA, 1967, Table 9, pages 78 to 84.

2. Percent slope is indicated by the map symbol. For example, HoC2 is a Hosmer silt loam, 6 to 12 percent slopes, eroded. A map unit without a slope indicator such as, Bird have a 0 to 2 percent slope.

    A - 0 to 2 percent slopes.
    B1 - 2 to 6 percent slopes.
    B2 - 2 to 6 percent slopes, eroded.
    B3 - 2 to 6 percent slopes, severely eroded.
    C2 - 6 to 12 percent slopes, eroded.
    C3 - 6 to 12 percent slopes, severely eroded.
    D2 - 12 to 18 percent slopes, eroded.
    D3 - 12 to 18 percent slopes, severely eroded.
    E2 - 18 to 25 percent slopes, eroded.
    F - 25 to 50 percent slopes.

Appendix G

Accumulative Site Specific Data from Appendices, OSM Interviews, Maps, and related Information:

Table G.1
Natural and Man-induced Site Conditions.
Structures listed have clays of high and medium swell potential.

Table G.2
Natural and Man-induced Site Conditions.
Structures listed have clays of low swell potential.

Table G.3
Natural and Man-induced Site Conditions.
Structures inspected for damage comparison by USGS.
Locations were not augered, gamma logged, and soil samples were not collected for analysis.

Table G.4
Natural and Man-induced Site Conditions.
Structures augered and gamma logged only. No boring data was collected.

Table G.5
Locations augered without structures for stratigraphic correlation.

Table G.1

Natural and Man-induced Site Conditions

(Structures Listed have Clays of High and Medium Swell Potential)

1	2	3	4	5 Related Site Conditons	
Borehole number and Location: IGS or OSM number/Struct-ure number and Resident or Road Identifi-cation (-- = no borehole).	Elevation in Ft. and Topo-graphic Surface: Upper, Middle, Lower. Auger Depth in Feet: Refusal (RD), Total (TD).	Relative up-dip Water Area: Small, Medium, Large	Basement Water Problem: Yes, No, Unknown. Basement Type: Full, Partial, Basement, Slab, Crawl.	Clay Depths in loess: Liquid Limit and Plasticity Index (LL/PI) values included. All depths are in feet. Drilling (*#) Sources are listed below.	Clay Depths below loess: Liquid Limit and Plasticity Index (LL/PI) values included. All depths are in feet. Drilling (*#) Sources are listed below.
				Relative up-dip water area pertains to bedrock dip and topography up-slope to projected outcrop intersection. Damage estimate is based on composite damage levels of all OSM respondents (1989). Soil sampling depths and Atterberg Limit values for potential clay swell are listed in the text.	

1990, October, November, IDNR, Indiana Geological Survey
* 1990, March, DOA, Corps of Engineers, Marietta, GA
# 1992, May, June, DOA Corps of Engineers, WES, Vicksburg, MS
** ** 1992, May, AmTech Engineering, Indianapolis, IN
*** 1986, January, Engineers International, Westmont, IL

1	2	3	4	5 Related Site Conditons	
35/202 Richey Complainant companion to Stevens 202A	520 U 11RD	Small (dependent on ls. conditions)	Yes, PB/C		8.0*** LL/PI 62/37 (High) 9.0-10.0* LL/PI 65/44 (High) 8.0-12.0** LL/PI 60/27 (Medium) High and Medium Swell Potential, 2.0*** Crumbled fragments (colluvium) of rock, 9.0-10.0 colluvium (?). Foundation is on expansive clay and limestone; Limestone is at 11.0 with open voids; Drill water was lost at 11.5; Water damage along rear basement wall; Water stands at one end of basement. Damage is severe.
01/118 Hoover	‹95 U 38 RD	Small	No, PB/C	1.0-2.5 LL/PI 51/28 Medium Swell Potential. Location is on the crest of a knoll; Ground water flows northwest along bedrock dip; Minimal quantities of ground water encounter the house with northwest flow. Damage is minor.	

1	2	3	4	5 Related Site Conditons	
--/302 Greenfield Complainant companion to Palmer 302A	475 U 40 TD	Large	Yes, PB/C		10.0-11.5** LL/PI 76/25 (Medium) Medium Swell Potential. Down-dip slope location; Evidence of piping in yard and down-slope; Foundation is on clay at 10-11.0; Basement water damage, 11 block high, water discolored mortar joints ground level to floor; 10 inch wide open dished concrete water drain follows ground level along exterior of house, water seepage on inside of same wall, front left; Most extensive water damage is on interior wall of partial basement; Water staining along horizontal cap plate and in front corner. Damage is moderate.
31/111 Brinker	475 U 33 RD	Small	No, FB		5.0-10.0 LL/PI 22/07 (Low) Massive clay, (widely spaced joints to 5.6) Location on East side of ridge crest; Bedrock dips to the northwest with ground water flow away from house; B31 is similar to "stoneline" at lower sites; Ground water effects are localized due to coarser texture over residual shale; Massive shale at 5.0-5.6. Damage is moderate.

1	2	3	4	5 Related Site Conditons	
--/301 Fink Complainant companion to Condict 301A	470 U 35 TD	Large	Yes, PB/C	5.0-6.5** LL/PI 59/31 (Medium) Medium Swell Potential, Loess to 8.5, Structure is on down-dip slope; Colluvium at 8.5-11.0; Basement is wet at 9.0 to 10.0; Weathered shale is at 11-14; Piping found beneath house, outside levels show settlement around steps, outside basement entrance, and brick sidewalks; Garage floor slab breakage and resulting void is believed due to soil piping. Damage is moderate/severe.	
33/113 Boettcher Complainant companion to Ogg 113A	465 U 20 RD 14 TD	Medium	Yes, PB/C		12.5-14.0** LL/PI 58/23 (Medium) Medium Swell Potential, Colluvium at 5.0-9.0. House is on down-dip slope; Basement water problem; Floor cracks in the basement began in 1955; Recent drainage system installed rear of house where the two wings meet. Damage is severe.

1	2	3	4	5 Related Site Conditons	
--/113A Ogg Non-complainant companion to Boettcher 113	475 U 14 TD	Small	No, PB/C		5.0- 6.5** LL/PI 57/27 (Medium) 7.5- 9.0** LL/PI 53/29 (Medium) 10.0-11.5** LL/PI 50/28 (Medium) 12.5-14.0** LL/PI 51/29 (Medium) Medium Swell Potential, Location is on East slope; Bedrock dips into hillside; Partial basement is on weathered shale; Damage is minor.
04/209 Gore	470 U 19 RD	Small to medium	Yes, PB/C		10.1-10.6 LL/PI 63/38 (High) High Swell Potential, 6.6- 8.3 Colluvium. Structure is on down-dip side of ridge crest; Down-section of West Franklin, beds dip northwest; Colluvium against basement wall with clay from 8.3-10.2; Shale is 10 and greater; Receives ground water from ridge zone; Basement water damage; Soil on basement floor from foundation break; Boxes on bricks for dryness; 11 block basement shows water staining about third course down to floor; Water has deteriorated wall with pieces dislodged; Shale with steeply dipping joints with sickensided faces at 10.2-10.5; BOM level-loop survey showed structure settlement; Damage is moderate.

1	2	3	4	5 Related Site Conditons	
--/107A Deutch Non-complainant companion to Harris 107	450 U 14 TD	Large	Yes, PB/C		7.5- 9.0** LL/PI 70/49 (High) 10.0-11.5** LL/PI 55/37 (Medium) High and Medium Expansive Potential, Auger material was not tested for colluvium. Structure is down-section of West Franklin Is.; Water drainage is to the northwest along bedrock; Damage is minor/moderate.
29/421 Osborn Complainant companion to Rozanski 421A	443 M 30 RD	Large	Yes, FB		7.0- 9.6 LL/PI 75/49 (High) 9.0-11.0* LL/PI 62/41 (High) 7.5- 9.0** LL/PI 50/26 (Medium) 10.0-11.5** LL/PI 61/34 (High) High and Medium Swell Potential, Colluvium at 7.0-8.0. Structure is in a cut slope position; Fifty feet of relief behind structure; Basement wall collapsed during construction from up-slope water drainage; Basement water damage; Competent shale at 12 feet; Damage is severe.

1	2	3	4	5 Related Site Conditons	
10/108 Raymond McCutchan Complainant companion to Zinn 108A	440 M 39 RD	Large	Yes, FB		4.0-6.0* LL/PI 98/73 (High) 7.0-7.5 LL/PI 66/38 (High) High Swell Potential, Structure is cut into a slope with 50 feet of relief; Colluvium at 4.0-5.0; Weathered shale form 5.0-9.0; Location is down-section of West Franklin ls.; Bedrock dips northwest into the hillside; Colluvium mantles slope behind structure, provides a permeable zone for water movement atop an erosional surface of shale, and ground water movement toward the structure; An approximate 700 foot driveway, ditched along the hillside, channels surface drainage to the rear right side of the garage; Surface drainage at garage end is discharged into the area along the patio side of the house; Up-slope garage end, basement wall of structure has void area of missing soil (dirt has washed into basement) (1993, GS, P.19); Photograph and video of garage entrance (patio side) show normal fault shear in mortar joints of brick in down-slope direction; Damage is severe.

1	2	3	4	5 Related Site Conditons
32/201 Effinger Complainant Effinger 201 has no companion structure	430 M 31 RD	Medium	Yes, FB	8.3- 8.6 LL/PI 47/20 (Marginal Low) 9.0-11.0*# LL/PI 47/24 (Marginal Low) Marginal Low Swell Potential Marginal, Colluvium at 7.2-7.8, and 9.0 to 11.0. Bedrock dip is westward and down-section of West Franklin ls.; Up-dip water catchment area is from the East; COE/WES calculated 2.1 T/Sq.Ft. on up-slope collapsing wall; Water inside basement floor, northwest down-dip corner of structure; Exterior veneer around window is cracked at same northwest corner; Damage is severe.
--/108A Zinn Non-complainant companion to McCutchan 108	430 M 32 RD	Small to Medium	No, PC/S	10.0-11.5** LL/PI 52/25 (Medium) Medium Swell Potential, Colluvium at 7.0-8.0. Structure is located in intermittent stream valley; Water filled auger hole (15-20 feet off front left corner of structure) to within 12 feet of surface; Pond is located about 300 feet down-slope of house; Colluvium and clay with medium swell potential appear to have had little effect on structure; Structure is constructed on concrete pads; Damage is minor.

1	2	3	4	5 Related Site Conditons	
37/215 Pate	430 M 19 RD	Small	Unknown, Unknown	1.3-1.8 LL/PI 56/33 (Medium) Medium Swell Potential. Basement shows moisture seepage at floor level; Mineral precipitate two block high; Damage is minor.	
08/105 B. Bohrer	387 L 18 RD	Large	Unknown, FB	1.7-2.2 LL/PI 51/30 (Medium) Medium Swell Potential. B soil horizon is severely eroded; IIB soil horizon is the top of physically weathered, fragmented shale at 6.8-7.3 feet; 9.5-11.0 feet silty clay, highly fragmental, clay (soft shale); Continued right.	Horizontal crack 70 foot long, first and second course of concrete block below ground level; Structure is located within 400 feet of N-S man-made drainage ditch; Surface and subsurface ground water flow is toward man-made ditch; Ground water merges from two sources, 1700 and 2800 away; Subsurface was not analyzed below 12 feet. Damage is moderate.

Table G.2
Natural and Man-induced Site Conditions
(Structures listed have clays of low swell potential)

1	2	3	4	5 Related Site Conditions
Borehole number and Location: IGS or OSM Number/Structure number and Resident or Road Identification (-- = no borehole)	Elevation in Feet and Topographic Surface: Upper, Middle, Lower. Auger Depth in Feet: Refusal (RD) Total (TD).	Relative up-dip Water Area: Small, Medium, Large.	Basement Water Problem: Yes, No, Unknown. Basement Type: Full, Partial, Basement, Slab, Crawl.	Relative up-dip water area pertains to bedrock dip and topography up-slope to projected outcrop intersection. Damage estimate is based on composite damage levels of all OSM respondents (1989). Soil sampling depths and Atterberg Limit values for potential Clay swell are listed in the text.
--/202A Stevens Non-complainant companion to Richey 202	520 U, 16 TD	Small (dependent on ls. conditions)	No, FC	Clays of low swell potential were found in soil samples #1 through #3** Limestone pebbles were returned between 10 and 14; Subsurface materials are loess, colluvium, shale/limestone; Foundation is inferred limestone; Damage is minor.
--/302A Palmer Non-complainant companion to Greenfield 302	475 U, 8 TD	Small	Unknown, FB	Clays of low swell potential were found in samples #1 through #3** Bedrock is shale, although not identified by contractor; Depth to shale was not determined; Damage is minor/moderate.

1	2	3	4	5 Related Site Conditions
--/301A Condict Non-complainant companion to Fink 301	475 U, 14 TD	Medium	Yes, FB	Clays of low swell potential were found in Samples #1 through #5** Structure is on down-dip slope; Evidence of moisture on inside basement walls; An up-slope tributary intercepts ground water drainage and reduces the amount received at the structure; Foundation is in loess/shale; Damage is minor/moderate.
--/107 Harris Complainant companion to Deutsch 107A	465 U, 44 TD	Large	Yes, PB/C	Clays of low swell potential were found in Samples #1 through #4** Colluvium at 7.0-8.0; Competent shale >8.0-9.0 (?), First significant velocity change in compression wave at 14.0; Structure is on down-dip slope; Long term water problem is inferred; Structure has two sump pumps, one of unknown installation date and a second on up-slope side of house installed in 1984; Need for second pump to accommodate down-slope water movement through colluvial zone is suggested by 1982 and 1983 precipitation before year of installation (Fig.8.3); BOM level-loop survey showed structure settlement; Damage is moderate/severe.
--/421A Rozanski Non-complainant companion to Osborn 421	440 M, 13 TD	Medium to large	Unknown, FB	Clays of low swell potential were found in samples #1 through 5** Colluvial material at 8.0-12.0; Competent shale at 12; Structure is on a flat area not in the direct path of ground water flow suggesting colluvium is well drained; Damage is minor.

1	2	3	4	5 Related Site Conditions
34/403 William McCutchan	430 M, 12 RD	Small	Unknown, Unknown	Clays of low swell potential were found at 2.0 and 7.0** Soils gleyed from 5 to 7; House is located on an inter-stream divide; Foundation appears to be constructed in the toe-slope of a colluvial fan; Ground water flow from fan apex is away from house; Soil is Gleyed from 5 to 7; Damage is minor.
--/115A Klausmeier Non-complainant companion to Christensen 115	411 M, 9 TD	Small	No, FC	Clays of low swell potential were found in samples #1 through 5** Ground water flow is not directed toward house; Damage is minor.
--/115 Christensen Complainant companion to Klausmeier 115A	402 M, 24 TD	Medium	Unknown, PB/C	Clays of low swell potential were found in samples #1 through 5** Depth to bedrock was not determined; Foundation is in weathered shale; NW corner of lot, West side of house is wet due to drainage off surrounding agricultural fields; Structure parallels ground water flow; Damage is severe.

1	2	3	4	5 Related Site Conditions
--/103 Zimmerman Complainant companion to Shelton 103A	395 L, 33 TD	Large	Unknown, FB	Clays of low swell potential were found in samples #1 through 4** The topographic map shows a contour crenation indicating (surface/subsurface) drainage in the direction of the structure located about 200' East of Green River Rd. on the down-slope side; Rear of house is about 5 foot below original ground surface with the foundation estimated to be in loess; Initial soil saturation conditions were 90.5% at 4.4', 95.4% at 6.8', and 94.3% at 13.2' along the SE corner of the property (1992, COE) ; Shale bedrock is estimated at 17 feet plus; Down-slope of structure two subsurface drainage ways converge to a man-made drainage ditch; Front of house has fill material (unknown permeability) that slopes gently toward Green River Road; Fill along the North side of the house tapers to the natural slope northward and eastward; A septic system is located at the NW (front left) corner of the structure; The basement floor contains numerous hairline cracks of various ages; One of the old (pre-1984) cracks is in the NW corner of the basement and is 17' long and up to an 1/8 in. wide; Damage is moderate.
--/103A Shelton Non-complainant companion to Zimmerman 103	390 L, 9 TD	Large	No, FC	Clays of low swell potential were found in samples #1 through 3; Depth to bedrock was not determined; Structure has full crawl space and does not encounter subsurface drainage; Damage is minor.

Table G.3
Natural and Man-induced Conditions
Structures Inspected for Damage Comparison (1993, USGS)
Locations were not Augered, Gamma Logged, and Soil Samples were not Collected

1	2	3	4	5
Structure Identification:	Foundation: Surface or Bedrock: Shale, Limestone	Relative Up-dip Water Area: Small, Medium, Large,	Basement Water Problem: Yes, No, Unknown Basement Type: Full, Partial, Basement, Slab, Crawl,	Known Site Conditions See USGS: Text, and Table 11 Category 1 and 2 buildings (1993).
--/104A LeCocq	Not Augered	Small	Unknown, FB	Non-complainant companion to Norton #104; Daylight, IN; Damage is minor.
--/103B Daugherty	Not Augered	Large	Unknown, FB	Non-complainant companion to Zimmerman #103; Daylight, IN vicinity; Damage is minor.
--/105A Miller	Surface, Not Augered	Medium	No, FC	Non-complainant companion to Bohrer #105; Daylight, IN; Damage is minor.

--/202B Heil	Not Augered	Small	Unknown, FB	Non-complainant to Richey #202; Blue Grass area; Down-section of West Franklin ls.; Damage is minor.
--/107B Hawles	Surface, Not Augered	Large	No, FC	Non-complainant companion to Harris #107; McCutchan Ridge area; Damage is minor.
--/108B Arnold	Not Augered	Small	Unknown, PB/C	Non-complainant Companion to McCutchan #108; McCutchan Ridge area; Located on a knoll along ridge divide; Damage is minor.
--/113B Lavallo	Not Augered	Medium	Unknown, FB	Non-complainant Companion to Boettcher #113; McCutchan Ridge area; Damage is minor/moderate.
--/114A Wolff	Not Augered	Small	Unknown, FB	Non-complainant Companion to Kinney #114; McCutchan Ridge area; Damage is minor.
--/115B Board	Surface, Not Augered	Small	No, FC	Non-complainant to Christensen #115; Daylight, IN vicinity; Drainage is East-West behind structure; Damage is minor.

Table G.4
Natural and Man-induced Site Conditions
Locations Augered and Natural Gamma Logged
(Soil Samples were not Collected for Analysis)

1	2	3	4	5 Related Site Information
Borehole number and Location: IGS or OSM Number/Structure number and Resident or Road Identification (-- = no borehole #).	Elevation in Feet and Topographic Surface: Upper, Middle, Lower. Auger Depth in Feet: Refusal (RD), Total (TD).	Relative Up-dip Water Area: Small, Medium, Large.	Basement Water Problem: Yes, No, Unknown. Basement Type: Full, Partial, Basement, Slab, Crawl.	Relative up-dip water area pertains to bedrock dip and topography up-slope to projected outcrop intersection. Damage estimate is based on composite damage levels of all OSM respondents (1989). No soil samples were taken for analysis.
30/401 Poston	520 U, 10 RD	Small	Unknown, PB/S	Blue Grass Cemetery Area; OSM Interview information is incomplete; Damage is minor/moderate.
36/411 Carter	470 U, 28 RD	Small	No, FC	Blue Grass Cemetery Area; OSM Interview information is incomplete; Damage is minor.
07/334 Titzer	422 M, 31 RD	Small	Unknown, FB	Base Line Road Area; Location is on ridge divide above highest contour; Soil horizons IIIB and IVB are inter-stratified shale and sandstone; Shale transition begins at 7.7; Bedrock is at 10; OSM Interview information is incomplete; Damage is minor.

1	2	3	4	5
Complainant Structures.				
--/104 Norton	Not Augered	Small	Unknown FB	Complainant Structure; Daylight, IN; Garage downspout (front left) discharges water directly to ground, soil adjacent to same wall was saturated at time of visit, inside area of same corner severely cracked; Garage slab is un-reinforced and without expansion joints; Damage is moderate.
--/114 Kinney	Not Augered	Small	Yes FB	Complainant Structure; McCutchan Ridge; Downspout to abandoned cistern discharges on the surface within 5 of foundation (rear right) corner; Downspout SW corner (front right) separation discharges water to ground not drain; Basement inside SW corner wet; Front left garage side downspout also separated; Improper downspout drainage discharges water directly to basement wall and foundation; Settlement at these areas, due to water, infers piping; Damage is moderate.
--/316 Gorbett	Not Augered	Small	Unknown FB	Complainant Structure; McCutchan Ridge; A downspout (left of the garage door) discharges water to a concrete slab within a foot of the outside wall; Discharge water must drain across the slab in front of garage; down-slope is to the right side of garage door; Damage to structure is minor.

Table G.5
Locations augered without structures for stratigraphic correlation.

1	2	3	4 Related Site Conditions
Locations below are without Structures. (**1992, May, AmTech Engineering, Indianapolis, IN)			
--/KK2 Oasis	510 U	17 TD	
05/Rd. Kansas	430 M	17 RD	
13/Rd. Kansas	400 M	28 RD	
12/Rd. Boonville, New Harmoney	388 L	24 RD	
--/KK1 Stahl	380 L	59 TD	

1	2	3	4 Related Site Information
Locations below are without structures. (1990, October, November, IDNR, Indiana Geological Survey, Bloomington, IN			
11/Rd. Kansas	415 M	30 RD	
28/Rd. Boonville-New Harmoney	400 M	16 RD	
06/Rd. Kansas	396 L	24 RD	
27/Rd. Kansas	395 L	44 RD	
25/Rd. Olmstead	385 L	89 RD	
23/Rd. Boonville-New Harmoney	382 L	58 RD	
14/Rd. Kansas	380 L	58 RD	
15/Rd. Kansas	380 L	34 RD	
16/Rd. Kansas	380 L	40 RD	
24/Rd. Millersburgh	380 L	80 RD	

1	2	3	4. Related Site Conditons	
Locations below are without structures. (1990, October, November, IDNR, Indiana Geological Survey Bloomington, IN				
03/-- Airport	430 M	40 RD		9.2-9.7 LL ND
20/-- Petersburg	430 M	15 RD		14.3-14.8 LL/PI 53/33
02/-- Kansas	392 L	24 RD		14.0-14.3 LL/PI 50/24
21/-- Kansas	385 L	33 RD	2.5-4.9 LL/PI 63/36	
09/-- Kansas	379 L	65 RD	2.0-4.6 LL/PI 54/31	10.0-12.9 LL ND
19/-- Kansas	378 L	60 RD	1.3-3.5 LL/PI 50/29	9.4-14.8 LL ND
17/-- Kansas	376 L	58 RD		10.3-10.8 LL ND
22/-- Kansas	376 L	62 RD	4.0-14.8 LL/PI 57/33	4.0-14.8 LL/PI 57/33

Appendix H.

Precipitation during 1987 and 1988 for Evansville, IN, Southwestern District 7, National Oceanic and Atmospheric Administration (NOAA) and National Weather Service (NWS).

Precipitation data is from the Weekly Weather and Crop Bulletin (WWCB) a joint venture of the USDOC and USDA. Explanations are included.

EXPLANATION

Precipitation for 1987 and 1988 including Palmer Drought Severity Index (PSDI), Available Water or Crop Moisture Index (CMI) for the Upper 5-ft of Soil Profile, and Weekly Precipitation in Total Inches for Evansville, IN, Southwestern District 7, National Oceanic and Atmospheric Administration (NOAA) and National Weather Service (NWS). Data is from Weekly Weather and Crop Bulletin (WWCB).

COLUMN 2:

PALMER DROUGHT SEVERITY INDEX (PDSI or DSI)

Above +4.0 extreme moist spell
3.0 to 3.9 Very Moist Spell
2.0 to 2.9 Unusual moist spell
1.0 to 1.9 Moist Spell
0.5 to 0.9 Incipient Moist Spell
0.4 to -0.4 Near Normal
-0.5 TO -0.9 Incipient Drought
-1.0 to -1.9 Mild Drought
-2.0 to 2.9 Moderate Drought
-3.0 to -3.9 severe drought
Below -4.0 Extreme Drought

COLUMN 3:

CROP MOISTURE INDEX (CMI)
AVAILABLE MOISTURE IN UPPER 5-FT SOIL PROFILE

(S) = Shaded (index increased or did not change)
Above 3 Excessively Wet, Some Fields Flooded
2 to 3 Too Wet, Some Standing Water
1 to 2 Prospects Above Normal, Some Field Too Wet
0 to 1 Moisture Adequate For Present Needs
0 to -1 Prospects Improved But Rain Still Needed
1 to -2 Some Improvement But Still Too Dry
-2 to -3 Drought Eased But Still Serious
-3 to -4 Drought Continues, Rain Urgently Needed
Below -4 Not Enough Rain, Still Extremely Dry

(U) = Unshaded (index decreased)
Above 3 Some Drying But Still Excessively Wet
2 to 3 More Dry Weather Needed, Work Delayed
1 to 2 Favorable, Except Still Too Wet In Spots
0 to 1 Favorable For Normal Growth And Fieldwork
0 to -1 Topsoil Moisture Short, Germination Slow
-1 to -2 Abnormally Dry, Prospects Deteriorating
-2 to -3 Too Dry, Yield Prospects Reduced
-3 to -4 Potential Yields Severely Cut By Drought
Below -4 Extremely Dry, Most Crops Ruined

Evansville, Indiana is in NOAA, NWS District 7 located in Southwestern Indiana. District 7 covers an area that is roughly equal to the SW third of the State of Indiana in both a North-South and East-West direction. This Appendix provides an explanation for the Palmer Drought Severity Index (PDSI or DSI) and Crop Moisture Index (CMI). Both indices show general conditions and not local variations caused by isolated rain. The CMI can change rapidly from week to week and provides insight into soil water availability. The weekly precipitation values are for Evansville, IN.

The Palmer Drought Severity Index (PDSI or DSI) is given in positive and negative values. Positive values show a moisture excess, values near zero show normal conditions, and values less than zero show drier than normal. An index of -3.0 to -3.9 is a severe drought, while an index of below -4 is an extreme drought of the worst condition (Table 8.2, column 2 explanation).

The Crop Moisture (CMI) index gives the short-term or current status of available water for the upper 5-ft. of soil profile for purely agricultural drought or moisture surplus. The WWCB provides CMI values in a shaded and unshaded map format. Shaded (S) values show changing water conditions or no change in water conditions. Unshaded (U) values show decreasing water conditions (column 3 explanation). Input to weekly calculations are the weekly precipitation total and average temperature, division constants (water capacity of the soil, etc.) and previous history of the indices. The PSDI is a climatological tool for evaluating the scope, severity, and frequency of prolonged periods of abnormally dry or wet weather. The CMI can measure the short-term status of dryness or wetness effecting warm season crops and field activities.

The last drought, prior to the Summer of 1988, that was substantially worse this early in the season happened in 1934, which contributed to the dust bowl era (1988, DOC, NOAA). By the end of June 1988, 29 percent of the continental United States was experiencing severe or extreme drought (1988, NOAA). In July 1988 portions of 35 states experienced PDSI of less than -4 (1988, NOAA).

In southwestern Indiana the drought was significant enough for the Vanderburgh County Office, Agricultural Stabilization and Conservation Service (ASCS) to apply for and receive Federal aid for farmers that have suffered loss of feed for livestock that use hay and pasture. Aid was from, the Emergency Feed Program (EFP) and the Emergency Feed Assistance Program, (EFPA). To be eligible for benefits under either program producers must have a 40% or greater loss to their hay, pasture, and grain crops (1992, ASCS, EFP, EFPA document transmittals).

YEAR - 1987			
1987 Vol. 74, Numbers 1 to 52	Palmer Drought Severity Index (PDSI) (Long Term Palmer)	Crop Moisture Index (CMI) Available Water in the Top 5-Ft. Soil Profile	Weekly Precipitation in Total Inches. Monthly Total in Parenthesis
1	2	3	4
1-3			0.1
1-10			0.2
1-17			0.1
1-24			0.4
1-31			0.1 (0.9)
2-7			0.5
2-14			0.5
2-21			0.6
2-28			1.9 (3.5)
3-7			0.1
3-14			0.0
3-21			0.9
3-28			0.4 (1.4)
4-2	-1.6 MILD		1.2
4-9			1.5
4-18	-1.2 MILD		Tr
4-25			Tr (2.7)
5-2	-1.5 MILD	U 0.4	Tr
5-9		U 0.9	0.3
5-16	-1.8 MILD	S 0.0	0.5
5-23		U -0.1	0.2
5-30	-1.8 MILD	S -0.1	2.3 (3.3)
6-9		S 0.0	1.7
6-13	-1.4 MILD	U 0.5	2.7
6-20		S 0.1	0.5
6-27	-1.5 MILD	S 0.0	0.8 (5.7)
7-4		S 1.1	0.7
7-11	0.7 INCIP.	U 0.8	0.8
7-18		U 0.5	0.9
7-25		U 0.2	0.0 (2.4)
8-1	0.4 NEAR NORM.	S 0.2	1.1
8-8		U -0.4	Tr
8-15	-1.9 MILD	U -1.4	Tr
8-22		U -1.9	Tr
8-29	-2.2 MOD.	S -1.8	0.4 (1.5)

YEAR - 1987			
1987 Vol. 74, Numbers 1 to 52	Palmer Drought Severity Index (PDSI) (Long Term Palmer)	Crop Moisture Index (CMI) Available Water in the Top 5-Ft. Soil Profile	Weekly Precipitation in Total Inches. Monthly Total in Parenthesis
9-5		U -2.2	0.0
9-12	-2.5 MOD.	U -2.3	Tr
9-19		S -1.1	1.3
9-26		U -1.1	0.0 (1.3)
10-3	-2.2 MOD.	S -0.5	0.7
10-10		S -0.2	0.7
10-17	-2.1 MOD.	S -0.2	0.1
10-24		S 0.1	0.2
10-31	-1.9 MILD	U -0.1	0.3 (2.0)
11-7			Tr
11-14			0.1
11-21			0.1
11-28			3.1 (3.3)
12-5			0.1
12-12			0.4
12-19			1.4
12-26			2.8 (4.7)

Total precipitation for 1987 is 32.7 inches.

YEAR - 1988			
1988 Vol. 75, Numbers 1 to 52	Palmer Drought Severity Index (PDSI) (Long Term Palmer)	Crop Moisture Index (CMI) Available Water in the Top 5-Ft. Soil Profile	Weekly Precipitation in Total Inches. Monthly Total in Parenthesis
1	2	3	4
1-2			1.1
1-10			1.1
1-17			0.1
1-23			2.2
1-30			Tr (4.5)
2-6			2.0
2-13			0.1
2-20			0.6
2-27			Tr (2.7)
3-5			1.2
3-12			0.3
3-19			0.1
3-26			0.7 (2.3)
4-2	-1.6 MILD		1.2
4-9			0.8
4-16	-1.2 MILD		0.0
4-23			0.5
4-30	-1.6 MILD	U 0.0	0.0 (2.5)
5-7		S 0.0	0.1
5-14	-2.1 MOD.	U -0.1	0.5
5-21		U 0.1	0.0
5-28	-2.1 MOD.	U -0.0	0.8 (1.4)
6-4		U -0.3	Tr
6-11	-1.8 MILD	U -0.5	0.7
6-18	-2.0 MOD.	U -1.0	Tr
6-25	-2.4 MOD.	U -1.8	0.2 (0.9)
7-2	-2.6 MOD.	U -2.2	0.2
7-9	-2.9 MOD.	U -2.9	Tr
7-16	-2.7 MOD.	S -1.7	1.9
7-23	-2.0 MOD.	S -1.0	2.5
7-30	-1.7 MILD	S -1.0	2.2 (6.8)
8-6	-1.8 MILD	S 0.0	0.6
8-13	-2.1 MOD.	U -1.1	0.3
8-20	-2.3 MOD.	U -1.7	1.2
8-27	-2.4 MOD.	S -1.0	0.4 (2.5

YEAR - 1988			
1988 Vol. 75, Numbers 1 to 52	Palmer Drought Severity Index (PDSI) (Long Term Palmer)	Crop Moisture Index (CMI) Available Water in the Top 5-Ft. Soil Profile	Weekly Precipitation in Total Inches. Monthly Total in Parenthesis
9-4	-2.4 MOD.	S -0.9	0.6
9-10	-2.4 MOD.	S -1.1	0.0
9-17	-2.4 MOD.	S -0.7	0.2
9-24		S -0.7	0.6 (1.4)
10-1	-2.4 MOD.	S -0.6	0.5
10-8		U -0.7	0.0
10-15	-2.4 MOD.	S -0.3	Tr
10-22		S 0.1	1.0
10-29	-2.2 MOD.	S 0.0	1.4 (2.9)
11-5			3.5
11-12			0.5
11-19			3.1
11-26			0.9 (8.0)
12-3			Tr
12-10			Tr
12-17			Tr
12-24			0.7 (0.7)

Total precipitation for 1988 is 36.6 inches.

Appendix I.

USGS Investigation of Building Damage in the McCutchanville-Daylight, IN Area (1993).

Table 11
Structure inspection and damage evaluation of Category 1 (complainant) and Category 2 (non-complainant companion structures).

Table 12
Structure inspection and damage evaluation of Category 3 buildings (Control area). Category 3 buildings were not augered. Soil to bedrock stratigraphy was not established.

SITE CATEGORY NAME/ADDRESS USGS ID/OSM ID	DESCRIPTION OF BUILDING	DAMAGE	SITE CONDITIONS
1 McCutchan 9435 Baumgart Rd. MCC/108	Built in 1967 One-story wood frame with all brick veneer. Plaster on sheet rock finish. Full basement with walkout. Unreinforced concrete block walls.	Exterior - Numerous wide cracks in veneer, with some displacement of brick in the walls. Foundation - Stair step cracks visible in walls. Severe crack running full length of basement slab. Interior - Nail pops and hairline cracks in wallboard in the first story.	BORING 108 0-4 ft B horizon and loess 4-5 ft colluvium 5-9 ft weathered shale, expansive- 2.5 tons/sqft >10 ft firm shale a. Large velocity mismatch at 13 ft (compressional), 4 ft, 9 ft (shear wave). b. The colluvium may be the source of water permeability c. The weathered shale shows slickensides d. Foundation is probably in weathered shale. e. One corner of foundation could be on firm shale (uphill side).
2 Zinn 9455 Baumgart Rd. ZIN/108A	Built in 1972. One-story wood frame with all brick veneer. Drywall finish. Partial crawl space and concrete slab. Unreinforced concrete block walls in crawl space.	Exterior - Few hairline cracks. Foundation - None. Interior - Few hairline cracks.	BORING 108A 0-2 ft fill? 2-7 ft B horizon and loess 7-8 ft colluvium 8-10 ft weathered shale - very expansive >10 ft shale a. A velocity change at 13-14 ft (compressional) a shear wave velocity change at 10-11 ft. b. Foundation is probably in the loess.
2 Arnold 9325 Baumgart Rd. ARN	Built in 1940's. One-story wood frame with stone veneer. Plaster on sheet rock finish. Partial basement with crawl space. Unreinforced concrete block walls.	Exterior - One small crack visible in stone wall, which the owner believed appeared in the 1980-89 time period. Foundation - None. Interior - Few small cracks in breakfast room ceiling.	
1 Kinney 8915 Baumgart Rd. KIN/114	Built in 1969. One-story wood frame with all brick veneer. Plaster on sheet rock finish. Full basement with walkout. Unreinforced concrete block walls.	Exterior - Cracking on exterior walls. Posts on the front porch are loose sometimes. Evidence of poor drainage is evident around the downspout on the uphill side of house, particularly in corner where considerable damage is present on the inside basement wall of the house. Foundation - Basement slab has a large North-South crack. Block walls have both horizontal and stairstep cracks. Interior - Cracking visible throughout.	
2 Wolff 9001 Baumgart WOF/114A	Built in 1945. One-story wood frame with all stone veneer. Plaster on sheet rock finish. Full basement with walkout. Unreinforced concrete block walls.	Exterior - Few hairline cracks. Foundation - Few hairline cracks. Interior - Few hairline cracks.	

Table 11. Category 1 and 2 buildings.

SITE CATEGORY NAME/ADDRESS USGS ID/OSM ID	DESCRIPTION OF BUILDING	DAMAGE	SITE CONDITIONS
1 Fink 9120 Petersburg Rd. FIN/301	Built in 1953 Two-story wood frame with all brick veneer. Plaster on sheet rock finish. Partial basement with walkout and with crawl space Unreinforced concrete block l	Exterior - Diagonal, horizontal, and vertical cracks were present around openings on the south wall. Other cracks were also present on the exterior. The ground showed signs of settlement, particularly around the perimeter of the foundation. The garage slab was severely cracked, being displaced over a foot next to the house. There was no evidence of reinforcement in the garage slab. Foundation - Cracks were present in all walls in the basement. Many ceiling tiles were displaced. The basement was damp and sometimes wet. Examination of the crawl space showed that exterior soil had literally washed into the crawl space. The flow pattern was traceable to the "sink hole" outside the house. Step footings were visible in the crawl space. One such step was located at the "sink hole." There was a vertical crack at the step and the footing appeared to be discontinuous at the step. Bricks supporting a steel beam supporting the upper stories were crushed. This steel beam, which is losing support, lines up with vertical cracks in the veneer outside the house. Interior - Cracks were present in the first and second floor although not severe. The biggest problem seemed to be sliding doors and windows that no longer worked well. There were openings between boards in the hardwood floor. Nails were working their way out of the floor.	BORING 301 0-8.5 ft small B Horizon and loess 8.5-11 ft colluvium, high permeability 11-14 ft weathered shale. >14 ft shale, siltstone. a. A moderate compressional velocity change is located at approximately 8-9 feet and at 11-12 ft. b. No expansive soils were found by the lab tests. c. Foundation is thought to be in the loess. d. It is thought that the shale (14') is an aquatard, the colluvium is the possible "pipe" to carry loess away from the foundation if a source of water can be found.
2 Condict 9200 Petersburg Rd. CON/301A	Built in early 1930's. Two-story wood frame with all brick veneer. Plaster on sheet rock finish. Full basement. Unreinforced poured concrete walls.	Exterior - A few cracks were found in the veneer around one window. Foundation - Numerous cracks were present in the basement walls with evidence of moisture penetration from the outside. Interior - A few ceiling and wall cracks were found. There was one crack in a patio floor.	
2 Cox 9202 Petersburg Road COX	Not Inspected		

SITE CATEGORY NAME/ADDRESS USGS ID/OSM ID	DESCRIPTION OF BUILDING	DAMAGE	SITE CONDITIONS
1 Effinger 1624 Swope Lane EFF/201	Built in 1980. One-story wood frame with all brick veneer. Drywall finish. Full basement. Unreinforced concrete block walls.	Exterior - Large horizontal and stairstep cracks are visible near doorways and windows. Foundation - Stairstep cracking present in corners with moisture on the slab in the northwest corner. The slab was also cracked in this corner. The entire north basement wall (about 60 ft) was bowed with cracks present in many of the mortor joints. Although the slab on the ground outside this wall was sloping inwards, possibly providing a path for moisture buildup, the wall did not appear water stained. Interior - Cracks present in walls throughout much of the upstairs. Cracking did not appear as bad as might have been anticipated given the degree of damage observed outside and in the basement.	BORING 201 0-9 ft B horizon and loess 9-11 ft colluvium and expansive (it took 2.1 tons/sf to contain it). 11-14 ft weathered shale, not expansive >14 ft shale a. No large velocity changes in the compressional wave, a possible large velocity change at 9 ft in shear wave. b. Foundation is probably in loess and/or colluvium. c. It is possible that the foundation is on different materials as a 2nd bore hole further away from the foundation showed a greater thickness of weathered shale and less colluvium.
No Companion			
1 Harris 8304 Whetstone FRI/107	Built in 1953 with 2nd story added in 1984. There may have been a modification between these two dates Two-story wood frame with stone veneer. Drywall finish. Partial basement with crawl space. Unreinforced poured concrete in main basement with unreinforced concrete block walls in part of basement and crawl space.	Exterior - Cracks present in mortor joints around the house. Foundation - Cracks are present in the both the poured concrete walls and the block walls of the basement. A few horizontal cracks were noticed in the crawl space area near the location oa an outside downspout. These cracks would have been noticed by an inspector. Stair step cracks visible in workshop walls. The slab was also cracked in this room. Mrs. Harris keeps track of crack growth by marking and dating and dating them. Interior - Cracks were present in many of the walls of the first story as were nail pops. Some were present in second story but to a lesser. degree.	BORING 107 0-7 ft B horizon and loess (nonexpansive clay and silt) 7-8 ft Colluvium. Probably nonexpansive. >8-9 ft Competent shale. a. 14 ft first significant velocity change in compression wave. b. 9 ft velocity change in shear wave velocity. c. No expansive clays at this location were found in the lab tests.--no tests in the 7-9 ft interval. d. Strange gamma log kick at 7 ft. e. Foundation thought to be on different material; that is, the center may be on competent shale where as each end may be located on the colluvium.
2 Deutsch 2271 Maple Lane ED/107A	Built in early 1950's. One-story wood frame with all brick veneer. Plaster on sheet rock finish. Partial basement with crawl space. Unreinforced concrete block walls.	Exterior - Vertical cracks were present in the veneer between the bottom of the windows and top of the basement/crawl space on three sides of the house. On the east face cracks were as wide as 1/4 in. Foundation - None. Interior - One minor crack in the ceiling.	f. Companion house bore hole shows expansive weathered shale 8-12 ft depth which is probably below the foundation level.
2 Halwes 2200 Maple Lane HAL	Built in 1953. One-story wood frame with all brick veneer. Plaster on sheet rock finish. Full crawl space. Unreinforced concrete block walls.	Exterior - Two minor cracks below windows on the east and west side of house. A crack was present in the floor slab of a screen porch that was added. Foundation - None. Interior - Few ceiling cracks in the center of the house.	

Table 11 continued. Category 1 and 2 buildings.

SITE CATEGORY NAME/ADDRESS USGS ID/OSM ID	DESCRIPTION OF BUILDING	DAMAGE	SITE CONDITIONS
1 Greenfield 8010 Petersburg Rd. GRE/302	Built in 1961. One-story wood frame with all brick veneer. Plaster on sheet rock finish. Partial walkout basement with crawl space. Unreinforced concrete block walls.	Exterior - The area around the north basement shows severe cracking. The owner spoke about depressions in the yard. Foundation - The basement walls had cracks, none were seen in the crawl space. Interior - The owner showed cracks in several rooms. The room on the north side was the most severe. The owner associated some cracks in the kitchen specifically with a blast. He said the house was inspected prior to purchase and the cracks were not there.	BORING 302 0-4 ft B horizon and loess. 4-6 ft weathered shale (no knowledge on expansiveness) 6-9.5 ft clayey shale, borderline expansive. 9.5-11.5 ft very expansive clay. >11.5 ft shale, siltstone, silty shale-unnamed Shelborn (sp) member just below the West Franklin. a. No significate compressional velocity changes in the upper 20 ft. Velocities show constant increase with depth. b. Many vertical (2-3+'deep) water drainage holes found down hill from house and lawn continued to shift level. c. Desiccant of clay, (cracks) is possible mechanism for concentration of ground water flow and erosion of holes. d. Foundation is in/on clay.
2 Palmer 8101 Petersburg Rd. —/302A	Built in 1950's. One-story wood frame with all brick and stone veneer. Plaster on sheet rock finish. Full basement. Unreinforced concrete block walls.	Exterior - Numerous severe stairstep and horizontal cracks were seen around the house. Foundation - Minor cracking was found. Interior - A number of ceiling and wall cracks were found throughout the house.	k. Companion house foundation is probably on shale at 8 ft depth. (The top of an underground storage tank may have been erroneously recorded as shale.)
1 Hoover 2225 Kansas Rd. —/118	Built in 1901 with major modifications. Two-story wood frame with wood siding. Original plaster on wood lath, more recent drywall finish. Partial basement with crawl space. Unreinforced brickwalls.	Exterior - None. Foundation - None. Interior - Hairline cracks the in first and second story walls and ceiling.	
No Companion			
1 Gorbett 11345 Browning Rd. —/316	Built in 1980. Two-story wood frame with all brick veneer. Drywall finish. Full basementwith walkout. Unreinforced concrete block walls.	Exterior - None. Foundation - Minor crack in slab. Interior - Minor crack inthe joint around the fireplace. The owner pointed out that soil had washed out from under the driveway slab on several occasions and that there had been modifications to the drainage to try to prevent this.	
No Companion			

Table 11 continued C

SITE CATEGORY NAME/ADDRESS USGS ID/OSM ID	DESCRIPTION OF BUILDING	DAMAGE	SITE CONDITIONS
1 Boettcher 8216 Petersburg Rd. BOE/113	Built in late 1950's. One-story wood frame with all brick veneer. Plaster on sheet rock finish/wood panelling. Partial walk-out basement with crawl space. Unreinforced concrete block walls.	Exterior - Long, wide cracks were found in the walls of the North-South wing of the L-shaped house. Foundation - Wall cracks and slab cracks were obvious in the basement. This pattern plus the exterior cracks indicate a rotation of this wing East-West wing with respect to the North-South wing. Interior - Rooms were panelled over the basement area of most severe damage. The panelling prevented seeing any interior damages.	BORING 113 0-5 ft B horizon and loess 5-8 ft Colluvium mix 8-9 ft weathered shale, marginal expansive >10 ft competent shale. a. Compressional velocity change at 9+-ft. b. Foundation lower part in loess, upper part on weathered shale.
2 Ogg 8219 Petersburg Rd. OGG/113A	Built in 1949. One-story wood frame with 50%stone veneer. Plaster on sheet rock finish. Partial walkout basement with crawl space. Unreinforced concrete block walls.	Exterior - None Foundation - None. Interior - One small crack was found.	c. Companion house foundation is on shale with slightly expansive weathered shale above.
2 Lavallo 8416 Petersburg Rd.	Built in ?? Two-story wood frame with all brick veneer. Plaster on sheet rock and drywall finish. Full basement. Unreinforced concrete block walls.	Exterior - Cracks were present around openings in the older part of the house Foundation - Basement walls had numerous cracks in the older part of the house. Interior - Hairline cracks were present in the drywall and plaster finish.	
2 Wayman 8300 Petersburg Road WAY	Not Inspected		
1 Osborne 2400 Schlensker Rd. OSB/421	Built in 1955. One-story wood frame with all brick veneer. Plaster on sheet rock finish. Full basement. Unreinforced concrete block walls. Attached garage with block walls.	Exterior - Cracks were visible in the veneer. Foundation - A few cracks were visible in the basement walls. Interior - Cracks above doors and windows were present throughout the house. Ceiling cracks were also present.	BORING 421 0-7 ft B horizon plus loess (reworked?) nonexpansive clays. 7-8 ft Stoneline material; sd, lean clay, good permeability, good down slope (gravity) drainage. 13 blow count. 9-12 ft weathered shale, moderate expansive (less than McCutchan) 26 blow count. 12 ft competent shale. a. 9 and 12 ft - good compressional wave velocity changes. b. Foundation is probably in the weathered shale layer.
2 Rozanski 2530 Schlensker Rd. ROZ/421A	Built in 1early 1950's. One-story wood frame with all brick veneer. Plaster on sheet rock finish. Full basement. Unreinforced concrete block walls.	Exterior - Minor. Foundation - A few cracks were present around windows. Interior - Cracks were present around doors and in the ceiling.	c. Companion house bore hole samples showed no weathered shale, Stoneline is at 8 to 12, shale at 12'.

Table 11 continued. Category 1 and 2 buildings.

SITE CATEGORY NAME/ADDRESS USGS ID/OSM ID	DESCRIPTION OF BUILDING	DAMAGE	SITE CONDITIONS
1 Richey 15101 Cemetery Rd. RIC/202	Built in 1967 with modifications in 1983. One-story wood frame with stone veneer. Wood panel finish. Partial basement with crawl space. Unreinforced concrete block walls.	Exterior - Many cracks were present and evidence of severe damage. Foundation - Large cracks were present in the basement. Could not tell about the extensive crawl space. Interior - Wood panelling prevented inspection.	BORING 202 0-5 ft B horizon plus clay/loess--nonexpansive. 5-9 ft weathered shale ? - expansive material. 9-10 ft weathered mix of materials, -colluvium? 10 ft West Franklin material (Ls, etc.) 10 ft good compressional wave velocity change at 9-11'. a. Foundation. The north foundation may be on loess and the south part of the foundation may be on the weathered shale. b. Basement wall is at same level as the expansive weathered shale.
2 Stevens 15045 Cemetery Rd. STE/202A	Built around 1970. One-story wood frame with partial brick veneer. Wood panel finish. Full crawl space. Unreinforced concrete block walls.	Exterior - Hairline cracks. Foundation - None. Interior - Wood panelling prevented inspection. Floor slopes and doors and windows stick.	c. Companion house bore hole samples do not show the weathered shale layer. The subsurface material goes from loess to colluvium to shale.
2 Heil 15056 Cemetery Rd. HEL/---	Built around 1970. One-story wood frame with all brick veneer. Wall panel finish. Full basement with walkout. Unreinforced concrete block walls.	Exterior - Few hairline cracks. Foundation - Few hairline cracks. Interior - Wood panelling prevented inspection.	
1 Christensen Route 3, Box 257 Baseline Road CHR/115	Construction date not known. One-story wood frame with all brick veneer. Drywall finish. Partial basement with crawl space. Unreinforced concrete block walls.	Exterior - Cracks were visible both in the veneer and around the corners. Vertical cracks were present along the chimney. Foundation - There were cracks and signs of some movement of upper story floor beam supports. Some of the floor beams under the master bedroom showed signs of compression bulging at the ends. Interior - Considerable cracking was evident in the walls in the first story. These cracks were particularly bad on the walls in the master bedroom. The floor gives the impression of sloping inward in this room. There is a water bed in the room.	BORING 115 0-7.5+-ft B horizon plus loess. 7.5-10 ft Nonexpansive weathered shale? 10 +- ft Bedrock ? sc/silt/sh interbedded (Shelburn Fm sp.?) a. 8 and 11 ft - good velocity shifts in compressional waves. b. Subsurface formations are located in the Shelburn fm sequence below the West Franklin Ls. c. Foundation thought to be in nonexpansive weathered shale.
2 Klausmeir 6604 Baseline Rd. ---/115A	Construction date not known, probably around 1970. One-story wood frame with brick veneer below window. Drywall finish. Full crawl space. Unreinforced concrete block walls.	Exterior - Hairline cracks in block walls. Foundation - See above. Interior - None.	d. Companion house is on similar material in the upper 9 ft.
2 Board 6616 Baseline Rd.	Built One-story wood frame with mostly aluminum siding. Full crawl space. Unreinforced concrete block walls.	Exterior - None Foundation - None Interior - Minor	

SITE CATEGORY NAME/ADDRESS USGS ID/OSM ID	DESCRIPTION OF BUILDING	DAMAGE	SITE CONDITIONS
1 Norton 13145 N. Green River Rd. NOR/104	Unknown construction, remodelled in 1966. One-story wood frame with 50% brick veneer. Plaster on sheet rock finish. Full basement. Unreinforced concrete block walls.	Exterior - Hairline cracks on the exterior. Foundation - Hairline cracks on walls and floor. Interior - Hairline cracks. The most severe damage was present in the block walls and slab in a separate building which was a three stall garage. All were severely cracked. Much of the damage appeared associated with a drainage problem around the building. There was no evidence of reinforcement in the severely cracked garage slab.	
2 LeCocq 13421 N. Green River Rd.	Built in 1981. One-story wood frame with all brick veneer. Drywall finish. Full basement. Unreinforced concrete block walls.	Exterior - None. Foundation - Hairline crack in one corner in the walls and floor slab. Evidence of some moisture penetration. Appeared well-drained outside. The owner believes it is associated with water supply lines. This bears watching and the owner appears to be doing so. Interior - Few hairline cracks.	
1 Zimmerman 10991 N. Green River Rd. ZIM/103	Built in 1974. One-story wood frame with all brick veneer. Drywall finish. Full basement with walkout. Unreinforced concrete block walls.	Exterior - Cracks were present on many walls. Foundation - Both walls and floor slab were cracked. Interior - Nail pops and cracks were present throughout the first story living area.	BORING 103 0-7+-ft Dry, B horizon plus some loess. 7-17 ft moist, silts and clays - no evidence of expansive clays from the samples. 17-20 ft good compressional wave velocity change. 17+- ft probable shale contact 14' clay squeezed in the hole at this depth?? a. Foundation thought to be in loess.
2 Shelton 10801 N. Green River Rd. SHE/103A	Built in 1989. One-story wood frame with all brick veneer. Drywall finish. Full crawl space. Unreinforced concrete block walls very close of crawl space walls.	Exterior - None. Foundation - None. Interior - None.	b. Companion house is on very similar material in the upper 9 ft.
2 Daugherty 10901 N. Green River Rd. DAU/---	Built in 1968. One-story wood frame with all brick veneer. Plaster on sheet rock finish. Full basement with walkout. Unreinforced concrete block walls.	Exterior - Few hairline cracks. Foundation - Few hairline cracks. Interior - Few hairline cracks.	

Table 11 continued. Category 1 and 2 buildings.

SITE CATEGORY NAME/ADDRESS USGS ID/OSM ID	DESCRIPTION OF BUILDING	DAMAGE	SITE CONDITIONS
1 Bohrer 4949 Daylight BOH/105	Built in 1966. One-story wood frame with all brick veneer. Plaster on sheet rockfinish. Full basement. Unreinforced concrete block walls.	Exterior - Some cracks were present in exterior veneer. Foundation - A horizontal crack was present along one wall of the basement. This may be where the block size changes since it was about at the ground line. Interior - Some cracks and nail pops were present in the interior finish surface.	
2 Miller 5101 Daylight MIL/—	Built in 1955. One-story wood frame with all brick veneer. Plaster on metal lath finish. Full crawl space. Unreinforced concrete block walls.	Exterior - Severe cracking in the sidewalk and driveway. Foundation - None Interior - A few cracks were visible	

Damage Descriptions

Exterior - A brief description of damage or conditions outside the house.
Foundation - A brief description of damage or conditions related to the basement, crawl space, and/or slab on grade as appropriate.
Interior - A brief description of damage or conditions related to the interior finish surfaces inside the house.

FOUNDATION/SUBSURFACE SUMMARIES FROM OCT. 13-16 MEETING IN BLOOMINGTON, ID.
Interpretations by: Ned Bleuer and Don Eggert, Indiana Geological Survey, Paul F. Hadala, US Army Corps of Engineers, Bernard Maynard, Office of Surface Mining, Ken King, U.S.G.S.

NOTE: Bore holes at homes went to depth of hard drill resistance; at companion house to a depth of 9 foot. All depths are estimates.

Table 11 continued Category 1 and 2 buildings

SITE CATEGORY NAME ADDRESS	DESCRIPTION OF BUILDING	DAMAGE
3 Niemeier 6800 New Harmony Rd.	Built in 1963. One-story wood frame will all brick veneer. Drywall finish. Full basement with walkout. Unreinforced concrete block walls.	Exterior - Hairline cracks in brick planter walls. Few cracks in brick around door of walkout basement. Foundation - None. Interior - None.
3 Berendes 6801 New Harmony Rd.	Built around 1930. Two-story wood frame will all brick veneer. Plaster on wood lath finish. Full basement with walkout. Unreinforced poured concrete walls.	Exterior - Two masonry walls by driveway entering below grade garage are being pushed in by soil pressure. Foundation - Cracks in west and south walls. Cracks have been sealed and show no sign of movement. Interior - Hairline cracks above doors and ceiling in a few rooms.
3 Smock 6819 New Harmony Rd.	Built in 1968. One-story wood frame will all brick veneer. Plaster on sheet rock finish. Partial basement with walkout and crawl space. Unreinforced concrete block walls.	Exterior - Some heaving of driveway slab. Some surface spalling of brick due to weathering. Foundation - Two floor-to-ceiling vertical cracks. Interior - Few cracks around two doors. Few cracks in ceiling. Diagonal crack near fireplace. Previous owner said it appeared after an earthquake.
3 Franks 6904 New Harmony Rd.	Built in 1987. One-story wood frame will all brick veneer. Drywall finish. Full basement with walkout. Unreinforced concrete block walls.	Exterior - None Foundation - None Interior - None
3 Niehaus 7120 New Harmony Rd.	Built in 1953., 2nd story added in mid 60's. Two-story wood frame will all brick veneer. Plaster on sheet rock and drywall finish. Full basement with walkout. Unreinforced concrete block walls.	Exterior - None Foundation - Hairline cracks in basement Interior - No cracks in first story. Minor cracks in one room on second story.
3 Boughton 7200 New Harmony Rd.	Built around 1940. One-story wood frame will brick veneer and aluminum siding over wood. Plaster on sheet rock finish. Partial basement with crawl space. Unreinforced poured concrete walls.	Exterior - Minor crack in concrete at entry. Slight movement of steps. Foundation - One vertical crack in basement. Interior - Interior was mostly papered. Owners said this was done because of cracks in the plaster. Owners did not feel the cracks were serious.
3 Neale 9800 Upper Mount Vernon Rd.	Unknown construction. Owner bought in 1979. One-story block construction with brick veneer on front. Finish surface was paneling and concrete block with a mortar coating for a finish. Full basement with walkout. Unreinforced concrete block walls.	Exterior - Hairline cracks on the exterior blocks in corners, stair step type. Large cracks in exterior veneer. This happened because the veneer was erroneously attached by supporting on the sidewalk instead of the foundation walls. Foundation - Few hairline cracks in corners. Interior - Few hairline cracks. Block wall is coated with a layer of mortar. Some hairline cracks which may be in the coating are present.

Table 12. Category 3 buildings.

SITE CATEGORY NAME ADDRESS	DESCRIPTION OF BUILDING	DAMAGE
3 Goebel 9808 Upper Mount Vernon Rd.	Built in late 1950's. One-story wood frame will stone veneer and vinyl siding. Drywall finish. Full crqwl space. Unreinforced concrete block walls.	Exterior - Two vertical cracks in back. Stair stepped cracks in north wall. Foundation - None. Interior - One crack in a bedroom. Others rooms were papered.
3 Feller 6924 Little Schaeffer Rd.	Built in 1971. One-story wood frame will all brick veneer. Drywall finish. Full basement with walkout. Unreinforced concrete block walls.	Exterior - Slight pulling away of front stoop. Foundation - Slight stairstep crack in basement on one wall. One horizontal crack in a joint 2 courses down. Slight bulging. Interior - None.
3 Lamb 7201 Little Schaeffer Rd.	Built in 1954. One-story wood frame will all brick veneer. Plaster on sheet rockfinish. Partial basement with walkout and crawl space. Unreinforced concrete block walls.	Exterior - Stair step around window in NE corner, probably bad drainage. Also stair step on NW corner. Foundation - None. Interior - Few in one bedroom and the hall around windows and doors.
3 Arhelger 7212 Little Schaefer Rd.	Built in 1966. One-story wood frame will all brick veneer. Drywall finish. Full basement with walkout. Unreinforced concrete block walls.	Exterior - Vertical crack below window on east wall. Foundation - Some horizontal in north wall near NW corner. Interior - One crack below a window, 2 or 3 in ceiling.
3 Humphrey 2917 Koressel Rd.	Built in 1975. One-story wood frame will all brick veneer. Drywall finish. Full basement. Unreinforced concrete block walls with pilasters.	Exterior - Two horizontal cracks above garage door and window. Foundation - Stairstep crack in northwest corner wall. Some slab cracks. Hairline crack on east wall, about eye level. One vertical hairline crack on the south wall. Some evidence of moisture leakage. Interior - Crack in living room around fireplace. The owner said the fire was too hot. Few cracks in hallway walls.
3 Warren 8480 Hogue Rd.	Built in 1958. One-story wood frame will all brick veneer. Plaster on wood lath finish. Partial crqwl space with slab. Reinforced concrete walls in crawl space.	Exterior - One cracked brick that occurred when a joist was being replaced. Foundation - None. Interior - Few cracks around one door and window. Few in ceiling.
3 Kares 8518 Hogue Rd.	Built in 1950's. One-story wood frame will all brick veneer. Plaster on sheet rock finish. Full basement with walkout. Unreinforced concrete block walls.	Exterior - Some masonry joint cracks on brick supporting front porch. Foundation - A hairline crack was present the 3rd course down. This was in the joint where the block size in the basement wall decreases from 8" to 4" in order to accomodate the brick veneer. Stair step cracks on each wall. One long crack in the floor. All cracks were hairline. Interior - Few cracks around windows. Cracks were typical at the corners of openings for heating vents. One ceiling crack in one bedroom.

Table 12 continued. Category 3 Buildings.

SITE CATEGORY NAME ADDRESS	DESCRIPTION OF BUILDING	DAMAGE
3 Helfrich 9401 Hogue Rd.	Built in 1910, extensively remodelled in 1980's. Two-story wood frame will 75% brick veneer. Drywall finish. Partial basement with walkout and crawl space. Unreinforced brick walls.	Exterior - One crack below second-story window above bay window. Foundation - None. Interior - None.
3 Effinger 8112 Marx Rd.	Built in 1957 add on in 1980. One-story wood frame will all brick veneer. Add on is vinyl siding Drywall finish. Full basement with walkout. Unreinforced concrete block walls.	Exterior - One vertical crack below window on east wall. Some cracks in block wall on south face. Foundation - Finished, could not tell if cracks were present. Interior - Few cracks in the living room. One in ceiling in hall.
3 Bauer 2324 Diefenbach Rd.	Built in 1940. One-story wood frame will aluminum siding over wood. Plaster on sheet rock finish. Full basement. Unreinforced concrete block walls.	Exterior - Few hairline cracks. Foundation - Lots of cracks due to a previous moisture problem which the owner corrected. Perimeter drains were added inside and out and the basement was waterproofed. This has solved the problem. Lots of slab cracks, mostly on the surface. Interior - Vertical crack in fireplace masonry. Horizontal crack at second floor level in stairwell. It was said to be getting worse. A few cracks were above doors and in the ceiling in the upstairs area.
3 Kelley 2623 Diefenbach Rd.	Built in 1954, attic finished later. One-story wood frame will all brick veneer. Plaster on sheet rock (drywall in attic) finish. Full crawl space. Unreinforced concrete block walls.	Exterior - Front stoop pulled away slightly. Foundation - None. Interior - Few hairline cracks in the bedroom. Worst cracks were in the entrance way. Wall cracks were particularly noticeable around an arched door. Some were associated with an earthquake in the 70's. The owner also considered some cracks in a breakfast room wall earthquake related.
3 Bender 8520 W. Chapel Rd.		Bender Exterior - Hairline crack above double car garage. Foundation - A full-length horizontal crack was present on the south wall. Interior - None.

Damage Description

Exterior - A brief description of damage or conditions outside the house.
Foundation - A brief description of damage or conditions related to the basement, crawl space, and/or slab on grade as appropriate.
Interior - A brief description of damage or conditions related to the interior finish surfaces inside the house.

Table 12 continued. Category 3 Buildings.

*U.S. GOVERNMENT PRINTING OFFICE: 1994-509-349/00006