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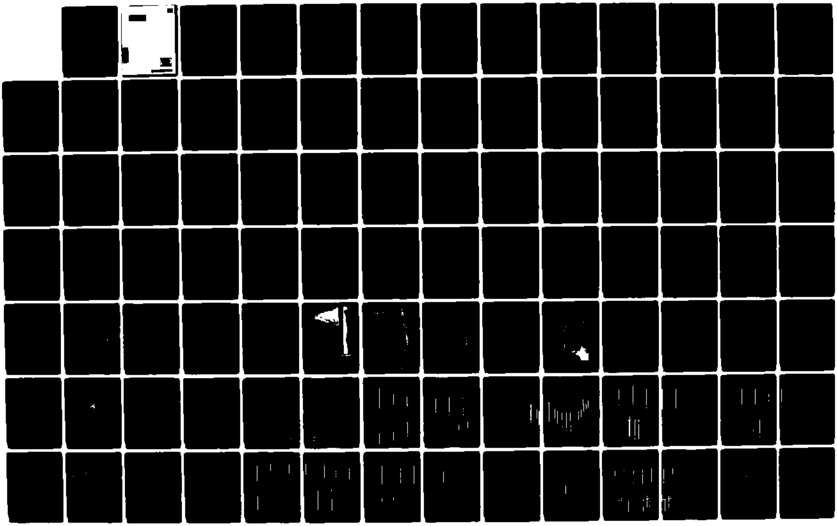

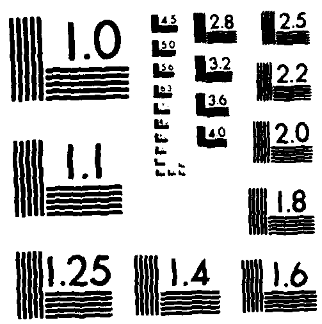

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PROJECT C8340

PAPILLION CREEK AND TRIBUTARIES LAKES, NEBRASKA

DAMSITES 11 AND 16

SEISMIC EVALUATION

Evaluation of Embankment and Foundation Liquefaction Potential

MAY 1983

U.S. ARMY ENGINEER DISTRICT, OMAHA

SUMMARY OF SEISMIC EVALUATION

PAPILLION CREEK DAMSITES 11 AND 16

The determination of maximum acceleration for the sites was based on the procedure developed by Cornell (1968). Seismotectonic zones were delineated in the study area based on known and inferred geologic structures. These seismotectonic zones were divided into point, line, and area sources for earthquakes. The earthquake record was used to develop magnitude-frequency relationships, in order to determine the magnitude of the earthquake with a 0.001 annual recurrence. This magnitude and frequency were used on the various sources in a combined probabilistic-deterministic analysis. This type of analysis is preferred for the Papillion Creek sites, due to the short seismic record and the lack of faulting evident at the surface.

The maximum site acceleration determined by this analysis would be 0.09 g. This acceleration would be due to the 0.001 annual recurrence earthquake with $m_b = 6.4$, occurring in the Nemaha Uplift area source. A peak acceleration of 0.11 g was adopted for the evaluation.

A rather simplistic procedure developed by Seed [1/] was used to evaluate embankment and foundation liquefaction potential for Papillion Creek Damsites 11 and 16. This procedure compares the cyclic shear strength resisting liquefaction, based on corrected Standard Penetration Test (SPT) data, with the average cyclic shear stress induced by the assumed earthquake. The embankment and foundation soil layers were considered seismically stable when safety factors of 1.5+ were obtained using this procedure.

The computed factors of safety against liquefaction for Papillion Creek Damsites 11 and 16 exceed evaluation criteria required for seismic stability. Based on this evaluation, Papillion Creek Damsites 11 and 16 are considered seismically stable for postulated earthquake conditions.

1/ Seed, H. B., "Soil Liquefaction and Cyclic Mobility Evaluation for Level Ground During Earthquakes," Journal of the Geotechnical Engineering Division, ASCE Vol. 105, No. GT2, February 1979, pp. 201-255.

PAPILLION CREEK AND TRIBUTARIES LAKES, NEBRASKA
DAMSITES 11 AND 16

SEISMIC EVALUATION

Evaluation of Embankment and Foundation Liquefaction Potential

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SEISMIC HAZARD ANALYSIS - PAPILLION CREEK DAMSITES 11 AND 16

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SEISMIC EVALUATION - PAPILLION CREEK DAMSITES 11 AND 16

Evaluation of Embankment and Foundation Liquefaction Potential

1. **PURPOSE AND SCOPE.** The Omaha District in accordance with Engineering Regulation (ER) 1110-2-1806, "Earthwork Design and Analysis for Corps of Engineers Dams," dated 30 April 1977, is conducting seismic evaluations for selected earthdam embankments on sand foundations. A rather simplistic procedure suggested by Seed 1/ was used to perform the evaluations for Papillion Creek Damsites 11 and 16 and this report summarizes the results. This procedure compares the cyclic shear strength resisting liquefaction, based on corrected Standard Penetration Test (SPT) data, with the average shear stress induced by the postulated earthquake. The embankment and foundation soil layers are considered seismically stable when safety factors of 1.5+ are obtained using this procedure. The scope includes (1) a discussion of seismic evaluation criteria and procedures; (2) a discussion of field testing, sampling procedures, and laboratory testing; (3) an evaluation of embankment and foundation liquefaction potential based on adopted criteria and assumed earthquake conditions; and (4) an assessment of anticipated project performance during the assumed earthquake.

2. **PROJECT DESCRIPTIONS.** Damsites 11 and 16 are located in the northeastern part of Douglas County, which is in the east central part of Nebraska. Damsite 11 is located on Knight Creek, approximately 1-1/2 miles upstream of its confluence with Thomas Creek and is approximately 1 mile northeast of Irvington, Nebraska. Damsite 16 is located on a right bank tributary of Big Papillion Creek and is approximately 4 road miles from Irvington, Nebraska, 3-1/2 miles west and 1/2 mile south. A location map and plan view of the sites are presented on plate 1. The 55-foot high embankments are basically homogeneous structures composed mostly of compacted clay material with traffic compacted downstream berms. Internal drainage is provided by 3-foot wide continuous vertical pervious sections that extend to the

1/ Seed, H B., "Soil Liquefaction and Cyclic Mobility Evaluation for Level Ground During Earthquakes," Journal of the Geotechnical Engineering Division, ASCE Vol. 105, No. GT2, Feb. 1979, pp. 201-255.

spillway crest elevations and by continuous 3-foot thick horizontal pervious outlets. A typical embankment section is presented on plate 1.

3. DRILLING AND SAMPLING PROCEDURES.

3.1 **DRILL RIGS**. Borings were drilled by rotary methods in the testing and sampling intervals, with cable-tool rigs limited to advancing the holes and setting the casing above the testing and sampling intervals.

3.2 **STANDARD PENETRATION TESTS**. The procedure used in performing SPT was as follows:

The split spoon was driven 18 inches and the resistance was recorded on the log for each 6 inches of penetration. The penetration resistance per blow, measured to the nearest quarter of an inch, was also measured and recorded. This required a graduated measuring rule securely attached to the hammer or rods and a reference point secured to the rig or ground. The SPT value was taken as the total number of blows required to drive the standard split spoon the last 12 inches of the 18-inch drive, using a 140-pound hammer falling from a height of 30 inches.

Refusal was defined as 100 blows within the first 6 inches or 60 blows within either the second or third 6- nch increment.

A disturbed jar sample was taken from each split-spoon sample.

4. SEISMIC EVALUATION CRITERIA.

4.1 **SEISMIC RISK**. Seismic risk studies for Papillion Creek Damsites 11 and 16 were based on a review of the geology and historical seismicity in the area.

4.1.1 **Seismotectonic Provinces**. A tectonic province is a region characterized by a relative consistency of the geologic features contained therein. Webster defines seismotectonic as "Designating or pertaining to structural features of the earth which are associated with, or revealed by, earthquakes." Hatheway 2/ recommends subdividing entire geographic areas into three levels of seismotectonic significance which results in leaving no area unsubdivided. These three levels of seismotectonic significance are:

1. **Seismotectonic Region.** The tectonic and major subplate boundaries are essentially recognized.

2. **Seismotectonic Province.** Significant subplate regions with demonstrably characteristic seismicity (or lack thereof) are included; and

3. **Seismotectonic Zone.** These are the smallest areas of seismic characterization. The zones are portions of provinces that consist of known or suspected geologic structures such as faults, fault zones, lineament bands or clusters, epicentral clusters, and particular styles of deformations and intrusions.

In this study, areas have been subdivided in accordance with the preceding criteria, as shown on plates 2, 3, and 4. Plate 2 is modified from Woolard's 3/ map and illustrates the relationship between earthquake epicenters and tectonic structures in the United States. Epicentral locations for earthquake occurrences from the years 1958 through 1978 have been added to Woolard's base map. Seismotectonic provinces are also delineated and named. Plate 3 illustrates the seismotectonic provinces for the central United States. Seismotectonic provinces and transitional areas in Nebraska and adjacent states are shown on plate 4. Epicentral locations, date of events, intensities, and body wave magnitudes, (m_b), are also shown on plate 4.

2/ Hatheway, A.W., Technical Review: "Seismic Hazard Analysis and Risk Recommendations for the Kansas City District, Corps of Engineers," U.S. Army Engineer Division, Missouri River, Internal Report dated 27 May 1982.

3/ Woolard, G.P., "Areas of Tectonic Activity in the United States as Indicated by Epicenters," Transactions American Geophysics Union, Vol. 39, No. 6, December 1958, pp. 1135-1150.

4.1.2 **Regional Geology**. The Papillion Creek damsites are located within the Dissected Till Plains section of the Central Lowlands physiographic province. This section is characterized by submaturely to maturely dissected till plains with moderate to low relief. The overburden soils of the region are typically glacially derived deposits of Pleistocene age. These deposits, mainly glacial till and windblown loess, taper out to the west where residual soils from weathered Cretaceous-aged bedrock predominate. The major portion of Central and Western Nebraska is overlain by the Tertiary aged Ogallala Group and residual or reworked soils derived from it. This includes the wind-deposited sands of the Sand Hills region. Pennsylvanian-aged bedrock lies beneath the damsites. Cretaceous aged bedrock lies to the west and north, with Tertiary-aged rock present in central and far western Nebraska. Pennsylvanian and Permian-aged bedrock are predominant in western Iowa. Bedrock is composed mainly of sandstones, limestones, and shales in the study region. Exposure of basement rock are very limited, consisting of a few outcrops of Sioux Quartzite in eastern South Dakota and southwestern Minnesota. The basement rock is commonly overlain by 1,000 to 2,000 feet of sedimentary rock, with some structural basins having more than 3,000 feet. Geologic maps for the states of Nebraska, Kansas, Iowa, and Missouri are presented on plates 5 through 8.

4.1.3 **Regional Structure**. The study area is characterized by subdued geologic structure. Only a few major fault systems and structures have been recognized, and the sedimentary bedrock displays only a very slight dip. Basement structure is characterized by relatively shallow basins and broad arches or uplifts. Plate No. 4 shows seven major structural domains represented in the Papillion Creek damsites area: (1) The Nemaha Uplift, (2) the Forest City Basin, (3) the Salina Basin, (4) the Central Nebraska Basin, (5) the Cambridge-Chadron Arch System, (6) the Siouxana Arch System of the Transcontinental Arch, and (7) the Midcontinent Gravity Anomaly. The Nemaha Arch extends from central Oklahoma to near Omaha, Nebraska. Its eastern side is bounded by the Humboldt fault system, along which the most severe disruption of the basement rock surface in the study area has occurred. On the west side of the fault in south eastern Nebraska, granitic rock is within 500 feet of the surface, while on the east side the basement rock is 3,000 feet deeper. The Humboldt fault system was active at least through the Permian, since Permian-aged sedimentary rocks are cut by its past movements. The Humboldt fault forms the western boundary of the Forest City Basin. This basin is deeper than 3,500 feet in southeastern Nebraska, northwestern Missouri, and southern Iowa. The southern and eastern flanks of the basin grade into the broad Ozark Uplift.

To the west of the Nemaha Arch is the broad, shallow Salina Basin which has a north-northwest trending axis that extends from north-central Kansas into central Nebraska. The deepest part of the basin is near Salina, Kansas, where the sedimentary rock sequence attains a thickness of over 4,000 feet. The northern extension of the Salina Basin is called the Central Nebraska Basin. It is bounded on the west by the Cambridge-Chadron Arch System and on the north by the northeast-trending Siouxana Arch section of the Transcontinental Arch. The Chadron Arch extends southeast from the Black Hills into northeastern Nebraska and is faulted on its west flank. The faulting has resulted in a basement offset of 500 feet or more.

The Cambridge Arch appears to be a broad, symmetrical uplift that extends south-southwest from the Chadron Arch. The Cambridge-Chadron Arch System represents the continuation in Nebraska of the Central Kansas Uplift trend that extends northwest from the Nemaha Arch near Wichita, Kansas. The Siouxana Arch segment of the Transcontinental Arch is a broad basement divide between the Central Nebraska Basin and a southern extension of the Williston Basin. This arch extends east-northeast from the Chadron Arch to the Sioux Uplift in southeastern South Dakota. Both the Siouxana Arch and the Sioux Uplift were part of the Transcontinental Arch, which was a prominent structure in the Precambrian and early Paleozoic that extended from Ontario, Canada, to Nebraska. The Sioux Uplift is part of the Sioux Ridge trend, which now extends westward from southwestern Minnesota to central South Dakota. This trend coincides with the presence of Sioux Quartzite in the subsurface.

The Midcontinent Gravity Anomaly has no distinct basement topographic expression but has a strong geophysical signature. This anomaly is associated with a Precambrian feature consisting of a linear belt of gabbroic intrusions and flanking sedimentary basins. It trends northeast from a point near Lincoln, Nebraska, to southern Minnesota. This feature is thought to be related to the Lake Superior graben and resulted from rifting processes that terminated in the Precambrian period. The Union fault system delineates the southeast edge of the gabbroic intrusives.

The Union fault intersects the Humboldt fault near Nebraska City, Nebraska, and marks the northern limit of the Nemaha Arch. The Humboldt fault zone terminates near the southern edge of the Midcontinent Gravity Anomaly, and does not extend into the area of Omaha, Nebraska.

4.1.4 <u>Site Geology</u>. Topography at the Papillion Creek Damsites 11 and 16 is one of rolling hills with moderate relief. Recent alluvium ranges from 30 feet to 70 feet thick in valleys. Nearly all other surficial materials consist of Pleistocene aged eolian (wind blown) deposits. These eolian deposits are represented by the Peorian loess and the underlying Loveland loess, which have a combined thickness of from 10 feet to 70 feet. The eolian deposits overlie Kansan and Nebraskan glacial drift ranging from 40 feet to over 100 feet in thickness. Bedrock at the damsites is 40 to 100 feet deep. The bedrock in the Papillion Creek Basin is commonly sandstone of the Cretaceous-aged Dakota Formation, with Pennsylvanian-aged limestone or shale in some locations. Bedrock in the damsite areas dips gently to the west.

4.1.5 <u>Seismotectonic Subdivisions in the Study Area</u>. Several distinct trends can be distinguished in the distribution of felt earthquakes that have occurred in the study area in the last 115 years. Correlations can be drawn between these trends and the known geologic structures. Using these correlations, a 200-mile radius circle, centered between Lincoln and Omaha, Nebraska, has been divided into seismotectonic provinces, subprovinces, and zones, as described above. The study area has been divided into 9 seismotectonic provinces and subprovinces. This was based on the known geologic structures and the 96 earthquakes in the historical record for eastern Nebraska, southeastern South Dakota, western Iowa, northern Kansas, and northwestern Missouri. A catalog of these earthquakes is presented in table 1.

TABLE 1

DETAILED DESCRIPTIONS - EARTHQUAKES IN NEBRASKA AND ADJACENT STATES

Date	Locality Lat. N.	Locality Long. W.	Intensity, MMI 1/ (Est'd Mag., m_b)	Description 2/
24 April 1867	Manhattan, KS 39°12'	96°18'	VII (5.3)	A shock centered near Manhattan slightly injured several people. A 2-foot wave formed in the Kansas River, many walls cracked, and stones were loosened from buildings. At Lawrence, Kansas, bottles broke on shelves, two stones fell from the top of a church, and plaster fell. Three shocks were felt there over a period of 30 seconds. Bottles fell off a shelf at Marysville, Kansas. Walls cracked at St. Joseph, Missouri, and Wamego, Kansas. At Junction City, a well was destroyed, and windows were broken at Topeka. The felt area also included: Atchinson, Kansas City, Leavenworth, Soloman, and

1/ Modified from Barstow, N.L., et al, "An Approach to Seismic Zonation for Siting Nuclear Electric Power Generating Facilities in the Eastern United States," U.S. Nuclear Regulatory Commission, NUREG/CR-1577, 1981.

2/ Modified from Docekal, J., 1970, "Earthquakes of the Stable Interior, with Emphasis on the Midcontinent," v. 2, A dissertation presented the faculty of the graduate college in the University of Nebraska in partial fulfillment of requirements for the degree of Doctor of Philosophy, Ann Arbor, Michigan, University Microfilms Ltd., p. 1-332.

TABLE 1 (cont'd)

DETAILED DESCRIPTIONS - EARTHQUAKES IN NEBRASKA AND ADJACENT STATES

Date	Locality Lat. N.	Locality Long. W.	Intensity, MMI 1/ (Est'd Mag., m_b)	Description 2/
24 April 1867 (cont'd)				Wyandotte, Kansas; Omaha, Nebraska; and parts of Arkansas and Missouri. Isolated reports came from Cairo and Chicago, Illinois; St. Louis, Missouri; and a questionable report from Carthage, Ohio. How these latter reports are treated greatly influences estimates of the size of the felt area. Branner (1933) places the area at 300,000 square miles which represents a maximum value.
28 April 1867	Nebraska City, NE 40°42'	95°54'	IV (3.8)	A shock stronger than that felt on 24 April 1867 was reported.
09 July 1872	Chillicothe, MO 39°48'	93°30'	IV (3.8)	A sharp distinct earthquake shook Chillicothe and several western Missouri counties. Rumbling was heard.
09 October 1872	Obert, NE 42°42'	97°00'	V (4.2)	The shock was severe in Yankton and White Swan, South Dakota.
08 November 1875	Valley Falls, KS 39°18'	95°30'	V (4.2)	An earthquake originating at Valley Falls awakened people, rattled dishes and windows, and some buildings rocked and

TABLE 1 (cont'd)

DETAILED DESCRIPTIONS - EARTHQUAKES IN NEBRASKA AND ADJACENT STATES

Date	Locality Lat. N.	Locality Long. W.	Intensity, MMI 1/ (Est'd Mag., m_b)	Description 2/
08 November 1875 (cont'd)				quivered. At Burlingame, Kansas, motion lasting 1 minute came from the west. Some people were awakened. Lawrence, Kansas, experienced two shocks lasting 1 minute each. The shock was quite strong at Topeka, and it was also felt at Leavenworth, Louisville, and Wakarusa, Kansas; and at Kansas City, Missouri. It was not felt in Arkansas. Branner (1933) estimated the felt area at 8,000 square miles.
09 December 1875	Nebraska City, NE 40°42'	95°54'	III (3.4)	A light shock was felt.
15 November 1877	In eastern Nebraska 41°00'	97°00'	VII (5.3)	A strong earthquake, with its epicenter somewhere between Lincoln and Columbus, Nebraska, caused damage throughout eastern Nebraska and was felt in parts of Iowa, South Dakota, Minnesota, and Missouri. Most damage occurred at Columbus where a 30-second shock split courthouse and schoolhouse walls. The motion

TABLE 1 (cont'd)

DETAILED DESCRIPTIONS - EARTHQUAKES IN NEBRASKA AND ADJACENT STATES

Date	Locality Lat. N.	Long. W.	Intensity, MMI 1/ (Est'd Mag., m_b)	Description 2/
15 November 1877 (cont'd)				seemed to come from the east and hit Omaha with three strong shocks which shook buildings. At Yankton, South Dakota, a severe shock rocked buildings and broke glass. The estimated area affected by the earthquake was approximately 140,000 square miles.
March 1879	Kirwin, KS 39°36'	99°06'	V (4.0)	A severe shock was felt.
29 December 1879	Yankton, SD 42°54'	97°18'	V (4.0)	The shock was felt at Yankton and Fort Scott.
19 May 1881	Lawrence, KS 39°00'	95°12'	III (3.3)	A slight shock was felt.
17 March 1884	North Platte, NE 41°06'	100°48'	IV (3.8)	A light shock was felt. Windows and crockery were rattled.
04 February 1896	Hartington, NE 42°36'	97°18'	III (3.4)	A shock was felt and rumbling occured.
02 December 1897	Kansas City, MO 39°06'	94°30'	IV (4.5)	A rather widespread earthquake occurred in eastern Kansas, or possibly eastern Oklahoma. It was poorly reported, because of the early hour and because the area was sparsely settled. At

TABLE 1 (cont'd)

DETAILED DESCRIPTIONS - EARTHQUAKES IN NEBRASKA AND ADJACENT STATES

Date	Locality Lat. N.	Long. W.	Intensity, MMI 1/ (Est'd Mag., m_b)	Description 2/
02 December 1897 (cont'd)				Kansas City, Missouri, doors and dishes were rattled and beds moved. A slight shock lasting 5 seconds was reported at Medicine Lodge Kansas; Rame, Kansas, also reported the shock; and Jefferson, Oklahoma, reported a severe shock that rocked buildings making them creak and crack.
16 September 1898	Hartington, NE 42°36'	97°18'	IV (3.8)	Two shocks, which lasted from 10 to 15 seconds and caused windows to rattle in every building, were felt.
28 July 1902	Battle Creek, NE 42°00'	97°36'	VI (4.5)	A shock in northeastern Nebraska lasting 30 seconds caused dishes to fall from shelves, plaster to crack, and water to spill from buckets. This shock was felt in Tilden and Elgin, Nebraska, Yankton, South Dakota, and several other small towns in northeastern Nebraska.
01 December 1904	West Point, NE 41°48'	96°42'	III (3.4)	Many towns in northeastern Nebraska felt the shock.

TABLE 1 (cont'd)

DETAILED DESCRIPTIONS - EARTHQUAKES IN NEBRASKA AND ADJACENT STATES

Date	Locality Lat. N.	Long. W.	Intensity, MMI 1/ (Est'd Mag., m_b)	Description 2/
13 April 1905	Keokuk, IA 40°24'	91°24'	IV-V (4.0)	Several shocks were felt.
08 January 1906	Manhattan, KS 39°18'	96°36'	VIII (5.5)	The earthquake threw down some chimneys, cracked walls, and broke objects in most houses. At Wamego and Juncion City, Kansas, plaster was knocked from walls. The 10,000-square mile felt area, where windows rattled and light moveable objects shook, was oval with its axis directed northeast. The earthquake began as a tremor and culminated in two distinct shocks generally, and then died away gradually. Roaring preceded the shock at Manhattan, and followed it to Topeka. Felt reports were received from Oskaloosa, Herrington, Auburn, Dover, Abilene, Marysville, Wichita, Emporia, Junction City, Alma, Beloit, and Kansas City, Kansas; Plattsmouth, Falls City, and Brock, Nebraska; Bethany, St. Joseph, and Kansas City, Missouri. The main shock was followed by four aftershocks.

TABLE 1 (cont'd)

DETAILED DESCRIPTIONS - EARTHQUAKES IN NEBRASKA AND ADJACENT STATES

Date	Locality Lat. N. Long. W.	Intensity, MMI 1/ (Est'd Mag., m_b)	Description 2/
14 January 1906	Manhattan, KS 39°18' 96°36'	II-III (3.0)	An aftershock was felt.
16 January 1906	Manhattan, KS 39°18' 96°36'	IV (3.8)	An aftershock lasting 2 seconds was felt at Manhattan, Wamego, and possibly at Minneapolis, Kansas, 50 miles to the west.
19 January 1906	Manhattan, KS 39°18' 96°36'	III (3.3)	An aftershock lasting 2 seconds was accompanied by sound.
23 January 1906	Manhattan, KS 39°18' 96°36'	III (3.3)	Two shocks, lasting 2 seconds each, were felt in the neighborhood of Manhattan and Wamego, Kansas. Other slight shocks were felt but the dates and times were not recorded.
09 May 1906	South Dakota, Nebraska Border 43°00' 101°18'	VI (4.7)	An earthquake centered along the South Dakota-Nebraska border lasted 8 seconds. It was reported all along the Niobrara Valley from Rushville to Valentine, Nebraska, and at Rosebud, South Dakota. The origin may have been in an Indian Reservation in South Dakota. Reid (unpublished) felt it was centered in eastern Washabaugh County, South Dakota, and estimated the

TABLE 1 (cont'd)

DETAILED DESCRIPTIONS - EARTHQUAKES IN NEBRASKA AND ADJACENT STATES

Date	Locality Lat. N.	Long. W.	Intensity, MMI 1/ (Est'd Mag., m_b)	Description 2/
09 May 1906 (cont'd)				felt area at 7,000 to 8,000 square miles. At Cody, Nebraska, plants fell from a window sill and towns for 60 miles in all directions felt the shock. It was felt at St. Paul, Nebraska, which may be well outside the felt area.
26 January 1909	Plainview, NE 42°18'	97°48'	IV-V (4.0)	The violent shock shook the schoolhouse at Plainview and was felt throughout Pierce and Knox Counties in Nebraska.
26 February 1910	Columbus, NE 41°24'	97°18'	IV-V (4.0)	Houses were shaken.
16 September 1915	Kirkwood, NE 42°48'	99°18'	III-IV (3.6)	The shock lasted 30 seconds and a loud explosion occurred.
23 October 1915	Kadoka SD 43°48'	101°30'	V (4.2)	The local earthquake caused one shock and a loud noise. Cracks in the ground were reported.
29 June 1916	Winner, SD 43°24'	99°54'	III (3.4)	A shock and rumbling was reported. Estimates of shock duration ranged from 20 seconds to 1 minute.
December 1916	Stapleton, NE 41°30'	100°24'	II-III (3.2)	A description is not available.

TABLE 1 (cont'd)

DETAILED DESCRIPTIONS - EARTHQUAKES IN NEBRASKA AND ADJACENT STATES

Date	Locality Lat. N.	Long. W.	Intensity, MMI 1/ (Est'd Mag., m_b)	Description 2/
03 October 1920	Harrisonville, MO 38°36'	94°18'	III (3.8)	Two shocks were felt.
16 March 1921	Sioux Falls, SD 43°30'	96°42'	III-IV (3.6)	The shock was felt by by several people.
24 September 1921	White Lake, SD 43°42'	98°42'	IV (3.8)	A description is not available.
02 January 1922	Chamberlain, SD 43°48'	99°18'	VI (4.7)	A "pronounced" earthquake lasting 1 minute threw chimneys down and broke dishes and windows.
10 September 1923	Tekamah, NE 41°42'	96°12'	III-IV (3.6)	Two distinct shocks followed a tremor at Tekamah.
24 September 1924	Gothenberg, NE 40°54'	100°06'	IV (3.8)	A trembling was felt by many.
26 January 1925	Waterloo, IA 42°30'	92°24'	II (2.8)	Several persons reported that the earthquake was accompanied by loud sounds.
25 August 1925	Near Menominee, NE 42°48'	97°24'	IV (3.8)	Buildings shook from the shock and rumbling was heard.
14 October 1927	Ord, NE 41°36'	98°54'	IV (3.8)	Dishes rattled, buildings creaked, and the shock was felt by many people.
07 January 1927	McPherson, KS 38°24'	97°42'	V (4.2)	The fairly strong earthquake awakened scores of people and shook the keystone from a bank window. Dishes rattled and a deep rumble was heard.

TABLE 1 (cont'd)

DETAILED DESCRIPTIONS - EARTHQUAKES IN NEBRASKA AND ADJACENT STATES

Date	Locality Lat. N.	Long. W.	Intensity, MMI 1/ (Est'd Mag., m_b)	Description 2/
18 March 1927	White Cloud, KS 39°54'	95°18'	V (4.2)	The brief earthquake rocked houses and caused people to rush out into the streets. All loose articles rattled. The shock was felt by a few at Highland, Kansas, and Oregon, Missouri.
08 November 1928	Beloit, KS 39°30'	98°06'	IV (3.8)	The local earthquake caused dishes and windows to rattle.
23 September 1929	Manhattan, KS 39°00'	96°36'	V (4.2)	Two shocks, of which the second was stronger, were felt. Houses shook and dishes rattled over a 3,500-square-mile area.
06 October 1929	Near Menominee, NE 42°48'	97°24'	V (4.2)	The earthquake, accompanied by rumbling, awakened many residents of Yankton, South Dakota. Dishes fell from shelves and windows rattled.
21 October 1929	Manhattan, KS 39°12'	96°30'	V (4.2)	This aftershock to the earthquake of 23 September rattled windows and cooking utensils.
23 October 1929	Near Junction City, KS 39°00'	96°48'	III (3.2)	A slight tremor was felt.
07 December 1929	Manhattan, KS 39°12'	96°30'	V (4.2)	The aftershock shook buildings, awakened many sleepers, and rattling windows.

TABLE 1 (cont'd)

DETAILED DESCRIPTIONS - EARTHQUAKES IN NEBRASKA AND ADJACENT STATES

Date	Locality Lat. N. Long. W.	Intensity, MMI 1/ (Est'd Mag., m_b)	Description 2/
17 January 1931	White Lake, SD 43°42' 98°42'	IV (3.8)	Many persons felt a trembling motion accompanied with loud sounds.
09 August 1931	Turner, KS 39°06' 94°42'	V (4.0)	The earthquake was fairly strong. The first and main shock was followed by two lesser tremors. Damage was confined to broken dishes and smaller articles. Branner (1933) estimated the felt area at 80 square miles.
29 January 1932	Ellis, KS 39°00' 99°36'	V (4.2)	Windows were shattered in farmhouses 15 miles north of Ellis. The shock was also felt in Trego County.
20 February 1933	Norton, KS 39°48' 99°48'	V (4.2)	The earthquake rattled windows and dishes, jingled phone bells, swayed houses, and caused some people to run outdoors. Many people in Kansas felt sick. Reports were received from Norcatur, Norton, and Oronoque, Kansas; and from Beaver City, Hendley, Oxford, and Stamford, Nebraska. Heck (1938) estimated the felt area at 6,000 square miles.

TABLE 1 (cont'd)

DETAILED DESCRIPTIONS - EARTHQUAKES IN NEBRASKA AND ADJACENT STATES

Date	Locality Lat. N. Long. W.	Intensity, MMI 1/ (Est'd Mag., m_b)	Description 2/
11 May 1934	North Loup, NE 41°30' 98°48'	IV (3.8)	The earthquake which lasted 30 seconds caused dishes and windows to rattle. It was also felt in Ord, Horace, Elyrie, and Scotia, Nebraska.
30 August 1934	Academy, SD 43°30' 99°06'	IV (3.6)	An abrupt trembling motion, accompanied by rumbling sounds, was felt by many persons. Pukwanna, South Dakota, also reported the shock.
08 November 1934	Wood Lake, NE 42°36' 100°12'	III (3.4)	The distinct local earthquake shook buildings. Reports were also received that it was felt 20 miles west at Johnson, Nebraska.
30 January 1935	Pawnee, MO 40°30' 94°00'	III (3.4)	A slight shock and rumble was reported. People in Eagleville also felt the shock.
26 February 1935	Burlington, IA 40°48' 91°06'	III (3.4)	Two abrupt trembling shocks were felt which caused rattling. This report is based on only one individual.
01 March 1935	Tecumseh, NE 40°18' 96°12'	VII (5.3)	Two shocks about 4 minutes apart were felt. The first was strong and the second weak. Many chimneys were reported cracked

TABLE 1 (cont'd)

DETAILED DESCRIPTIONS - EARTHQUAKES IN NEBRASKA AND ADJACENT STATES

Date	Locality Lat. N.	Long. W.	Intensity, MMI 1/ (Est'd Mag., m_b)	Description 2/
01 March 1935 (cont'd)				and a few toppled. Some windows were broken, plaster cracked, a few walls cracked, dishes were broken, and sleepers were awakened. Lugn (1935) attributed the disturbance to slippage along the Humboldt fault along the east side of the Nemaha Ridge. Heck (1938) estimated the felt area at 50,000 square miles; Lugn (1935) placed it between 50,000 and 70,000 square miles.
22 March 1935	Southeastern Nebraska 40°18'	96°12'	IV (3.8)	Slight shocks were felt in several communities in southeastern Nebraska.
01 November 1935	Egan, SD 44°00'	96°36'	III (3.4)	A mild earthquake was reported.
08 November 1938	Dubuque, IA 42°30'	90°42'	II (2.8)	Two shocks were felt.
01 October 1938	Chamberlain, SD 43°48'	99°18'	V (4.2)	The shock was fairly strong. It was felt by all persons. Over 50 percent of the inhabitants ran from their houses. Dishes fell, loose objects moved, plaster cracked, and a rumble was heard. The duration of shaking was from 10 to 30 seconds.

TABLE 1 (cont'd)

DETAILED DESCRIPTIONS - EARTHQUAKES IN NEBRASKA AND ADJACENT STATES

Date	Locality Lat. N.	Long. W.	Intensity, MMI 1/ (Est'd Mag., m_b)	Description 2/
11 October 1938	Sioux Falls, SD 43°36'	96°42'	V (4.2)	The fairly strong shock lasted from 10 to 30 seconds. Houses were shaken and dishes and windows were rattled at many places. Heck (1947) lists the felt area as 3,000 square miles.
04 November 1938	South Central, SD 43°12'	98°54'	IV (3.8)	A series of shocks with east-west movement was felt for 3 minutes. Dishes were rattled.
10 June 1939	Fairfax, SD 43°00'	98°54'	IV (3.8)	The tremor consisted of gradual bumping for 15 seconds. The disturbance, which appeared to come from the northwest, was felt by many persons both indoors and outdoors. Rumbling was heard.
24 November 1939	Davenport, IA 41°36'	90°36'	II-III (3.3)	A very slight shock was reported.
10 September 1942	Hays, KS 38°54'	99°18'	IV (3.8)	The tremors awakened some sleepers. The tremors were also felt at Stockton and Plainville. These cities form a 30-mile north-south strip.

TABLE 1 (cont'd)

DETAILED DESCRIPTIONS - EARTHQUAKES IN NEBRASKA AND ADJACENT STATES

Date	Locality Lat. N.	Long. W.	Intensity, MMI 1/ (Est'd Mag., m_b)	Description 2/
10 November 1945	Tyndall, SD 42°54'	97°48'	IV (3.8)	The slight shock rattled dishes. It was felt in Bon Homme and Yankton Counties and in the border areas of counties to the north and west.
25 August 1947	Bonesteel, SD 43°06'	98°54'	IV (3.8)	The earthquake shook houses and rattled windows and dishes.
07 April 1948	Broken Bow, NE 41°24'	99°36'	II-III (3.2)	A slight tremor was felt.
20 April 1948	Iowa City, IA 41°42'	91°48'	IV (3.8)	The earthquake caused houses to tremble for 20 seconds.
13 May 1949	Atkinson, NE 42°30'	99°00'	IV (3.8)	An area extending 18 miles south, 18 miles north, and 20 miles west of Atkinson felt a 4-second shock. Higher intensities were felt in Atkinson and Stuart, Nebraska. Two weeks prior to the shock, a 30-acre landslide occurred 30 miles west of Atkinson.
14 December 1949	Gregory, SD 43°12'	99°30'	III (3.4)	Slight vibrations lasting a few seconds were felt by the whole community.
31 December 1953	Burke, SD 43°06'	99°18'	IV (3.8)	The earthquake had its epicenter somewhere between Burke, South Dakota, and

TABLE 1 (cont'd)

DETAILED DESCRIPTIONS - EARTHQUAKES IN NEBRASKA AND ADJACENT STATES

Date	Locality Lat. N. Long. W.	Intensity, MMI 1/ (Est'd Mag., m_b)	Description 2/
31 December 1953 (cont'd)			Jamison, Nebraska. Doors and windows rattled, the ground shook, and explosion-like noises were heard.
25 February 1955	Cotesfield, NE 41°18' 98°36'	IV (3.8)	An earthquake felt along a 35-mile strip along the North Loup River was centered at Cotesfield. The shock caused windows to rattle, furniture to tremble, and dishes to bounce.
03 December 1957	Mt. Vernon and Mitchell, SD 43°48' 98°12'	IV (3.8)	Buildings creaked, windows and small objects rattled, and cattle were alarmed.
13 April 1961	Kansas-Nebraska Border 39°54' 100°00'	V (4.2)	A local shock was centered near the Kansas-Nebraska border, about 10 to 15 miles north of Norton, Kansas. The depth of focus was reported as 25 kilometers. At Beaver City, Nebraska, canned goods fell off shelves. Water bounced in a tank and a stove rattled at Alma, Nebraska. Similar intensities were observed at Norton and Almena, Kansas.

TABLE 1 (cont'd)

DETAILED DESCRIPTIONS - EARTHQUAKES IN NEBRASKA AND ADJACENT STATES

Date	Locality Lat. N.	Long. W.	Intensity, MMI 1/ (Est'd Mag., m_b)	Description 2/
25 December 1961	Excelsior Springs, MO 39°24'	94°12'	V (4.2)	Two shocks were felt. The first had a maximum intensity of IV and the second had a maximum intensity of V. The shocks originated at depths of 20 to 30 kilometers. Plaster was cracked, objects fell off shelves, a. l many persons were awakened. Dellwig (1962) estimated the felt area as being near 10,000 square miles.
06 June 1963	Syracuse, NE 40°42'	96°12'	III (3.2)	A description is not available.
28 March 1964	Merriman, NE 42°54'	101°36'	VII (5.1)*	Dishes were shaken from tables, can goods fell from shelves, cracks appeared in the road, and the banks of the Niobrara River slumped. Four shocks were felt about 4 minutes apart, originating from the northwest and accompanied by thunder-like noises. A number of towns reported slight damage consisting chiefly of cracked or fallen plaster and broken dishes. The depth of

*Magnitude Was Instrumentally Determined.

TABLE 1 (cont'd)

DETAILED DESCRIPTIONS - EARTHQUAKES IN NEBRASKA AND ADJACENT STATES

Date	Locality Lat. N.	Long. W.	Intensity, MMI 1/ (Est'd Mag., m_b)	Description 2/
28 March 1964 (cont'd)				focus was about 41 km and the magnitude was 5.1. Von Hake and Cloud (1966) estimated the felt area at 90,000 square miles.
26 August 1964	Conata, SD 43°48'	102°12'	IV (4.4)*	The shock had a focal depth of 15 km.
28 September 1964	Pipestone, MN 44°00'	96°24'	III (3.4)	A description is not available.
23 November 1967	Chamberlain, SD 43°42'	99°24'	V (4.4)*	The moderately strong shock was centered near the Winner-Rosebud-White River area of SD. Houses shook and dishes fell. At Gregory, many people were frightened, furniture shifted, and windows cracked slightly. The shock was also felt at Colome, Carter, Martin, Mission, and Stephen, SD, and Dunnin and Ainsworth, NE.
19 October 1971	Capa, SD 44°00'	101°00	IV (3.0)	A description is not available.
16 October 1972	Rose, NE 42°20'	99°35'	V (3.7)*	No damage was reported.

TABLE 1 (cont'd)

DETAILED DESCRIPTIONS - EARTHQUAKES IN NEBRASKA AND ADJACENT STATES

Date	Locality Lat. N.	Long. W.	Intensity, MMI 1/ (Est'd Mag., m_b)	Description 2/
13 May 1975	Northeastern Nebraska 42°07'	98°27'	VI (4.3)*	This shock cracked stucco at Bartlett, Nebraska, and was felt at Chambers, Nebraska, and Hudson, South Dakota.
18 August 1977	East Central Nebraska 41°08'	98°35'	-- (2.7)*	A description is not available.
01 December 1977	Arapahoe, NE 40°14'	99°53'	-- (2.7)*	A description is not available.
03 February 1978	Near Lebanon, NE 40°05'	100°19'	III (2.7)*	A description is not available.
07 May 1978	Hyannis, NE 42°18'	101°56'	IV (4.3)*	A description is not available.
20 May 1978	Near Lebanon, NE 40°07'	100°19'	-- (2.8)*	A description is not available.
14 September 1978	Farnam, NE 40°40'	100°17'	-- (2.8)*	A description is not available.
08 April 1979	East Central Nebraska 41°19'	98°41'	-- (2.8)*	The shock was northwest of Grand Island.
06 June 1979	Near Lebanon, NE 40°14'	100°23'	III (2.7)*	A description is not available.
30 June 1979	Washington KS 39°56'	97°16'	VI (3.3)*	The shock was also felt in Republic County, Kansas and in Chester, Nebraska.

TABLE 1 (cont'd)

DETAILED DESCRIPTIONS - EARTHQUAKES IN NEBRASKA AND ADJACENT STATES

Date	Locality Lat. N. Long. W.	Intensity, MMI 1/ (Est'd Mag., m_b)	Description 2/
16 July 1979	Bartley, NE 40°11' 100°23'	III (3.2)*	The earthquake was felt in the southwestern part of state. It was felt in Red Willow County, Nebraska, and at Indianola, Nebraska.
13 September 1981	Nebraska, South Dakota Border 43°00' 101°48'	IV (3.4)*	The shock was felt at Martin and Vetal, South Dakota.
11 July 1982	Colman, SD 44°01' 96°43'	V (3.6)*	A description is not available.
14 November 1982	Southeast South Dakota 43°05' 97°47'	V (4.3)*	The shock was felt by residents in Yankton, Avon, Vermillion, Tyndall, and Springfield, SD, and Crofton, Nebraska. The 20-second earthquake was strong enough to shake an entire house.

Isoseismal maps for some of the larger earthquakes in the midcontinent area were developed by Docekal, Reference 2, Table 1. Plates 8A, 8B, 8C, 8D, 8E, and 8F show six of these isoseismal maps for earthquakes in the vicinity of the Papillion Creek damsites. These maps show the relative effects (MMI) of the earthquake in the area around the epicenter.

Isoseismal maps have some value in confirming source zones and desribing areas of concern. An example is the isoseismal map in plate 8A, with the main affected area of intensity IV or above closely following the Midcontinent Gravity Anomaly. This plate also shows that towns or cities can have higher intensities than the areas between them and the epicenter. This appears to be especially true for cities with structures built on alluvium. These "hot spots" outside the main epicentral area illustrate that most isoseismal maps are inherently biased toward more populous areas, especially those areas built on seismically susceptible materials.

Isoseismal maps must be used with an understanding of their lack of objectivity, since they are based on old, second-hand, noninstrumentally determined data. Isoseismal maps are of less importance in interpreting recent earthquakes, due to the availability of instrumentally recorded data and a clearer understanding of the mechanics of earthquake-produced damage.

For the purposes of this report, it was assumed that earthquakes occur primarily along faults at the boundaries or axes of structures. The provinces and subprovinces on plate 4 were determined based on this assumption. The six seismotectonic provinces are: (1) Transcontinental Arch, (2) Kansas-Nebraska Arches, (3) Central Platform, (4) Nemaha Uplift/ Mid-Continent Gravity Anomaly, (5) Williston Basin, and (6) Rocky Mountain Foreland. Three subprovinces are also defined: (1) Sioux Ridge, (2) Mid-Continent Gravity Anomaly, and (3) Precambrian Basin.

The Transcontinental Arch has a relatively high frequency of earthquakes along a broad band roughly coincident with the trend of that Paleozoic feature. The southern boundary of the province in Nebraska has been drawn based on an apparent linear trend of earthquakes, and has been used as a line source seismotectonic zone for the following hazard calculations. The Sioux Ridge subprovince and the Siouxana Arch have been considered as area source seismotectonic zones.

The Kansas-Nebraska Arches province was suggested by the linear nature of the small number of quakes corresponding to the Northwest trending uplifts. This was considered as a linear source seismotectonic zone for the hazard calculations.

There is little seismicity associated with the Central Platform seismotectonic province. However, several areas of the Central Platform have a somewhat higher incidence of quakes, including the Central Nebraska Basin, the Salina Basin, and the Forest City Basin. These were considered as area source seismotectonic zones.

There is no activity along the trend of the Midcontinent Gravity Anomaly in Iowa, so it was not used as a seismotectonic zone. The structural feature closest to the damsites with considerable earthquake activity is the Nemaha Uplift. Enigmatically, little activity is associated with the Humboldt Fault, which parallels the Nemaha Uplift. The Nemaha Uplift was considered as an area source, both with and without the basin to the east of the Humboldt Fault.

4.1.6 **Seismic Hazard Analysis for the Papillion Creek Damsites 11 and 16.** Previous discussions have described the geology, structure, and seismicity in the vicinity of the damsites. The rationale for using this information to develop seismotectonic provinces and subprovinces has also been described. The resulting seismotectonic map, shown on plate 4, was then used in a combined deterministic-probabilistic seismic hazard analysis method introduced by Cornell. 5/

5/ Cornell, C. A., "Engineering Seismic Risk Analysis," Bulletin, Seismological Society of America," Vol. 58, No. 5, 1968, pp. 1583-1606.

Cornell's method for calculating engineering seismic risks incorporated earthquake magnitudes, point, line and areal sources, and body wave attenuation into statistical analyses. Cornell's equations for various geometrical configurations are shown on figures A-1 through A-4 in appendix A. This method results in a peak intensity "i" at a project site for earthquakes of magnitude M_o that equal or exceed a selected value and have a specified return period.

In the development of his statistical model in 1968, Cornell used empirical attenuation constants developed by Esteva and Rosenblueth for the Western United States. Cornell and Merz [6/] further refined Cornell's earlier model by developing new empirical attenuation constants for the Central and Eastern United States. Nuttli and Gupta [7/] recommended using the higher value for constant C_1 reported by Cornell and Merz in their 1974 work. The values recommended by Nuttli and Gupta were used in this study and the derivations are presented on figure A-5 in Appendix A. Site intensities derived from Cornell's model were converted to body wave magnitude, m_b, using equations developed by Nuttli and Herrmann [8/]. Maximum site accelerations were calculated using attenuation equations recommended by Herrmann [9/] for the Central United States. Calculations of site intensity and maximum acceleration for Papillion Creek Sites 11 and 16 are shown in appendix A.

6/ Cornell, C. A., and Merz, H. A., "A Seismic Risk Analysis of Boston," NSF, Report 22, April 1974, 29 pages

7/ Nuttli, O. W., and Gupta, I. N., "Special Attenuation of Intensities for Central U.S. Earthquakes," Bulletin, Seismological Society of America, Vol. 66, No. 3, June 1976, pp. 743-751

8/ Nuttli, O.W., and Herrmann, R.B., "Credible Earthquakes for the Central United States," State-of-the-Art for Assessing Earthquake Hazards in the United States, Miscellaneous Paper S-73-1, Report 12 of Series, U.S. Army, Corps of Engineers, Waterways Experiment Station, December 1978, 99 pages.

9/ Herrmann, R.B., "Seismicity Study and Design Earthquakes for Missouri River Dams in North Dakota and South Dakota, "Report for U.S. Army Corps of Engineers, Omaha District, Corps of Engineers," 13 March 1981.

Curves of the annual frequency versus magnitude were developed for each source studied, using the estimated magnitudes for all earthquakes within the 115 year historical record. The curves were generated by a best fit method utilizing a "b" value of 0.92 in the equation $\log N_c = a - bm_b$ where N_c is the cumulative number of earthquakes of magnitude m_b and greater. Herrmann 10/ reported that this value, based on previous studies, is typical for the Central United States.

The magnitude of an earthquake with a 1,000-year recurrence, based on the magnitude-frequency curves, was used in all calculations. This recurrence interval may be considered conservative, since 1,000 years is several times the useful life of the project, but not excessively conservative since analysis of earthquake phenomena at this time are largely based upon empirical relationships.

Some minor adjustments have been made in some magnitude-frequency curves as the magnitude of the 1,000-year earthquake approached $m_b = 6.5$. Tocher 11/ reported that every earthquake in California and Nevada since 1906 with magnitude $M = 6.5$ or greater has been accompanied by some breakage of the earth's surface. Magnitude $M = 6.5$ equates to $m_b = 6.6$ using the relationship $m_b = 2.5 + 0.63M$ reported by Richter 12/. No faulting of sediments since the Pleistocene has been observed in the study area, so there is no evidence of an earthquake of $m_b = 6.6$ or greater in the last 2 million years. It can therefore be deduced that no mechanism capable of producing an earthquake exceeding $m_b = 6.5$ is active in the region.

The results of the seismic hazard analysis are presented as the acceleration at the surface of the damsites due to the 1000-year earthquake. This acceleration value was calculated for each significant source and is shown in appendix A.

10/ Ibid Footnote 9.

11/ Tocher, D., "Earthquake Energy and Ground Breakage," Geological Society of America Bulletin, Vol. 48, Apr. 1958, pp. 147-153.

12/ Richter, C.F., "Elementary Seismology," W.H. Freeman and Company, 1958, 768 pages.

4.1.7 **Summary and Conclusions**. This hazard analysis used known geologic structures and the historical record of seismicity to determine site acceleration. The values for site acceleration, presented in appendix A, are credible for the source areas they represent.

The site accelerations for the 1000-year events at each source ranged from 0.023 g to 0.090 g. The highest acceleration of 0.09 g would come from the 1,000-year event located in the Nemaha Uplift as an area source, or from the Nemaha Uplift excluding that portion east of the Humboldt Fault. The next highest acceleration of 0.078 g at the damsites would result from the 1,000-year earthquake at a point source centered in the epicenter cluster near Manhattan, Kansas.

The maximum calculated site acceleration is 0.09 g, although increased acceleration values may be acceptable in the stability analysis if an additional safety factor is desired.

4.2 **POSTULATED EARTHQUAKE**. Based on the above review of the site geology and the historical seismicity of the area, the $m_b = 6.4$ event with a 0.001 annual recurrence, occurring in the Nemaha Uplift area source, produced the highest acceleration, 0.09 g, for Papillion Creek damsites 11 and 16. A more conservative maximum peak acceleration of 0.11 g was used in the analysis.

4.3 **SEISMICALLY STABLE SOILS**. For the purpose of this evaluation, seismically stable soils have been defined as follows.

4.3.1 **Seismically Stable Cohesive Soils**. These soils include:

(1) Soils having a Unified Soil Classification of Lean Clay (CL), Fat Clay (CH), Sandy Clay (SC), or Gravelly Clay (GC);

(2) Soils with a clay content (determined by the percent passing the 0.005 millimeter (mm) sieve) greater than 20 percent; and

(3) Clayey soils (Clay, Sandy Clay, Silty Clay, and Clayey Sand,) where the water content is less than 90 percent of the Liquid Limit.

4.3.2 **Seismically Stable Cohesionless Soils**. These soils include:

(1) Soils located above the highest potential ground water level.

(2) Soils that have a corrected Standard Penetration Test (SPT) blow count of 24 or more.

5. SEISMIC EVALUATION PROCEDURES.

5.1 **PRELIMINARY EVALUATION BASED ON RELATIVE DENSITY**. Soils not meeting the requirements for seismically stable cohesionless soils having a Unified Soil Classification of poorly graded Sand or Gravel (SP), well graded Sand or Gravel (SW), Silty Sand (SM-SP or SM), and Silt (ML) are considered seismically stable if (a) three-fourths of the Relative Densities determined from corrected SPT data are equal or greater than 70 percent, and (b) if there are no consistent patterns of low Relative Density Soils in definable zones or layers in a cross section. Relative Densities are determined using SPT data which are corrected using procedures suggested in reference 1. These procedures are summarized in figures 1 and 3 on plate 9. These Relative Densities are used in the preliminary evaluation to determine if the site is clearly liquefiable, marginally safe against liquefaction, or safe against liquefaction. Table 2 summarizes this evaluation criteria.

TABLE 2

PRELIMINARY EVALUATION CRITERIA
BASED ON
RELATIVE DENSITIES FROM CORRECTED SPT RESULTS

Corrcted SPT Blow Counts	Estimated Relative Density, %	Liquefaction Potential
0-10	0-50	Clearly Liquefiable
11-24	49-70	Marginally Safe Against Liquefaction
24+	70+	Safe Against Liquefaction

5.2 Final Evaluation Based on Cyclic Shear Strength. Cohesionless soils considered clearly liquefiable or marginally safe against liquefaction based on estimated relative densities are considered seismically stable if (a) the computed safety factor is equal to 1.5+ when comparing the cyclic shear strength resisting liquefaction (based on comparisons of corrected SPT data at the site with similar values known to be associated with nonliquefaction in the field) with the average cyclic shear stress induced by the postulated earthquake, and (b) if there are no consistent patterns in a cross section where the computed safety factor is less than 1.0. The data presented in figure 4 on plate 9 summarizes past field performance at other sites concerning liquefaction or nonliquefaction during earthquake shaking. Also presented in this figure is an indication of cyclic shear strength based on corrected SPT data. These cyclic strength values were compared to the cyclic shear stress induced by the postulated earthquake (Equation 1, plate 9) to determine the safety factor against liquefaction.

6. EVALUATION OF EMBANKMENT AND FOUNDATION LIQUEFACTION POTENTIAL - DAMSITE 11.

6.1 GENERAL. The subsurface investigation for the seismic evaluation of damsite 11 consisted essentially of reviewing the boring data from original project design, reviewing construction records, and making additional borings with Standard Penetration Tests as necessary to locate potentially liquefiable materials. The 23 project design embankment area borings and the 2 additional borings with Standard Penetration Tests are shown on the General Plan and Plan of Borings, plate 10. Detailed logs for representative borings are presented on plates 11, 13, and 14. Table 3 lists all the borings including the locations, depths, and sampling zones.

TABLE 3

BORING LOCATIONS, DEPTHS, AND SAMPLING ZONES - DAMSITE 11

Boring	Station	Range (ft)	Surface Elevation (ft. mean sea level)	Depth (ft)	Testing and Sampling Zones
70-2	1+50	C/L	1141.5	90	Foundation (Fdn), Alternating (Alt) Disturbed (Dsd) and Undisturbed (Udsd) for entire depth
70-20	4+10	C/L	1115.4	46	Fdn; Alt SPT and Udsd for entire depth
70-1	5+10	C/L	1105.9	60	Fdn; Alt Dsd and Udsd for entire depth
71-1	7+20	C/L	1095.5	77	Fdn; Alt SPT and Udsd for entire depth
71-4	9+20	C/L	1097.0	84	Fdn; SPT every 5' for entire depth
71-5	10+90	C/L	1095.7	134	Fdn; SPT and Udsd for entire depth
71-7	14+70	C/L	1102.0	50	Fdn; SPT every 5' for entire depth
71-22	15+20	C/L	1104.5	84	Fdn; Dsd, SPT and repres Udsd for entire depth
71-8	15+60	C/L	1108.6	40	Fdn; SPT every 5' for entire depth
80-1	16+20	C/L	1152.0	67	Embankment (Emb) and Fdn; Continuous SPT for entire depth
71-25	16+90	C/L	1121.5	38	Fdn; SPT every 5' for entire depth
71-21	17+95	C/L	1132.8	26	Fdn; SPT every 5' for entire depth
70-3	19+00	C/L	1146.7	40	Fdn; Alt Dsd and Udsd for entire depth

TABLE 3 (cont'd)

BORING LOCATIONS, DEPTHS, AND SAMPLING ZONES - DAMSITE 11

Boring	Station	Range (ft)	Surface Elevation (ft. mean sea level)	Depth (ft)	Testing and Sampling Zones
80-2	7+50	115 D/S	1116.0	91	Emb and Fdn; contin SPT from 11'-26' and from 71'-90'
71-23	16+50	95 D/S	1115.0	33	Fdn; SPT every 5' for entire depth
71-24	16+90	90 D/S	1121.0	40	Fdn; SPT every 5' for entire depth
71-10	6+00	200 D/S	1095.9	71	Fdn; SPT every 5' for entire depth
71-11	9+70	200 D/S	1195.1	85	Fdn; SPT every 5' for entire depth
71-12	11+40	200 D/S	1194.9	82	Fdn; SPT every 5' for entire depth
71-14	16+55	80 U/S	1115.9	40	Fdn; SPT every 5' for entire depth
71-15	16+95	80 U/S	1119.2	40	Fdn; SPT every 5' for entire depth
71-2	6+40	210 U/S	1098.4	74	Fdn; Alt SPT and Udsd for entire depth
71-3	9+00	210 U/S	1097.1	84	Fdn; Alt SPT and Udsd for entire depth
71-6	11+00	210 U/S	1096.3	83	Fdn; Alt SPT and Udsd for entire depth

6.2 **Evaluation of Foundation Liquefaction Potential**. Sections 1-1, 2-2, 3-3, and 4-4, located along the embankment center line, 200 feet downstream, 200 feet upstream, and at Station 7+00, respectively, are shown in plan on plate 10 and in elevation on plates 12, 13, 14, and 15. The 23 preconstruction embankment area borings and the 2 seismic evaluation borings were utilized to develop the foundation profiles and sections. These data indicate that the embankment foundation, with the exception of the alluvium in the valley, is mantled by Peorian-Loveland (undifferented) loess. The loess varies from 7 to 72 feet in thickness and consists primarily of lean clay and clayey silt. Recent alluvium, comprising both the flood plain alluvium and older alluvial sediments, range from 68 to 73 feet in thickness throughout the deepest part of the valley section. These alluvial materials consist primarily of lean and fat clay with lesser amounts of silty clay, clayey silt, and silt. The underlying material is Kansan Glacial Drift. This material consists of till (sandy clay and lean clay) and associated sands and gravels. Bedrock was not encountered within the depths penetrated by the borings. The bedrock is known to be represented by Pennsylvanian limestones in the vicinity of the dam.

The boring data and construction records indicate that, except for the embankment drain, the embankment materials are generally impervious, and, therefore not subject to liquefaction. The developed cross sections and profiles indicate that, except for a limited zone of potentially liquefiable sand and gravel, the embankment foundation materials are also impervious. plates 12, 13, 14, and 15 and table 4 summarize the seismic evaluation of the liquefaction potential of embankment sand drain and the cohesionless foundation soils.

TABLE 4

DAMSITE 11

SUMMARY OF SEISMIC EVALUATION BASED ON SPT DATA

Boring	Station or Distance from C/L, ft.	Depth to Layer, ft	Corrected SPT, N_1	Relative Density,%	Safety Factor Against Liquefaction
Section 1-1 (Profile Along C/L):					
70-3	19+00	40	12(Est'd)	52	1.8
80-1	16+20	58	12	52	2.0
71-5	10+90	96	12(Est'd)	52	2.3
71-5	10+90	127	12(Est'd)	52	2.2
71-4	9+20	130	12(Est'd)	52	2.1
71-1	7+20	133	12(Est'd)	52	2.5
70-1	5+10	99	12(Est'd)	52	2.3

TABLE 4 (cont'd)

DAMSITE 11

SUMMARY OF SEISMIC EVALUATION BASED ON SPT DATA

Boring	Station or Distance from C/L, ft.	Depth to Layer, ft	Corrected SPT, N_1	Relative Density,%	Safety Factor Against Liquefaction
Section 2-2 (Profile - 200 ft. Downstream):					
80-2	7+50	20	28(Emb.drain)	75	5.3
80-2	7+50	80	18	61	3.3
71-11	9+70	87	13	53	2.1
Section 3-3 (Profile - 200 ft. Upstream):					
71-2	6+40	75	12(Est'd)	52	1.6
71-3	9+00	84	12(Est'd)	52	1.6
71-6	11+00	76	12	52	1.6
71-6	11+00	182	17	59	2.3
Section 4-4 (Station 7+00):					
71-2	210 U/S	75	12(Est'd)	52	1.6
71-1	0	133	12(Est'd)	52	2.5
80-2	115 D/S	20	28(Emb.drain)	75	5.3
80-2	115 D/S	80	18	61	3.3
71-10	200 D/S	73	12	52	2.0

6.3 **Evaluation Summary:** The preliminary evaluation, based on Relative Density data, indicates that the embankment sand drain would be safe against liquefaction. These data also indicate that the limited zone of foundation sand and gravel would be marginally safe against liquefaction during earthquake shaking. However, when the cyclic strength of these materials is compared to the average cyclic stress induced by the postulated earthquake, the computed safety factors against liquefaction exceed final evaluation criteria required for seismic stability. Based on this evaluation the embankment and foundation are considered seismically stable for postulated earthquake conditions.

7. EVALUATION OF EMBANKMENT AND FOUNDATION LIQUEFACTION POTENTIAL - DAMSITE 16.

7.1 GENERAL. The subsurface investigation for the seismic evaluation of damite 16 consisted essentially of reviewing the boring data from original project design, reviewing construction records, and making additional boring with Standard Penetration Tests as necessary to locate potentially liquefiable materials. The 24 project design embankment area borings and the one additional seismic evaluation boring with continuous Standard Penetration Tests (80-1) are shown on plate 16. Detailed logs for representative borings are presented on plates 17, 18, 20, and 21. Table 5 lists all the borings including the locations, depths, and sampling zones.

TABLE 5

BORING LOCATIONS, DEPTHS, AND SAMPLING ZONES - DAMSITE 16

Boring	Station	Range (ft)	Surface Elevation (ft. mean sea level)	Depth (ft)	Testing and Sampling Zones
70-32	3+80	C/L	1096.9	35.0	Foundation (Fdn); Alternating (Alt) Disturbed (Dsd) and SPT every 5 ft. for entire depth
70-11	5+80	8 D/S	1084.0	32.0	Fdn; Dsd and representive (repr) Undisturbed (Udsd) for entire depth
70-12	9+80	15 D/S	1084.0	45.4	Fds; Dsd and repr Udsd for entire depth
70-4	10+40	8 D/S	1090.0		Fdn; Dsd and repr Udsd for entire depth
70-20	11+40	35 D/S	1093.7	50.0	Fdn; Alt Dsd and SPT every 5ft for entire depth
70-21	12+10	30 D/S	1098.1	51.0	Fdn; Alt Dsd and SPT every 5ft for entire depth

TABLE 5 (cont'd)

BORING LOCATIONS, DEPTHS, AND SAMPLING ZONES - DAMSITE 16

Boring	Station	Range (ft)	Surface Elevation (ft. mean sea level)	Depth (ft)	Testing and Sampling Zones
70-28	12+40	30 D/S	1101.8	45.0	Fdn; Alt Dsd and SPT every 5ft for entire depth
70-25	13+40	40 D/S	1113.6	52.0	Fdn; Alt Dsd and SPT every 5ft for entire depth
70-26	14+20	50 D/S	1124.8	18.0	Fdn; Alt Dsd and Udsd for entire depth
70-7	7+00	65 D/S	1077.0 (est'd)	53.0	Fdn; Alt SPT and Udsd every 5ft for entire depth
70-33	3+80	150 D/S	1097.2	35.0	Fdn; Alt SPT and Dsd every 5ft for entire depth
70-31	4+30	160 D/S	1093.0	30.0	Fdn; SPT every 5ft for entire depth
70-10	6+00	170 D/S	1078.6	49.4	Fdn; SPT every 5ft for entire depth with repr Udsd
70-15	9+00	200 D/S	1078.9	52.2	Fdn; SPT every 5ft for entire depth with repr Udsd
80-1	10+00	125 D/S	1100.0	65.0	Embankment (Emb) and Fdn; Continuous SPT for entire depth
70-13	10+50	125 D/S	1085.6	44.0	Fdn; SPT every 5ft for entire depth with repr Udsd
70-8	3+00	30 U/S	1105.8	25.6	Fdn; Alt Dsd and Udsd for entire depth
70-2	3+00	80 U/S	1105.5	40.0	Fdn; Alt Dsd and Udsd every 5ft for entire depth
70-6	4+30	70 U/S	1091.6	40.0	Fdn; Dsd every 5ft for entire depth with repr Udsd

TABLE 5 (cont'd)

BORING LOCATIONS, DEPTHS, AND SAMPLING ZONES - DAMSITE 16

Boring	Station	Range (ft)	Surface Elevation (ft. mean sea level)	Depth (ft)	Testing and Sampling Zones
70-3	6+50	60 U/S	11078.6	52.0	Fdn; SPT every 5ft for entire depth with repr Udsd
70-29	12+40	40 U/S	1102.0 (est'd)	45.0	Fdn; Alt, Dsd, and SPT for entire depth
70-34	3+80	150 U/S	1094.2	40.0	Fdn; SPT every 5ft for entire depth
70-9	6+50	200 U/S	1078.8	52.7	Fdn; SPT every 5ft for entire depth with repr Udsd
70-14	8+70	130 U/S	1082.3	55.4	Fdn; SPT every 5ft for entire depth with repr Udsd

7.2 EVALUATION OF FOUNDATION LIQUEFACTION POTENTIAL. Sections 1-1, 2-2, 3-3, and 4-4, located along the embankment centerline, 160 feet downstream, 175 feet upstream, and at Station 8-8, respectively, are shown in plan on plate 13 and in elevation on plates 19, 20, 21, and 22. The 24 preconstruction embankment area borings and the one seismic evaluation boring were utilized to develop the foundation profiles and the typical section. These data indicate that the embankment foundation, with the exception of the alluvium in the valley, is mantled by Peorian-Loveland (undifferented) loess. The loess varies from 5 to 86 feet in thickness and consists primarily of lean clay and clayey silt. Recent alluvium, comprising both the flood plain alluvium and older alluvial sediments, range from 45 to 55 feet in thickness throughout the deepest part of the valley section. These alluvial materials consist primarily of very soft to medium stiff fat clays, lean clays, and silty clays. Soft horizons are very common in this deposit, as indicated by the borings, and range from 8 to 30 feet in thickness. The underlying material is Kansan Glacial Drift. This material consists of till (sandy clay, lean clay, and fat clay) and associated sands and gravels. The bedrock is represented by the Dakota formation of Cretaceous Age.

The boring data and construction records indicate that except for the embankment drain, the embankment materials are generally impervious, and, therefore not subject to liquefaction. The developed sections and profiles indicate that, except for a limited zone of potentially liquefiable sand and gravel, the foundation materials are also impervious.

Both laboratory tests and field performance data have shown that the great majority of clayey soils will not liquefy during earthquakes. However, recent studies in China[13/] have shown that certain types of clayey materials may be vulnerable to severe strength loss as a result earthquake shaking. These soils appear to have the following characteristics:

Percent finer than 0.005 mm less than 15%
Liquid Limit less than 35
Water Content more than 0.9 x Liquid Limit

The laboratory test results, summarized on plates 17, 18, and 21, indicate that the soft clayey foundation soil do not have these necessary characteristics. Therefore, these soils are not considered vulnerable to severe strength loss (liquefaction) during earthquake shaking. The seismic evaluation of liquefaction potential of the embankment sand drain and the cohesionless foundation soils is summarized on plate 22 and in table 6.

13/ Seed, H.B., Idriss, I.M., "Evaluation of Liquefaction Potential of Sand Deposits Based on Observations of Performance in Previous Earthquakes," <u>In-Situ Testing to Evaluate Liquefaction Susceptibility</u>, ASCE Conference, St. Louis, October 26-31, 1982 (Preprint).

TABLE 6

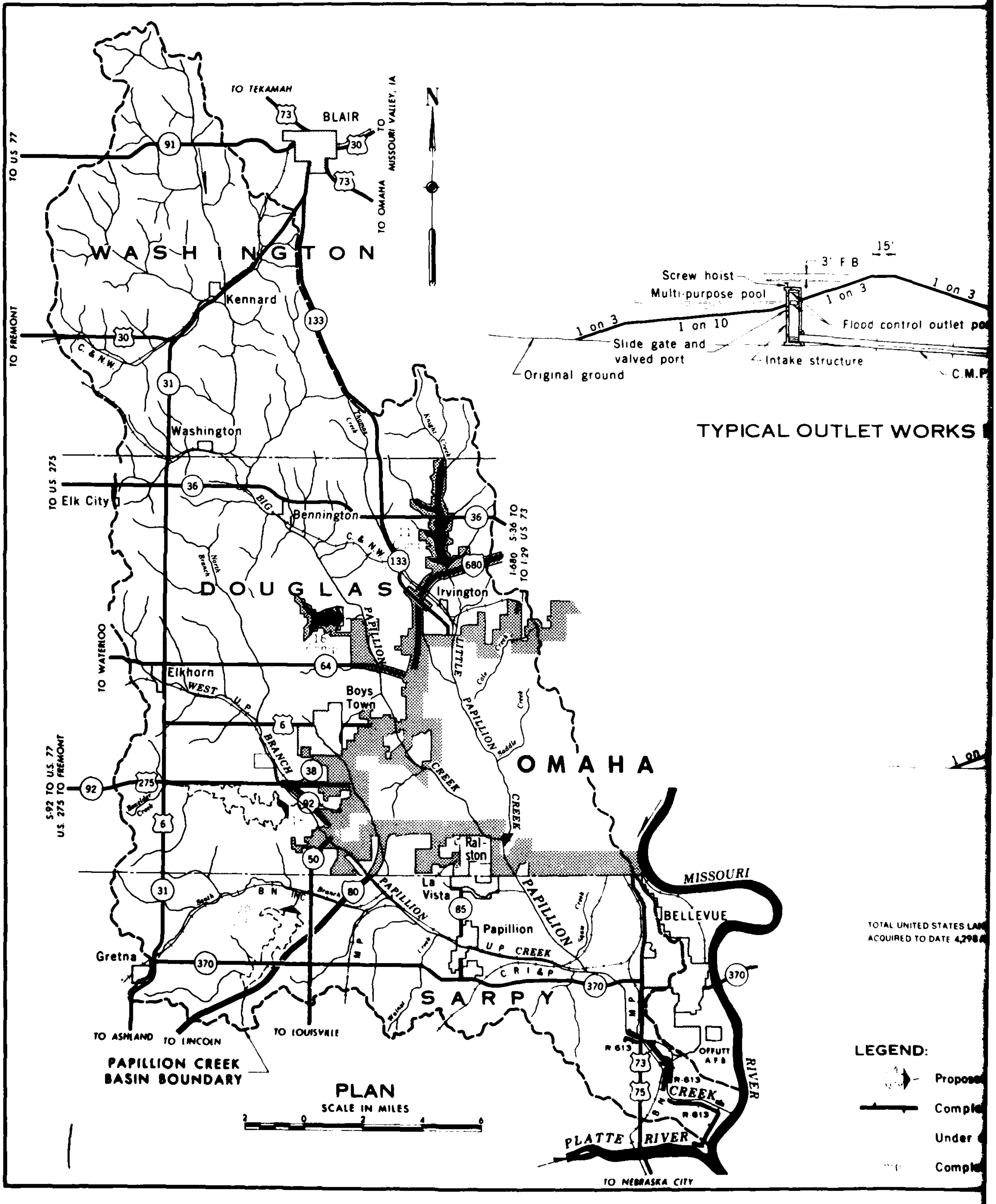
DAMSITE 16

SUMMARY OF SEISMIC EVALUATION BASED ON SPT DATA

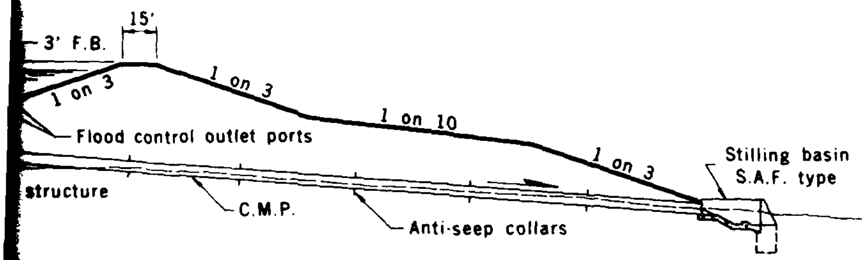
Boring	Station or Distance from C/L, ft	Depth to Layer, ft	Corrected SPT, N_1	Relative Density, %	Safety Factor Against Liquefaction
Section 4-4 (Station 8+00)					
70-9	200 U/S	60	11	50	1.5
70-3	60 U/S	83	50+	90+	5.8
70-7	65 D/S	35	50+	90+ (Emb. Drain)	6.5
70-7	65 D/S	85	12	52	2.5
70-10	170 D/S	17	50+	90+ (Emb. Drain)	5.8

7.3 **Evaluation Summary:** The preliminary evaluation, based on relative density data, indicate that the embankment sand drain would be safe against liquefaction. These data also indicate that the limited zone of foundation sand and gravel would be marginally safe against liquefaction during earthquake shaking. However, when the cyclic strength of these materials is compared to the average cyclic stress induced by the postulated earthquake, the computed safety factors against liquefaction exceed final evaluation criteria required for seismic stability. Based on this evaluation the embankment and foundation are considered seismically stable for postulated earthquake conditions.

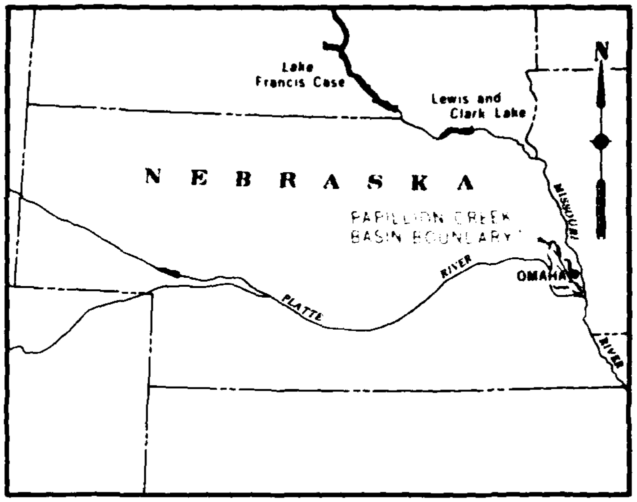
8. **OVERALL EVALUATION.** The computed factors of safety against liquefaction for Papillion Creek Damsites 11 and 16 exceed evaluation criteria required for seismic stability. Based on this evaluation, Papillion Creek Damsites 11 and 16 are considered seismically stable for postulated earthquake conditions.



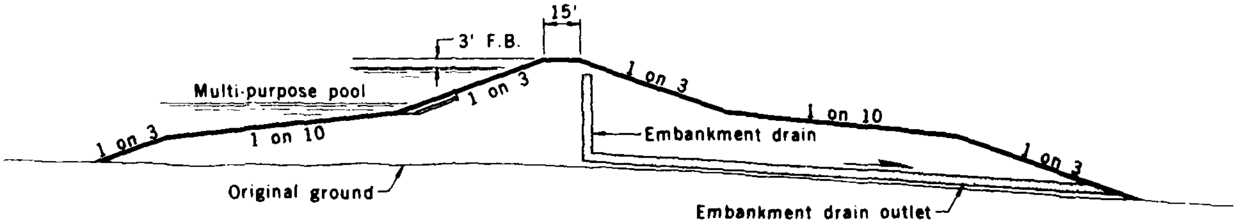
TO TEKAMAH
BLAIR
TO MISSOURI VALLEY, IA
TO OMAHA
TO US 77
TO FREMONT
WASHINGTON
Kennard
C. & N.W.
Washington
TO U.S. 275
Elk City
BIG
Bennington
C. & N.W.
Irvington
S-36 TO US 73
I-680 TO I-29
DOUGLAS
PAPILLION
LITTLE PAPILLION
TO WATERLOO
Elkhorn
WEST
U P
BRANCH
Boys Town
OMAHA
CREEK
S-92 TO U.S. 77
U.S. 275 TO FREMONT
Ralston
La Vista
Papillion
PAPILLION
CREEK
MISSOURI
BELLEVUE
U P CREEK
C R I & P
Gretna
SARPY
TO ASHLAND
TO LINCOLN
TO LOUISVILLE
OFFUTT AFB
CREEK
PLATTE RIVER
RIVER
TO NEBRASKA CITY
PAPILLION CREEK BASIN BOUNDARY
PLAN
SCALE IN MILES
2 0 2 4 6
15'
3' F B
Screw hoist
Multi-purpose pool
1 on 3
1 on 10
1 on 3
1 on 3
Slide gate and valved port
Original ground
Intake structure
Flood control outlet po
C.M.P
TYPICAL OUTLET WORKS
TOTAL UNITED STATES LA
ACQUIRED TO DATE 4,298 A
LEGEND:
Propose
Comple
Under
Comple



UTLET WORKS PROFILE



LOCATION MAP



TYPICAL EMBANKMENT SECTION

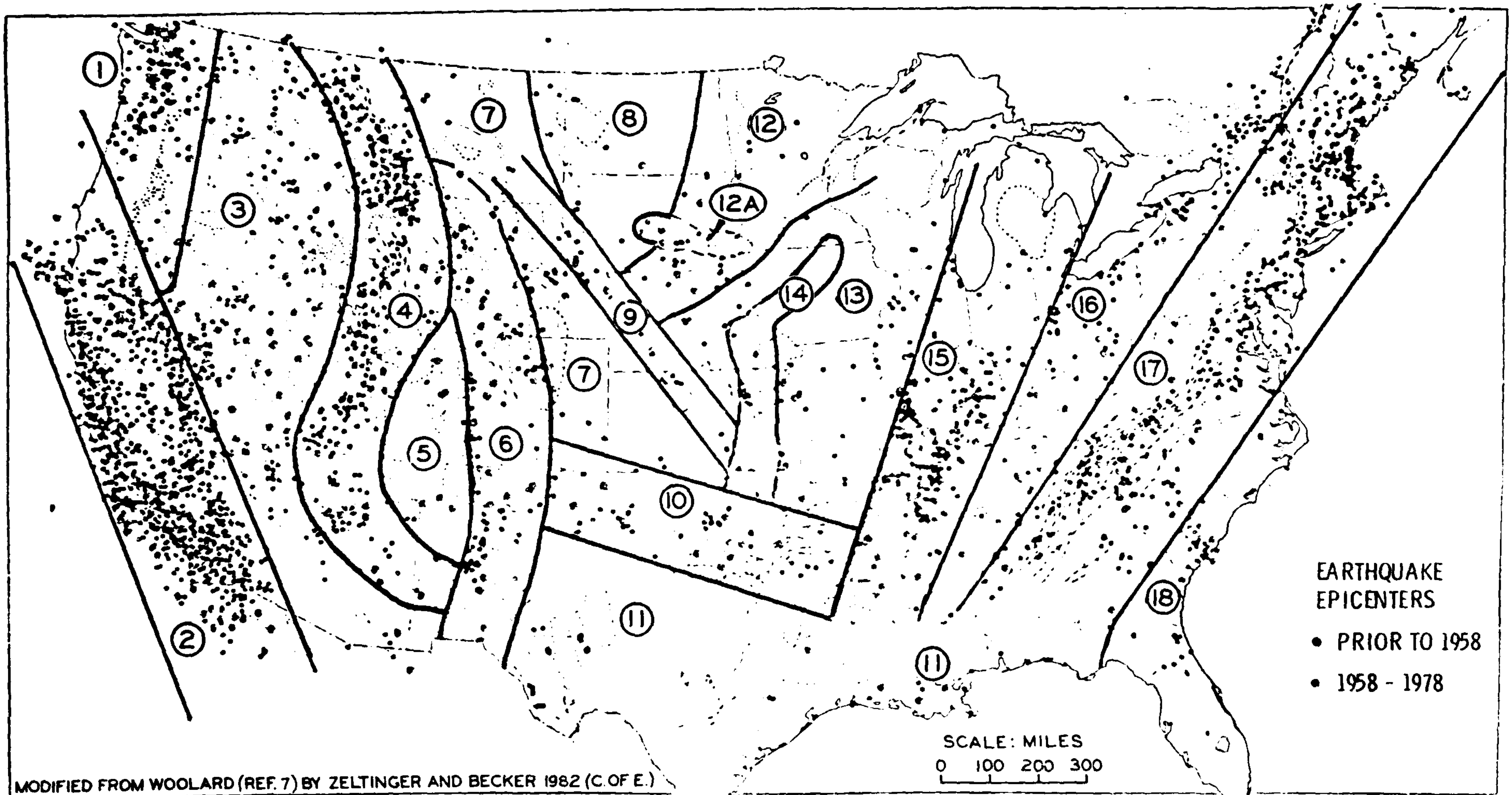
TOTAL UNITED STATES LAND
ACQUIRED TO DATE 4,298 ACRES

LEGEND:

	Proposed dam sites this project
	Completed federal levee not in this project
U.C.	Under construction
Comp	Completed damsites

PAPILLION CREEK AND TRIBUTARIES LAKES, NEBRASKA
SITES 11 AND 16
SEISMIC EVALUATION
VICINITY MAP, LOCATION MAP AND TYPICAL SECTIONS
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA

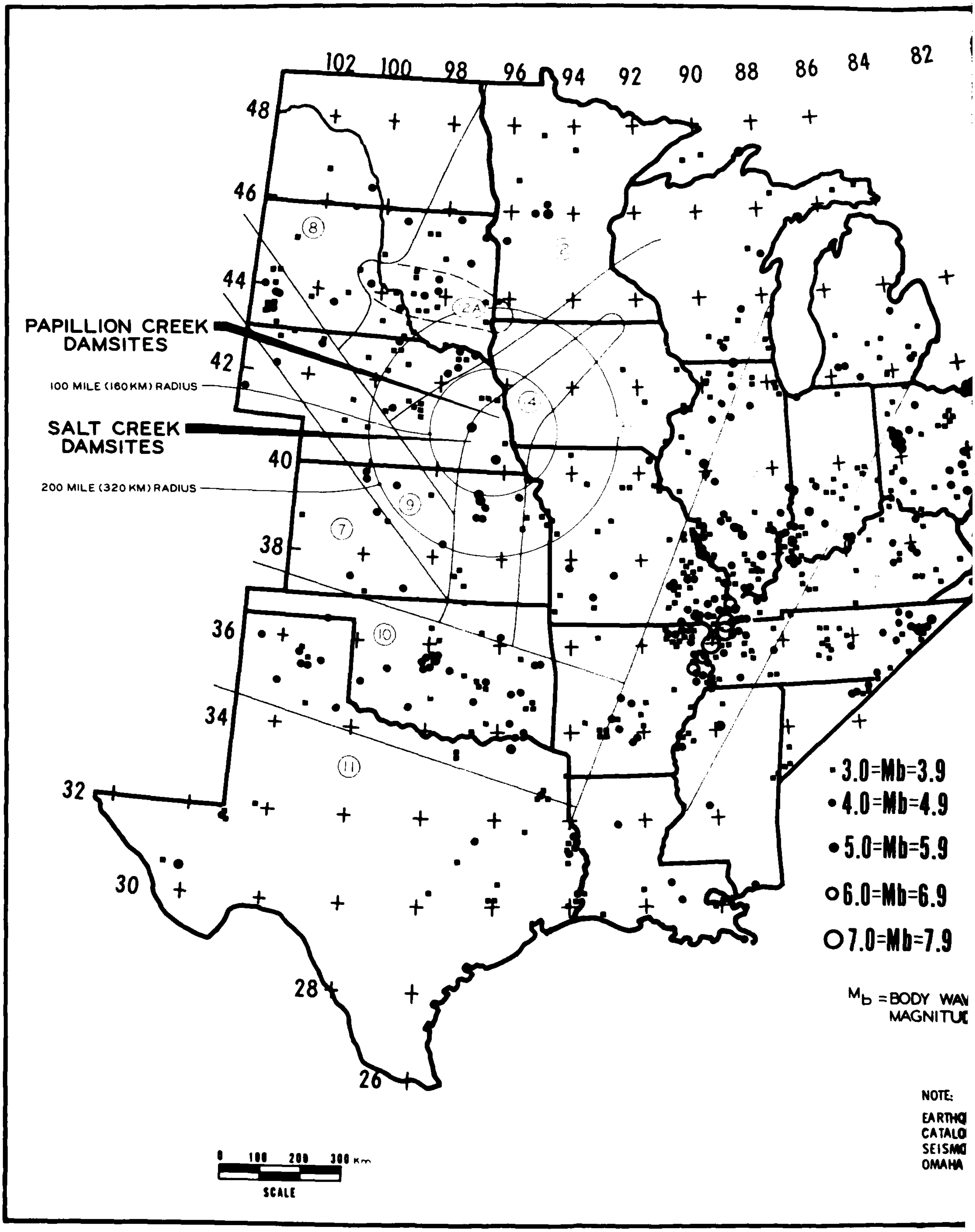
PLATE



1. CASCADES
2. SAN ANDREAS-SIERRAS
3. BASIN AND RANGE -COLUMBIA PLATEAU
4. OVERTHRUST-WASATCH-VOLCANIC BELT
5. COLORADO PLATEAU
6. FRONT RANGES-RIO GRANDE RIFT
7. ROCKY MOUNTAIN FORELAND
8. WILLISTON BASIN
9. BLACK HILLS-KANSAS-NEBR. ARCHES
10. WICHITA-OUACHITA
11. TEXAS-GULF COAST
12. TRANSCONTINENTAL (SIOUX ARCH-12A)
13. CENTRAL PLATFORM
14. MID-CONTINENT GRAVITY ANOMALY- NEMAHA UPLIFT
15. MISSISSIPPI EMBAYMENT- ILLINOIS-MICHIGAN BASINS
16. CINCINNATI-ALGONQUIN ARCH
17. APPALACHIAN MTN. SYSTEM
18. SOUTH ATLANTIC COAST

MISSOURI RIVER
PAPILLION CREEK AND TRIBUTARIES LAKES, NEBR
SEISMIC EVALUATION
SEISMOTECTONIC PROVINCES
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA

PLATE 2


102 100 98 96 94 92 90 88 86 84 82
48
46
44
42
40
38
36
34
32
30
28
26
PAPILLION CREEK DAMSITES
100 MILE (160 KM) RADIUS
SALT CREEK DAMSITES
200 MILE (320 KM) RADIUS
8
2A
4
9
7
10
11
3.0=Mb=3.9
4.0=Mb=4.9
5.0=Mb=5.9
6.0=Mb=6.9
7.0=Mb=7.9
Mb =BODY WAV
MAGNITUD
NOTE:
EARTHQ
CATALO
SEISMO
OMAHA
0 100 200 300 Km
SCALE

- 3.0=Mb=3.9
- 4.0=Mb=4.9
- 5.0=Mb=5.9
- 6.0=Mb=6.9
- 7.0=Mb=7.9

M_b = BODY WAVE MAGNITUDE

(7) ROCKY MOUNTAIN FORELAND
(8) WILLISTON BASIN
(9) BLACKHILLS - KANSAS-NEBR. ARCHES
(10) WICHITA-OUACHITA
(11) TEXAS - GULF COAST
(12) TRANSCONTINENTAL ARCH
(12A) SIOUX ARCH
(13) CENTRAL PLATFORM
(14) MID-CONTINENT GRAVITY ANOMALY-NEMAHA UPLIFT
(15) MISSISSIPPI EMBAYMENT-ILLINOIS-MICHIGAN BASINS
(16) CINCINNATI-ALGONQUIN ARCH

NOTE:

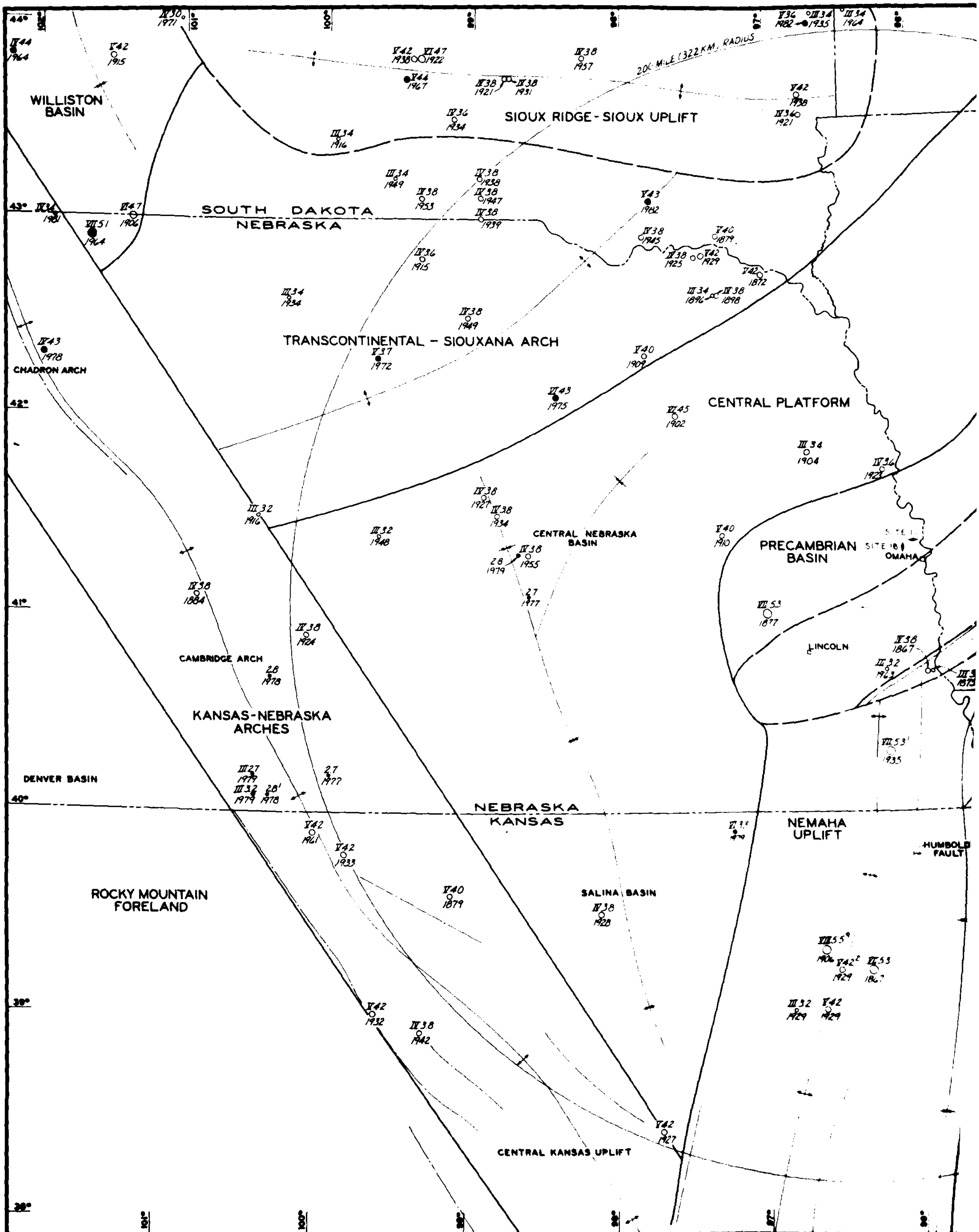
EARTHQUAKES FROM NUTTLI (1978)
CATALOG OF EARTHQUAKES IN THE CENTRAL U. S.
SEISMOTECTONIC PROVINCES FROM ZELTINGER AND BECKER (1982)
OMAHA DISTRICT-CORPS OF ENGINEERS.

PAPILLION CREEK AND TRIBUTARIES LAKES, NEBRASKA
SITES 11 AND 16
SEISMIC EVALUATION

EARTHQUAKES AND SEISMOTECTONIC PROVINCES IN CENTRAL U.S.

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA

PLAT


WILLISTON BASIN
SIOUX RIDGE - SIOUX UPLIFT
SOUTH DAKOTA
NEBRASKA
TRANSCONTINENTAL - SIOUXANA ARCH
CHADRON ARCH
CENTRAL PLATFORM
CENTRAL NEBRASKA BASIN
PRECAMBRIAN BASIN
OMAHA
LINCOLN
CAMBRIDGE ARCH
KANSAS-NEBRASKA ARCHES
DENVER BASIN
NEBRASKA
KANSAS
NEMAHA UPLIFT
ROCKY MOUNTAIN FORELAND
SALINA BASIN
CENTRAL KANSAS UPLIFT
200 MILE (322 KM) RADIUS

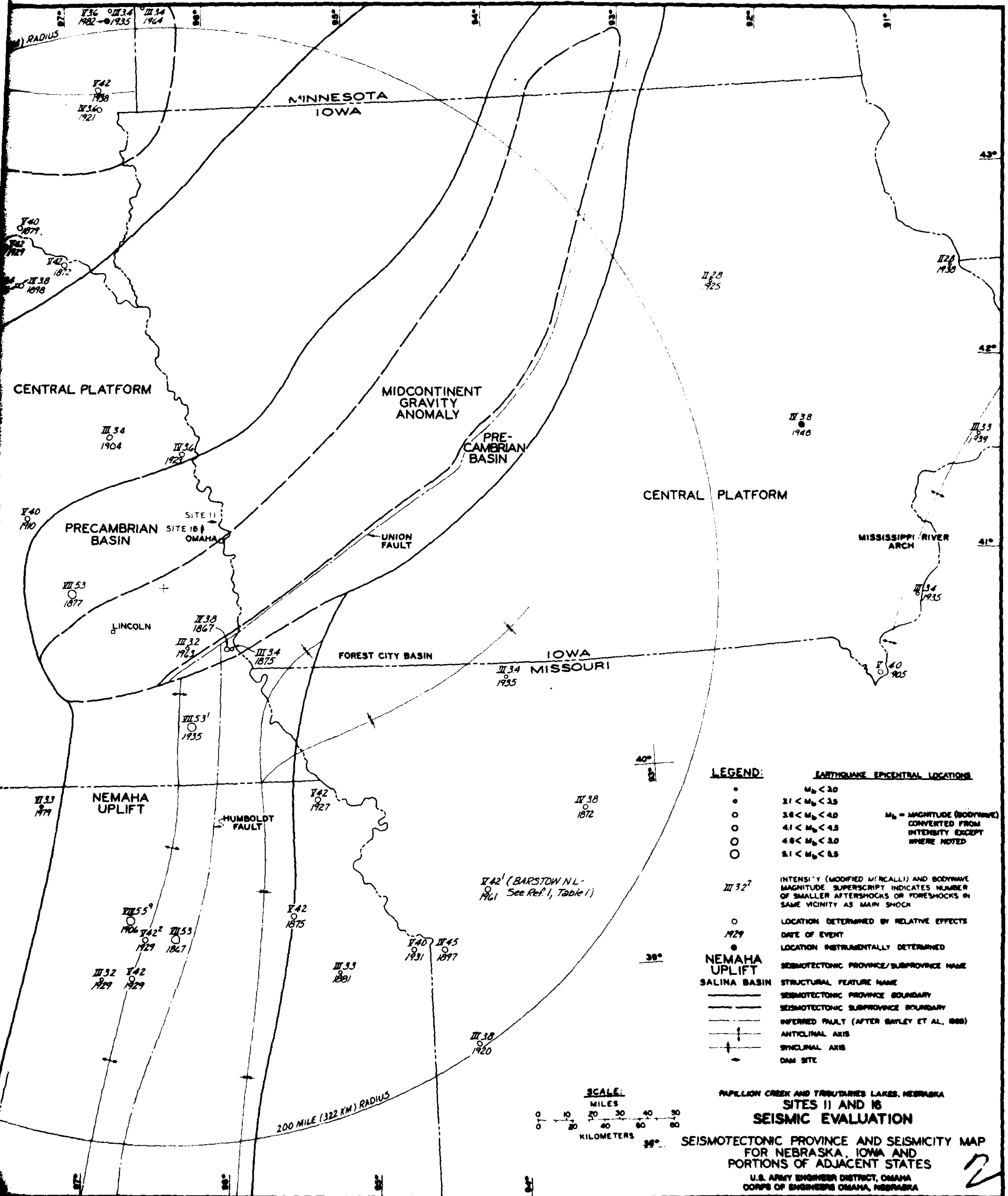
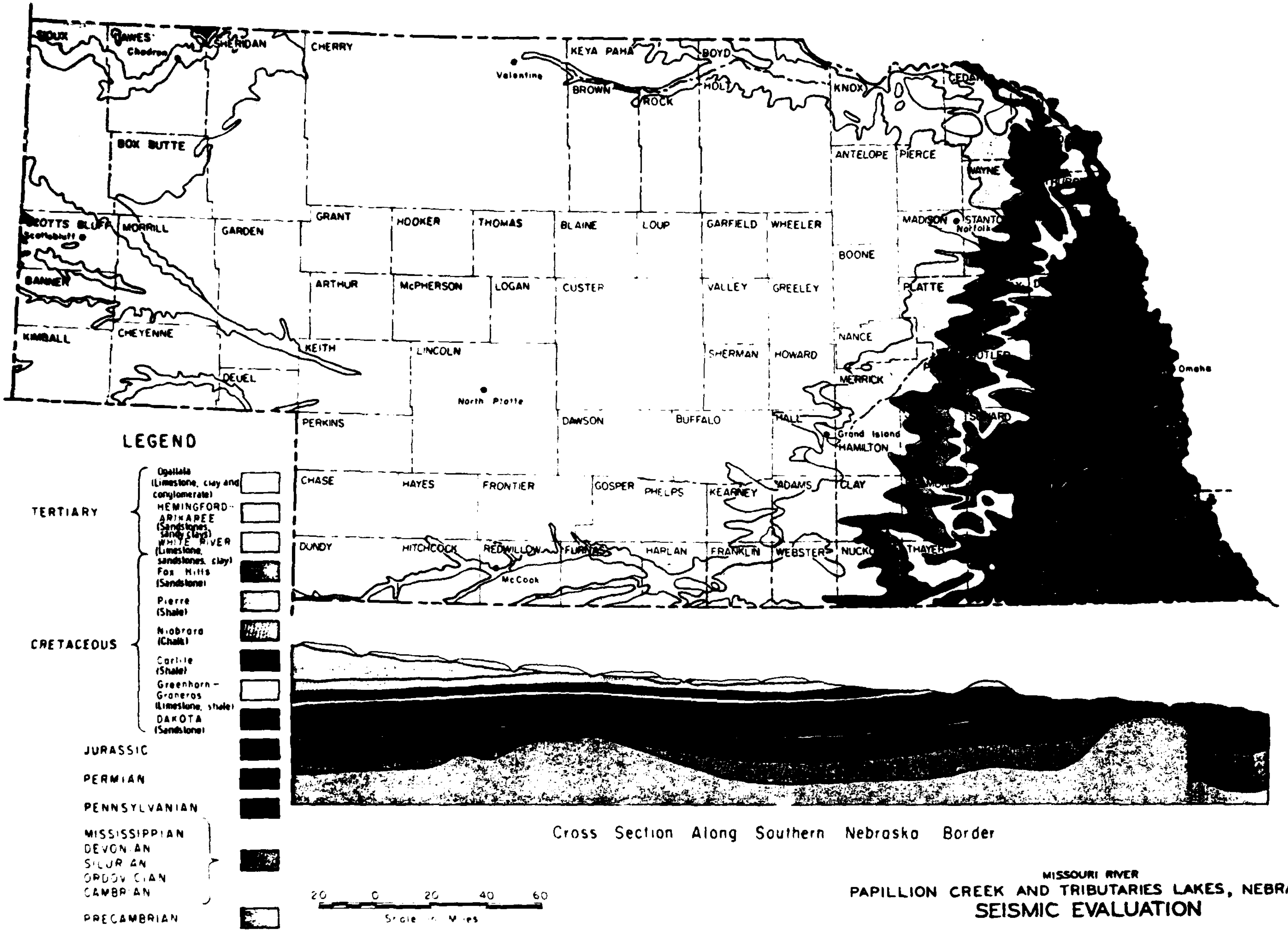

MINNESOTA
IOWA
CENTRAL PLATFORM
MIDCONTINENT
GRAVITY
ANOMALY
PRE-
CAMBRIAN
BASIN
CENTRAL PLATFORM
PRECAMBRIAN
BASIN
SITE 11
SITE 18
OMAHA
UNION
FAULT
MISSISSIPPI RIVER
ARCH
LINCOLN
FOREST CITY BASIN
IOWA
MISSOURI
NEMAHA
UPLIFT
HUMBOLDT
FAULT
(BARSTOW N.L.-
See Ref. 1, Table 1)
200 MILE (322 KM) RADIUS
LEGEND:
EARTHQUAKE EPICENTRAL LOCATIONS
MAGNITUDE (BODYWAVE) CONVERTED FROM INTENSITY EXCEPT WHERE NOTED
INTENSITY (MODIFIED MERCALLI) AND BODYWAVE MAGNITUDE. SUPERSCRIPT INDICATES NUMBER OF SMALLER AFTERSHOCKS OR FORESHOCKS IN SAME VICINITY AS MAIN SHOCK
LOCATION DETERMINED BY RELATIVE EFFECTS
DATE OF EVENT
LOCATION INSTRUMENTALLY DETERMINED
NEMAHA UPLIFT
SEISMOTECTONIC PROVINCE/SUBPROVINCE NAME
SALINA BASIN
STRUCTURAL FEATURE NAME
SEISMOTECTONIC PROVINCE BOUNDARY
SEISMOTECTONIC SUBPROVINCE BOUNDARY
INFERRED FAULT (AFTER BAYLEY ET AL, 1960)
ANTICLINAL AXIS
SYNCLINAL AXIS
DAM SITE
SCALE:
MILES
KILOMETERS
PAPILLION CREEK AND TRIBUTARIES LAKES, NEBRASKA
SITES 11 AND 16
SEISMIC EVALUATION
SEISMOTECTONIC PROVINCE AND SEISMICITY MAP
FOR NEBRASKA, IOWA AND
PORTIONS OF ADJACENT STATES
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA

PLATE 4



UNIVERSITY OF NEBRASKA
NEBRASKA GEOLOGIC SURVEY
1969

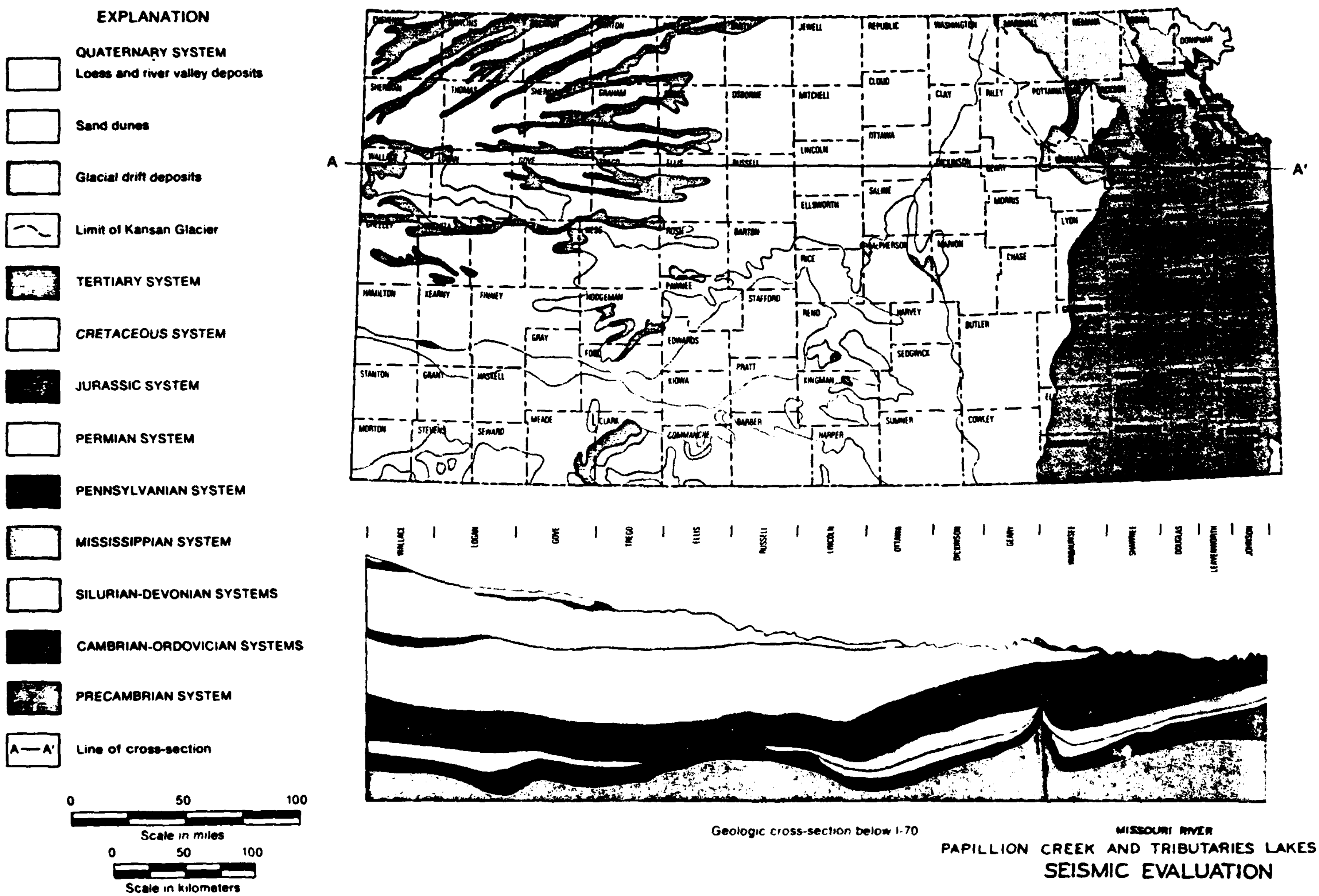
MISSOURI RIVER
PAPILLION CREEK AND TRIBUTARIES LAKES, NEBRASKA
SEISMIC EVALUATION

GEOLOGIC MAP OF NEBRASKA

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA

PLATE 5

GENERALIZED GEOLOGIC MAP OF KANSAS



Geologic cross-section below I-70

MISSOURI RIVER
PAPILLION CREEK AND TRIBUTARIES LAKES, NEB
SEISMIC EVALUATION
GEOLOGIC MAP OF KANSAS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA

PLATE 6

GENERALIZED GEOLOGIC MAP OF KANSAS

EXPLANATION

QUATERNARY SYSTEM
- Loess and river valley deposits
- Sand dunes
- Glacial drift deposits
- Limit of Kansan Glacier

TERTIARY SYSTEM

CRETACEOUS SYSTEM

JURASSIC SYSTEM

PERMIAN SYSTEM

PENNSYLVANIAN SYSTEM

MISSISSIPPIAN SYSTEM

SILURIAN-DEVONIAN SYSTEMS

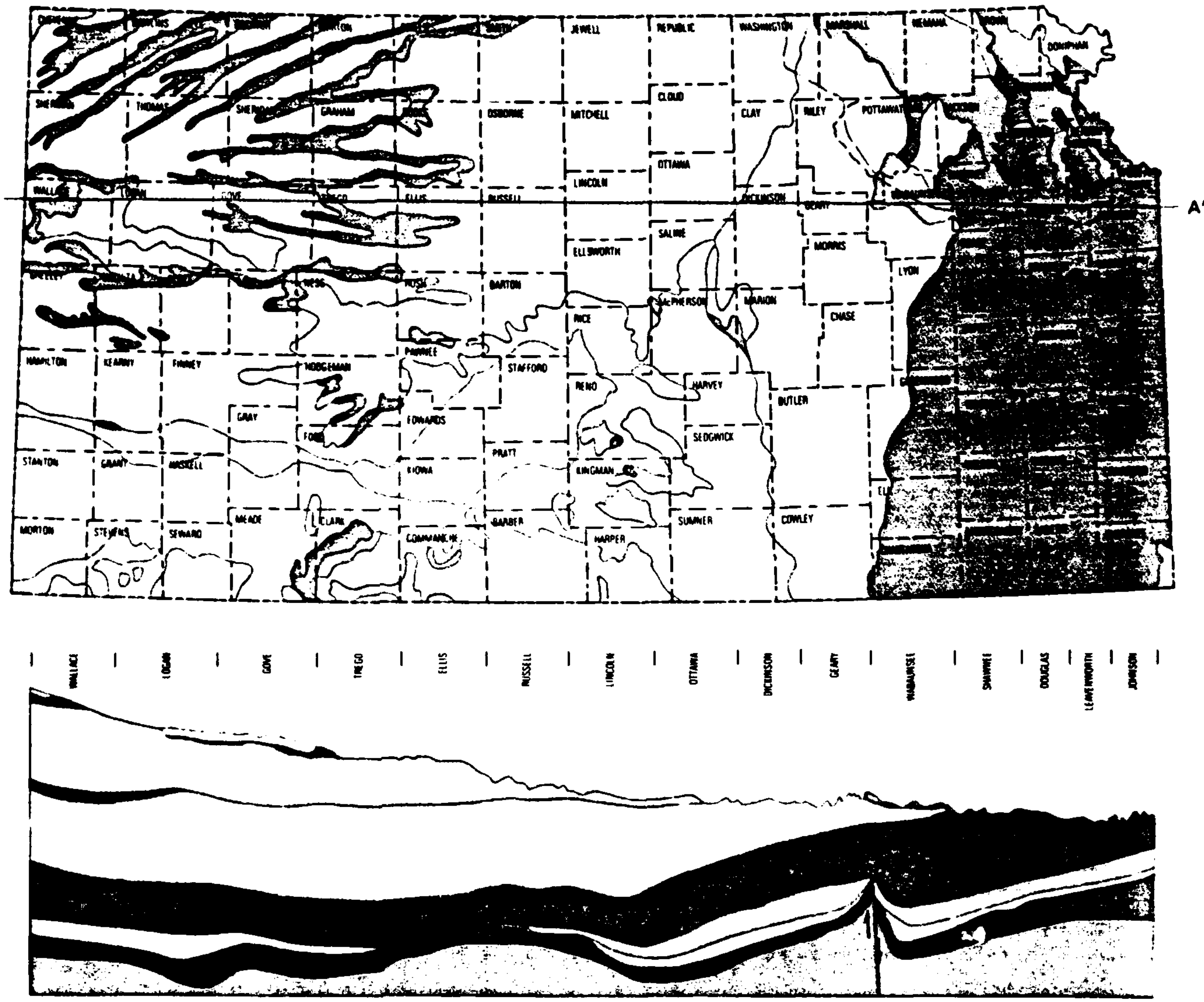
CAMBRIAN-ORDOVICIAN SYSTEMS

PRECAMBRIAN SYSTEM

A—A' Line of cross-section

0 50 100
Scale in miles

0 50 100
Scale in kilometers



Geologic cross-section below I-70

MISSOURI RIVER
PAPILLION CREEK AND TRIBUTARIES LAKES, NEE
SEISMIC EVALUATION
GEOLOGIC MAP OF KANSAS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA

PLATE 6

BEDROCK OF IOWA

LEGEND

CRETACEOUS

- Ku — Undifferentiated (Shales, sandstones, carbonates)

`ASSIC

- Jfd — Fort Dodge Beds (Gypsum, shale)

PENNSYLVANIAN

- Pv — Virgil (Cyclic limestones W/ shales)
- Pm — Missouri (Cyclic limestones W/ shales)
- Pdm — Des Moines (Cyclic limestones W/ shales)

MISSISSIPPIAN

- Mu — Undifferentiated (Limestones and dolomite)

DEVONIAN

- Du — Upper (Carbonates, shales, mudstones)
- Dm — Middle (Limestones)

SILURIAN

- Su — Undifferentiated (Dolomite)

ORDOVICIAN

- Ou — Undifferentiated (Carbonates, shales, sandstones)

CAMBRIAN

- Cu — Undifferentiated (Sandstones, some carbonates)

PRECAMBRIAN

- pCc — Crystalline (Granite, gneiss)
- Sioux (Quartzite)

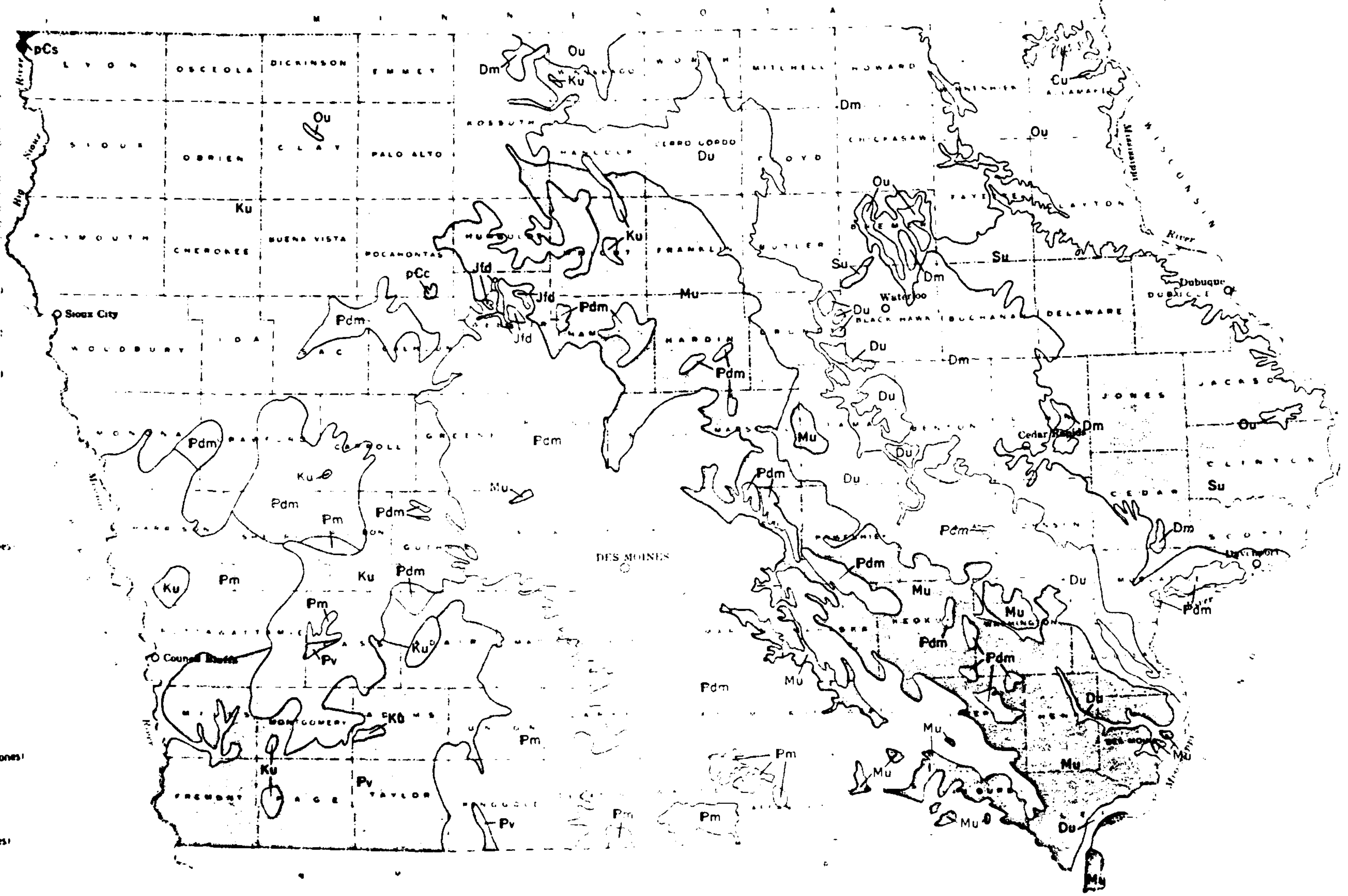


PLATE 7

IOWA GEOLOGICAL SURVEY

H. GARLAND HERSHEY

DIRECTOR AND STATE GEOLOGIST

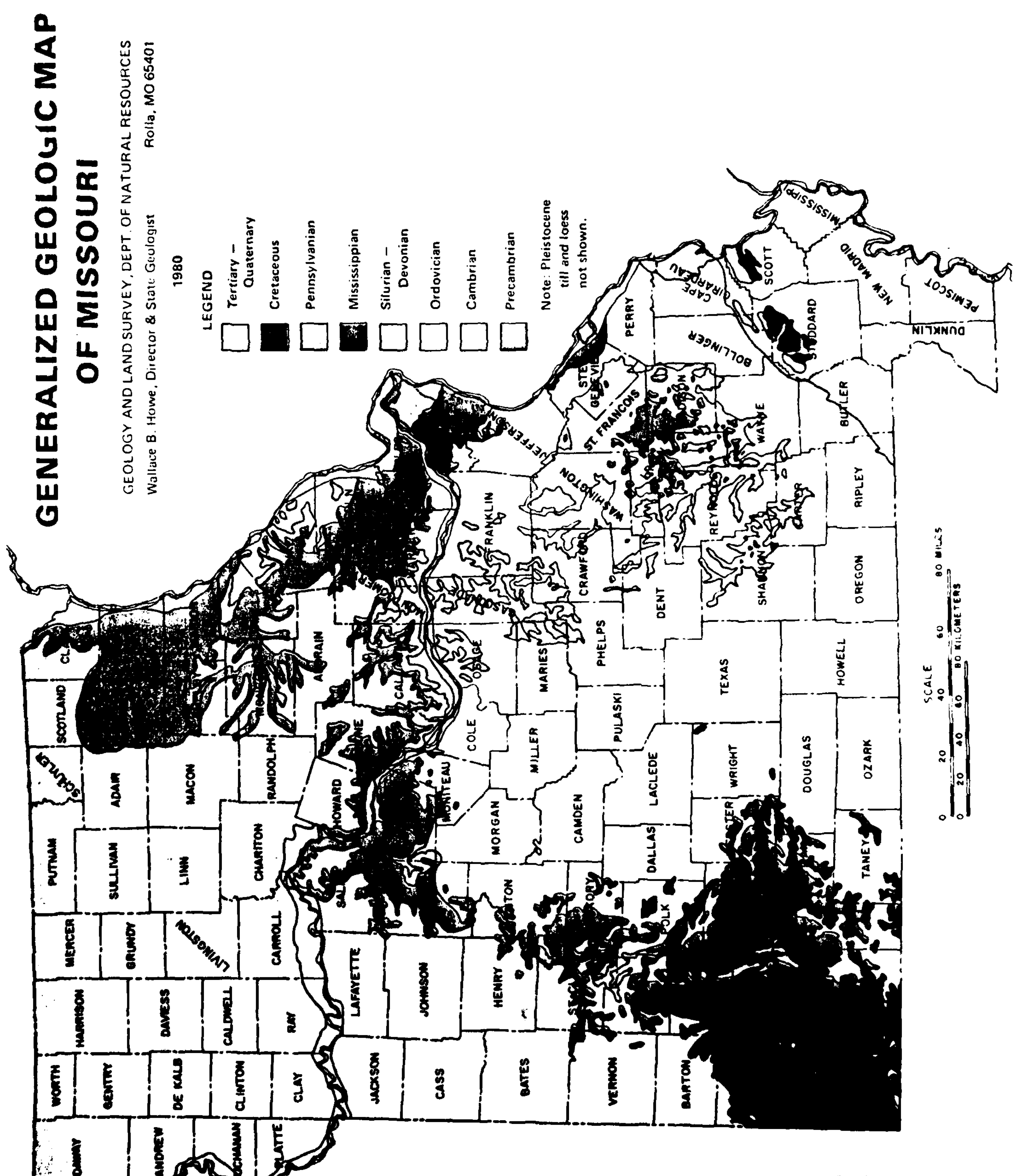
MISSOURI RIVER

PAPILLION CREEK AND TRIBUTARIES LAKES, NEBRASKA

SEISMIC EVALUATION

GEOLOGIC MAP OF IOWA

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA

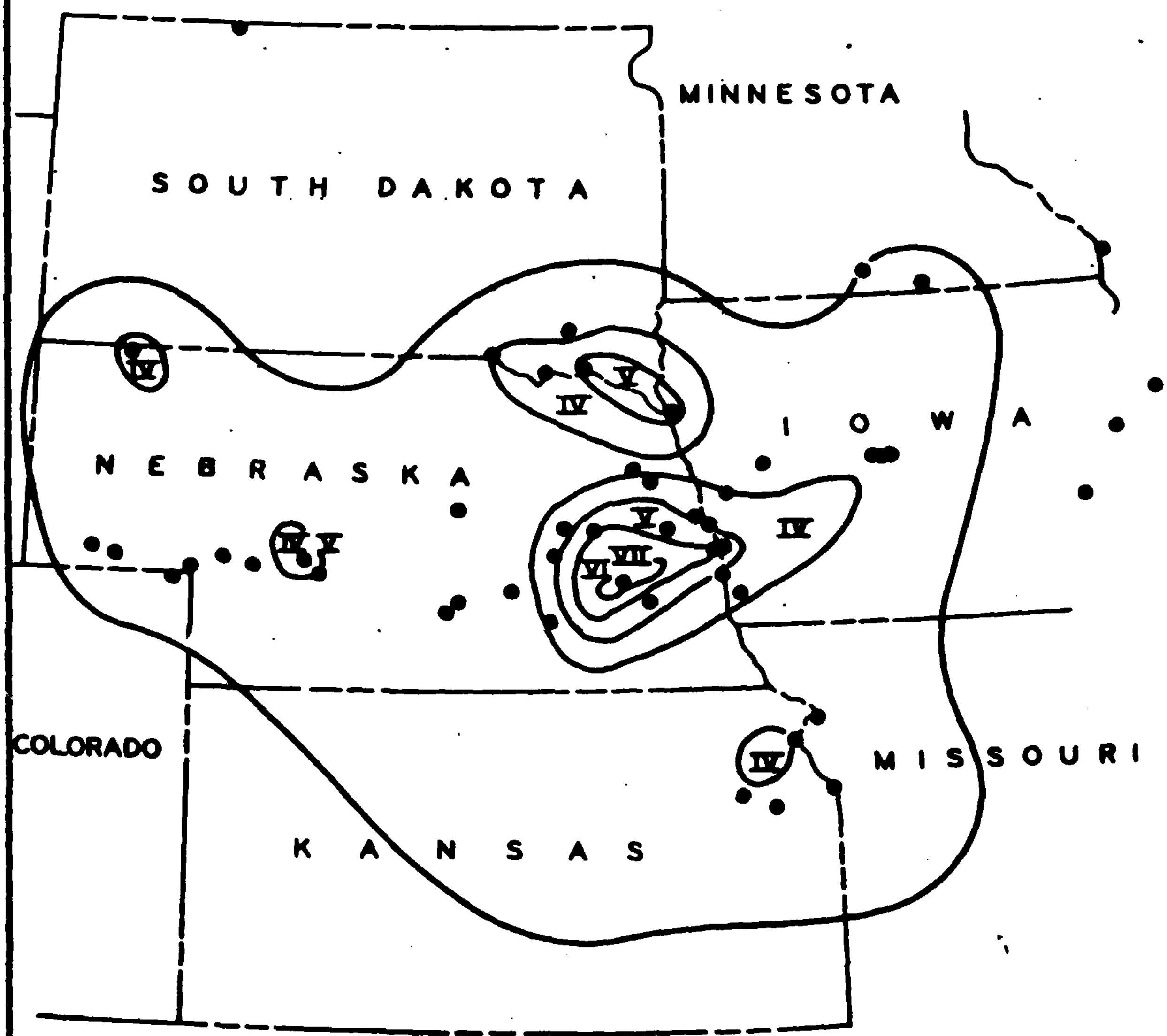


MISSOURI RIVER
PAPILLION CREEK AND TRIBUTARIES LAKES, NEBRASKA
SEISMIC EVALUATION

GEOLOGIC MAP OF MISSOURI

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA

PLATE 8



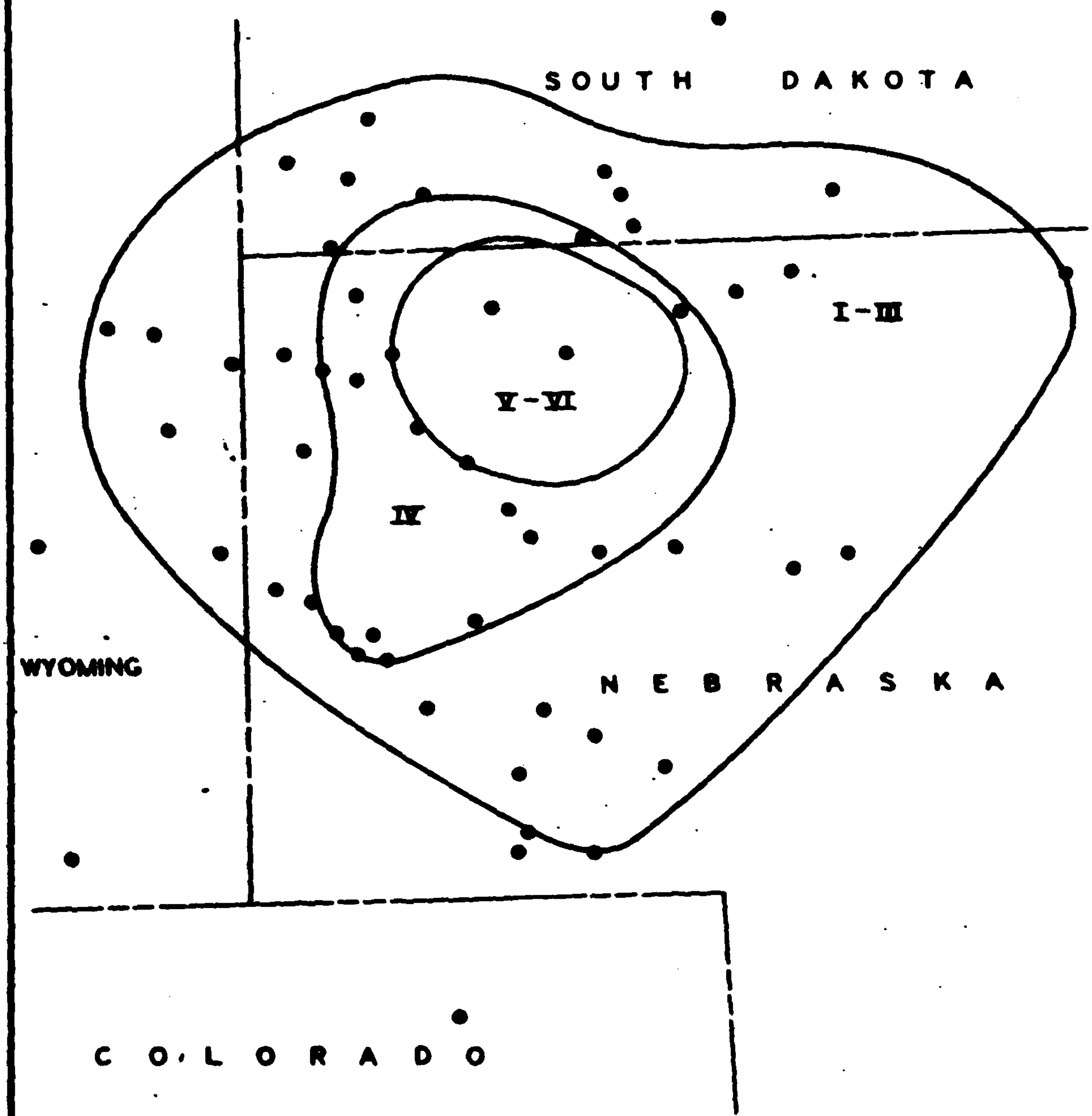
● INDICATES LOCATIONS REPORTING EFFECTS OF EARTHQUAKE
ISOSEISMAL CONTOURS

ISOSEISMAL MAP OF THE EASTERN NEBRASKA EARTHQUAKE

NOVEMBER 15, 1877 185,000 SQ. MI. FELT AREA (FROM DOCEKAL, 1970)

PAPILLION CREEK SITES 11 AND 16 – SEISMIC EVALUATION

PLATE 8A



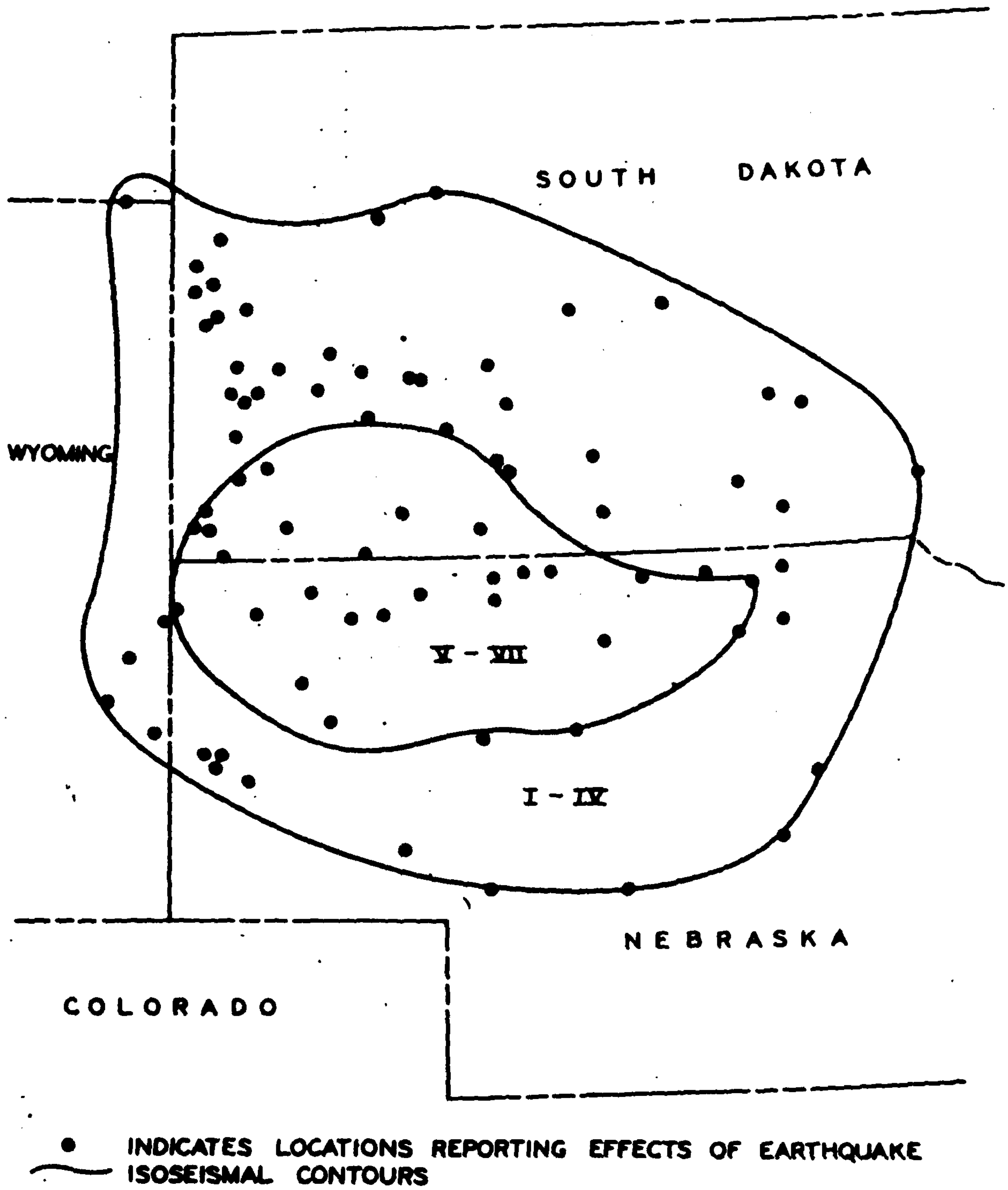
• INDICATES LOCATIONS REPORTING EFFECTS OF EARTHQUAKE

—— ISOSEISMAL CONTOURS

ISOSEISMAL MAP OF THE CHADRON, NEBRASKA EARTHQUAKE

JULY 30, 1934 23,300 SQ. MI. FELT AREA (FROM DOCEKAL, 1970)

PAPILLION CREEK SITES 11 AND 16 - SEISMIC EVALUATION

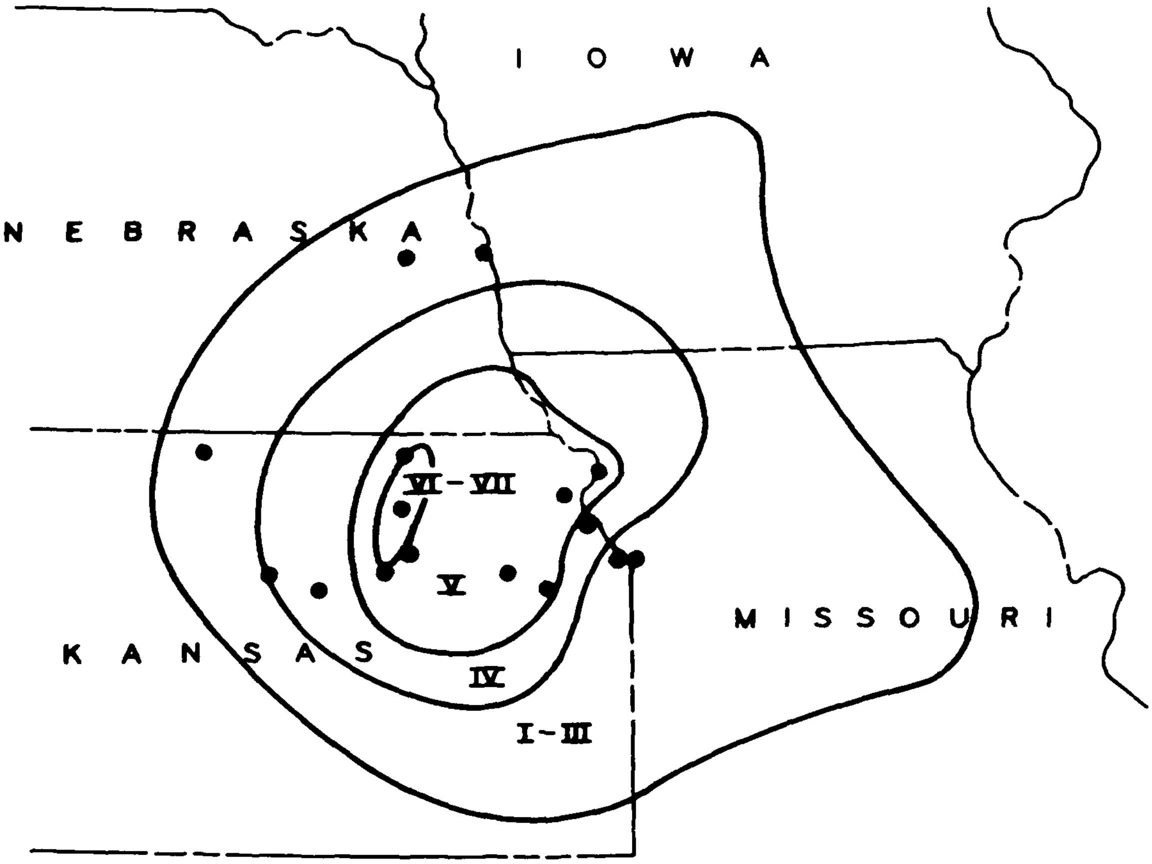


ISOSEISMAL MAP OF THE MERRIMAN, NEBRASKA EARTHQUAKE

MARCH 28, 1964 105,000 SQ. MI. FELT AREA (FROM DOCEKAL, 1970)

PAPILLION CREEK SITES 11 AND 16 - SEISMIC EVALUATION

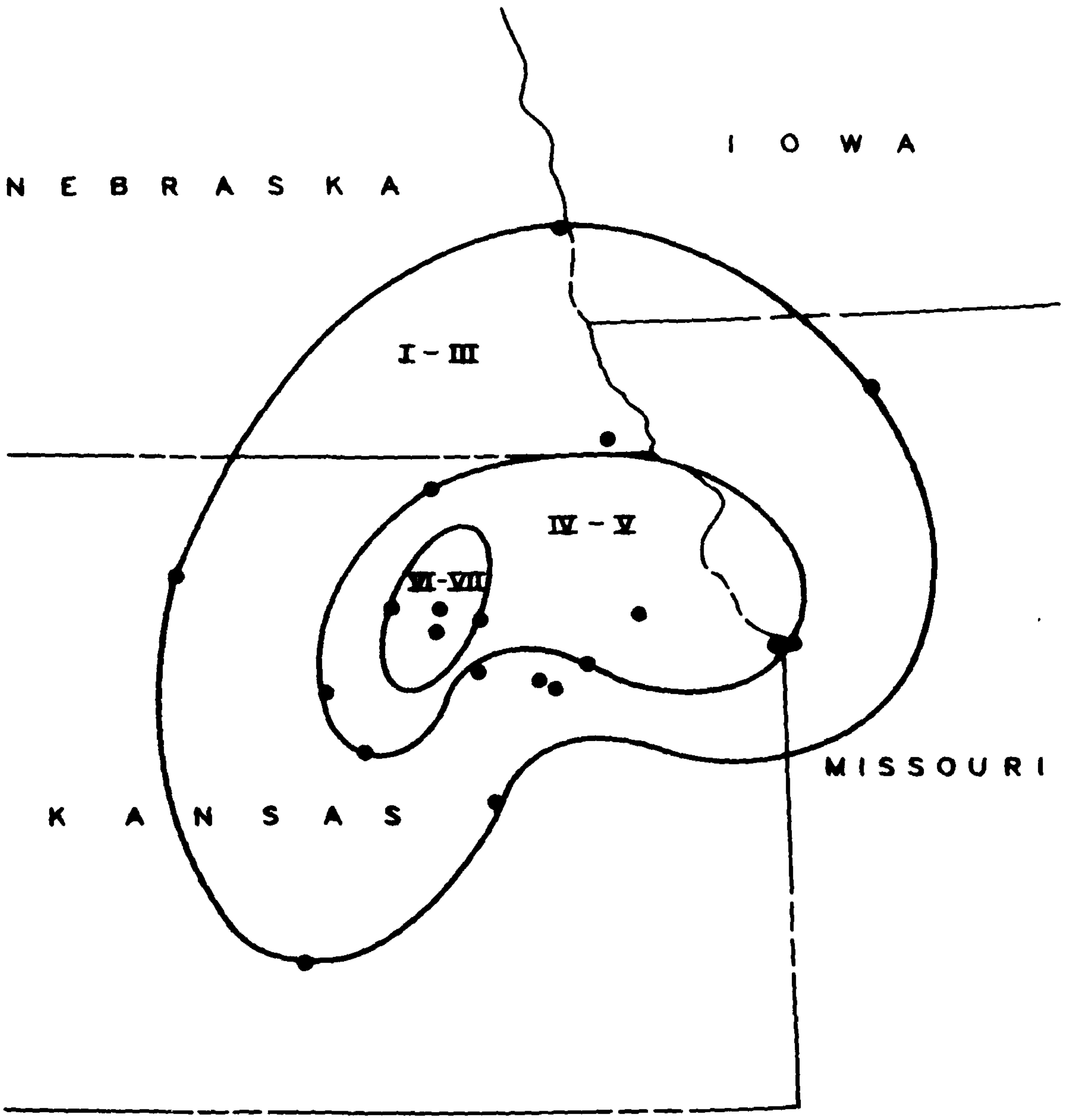
PLATE 8C



● INDICATES LOCATIONS REPORTING EFFECTS OF EARTHQUAKE
ISOSEISMAL CONTOURS

ISOSEISMAL MAP OF THE MANHATTAN, KANSAS EARTHQUAKE

APRIL 24, 1867 95,000 SQ. MI. FELT AREA (FROM DOCEKAL, 1970)



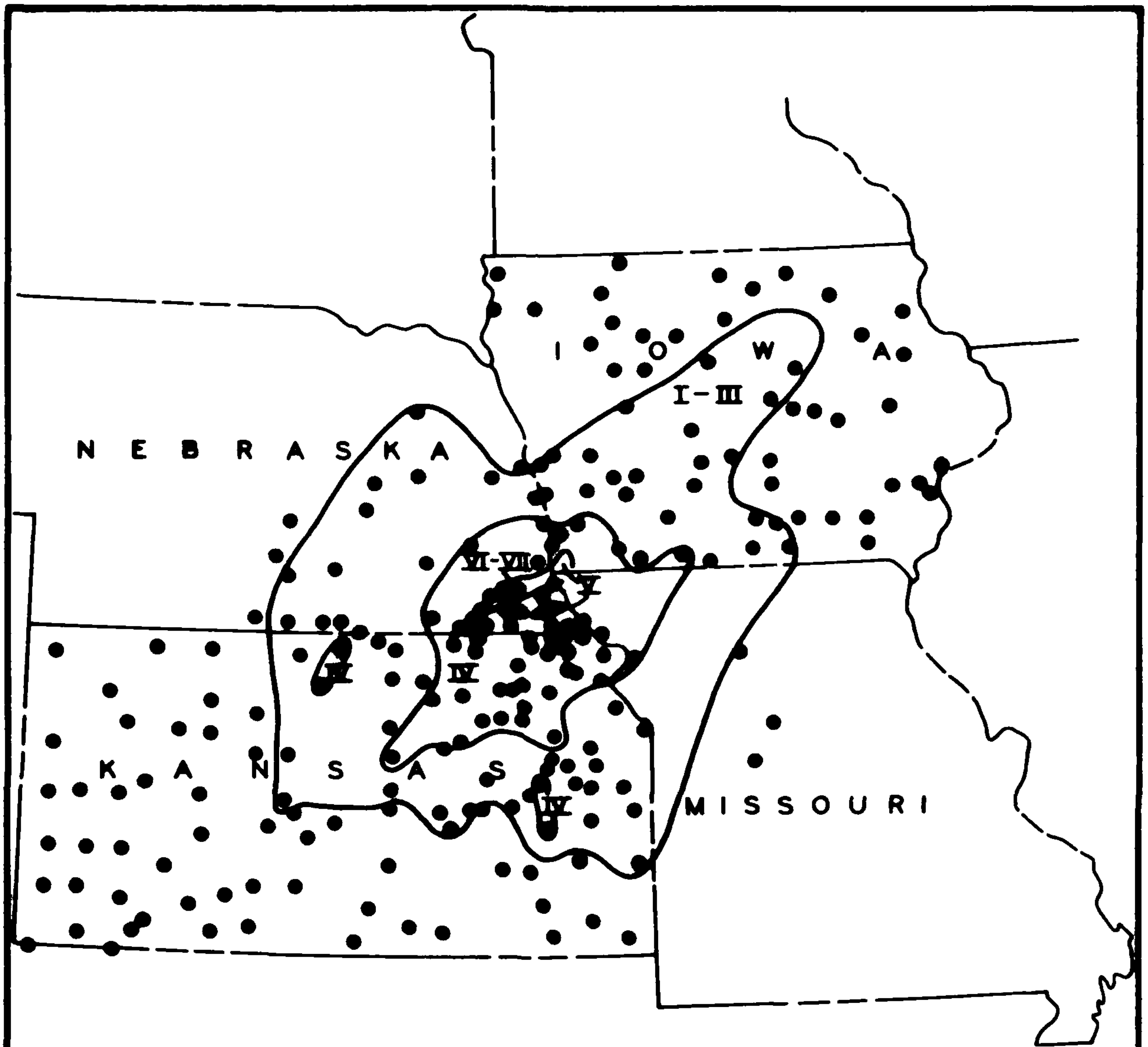
● INDICATES LOCATIONS REPORTING EFFECTS OF EARTHQUAKE
〜 ISOSEISMAL CONTOURS

ISOSEISMAL MAP OF THE MANHATTAN, KANSAS EARTHQUAKE

JANUARY 8, 1906 36,000 SQ. MI. FELT AREA (FROM DOCEKAL, 1970)

PAPILLION CREEK SITES 11 AND 16 – SEISMIC EVALUATION

PLATE 8E

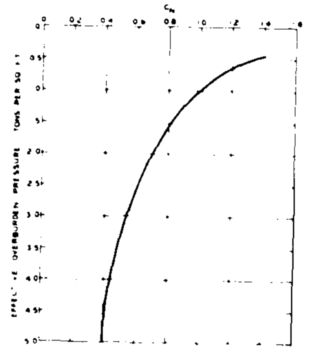


• INDICATES LOCATIONS REPORTING EFFECTS OF EARTHQUAKE

~ ISOSEISMAL CONTOURS

ISOSEISMAL MAP OF THE TECUMSEH, NEBRASKA EARTHQUAKE

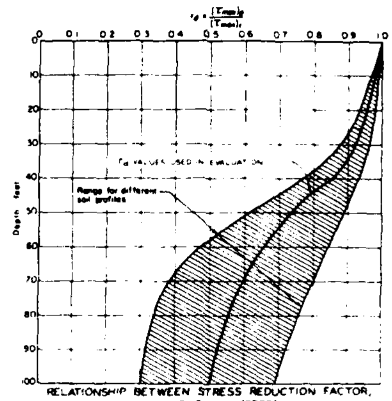
MARCH 1, 1935 82,500 SQ. MI. FELT AREA (FROM DOCEKAL, 1970)



RELATIONSHIP BETWEEN C_N AND EFFECTIVE OVERBURDEN PRESSURE

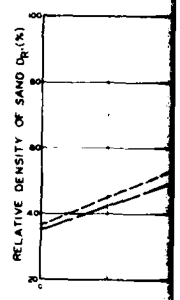
SEED

FIGURE 1



RELATIONSHIP BETWEEN STRESS REDUCTION FACTOR, r_d, AND DEPTH (SEED)

FIGURE 2



N_1 = $C_N \cdot N$ or $C_N \cdot \bar{N} \cdot 1.2$[□] (Reference 1)

where N_1 = SPT penetration resistance corrected to an effective overburden pressure of one ton per square foot.

$C_N \approx 1.0 - 0.93 \log \frac{\sigma'_0}{\sigma'_1}$ (Min. C_N = 0.4)

where σ'_0 = Effective overburden pressure in tons per square foot.

σ'_1 = One ton per square foot

N = *Uncorrected SPT results - Rope and Drum System*

$\bar{N}$ = Uncorrected SPT results - Automatic Trip Hammer System

For silty sands and silts plotting below the A-line with D_{50} *less than 0.15 mm, add 7.5 to computed* N_1 *value.* (Reference 2)

□ *Factor for converting from Automatic Trip Hammer* System to Rope and and Drum System

The Cyclic Stress Ratio causing liquefaction can be determined from the relationship.

$$\frac{\tau_{av}}{\sigma'_0} \approx 0.65 \cdot \frac{a_{max}}{g} \cdot \frac{\sigma_0}{\sigma'_0} \cdot r_d \text{ (Equation 1)}$$

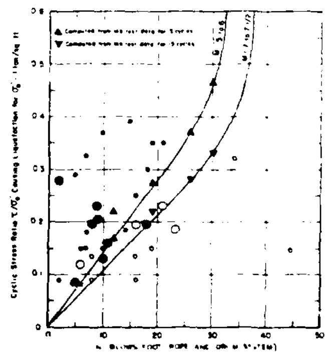
where

a_{max} = *maximum acceleration at the ground* surface

σ_0 = total overburden pressure on sand layer under consideration

σ'_0 = effective overburden pressure on sand layer under consideration

r_d = stress reduction factor (See Figure 2)

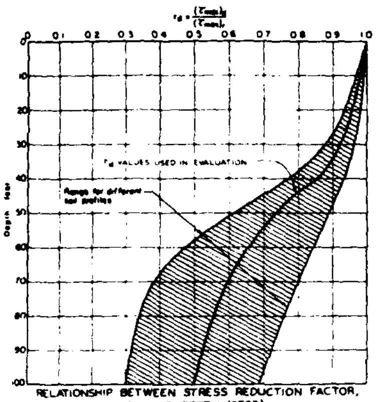


CORRELATION BETWEEN STRESS RATIO CAUSING VARIOUS DEGREES OF LIQUEFACTION IN THE FIELD AND IN THE LABORATORY AND PENETRATION RESISTANCE OF SAND

SEED

FIGURE 4

LEGEND:



RELATIONSHIP BETWEEN STRESS REDUCTION FACTOR, r_d, AND DEPTH (SEED)

FIGURE 2

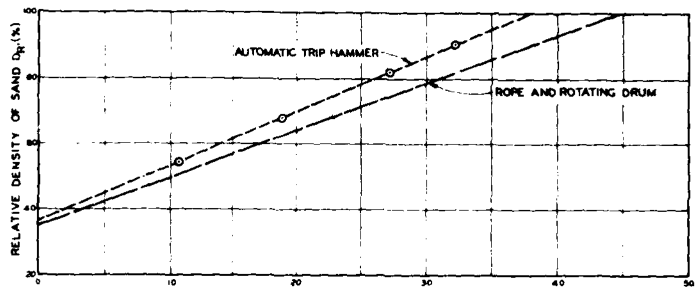
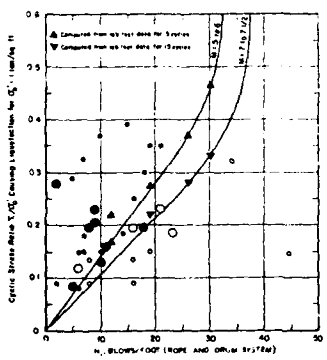


FIGURE 3



CORRELATION BETWEEN STRESS RATIO CAUSING VARIOUS DEGREES OF LIQUEFACTION IN THE FIELD AND IN THE LABORATORY AND PENETRATION RESISTANCE OF SAND (SEED)

FIGURE 4

LEGEND:

- • Liquefaction: stress ratio based on estimated acceleration
- ● Liquefaction: stress ratio based on good acceleration data
- ∘ No liquefaction: stress ratio based on estimated acceleration
- ○ No liquefaction: stress ratio based on good acceleration data

THIS DRAWING HAS BEEN REDUCED TO THREE-EIGHTHS THE ORIGINAL SCALE.

PAPILLION CREEK AND TRIBUTARIES LAKES, NEBRASKA

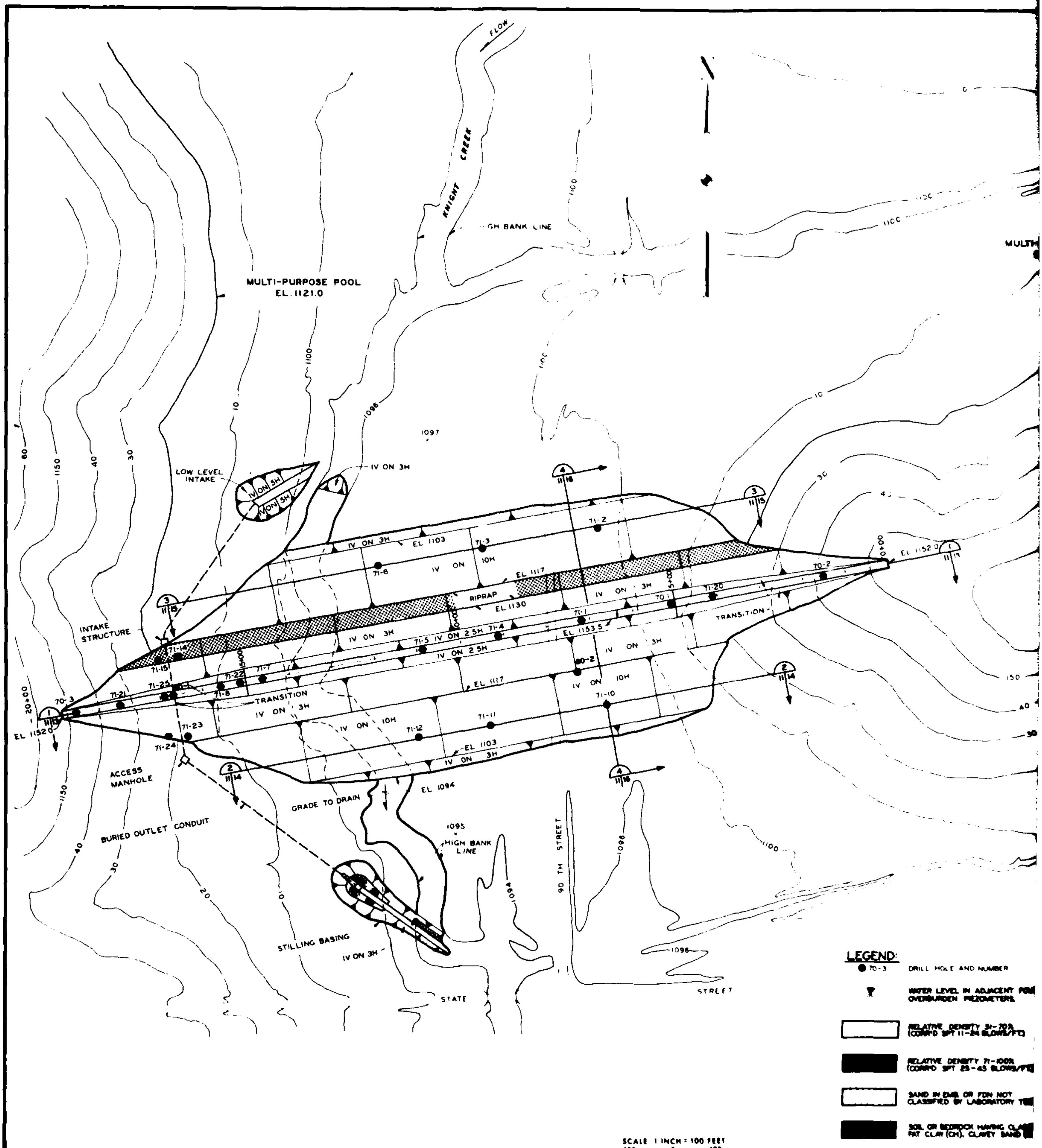
SITES 11 AND 16

SEISMIC EVALUATION

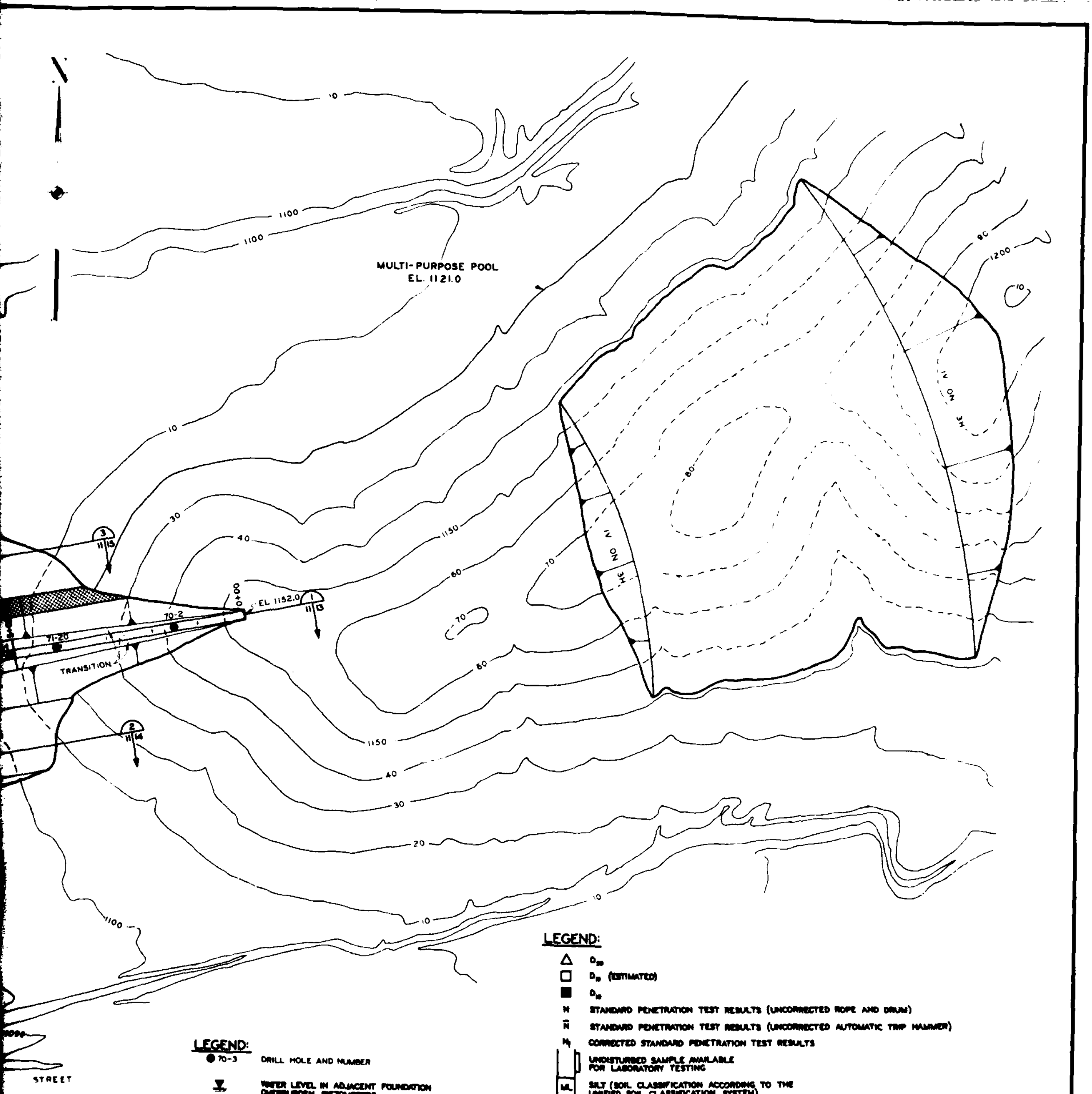
SUMMARY OF EVALUATION PROCEDURES

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA

2



FLOW
KNIGHT CREEK
HIGH BANK LINE
MULTI-PURPOSE POOL
EL. 1121.0
LOW LEVEL INTAKE
IV ON 5H
IV ON 3H
INTAKE STRUCTURE
EL 1103
EL 1117
RIPRAP
EL 1130
EL 1153.5
IV ON 10H
IV ON 2.5H
TRANSITION
EL 1152.0
EL 1094
ACCESS MANHOLE
BURIED OUTLET CONDUIT
GRADE TO DRAIN
STILLING BASING
90 TH STREET
STATE
STREET
LEGEND:
DRILL HOLE AND NUMBER
WATER LEVEL IN ADJACENT OVERBURDEN PIEZOMETERS
RELATIVE DENSITY 31-70% (CORR'D SPT 11-24 BLOWS/FT)
RELATIVE DENSITY 71-100% (CORR'D SPT 25-43 BLOWS/FT)
SAND IN EMB. OR FDN NOT CLASSIFIED BY LABORATORY
SOIL OR BEDROCK HAVING FAT CLAY (CH), CLAYEY SAND
SCALE 1 INCH = 100 FEET



LEGEND:

- ● 70-3 — DRILL HOLE AND NUMBER
- ▽ — WATER LEVEL IN ADJACENT FOUNDATION OVERBURDEN PIEZOMETERS
- (open box) — RELATIVE DENSITY 51-70% (CORR'D SPT 11-24 BLOWS/FT.)
- (solid box) — RELATIVE DENSITY 71-100% (CORR'D SPT 25-45 BLOWS/FT.)
- (hatched box) — SAND IN EMB. OR FDN. NOT CLASSIFIED BY LABORATORY TESTS
- (solid box) — SOIL OR BEDROCK HAVING CLASSIFICATION OF LEAN CLAY (CL) FAT CLAY (CH), CLAYEY SAND (SC) OR CLAYEY GRAVEL (GC).

LEGEND:

- △ D_{50}
- □ D_{10} (ESTIMATED)
- ■ D_{10}
- N — STANDARD PENETRATION TEST RESULTS (UNCORRECTED ROPE AND DRUM)
- $\tilde{N}$ — STANDARD PENETRATION TEST RESULTS (UNCORRECTED AUTOMATIC TRIP HAMMER)
- N_1 — CORRECTED STANDARD PENETRATION TEST RESULTS
- UNDISTURBED SAMPLE AVAILABLE FOR LABORATORY TESTING
- ML — SILT (SOIL CLASSIFICATION ACCORDING TO THE UNIFIED SOIL CLASSIFICATION SYSTEM)
- SM — UNDISTURBED SAMPLE - LABORATORY TESTED
- LEAN CLAY (SOIL CLASSIFICATION BY FIELD INSPECTOR)

SECTION NUMBER
DRAWING NUMBER ON WHICH SECTION IS DETAILED *
DRAWING NUMBER ON WHICH SECTION IS CUT *
* DRAWING NUMBERS OMITTED IF SECTION IS CUT AND DETAILED ON SAME DRAWING

SECTION IDENTIFICATION

PAPILLION CREEK AND TRIBUTARIES LAKES, NEBRASKA

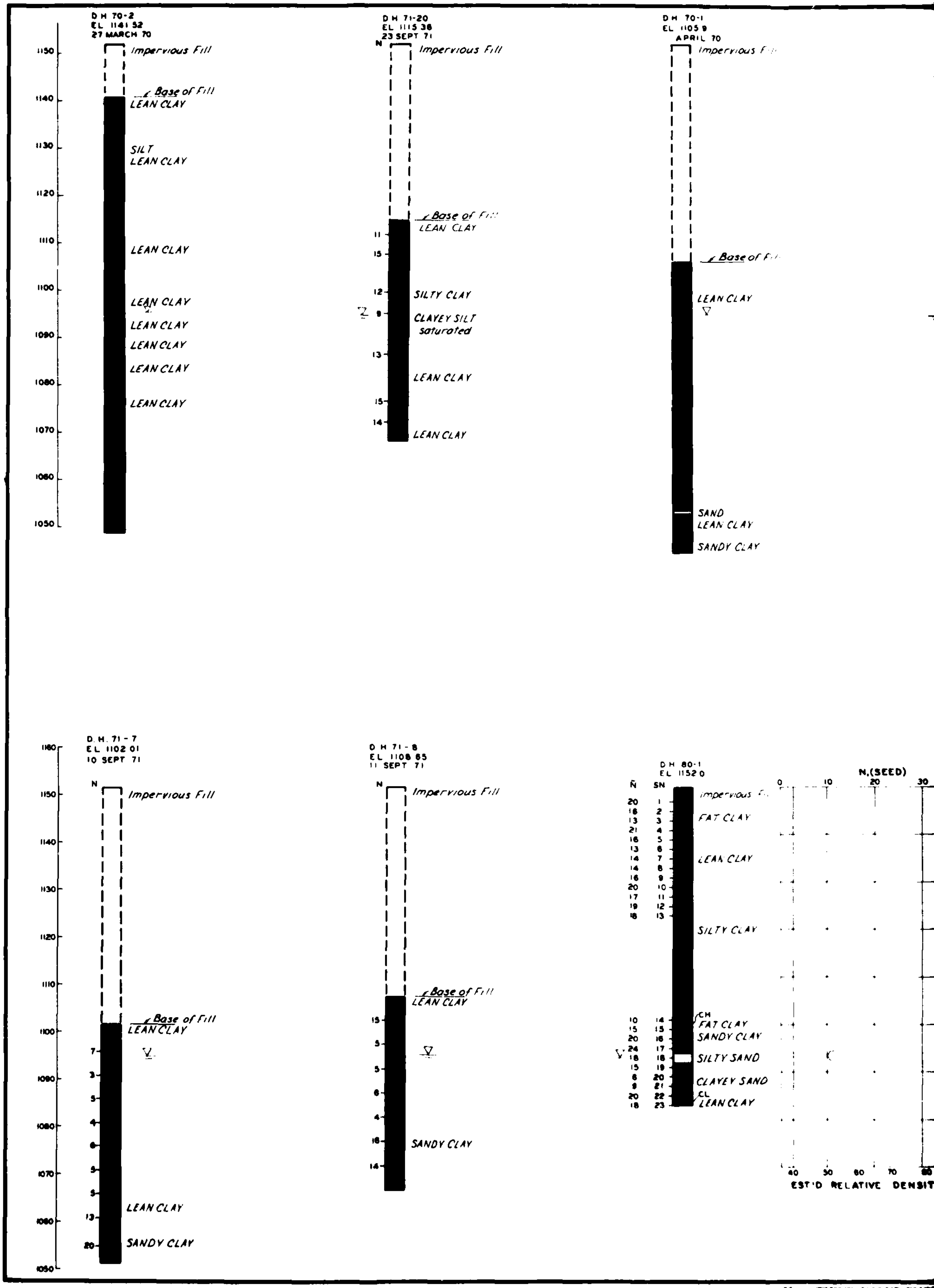
SITES 11 AND 16
SEISMIC EVALUATION

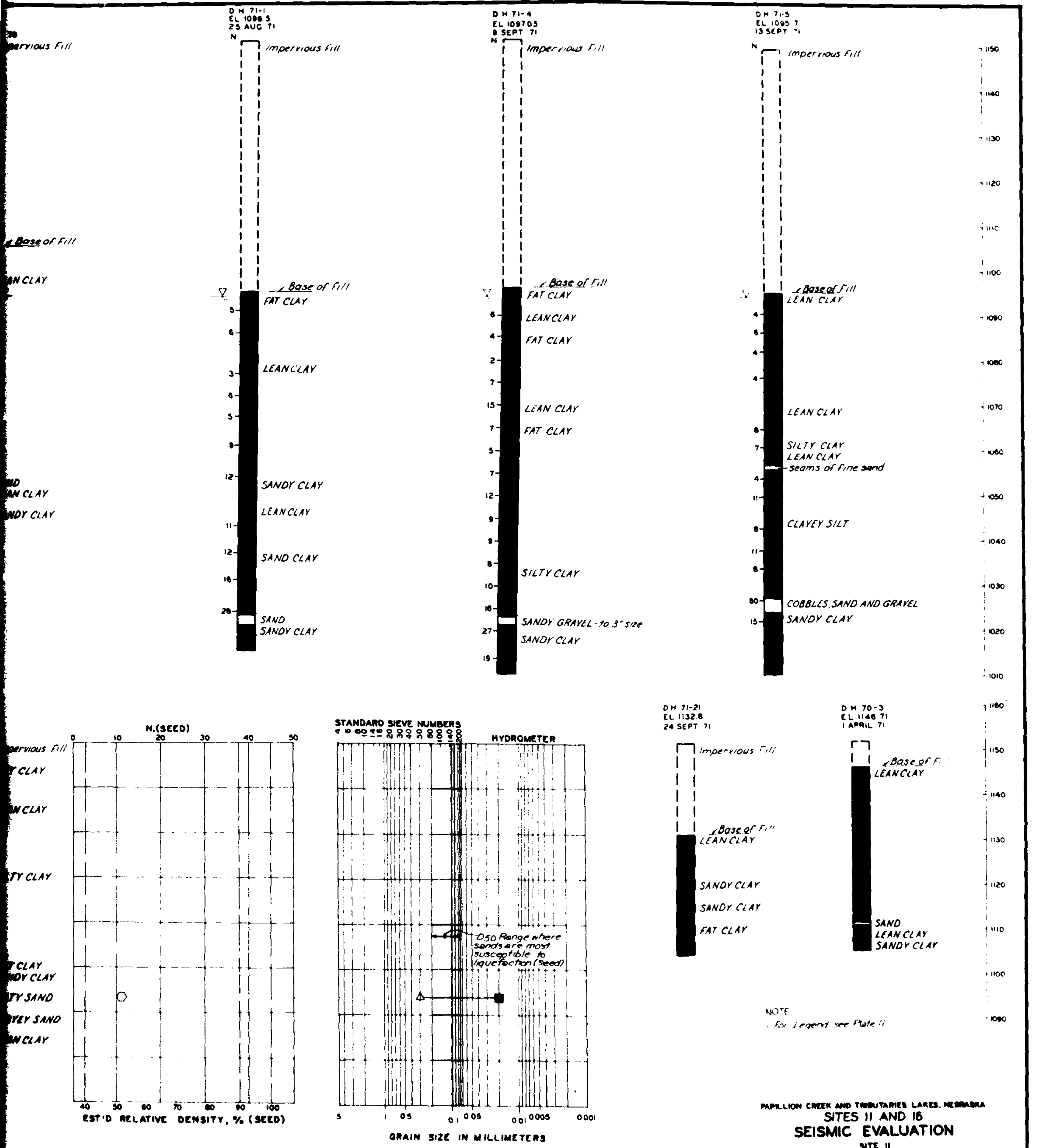
SITE 11

GENERAL PLAN AND PLAN OF BORINGS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA

PLATE 10


D H 70-2
EL 1141 52
27 MARCH 70
Impervious Fill
Base of Fill
LEAN CLAY
SILT
LEAN CLAY
LEAN CLAY
LEAN CLAY
LEAN CLAY
LEAN CLAY
LEAN CLAY
LEAN CLAY
D H 71-20
EL 1115 38
23 SEPT 71
Impervious Fill
LEAN CLAY
SILTY CLAY
CLAYEY SILT saturated
LEAN CLAY
LEAN CLAY
D H 70-1
EL 1105 9
APRIL 70
LEAN CLAY
SAND
LEAN CLAY
SANDY CLAY
D. H. 71 - 7
EL 1102 01
10 SEPT 71
Impervious Fill
Base of Fill
LEAN CLAY
LEAN CLAY
SANDY CLAY
D H 71 - 8
EL 1108 85
11 SEPT 71
Impervious Fill
Base of Fill
LEAN CLAY
SANDY CLAY
D H 80-1
EL 1152 0
FAT CLAY
LEAN CLAY
SILTY CLAY
CH
FAT CLAY
SANDY CLAY
SILTY SAND
CLAYEY SAND
CL
LEAN CLAY
N,(SEED)
EST'D RELATIVE DENSIT



PAPILLION CREEK AND TRIBUTARIES LAKES, NEBRASKA

SITES 11 AND 16

SEISMIC EVALUATION

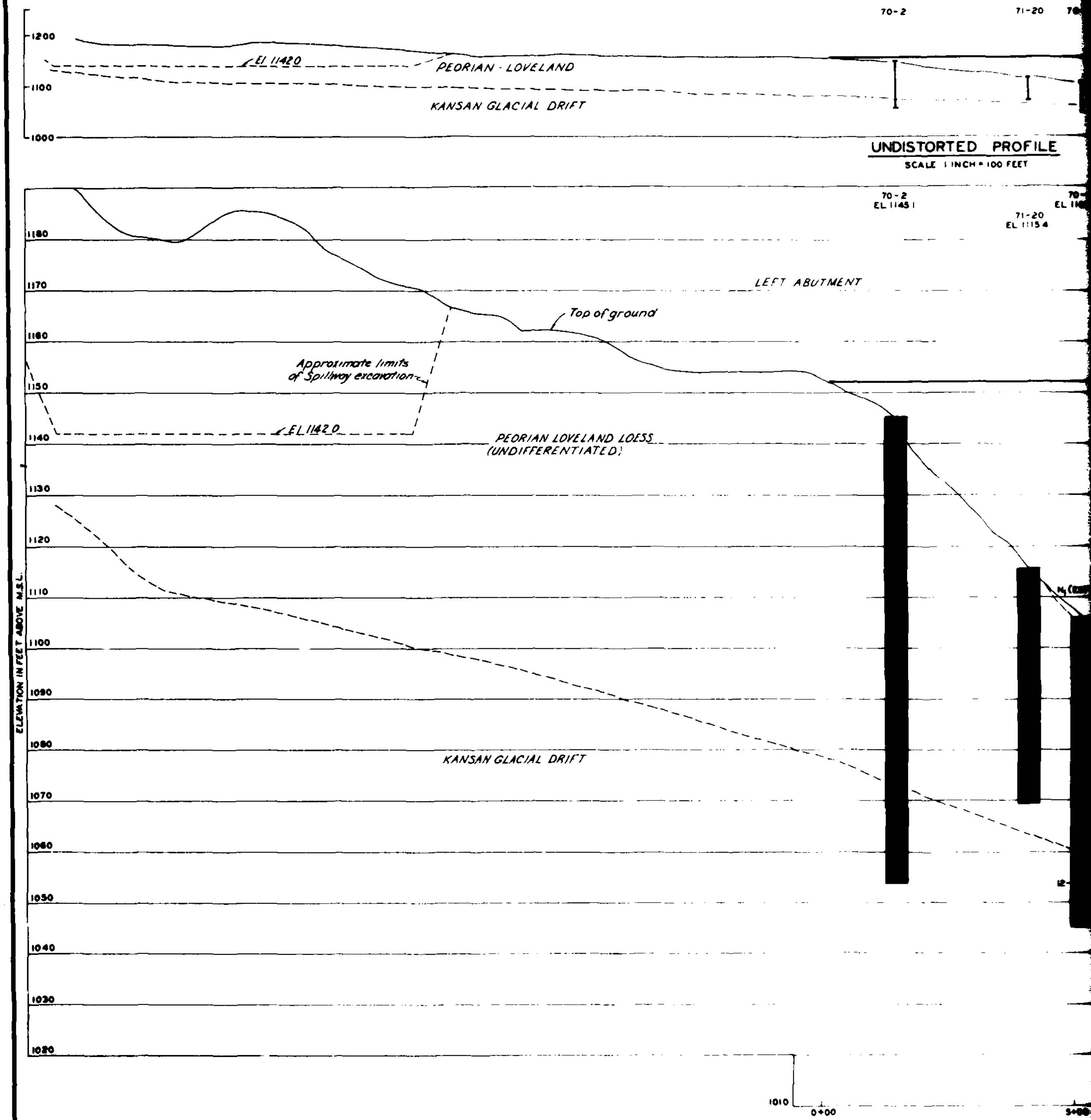
SITE 11

LOG OF BORINGS

ALONG EMBANKMENT ℄ (PROFILE 1-1)

U.S. ARMY ENGINEER DISTRICT, OMAHA

CORPS OF ENGINEERS OMAHA, NEBRASKA

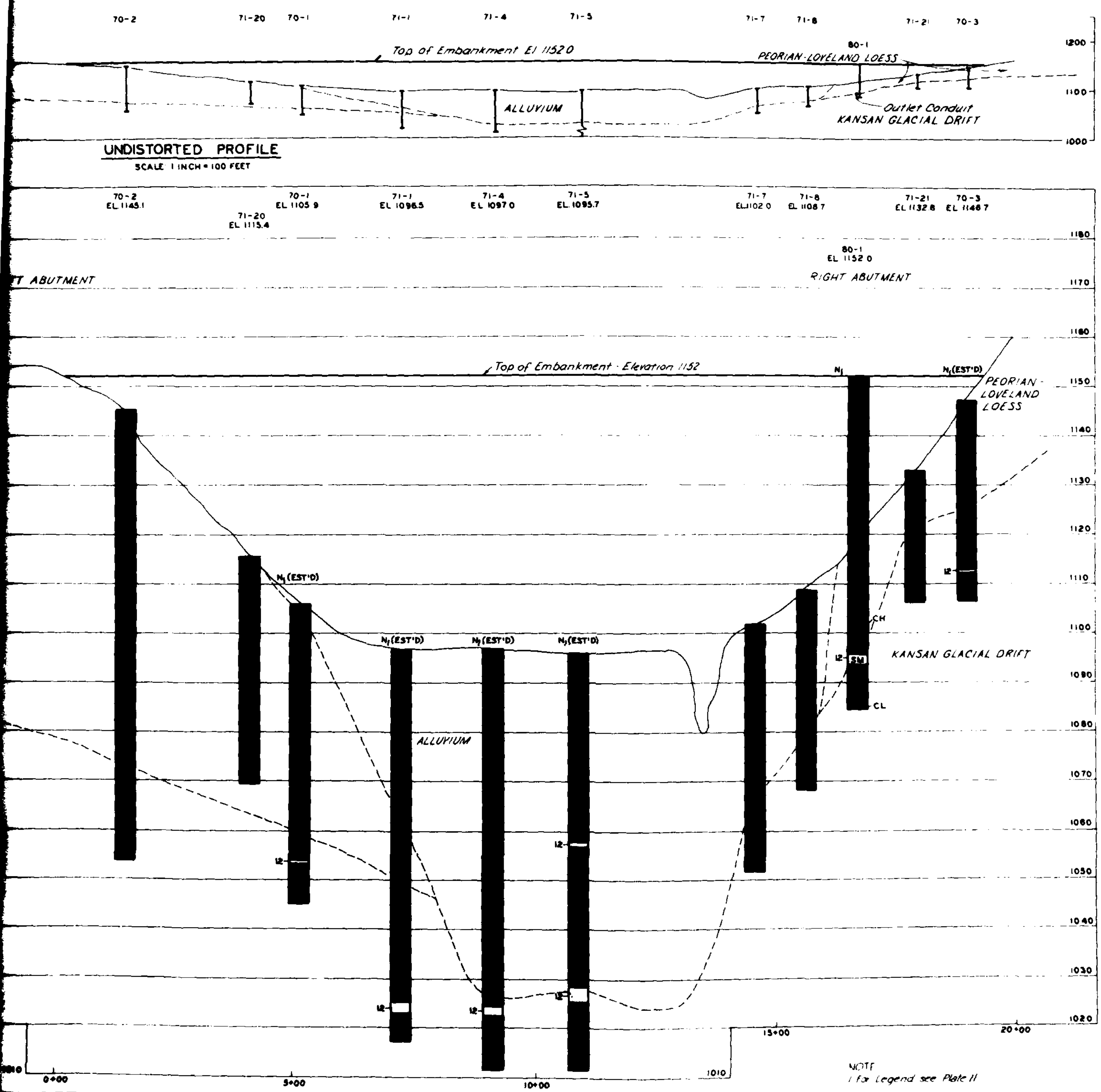


SCALE VERT 1 INCH = 10 FEET
HORIZ 1 INCH = 100 FEET

℄ PROFILE

SUMMARY OF EVALUATION

HOLE NO.	DEPTH TO LAYER, FT.	DEPTH TO SAT'D ZONE, FT.	DEPTH OF SAT'D ZONE, FT.	UPLIFT AT BASE OF LAYER, FT.	UPLIFT PRESSURE P S F	TOTAL OVB. PRESSURE P S F	EFF. OVB. PRESSURE P S F	C S R FROM DESIGN ETHQK	N_1	RESISTING C. S. R. (SPT)	F. S. AGAINST LIQUEF. (SPT.)
70-3	40	31	9	9	585	4862	4,277	0.0942	12	0.17	1.8
80-1	58	31	27	27	1,674	7068	5,394	0.0830	12	0.17	2.0
71.5	96	31	65	65	4,050	11,780	7,750	0.0741	12	0.17	2.3
71.5	127	31	96	96	5,952	15,624	9,672	0.0787	12	0.17	2.2
71.4	130	31	99	99	6,138	15,996	9,858	0.0791	12	0.17	2.1
71.1	133	35	98	98	6,076	16,352	10,276	0.0672	12	0.17	2.5
70.1	99	31	68	68	4,216	12,152	7,936	0.0746	12	0.17	2.3



SCALE VERT. 1 INCH = 10 FEET
HORIZ 1 INCH = 100 FEET

℄ PROFILE 4.11|13

F.S. AGAINST LIQUEF. (SPT.)
1.8
2.0
2.3
2.2
2.1
2.5
2.3

PAPILLION CREEK AND TRIBUTARIES LAKES, NEBRASKA

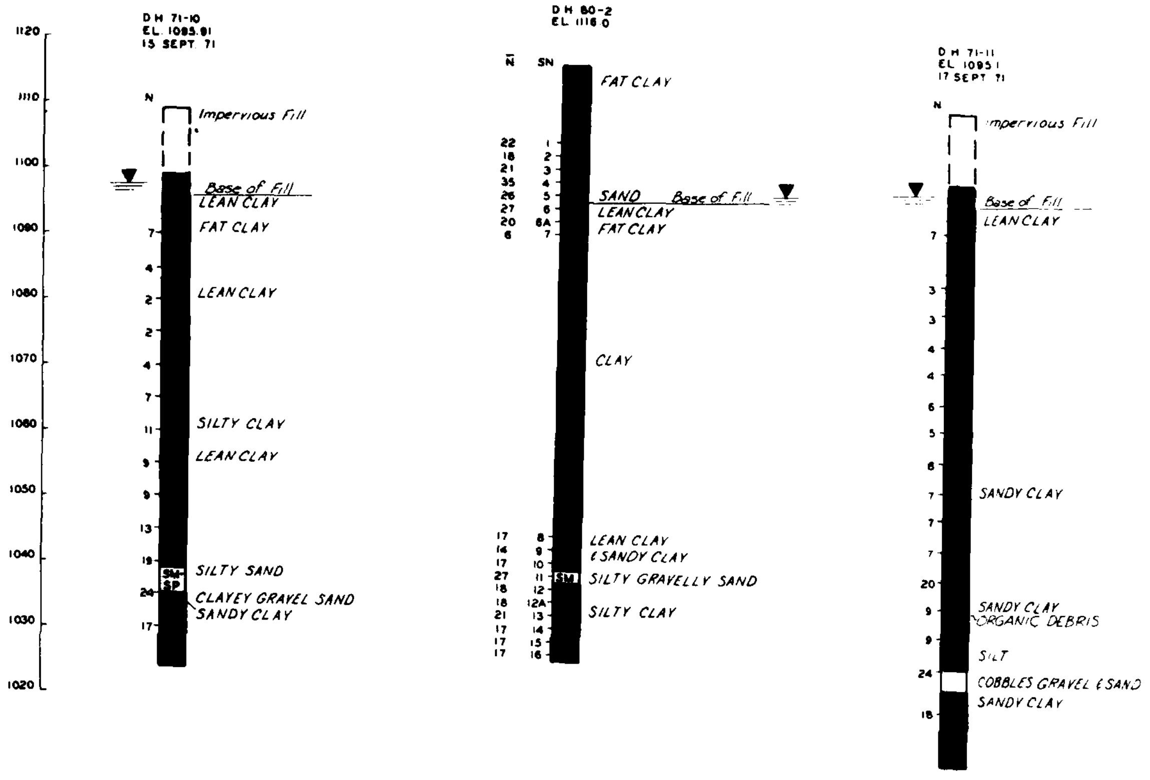
SITES 11 AND 16

SEISMIC EVALUATION

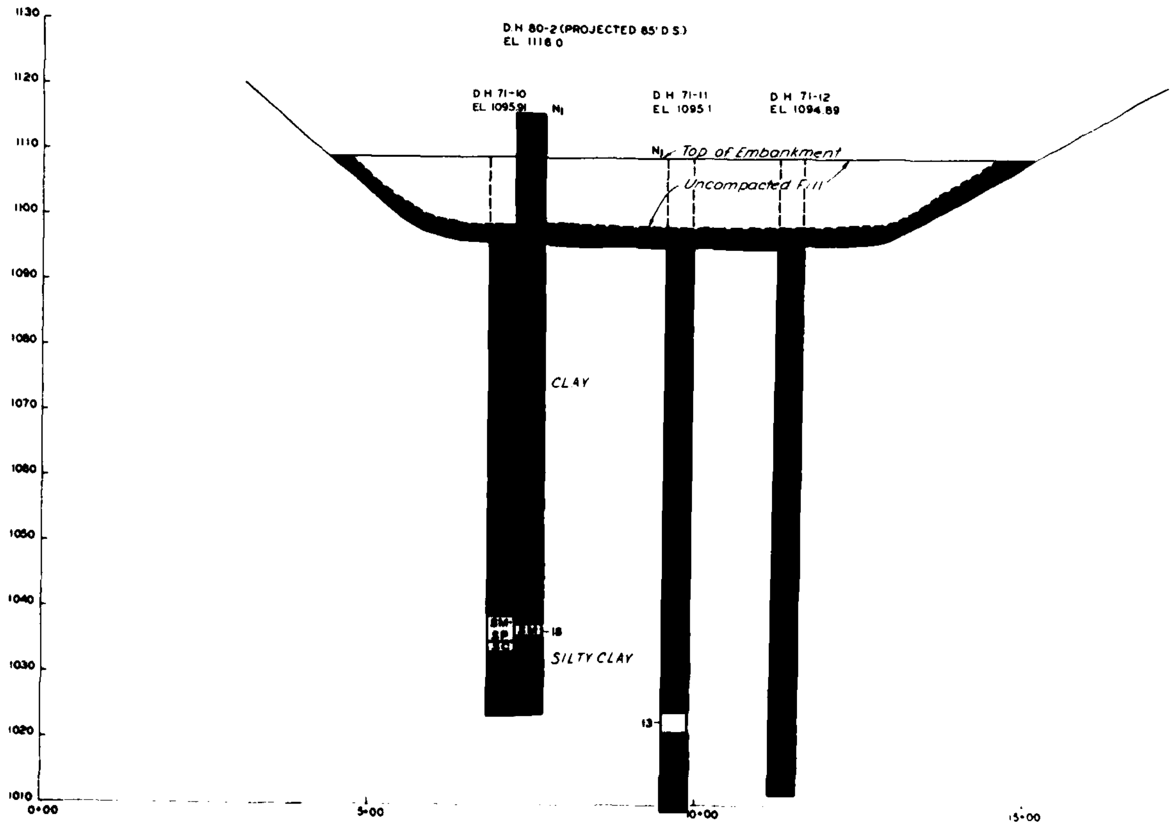
SITE 11

EVALUATION OF LIQUEFACTION POTENTIAL ALONG EMBANKMENT ℄

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA

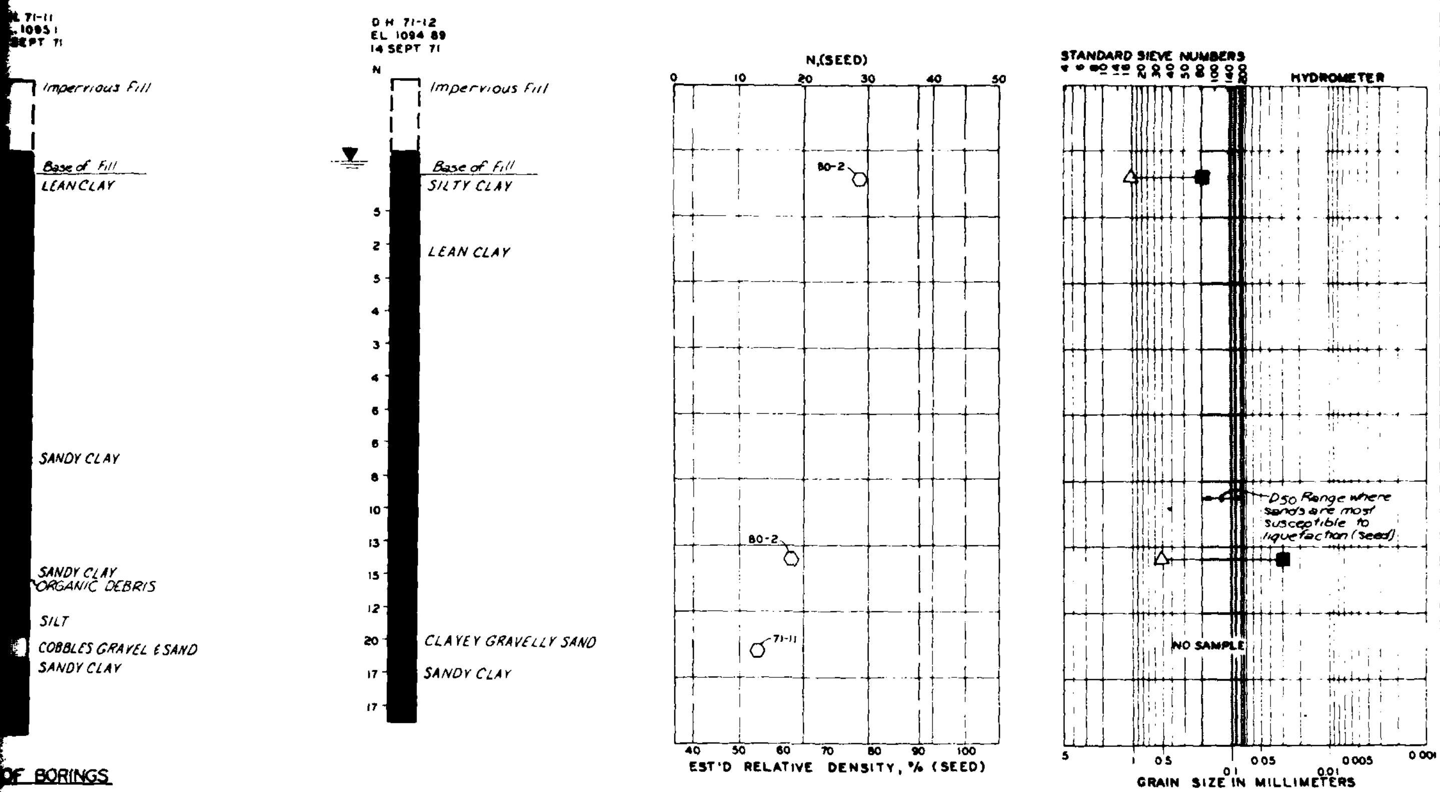


LOG OF BORINGS

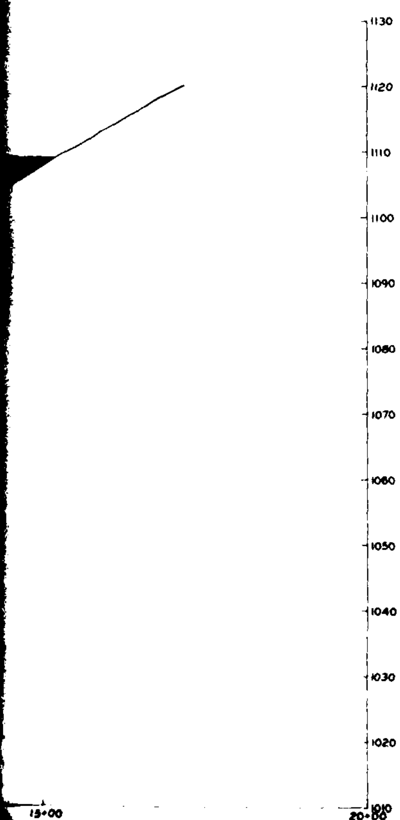


PROFILE 200' D.S.

SCALE VERT 1 INCH = 10 FEET
HORIZ 1 INCH = 100 FEET



OF BORINGS



SUMMARY OF EVALUATION											
HOLE NO.	DEPTH TO LAYER, FT.	DEPTH TO SAT'D ZONE, FT.	DEPTH OF SAT'D ZONE, FT.	UPLIFT AT BASE OF LAYER, FT.	UPLIFT PRESSURE P S F	TOTAL OVB. PRESSURE P S F	EFF. OVB. PRESSURE P S F	C S R FROM DESIGN ETHQK	N_1	RESISTING C. S. R. (SPT)	F. S. AGAINST LIQUEF. (SPT.)
80-2	20	0	0	0	0	2,400	2,400	0.0802	28	0.43	5.3
80-2	80	20	60	60	3720	9,840	6,120	0.0747	18	0.25	3.3
71-11	87	18	69	69	4278	10,716	6,438	0.0896	13	0.19	2.1

NOTE
1 For Legend see Plate 11

PAPILLION CREEK AND TRIBUTARIES LAKES, NEBRASKA

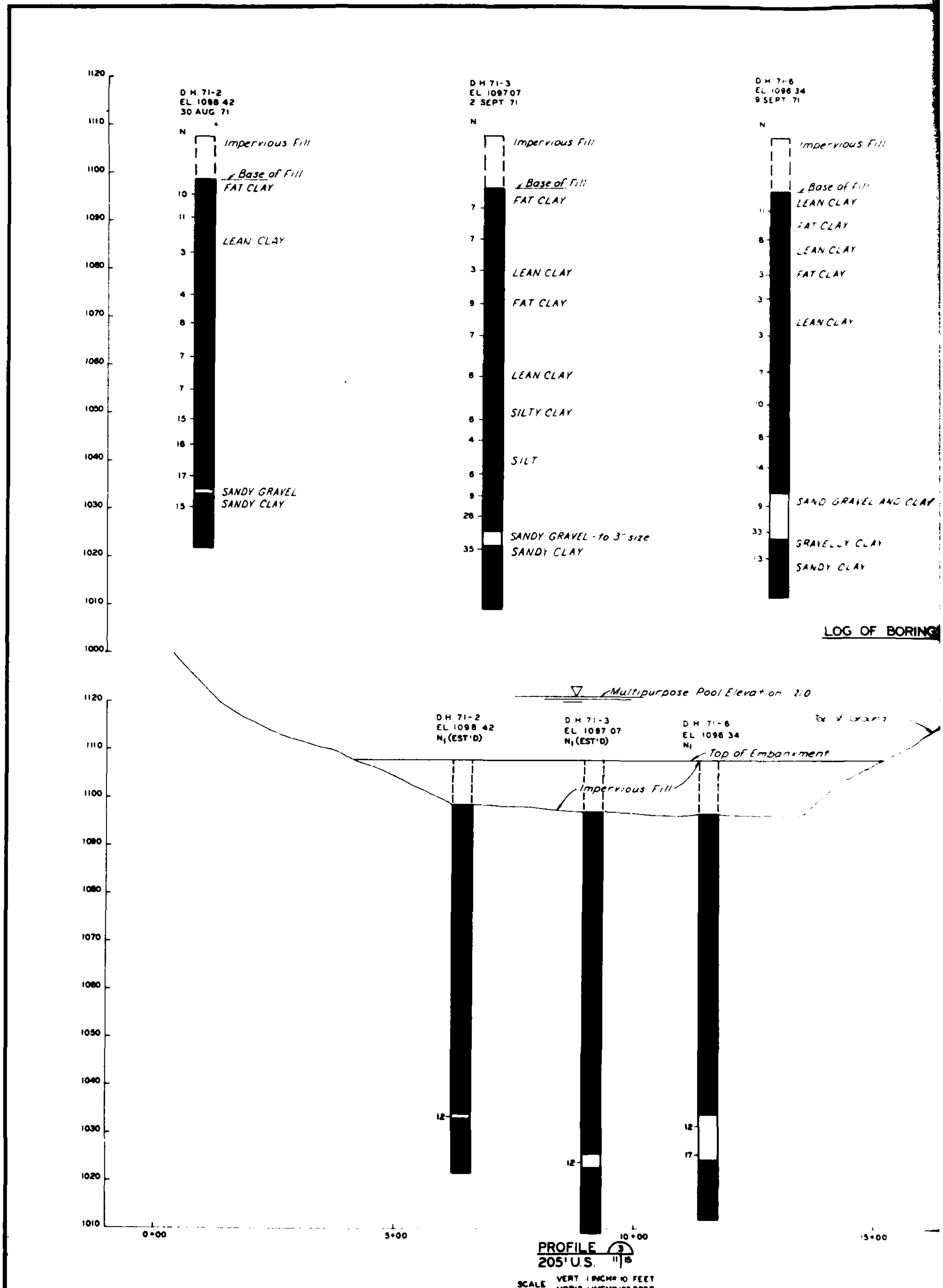
SITES 11 AND 16

SEISMIC EVALUATION

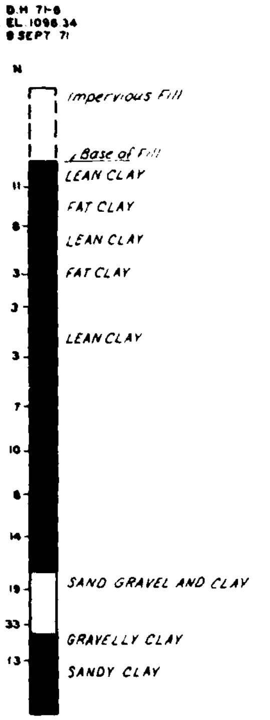
SITE 11

EVALUATION OF LIQUEFACTION POTENTIAL 200 FT. DOWNSTREAM OF EMBANKMENT ℄ (PROFILE 2-2)

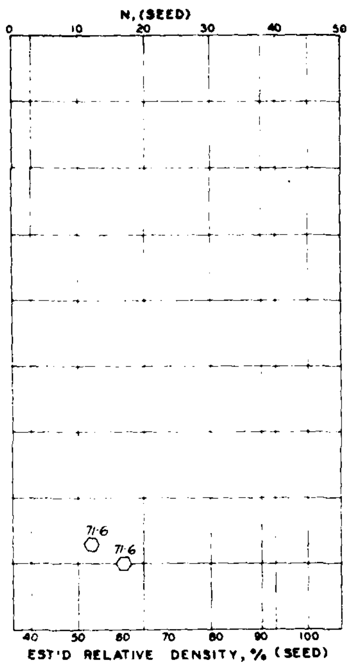
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA

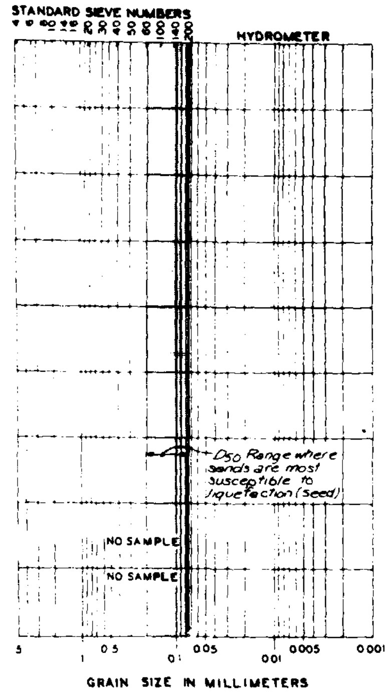


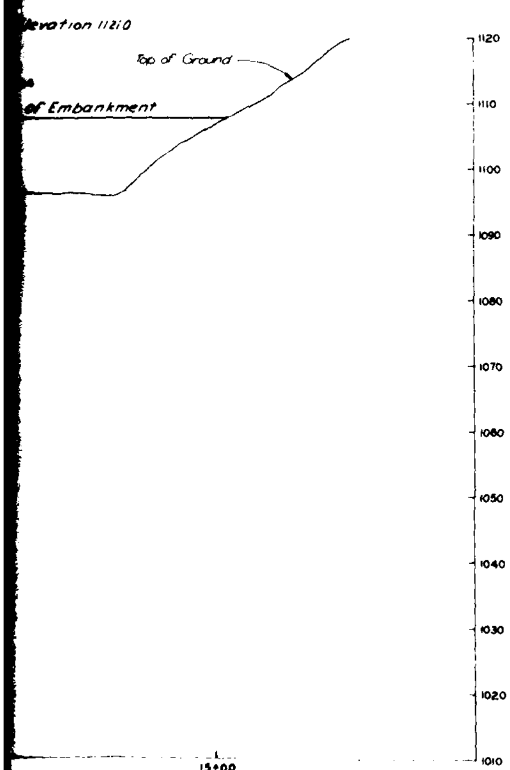
D H 71-2
EL 1098 42
30 AUG 71
Impervious Fill
Base of Fill
FAT CLAY
LEAN CLAY
SANDY GRAVEL
SANDY CLAY
D H 71-3
EL 1097 07
2 SEPT 71
Impervious Fill
Base of Fill
FAT CLAY
LEAN CLAY
FAT CLAY
LEAN CLAY
SILTY CLAY
SILT
SANDY GRAVEL - to 3" size
SANDY CLAY
D H 71-6
EL 1096 34
9 SEPT 71
Impervious Fill
Base of Fill
LEAN CLAY
FAT CLAY
LEAN CLAY
FAT CLAY
LEAN CLAY
SAND GRAVEL AND CLAY
GRAVELLY CLAY
SANDY CLAY
LOG OF BORING
Multipurpose Pool Elevation
D H 71-2
EL 1098 42
N1 (EST'D)
D H 71-3
EL 1097 07
N1 (EST'D)
D H 71-6
EL 1096 34
N1
Top of Embankment
Impervious Fill
0+00
5+00
10+00
15+00
PROFILE
205' U.S.
SCALE VERT 1 INCH= 10 FEET
HORIZ 1 INCH= 100 FEET



LOG OF BORINGS







SUMMARY OF EVALUATION											
HOLE NO.	DEPTH TO LAYER, FT.	DEPTH TO SAT'D ZONE, FT.	DEPTH OF SAT'D ZONE, FT.	UPLIFT AT BASE OF LAYER, FT.	UPLIFT PRESSURE P S F	TOTAL OVB. PRESSURE P S F	EFF. OVB. PRESSURE P S F	C S R FROM DESIGN ETHOK	N_1	RESISTING C. S. R. (SPT)	F. S. AGAINST LIQUEF. (SPT)
71-2	75	0	75	75	4,650	9,300	4,650	0.1048	12	0.17	1.6
71-3	84	0	84	84	5,208	10,416	5,208	0.1053	12	0.17	1.6
71-6	76	0	76	76	4,712	9,424	4,712	0.1092	12	0.17	1.6
71-6	82	0	82	82	5,084	10,168	5,084	0.1053	17	0.24	2.3

NOTE
For Legend see Plate

PAPILLION CREEK AND TRIBUTARIES LAKES, NEBRASKA

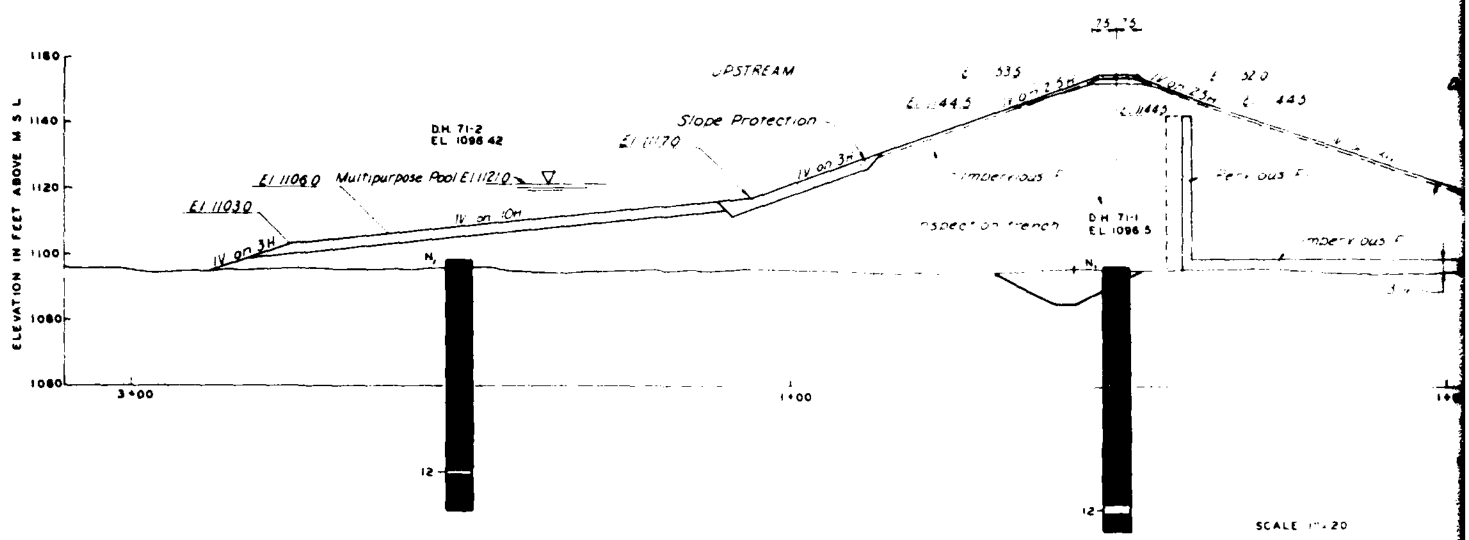
SITES 11 AND 16

SEISMIC EVALUATION

SITE 11

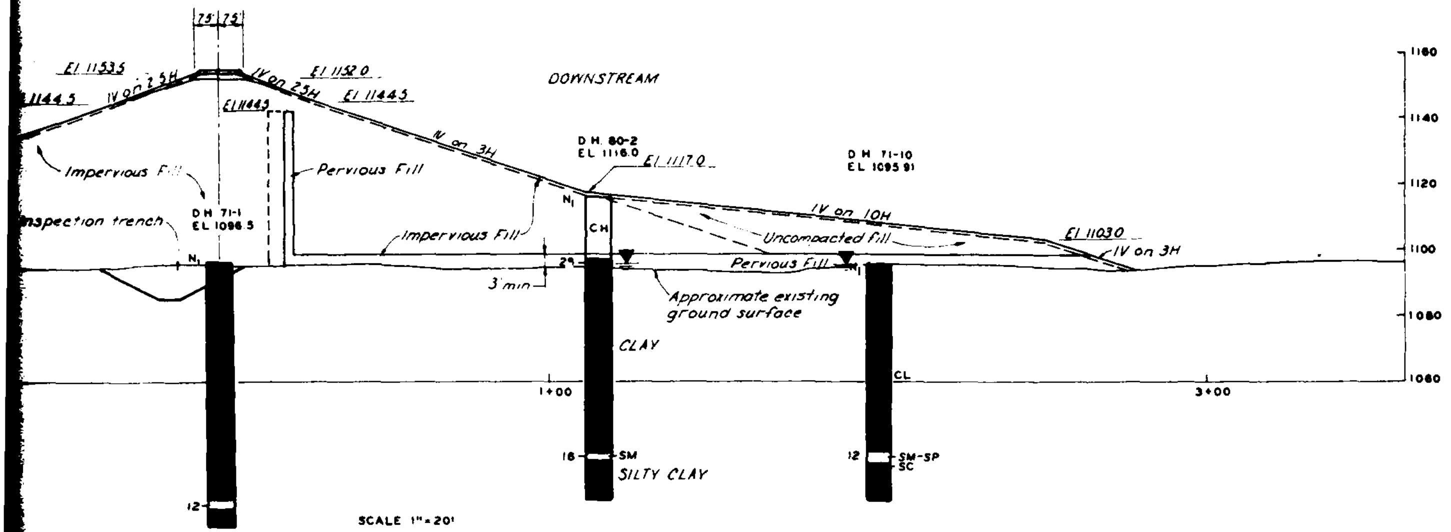
EVALUATION OF LIQUEFACTION POTENTIAL
205 FT. UPSTREAM OF
EMBANKMENT ℄ (PROFILE 3-3)

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA



SECTION 4 11/16

SUMMARY OF EVALUATION											
HOLE NO.	DEPTH TO LAYER, FT.	DEPTH TO SAT'D ZONE, FT.	DEPTH OF SAT'D ZONE, FT.	UPLIFT AT BASE OF LAYER, FT.	UPLIFT PRESSURE P S F	TOTAL OVB. PRESSURE P S F	EFF. OVB. PRESSURE P S F	C S R FROM DESIGN ETHQK.	N_1	RESISTING C. S. R. (SPT)	F. S. AGAINST LIQUEF. (SPT.)
71-2	75	0	75	75	4,650	9,300	4,650	0.1048	12	0.17	1.6
71-1	133	35	98	98	6,076	16,352	10,276	0.0672	12	0.17	2.5
80-2	20	20	0	0	0	2,400	2,400	0.0802	28	0.43	5.3
80-2	80	20	60	60	3,720	9,840	6,120	0.0747	18	0.25	3.3
71-10	73	13	60	60	3,720	9,000	5,280	0.0835	12	0.17	2.0



SECTION 4 11|16

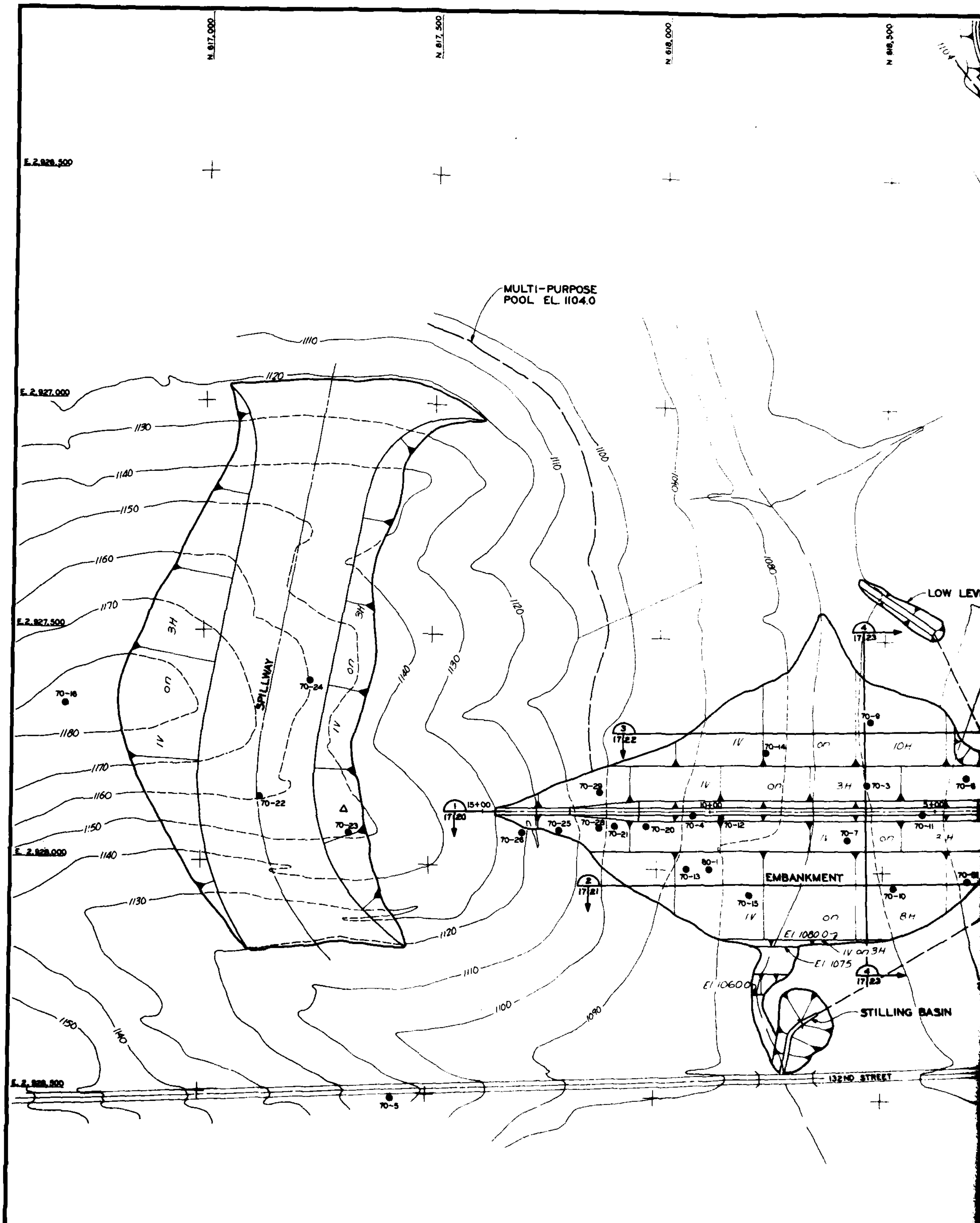
EFF. OVB. PRESSURE P S F	C S R FROM DESIGN ETHQK.	N_1	RESISTING C. S. R. (SPT)	F. S. AGAINST LIQUEF. (SPT.)
4,650	0.1048	12	0.17	1.6
10,276	0.0672	12	0.17	2.5
2,480	0.0802	28	0.43	5.3
6,120	0.0747	18	0.25	3.3
5,280	0.0835	12	0.17	2.0

NOTE
1 For Legend see Plate 11

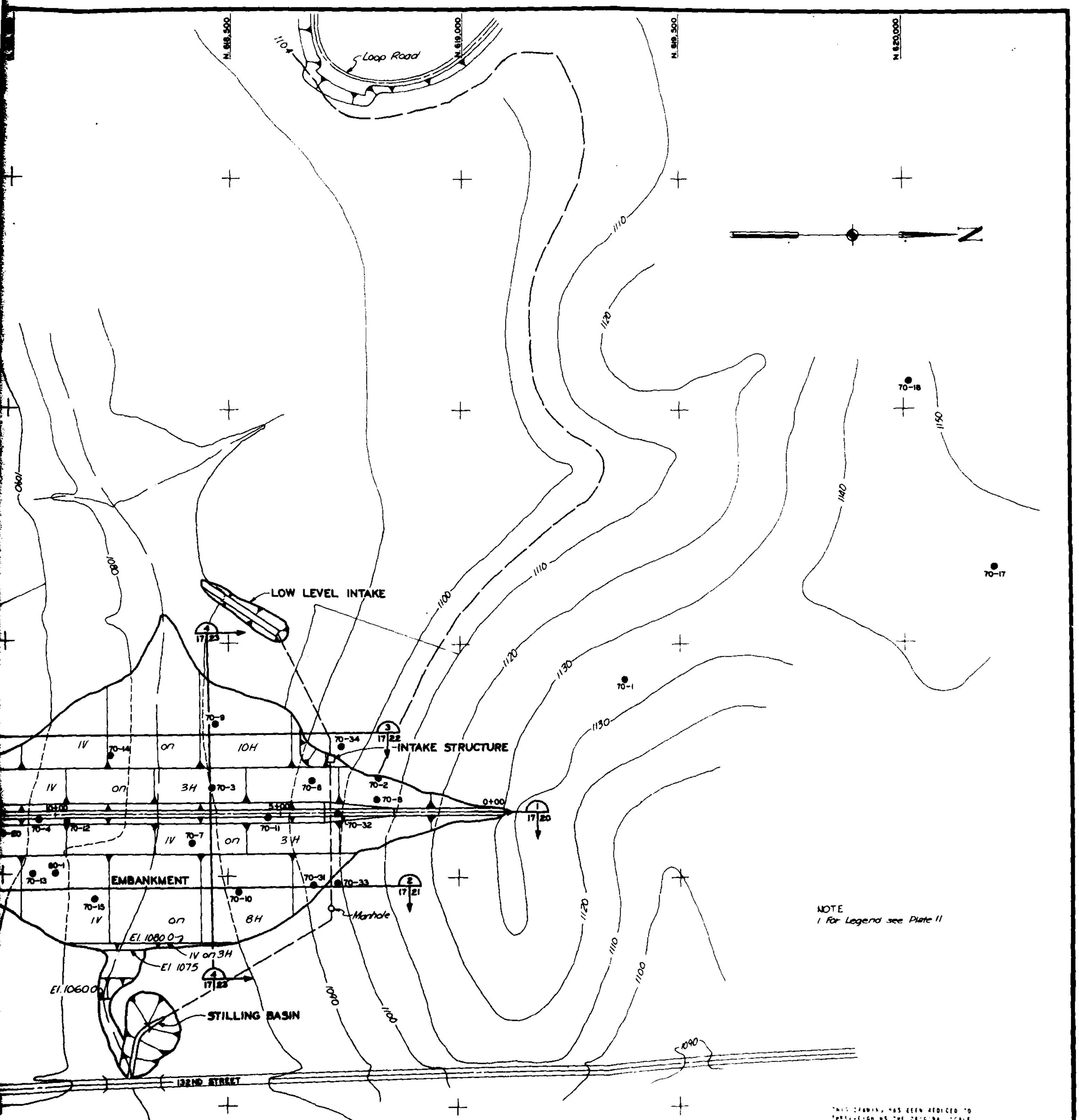
PAPILLION CREEK AND TRIBUTARIES LAKES, NEBRASKA
SITES 11 AND 16
SEISMIC EVALUATION
SITE 11
EVALUATION OF LIQUEFACTION POTENTIAL
ALONG SECTION 4-4 (STA. 7+00)

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA

$$ – THINK VALUE ENGINEERING – $$



N 817,000
N 817,500
N 818,000
N 818,500
E 2,926,500
E 2,927,000
E 2,927,500
E 2,928,000
E 2,928,500
MULTI-PURPOSE
POOL EL 1104.0
SPILLWAY
EMBANKMENT
STILLING BASIN
LOW LEVE
132ND STREET



PAPILLION CREEK AND TRIBUTARIES LAKES, NEBRASKA

SITES 11 AND 16

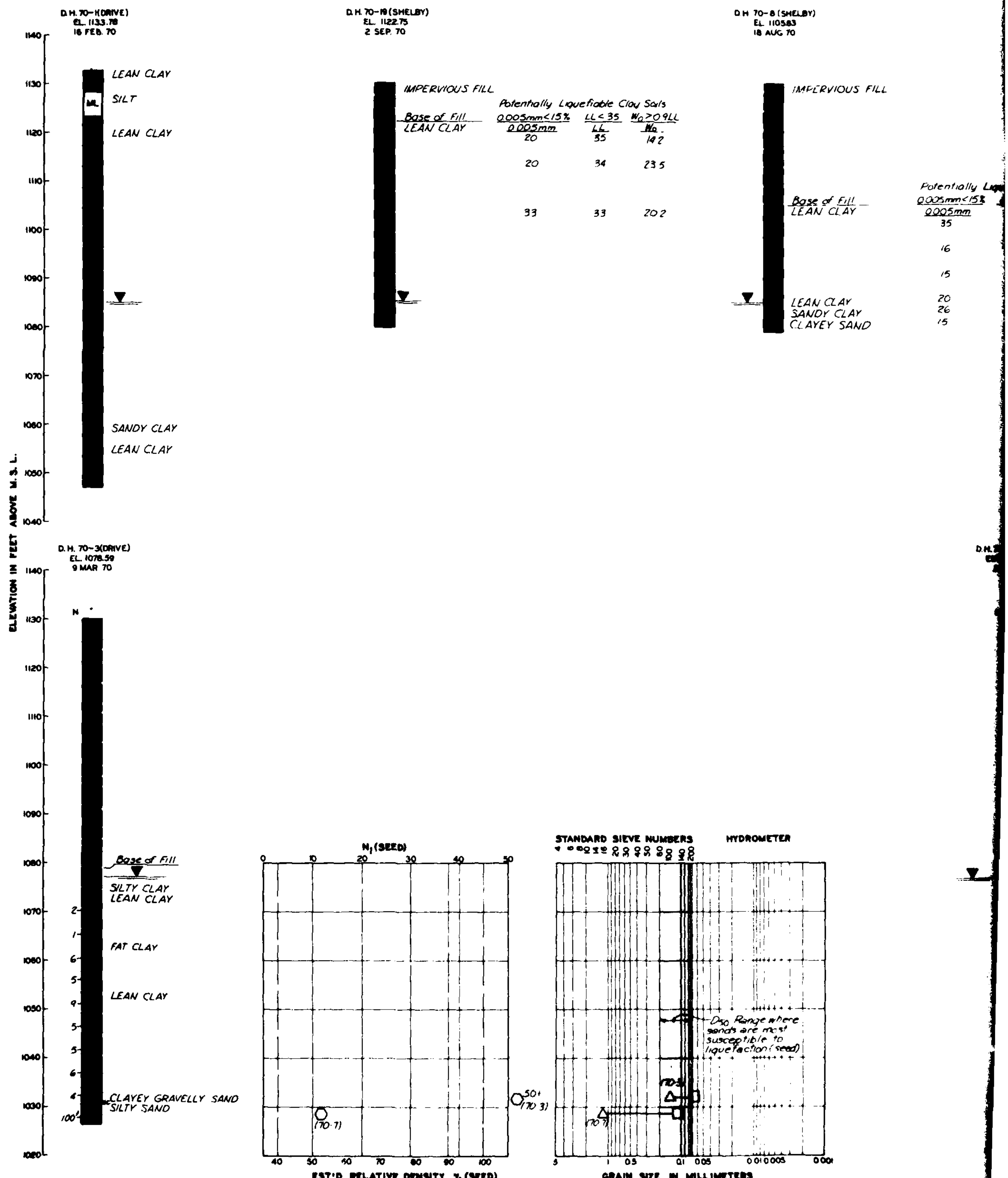
SEISMIC EVALUATION

SITE 16

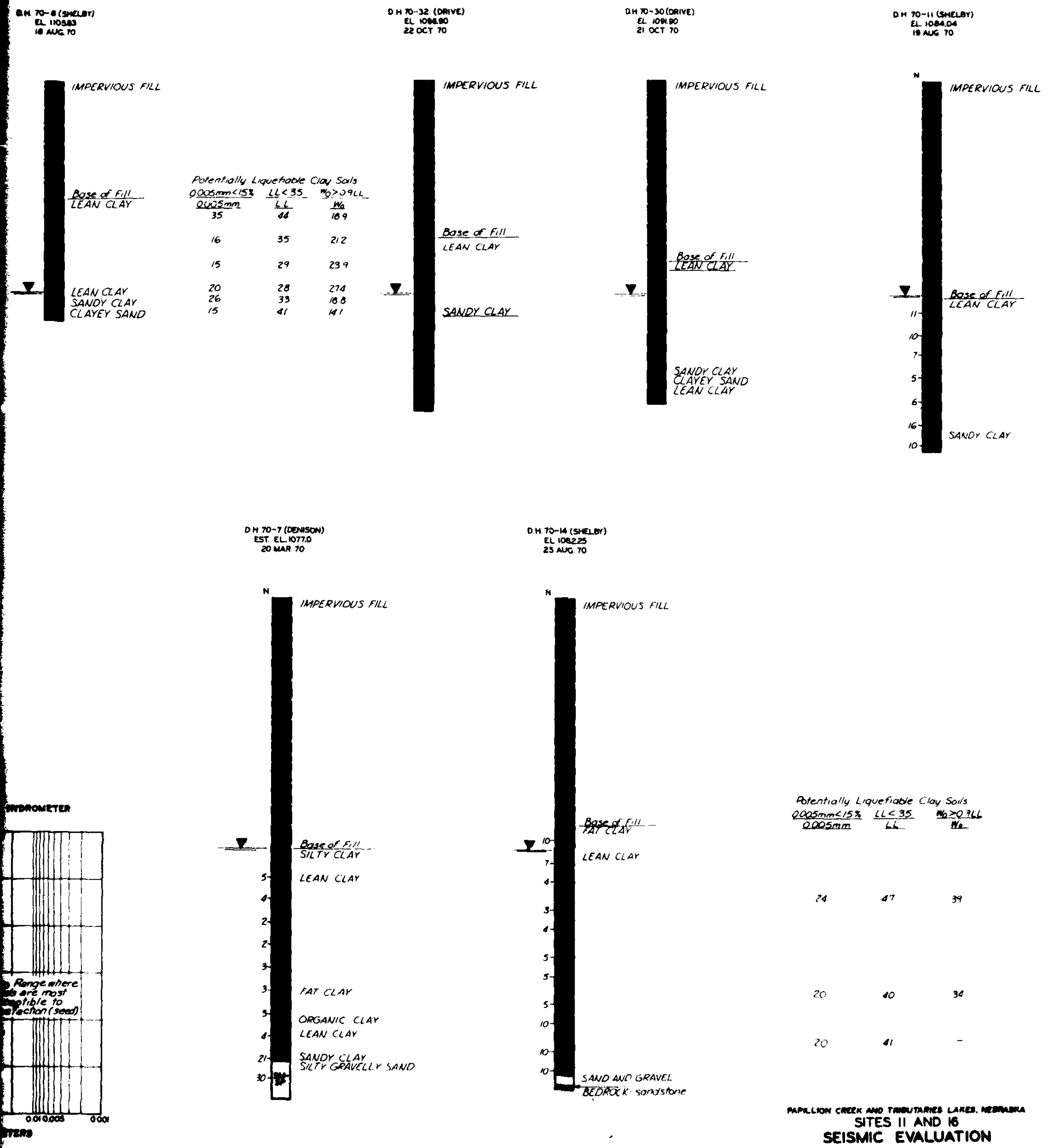
GENERAL PLAN AND PLAN OF BORINGS

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA

$$ – THINK VALUE ENGINEERING – $$

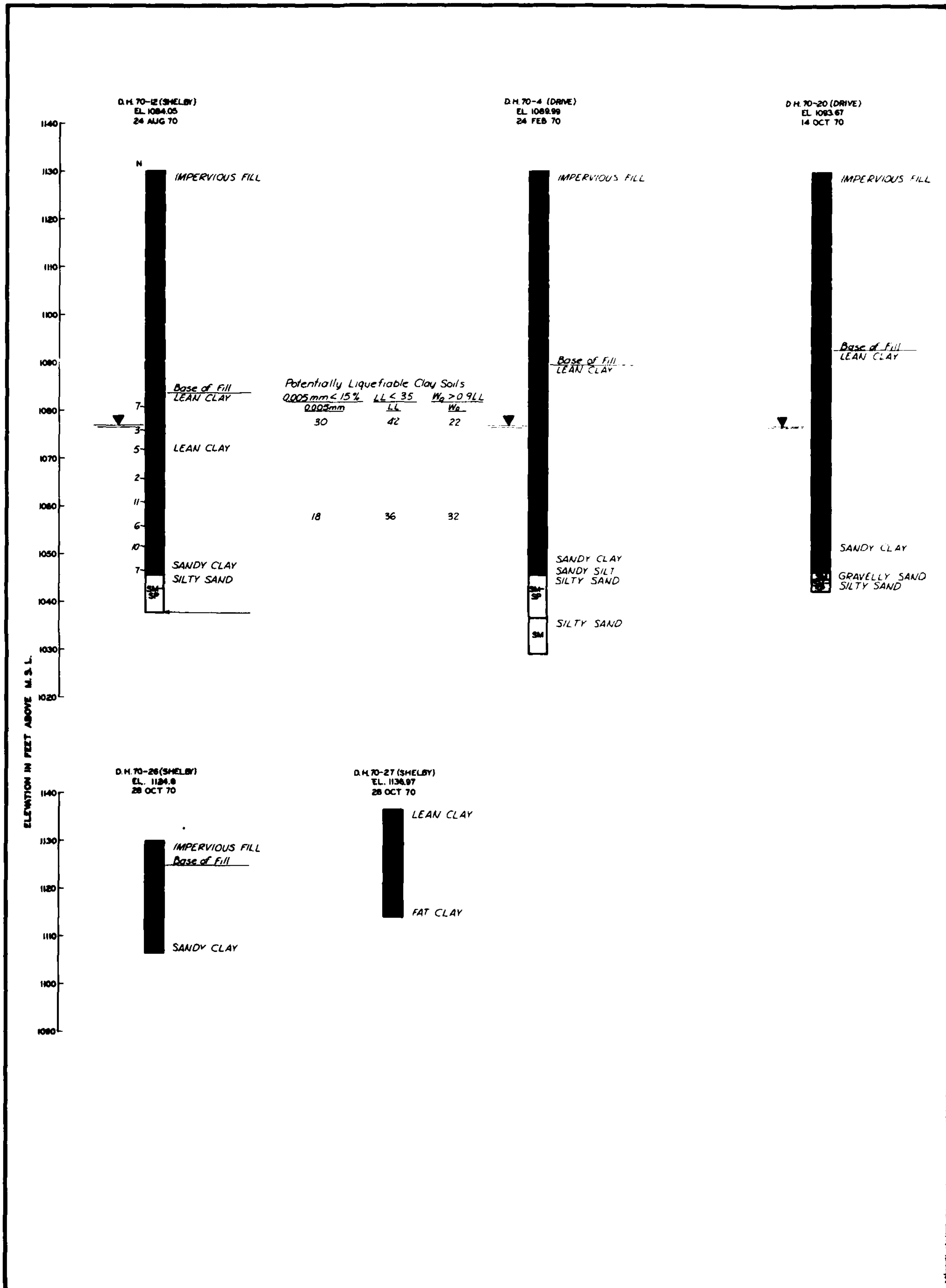


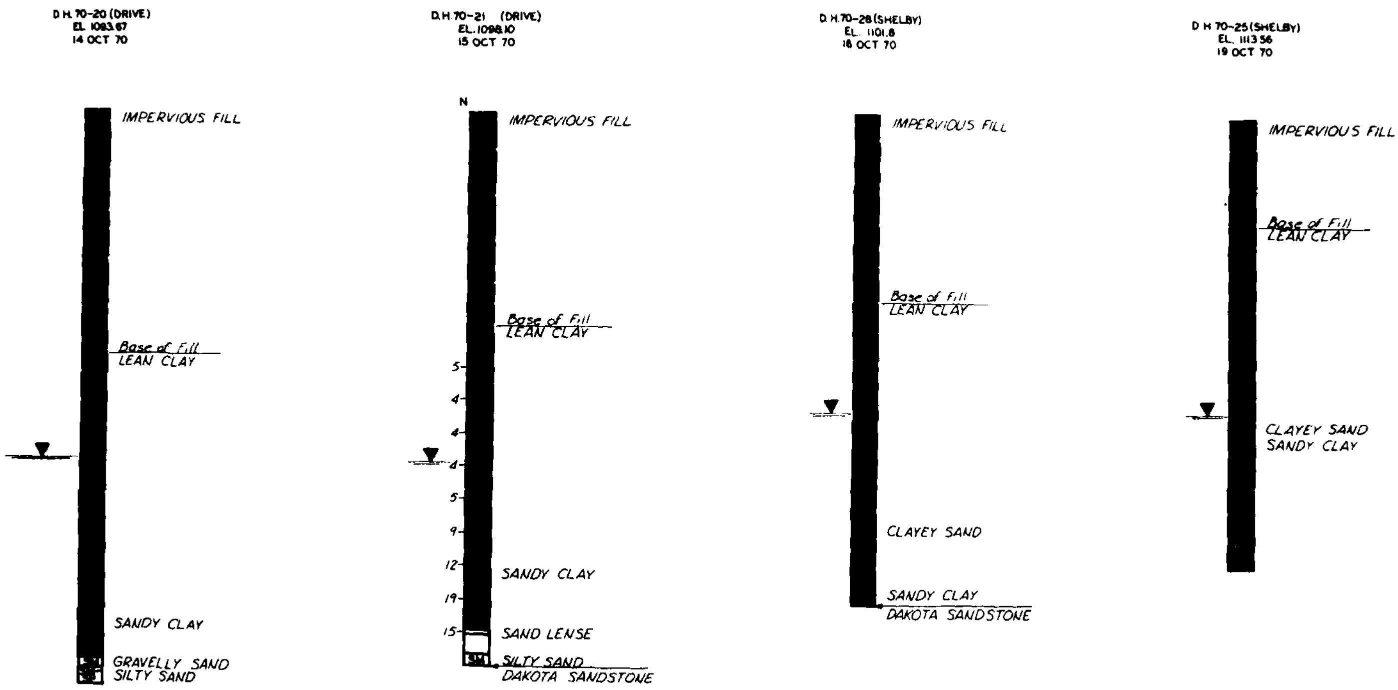
D.H. 70-1(DRIVE)
EL. 1133.78
16 FEB. 70
D.H. 70-19 (SHELBY)
EL. 1122.75
2 SEP. 70
D.H. 70-8 (SHELBY)
EL. 1105.83
18 AUG 70
ELEVATION IN FEET ABOVE M.S.L.
LEAN CLAY
SILT
LEAN CLAY
SANDY CLAY
LEAN CLAY
IMPERVIOUS FILL
Potentially Liquefiable Clay Soils
Base of Fill
LEAN CLAY
0.005mm<15%
LL<35
Wo>0.9LL
SANDY CLAY
CLAYEY SAND
D.H. 70-3(DRIVE)
EL. 1078.59
9 MAR 70
SILTY CLAY
FAT CLAY
CLAYEY GRAVELLY SAND
SILTY SAND
N1 (SEED)
EST'D RELATIVE DENSITY, % (SEED)
STANDARD SIEVE NUMBERS
HYDROMETER
D50 Range where sands are most susceptible to liquefaction (seed)
GRAIN SIZE IN MILLIMETERS



NOTE
1 For Legend see Plate 11

PAPILLION CREEK AND TRIBUTARIES LAKES, NEBRASKA
SITES 11 AND 16
SEISMIC EVALUATION
SITE 16
LOG OF BORINGS
ALONG EMBANKMENT ℄ (PROFILE 1-1)
SHEET 1 OF 2
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA

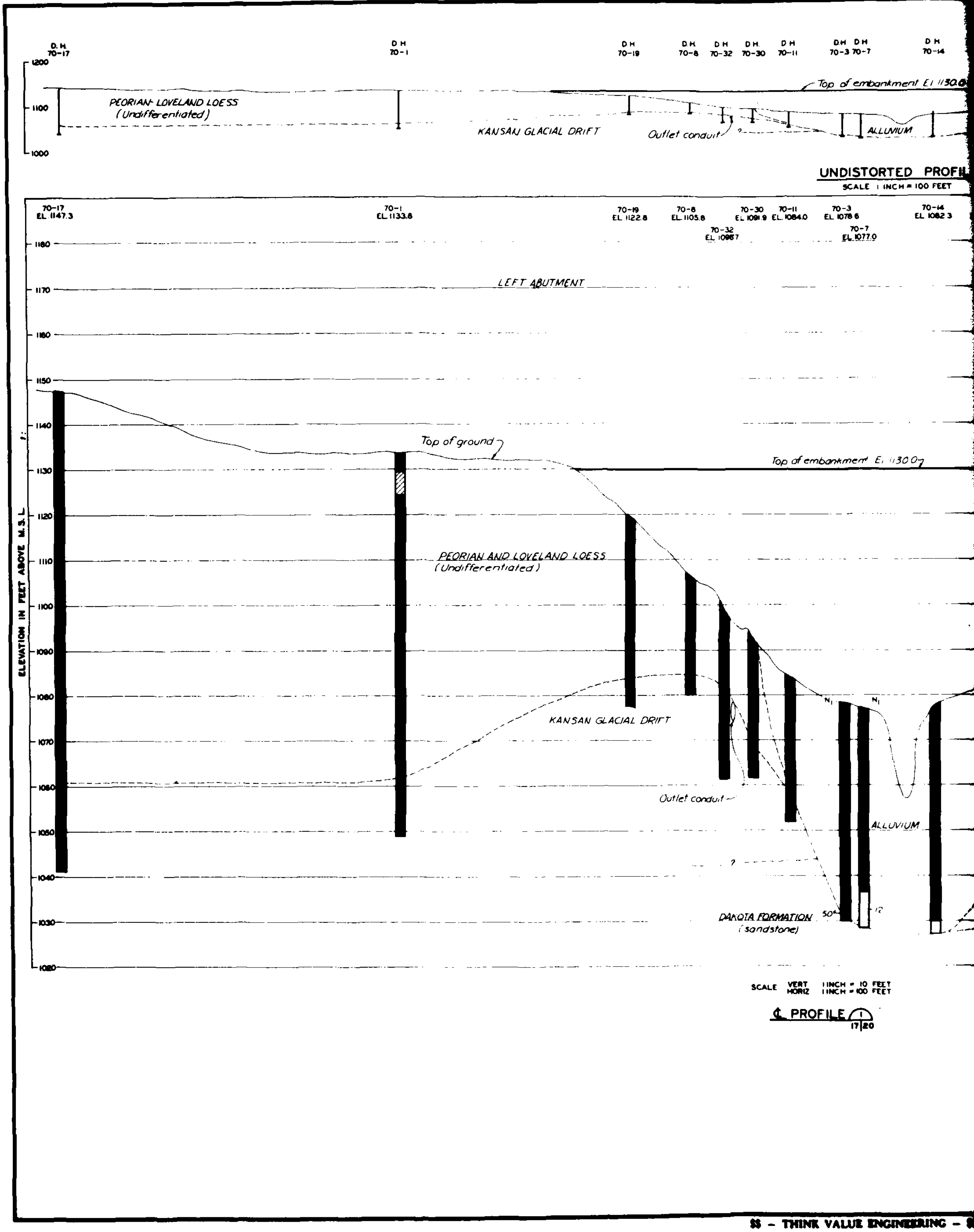

D.H. 70-12 (SHELBY)
EL 1084.05
24 AUG 70
D.H. 70-4 (DRIVE)
EL 1089.99
24 FEB 70
D.H. 70-20 (DRIVE)
EL 1093.67
14 OCT 70
IMPERVIOUS FILL
Base of Fill
LEAN CLAY
SANDY CLAY
SILTY SAND
SANDY SILT
GRAVELLY SAND
SM-SP
SM
Potentially Liquefiable Clay Soils
0.005mm < 15%
LL < 35
Wo > 0.9LL
30
42
22
18
36
32
ELEVATION IN FEET ABOVE M.S.L.
D.H. 70-26 (SHELBY)
EL. 1134.6
28 OCT 70
D.H. 70-27 (SHELBY)
EL. 1136.97
28 OCT 70
FAT CLAY

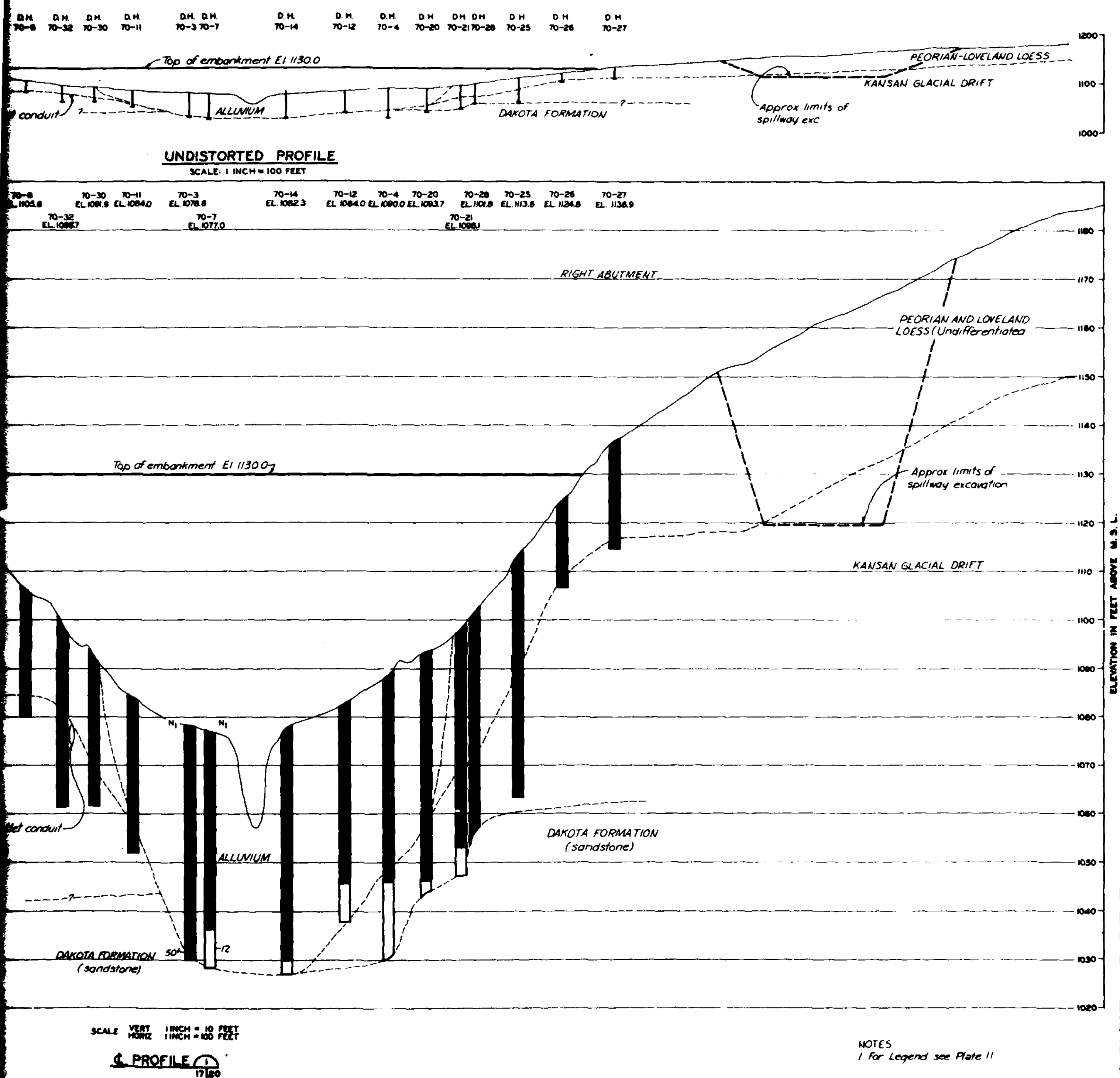


NOTE
1 For Legend see Plate 11

PAPILLION CREEK AND TRIBUTARIES LAKES, NEBRASKA
SITES 11 AND 18
SEISMIC EVALUATION
SITE 18
LOG OF BORINGS
ALONG EMBANKMENT ℄ (PROFILE 1-1)
SHEET 2 OF 2
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA

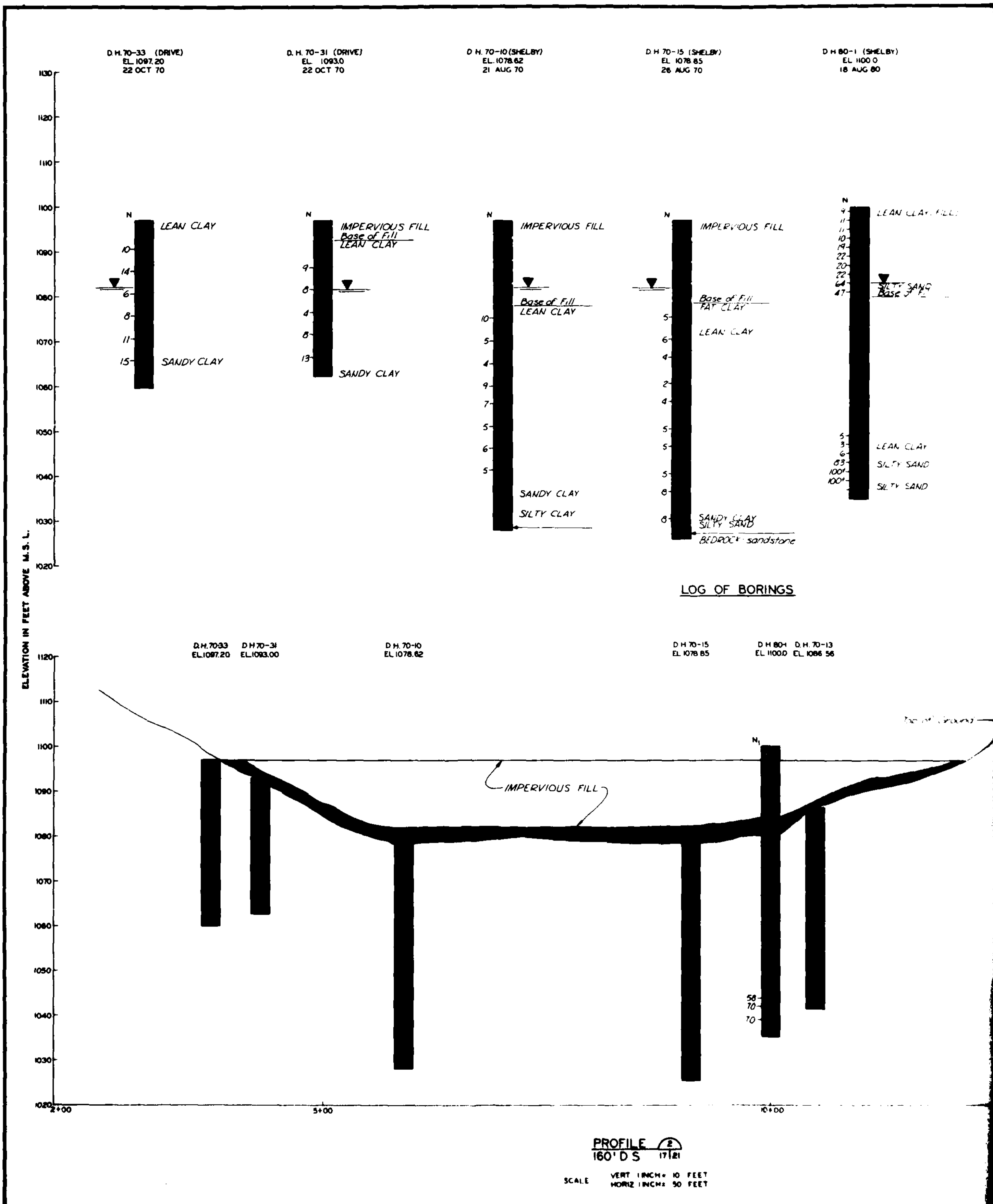
$$ – THINK VALUE ENGINEERING – $$


D. H. 70-17
D H 70-1
D H 70-19
D H 70-8
D H 70-32
D H 70-30
D H 70-11
D H 70-3
D H 70-7
D H 70-14
1200
1100
1000
Top of embankment El 1130.0
PEORIAN-LOVELAND LOESS (Undifferentiated)
KANSAN GLACIAL DRIFT
Outlet conduit
ALLUVIUM
UNDISTORTED PROFIL
SCALE 1 INCH = 100 FEET
70-17 EL 1147.3
70-1 EL 1133.8
70-19 EL 1122.8
70-8 EL 1105.8
70-32 EL 1096.7
70-30 EL 1091.9
70-11 EL 1084.0
70-3 EL 1078.6
70-7 EL 1077.0
70-14 EL 1082.3
LEFT ABUTMENT
Top of ground
Top of embankment El 1130.0
ELEVATION IN FEET ABOVE M.S.L.
PEORIAN AND LOVELAND LOESS (Undifferentiated)
KANSAN GLACIAL DRIFT
Outlet conduit
ALLUVIUM
DAKOTA FORMATION (sandstone)
SCALE VERT 1 INCH = 10 FEET
HORIZ 1 INCH = 100 FEET
℄ PROFILE 1 17|20

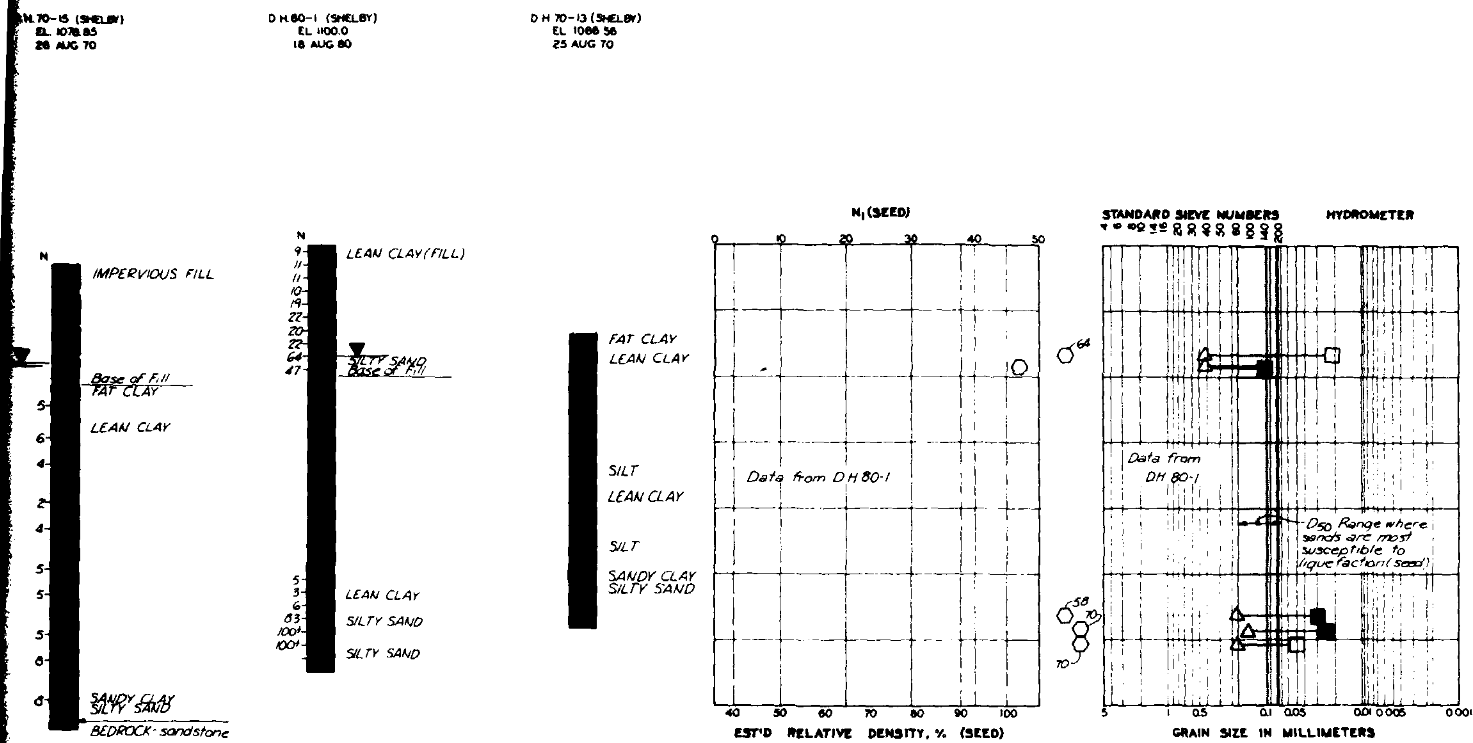


NOTES
1 For Legend see Plate 11

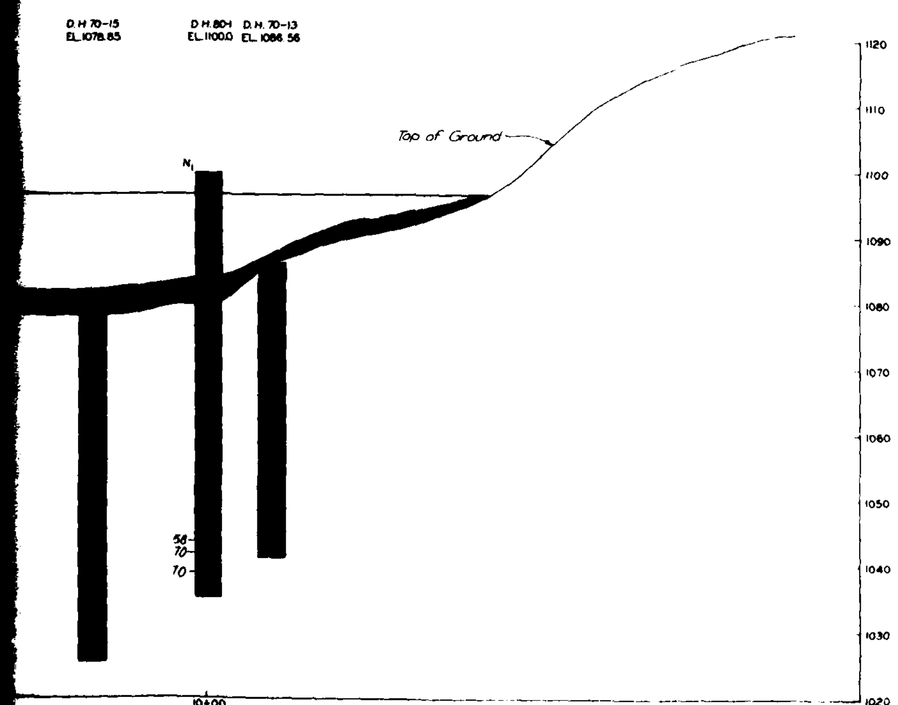
PAPILLION CREEK AND TRIBUTARIES LAKES, NEBRASKA
SITES 11 AND 16
SEISMIC EVALUATION
SITE 16
GEOLOGIC PROFILE
ALONG EMBANKMENT ℄
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA



D.H. 70-33 (DRIVE)
EL. 1097.20
22 OCT 70
D.H. 70-31 (DRIVE)
EL. 1093.0
22 OCT 70
D.H. 70-10 (SHELBY)
EL. 1078.62
21 AUG 70
D.H. 70-15 (SHELBY)
EL. 1078.85
26 AUG 70
D.H. 80-1 (SHELBY)
EL. 1100.0
18 AUG 80
ELEVATION IN FEET ABOVE M.S.L.
LEAN CLAY
SANDY CLAY
IMPERVIOUS FILL
Base of Fill
LEAN CLAY
SANDY CLAY
IMPERVIOUS FILL
Base of Fill
LEAN CLAY
SANDY CLAY
SILTY CLAY
IMPERVIOUS FILL
Base of Fill
FAT CLAY
LEAN CLAY
SANDY CLAY
SILTY SAND
BEDROCK sandstone
LEAN CLAY FILL
SILTY SAND
LEAN CLAY
SILTY SAND
SILTY SAND
LOG OF BORINGS
D.H. 70-33
EL. 1097.20
D.H. 70-31
EL. 1093.00
D.H. 70-10
EL. 1078.62
D.H. 70-15
EL. 1078.85
D.H. 80-1
EL. 1100.0
D.H. 70-13
EL. 1086.56
Top of Ground
IMPERVIOUS FILL
2+00
5+00
10+00
PROFILE
160' D S
SCALE
VERT 1 INCH = 10 FEET
HORIZ 1 INCH = 50 FEET



LOG OF BORINGS



PAPILLION CREEK AND TRIBUTARIES LAKES, NEBRASKA

SITES 11 AND 16

SEISMIC EVALUATION

SITE 16

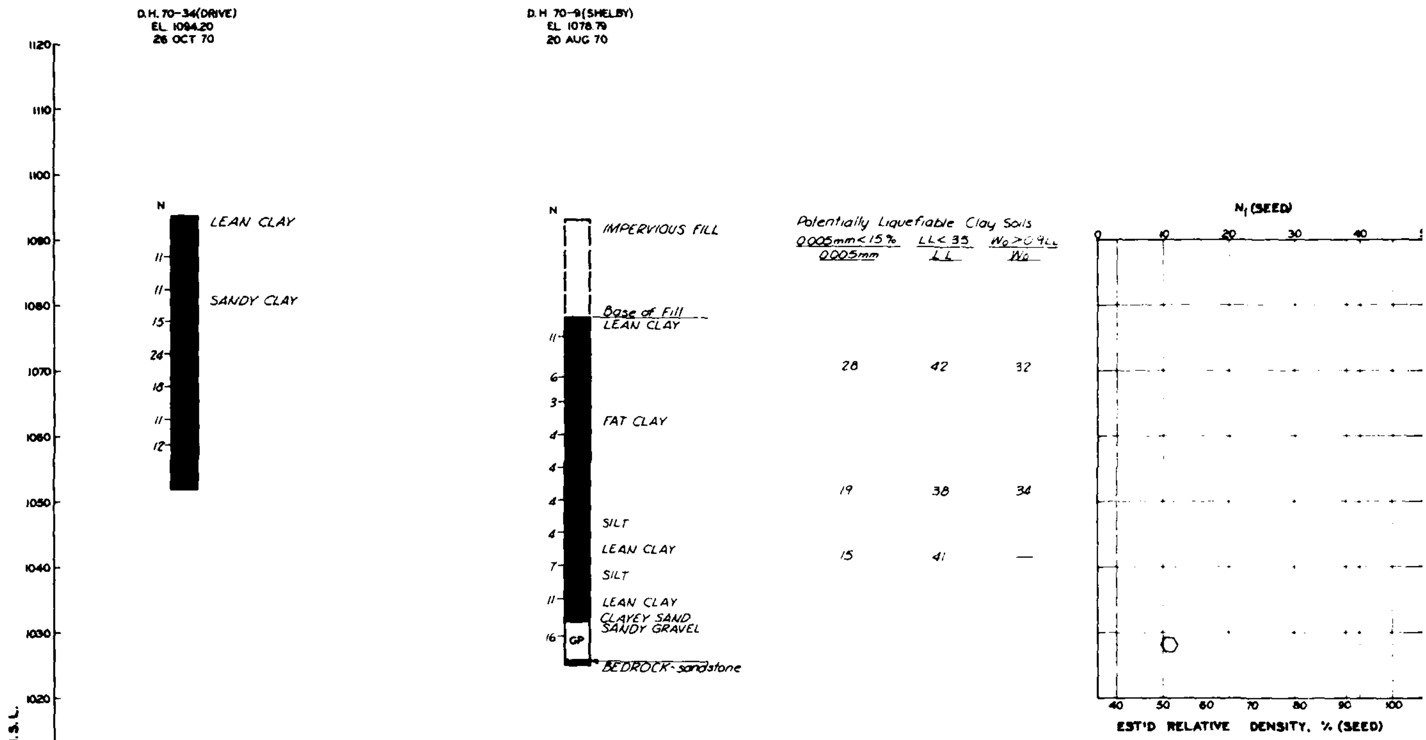
LOGS OF BORINGS

ALONG GEOLOGIC PROFILE

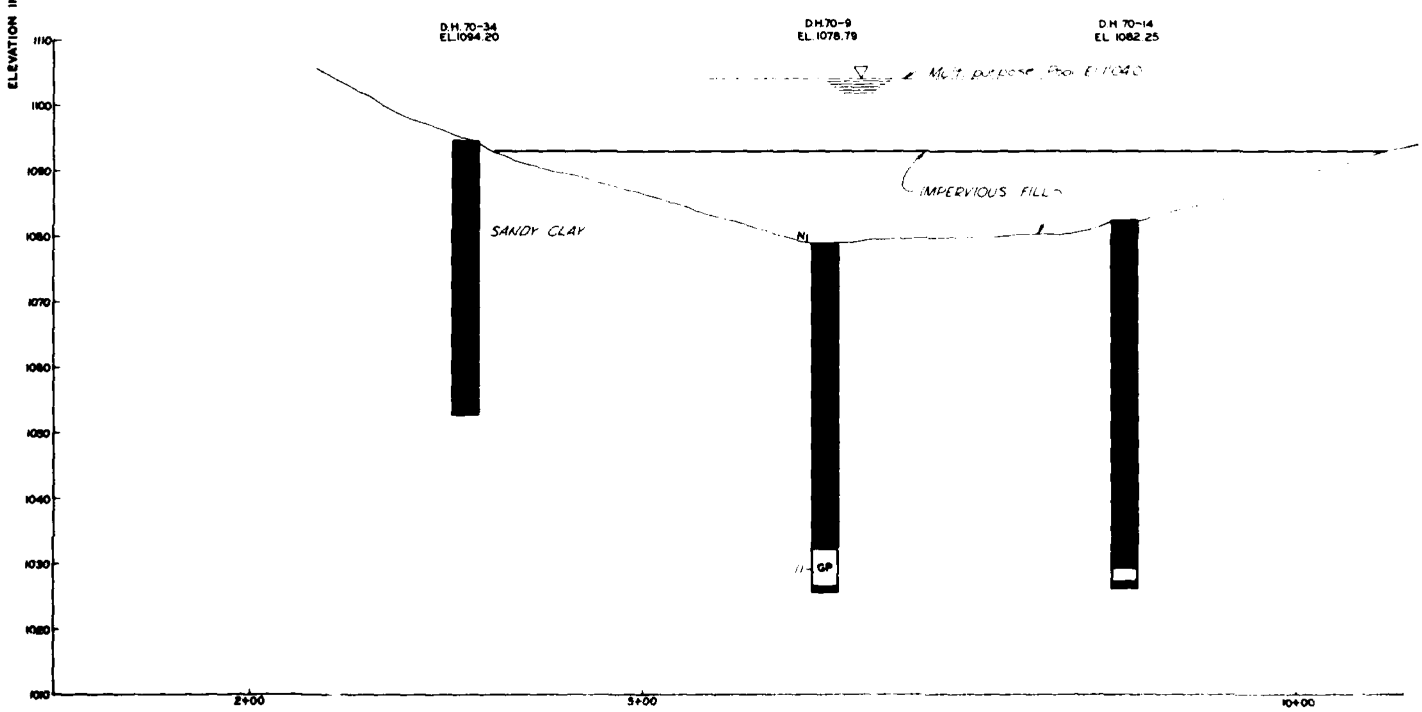
160 FT DOWNSTREAM OF ℄ (PROFILE 2-2)

U.S. ARMY ENGINEER DISTRICT, OMAHA

CORPS OF ENGINEERS OMAHA, NEBRASKA

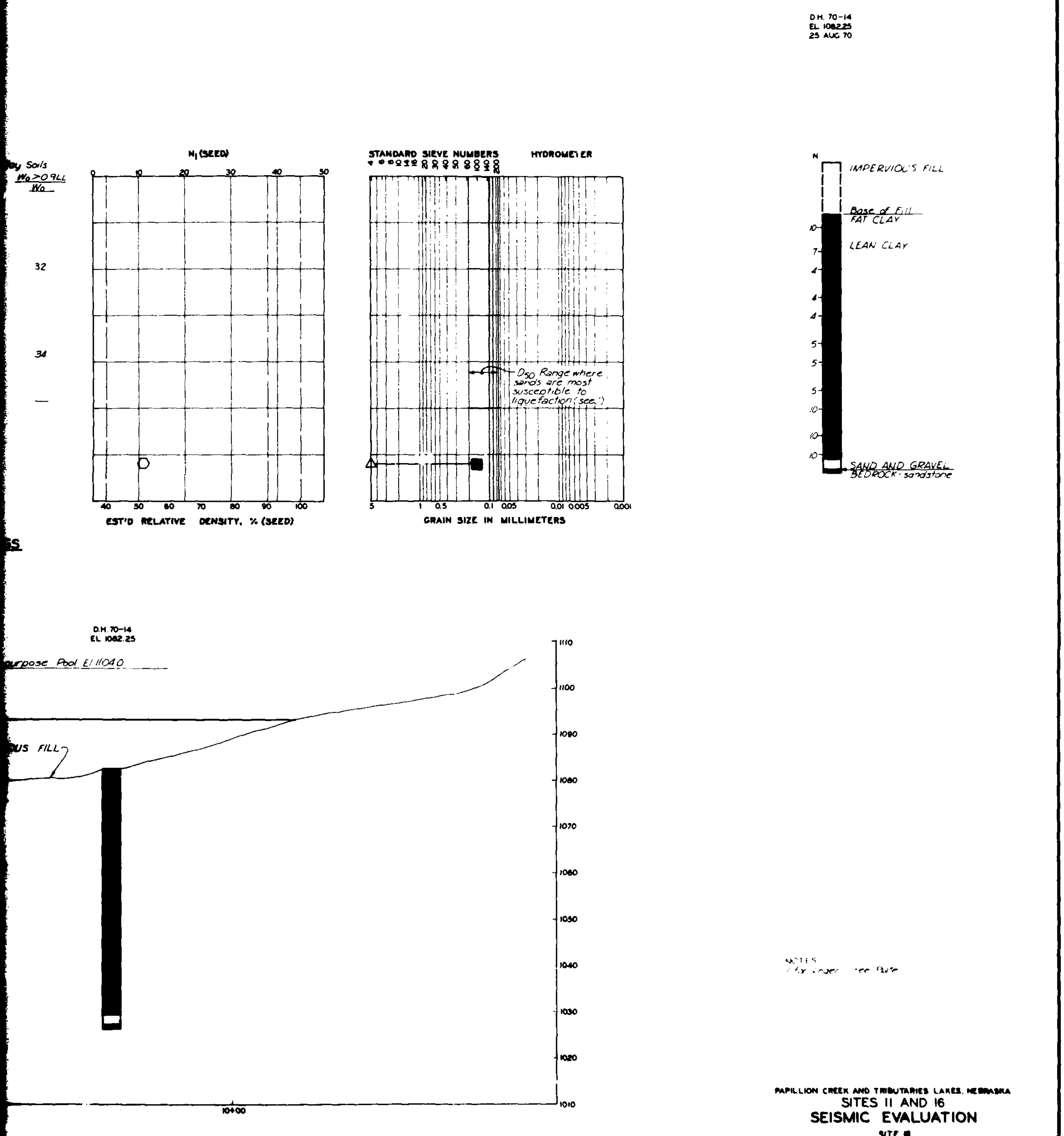


LOG OF BORINGS



PROFILE
175' U S

SCALE VERT 1 INCH = 10 FEET
HORIZ 1 INCH = 50 FEET



PAPILLION CREEK AND TRIBUTARIES LAKES, NEBRASKA

SITES 11 AND 16

SEISMIC EVALUATION

SITE 16

LOG OF BORINGS
ALONG GEOLOGIC PROFILE
175 FT UPSTREAM OF ℄ (PROFILE 3-3)

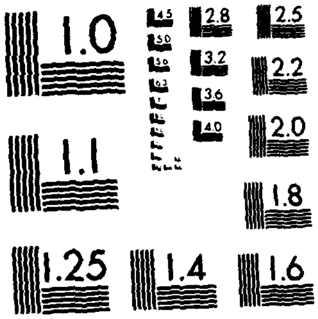
U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA

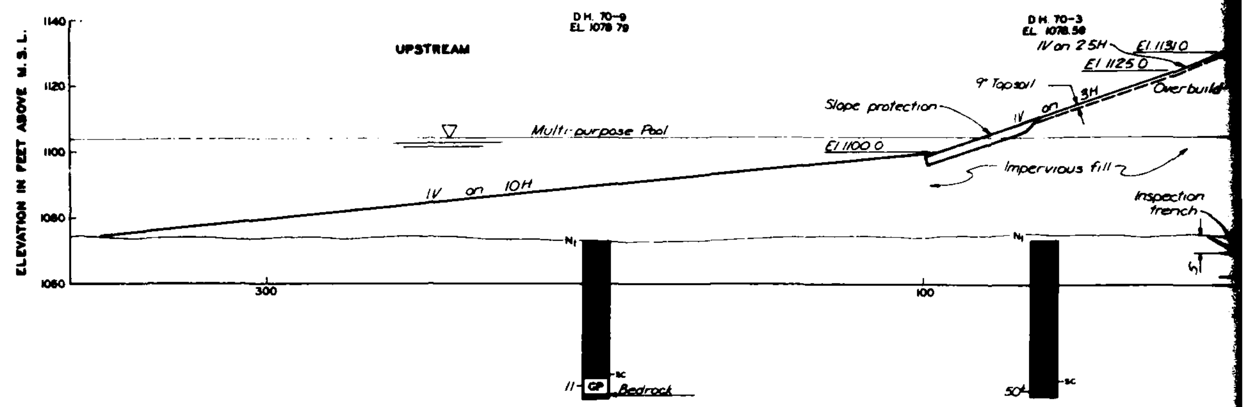
AD-A142 954 EVALUATION OF EMBANKMENT AND FOUNDATION LIQUEFACTION POTENTIAL PAPILLION..(U) CORPS OF ENGINEERS OMAHA NE MAY 83

2/2

UNCLASSIFIED F/G 13/13 NL

END
DATE
FILMED
8 84
DTIC

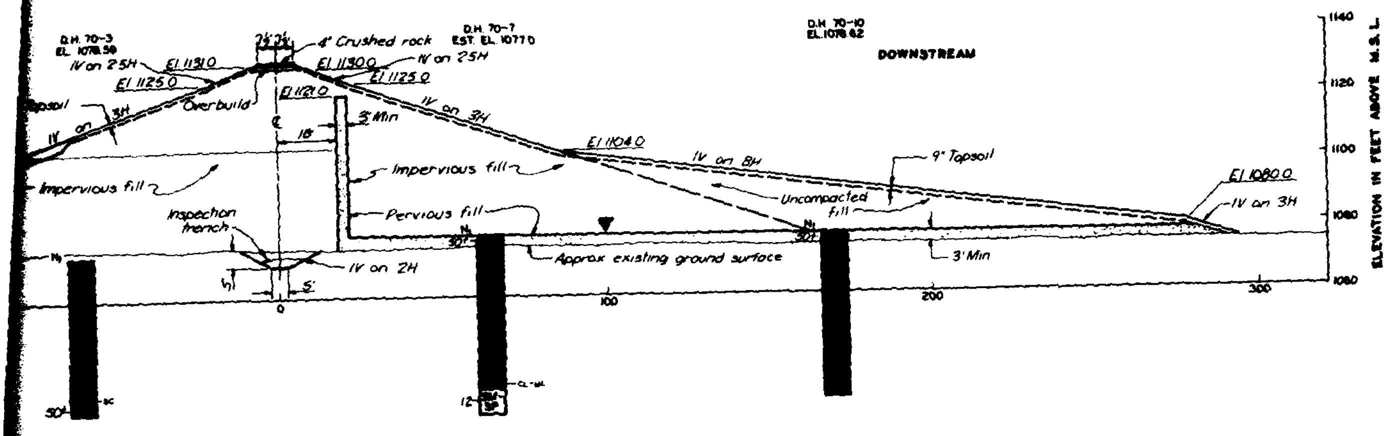

1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0



SECT

SCALE: 8
20

SUMMARY OF EVALUATION										
HOLE NO.	DEPTH TO LAYER, FT.	DEPTH TO SAT'D ZONE, FT.	DEPTH OF SAT'D ZONE, FT.	UPLIFT AT BASE OF LAYER, FT.	UPLIFT PRESSURE PSF	TOTAL OVB. PRESSURE PSF	EFF. OVB. PRESSURE PSF	C S R FROM DESIGN ETHQK.	N_1	RESISTING C S R (SPT)
70-9	60	0	60	60	3720	7440	3,720	0.1098	11	0.16
70-3	83	6	77	77	4774	10,268	5,494	0.0869	50+	0.50+
70-7	35	34	1	1	62	4,204	4,142	0.0771	50+	0.50+
70-7	85	34	51	51	3,162	10,404	7,242	0.0667	12	0.17
7-10	17	15	2	2	124	2,048	1924	0.0854	50+	0.50+



SECTION 4/17 23

SCALE: 1 INCH = 20 FEET

EFF. OVB. PRESSURE PSF	C S R FROM DESIGN ETHQK.	N_1	RESISTING C S R (SPT)	F. S. AGAINST LIQUEF. (SPT)
[illegible],720	0.1098	11	0.16	1.5
[illegible],604	0.0869	50+	0.50+	5.8
[illegible],142	0.0771	50+	0.50+	6.5
7,242	0.0667	12	0.17	2.5
3920	0.0854	50+	0.50+	5.8

NOTE
1. For Legend see Plate 11

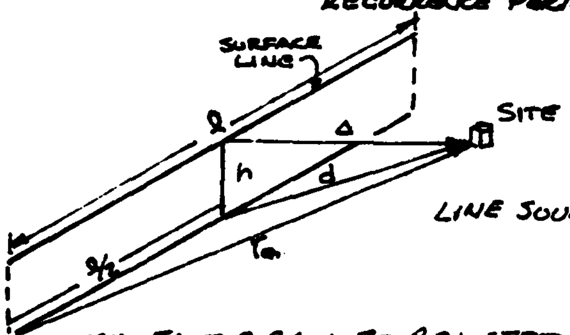
PAPILLION CREEK AND TRIBUTARIES LAKES, NEBRASKA
SITES 11 AND 16
SEISMIC EVALUATION
SITE 16
EVALUATION OF LIQUEFACTION POTENTIAL
ALONG SECTION 4-4 (STA. 8+00)

U.S. ARMY ENGINEER DISTRICT, OMAHA
CORPS OF ENGINEERS OMAHA, NEBRASKA

PLATE 22

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT Seismic Hazard Analysis - Papio 11 and 16	SHEET NO.	OF
ITEM Cornell's (1968) Equations for Calculating Maximum Intensities at a Site from a Line Source	BY Becker	DATE
	CHKD. BY	DATE

M_0 = MAXIMUM MAGNITUDE QUAKE ALONG SOURCE RECURRING IN 1000 YRS
Δ = DISTANCE (Km) FROM DAM TO CLOSEST POINT ON SOURCE
h = FOCAL DEPTH - ASSUMED TO BE 20 Km.
$d = \sqrt{\Delta^2 + h^2}$ = DISTANCE (Km) TO PT 20 Km BELOW CLOSEST PT ON SOURCE
ℓ = LENGTH OF SOURCE (Km)
$b = .92$ = SLOPE OF LINE RELATING CUM. ANN. FREQ. VS. MAGNITUDE
$\beta = b \ln 10 = 2.1$
$C_1 = .21$, $C_2 = 2.0$, $C_3 = 1.3$ } COEFFICIENTS FROM EQUATION RELATING INTENSITY TO MAGNITUDE See Page A3
N_{m_0} = RECURRENCE ANNUAL FREQ. FOR m_0 - CHOSEN AT .001
$\ell/2$ = HALF LENGTH OF SOURCE
$r_0 = \sqrt{d^2 + \ell^2/4}$ SEE DIAGRAM BELOW
$\hat{\nu}$ = EVENTS/YR/ℓ FREQUENCY OVER LENGTH OF SOURCE
$\gamma = \beta C_3/C_2 - 1 = .37$ USED IN DETERMINING GEOMETRY FACTOR G
$C = e^{(\beta(C_1/C_2 + M_0))} = e^{(2.1(\frac{.21}{2} + M_0))}$
r_0/d = USED FOR DETERMINING Γ FUNCTION VALUE
$\Gamma(\gamma)$, $\Gamma(\frac{\gamma+1}{2}) = \Gamma(.68) =$ } READ FROM GRAPH (SEE NEXT PAGE)
$G = \frac{2\pi}{(2\times d)^\gamma} \frac{\Gamma(\gamma)}{[\Gamma(\frac{\gamma+1}{2})]^2}$ = GEOMETRY FACTOR FOR SOURCE
T_i = RECURRENCE PERIOD OF EARTHQUAKE OF INTEREST
$i = \frac{C_2}{\beta} \ln(\hat{\nu} C G T_2)$ = MAX. INTENSITY AT SITE IN 1000 YRS GIVEN THAT MAX. MAGNITUDE OCCURRING ONCE IN 1000 YRS IS M_0 (T_2 = 1000 YR RECURRENCE PERIOD)

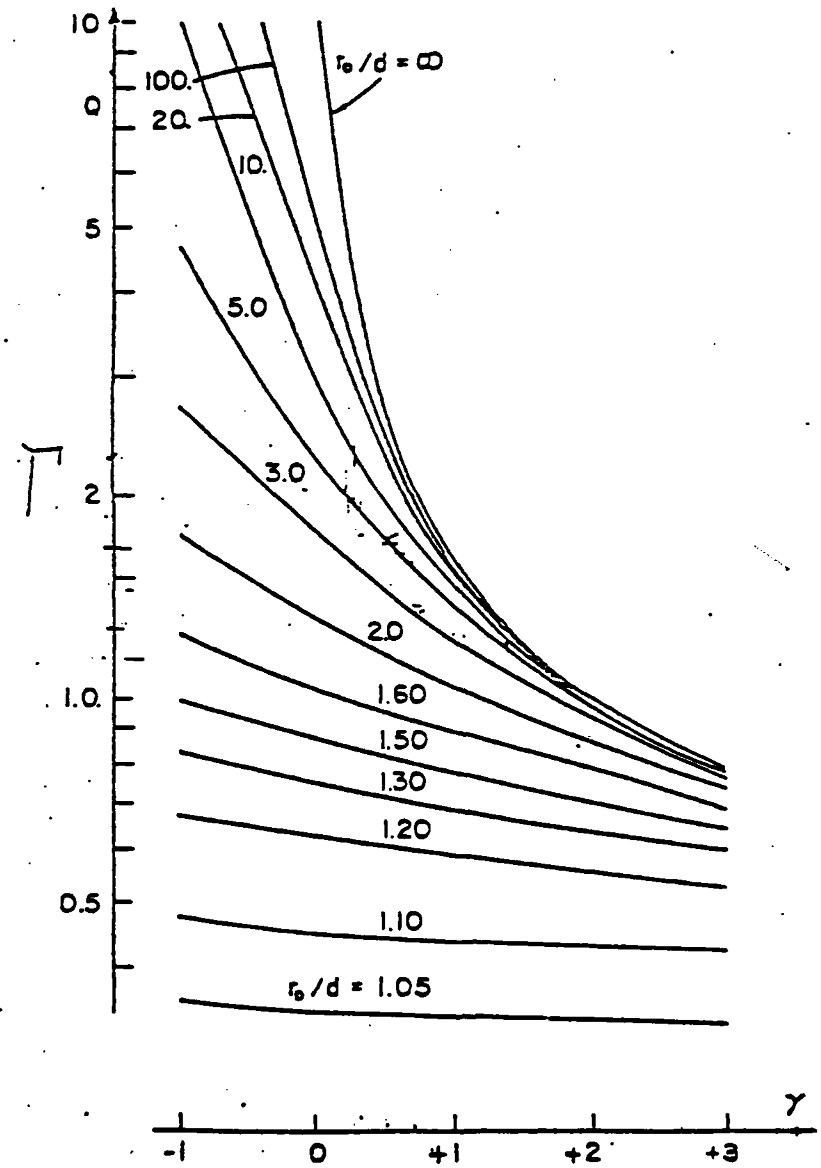


LINE SOURCE GEOMETRY

GEOMETRY FACTOR CAN BE ADJUSTED IF SITE IS NOT CENTERED RELATIVE TO SOURCE BY TREATING EACH SIDE OF THE SOURCE AS HALF OF DIFFERENT LENGTH FAULTS, THEN MULTIPLYING THE RESPECTIVE G FACTORS BY 1/2 AND SUMMING THEM. USING THE TOTAL G FACTOR, i CAN BE CALCULATED NORMALLY. A SIMILAR PROCESS CAN BE USED IF THE SOURCE LINE IS ENTIRELY SKEWED TO ONE SIDE; THE G FACTOR FOR THE 'MISSING' SEGMENT SUBTRACTED OFF.

MRO FORM 1580 1 OCT 72

FIGURE A1

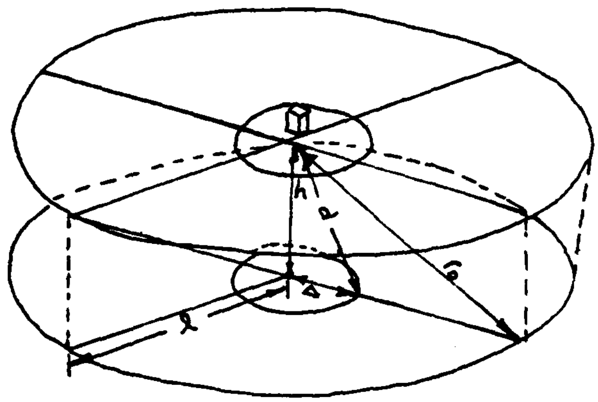


NUMERICAL VALUES FOR THE GAMMA FUNCTION
(FROM CORNELL, 1968)

FIGURE A2

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT SEISMIC HAZARD ANALYSIS - PAPIO 11 and 16		SHEET NO.	OF
ITEM CORNELL'S (1968) EQUATIONS FOR CALCULATING MAX. INTENSITIES AT A SITE FROM AN ANNULAR SOURCE		BY BECKER	DATE
		CHKD. BY	DATE

$m_0, h, b, \beta, N_{m_0}, C_1, C_2, C_3, C, \gamma, i$ - ALL REPRESENT SAME QUANTITIES AS FOR LINE SOURCE, AND ARE CALCULATED THE SAME WAY.



ANNULAR SOURCE GEOMETRY

ℓ = RADIUS OF OUTSIDE OF ANNULUS

Δ = RADIUS OF INSIDE OF ANNULUS (CAN BE ZERO)

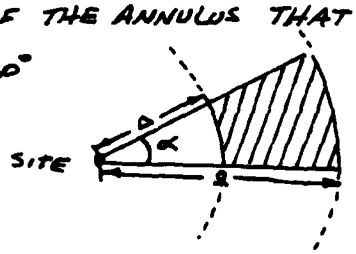
$d = \sqrt{h^2+\Delta^2}$

$r_0 = \sqrt{h^2+\ell^2}$

$\hat{\nu} = N_{m_0}/AREA = N_{m_0}/\pi(\ell^2-\Delta^2)$ EVENTS PER YEAR PER UNIT AREA (Km

$G = \frac{2\pi}{(\gamma-1)d^{(\gamma-1)}}\left[1-\left(\frac{r_0}{d}\right)^{-(\gamma-1)}\right]$ GEOMETRY FACTOR

GEOMETRY FACTOR CAN BE ADJUSTED FOR ONLY A SEGMENT OF AN ANNULUS BY MULTIPLYING G BY THE PORTION OF THE ANNULUS THAT THE SEGMENT SUBTENDS - $\alpha/360°$



$G_{segment} = \frac{\alpha}{360°} G_{ANNULUS}$

α IN DEGREES

G FACTORS CAN BE SUMMED FOR SEVERAL ANNULAR SEGMENTS USED TO MODEL AN IRREGULAR AREAL SOURCE - $\hat{\nu} G_{TOT.} = \hat{\nu} \sum_{i=1}^{n} G_i$

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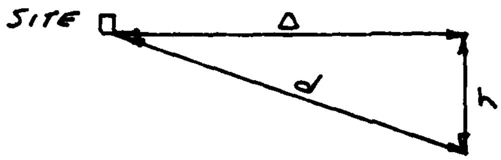
FIGURE A3

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT SEISMIC HAZARD ANALYSIS - PAPIO 11 and 16	SHEET NO.	OF
ITEM CORNELL'S (1968) EQUATIONS FOR CALCULATING MAX. INTENSITIES AT A SITE FROM A POINT SOURCE	BY BECKER	DATE
	CHKD. BY	DATE

$m_0, h, b, \beta, N_{m_0}, C_1, C_2, C_3, C, \gamma, i$ - ALL REPRESENT SAME QUANTITIES AS FOR LINE SOURCE, AND ARE CALCULATED THE SAME WAY.



Δ - DISTANCE TO PT. SOURCE FROM SITE (ALONG SURFACE)

$d = \sqrt{\Delta^2 + h^2}$ - DISTANCE TO FOCUS FROM SITE

$G = d^{-(\gamma+1)}$

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FIGURE A4

OMAHA DISTRICT — COMPUTATION SHEET — CORPS OF ENGINEERS

PROJECT SEISMIC HAZARD ANALYSIS - PAPIO 11 and 16	SHEET NO. OF
ITEM CONVERSION OF CORNELL AND MERZ COEFFICIENTS FOR EASTERN U.S.	BY BECKER DATE
	CHKD. BY DATE

ATTENUATION OF INTENSITY EQUATION FROM CORNELL AND MERZ AS QUOTED IN NUTTLI AND GUPTA (1976) UNITS OF DISTANCE ARE IN MILES, CONVERTING FOR USE OF KILOMETERS

$$I_{SITE} = 3.1 + I_{EPICENTER} - 1.3 \ln(R_{MILES}) \quad (1) \qquad R_{MILE} = \frac{R_{KM}}{1.6}$$

$$= 3.1 + I_{EPICENTER} - 1.3 \ln(R_{Km}/1.6)$$

$$= 3.1 + I_{EPICENTER} - 1.3[\ln(R_{Km}) - \ln(1.6)]$$

$$= 3.1 + I_{EPICENTER} + 1.3 \ln 1.6 - 1.3 \ln R_{Km}$$

$$= 3.1 + I_{EPICENTER} + .61 - 1.3 \ln R_{Km}$$

$$I_{SITE} = 3.71 + I_{EPICENTER} - 1.3 \ln R_{Km} \quad (2)$$

USING NUTTLI AND HERRMANN'S RELATION FOR MAGNITUDE AND EPICENTER INTENSITY (SEE 1978 WES MISC. PAPER S73-1 REPORT 12)

$$I_{EPICENTER} = 2.0 m_b - 3.5 \quad (3)$$

SUBSTITUTING THIS INTO (2)

$$I_{SITE} = 3.71 + (2.0 m_b - 3.5) - 1.3 \ln R_{Km}$$

$$I_{SITE} = .21 + 2.0 m_b - 1.3 \ln R_{Km} \quad (4)$$

FOR CORNELL'S (1968) EQUATIONS FOR INTENSITY

$C_1 = .21$

$C_2 = 2.0$

$C_3 = 1.3$

HERRMANN'S (1981) EQUATIONS FOR MAXIMUM ACCELERATION

FOR $R \leq 15 Km$

USE LESSER OF: $\log_{10} a = 0.55 + 0.50 m_b - 0.83 \log_{10} 15 - 0.0019(15)$

$\ln_e a = 0.933 m_b$

FOR $R \geq 15 Km$: $\log_{10} a = 0.55 + 0.50 m_b - 0.83 \log_{10} R - 0.0019 R$

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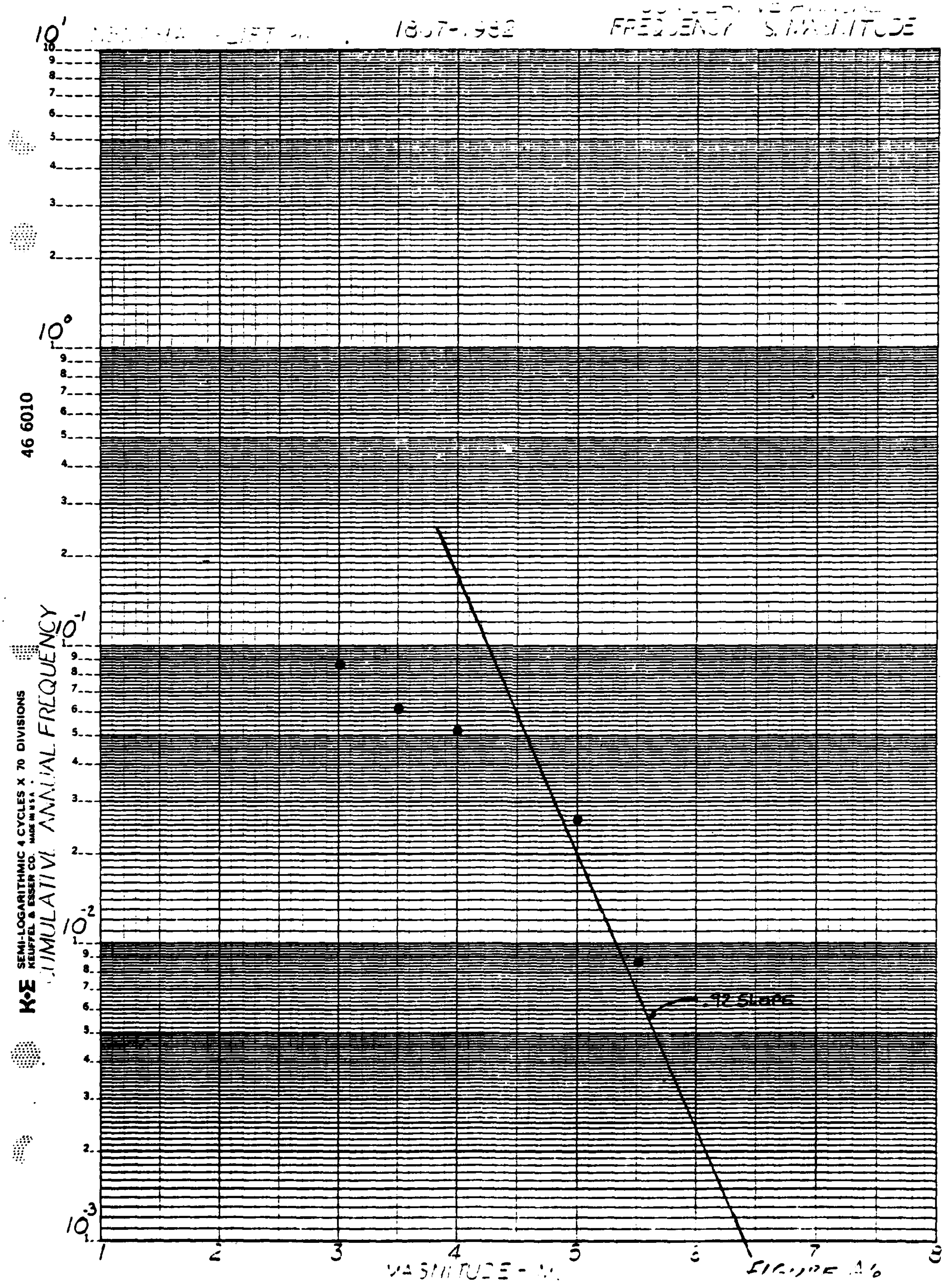
FIGURE A5



FREQUENCY
.92 SLOPE
10^1
10^0
10^-1
10^-2
10^-3
1
2
3
4
5
7
8
46 6010
K•E SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

OMAHA DISTRICT — **COMPUTATION SHEET** — CORPS OF ENGINEERS

PROJECT Seismic Hazard Analysis - Papio 11 and 16	SHEET NO.	OF
ITEM Hazard From Nemaha Uplift Subprovince	BY Becker	DATE
	CHKD. BY	DATE

$M_o = 6.4$

$\Delta = 63.5\,Km \quad h = 15\,Km$

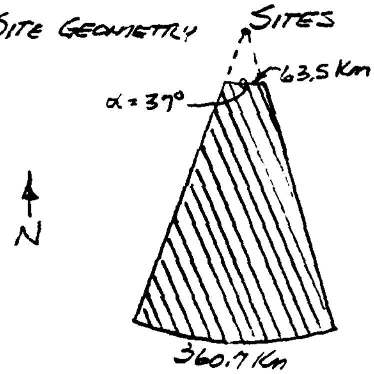
$d = \sqrt{\Delta^2 + h^2} = 65.2\,Km$

$\ell = 360.7\,Km$

$r_o = \sqrt{\ell^2 + h^2} = 361.0\,Km$

$\alpha = 37^\circ$

Site Geometry



1'' = 200 Km

$b = .92$

$\beta = b \ln 10 = 2.1$

$c_1 = .21$

$c_2 = 2.0$

$c_3 = 1.3$

$\gamma = \beta(c_3/c_2) - 1 = .37$

$C = e^{(\beta(c_1/c_2 + m_o))} = e^{[2.1(\frac{.21}{2.0} + 6.4)]} = 8.6 \times 10^5$

$N_{m_o} = .001$

$\hat{\nu} = \frac{N_{m_o}}{A_{TOTAL}} = \frac{.001}{\Sigma A_i} = .001 / \pi\left[\frac{37}{360}(360.7^2 - 63.5^2)\right] = 2.5 \times 10^{-8}$

$G = \frac{\alpha}{360}\frac{2\pi}{(\gamma-1)d^{(\gamma-1)}}\left[1 - \left(\frac{r_o}{d}\right)^{-(\gamma-1)}\right] = \frac{37}{360}\frac{2\pi}{(.37-1)65.2^{(.37-1)}}\left[1 - \left(\frac{361.0}{65.2}\right)^{-(.37-1)}\right]$

$= 27.6$

$T_i = 1000$ yrs.

$i = \frac{c_2}{\beta}\ln(G\hat{\nu}CT_i) = \frac{2.0}{2.1}\ln(27.6 \cdot 2.5\times10^{-8} \cdot 8.6\times10^5 \cdot 1000) = 6.1$

$m_b = \frac{i + 3.5}{2} = \frac{6.1 + 3.5}{2} = 4.8$

$\log a = .55 + .5(4.8) - .83 \log 15 - .0019(15)$

$= 1.95$

$a = 89.\ cm/sec^2 = .091g$

or

$\ln a = .933(4.8) = 4.48$

$a = 88.\ cm/sec^2 = .090g$

Use .090g.

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FIGURE A7

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT SEISMIC HAZARD ANALYSIS – PAPIO 11 and 16	SHEET NO.	OF
ITEM HAZARD FROM NEMAHA ARCH-AREA SOURCE BOUNDED BY HUMBOLDT FAULT	BY BECKER	DATE
	CHKD. BY	DATE

$M_o = 6.4$

$\Delta_1 = \Delta_2 = 63.5 Km \quad h = 15 Km$

$d_1 = d_2 = \sqrt{\Delta^2 + h^2} = 65.2 Km$

$\ell_1 = 360.7 Km$

$\ell_2 = 191.8 Km$

$r_{o_1} = \sqrt{\ell_1^2 + h^2} = 361.0 Km$

$r_{o_2} = \sqrt{\ell_2 + h^2} = 192.4 Km$

$\alpha_1 = 21° \quad \alpha_2 = 10°$

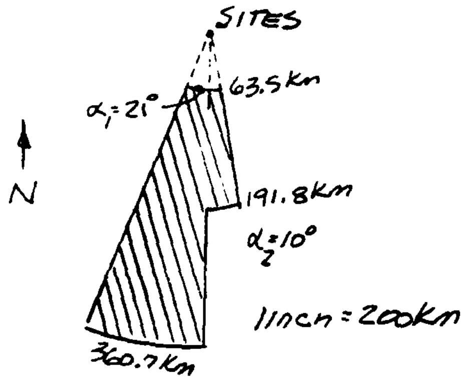
$b = .92$

$\beta = b \ln 10 = 2.1$

$C_1 = .21$

$C_2 = 2.0$

$C_3 = 1.3$



$\gamma = \beta(C_3/C_2) - 1 = .37$

$c = e^{(\beta(C_1/C_2 + m_o))} = e^{[2.1(\frac{.21}{2.0} + 6.4)]} = 8.6 \times 10^5$

$N_{m_o} = .001$

$\hat{\nu} = \frac{N_{m_o}}{A_{TOTAL}} = \frac{.001}{\Sigma A_i} = .001 / \pi \left[\frac{21}{360}(360.7^2 - 63.5^2) + \frac{10}{360}(191.8^2 - 63.5^2)\right]$

$= 3.85 \times 10^{-8}$

$G_1 \frac{\alpha}{360} \frac{2\pi}{(\gamma-1) d_1^{(\gamma-1)}}\left[1 - \left(\frac{r_o}{d_1}\right)^{-(\gamma-1)}\right] = \frac{21}{360}\frac{2\pi}{(.37-1)65.2^{(.37-1)}}\left[1 - \left(\frac{361.0}{65.2}\right)^{-(.37-1)}\right] = 15.7$

$G_2 = \frac{10}{360}\frac{2\pi}{(.37-1)65.2^{(.37-1)}}\left[1 - \left(\frac{192.4}{65.2}\right)^{-(.37-1)}\right] = 3.8$

$G\hat{\nu} = \hat{\nu}\Sigma G_i = 3.85 \times 10^{-8}(15.7 + 3.8) = 3.85 \times 10^{-8}(19.5)$

$= 7.5 \times 10^{-7}$

$T_i = 1000 \text{ yrs}$

$i = \frac{C_2}{\beta}\ln(G\hat{\nu} c T_i) = \frac{2.0}{2.1}\ln(7.5 \times 10^{-7} \cdot 8.6 \times 10^5 \cdot 1000) = 6.2$

$m_b = \frac{i + 3.5}{2} = \frac{6.2 + 3.5}{2} = 4.8$

$\log a = .55 + .5(4.8) - .83 \log 15 - .0019(15)$

$= 1.95$

$a = 89 \text{ cm/sec}^2 = .091g$

or

$\ln a = .933(4.8)$

$a = 88.1 \text{ cm/sec}^2 = .090g$

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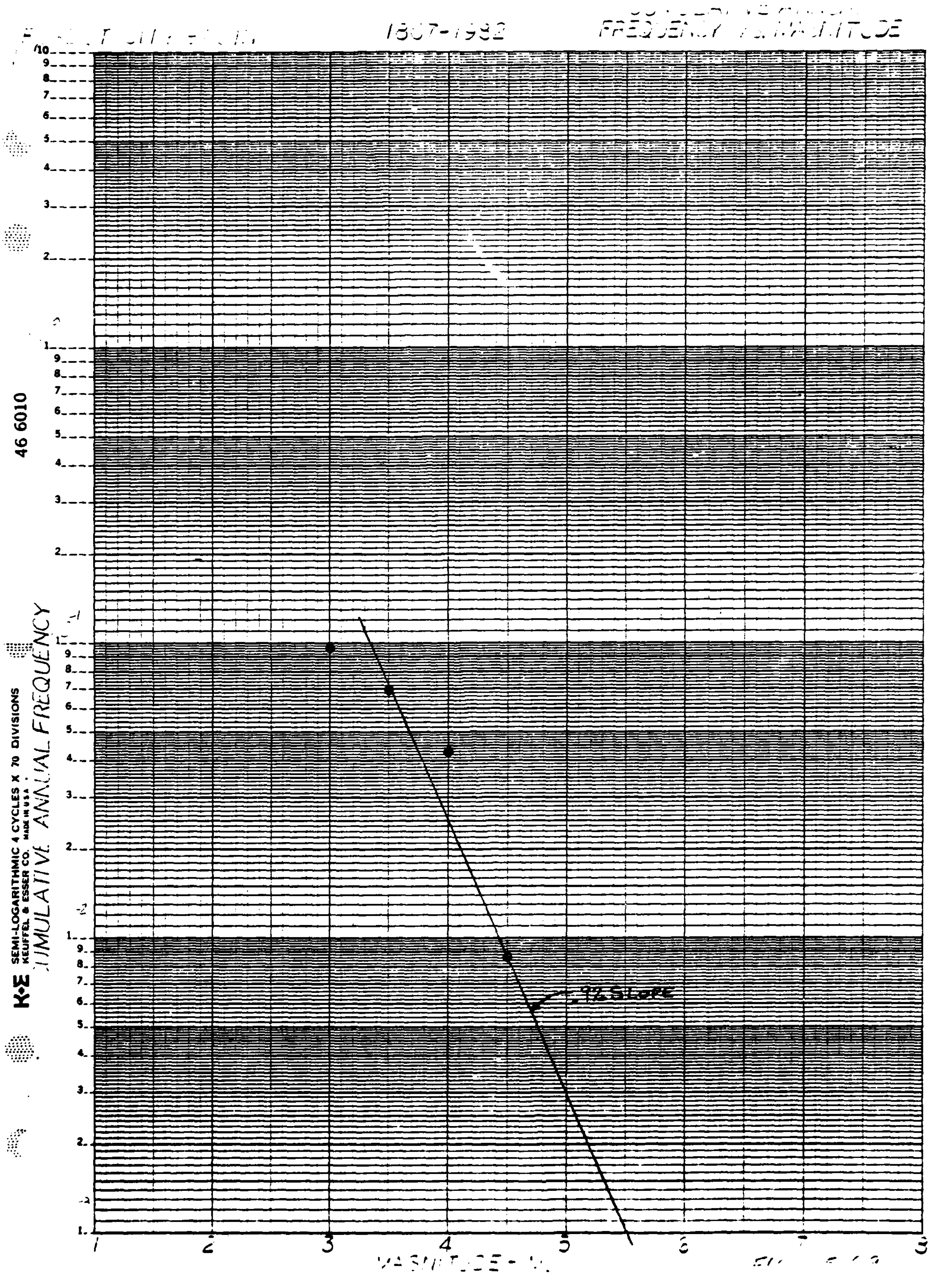
1 OCT 72

FIGURE A8


1807-1982
FREQUENCY
UMULATIVE ANNUAL FREQUENCY
.92 SLOPE
46 6010
K+E SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.
1
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8

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT SEISMIC HAZARD ANALYSIS - PAPIO 11 and 16		SHEET NO.	OF
ITEM HAZARD FROM FOREST CITY BASIN WITHIN 200 MILE RADIUS		BY BECKER	DATE
		CHKD. BY	DATE

$M_0 = 5.5$

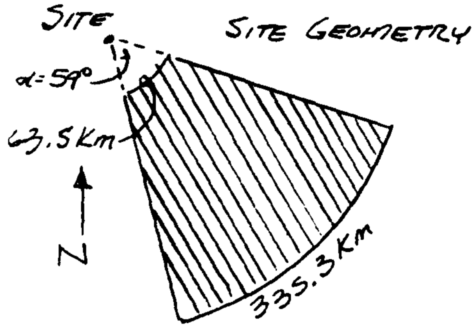
$\Delta = 63.5\,Km$

$d = \sqrt{\Delta^2 + h^2} = 65.2\,Km$

$l = 335.3\,Km$

$r_0 = \sqrt{l^2 + h^2} = 335.6$

$\alpha = 59°$



$b = .92$

$B = b\ln 10 = 2.1$

$C_1 = .21$

$C_2 = 2.0$

$C_3 = 1.3$

$\gamma = B(C_3/C_2) - 1 = .37$

$C = e^{(B(C_1/C_2 + M_0))} = e^{[2.1(\frac{.21}{2.0} + 5.5)]} = 1.3\times10^5$

$N_{m_0} = .001$

$\hat{\nu} = \frac{N_{m_0}}{A_{TOTAL}} = \frac{.001}{\Sigma A_i} = .001/\pi\left[\frac{59}{360}(335.3^2 - 63.5^2)\right] = 1.8\times10^{-8}$

$G_i = \frac{\alpha}{360}\frac{2\pi}{(\gamma-1)d^{(\gamma-1)}}\left[1 - \left(\frac{r_0}{d}\right)^{-(\gamma-1)}\right]$

$= \frac{59}{360}\frac{2\pi}{(.37-1)65.2^{(.37-1)}}\left[1 - \left(\frac{335.6}{65.2}\right)^{-(.37-1)}\right]$

$= 41.1$

$T_i = 1000\ yrs$

$i = \frac{C_2}{B}\ln(G\hat{\nu}CT_i) = \frac{2.0}{2.1}\ln(41.1 \cdot 1.8\times10^{-8} \cdot 1.3\times10^5 \cdot 1000) = 4.3$

$m_b = \frac{i + 3.5}{2} = \frac{4.3 + 3.5}{2} = \frac{7.8}{2} = 3.9$

$\log a = .55 + .5(3.9) - .83\log 15 - .0019(15)$

$= 1.5$

$a = 31.3\ cm/sec^2 = .032g$

or

$\ln a = .933(3.9) = 3.64$

$a = 38.0\ cm/sec^2 = .039g$

Use .032g

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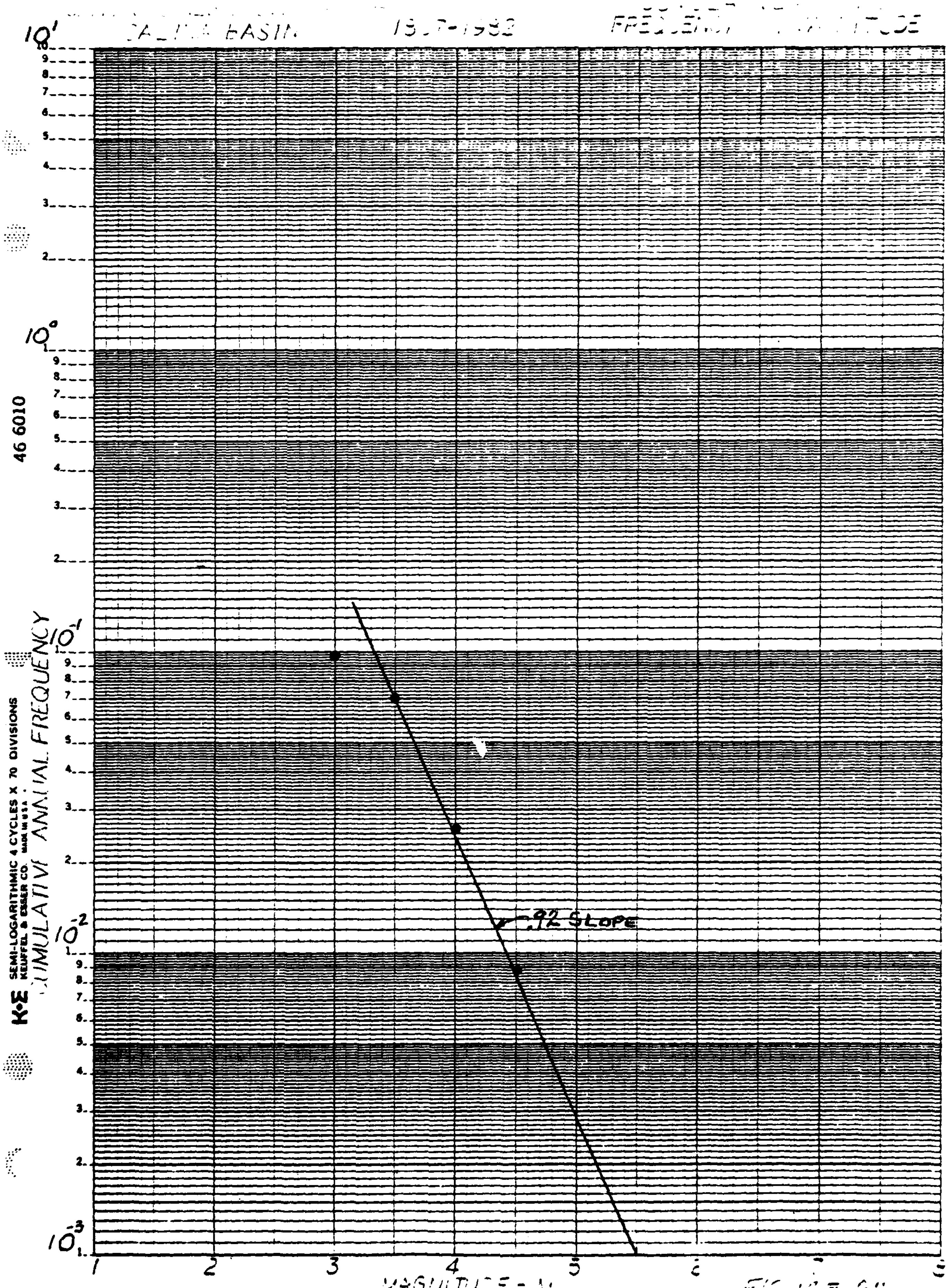
FIGURE A10


BASIN
FREQUENCY
10^1
10^0
10^{-1}
10^{-2}
10^{-3}
CUMULATIVE ANNUAL FREQUENCY
.92 SLOPE
1
2
3
4
5
MAGNITUDE - M
46 6010
K•E SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

OMAHA DISTRICT — **COMPUTATION SHEET** — CORPS OF ENGINEERS

PROJECT Seismic Hazard Analysis - Papio Dams 11 and 16	SHEET NO.	OF
ITEM Hazard from Central Nebraska Basin - Salina Basin	BY Becker	DATE
	CHKD. BY	DATE

$M_o = 5.5$

$\Delta_1 = 40.6\ Km \quad \Delta_2 = 101.6\ Km \quad h = 15\ Km$

$d_1 = \sqrt{\Delta_1^2 + h^2} = 43.3\ Km$

$d_2 = \sqrt{\Delta_2^2 + h^2} = 102.7\ Km$

$l_1 = 175.3\ Km \quad l_2 = 307.3\ Km$

$r_{o1} = \sqrt{l_1^2 + h^2} = 175.9\ Km$

$r_{o2} = \sqrt{l_2^2 + h^2} = 307.7\ Km$

$\alpha_1 = 66° \quad \alpha_2 = 82°$

$b = .92$

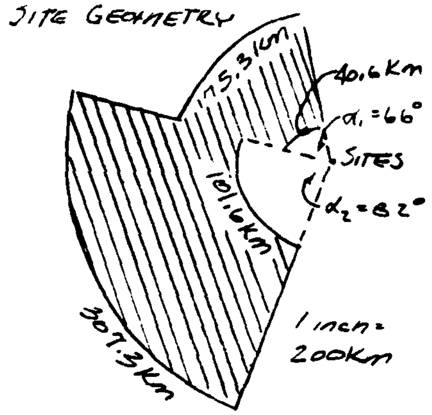
$\beta = b \ln 10 = 2.1$

$C_1 = .21$

$C_2 = 2.0$

$C_3 = 1.3$

$\gamma = \beta(C_3/C_2) - 1 = .37$



$C = e^{(\beta(C_1/C_2 + M_o))} = e^{[2.1(\frac{.21}{2.0} + 5.5)]} = 1.3 \times 10^5$

$N_{M_o} = .001$

$\hat{\nu} = \frac{N_{M_o}}{A_{TOTAL}} = \frac{.001}{\Sigma A_i} = .001/\pi\left[\frac{66}{360}(175.3^2 - 40.6^2) + \frac{82}{360}(307.3^2 - 101.6^2)\right]$

$= 1.3 \times 10^{-8}$

$G_1 = \frac{\alpha_1}{360} \frac{2\pi}{(\gamma-1)d_1^{(\gamma-1)}}\left[1 - \left(\frac{r_{o1}}{d_1}\right)^{-(\gamma-1)}\right] = \frac{66}{360} \frac{2\pi}{(.37-1)43.3^{(.37-1)}}\left[1 - \left(\frac{175.9}{43.3}\right)^{-(.37-1)}\right] = 27.9$

$G_2 = \frac{82}{360} \frac{2\pi}{(.37-1)102.7^{(.37-1)}}\left[1 - \left(\frac{307.7}{102.7}\right)^{-(.37-1)}\right] = 41.8$

$G\hat{\nu} = \hat{\nu}\,\Sigma G_i = 1.3 \times 10^{-8}(27.9 + 41.8) = 9.1 \times 10^{-7}$

$T_i = 1000$ YRS

$i = \frac{C_2}{\beta}\ln(G\hat{\nu}CT_i) = \frac{2.0}{2.1}\ln(9.1 \times 10^{-7} \cdot 1.3 \times 10^5 \cdot 1000) = 4.5$

$m_b = \frac{i + 3.5}{2} = \frac{4.5 + 3.5}{2} = 4.0$

$\text{Log } a = .55 + .5(4.0) - .83 \text{ Log } 15 - .0019(15)$

$= 1.54$

$a = 35.1\ cm/sec^2 = .036g$

or

$\ln a = .933(4.0) = 3.73$

$a = 41.8\ cm/sec^2 = .043g$

Use .036g

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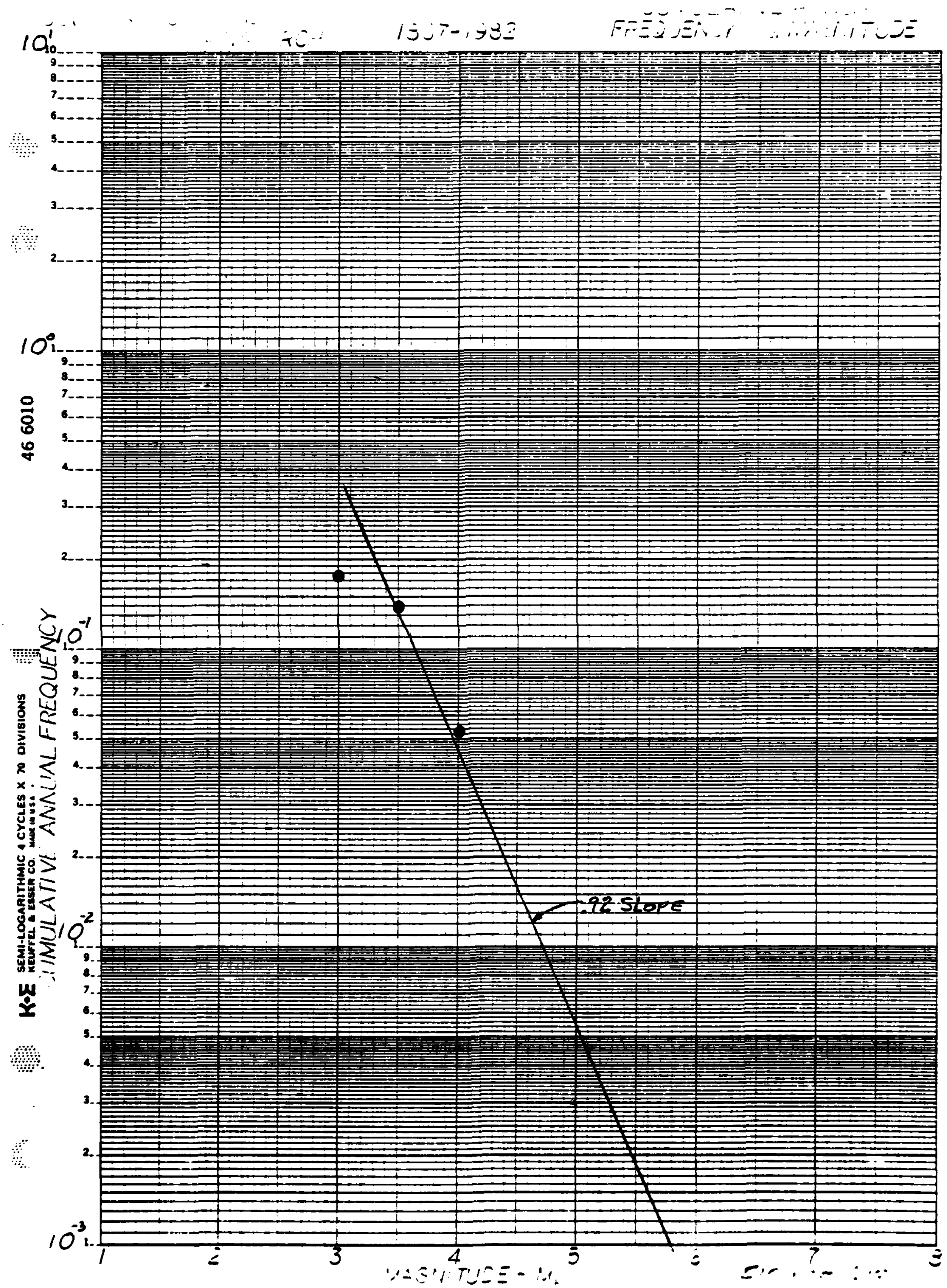
1 OCT 72

FIGURE A12



1857-1982
FREQUENCY
CUMULATIVE ANNUAL FREQUENCY
.92 SLOPE
MAGNITUDE - M
46 6010
K•E SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT SEISMIC HAZARD ANALYSIS - PAPIO 11 and 16	SHEET NO.	OF
ITEM HAZARD FROM TRANSCONTINENTAL - SIOUXANA ARCH SOUTH OF SIOUX RIDGE	BY BECKER	DATE
	CHKD. BY	DATE

$M_0 = 5.8$

$\Delta_1 = \Delta_2 = \Delta_3 = 175.6 Km \quad \Delta_4 = 307.3 Km \quad h = 15 Km$

$d_1 = d_2 = d_3 = \sqrt{\Delta_1^2 + h^2} = 175.9 Km$

$d_4 = \sqrt{\Delta_4^2 + h^2} = 307.7 Km$

$\ell_1 = 256.5 Km, \ell_2 = 360.7 Km, \ell_3 = 469.9 Km, \ell_4 = 419.1 Km$

$r_{o_1} = \sqrt{h^2 + \ell_1^2} = 256.9 Km \quad r_{o_2} = \sqrt{h^2 + \ell_2^2} = 361.0 Km$

$r_{o_2} = \sqrt{h^2 + \ell_3^2} = 470.1 Km \quad r_{o_4} = \sqrt{h^2 + \ell_4^2} = 419.4 Km$

$\alpha_1 = 19° \quad \alpha_2 = 13° \quad \alpha_3 = 21° \quad \alpha_4 = 10°$

$b = .92$

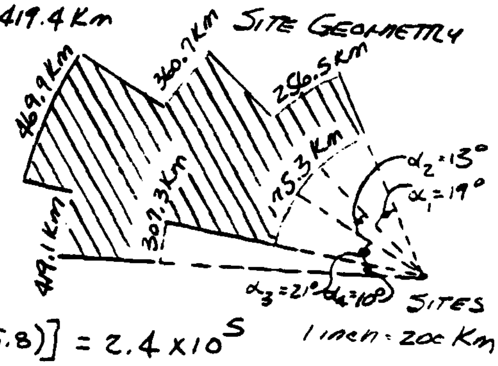
$\beta = b \ln 10 = 2.1$

$C_1 = .21$

$C_2 = 2.0$

$C_3 = 1.3$

$\gamma = \beta (C_3/C_2) - 1 = .37$



$C = e^{(\beta(C_1/C_2 + m_0))} = e^{[2.1(\frac{.21}{2.0} + 5.8)]} = 2.4 \times 10^5$

$N_{m_0} = .001$

$\hat{\nu} = \frac{N_{M_0}}{A_{TOTAL}} = \frac{.001}{\Sigma A_i} \quad .001 / \pi \left[\frac{19}{360}(256.5^2 - 175.6^2) + \frac{13}{360}(360.7^2 - 175.6^2) + \frac{21}{360}(469.9^2 - 175.6^2) + \frac{10}{360}(419.1^2 - 307.3^2) \right] = 1.7 \times 10^{-8}$

$G_1 = \frac{\alpha_1}{360} \frac{2\pi}{(\gamma - 1)} d_1^{(\gamma - 1)} \left[1 - \left(\frac{r_{o_1}}{d_1} \right)^{-(\gamma - 1)} \right] = \frac{19}{360} \frac{2\pi}{(.37-1) 175.9^{(.37-1)}} \left[1 - \left(\frac{256.9}{175.9} \right)^{-(.37-1)} \right] = 3.7$

$G_2 = \frac{13}{360} \frac{2\pi}{(.37-1) 175.9^{(.37-1)}} \left[1 - \left(\frac{361.0}{175.9} \right)^{-(.37-1)} \right] = 5.4$

$G_3 = \frac{21}{360} \frac{2\pi}{(.37-1) 175.9^{(.37-1)}} \left[1 - \left(\frac{470.1}{175.9} \right)^{-(.37-1)} \right] = 13.0$

$G_4 = \frac{10}{360} \left[2\pi / (.37-1) 307.7^{(.37-1)} \right] \left[1 - \left(\frac{419.4}{307.7} \right)^{-(.37-1)} \right] = 2.2$

$G\hat{\nu} = \nu \Sigma G_i = 1.7 \times 10^{-8} (3.7 + 5.4 + 13.0 + 2.2) = 4.1 \times 10^{-7}$

$T_i = 1000$ yrs

$i = \frac{C_2}{\beta} \ln (G\hat{\nu} C T_i) = \frac{2.0}{2.1} \ln (4.1 \times 10^{-7} \cdot 2.4 \times 10^5 \cdot 1000) = 4.4$

$m_b = \frac{i + 3.5}{2} = \frac{4.4 + 3.5}{2} = 3.9$

$\text{Log } a = .55 + .5(3.9) - .83 \text{ Log } .15 - .0019(15)$
$= 1.51$

$a = 32.6 \text{ cm/sec}^2 = .033g$

or

$\ln a = .933(3.9) = 3.64$

$a = 38 \text{ cm/sec}^2 = .039g$

use .033g

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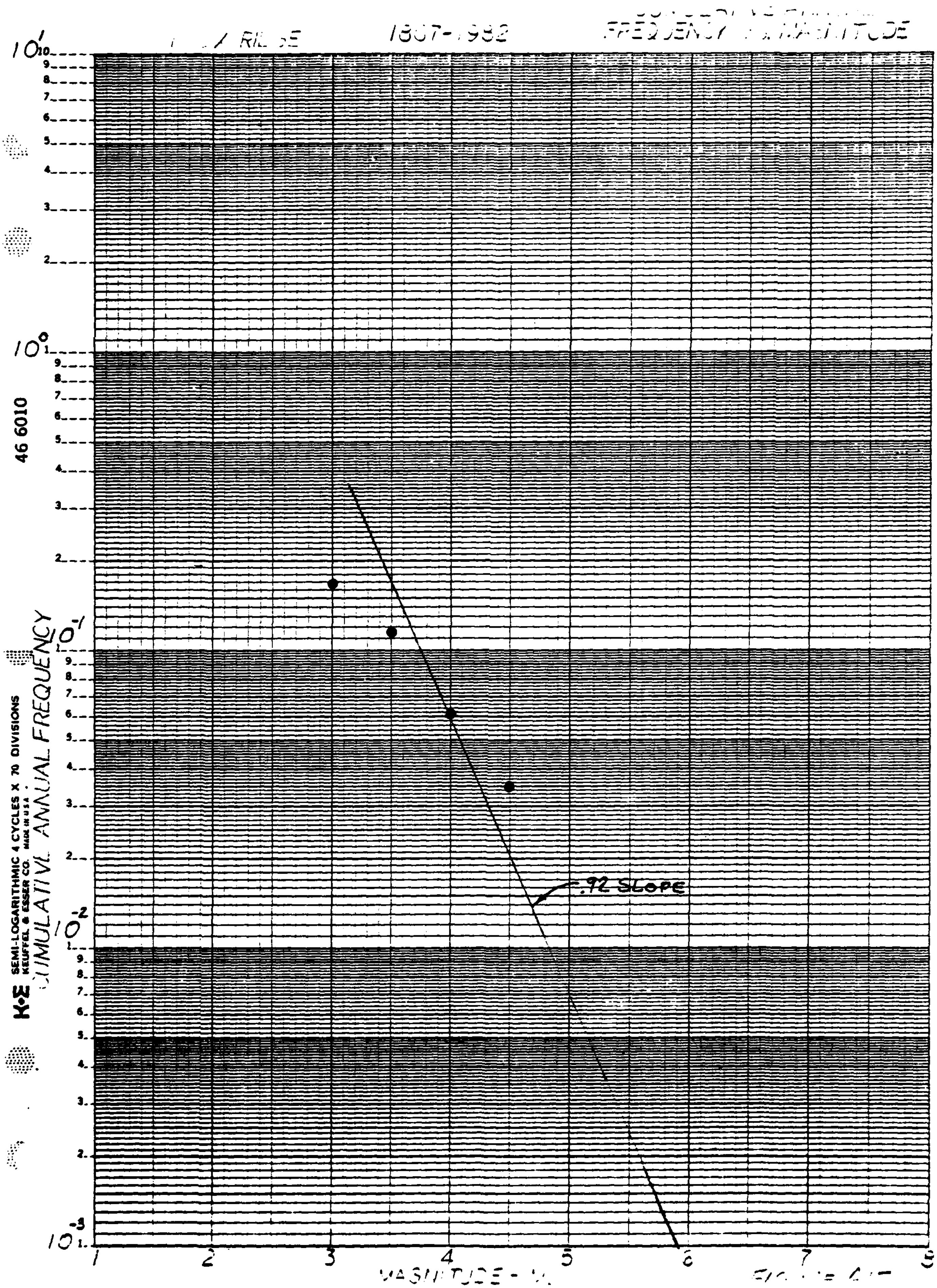
FIGURE A14


1807-1982
FREQUENCY
.92 SLOPE
CUMULATIVE ANNUAL FREQUENCY
46 6010
K·E SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

OMAHA DISTRICT | **COMPUTATION SHEET** | **CORPS OF ENGINEERS**

PROJECT SEISMIC HAZARD ANALYSIS – PAPIO 11 and 16 | **SHEET NO.** | **OF**

ITEM HAZARD FROM THE SIOUX RIDGE | **BY** BECKER | **DATE**

CHKD. BY | **DATE**

$M_o = 5.9$

$\Delta_1 = 223\ Km \quad \Delta_2 = 257\ Km \quad \Delta_3 = 361\ Km \quad h = 15\ Km$

$d_1 = \sqrt{\Delta_1^2 + h^2} = 223.5\ Km \quad d_2 = \sqrt{\Delta_2 + h^2} = 257.4$

$d_3 = \sqrt{\Delta_3^2 + h^2} = 361.3\ Km$

$\ell_1 = 334\ Km \quad \ell_2 = 389\ Km \quad \ell_3 = 577\ Km$

$ro_1 = \sqrt{\ell_1 + h^2} = 334.3\ Km \quad ro_2 = \sqrt{\ell_2 + h^2} = 389.3\ Km$

$ro_3 = \sqrt{\ell_3 + h^2} = 577.2\ Km$

$\alpha_1 = 18^\circ \quad \alpha_2 = 18^\circ \quad \alpha_3 = 13^\circ$

$b = .92$

$B = b \ln 10 = 2.1$

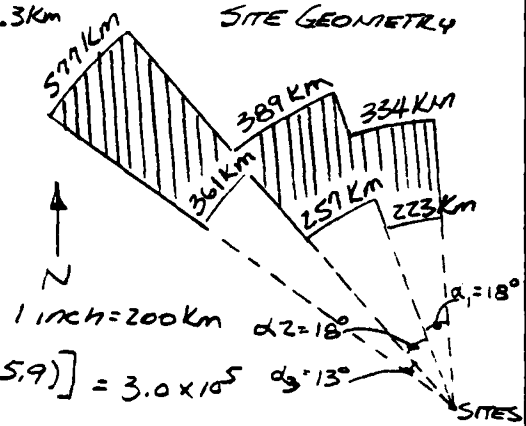
$C_1 = .21$

$C_2 = 2.0$

$C_3 = 1.3$

$\gamma = \beta(C_3/C_2) - 1 = .37$

$C = e^{(B(C_1/C_2) + M_o)} = e^{[2.1(\frac{.21}{2.0} + 5.9)]} = 3.0 \times 10^5$



$N_{mo} = .001$

$$\hat{\nu} = \frac{N_{mo}}{A_{TOTAL}} = \frac{.001}{\Sigma A_i} = \frac{.001}{\pi}\Big[\frac{18}{360}(334^2 - 223^2) + \frac{18}{360}(389^2 - 257^2) + \frac{13}{360}(577^2 - 361^2)\Big] = 2.2 \times 10^{-8}$$

$$G_1 = \frac{\alpha_1}{360}\frac{2\pi}{(\gamma-1)} d_1^{(\gamma-1)}\Big[1 - \Big(\frac{ro}{d_1}\Big)^{-(\gamma-1)}\Big] = \frac{18}{360}\frac{2\pi}{(.37-1)} 223.5^{(.37-1)}\Big[1 - \Big(\frac{334.3}{223.5}\Big)^{-(.37-1)}\Big] = 4.3$$

$$G_2 = \frac{18}{360}\frac{2\pi}{(.37-1)} 257.4^{(.37-1)}\Big[1 - \Big(\frac{389.3}{257.4}\Big)^{-(.37-1)}\Big] = 4.9$$

$$G_3 = \frac{13}{360}\frac{2\pi}{(.37-1)} 361.3^{(.37-1)}\Big[1 - \Big(\frac{577.2}{361.3}\Big)^{-(.37-1)}\Big] = 5.1$$

$G\hat{\nu} = \hat{\nu}\,\Sigma G_i = 2.2 \times 10^{-8}(4.3 + 4.9 + 5.1) = 2.2 \times 10^{-8}(14.3)$

$T_i = 1000$ YRS

$i = \frac{C_2}{B}\ln(G\hat{\nu}CT_i) = \frac{2.0}{2.1}\ln(3.15 \times 10^{-7} \cdot 3 \cdot 10^5 \cdot 1000) = 4.3$

$m_b = \frac{i + 3.5}{2} = \frac{4.3 + 3.5}{2} = 3.9$

$\log a = .55 + .5(3.9) - .83 \log 15 - .0019(15)$

$= 1.5$

$a = 31.3\ cm/sec^2 = .031g$

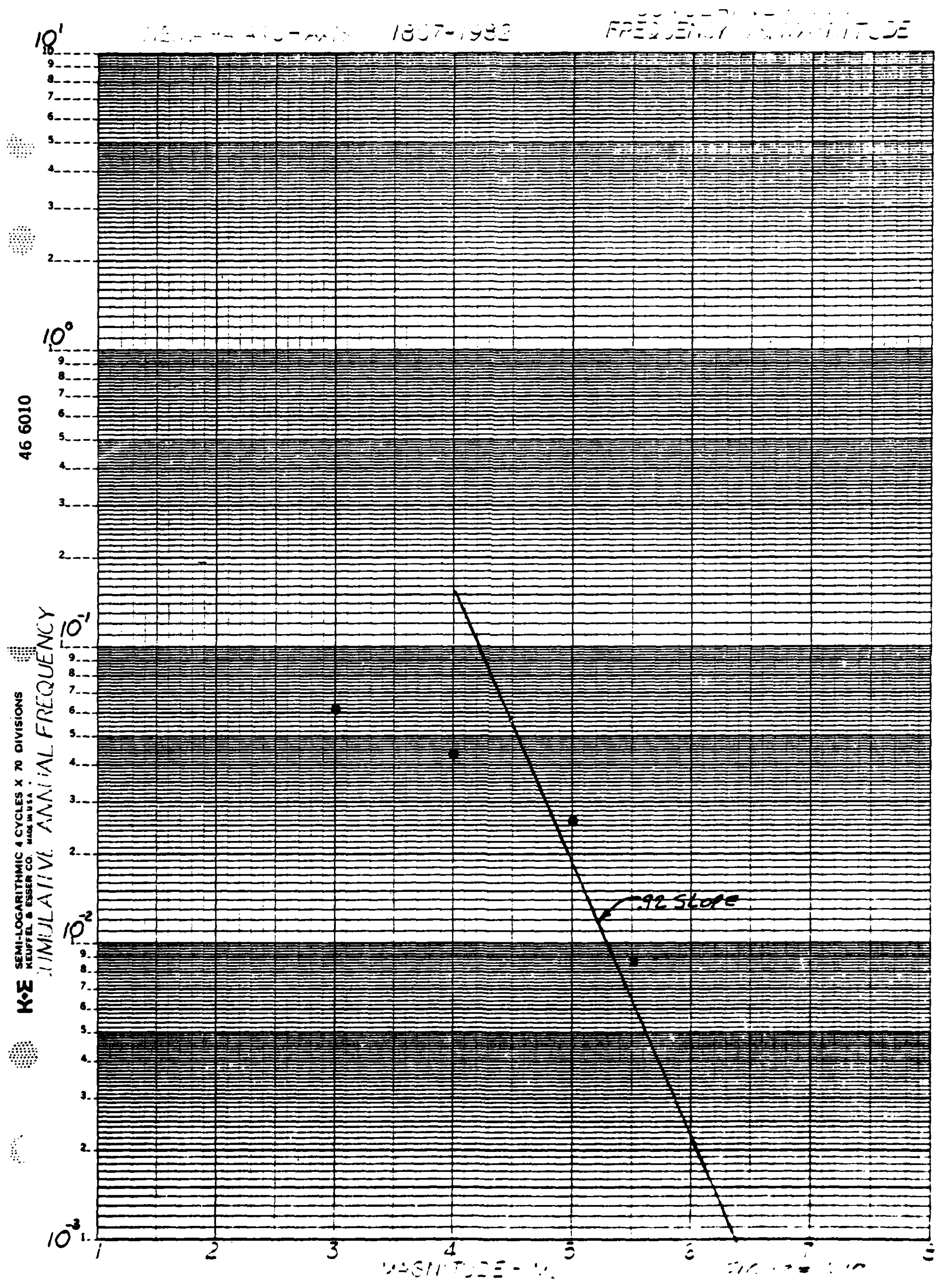
or

$\ln a = .933(3.9) = 3.64$

$a = 38.0\ cm/sec^2 = .039g$

Use .031g

FIGURE A16



1807-1982
CUMULATIVE ANNUAL FREQUENCY
.92 Slope
46 6010
K+E SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT Seismic Hazard Analysis - PAPIO 11 and 16		SHEET NO.	OF
ITEM Hazard from Axis of Nemaha Arch within 200 mile circle		BY BECKER	DATE
		CHKD. BY	DATE

$M_o = 6.4$ $\quad T_i = 1000$ yrs

$\Delta = 7.6$ Km

$h = 15$ Km

$d = \sqrt{\Delta^2 + h^2} = \sqrt{282.8} = 16.8$ Km

ℓ = apparent length = 721 Km $\quad \ell'$ = True length = 279 Km

Missing Segment $K = 164$ Km

$b = .92$

$\beta = b \ln 10 = 2.1$

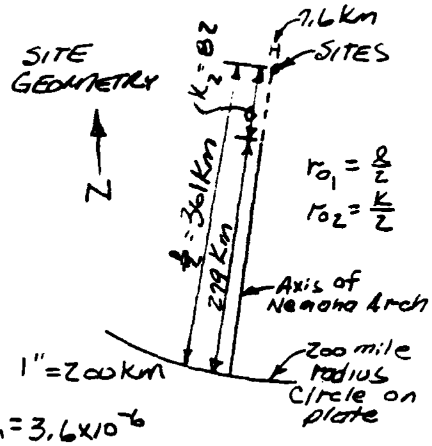
$C_1 = .21$

$C_2 = 2.0$

$C_3 = 1.3$

$N_{m_o} = .001$

$\ell/2 = 360.5$ Km



$r_{o_1} = \sqrt{d^2 + \left(\frac{\ell}{2}\right)^2} = 361.4$ Km $\quad r_{o_2} = 83.7$ Km $\quad$ 1" = 200 km

$\hat{v}$ = events/yr/ℓ' = $\frac{1 \text{ event}}{1000 \text{ yrs}} / 279 \text{ Km} = 3.6 \times 10^{-6}$

$\gamma = \beta\left(\frac{C_3}{C_2}\right) - 1 = .37$

$c = e^{(\beta(C_1/C_2 + M_o))} = e^{[2.1(\frac{.21}{2.0} + 6.4)]} = 8.56 \times 10^5$

$r_{o_1}/d = 21.5 \qquad r_{o_2}/d = 4.98$

$\Gamma_1(\gamma) = 2.6 \quad \Gamma_2(\gamma) = 1.8$ from graph

$\Gamma\left(\frac{\gamma+1}{2}\right) = \Gamma_1(.68) = 1.9 \quad \Gamma_2(.68) = 1.6$ from graph

$G_1 = \frac{2\pi}{(2 \times d)^\gamma} \frac{\Gamma_1(\gamma)}{\left[\Gamma_1\left(\frac{\gamma+1}{2}\right)\right]^2} = \frac{2\pi}{(2 \times 16.8)^{.37}} \frac{2.6}{(1.9)^2} = 1.23$

$\frac{1}{2} G \hat{v} = \frac{1}{2}(1.23 \cdot 3.6 \times 10^{-6}) = 2.214 \times 10^{-6}$

$G_2 = \frac{2\pi}{(2 \times d)^\gamma} \frac{\Gamma_2(\gamma)}{\left[\Gamma_2\left(\frac{\gamma+1}{2}\right)\right]^2} = \frac{2\pi}{(2 \times 16.8)^{.37}} \frac{1.8}{(1.6)^2} = 1.20$

$\frac{1}{2} G_2 \hat{v} = \frac{1}{2}(1.20 \cdot 3.6 \times 10^{-6}) = 2.16 \times 10^{-6}$

$G\hat{v}_{Tot} = \left| \frac{1}{2} G_1 \hat{v} - \frac{1}{2} G_2 \hat{v} \right| = 5.4 \times 10^{-8}$

$i = \frac{C_2}{\beta} \ln\left[(G_{Tot}\hat{v}) c \, T_i\right] = \frac{2.0}{2.1} \ln(5.4 \times 10^{-8} \cdot 8.56 \times 10^5 \cdot 1000 \text{yr}) = 3.65$

$\log a = .55 + .5(3.6) - .83 \log(15) - .009(15)$

$= 1.35$

$m_b = \frac{7 + 3.5}{2} = 3.6 \qquad a = 22.4 \text{ cm/sec}^2 = .023g$

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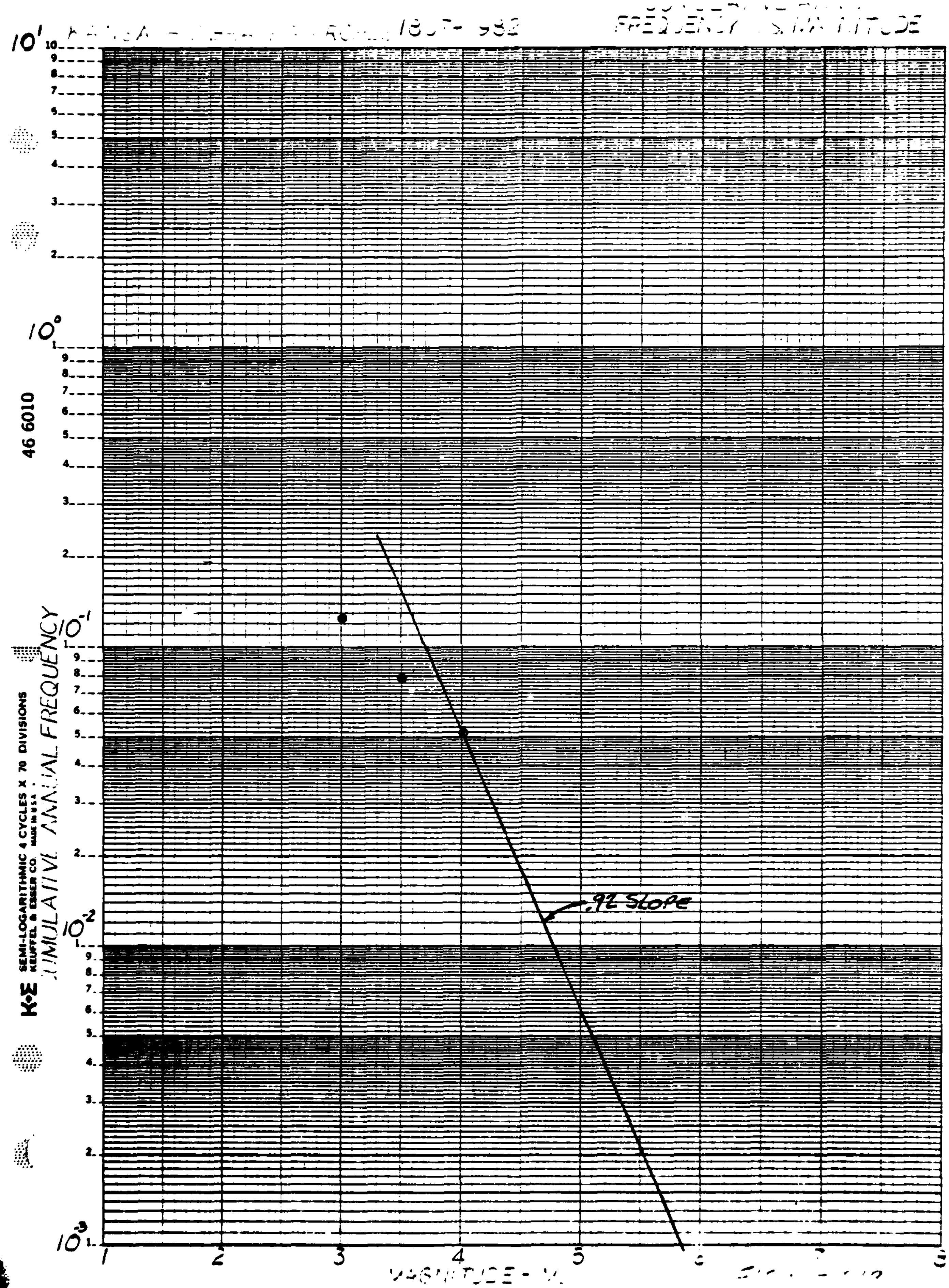
FIGURE A18



FREQUENCY VS. MAGNITUDE
CUMULATIVE ANNUAL FREQUENCY
.92 SLOPE
46 6010
K•E SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT SEISMIC HAZARD ANALYSIS – PAPIO 11 and 16		SHEET NO.	OF
ITEM HAZARD FROM KANSAS-NEBRASKA ARCHES NORTHWEST SEGMENT-TREATED AS A LINE SOURCE		BY BECKER	DATE
		CHKD. BY	DATE

$M_0 = 5.85$

$\Delta = 343\,Km$

$h = 15$

$d = \sqrt{\Delta^2 + h^2} = 343.2$

ℓ = apparent length = 864 Km $\qquad$ ℓ' = True length = 686 Km

$b = .92$

$\beta = b \ln 10 = 2.1$

$C_1 = .21$

$C_2 = 2.0$

$C_3 = 1.3$

$N_{m_0} = .001$

$\ell/2 = 432\,Km$

$r_0 = \sqrt{d^2 + (\frac{\ell}{2})^2} = 552$

$\hat{\nu}$ = events/yr/ℓ' = 1.5×10^{-6}

$\gamma = \beta\left(\frac{C_3}{C_2}\right) - 1 = .37$

$C = e^{(\beta(C_1/C_2 + m_0))} = e^{[2.1(\frac{.21}{2.0} + 5.85)]} = 2.7 \times 10^5$

$r_0 / d = 1.6$

$\Gamma(\gamma) = .98$ from graph

$\Gamma\left(\frac{\gamma+1}{2}\right) = \Gamma(.68) = .91$ from graph

$$G = \frac{2\pi}{(2 \times d)^{\gamma}} \frac{\Gamma(\gamma)}{\left[\Gamma\left(\frac{\gamma+1}{2}\right)\right]^2} = \frac{2\pi}{(2 \cdot 343.2)^{.37}} \frac{.98}{(.91)^2} = .66$$

$\frac{1}{2} G \hat{\nu} = \frac{1}{2}(.66 \cdot 1.5 \times 10^{-6}) = 4.95 \times 10^{-7}$

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FIGURE A20

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT SEISMIC HAZARD ANALYSIS - PAPIO 11 AND 16		SHEET NO.	OF
ITEM HAZARD FROM KANSAS-NEBRASKA ARCHS SOUTHEAST SEGMENT-TREATED AS A LINE SOURCE		BY BECKER	DATE
		CHKD. BY	DATE

$M_o = 5.85$ $T_i = 1000$ yrs

$\Delta = 343$ Km

$h = 15$ Km

$d = \sqrt{\Delta^2 + h^2} = 343.2$

ℓ_1 = apparent length = 508 Km ℓ' = True length = 686 Km

$b = .92$

$\beta = b \ln 10 = 2.1$

$C_1 = .21$

$C_2 = 2.0$

$C_3 = 1.3$

$N_{m_0} = .001$

$\ell_{1/2} = 254$

$r_{o_1} = \sqrt{d^2 + (\frac{\ell}{2})^2} = 427$ Km

$\hat{\nu}$ = events/yr/ℓ' = $\frac{1 \text{ event}}{1000 \text{ yr}}$/686 Km $= 1.5 \times 10^{-6}$

$\gamma = \beta\left(\frac{C_3}{C_2}\right) - 1 = .37$

$C = e^{(\beta(C_1/C_2 + M_o))} = e^{[2.1(\frac{.21}{2.0} + 5.85)]} = 2.7 \times 10^5$

$r_{o_1}/d = 1.24$

$\Gamma(\gamma) = .66$ from graph

$\Gamma\left(\frac{\gamma+1}{2}\right) = \Gamma(.68) = .64$ from graph

$$G = \frac{2\pi}{(2 \times d)^\gamma} \frac{\Gamma(\gamma)}{\left[\Gamma\left(\frac{\gamma+1}{2}\right)\right]^2} = \frac{2\pi}{[2(343.2)]^{.37}} \frac{.66}{(.64)^2} = .90$$

$$\frac{1}{2} G \hat{\nu} = \frac{1}{2}(.90 \cdot 1.5 \times 10^{-6}) = 6.75 \times 10^{-7}$$

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1 OCT 72

FIGURE A21

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT Seismic Hazard Analysis - Radio 11 and 16	SHEET NO.	OF
ITEM Sum of Hazards from Kansas-Nebraska Arches - Treated as a Line Source	BY Becker	DATE
	CHKD. BY	DATE

$$G_{TOT}\hat{V} = \Sigma\left(\tfrac{1}{2}G\hat{V}\right) = 6.75\times10^{-7} + 4.95\times10^{-7} = 1.17\times10^{-6}$$

$$i = \frac{C_2}{B}\ln\left[(G_{TOT}\hat{V})\,C\,T_i\right] = \frac{2.0}{2.1}\ln\left(1.17\times10^{-6}\cdot 2.7\times10^{5}\cdot 1000\,\text{yrs}\right)$$
$$= 5.5$$

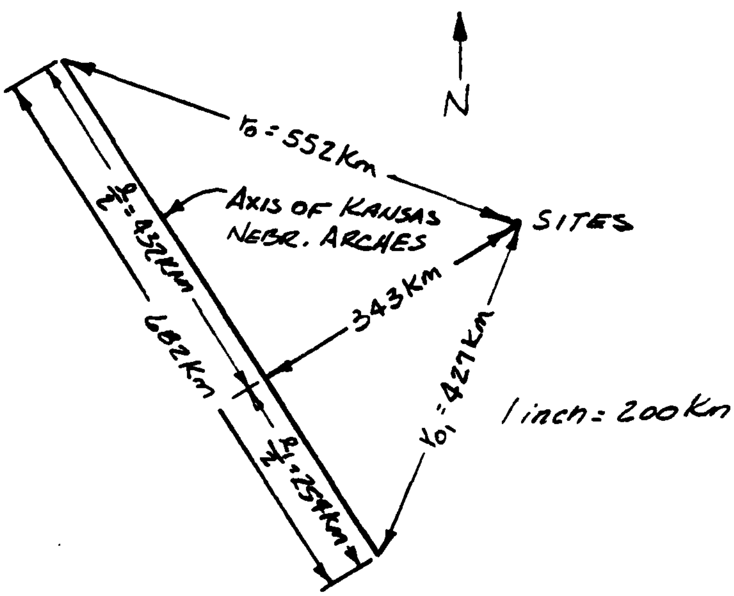
$$m_b = \frac{i+3.5}{2} = \frac{5.5+3.5}{2} = 4.5$$

$$\text{Log } a = .55 + .5(4.5) - .83\log(15) - .0019(15)$$
$$= 62.4\ \text{cm/sec}^2 = .064\,g$$

OR

$$\ln a = .933(4.5)$$
$$= 4.2$$
$$a = 66.6\ \text{cm/sec}^2 = .068\,g$$

use .064g.



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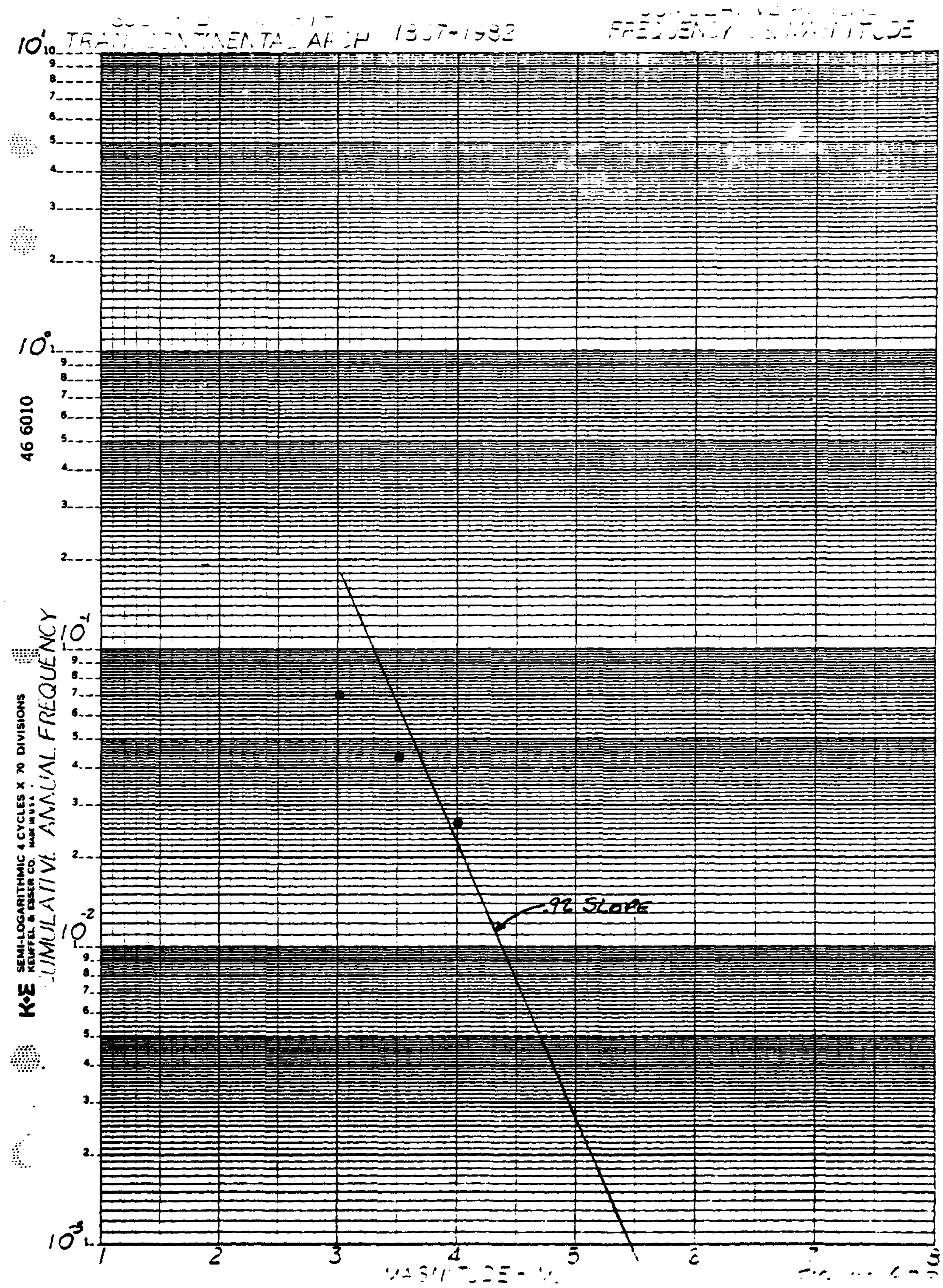
1 OCT 72

FIGURE A22


TRANSCONTINENTAL ARCH 1907-1982
FREQUENCY VS MAGNITUDE
CUMULATIVE ANNUAL FREQUENCY
.92 SLOPE
MAGNITUDE - M
46 6010
K•E SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT SEISMIC HAZARD ANALYSIS - RADIO 11 and 16	SHEET NO.	OF
ITEM HAZARD FROM SOUTHERN BOUNDARY OF TRANSCONTINENTAL - SIOUXANA ARCH - SOUTH-WEST SEGMENT	BY BECKER	DATE
	CHKD. BY	DATE

$M_o = 5.5$ $T_i = 1000$ yrs

$\Delta = 159$ Km

$h = 15$ Km

$d = \sqrt{\Delta^2 + h^2} = 159.5$ Km

ℓ = apparent length = 594 Km ℓ' = True length = 500 km

$b = .92$

$\beta = b \ln 10 = 2.1$

$C_1 = .21$

$C_2 = 2.0$

$C_3 = 1.3$

$N_{m_o} = .001$

$\ell/2 = 297$ km

$r_o = \sqrt{d^2 + (\ell/2)^2} = 337.1$ Km

$\hat{\nu}$ = events/yr/ℓ' = $\frac{1\ \text{event}}{\text{yr}}$/500Km $= 2.0 \times 10^{-6}$

$\gamma = \beta\left(\frac{C_3}{C_2}\right) - 1 = .37$

$C = e^{(\beta(C_1/C_2 + m_o))} = e^{\left[2.1\left(\frac{.21}{2.0} + 5.5\right)\right]} = 1.29 \times 10^5$

$r_o / d = 2.1$

$\Gamma(\gamma) = 1.2$ from graph

$\Gamma\left(\frac{\gamma+1}{2}\right) = \Gamma(.68) = 1.1$ from graph

$G = \frac{2\pi}{(2 \times d)^\gamma} \frac{\Gamma(\gamma)}{\left[\Gamma\left(\frac{\gamma+1}{2}\right)\right]^2} = \frac{2\pi}{(2 \cdot 159.5)^{.37}} \frac{1.2}{(1.1)^2} = .738$

$\frac{1}{2} G \hat{\nu} = \frac{1}{2}(.738 \cdot 2.0 \times 10^{-6}) = 7.38 \times 10^{-7}$

MRO FORM 1550
1 OCT 72

FIGURE A24

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT SEISMIC HAZARD ANALYSIS – Papio 11 and 16		SHEET NO.	OF
ITEM HAZARD FROM SOUTHERN BOUNDARY OF TRANSCONTINENTAL-SIOUKANA ARCH – NORTH-EAST SEGMENT		BY BECKER	DATE
		CHKD. BY	DATE

$M_0 = 5.5$ $T_L = 1000$ Yrs

$\Delta = 159$ Km

$h = 15$ Km

$d = \sqrt{\Delta^2 + h^2} = 159.5$ Km

ℓ_1 = apparent length = 406 Km ℓ' = True length = 500 Km

$b = .92$

$\beta = b \ln 10 = 2.1$

$C_1 = .21$

$C_2 = 2.0$

$C_3 = 1.3$

$N_{m_0} = .001$

$\ell/2 = 203$

$r_0 = \sqrt{d^2 + \left(\frac{\ell_1}{2}\right)^2} = 258.2$ Km

$\hat{\nu}$ = events/yr/ℓ' = 2.0×10^{-6}

$\gamma = \beta\left(\frac{C_3}{C_2}\right) - 1 = .37$

$c = e^{[\beta(C_1/C_2 + m_0)]} = e^{[2.1(\frac{.21}{2.0} + 5.5)]} = 1.29 \times 10^5$

$r_0 / d = 1.6$

$\Gamma(\gamma) = .96$ from graph

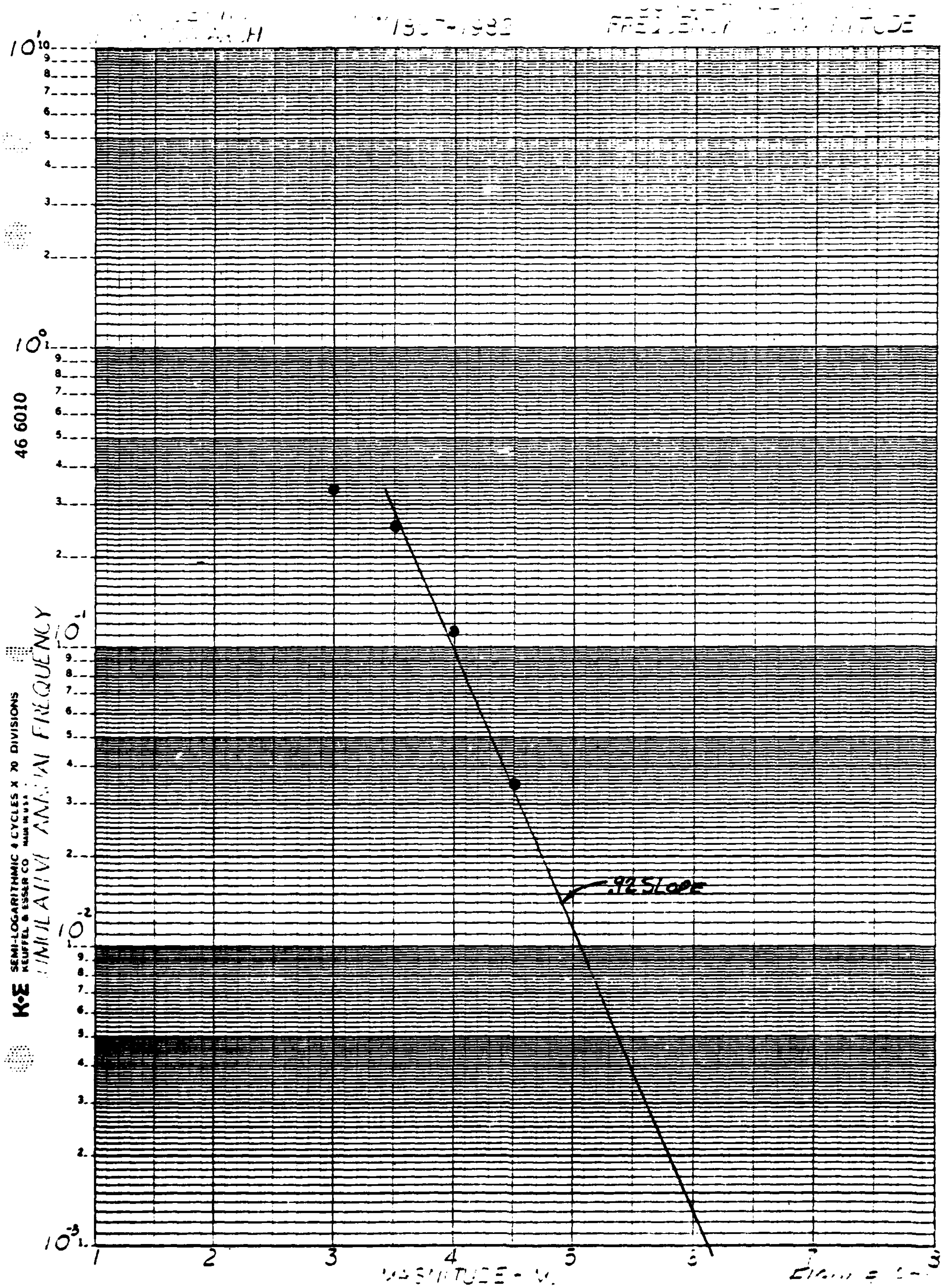
$\Gamma\left(\frac{\gamma+1}{2}\right) = \Gamma(.68) = .93$ from graph

$$G = \frac{2\pi}{(2 \times d)^\gamma} \frac{\Gamma(\gamma)}{\left[\Gamma\left(\frac{\gamma+1}{2}\right)\right]^2} = \frac{2\pi}{(2 \times 159.5)^{.37}} \frac{.96}{.93^2} = .826$$

$$\frac{1}{2} G \hat{\nu} = \frac{1}{2}(.826 \cdot 2 \times 10^{-6}) = 8.26 \times 10^{-7}$$

MRO FORM 1550
1 OCT 72

FIGURE A25



.92 SLOPE
1
2
3
4
5
6
8
46 6010
K·E SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO.

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT Seismic Hazard Analysis - Pardo 11 and 1c	SHEET NO.	OF
ITEM Sum of Hazards from Southern Boundary of Transcontinental-Siouxana Arch	BY Becker	DATE
	CHKD. BY	DATE

$G_{TOT}\hat{V} = \Sigma(\frac{1}{2}G_i\hat{V}) = 7.38\times10^{-7} + 8.28\times10^{-7} = 1.57\times10^{-6}$

$i = \frac{C_2}{B}\ln(G_{TOT}\hat{V}) \subset T_i = \frac{2.0}{2.1}\ln(1.57\times10^{-6}\cdot 1.29\times10^{5}\cdot 1000\,yrs)$

$= 5.1$

$M_o = \frac{i+3.5}{2} = 4.3$

$\log a = .55 + .5(4.3) - .83\log(15) - .0019(15)$

$= 1.7$

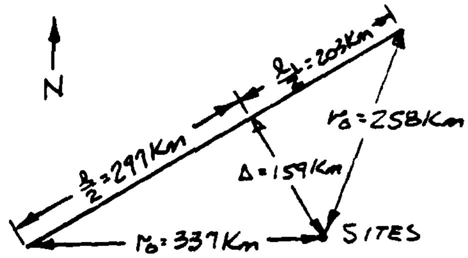
$a = 49.6\ cm/sec^2 = .051g$

or

$\ln a = .933(4.3) = 4.01$

$a = 55\ cm/sec^2 = .055g$

Use .05g



Southern Bound. - Transcontinental-Siouxana Arch

1 inch = 200 Km

MRO FORM 1 OCT 72 1550

FIGURE A27

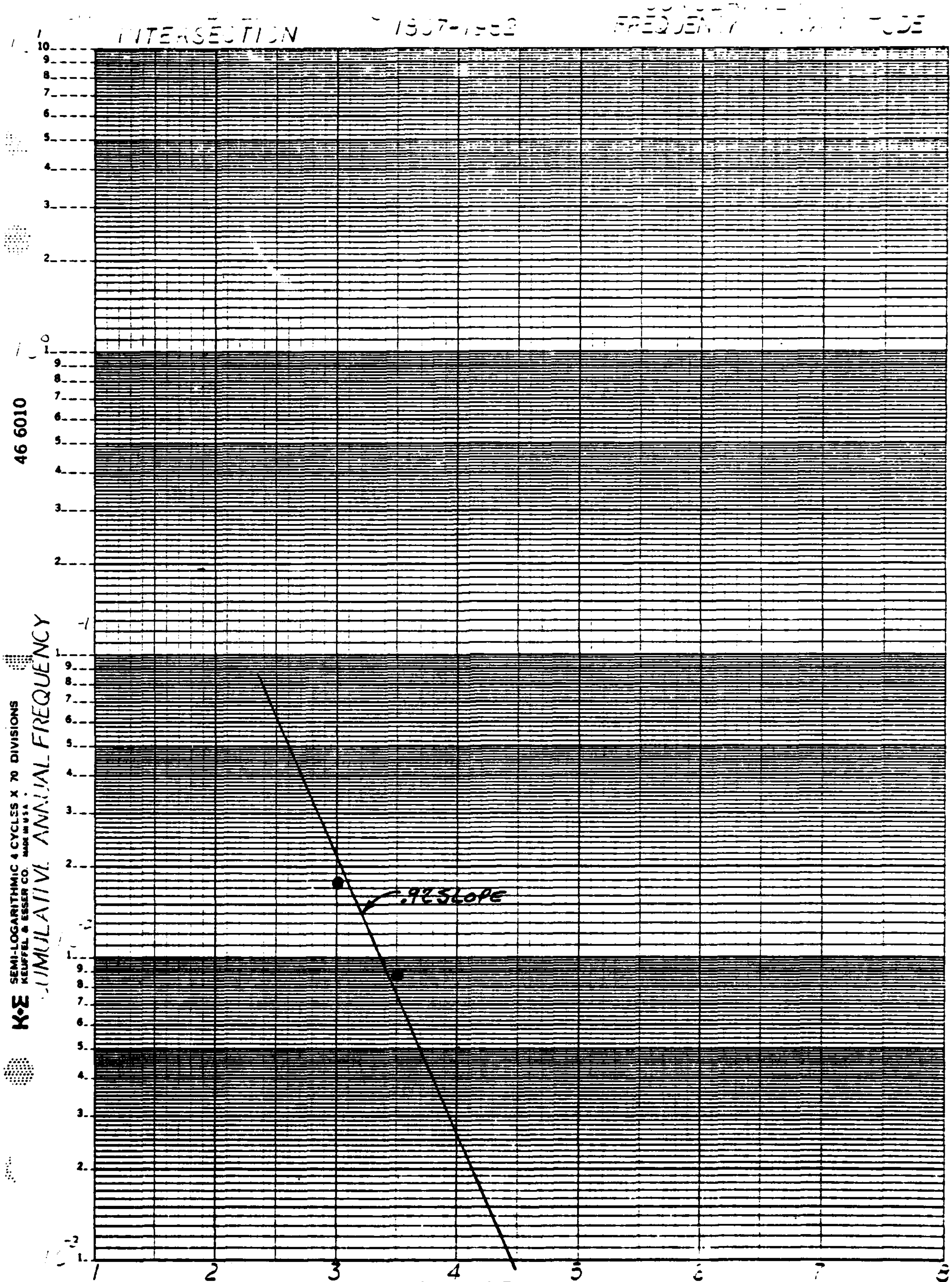

INTERSECTION
FREQUENCY
CUMULATIVE ANNUAL FREQUENCY
.923 SLOPE
MAGNITUDE - M.
46 6010
K+E SEMI-LOGARITHMIC 4 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO. MADE IN U.S.A.

FIGURE A-[illegible]

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS	
PROJECT Seismic Hazard Analysis - Papio 11 and 16		SHEET NO.	OF
ITEM Hazard from Point Source at Intersection of Humboldt and Union Faults		BY Becker	DATE
		CHKD. BY	DATE

$M_0 = 4.5$

$\Delta = 69.9$ Km

$h = 15$ Km

$d = \sqrt{\Delta^2 + h^2} = 71.4$ Km

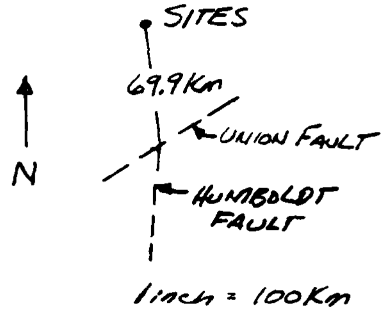
$b = .92$

$\beta = b \ln 10 = 2.1$

$C_1 = .21$

$C_2 = 2.0$

$C_3 = 1.3$



$N_{m_0} = .001 = \hat{\nu}$ events/yr

$\gamma = \beta C_3/C_2 - 1 = .37$

$G = d^{-(\gamma+1)} = .0029$

$G\hat{\nu} = 2.9 \times 10^{-6}$

$C = e^{[\beta(C_1/C_2 + m_0)]} = e^{[2.1(\frac{.21}{2.0} + 4.5)]} = 1.6 \times 10^4$

$T_i = 1000$ yrs

$i = \frac{C_2}{\beta} \ln[(G\hat{\nu}) C T_i] = \frac{2.0}{2.1} \ln(2.9 \times 10^{-6} \cdot 1.6 \times 10^4 \cdot 1000)$

$= 3.7$

$m_b = \frac{i + 3.5}{2} = \frac{3.7 + 3.5}{2} = 3.6$

$\log a = .55 + .5(3.6) - .83 \log(15) - .0019(15)$

$= 1.35$

$a = 22.4$ cm/sec² $= .023g$

or

$\ln a = .933(m_b) = .933(3.6)$

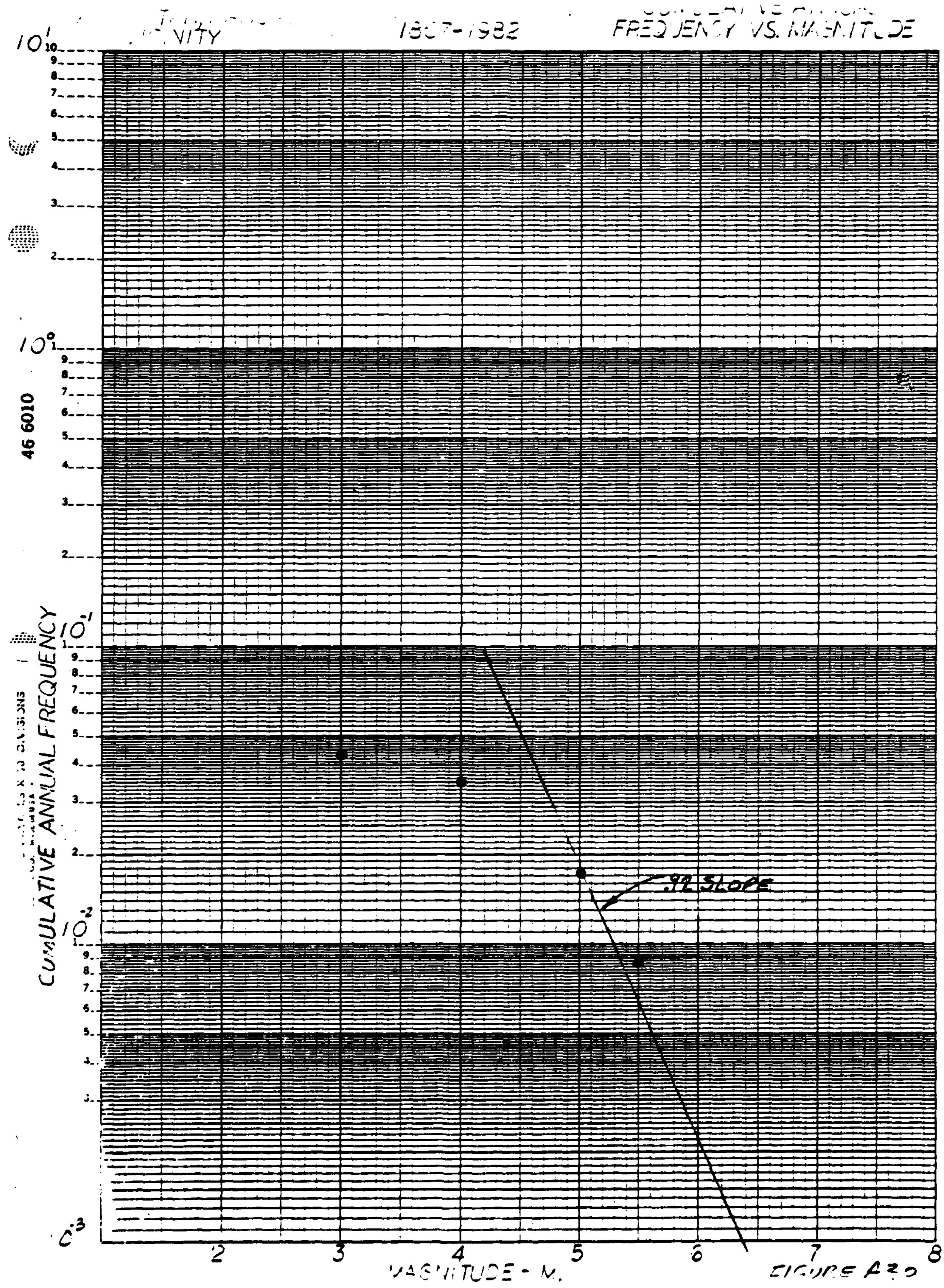
$= 3.36$

$a = 28.8$ cm/sec² $= .029g$

Use .023g.

MRO FORM 1 OCT 72 1550

FIGURE A29



NITY
1807-1982
FREQUENCY VS. MAGNITUDE
CUMULATIVE ANNUAL FREQUENCY
46 6010
.92 SLOPE
MAGNITUDE - M.

FIGURE A32

OMAHA DISTRICT	COMPUTATION SHEET	CORPS OF ENGINEERS
PROJECT Seismic Hazard Analysis - PA,MO 11 and 16	SHEET NO.	OF
ITEM Hazard from Point Source Centered Near Manhattan Kansas	BY Becker	DATE
	CHKD. BY	DATE

$M_0 = 6.4$

$\Delta = 241.3 Km$

$h = 15 Km$

$d = \sqrt{\Delta^2 + h^2} = 241.8$

$b = .92$

$\beta = b \ln 10 = 2.1$

$C_1 = .21$

$C_2 = 2.0$

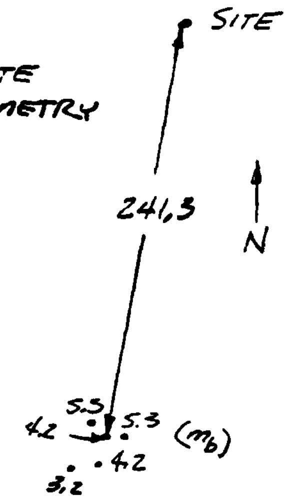
$C_3 = 1.3$

$N_{m_0} = .001 = \hat{\nu}$ events/yr

$\gamma = \beta^{C_3}/C_2 - 1 = .37$

$G = d^{-(\gamma+1)} = (241.8)^{-(.37+1)} = 5.4 \times 10^{-4}$

SITE GEOMETRY



$G\hat{\nu} = .00054 (.001) = 5.4 \times 10^{-7}$

$C = e^{(\beta(C_1/C_2 + M_0))} = e^{(2.1(\frac{.21}{2.0} + 6.4))} = 8.6 \times 10^5$

$T_i = 1000$ yrs

$i = \frac{C_2}{\beta} \ln[(G\hat{\nu}) C T_i] = \frac{2.0}{2.1} \ln(5.4 \times 10^{-7} \cdot 8.6 \times 10^5 \cdot 1000)$

$= 5.85$

$m_b = \frac{5.85 + 3.5}{2} = 4.7$

$\log a = .55 + .5(4.7) - .83 \log(15) - .0019(15)$
$= 1.89$

$a = 77.6$ cm/sec² $= .079g$

or

$\ln a = .933(m_b) = .933(4.7)$
$= 4.39$

$a = 80.2$ cm/sec² $= .082g$

Use .078g

MRO FORM 1550
1 OCT 72

FIGURE A31

F

8