REPORT

GROUND-WATER INVESTIGATIONS

PHASE IV FUEL STORAGE CAPACITY EXPANSION
NEAR MORRIS, ILLINOIS

GENERAL ELECTRIC COMPANY

Prepared by
DAMES & MOORE

August 3, 1977
Job No. 1674-101-07

DAMES & MOORE

August 3, 1977

General Electric Company
Nuclear Energy Division
175 Curtner Avenue
San Jose, California 95125

Attention: Mr. F. H. Shadel
Mail Code 380

Gentlemen:

Re: P.O. 529-JIT-99X
Report
Ground-Water Investigations
Project IV - Fuel Storage Capacity Expansion
Near Morris, Illinois
General Electric Company

This letter transmits seven copies of our "Report - Ground-Water Investigations Project IV - Fuel Storage Capacity Expansion near Morris, Illinois". This report has been revised to include General Electric's comments and is a partial completion of the work required by Task A, Phase I, charge PGDRX-811-FDX40-M89 of the referenced purchase order. The Geologic Report, the final report covered by this charge, will be submitted under separate cover following receipt of comments from General Electric.

If there are any questions regarding this report, or any other work being performed for the Morris Facility, please contact us.

Very truly yours,

DAMES & MOORE

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MLK/JST:lhk
Enclosure

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PROJECT IV-FUEL STORAGE CAPACITY EXPANSION

NEAR MORRIS, ILLINOIS

FOR

THE GENERAL ELECTRIC COMPANY

INTRODUCTION

This report presents the results of ground-water investigations performed by Dames & Moore for the proposed expansion of the spent fuel storage facility near Morris, Illinois. The purpose of these investigations is to evaluate and document site and regional ground-water conditions for inclusion in the Consolidated Safety Analysis Report for the facility.

SCOPE OF WORK

The scope of work performed for this investigation included:

1. A review of previous site investigations;
2. A review of published literature;
3. Evaluation of site boring data, ground-water level data, and pressure testing results;
4. Evaluation of the ground-water regime in the site area;
5. Evaluation of ground-water movement and use at the site and in the region.

GENERAL FEATURES OF THE AREA

The site is located east of Morris, Illinois, in the southeast 1/4 of Section 35, Township 34 North, Range 8 East, in Grundy County. The cities of Joliet and Chicago are 14 miles and 48 miles northeast of the site, respectively. The site is approximately 6000 feet southwest of the confluence of the Kankakee and Des Plaines Rivers. These rivers form the Illinois River, which flows in a westward direction. Figure 1, Site Vicinity Map, shows the site location in relation to local features.

The site is located on a topographic high that is about 530 feet above mean sea level (MSL). The topographic relief in the vicinity of the site is on the order of 25 feet. The Kankakee River is approximately 3000 feet east of the site and the Illinois River is about 6500 feet north of the site; both rivers have an average water elevation (near the site) of 505 feet MSL.

The climate of the region is continental with warm summers and cold winters. The average annual precipitation of the site area is 33 inches (Walton, 1965). June is generally the wettest month and February the driest (Suter, et al., 1959). The average annual runoff in the area as measured on the Kankakee River near Wilmington (see Figure 1) is 10 inches (U.S. Geological Survey, 1972).

PREVIOUS INVESTIGATIONS

Several geotechnical investigations have been made at the site in the past by Dames & Moore. The results of these studies, as well as boring and piezometer data, have been used to provide data for this investigation. These Dames & Moore reports are included in the general reference list at the end of this report. Additional information was drawn from other studies conducted in surrounding areas.

METHOD OF INVESTIGATION

The drilling program for this investigation was begun on March 26, 1976 and was completed on April 23, 1976. Twenty-two borings (B-1, B-3 through B-18, and D-1 through D-5) were drilled to investigate geologic and ground-water conditions at the site. Borings B-5 through B-18 were vertical borings. Borings B-1, B-3, and B-4 were drilled on a 60-degree angle from the horizontal to intersect the fault zone. Five additional vertical borings (D-1 to D-5) were drilled with rotary equipment and tricone bits. Borings ranged in depth from 10 to 186 feet. A description of the drilling program and the logs of borings are presented in the Dames & Moore Geologic Investigation Report (1977).

In-situ pressure testing of the bedrock was conducted in Borings B-1, and B-3 through B-9. Selected intervals in the borings were isolated with packers and pressure tested under

pressures ranging from 15 to 85 pounds per square inch. Permeability of the interval tested was calculated using the following formula (U.S. Bureau of Reclamation, 1963):

$$K = \frac{Q}{2\pi LH} \cdot \log_e \frac{L}{R}$$

where K = permeability
H = differential head of water
Q = constant rate of flow into boring
L = length of hole tested
R = radius of the boring

Permeability values determined from the pressure testing are shown in Table 1. These values are generally the average of two tests in each interval.

Piezometers were installed in 12 borings (B-1, B-3 through B-7, B-9 and D-1 through D-5) following drilling and pressure testing. In angle borings B-1, B-3 and B-4, 3/4-inch diameter PVC (polyvinyl chloride) pipe was used. All other piezometers installed consisted of 2-inch inside diameter PVC pipe slotted to monitor a specific interval. The pipe was lowered to the selected depth and the annular space around the slotted interval of the pipe was backfilled with clean pea gravel. About 2 feet of clean sand was placed over the pea gravel and from 1 to 2 feet of bentonite balls was placed over the sand to prevent migration of grout into the pea gravel. The remainder of the boring was then backfilled to ground surface with a cement-bentonite grout. The PVC pipe was protected with a 5-foot length of embedded steel pipe and steel

cap at the ground surface. Piezometer installation data are shown in Table 2 and piezometer locations are shown on Figure 2, Plot Plan.

A water-level monitoring program has been conducted at the site since the installation of the piezometers in the spring of 1976. In this program, water levels have been measured in all piezometers installed during this investigation as well as piezometers in Borings B-101, B-102, B-103, B-106, B-111, B-112 and B-113 installed during the investigation completed in September 1975, and piezometers (General Electric designations) 2"LAW, 6"LAW, sand filter, and NEW, installed during past investigations. In general, water-level measurements have been made twice a week and are continuing at the present. Initial measurements were made by Dames & Moore field personnel during March and April 1976, and subsequent measurements have been made by General Electric Company personnel.

REGIONAL GROUND-WATER CONDITIONS

GENERAL GEOLOGY

Following is a short summary of the geologic conditions in northeast Illinois, which are presented in greater detail in the Dames & Moore Geologic Investigation Report (1977). The stratigraphic section in northeast Illinois consists of about 2000 to over 4000 feet of layered sedimentary bedrock units (series of dolomite, limestone, sandstone and

shale ranging from Cambrian to Pennsylvanian in age) overlying igneous and metamorphic rocks of Precambrian age. Unconsolidated deposits of Pleistocene and Holocene age overlie the sedimentary rocks and range in thickness from less than 1 foot to over 400 feet (Suter, et al., 1959). A stratigraphic description of the geologic units in northern Illinois is summarized in Table 3. A surficial bedrock geology map of the regional area is presented on Figure 3. A regional geologic cross section showing the subsurface bedrock units between Morris, Illinois and Chicago is presented on Figure 4.

The glacial history of northern Illinois includes several periods of glacial advances and recessions. Most of the surface of the region is mantled with deposits of silty or clayey till. The coarser, more permeable and generally thicker glacial-fluvial deposits fill topographic lows and glacial valleys and constitute the main unconsolidated aquifers in northern Illinois.

The major geologic structures within 40 to 60 miles of the site are the Sandwich Fault Zone and the LaSalle Anticlinal Belt (Figure 5). The Sandwich Fault Zone trends west-northwest across northern Illinois and is approximately 6 miles northeast of the site. The site lies on the east flank of the LaSalle Anticlinal Belt, a major band of folded rocks trending north-northwest.

REGIONAL GEOHYDROLOGY

The main aquifers present within the site region are glacial deposits and the bedrock units of sandstone and dolomite. The glacial and bedrock aquifers in northern Illinois are indicated in Table 3.

Glacial Drift Aquifers

The uppermost aquifers in northern Illinois are the glacial drift aquifers as defined by Suter, et al. (1959). These consist mostly of sands and gravels deposited as glacial outwash in some of the major valleys. The glacial drift aquifers have a limited areal extent. The major glacial drift aquifers in the region occur along the Fox, Des Plaines, Kankakee, and Illinois Rivers. Water users in several areas in northern Illinois utilize these aquifers for water supplies; however, no glacial aquifers are utilized for significant water supplies within about 1 to 2 miles of the site. The city of Joliet pumps large amounts of ground water from a glacial drift aquifer about 16 miles northeast of the site. In Champaign County (south of the study area) and in Will County (northeast of Joliet), glacial drift aquifers are being pumped in excess of 3785 cubic meters per day (1 million gallons per day).

The glacial drift aquifers receive recharge mostly by vertical leakage through overlying glacial deposits. Under natural conditions, the glacial drift aquifers discharge to

rivers and streams directly or indirectly connected to the aquifer. Normally, recharge balances the amount of discharge from the aquifer. Where heavy pumpage from these aquifers decreases the natural ground-water levels, the amount of recharge from overlying beds will usually increase because of the increased head differential, and the rate of natural discharge will likely decrease.

Shallow Dolomite Aquifer

The uppermost bedrock aquifer in the region is the shallow dolomite aquifer (Suter, et al., 1950). This aquifer consists mainly of dolomites of Silurian and Ordovician age. The aquifer permeability is not uniform and well yields vary considerably depending upon the number and development of the fracture systems penetrated by a well.

The shallow dolomite aquifer is most important for ground-water supplies in areas north and east of the site where it is the uppermost bedrock unit. The aquifer is recharged mainly by vertical leakage from precipitation through overlying glacial deposits (Walton, 1965). Locally, small amounts of recharge also occur by induced infiltration through stream bottoms.

Cambrian-Ordovician Aquifer

Generally underlying the shallow dolomite aquifer in the region are shales of the Maquoketa Group. The Maquoketa

Group consists of (from younger to older) the Brainard Formation, Fort Atkinson Limestone, and Scales Shale. Rocks of this group act as the primary confining bed between the shallow dolomite aquifer and the underlying Cambrian-Ordovician aquifer.

Where present at the surface, the Fort Atkinson Limestone is usually considered a part of the shallow dolomite aquifer. The Cambrian-Ordovician aquifer (Suter, et al., 1959) consists of several formations that are generally considered as a single aquifer unit (see Table 3). The water-bearing properties of these units are summarized in Table 3.

Regionally, recharge to the Cambrian-Ordovician aquifer has been altered considerably from the natural conditions that occurred prior to development of ground-water resources. The decline in the potentiometric surface in the Cambrian-Ordovician aquifer is illustrated on Figures 6 and 7, which show the potentiometric levels in the aquifer in 1915, 1958, and 1971. According to Suter, et al. (1959), natural recharge to the Cambrian-Ordovician aquifer in 1865, prior to development of this aquifer, was low and ground-water moved southeast and south from areas in McHenry, Kane and DeKalb Counties and discharged by vertical leakage upward through the Maquoketa shales and into parts of the Illinois River Valley.

As ground-water development and pumping in northeast Illinois increased, the artesian water levels or potentiometric

surface around the main ground-water use areas declined, creating cones of depression as shown on Figure 7. The gradual lowering of the potentiometric surface has increased: 1) vertical hydraulic gradients; 2) the rate of recharge from vertical leakage; and 3) the rate of ground-water movement toward the cones of depression.

Mt. Simon Aquifer

The Cambrian-Ordovician aquifer is underlain by the Eau Claire shales and siltstones in northern Illinois. The Eau Claire shales act as a confining bed overlying the deepest bedrock aquifer in the region, the Mt. Simon aquifer, which is composed of the Mt. Simon Sandstone and the basal Eau Claire Formation (Table 3). This aquifer is widely used further to the north and northwest in Illinois where it is not as deep.

GEOHYDROLOGIC PARAMETERS

The significant hydraulic properties of aquifers are expressed mathematically by the transmissivity (T), permeability (K) and storage coefficient (S). The capacity of a formation to transmit ground water is expressed by its transmissivity, defined as: the unit rate of flow of water through a vertical strip of a saturated aquifer of unit width under a hydraulic gradient of 100 percent at the prevailing temperature of the water. The transmissivity is determined by aquifer test

methods. The permeability of an earth material is defined as: the unit rate of flow of water per unit area of aquifer under a hydraulic gradient of 100 percent. The permeability may be expressed as the transmissivity divided by the saturated thickness of the aquifer. The storage properties of an aquifer are expressed by the storage coefficient. This is defined as the volume of water released from or taken into storage per unit surface area of the aquifer per unit change in hydraulic head.

Glacial Drift Aquifers

Data on geohydrologic parameters for the glacial drift aquifers indicate a wide range of transmissivity values. According to Suter, et al. (1959), transmissivities of the glacial drift aquifers in northeastern Illinois range from about 40 to 1240 square meters per day (m^2/day)(3400 to 100,000 gpd/ft) and average about 310 m^2/day (25,000 gpd/ft). The range in storage coefficients is not known but is probably about 0.1 to 0.0003 depending if the aquifer is unconfined or confined (water table or artesian).

Shallow Dolomite Aquifers

The well yield and transmissivity of the shallow dolomite aquifer are quite variable. The transmissivity in northeastern Illinois ranges from a high of 1240 m^2/day (100,000 gpd/ft) in DuPage County to a low of about 110 m^2/day

(9,000 gpd/ft) in Lake County (Suter, et al., 1959). The shallow dolomite aquifer is generally under water-table or leaky artesian conditions in the region, depending primarily on the tightness of the overlying glacial deposits. Where the aquifer is under water-table conditions, the storage coefficient is probably about 0.03 as determined by Prickett, et al. (1964) in the Chicago Heights area. The aquifer's storage coefficient under leaky artesian conditions is about 0.0003, although it may vary considerably.

Cambrian-Ordovician Aquifer

The transmissivity of the Cambrian-Ordovician aquifer in northeastern Illinois ranges from about 134 m^2/day (10,800 gpd/ft) to 334 m^2/day (26,900 gpd/ft) and averages 216 m^2/day (17,400 gpd/ft)(Suter, et al., 1959). The work done by Suter, et al. indicates that the average coefficient of transmissivity decreases to the southeast from an average value of 273 m^2/day (22,000 gpd/ft) in Boone, DeKalb, and LaSalle Counties to an average of 186 m^2/day (15,000 gpd/ft) in the southern parts of Cook and Will Counties. The storage coefficient for the Cambrian-Ordovician aquifer is characteristic of artesian conditions and ranges from about 0.00016 to 0.00068 and averages about 0.00035 (Suter, et al., 1959).

REGIONAL GROUND-WATER USE

The site lies southwest of the largest area of ground-water usage in northeastern Illinois. This withdrawal area centers around Chicago and Joliet and reflects the dense urban population, and to a lesser degree, industrialization. There is also little ground-water development south and west of the site. Thus, the regional ground-water use study for this site consists of an eight-county area, generally north and northeast of the site. Included in this area are: McHenry, Lake, Kane, DuPage, Cook, Kendall, Will and Grundy Counties.

Historic and predicted ground-water withdrawals from this eight-county area are shown in Table 4 for various years from 1957 to 2020 (Suter, et al., 1959; Schicht and Moench, 1971). In 1957, total regional ground-water withdrawals were about 484,000 cubic meters per day (m^3/day) (128 mgd). Of this total, approximately 56.7 percent was withdrawn from the Cambrian-Ordovician aquifer. As shown in Table 4, ground-water withdrawals increased from 1957 to 1970 by 408,000 m^3/day (107.7 mgd) or approximately 84 percent. The estimates of future ground-water demand were determined for years 1980, 2000 and 2020 by Schicht and Moench (1971) and are based upon historical relationships between per capita consumption, population, and manufacturing employment. The demand for ground-water supplies in the eight-county area is expected to triple between 1980 and 2020.

Ground-water use trends in Grundy County generally reflect the ground-water use patterns throughout the eight-county area. Ground-water use is expected to increase sharply in the future. The following tabulation presents historical and predicted future withdrawal rates for Grundy County:

Historic and Predicted
Ground-Water Withdrawals
Grundy County

Year	Pumpage: cubic meters per day	Pumpage: million gallons per day
1957	6400	1.7
1970	21600	5.7
1980	30300	8.0
2000	56800	15.0
2020	90800	24.0

The withdrawal rates for 1957 and 1970 are from Suter, et al. (1958) and Sasman, et al. (1974), respectively, while the predicted withdrawals are based on the premise that the predicted withdrawals for Grundy County will increase at the same rate as the predicted withdrawals for the eight-county area used by Schicht and Moench (1971).

Of the total volume of ground water used in Grundy County in 1970, approximately 45 percent was used for industrial purposes, 32 percent for public supplies, and 14 percent for domestic supplies (Sasman, et al., 1974). According to Sasman, et al. (1974), the three largest municipal users of ground water in the county were Coal City, Gardner, and Morris.

SITE GROUND-WATER CONDITIONS

SITE GEOLOGY

At the site, sedimentary bedrock units ranging from Pennsylvanian to Ordovician in age are overlain by a thin layer of unconsolidated materials. The main geologic structure at the site is a northwest-southeast trending fault zone (see Figure 2 for location). A generalized geologic cross section of the site is presented on Figure 8.

The site geologic conditions are summarized below and are described in detail in the Dames & Moore Geologic Investigation Report (1977).

Unconsolidated Materials

The site is generally mantled with a thin (1 to 2 feet) layer of soil overlying an undulating, erosional bedrock surface. The unconsolidated material is primarily ice-deposited glacial till, water-deposited lacustrine sediments, and topsoil derived from the till. Weathered bedrock is generally present within 1 foot of the surface.

The glacial till found at the site has been identified as the Malden Till Member of the Wedron Formation (deposited about 15,000 to 17,000 years ago). Mineralogic analyses done by the Illinois State Geologic Survey indicate that, at the site, the Malden Till consists primarily of materials

derived from local bedrock. This material consists of an unsorted mixture of mottled brownish-yellow and gray clay, silt, and sand with rounded to angular rock fragments.

Bedrock Units

The bedrock units penetrated by borings and/or trenches are, in descending stratigraphic order: the Spoon Formation of Pennsylvanian age; Brainard Shale, Fort Atkinson Limestone, and Scales Shale of the Maquoketa Group of Ordovician age; and the Galena Group of Ordovician age.

Spoon Formation - The Spoon Formation is the uppermost bedrock unit at the site and is a light gray, fine to medium-grained, thin to medium-bedded sandstone, containing mica and some clay. The sandstone is locally calcareous and commonly has iron staining along bedding planes and fractures. It is moderately to highly weathered. In the site area, the Spoon Formation is best developed southwest of the fault zone and was not found within the area of the proposed fuel storage capacity expansion. Borings in the site vicinity indicate that, where present, the unit ranges from about 2 to 8.3 feet thick. The average thickness of the unit, where encountered, is 4.8 feet.

Brainard Shale - The Brainard Shale consists of gray to greenish-gray shale with interbeds of light gray, calcareous and argillaceous siltstone. The shale is thinly laminated,

highly weathered, locally calcareous, and contains occasional zones of broken fossil debris. The Brainard has been removed by erosion near the new basin location but reaches a maximum thickness of 13 feet in the extreme southeastern portion of the site where it overlies the Fort Atkinson.

Fort Atkinson Limestone - The Fort Atkinson Limestone consists of an upper unit (up to 11 feet thick) of interbedded gray shale and limestone and a lower unit (up to 38 feet thick) of light gray to white crystalline limestone. The upper unit is extremely fossiliferous and exhibits contorted bedding and thin laminations of dark gray, silty, calcareous shale. This unit grades downward into the relatively clean, light gray, coarse crystalline limestone.

The lower, coarse, crystalline limestone is fossiliferous, stylolitic, and contains occasional green clay partings. The limestone grades downward to slightly vuggy limestone, with pinpoint to 1/2-inch vugs, occasionally lined with pyrite and secondary calcite.

A transitional zone occurs at the base of the Fort Atkinson Limestone. This zone is from 1 foot to about 5 feet in thickness and consists of interbedded greenish-gray silty limestone and greenish-gray silty clay with the silty clay layers increasing downward in number and thickness. The contact with the underlying Scales Shale is generally accompanied by a distinct color change from greenish-gray limestone and siltstone to dark or medium gray shale.

The Fort Atkinson is the upper bedrock unit on the upthrown side of the fault zone and ranges from 10 to 15 feet thick at the site of the new spent fuel storage basin. The full section of the unit, where not influenced by faulting or erosion, averages 40 feet thick.

Scales Shale - The Scales Shale is a medium to dark gray, calcareous shale that is locally fossiliferous. It varies from massive and very silty (50 percent) to thinly-bedded with less silt content (25 to 50 percent), and contains some secondary pyrite along fractures.

At the site of the new basin, the top of the Scales Shale is about 10 to 15 feet below land surface and the unit averages 68 feet thick.

Galena Group - The Galena Group consists of medium to light gray dolomite with some galena mineralization. It is argillaceous, finely crystalline, medium to thick bedded and locally vuggy. The unit was only partially penetrated by borings and, therefore, the total thickness of the unit at the site is not known.

Site Structures

The main geologic structure at the site is a northwest trending fault zone shown on Figure 2. Based on previous and present Dames & Moore site investigations, the fault zone is an en echelon series of high angle (approximately 10 to 15 degrees from vertical) normal faults dipping to the southwest.

The southwest side of the fault zone has dropped down in relation to the northeast side with a total displacement of 35 to 40 feet. The fault zone is curvilinear and strikes essentially northwest through the plant area (Figure 2). For more detail, refer to the Dames & Moore Geologic Investigation Report (1977).

The Fort Atkinson Limestone is generally the upper bedrock unit on the northeast (upthrown) side of the fault zone and is generally unconformably overlain by the Pennsylvanian age Spoon Formation on the southwest side of the fault zone.

SITE GEOHYDROLOGY

All of the regional aquifer units are present at the site although some of the units are not thick enough or permeable enough to be an important source of water. The glacial drift overlying the bedrock is so thin and high in silt and clay content that it cannot be considered an aquifer at the site. The Fort Atkinson Limestone is a part of the shallow dolomite aquifer but is not considered an aquifer at the site of the new basin. The Scales Shale serves as the primary confining bed for the Cambrian-Ordovician aquifer. The Galena Group dolomites are the upper unit of the Cambrian-Ordovician aquifer. No known wells in the site vicinity have been drilled deep enough to penetrate the Mt. Simon aquifer.

Geohydrologic Parameters

Geohydrologic parameters for the bedrock units at the site were evaluated primarily by analyzing the field pressure test results and piezometer readings and comparing this data with data in published reports by the Illinois State Water Survey. The test data were used to determine the horizontal permeability of the rocks. In addition, estimates have been made of porosity and effective porosity of the different rock types based on rock density measurements of core samples from the Dames & Moore Site Evaluation Study at the Dresden Nuclear Power Station (1965) and data given by Walton (1970). Effective porosity is that portion of the rock through which flow occurs. Specific yield is the portion of water that will drain from a unit volume of saturated rock. While not the same, effective porosity and specific yield are generally similar.

The upper bedrock units, the Fort Atkinson Limestone, the Scales Shale and the Galena Dolomite were pressure tested using inflatable packers to isolate different zones in the boreholes. Results of pressure testing during the 1976 field investigations by Dames & Moore are given in Table 1.

Spoon Formation - The Spoon Formation was not pressure tested due to its shallow depth and thinness. The permeability of the Spoon was conservatively estimated to be 3.9×10^{-4} centimeters per second (cm/sec)(400 ft/yr). Although no permeability tests were conducted on the Spoon, the

above value is believed to be representative for a fine-grained sandstone with some clay content. Walton (1970) gives a range of permeability of 2.4×10^{-5} to 2.4×10^{-3} cm/sec for sandstones. The estimated value falls within the upper range of these values.

Density data indicate the total porosity of the Spoon is about 21 percent. Walton (1970) indicates the range of specific yield (effective porosity) for sandstone is 5 to 15 percent. The average effective porosity of the Spoon Formation was thus estimated to be about 10 percent.

Fort Atkinson Limestone - Tests within the Fort Atkinson Limestone resulted in a wide range of permeability. Values ranged from about 7.7×10^{-4} to 9.7×10^{-7} cm/sec (800 to less than 1 foot per year). The median permeability from the pressure tests in the Fort Atkinson Limestone at the site was about 1.1×10^{-4} cm/sec (110 ft/yr). Based on field observations during test pit excavations, the upper 10-foot zone of the Fort Atkinson is often highly weathered and locally may have permeabilities much higher than the values determined by pressure testing.

Tests of rock samples indicate that the total porosity of the Fort Atkinson ranges from about 1 to 9 percent. Walton (1970) gives the range of specific yield for limestones and shales as 0.5 to 5 percent. The specific yield is equivalent to the effective porosity or that portion of the total pore volume that transmits fluids. The average effective porosity of the Fort Atkinson is estimated to be 2 percent.

Scales Shale - Horizontal permeabilities of the Scales Shale ranged from about 6.6×10^{-4} to 9.7×10^{-7} cm/sec (700 to less than 1 ft/yr). The median horizontal permeability for the Scales at the site was 5.8×10^{-6} cm/sec (6 ft/yr). In general, the horizontal permeability of the Scales Shale appeared to decrease with depth at the site. Several of the zones tested in the Scales took virtually no water at the pressures used during the testing (15 to 85 pounds per square inch). The vertical permeability of the Scales Shale was assumed to be equal to the average vertical permeability for the Maquoketa Group shales in northeastern Illinois, as the Scales Shale is the lower unit of the Maquoketa Group and appears to be typical of the shales of this group. According to Walton (1965), the average coefficient of vertical permeability of the Maquoketa Group is 2.3×10^{-9} cm/sec (0.0024 ft/yr). This value is assumed to be representative for the Scales Shale at the site. The large apparent difference in the horizontal and vertical permeability values in the Scales Shale is believed to be primarily due to the nature of the rock. The mainly horizontal bedding planes in the shale and preferential horizontal orientation of the clay minerals in the shale both serve to restrict vertical flow much more than horizontal flow.

Bulk density determinations of samples of Scales Shale made by Dames & Moore in 1965 on samples collected about 3000 feet northeast of the site indicate that total porosity of the Scales Shale ranges from about 5 to 17 percent (Dames &

Moore, 1965). Based on the range (0.5 to 5 percent) of specific yield for shale mentioned by Walton (1970), it is likely that only a small portion of the total pore space will transmit water through the shale. The average effective porosity of the Scales is estimated to be 2 percent.

Galena Dolomite - Pressure tests of the upper Galena Dolomite at Borings B-101 and B-110 in the Dames & Moore study completed in September 1975 indicated permeabilities less than 5×10^{-6} cm/sec (5 ft/yr). These tests were only in the upper portion of the unit and may not be representative of the overall Galena.

The water well on the site was test pumped to estimate geohydrological parameters in the upper Cambrian-Ordovician aquifer. The 788-foot deep well taps the Galena-Platteville dolomites, Glenwood-St. Peter sandstones and the New Richmond Sandstone. The most productive part of the aquifer, the Ironton-Galesville Sandstone, was not tapped by this well. The well was test pumped at rates ranging from 545 to 1850 m^3/day (100 to 339 gallons per minute). The specific capacities ranged from 55 to 20 m^3/day per meter of drawdown (3.1 to 1.1 gallons per minute per foot of drawdown) at the minimum and maximum pumping rates, respectively. Based on this data, the estimated transmissivity of this portion of the Cambrian-Ordovician aquifer ranges from about 25 to 87 m^2/day (2000 to 7000 gallons per day per foot). Dividing the transmissivity by

the approximate saturated thickness of rock tapped by the well gives an average permeability range of 1.9×10^{-4} to 6.6×10^{-4} cm/sec (195 to 683 ft/yr). According to Suter, et al. (1959), the permeability of the Galena is commonly quite low when the unit is overlain by shale and the permeability of the Galena is usually much lower than the sandstones below the Galena-Platteville dolomites. Therefore, we have estimated the permeability of the Galena Dolomite at the site to be about 2×10^{-4} cm/sec (200 ft/yr). Based on site pressure test results, it appears that the permeability of the Galena is probably somewhat less than the value above. This value is conservative and will give faster travel times than will likely occur.

Based on similarities between the Galena Dolomite and Fort Atkinson and the lack of specific test data, the effective porosity of the Galena in the site vicinity is conservatively estimated to be about 2 percent (Table 6).

Ground-Water Levels

Ground-water movement at the site was evaluated mainly by analyzing water-table contour maps made from water levels measured in the site piezometers. Contour maps showing ground-water levels in the Fort Atkinson Limestone and Scales Shale in December 1976 are presented on Figures 9 and 10. In addition to the two ground-water contour maps, additional ground-water level data are given on Figure 11 and in Table 5.

Figure 11 shows the ground-water level fluctuations at four selected piezometers from March 1976 to April 1976. Ground-water levels measured at the site piezometers are given in Table 5.

The primary source of ground water in the Spoon Formation, Fort Atkinson Limestone, and Scales Shale at the site is local precipitation, which infiltrates and percolates through the thin veneer of glacial till that overlies the bedrock, or directly infiltrates the bedrock units where they outcrop at the site.

Based on site water-level measurements, the Spoon Formation, Fort Atkinson Limestone, and the Scales Shale are hydraulically interconnected to some degree. Water levels in piezometers tapping these units are all generally within 5 to 10 feet of each other (Table 5 and Figures 9, 10 and 11). However, where piezometers tapping the different units are in close proximity, there is, generally a higher water level in the upper unit in relation to the lower unit (compare water levels in D-3 with D-4 and B-102 with B-103 in Table 5). This indicates that there is a vertical hydraulic gradient downward in the site area.

Ground-water levels in the upper bedrock units generally are a slightly subdued reflection of the topography. The site of the new spent fuel storage basin is on a local topographic high, and, as indicated by the water-table contour maps, ground water flows from this area to the east, south, and

west. Previous geologic investigations at the site indicate that generally the low swampy areas at the site have alluvial soils, glacial deposits including till and lacustrine clays, and residual clays near the surface. The ground water probably discharges to the swamps and drains by slow seepage through the unconsolidated deposits.

Ground-water levels in piezometers tapping the Spoon Formation, Fort Atkinson Limestone, or Scales Shale range from about 1 to 20 feet below ground surface. Figure 11 shows ground-water level hydrographs for selected piezometers at the site. In general, ground-water levels fluctuated more rapidly and over a larger range in the shallower piezometers than in the deeper piezometers. Response of ground-water levels to precipitation or other recharge events was usually rapid in piezometers tapping the Fort Atkinson, slower in the piezometers tapping the upper Scales Shale, and slower still in piezometers tapping only the lower Scales Shale. This is believed to be due to the difference in relative permeabilities of these units, with the Fort Atkinson being highest and the lower Scales the lowest, and to the insulating effect of each of the units subduing the shallow fluctuation with depth.

During the period of water-level monitoring at the site (March 1976 to present), the range or amplitude of water-level fluctuations was generally from about 4 to 11 feet depending upon the unit tapped. The shallow piezometers usually

had the highest range of water levels while the deeper piezometers usually had smaller fluctuations. On a long-term basis, the ground-water levels may be expected to fluctuate an additional several feet. This would depend primarily on extreme weather patterns in the vicinity, such as several consecutive wet or dry years.

The dolomites of the Galena Group are hydraulically separated from the upper bedrock units by the Scales Shale. Piezometer D-1 at the site is used to monitor ground-water levels in the Galena Group. A hydrograph of water-level fluctuations in the Galena is shown on Figure 11. The observed water levels generally agree with regional potentiometric levels reported for the Cambrian-Ordovician aquifer (Figure 7).

The elevation of the Galena potentiometric surface at the site based on Piezometer D-1 ranged from about 382 to 387 feet above MSL during the past year.

Piezometers B-101 and B-110 were also installed to allow monitoring of the Galena Group; however, these piezometers only penetrated into the Galena to elevation 402 and 404, respectively, and both piezometers have been generally dry following installation.

Rate of Ground-Water Movement

Ground-water flow under existing conditions at the site was evaluated by measuring average hydraulic gradients

from water-level data and using permeabilities and effective porosities presented previously. The parameters used to compute average ground-water velocities at the site are given in Table 6. Average ground-water velocities were estimated using the Dupuit-Forchheimer modification (Harr, 1962) to the Darcy equation:

$$v = ki/n_e$$

where v = average ground-water velocity
k = coefficient of permeability
i = hydraulic gradient
n_e = effective porosity

Spoon Formation - The Spoon Formation Sandstone is primarily present southwest (on the downthrown side) of the northwest-southeast trending fault zone. However, scattered isolated patches have been found on the upthrown block. Ground-water flow in this unit appears to be to the southwest at an average hydraulic gradient of about 1 percent. Since the water levels in the Spoon are above those in the Fort Atkinson, there is some downward movement of ground water into the Fort Atkinson. Average ground-water velocities in the Spoon were calculated to be about 12 meters per year (m/yr) (40 ft/yr) using a permeability of 3.9×10^{-4} cm/sec (400 ft/yr) and an effective porosity of 10 percent.

Fort Atkinson Limestone - Water-level measurements from piezometers tapping the Fort Atkinson at the site indicate an average hydraulic gradient of about 1.5 percent. Using a

gradient of 1.5 percent, a coefficient of permeability of 1.1×10^{-4} cm/sec (110 ft/yr), and an effective porosity equivalent to 0.02, the average ground-water velocity in the site area is about 25 m/yr (82 ft/yr) in the Fort Atkinson. Locally, the ground-water velocities may be much higher due to higher permeabilities, especially in the upper few feet.

Scales Shale - The Scales Shale at the site receives recharge mainly from the overlying Fort Atkinson Limestone and possibly from direct recharge where the unit is at the surface north of the site. Ground-water movement is generally away from the topographic high and in a direction perpendicular to the ground-water contours (Figure 10).

The average hydraulic gradient at the site was measured to be about 1.4 percent. Using this value, a coefficient of permeability of 5.8×10^{-6} cm/sec (6 ft/yr), and an effective porosity of 0.02, the average horizontal ground-water velocity in the Scales Shale at the site was determined to be approximately 1.2 m/yr (4 ft/yr).

The Scales Shale is the primary confining bed over the Cambrian-Ordovician aquifer. Some downward leakage through the Scales Shale to the Galena Dolomite is induced mainly by the large potentiometric head difference between the Scales and the Cambrian-Ordovician aquifer. Presently, the ground-water elevation in the Scales is about 520 to 525 feet (MSL) at the site, and the piezometric elevation in the Cambrian-Ordovician aquifer is about 385 feet (MSL). Since the top of the Galena

is about elevation 440 to 450 feet MSL, the upper 60 feet are unsaturated. The vertical hydraulic gradient through the Scales is downward and is determined by dividing the head differential from the top of the Scales to the bottom by the thickness of the shale. The vertical gradient was calculated to be about 110 percent.

Travel times through the shale were calculated, assuming the above gradient, an effective porosity of 0.02, and the coefficient of vertical permeability (Walton, 1965) of 2.3×10^{-9} cm/sec (0.0024 ft/yr). This resulted in an average vertical ground-water velocity of 0.04 m/yr (0.13 ft/yr) through the Scales.

Galena Group - Ground-water flow in the Galena Group section of the Cambrian-Ordovician aquifer is toward the east due to the cones of depression created by heavy ground-water pumping in the Joliet area. Average ground-water velocities in the Galena Group were estimated using a hydraulic gradient of 0.7 percent (measured on Figure 7), a coefficient of permeability of 1.9×10^{-4} cm/sec (200 ft/yr), and an estimated effective porosity of 0.02. With these parameters, the average ground-water velocity was about 21 m/yr (70 ft/yr).

Effect of Fault Zone on Ground-Water Movement

Water-level measurements made in piezometers installed in and near the fault zone and pressure test data in

the fault zone southwest of the new basin location indicate that the fault zone acts as a relatively impermeable zone that does not transmit appreciable quantities of ground water.

Three piezometers (B-1, B-3 and B-4) were installed in angle borings that intersected the fault zone. If the fault zone were a hydraulically interconnected zone of high permeability, the water levels in these piezometers should be similar. It was found, however, that the ground-water elevation varies about 5 to 6 feet between piezometers B-1, B-3 and B-4. The fault restricts ground-water flow, as ground-water levels in the Fort Atkinson southwest of the fault zone are generally 5 to 7 feet below those in the Fort Atkinson northeast of the fault zone (see Figure 9). In addition, the ground-water gradient is higher across the fault zone than northeast and southwest away from the fault zone. If the fault zone were transmitting appreciable quantities of water, this head differential should be rapidly dissipated and the ground-water gradient should be about the same as it is away from the fault zone. The gradient in the Scales Shale is also considerably steeper in the immediate vicinity of the fault zone than on either side of the fault zone (see Figure 10).

Pressure test data from Borings B-1, B-3, and B-4 also substantiate that the permeabilities in the fault zone are generally equal to or lower than the rock on either side of the zone (Table 1). In some cases, no measurable quantities of water could be injected into the tested intervals.

ON-SITE GROUND-WATER USE

The spent fuel storage facility utilizes ground water as make-up water for cooling. Water is obtained from a 788-foot deep well at the site (location shown on Figure 2) tapping much of the Cambrian-Ordovician aquifer including the Galena-Platteville dolomites, Glenwood-St. Peter sandstones and the New Richmond Sandstone. The well is about 10 inches in diameter and is equipped with a pump capable of yielding about 545 m^3/day (100 gpm). The pump test indicated that the well could yield about 1365 m^3/day (250 gpm) on a continuous basis.

The average requirement for cooling water make-up is estimated to be about 7.6 m^3/day (2140 gpd)(Eger, 1977). This volume of water can be easily supplied by the existing well at the site.

At the Dresden Nuclear Power Station (about 3000 feet northeast of the site), two deep wells tap the lower Cambrian-Ordovician aquifer and pump about 165 to 220 m^3/day (30 to 40 gpm). The location of the closest well is shown on Figure 1B.

The present on-site and nearby off-site withdrawals of ground water from the Cambrian-Ordovician aquifer will have no detectable effect on the shallow ground-water regime at the site due to the separation of shallow and deep ground-water systems by the Maquoketa Group, specifically the Scales Shale. Ground-water levels in the Cambrian-Ordovician aquifer will likely continue to gradually decline as regional pumpage continues to increase. The water levels in the Fort Atkinson

Limestone and the Scales Shale range from about 512 to 530 feet at the site area, and the water levels in the Galena Dolomite range from about 382 to 387 at the site for the period of record (Figure 11). Even though there is some potential for downward migration of ground water, the relatively impermeable shale hydraulically separates the deep and shallow systems and precludes any significant leakage from shallow units to the Galena Dolomite. There should not be any increase in the rate of downward leakage through the Maquoketa shales in response to declining water levels in the Cambrian-Ordovician aquifer since the potentiometric level in the Cambrian-Ordovician aquifer is already below the base of the Maquoketa Group shales and the top of the aquifer.

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The attached tables and figures complete this report.

Respectfully submitted,

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TABLE 1

PERMEABILITY VALUES DETERMINED
FROM FIELD PRESSURE TESTING

Boring No.	Depth of Tested Interval (feet)	Unit Tested	Number of Tests	Average Permeability (cm/sec)
B-1	12 - 22	FA	1	6.2×10^{-5}
	14 - 24	FA	1	2.0×10^{-4}
	19 - 29	FA	1	4.9×10^{-4}
	20.5 - 30.5	FA	1	6.0×10^{-4}
	29 - 39	FA/SC	2	1.1×10^{-4}
	39 - 49	SC	2	1.5×10^{-4}
B-3	52.5 - 62.5	SC	2	9.7×10^{-7}
	62.5 - 72.5	SC*	2	4.8×10^{-5}
	72.5 - 82.5	SC	2	4.4×10^{-6}
	82.5 - 92.5	SC	3	6.1×10^{-6}
B-4	47.5 - 57.5	FA/SC	2	2.2×10^{-4}
	57.5 - 67.5	SC*	2	9.7×10^{-7}
	67.5 - 77.5	SC*	2	1.2×10^{-6}
	77.5 - 87.5	SC	2	8.0×10^{-6}
	87.5 - 97.5	SC/GL	2	9.7×10^{-7}
B-5	9.5 - 19.5	FA	1	8.2×10^{-5}
	11.5 - 21.5	FA	1	6.3×10^{-4}
	14.5 - 24.5	FA	2	5.4×10^{-4}
	24.5 - 34.5	FA	2	1.5×10^{-6}
	34.5 - 44.5	FA	2	1.7×10^{-4}
	44.5 - 54.5	FA/SC	2	7.5×10^{-4}
	49.5 - 59.5	FA/SC	1	3.9×10^{-7}

TABLE 1 (Continued)

Boring No.	Depth of Tested Interval (feet)	Unit Tested	Number of Tests	Average Permeability (cm/sec)
B-6	9 - 19	SP/FA	1	2.0×10^{-5}
	46.5 - 56.5	FA	2	9.7×10^{-7}
	56.5 - 66.5	FA	1	1.2×10^{-6}
	64.5 - 74.5	FA	2	1.3×10^{-6}
	74.5 - 84.5	FA	2	7.7×10^{-7}
	84.5 - 94.5	FA/SC	2	6.8×10^{-7}
B-7	12 - 22	FA/SC	2	3.9×10^{-4}
	17 - 27	SC	2	6.6×10^{-4}
	27 - 37	SC	2	3.5×10^{-4}
	37 - 47	SC	2	9.7×10^{-7}
	47 - 57	SC	2	9.3×10^{-5}
	49 - 59	SC	2	1.2×10^{-4}
	59 - 69	SC	2	9.7×10^{-7}
B-8	22.5 - 32.5	SC	2	2.5×10^{-4}
	39.5 - 49.5	SC	2	8.7×10^{-6}
	44.5 - 54.5	SC	2	1.9×10^{-5}
	56.5 - 66.5	SC	3	1.5×10^{-5}
B-9	13.5 - 23.5	SC	2	8.5×10^{-5}
	23.5 - 33.5	SC	2	6.4×10^{-5}
	33.5 - 43.5	SC	2	9.1×10^{-6}
	43.5 - 53.5	SC	2	3.0×10^{-5}
	53.5 - 63.5	SC	2	1.5×10^{-5}

Notes:
1) General range of input pressure was 20 to 50 psi with minimum of 15 and maximum of 85 psi.
2) SP - Spoon Formation
FA - Fort Atkinson Limestone
SC - Scales Shale
GL - Galena Group
3) Asterik indicates test was in fault zone.

TABLE 2

PIEZOMETER INSTALLATION DATA

Piezometer	Ground Elevation (ft above MSL)	Interval Tapped (ft below ground)	Geologic Units Tapped
B-1 (1)	531.2	18.0 - 50.1	FA-SC-Flt
B-3 (1)	530.9	48.0 - 96.6	FA-SC-Flt
B-4 (1)	530.5	59.0 - 91.5	SC-Flt
B-5	531.5	3.5 - 9.5	SP
B-6	530.2	3.5 - 13.0	SP
B-7	532.2	18.0 - 42.0	SC
B-9	532.0	18.0 - 42.0	SC
D-1	529.6	128.0 - 186.0	GL
D-2	529.6	39.0 - 65.0	FA-SC
D-3	529.6	3.5 - 10.0	SP
D-4	531.5	32.0 - 55.0	FA-SC
D-5	530.2	43.0 - 70.0	FA-SC
B-101	526.7	106.1 - 124.8	GL
B-102	532.7	2.8 - 29.0	FA
B-103	531.1	33.4 - 51.0	SC
B-106	533.0	3.0 - 23.0	FA
B-111	519.9	39.8 - 53.7	SC
B-112	531.4	4.5 - 33.2	FA
B-113	525.7	34.0 - 48.4	SC

Notes:
1) Holes were drilled on 60° angle from horizontal
2) SP - Spoon Formation
FA - Ft. Atkinson Limestone
SC - Scales Shale
GL - Galena Group dolomite
Flt- Fault zone

TABLE 3

GENERALIZED STRATIGRAPHY AND WATER-YIELDING PROPERTIES OF THE ROCKS IN NORTHERN ILLINOIS

System	Series	Group or Formation	Geohydrologic Unit*		Approximate range in thickness (feet)	Description	Water-yielding properties
Quaternary	Pleistocene		Glacial Drift Aquifers		0-500	Unconsolidated clay, silt, sand, gravel, and boulders deposited as till, outwash, pond water deposits, and loess	Probabilities for ground-water development range from poor to excellent. Outwash sand and gravel yield more than 1000 gpm to wells at places. Large supplies generally obtained from permeable outwash in major valleys. Glacial aquifers used for many small water supplies because they are shallow.
Pennsylvanian		Carbondale; Tradewater			0-500	Shale; sandstones, fine-grained; limestone; coal; clay	Jointed beds yield small supplies locally.
Mississippian	Kinderhook				0-350	Shale, green and brown, dolomitic; dolomite, silty	Limited areal extent; generally not used as aquifers.
Devonian					0-100	Shale, calcareous; limestone beds, thin	
Silurian	Niagaran	Fort Byron Racine Waukesha Joliet		Shallow dolomite aquifers	0-500	Dolomite; silty at base, locally cherty	Not consistent; some wells yield more than 1000 gpm. Crevices and solution channels more abundant near surface.
	Alexandrian	Kankakee Edgewood					
Ordovician	Cincinnatian	Maquoketa			0-250	Shale, gray or brown; locally dolomite and/or limestone, argillaceous	Shales, generally not water yielding, act as confining beds between shallow and deep aquifers. Crevices in dolomite yield small amounts of water.
	Mohawkian	Galena Decorah Platteville	Galena-Platteville Dolomite		0-350	Dolomite and/or limestone, cherty, sandy at base, shale partings	Where formation lies below shales, development and yields of crevices are small; where not capped by shales, dolomites are fairly permeable.
		Glenwood	Glenwood-St. Peter Sandstone	Bedrock Aquifers	0-650	Sandstone, fine- and coarse-grained; little dolomite; shale at top Sandstone, fine- to medium-grained; locally cherty red shale at base	Small to moderate quantities of water. Coefficient of transmissibility probably averages about 15 per cent of that of Cambrian-Ordovician Aquifer.
	Chazyan	St. Peter					
	Prairie du Chien	Shakopee New Richmond Oneota		Cambrian-Ordovician Aquifer	0-400	Dolomite, sandy, cherty; sandstone. Sandstone interbedded with dolomite, white to pink, coarse-grained, cherty, sandy	Crevices in dolomite and sandstone generally yield small to moderate quantities of water. Trempealeau, locally well crevices and partly responsible for accep...small high yields of several deep wells. Coefficient of transmissibility probably averages about 35 per cent of that of Cambrian-Ordovician Aquifer.
Cambrian	St. Croixian	Trempealeau			0-225	Dolomite, white, fine-grained, sandy quartz, sandy at base	
		Franconia			45-175	Dolomite, sandstone, and shale glauconitic, green to red, micaceous	
		Ironton	Ironton-Galesville Sandstone		105-270	Sandstone, fine- to medium-grained, well sorted, upper part dolomitic	Most productive unit of Cambrian-Ordovician Aquifer. Coefficient of transmissibility probably averages about 50 per cent of that of Cambrian-Ordovician Aquifer.
		Galesville					
		Eau Claire	Eau Claire		235-450	Shale and siltstone, dolomitic, glauconitic; sandstone, dolomitic, glauconitic	Shales generally not water yielding. Act as confining bed between Ironton-Galesville and Mt. Simon
		Mt. Simon		Mt. Simon Aquifer	1200-2000±	Sandstone, coarse-grained, white, red in lower half; lenses of shale and siltstone, red, micaceous	Moderate amounts of water; permeability intermediate between that of Glenwood-St. Peter and Ironton-Galesville.
Precambrian crystalline rocks							

Modified from Suter, et al., 1959 and Walton and Csallany, 1962.

* Maquoketa Group at site includes from youngest to oldest: Brainard Shale, Fort Atkinson Limestone, and Scales Shale.

TABLE 4

REGIONAL GROUND WATER USE[a]

Year	TOTAL PUMPAGE (Million Gallons Per Day)	AQUIFER PERCENTAGE OF TOTAL PUMPAGE		
		Glacial Sand & Gravel	Silurian Dolomite	Cambrian-Ordovician Aquifer
1957	127.9	11.1	32.2	56.7
1962	200.2	11.4	36.7	51.9
1970	235.6	12.4	34.1	53.3
Future Predicted Demand[b]				
1980	325			
2000	610			
2020	1025			

[a]Based on data from eight-county area: Cook, DuPage, Grundy, Kane, Kendall, Lake, McHenry, Will (Suter, et al., 1959 and Sasman, et al., 1974).

[b]Based on projections by Schicht and Moench (1971).

TABLE 5

SITE GROUND-WATER LEVELS

Distance From Ground Surface to Water Surface
(feet-inches)

Piezometer No.

DATE	B1	B3	B4	B5	B6	B7	B9	D1	D2	D3	D4	D5	B102	B103	B106	B111	B112	B113	6" LAW	2" LAW	SAND FILT.	NEW
2-12-76	-	-	-	-	-	-	-	-	--	-	-	-	3-4	11-9	4-6	2-5	4-10	11-3	14-6	-	9-9	9-9
3-14-76	-	-	-	-	-	-	-	-	--	-	-	-	3-2½	10-6	4-2	1-1	3-½	9-10½	10-3	-	6-3½	6-10.
3-23-76	-	-	-	-	-	-	-	-	--	-	-	-	3-5½	10-5½	5-5½	1-3	4-½	10-8½	11-1	-	6-10	7-2
4-13-76	-	-	-	-	-	-	-	-	--	-	-	-	7-3½	13-11½	8-10½	1-10	-	7-10½	12-3	-	7-3	8-9
5-01-76	5-1	7-11	8-9	5-4½	2-8	5-2½	4-8	143-2	7-4	3-0	8-7	6-7	3-11	11-5½	4-5½	1-1	3-10½	10-6½	10-4	4-8	6-9	8-5
5-05-76	5-11½	8-6	9-4½	5-11½	3-1½	5-10½	5-3½	142-11	8-3	3-4	10-6	8-1	-	-	-	-	-	-	-	-	-	-
5-08-76	3-4	6-8	6-9½	3-11	2-0	3-11½	3-4½	143-9	4-4	2-1½	5-7	4-2	2-2½	11-1½	2-2½	0-4½	1-3½	10-7½	9-2	4-4	5-11	7-11
5-12-76	4-6	7-4	8-4½	5-0	2-5½	4-9½	4-2	148-9	6-8	2-10	8-10	5-1	-	-	-	-	-	-	-	-	-	-
5-16-76	5-5	7-10	0-1	5-8	3-0	5-5½	5-0	142-11	8-8½	3-0	9-11	7-7½	5-3	10-8	6-½	1-3	5-5½	9-11½	10-5	4-6	6-10	7-10½
5-20-76	6-6	8-9	9-9	6-4	3-8	6-3	5-8	143-11	10-0	3-8	11-8	8-7	-	-	-	-	-	-	-	-	-	-
5-22-76	6-11½	9-1	10-5	6-6½	3-8	6-8	6-2	143-4	10-6	3-9½	11-9	9-1	6-11½	10-8½	7-7½	1-9	7-11½	10-7½	12-6	6-3	9-1	8-3
5-26-76	7-10	9-8	11-1½	7-4	4-8	7-4½	6-10½	143-7	11-8	4-7	12-11	10-2	-	-	-	-	-	-	-	-	-	-
5-30-76	7-10½	9-9	11-2	7-1	4-0	7-5	6-9	143-2½	11-6½	3-10	13-0	10-2	8-2½	12-2½	8-6	2-3	10-8½	10-11½	12-5	6-1	8-11	7-6
6-02-76	6-7	8-8	10-0	6-2	3-4	6-4	5-8	143-7	10-1	3-4½	11-5	8-10	-	-	-	-	-	-	-	-	-	-
6-06-76	7-3½	9-2½	10-9½	6-8	4-1	6-11½	6-5	144-1	11-0	4-½	12-2½	9-6	7-8	14-3½	8-2½	2-4	9-4½	11-9½	12-10	6-11½	9-6½	8-7½
6-09-76	7-10	9-9½	11-4	7-2	4-7½	7-6½	6-5½	143-11½	11-6½	4-6	13-½	10-3½	-	-	-	-	-	-	-	-	-	-
6-13-76	8-6½	10-3	11-9½	7-5	5-1½	8-0	7-4	143-6	12-1½	5-0	13-8	10-10½	-	-	-	-	-	-	-	-	-	-
6-17-76	9-5	11-1½	12-7	7-10½	5-11	8-2½	8-0	144-5	13-2½	5-8½	14-7½	11-10	-	-	-	-	-	-	-	-	-	-
6-20-76	9-1	11-0	12-7	8-2	5-11	8-8	8-2	144-3	13-4	5-8	15-0	11-11	-	-	-	-	-	-	-	-	-	-
6-23-76	9-3½	11-1	12-9	8-½	5-11½	8-7½	8-1½	144-1	13-2½	5-9	14-11	12-0	-	-	-	-	-	-	-	-	-	-
6-26-76	8-0	10-0	11-8½	6-11	4-6	7-5	6-9	143-8½	12-4	4-5	14-0	11-1	9-5	11-9½	8-11½	8-6	11-4½	11-11½	12-5	6-11	9-0	8-8½
6-30-76	7-5	9-6	11-4½	6-4	3-9	7-0	6-4	144-5	8-½	3-9½	12-6	10-0	-	-	-	-	-	-	-	-	-	-
7-03-76	7-4	8-1	11-9	6-1	5-0	7-5	6-8	143-11½	9-0	3-11	12-7	9-11	8-5½	12-7½	8-3½	8-½	11-2½	12-6	12-3	6-7	9-0	8-10
7-12-76	7-5	9-4	11-3	6	4-7	7-1	6-4	143-0	10-7	4-3	12-0	9-8	7-9½	12-9½	7-10½	8-1	12-6½	11-8½	11-11	5-9	8-5	8-9
7-14-76	7-9	9-8	11-7	6-[illegible]	4-9	7-2	6-7	143-9	11-0	4-7	12-7	10-0	-	-	-	-	-	-	-	-	-	-
7-18-76	8-5	10-3½	12-3	7-1	5-2	7-0	7-3	143-10	11-10	5-0	13-6	10-9	8-1½	12-9½	8-6	7-11½	10-5½	11-10½	12-8	6-2	9-0	9-1
7-21-76	6-7	9-2	11-4	6-0	3-0	6-[illegible]	5-7	144-2	10-2	3-11	11-7	9-4½	-	-	-	-	-	-	-	-	-	-
7-24-76	6-6	8-11	11-0	5-11	3-11	6-5½	5-8½	144-0	10-0	3-10	11-3½	9-1½	7-8	12-10	7-6	8-0	9-10½	12-2½	11-6½	5-3[illegible]	8-0	8-10½
7-28-76	7-6½	9-5	11-7½	6-6	4-6½	6-11	6-5	143-8	10-7½	4-5	12-3	9-9	-	-	-	-	-	-	-	-	-	-
7-31-76	8-2	9-10	12-3	7-4	5-0	7-7½	7-0	143-11	11-5½	4-10	12-11	10-4	8-2½	12-2½	8-4½	7-11½	10-3½	11-11	12-7	5-11½	8-9½	8-10
8-04-76	8-9	10-6½	12-11½	7-7	5-6	8-1	7-7½	143-11	12-4	5-5½	13-10	11-3	-	-	-	-	-	-	-	-	-	-
8-07-76	3-7	9-2	11-5	4-0	3-3	3-11	5-5	144-1	9-9	2-9	8-10	9-0	7-3½	12-½	6-9½	8-4	10-5½	11-11½	11-6	5-6	8-1	9-2
8-12-76	6-10	9-0	11-3	6-3	3-6	6-6½	5-10	144-1½	4-10	3-10	11-8	9-4	-	-	-	-	-	-	-	-	-	-
8-15-76	7-5	9-5	11-9½	6-8	4-4½	8-0	6-5	144-3	10-10	4-2	12-3	9-10	7-1½	11-11½	7-7½	8-2½	9-10½	11-9½	11-9	5-4½	8-1	8-9
8-17-76	7-11	9-10	12-2	7-1	4-8	7-7	6-8	144-7	11-2	4-6	12-11	10-0	-	-	-	-	-	-	-	-	-	-
8-20-76	8-1	10-3	12-0	7-4	5-2	8-1	7-3	144-7	12-0	5-0	13-6	11-1	7-11½	12-1½	3-4½	8-1	10-4½	11-8½	12-5	5-6	8-11	8-10
8-25-76	9-1	10-9	13-4	7-9	5-8½	8-3	7-10½	144-5½	12-10	5-7½	14-4½	11-9½	-	-	-	-	-	-	-	-	-	-
8-27-76	9-1½	10-11	13-5	7-7	6-0	8-5½	7-11	144-4½	12-10½	5-8½	14-8	12-3	8-10	12-4½	8-9½	7-11	11-2½	11-4½	13-3½	6-10½	9-7	9-3
9-01-76	9-8½	11-5½	14-1	8-½	6-6	8-10	8-7	144-5	13-9	6-5	15-6	13-3	-	-	-	-	-	-	-	-	-	-
9-05-76	10-0	11-11	14-6	8-2	7-0	9-7	8-11	144-8	14-4	6-8	16-1	13-10	10-6½	12-7½	10-4½	8-8	11-11½	11-6½	14-1	7-10	10-5	10-2
9-09-76	8-11	11-3	14-4	8-1	4-4	8-3	7-3	144-8	13-6	6-3	15-3	13-2	-	-	-	-	-	-	-	-	-	-
9-12-76	8-5	10-4½	13-1	7-3	5-4	7-10	7-10	144-8	12-7	5-2	14-1	12-½	9-1½	12-11½	8-11½	8-8	12-10	12-1	12-11½	6-3½	9-3½	10-4
9-15-76	8-10	9-5½	13-4½	7-8	5-10	8-1	7-5	144-9½	13-6	5-7½	15-0	12-11	-	-	-	-	-	-	-	-	-	-
9-18-76	9-2	10-9½	13-8	7-10	6-1	8-4	7-9	144-8	14-3	5-11	15-9	13-8	9-6½	13-½	9-1	9-2	11-7½	12-2½	13-8½	7-3	9-9	10-2

* Water level measurements made by General Electric personnel.

TABLE 5 (Continued)

DATE	B1	B3	B4	B5	B6	B7	B9	D1	D2	D3	D4	D5	B102	B103	B106	B111	B112	B113	6" LAW	2" LAW	SAND FILT.	[illegible]
9-22-76	9-2	10-10	13-10	7-0	6-0	8-4	7-9	144-5	14-2	5-9	15-11	13-10	-	-	-	-	-	-	-	-	-	10-
9-25-76	10-0	11-8½	14-6	8-3	6-10	9-0	8-5½	144-8	15-2	6-7½	17-½	14-11	9-10½	13-7½	10-½	10-2	12-5½	12-11½	14-2½	7-9	10-3	10-
10-02-76	3-5	10-2	13-0	7-1	5-6	7-8	7-2	145-4	12-8	5-6	14-4	11-6	8-1½	12-11½	6-7½	10-1	10-8½	12-8½	12-10	6-2	9-0	-
10-06-76	7-4	10-1	13-2	6-8	3-6	7-2	6-5	145-6	11-10	4-6	13-3	10-10	-	-	-	-	-	-	-	-	-	9-
10-10-76	7-8½	9-9	12-7	6-5	4-11	7-3½	6-8	145-4	11-4	4-9½	12-7	10-5	6-5½	13-2½	6-8½	8-7	8-9½	12-8½	12-5½	5-7	8-7	-
10-13-76	8-5	10-6	13-3	7-2	5-5½	7-9½	7-4	145-4	12-8	5-3	14-2	11-7	-	-	-	-	-	-	-	-	-	9-
10-16-76	9-1	10-8	13-6	7-8	5-8	8-3	7-8½	145-6	13-1	5-8	14-10	12-4	8-6½	12-11½	8-½	8-9	9-8½	12-6½	13-5½	6-4	9-5	-
10-20-76	9-8	11-8	14-[illegible]	8-2½	6-5½	8-11	8-3	145-6	15-½	6-5	16-6½	13-4	-	-	-	-	-	-	-	-	-	9-
10-23-76	10-1	11-11	14-.1	8-5	7-3	9-3	8-9	145-6	16-0	6-11	17-8	15-4	8-10½	13-3	9-5½	10-2	10-10½	12-8½	-	-	-	-
10-27-76	10-6	12-5	15-2	8-8	7-4	9-6	9-1	146-3	16-11	7-1	18-5	16-2	-	-	-	-	-	-	14-7	8-0	10-8	9-
11-01-76	10-4	12-7	15-6	8-8	7-4	9-6	8-11	146-1	16-11	7-6	18-9	16-6	10-7½	13-1½	10-4½	10-11	12-½	13-2½	-	-	-	-
11-03-76	10-5	12-4	15-5	8-10	7-1	9-8	8-10	145-9	16-10	7-3	18-0	16-7	-	-	-	-	-	-	14-9	8-2	10-9	9-
11-06-76	10-6	12-0	15-6	8-9	7-7	9-9	9-4	145-9	17-1	7-6	18-7	16-9	10-8½	13-4½	10-5	11-3	12-5½	13-2½	-	-	-	-
11-10-76	11-0	13-1	15-11	8-9	7-7	10-0	9-4	145-9	17-7	7-7	18-11	17-1	-	-	-	-	-	-	15-4	8-8	11-5	9-
11-13-76	11-4	13-8	16-3	8-5	7-10	10-4	9-9	146-8	18-0	8-0	19-6	17-6	11-3½	13-7½	11-3½	11-7	13-½	14-4½	-	-	-	-
11-17-76	11-4	13-9	16-8	8-8	8-3	10-4	9-10	145-10	17-0	8-2	19-2	16-9	-	-	-	-	-	-	16-0	8-11	11-6	10-
11-20-76	11-10	14-0	16-10½	8-9	9-1½	10-6	10-1	145-10	17-2½	8-4	19-0	17-0	11-6½	13-5½	11-4½	10-6	13-1½	13-3½	-	-	-	-
11-24-76	11-11	14-3	17-2½	8-9	8-2	10-8	10-2	145-10½	17-5	8-8	19-4	17-5	-	-	-	-	-	-	15-8	8-9	11-2	10-
11-29-76	10-10	-	16-8	8-9	7-2	10-0	9-4	146-3	16-3	7-3	18-2	16-1	11-1½	13-8½	10-½	10-6	13-8½	13-5½	-	-	-	-
12-01-76	10-6	13-7	16-6	8-8½	7-1	9-8½	9-1	146-2½	16-1½	7-2½	17-8½	15-10	-	-	-	-	-	-	15-9	8-5	11-1	10-
12-04-76	10-10	13-14	16-9	8-9	7-8	10-0	9-4	146-8	16-7	7-4	18-2	16-1	10-6½	13-10½	10-2½	10-8	13-4½	13-3½	-	-	-	-
12-08-76	11-0	-	16-10	8-5	7-5	-	9-6	146-5	16-9	7-7	18-5	16-6	-	-	-	-	-	-	16-0	8-8	11-1	10-
12-11-76	11-1	14-3	17-0	8-10	7-10	10-1	9-8	146-½	16-9	8-0	18-8	16-6	16-0	11-4½	13-10½	10-8½	13-1½	13-5½	-	-	-	-
12-15-76	11-4	14-3	17-0	8-6	8-0	10-2½	9-7½	146-0	16-9	8-2	18-5	16-8	-	-	-	-	-	-	16-4½	9-1	11-7	11-
12-19-76	11-6	14-6	17-2	7-11	8-1	10-6	9-15	145-9	16-9	8-11	18-6	16-11	11-3½	13-9½	11-5½	10-8	13-5½	13-½	-	-	-	-
12-22-76	-	-	17-7	8-6	8-0	10-8	10-0	145-8	16-10	8-4	18-2	16-6	-	-	-	-	-	-	-	-	-	-
12-30-76	-	-	18-1	8-2	8-8	11-0	10-6	145-9	16-11	9-0	19-0	16-10	-	-	-	-	-	*	17-4	9-8	12-4	11-
1-02-77	-	-	19-0	8-6	8-10	11-4	11-1	146-6	17-9	9-2	19-10	17-8	11-7½	13-10½	11-8½	10-6	13-8½	-	-	-	-	-
1-06-77	-	-	18-7	8-8	-	11-3	10-9	146-0	17-2	8-11	19-4	17-5	-	-	-	-	-	-	17-7	9-9	12-6	12-
1-09-76	-	15-9	18-8	8-9	8-6½	11-5	10-9	146-4	17-8	8-9	19-4	17-7	12-6½	13-11½	11-11½	10-5	13-10½	-	-	-	-	-
1-12-76	-	16-2	18-10	8-9	8-9	11-4	10-9	146-10	15-7	8-9	17-5½	15-11	-	-	-	-	-	13-9½	18-1	10-0	13-0	12-
1-16-76	-	15-11	9-1	8-6	9-3	11-6	10-8	145-11	15-6	9-4	16-10	15-11	12-11½	14-3½	11-10½	11-2	14-6½	-	-	-	-	-
1-20-76	-	16-3	19-3	8-9	0-8	11-7	11-0	146-8	17-9	9-2	19-7	17-8	12-10½	14-5½	12-7½	11-2	14-8½	13-½	18-1	10-0	12-10	12-
1-23-76	-	16-3	19-3	8-9	0-9	11-7	11-0	146-8	17-9	9-2	10-7	17-8	12-10½	14-5½	12-7½	-	-	-	-	-	-	-
1-27-76	-	16-2	18-10	8-8	9-10	11-1	10-11	146-3	17-10	11-11	19-6	17-9	-	-	-	-	-	14-½	18-7	10-0	13-1	12-
1-30-76	-	16-5	19-1	8-8	10-0	12-1	11-2	146-9	18-0	9-3	19-8	18-1	12-9½	14-6½	12-10½	10-11	-	-	-	-	-	-
2-02-76	-	16-9	19-4	8-8	10-0	11-8	11-2	146-6	18-0	8-11	19-9	18-2	-	-	-	-	-	-	18-8	10-0	13-4	12-
2-05-76	-	16-6	20-0	8-9	10-2	11-10	10-10	146-6	18-0	9-11	19-9	18-2	-	-	-	-	-	-	-	-	-	-
2-09-76	-	16-8½	19-6	8-7	10-5	11-9	11-2	146-8	17-10	8-10	19-8	17-11	-	-	-	-	-	13-8½	17-10	9-6	12-9	13-
2-12-76	13-2	-	19-4	8-0	10-8	11-7	10-9	146-0	16-9	8-11	19-6	17-1	10-5½	14-5½	9-9½	11-1	14-2½	-	-	-	-	-
2-17-76	11-8	-	18-9	8-8½	11-1	10-9	9-15	146-6	16-4	9-1	17-4	16-6	-	-	-	-	-	13-9½	17-11	8-2	12-2	12-
2-20-76	12-0	-	18-5	8-8	11-8	10-7	9-5	147-0	16-8	9-1	17-9	16-9	7-7½	14-6½	7-7½	7-8	10-½	-	-	-	-	-
2-24-76	11-3	-	18-1	8-8	11-2	10-2	9-6	146-2	15-4	9-0	17-7	15-6	-	-	-	-	-	13-3½	17-7	7-11	11-7	12-
2-27-76	11-1	-	18-0	7-10	10-10	10-1	9-7	146-10	15-1	9-1	16-11	15-5	5-7½	14-2½	6-1½	5-6	8-9½	-	-	-	-	-
3-02-76	11-2	-	17-10	8-0	10-7	10-1	9-4	147-3	16-3	9-1	17-9	16-0	-	-	-	-	-	-	-	-	-	-
3-05-76	10-6	-	17-4	8-8	10-6	9-8	8-8½	146-7	14-11	8-11	16-11	15-5	4-3½	14-½	5-9½	5-1	8-2½	13-3½	17-2½	7-8	11-1½	11-
3-09-77	9-9	14-3	16-11	6-10	10-1	9-1	8-5	146-8	14-5	8-9	15-11	14-6½	-	-	-	-	-	-	-	-	-	-
3/12/13/77	8-10	13-4	14-6	8-8	7-1	8-5	7-8	146-4	12-5	8-7	14-0	12-11	2-1½	13-7½	3-2½	2-7	3-7½	12-10½	16-2	7-2	8-10	11-
3/17/77	3-0	13-4	14-11	8-7	6-8	7-5	7-2	147-1	10-0	7-3	10-11	9-11	-	-	-	-	-	-	-	-	-	-
3/20/77	7-4	12-9	13-10	5-4	5-6	7-5	6-6	147-1	9-1[illegible]	4-9	9-9	9-6	2-10½	13-3½	3-11½	1-6	4-½	12-8½	15-2	5-6	9-3	10-
3/24/77	7-6	11-2	12-5	4-11	2-10½	5-6	5-1½	147-4	6-8	2-10	7-11	6-6	-	-	-	-	-	-	-	-	-	-
3/26/77	5-8	11-1	12-3	5-1	2-7	6-0	5-5	147-2	7-5	2-6	8-6	6-10	2-9½	13-½	3-8½	1-1	3-5½	12-1½	13-10	4-10	7-9	9-
3/31/77	4-2	9-11	11-0	4-4	1-10	4-10	4-3	147-4	5-1	1-11	6-4	4-10	-	-	-	-	-	-	-	-	-	-

TABLE 5 (Continued)

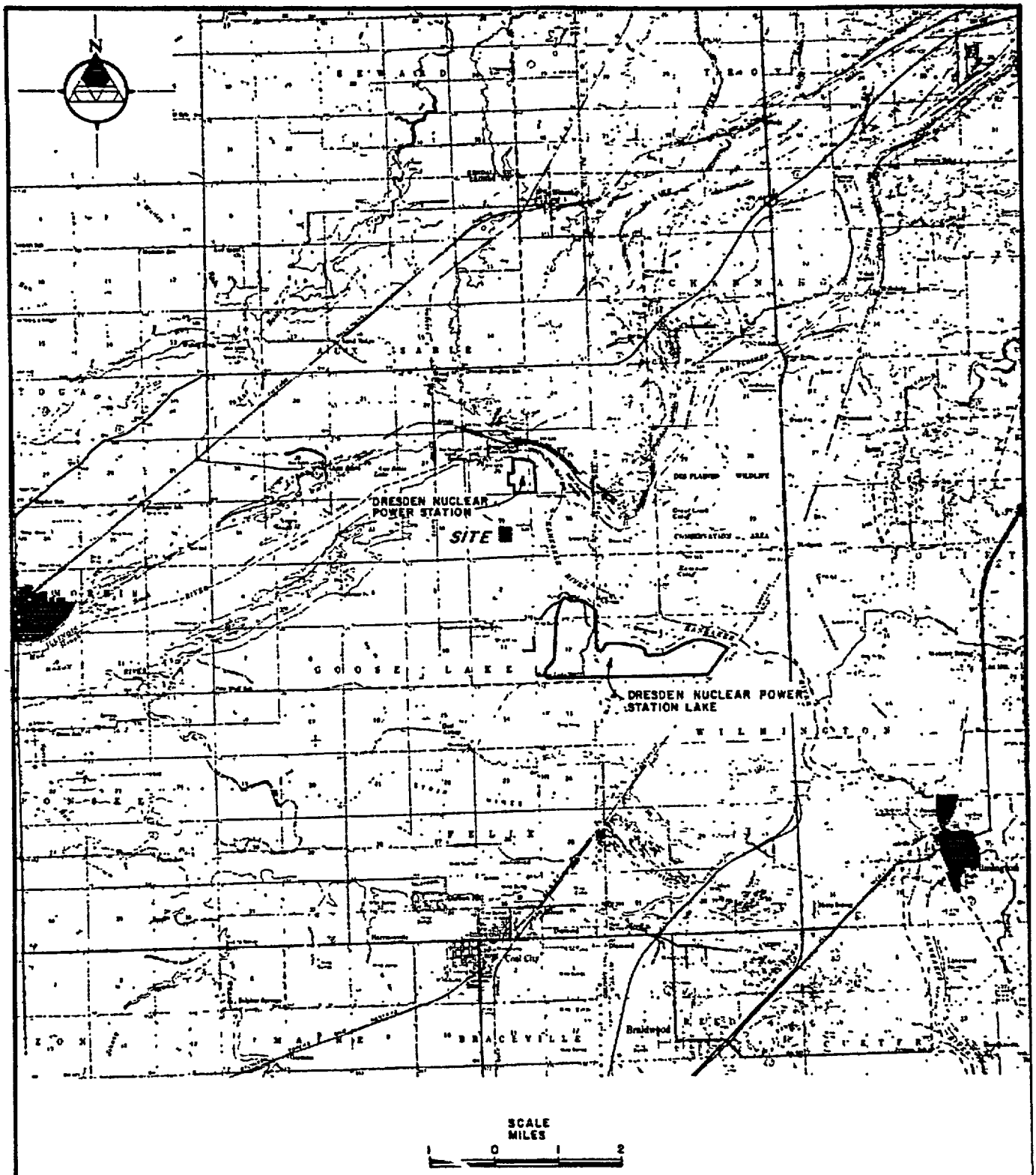
DATE	B1	B3	B4	B5	B6	B7	B9	D1	D2	D3	D4	D5
4-02-77	4-0	9-5	10-6	4-7½	1-1½	4-6	3-11	146-6	5-7	1-11	6-7½	5-0
4-06-77	4-5½	9-10	11-0	4-8½	2-2	5-0	4-5	147-2	6-2½	2-3	7-4	5-7
4-09-77	5-1	9-4	11-6	4-11	2-7	5-5	4-9	147-0	7-3	2-4	8-6	6-6
4-13-77	6-2	10-5	12-4	5-6	3-2	6-0	5-7	147-0	8-2	3-2	10-6	8-0
4-16-77	6-10	9-8	13-0	5-11	3-6	6-7	5-11	147-6	10-2	3-3	11-4	9-0
4-21-77	7-7	11-8	13-10	6-7	3-10	7-5	6-9	147-5	11-1	3-8	12-5	9-8
4-23-77	7-10	12-2	13-11	6-7	3-4	7-5	6-9	147-4	11-2	3-2	12-6	9-9
4-27-77	8-0	12-1	14-3	6-9	3-0	7-7	6-11	146-11	11-4	3-7	12-10	10-0
4-30-77	8-3½	12-5½	14-6	7-0	4-1	7-10	7-1	147-6	11-40	3-9	13-4	10-6
5-04-77	8-4	12-6	14-10	7-2	4-3	7-11	7-0	147-2	12-0	3-10	13-7	10-9
5-07-77	6-0	11-2	13-6	5-3	2-1	6-0	5-5	147-7	8-5	2-3	9-6	7-3
5-11-77	6-11	11-1	13-3	5-7	2-10	6-10	5-11	147-6	9-4	3-0	10-6	8-1
5-14-77	7-3	11-6	13-10	6-1	3-9	7-1	6-6	147-5	10-6	3-0	11-10	9-9
5-18-77	8-6	12-1	14-7	6-11½	5-6	7-11	7-1	147-8	9-6	3-11	13-1	10-6
5-22-77	9-0	13-8	15-2	7-6	5-9	8-3	7-8	147-4	12-3	3-8½	13-11	11-2
5-26-77	9-4	13-3	14-4	7-9	5-10	8-8	8-1	147-5	13-6	3-11	15-1	12-2
5-28-77	9-5	13-4	14-3	7-10	5-10	8-8	8-0	147-2	13-7	4-2	15-2	12-1
6-01-77	9-6	13-7	14-7	8-1	5-10	8-10	8-3	147-2	13-3	4-6	14-11	12-0

DATE	B102	B103	B106	B111	B112	B113	6" LAW	2" LAW	SAND FILT.	NEW
4-02-77	2-4½	12-3½	2-10½	0-9	2-1½	10-10	12-4	4-2	6-4	8-5
4-06-77	-	-	-	-	-	-	-	-	-	-
4-09-77	3-7	12-3½	4-11½	1-1	3-10	11-2½	13-2	4-7	7-0	8-9
4-13-77	-	-	-	-	-	-	-	-	-	-
4-16-77	6-1½	11-9½	6-7½	1-9	6-7½	11-½	13-11	5-4	8-2	8-0
4-21-77	-	-	-	-	-	-	-	-	-	-
4-23-77	6-11½	11-9½	7-11½	1-10	8-4½	11-½	14-9	6-2	8-10	8-1
4-27-77	-	-	-	-	-	-	-	-	-	-
4-30-77	8-3	11-11½	8-5½	2-4	9-4½	11-5½	15-1	6-9	9-4½	8-5
5-04-77	-	-	-	-	-	-	-	-	-	-
5-07-77	3-5½	6-½	4-3½	2-0	6-5½	11-6½	14-2	5-9	8-4	8-6
5-11-77	-	-	-	-	-	-	-	-	-	-
5-14-77	6-4½	12-3½	6-7½	2-2	7-2½	11-6½	14-11	5-8	8-6	8-6
5-18-77	-	-	-	-	-	-	-	-	-	-
5-22-77	7-3½	12-1½	8-2½	2-9	9-½	11-7	15-9	6-8	9-6	8-8
5-26-77	-	-	-	-	-	-	-	-	-	-
5-28-77	8-8½	12-6½	9-½	4-11	10-½	11-2½	16-3	7-2	9-11	8-9
6-01-77	-	-	-	-	-	-	-	-	-	-

TABLE 6

GEOHYDROLOGIC PARAMETERS OF
BEDROCK UNITS AT THE SITE

Unit	Permeability cm/sec	Total Porosity	Effective Porosity	Average Hydraulic Gradient
Spoon Formation	3.9×10^{-4}	0.21	0.10	0.010
Fort Atkinson Limestone	1.1×10^{-4}	0.05	0.02	0.015
Scales Shale	5.8×10^{-6}	0.12	0.02	0.014
(vertical)	2.3×10^{-9}	0.12	0.02	1.1
Galena Dolomite	2.0×10^{-4}	0.05	0.02	0.018

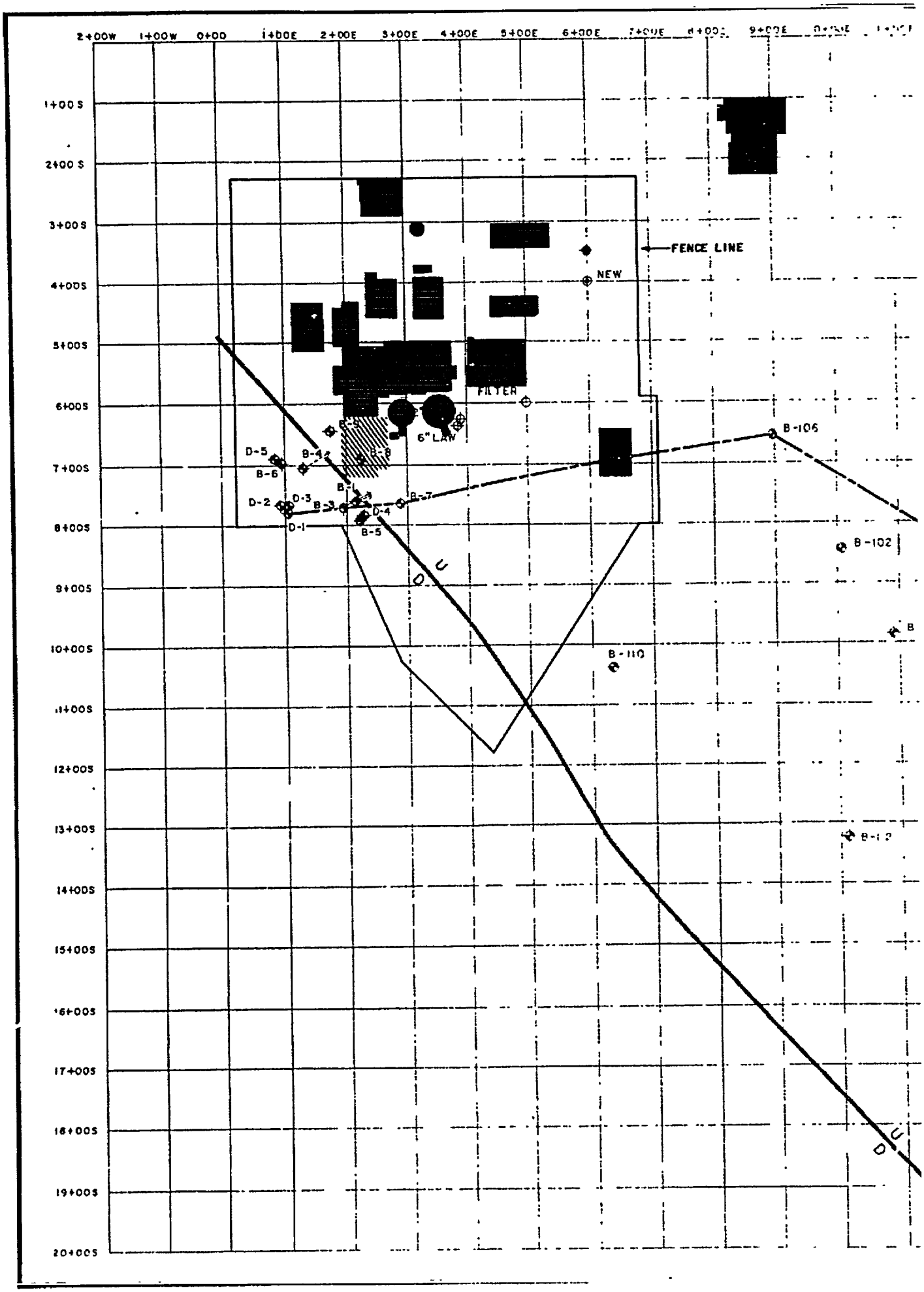


BASE MAP REFERENCE:
PORTION OF MORRIS AND WILMINGTON, ILLINOIS, 15 MIN. U.S.G.S. TOPOGRAPHIC QUADRANGLES, 1954.

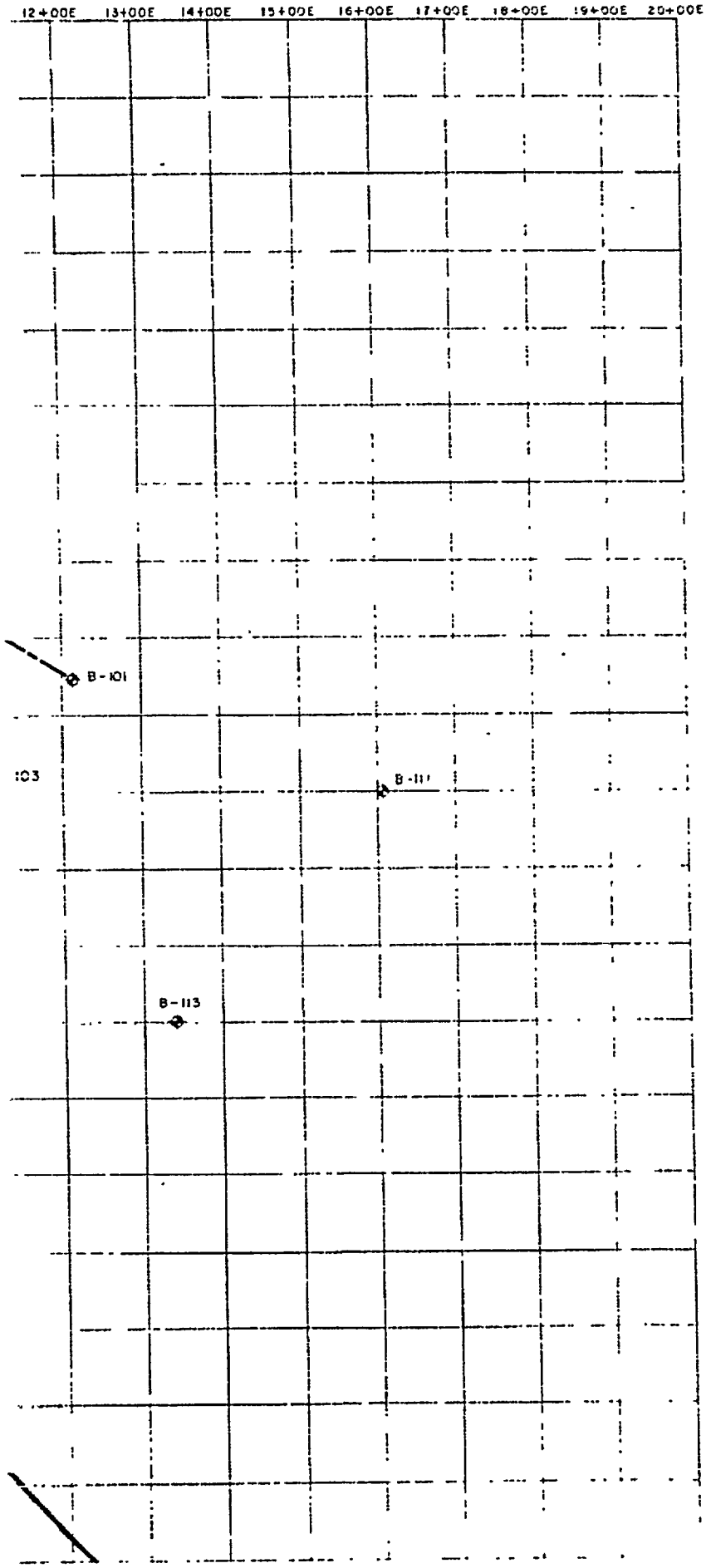
SITE VICINITY MAP

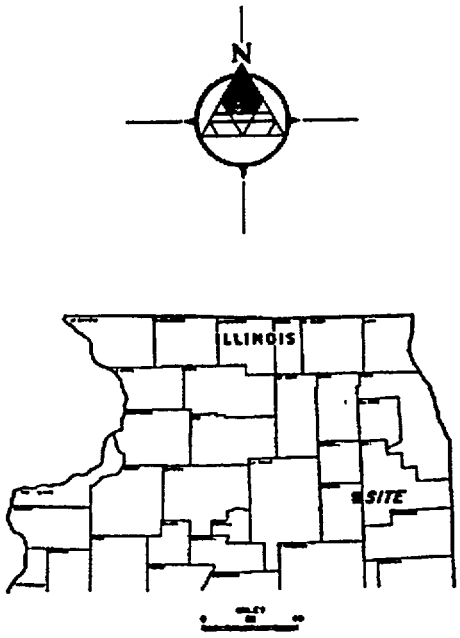
DAMES & MOORE

1674-101-07


2+00W
1+00W
0+00
1+00E
2+00E
3+00E
4+00E
5+00E
6+00E
1+00 S
2+00 S
3+00 S
4+00 S
5+00 S
6+00 S
7+00 S
8+00 S
9+00 S
10+00 S
12+00 S
13+00 S
14+00 S
15+00 S
16+00 S
17+00 S
18+00 S
19+00 S
20+00 S
FENCE LINE
NEW
FILTER
6" LAW
B-5
B-8
D-5
B-4
B-6
B-1
D-2
D-3
B-3
D-4
B-7
D-1
B-5
B-106
B-102
B-110
O U
O U

1874-101-07





INDEX MAP

EXPLANATION:

- DRILLED BY GENERAL ELECTRIC FOR MONITORING
- LOCATION OF TEST BORINGS WITH PIEZOMETER FROM DAMES & MOORE'S REPORT DATED FEBRUARY 25, 1970
- LOCATION OF TEST BORINGS WITH PIEZOMETER FROM DAMES & MOORE'S REPORT DATED SEPTEMBER 3, 1975
- LOCATION OF TEST BORINGS WITH PIEZOMETER FROM THIS INVESTIGATION
- LOCATION OF GENERAL ELECTRIC'S WATER WELL
- LOCATION OF FAULT ZONE
- LOCATION OF EXISTING BUILDINGS
- LOCATION OF PROPOSED BASIN EXPANSION
- GENERALIZED GEOLOGIC CROSS-SECTION, SEE FIGURE 8 FOR DETAILED DRAWING

NOTE:

NO PIEZOMETER INSTALLED IN BORING B-8.

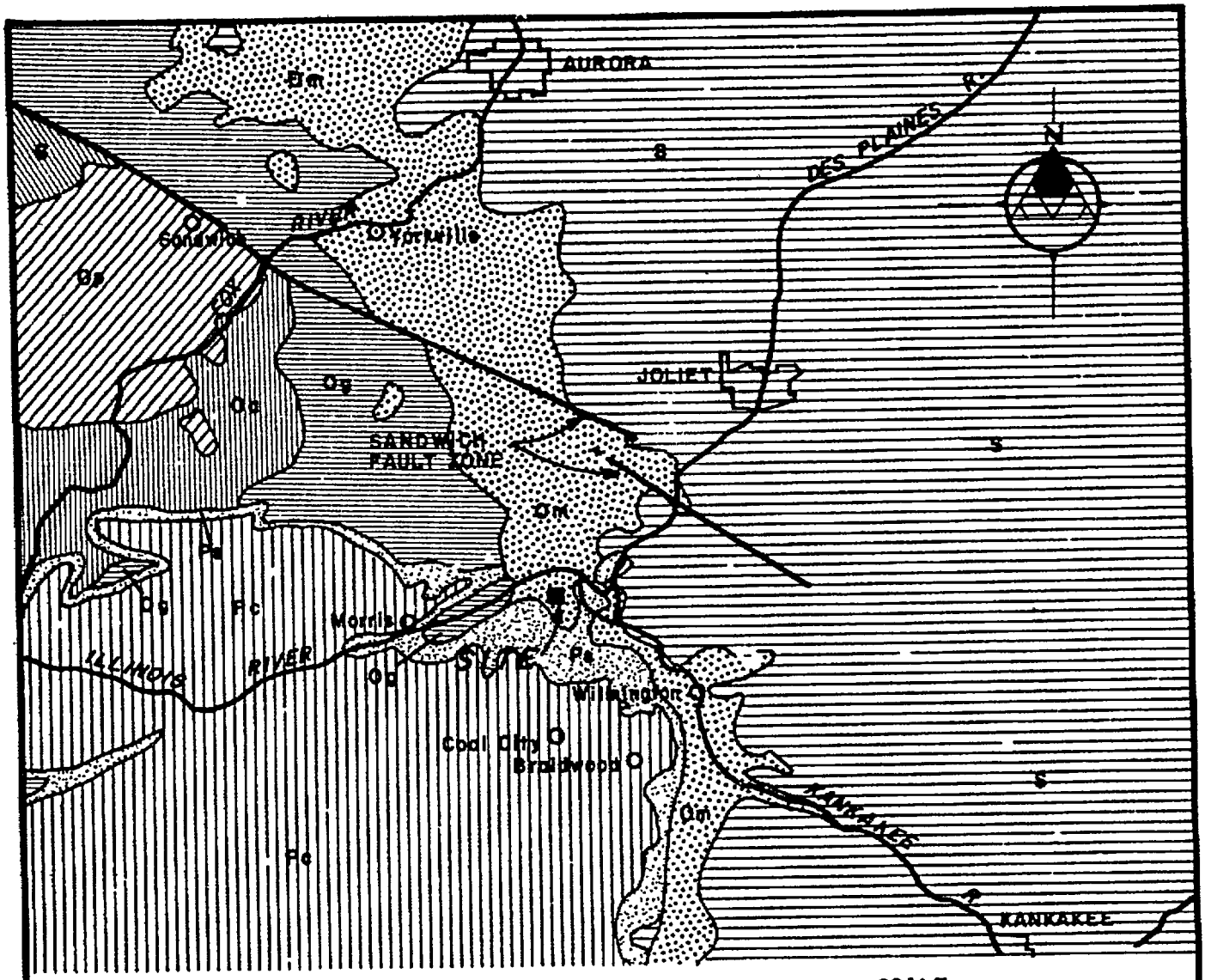
DRAWING REFERENCE:
TITLED: CONSTRUCTION ACCESS AND TEMPORARY FACILITIES PROJECT IV - BASIN EXPANSION
BY: GENERAL ELECTRIC
DRAWING NUMBER: C543.3E-545
DATED: MARCH 31, 1977

SCALE
FEET
100 0 100 200

PLOT PLAN

DAMES & MO

FIGURE 2



SCALE MILES 0 10

EXPLANATION:

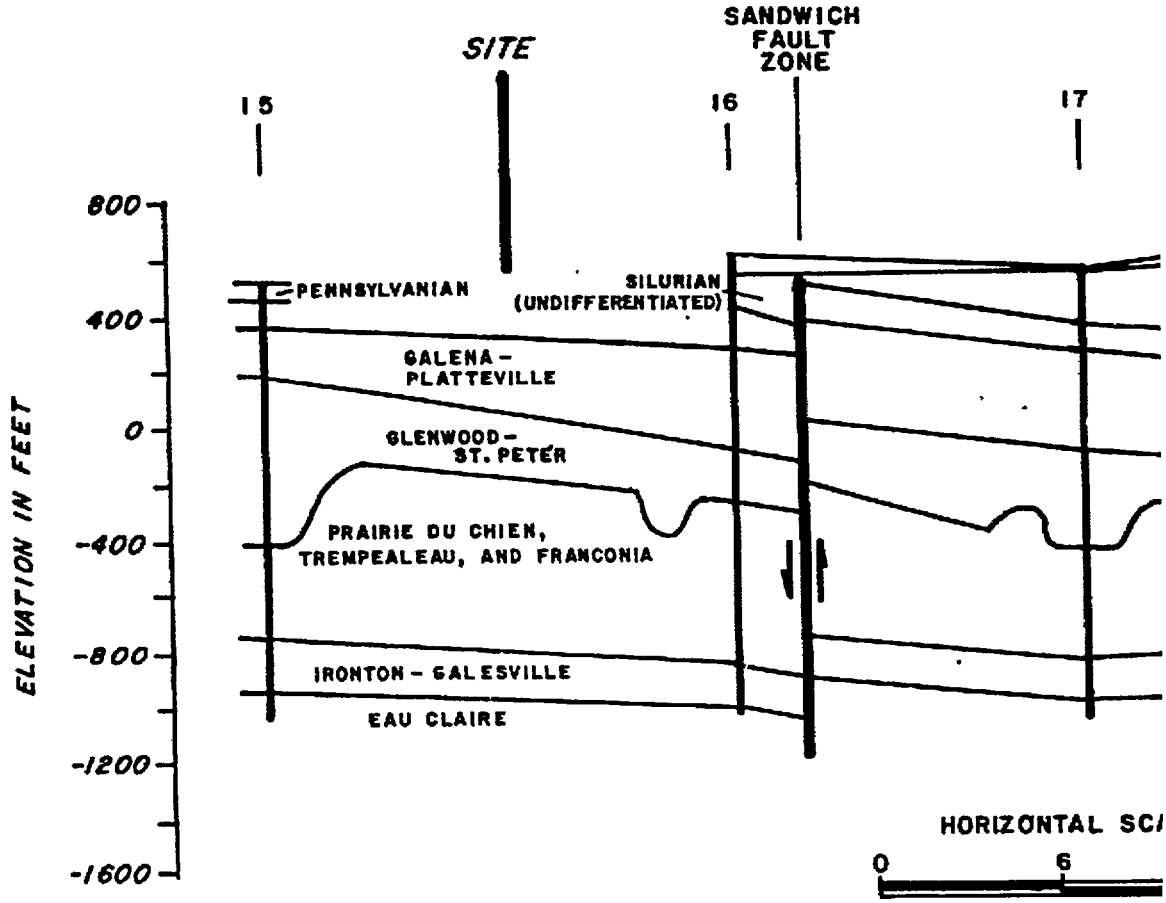
PENNSYLVANIAN	Pc	CARBONDALE FORMATION
	Ps	SPOON FORMATION
SILURIAN	S	SILURIAN SYSTEM
ORDOVICIAN	Om	MAQUOKETA GROUP
	Og	GALENA - PLATTEVILLE GROUP
	Oa	ANCELL GROUP (GLENWOOD - ST. PETER)
	Op	PRAIRIE DU CHIEN GROUP
CAMBRIAN	Є	CAMBRIAN SYSTEM

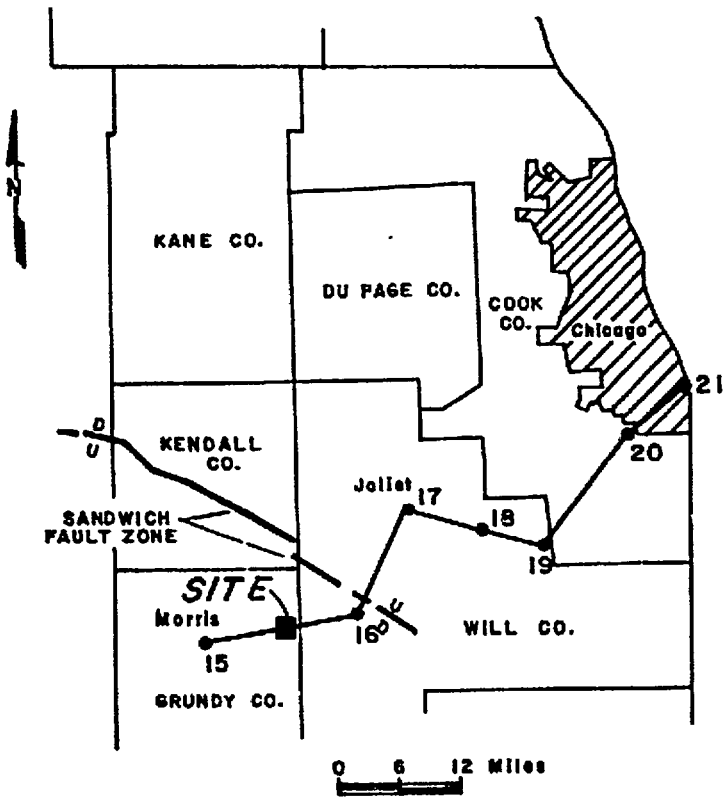
MAP MODIFIED FROM: GEOLOGIC MAP OF ILLINOIS, BY WILLMAN AND OTHERS, 1967.

REGIONAL BEDROCK GEOLOGIC MAP

DAMES & MOORE

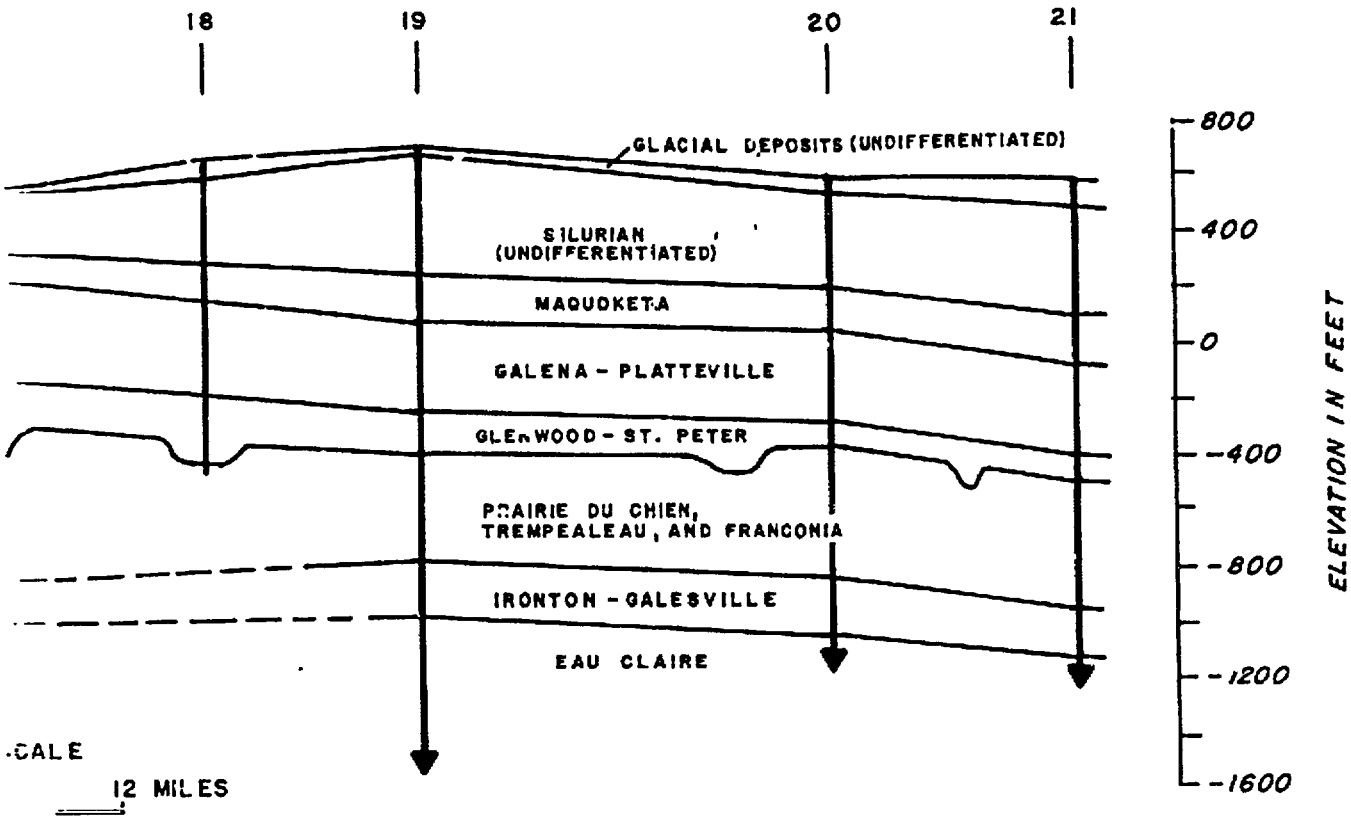
1674-101-07





INDEX MAP

1674-101-07

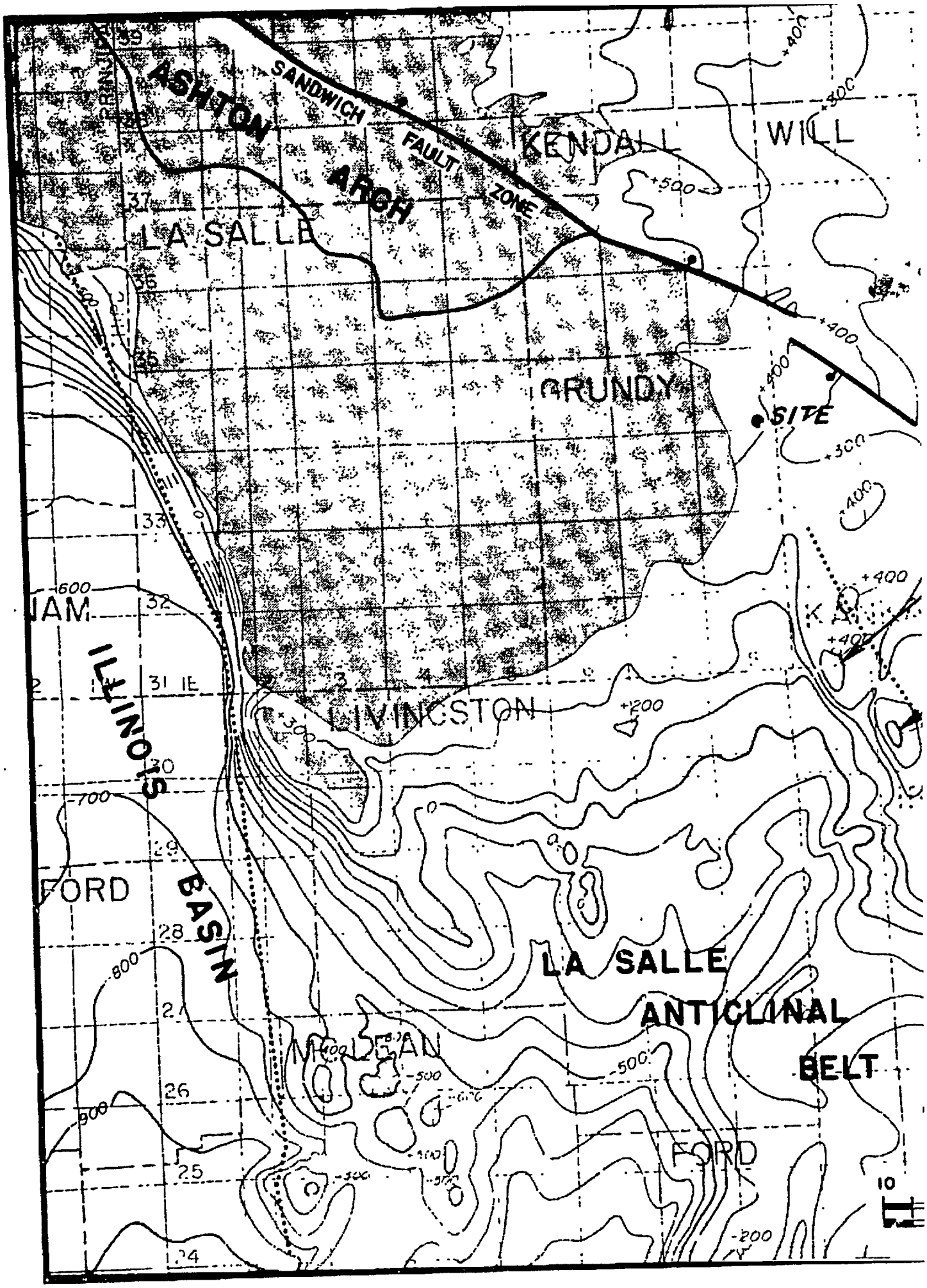


NOTE: THE GLACIAL DEPOSITS (UNDIFFERENTIATED), AND MAQUOKETA GROUP ARE NOT SHOWN AT THE SITE.

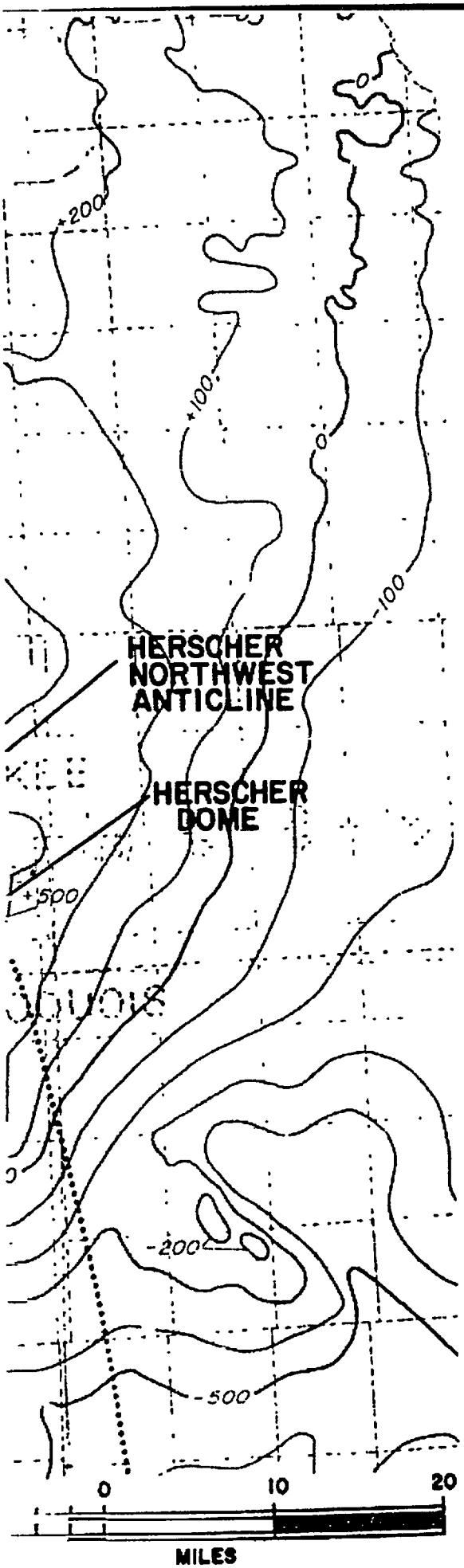
INDEX MAP AND SECTION MODIFIED FROM SASMAN, et al, 1973.

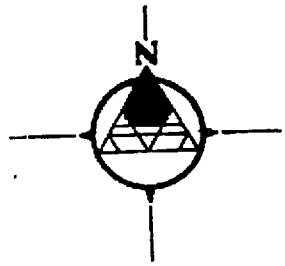
REGIONAL GEOLOGIC CROSS-SEC

DAMES &


ASHTON ARCH
SANDWICH FAULT ZONE
KENDALL
WILL
LA SALLE
GRUNDY
SITE
LIVINGSTON
ILLINOIS BASIN
FORD
LA SALLE ANTICLINAL BELT
MCLEAN
FORD

1674-099-U





EXPLANATION

-500 CONTOUR INTERVAL 100 FEET; DATUM SEA LEVEL

MAQUOKETA ABSENT, TOP OF GALENA ERODED

FAULT, DOWNTHROWN SIDE INDICATED

APPROXIMATE BOUNDARY OF THE LA SALLE ANTICLINAL BELT

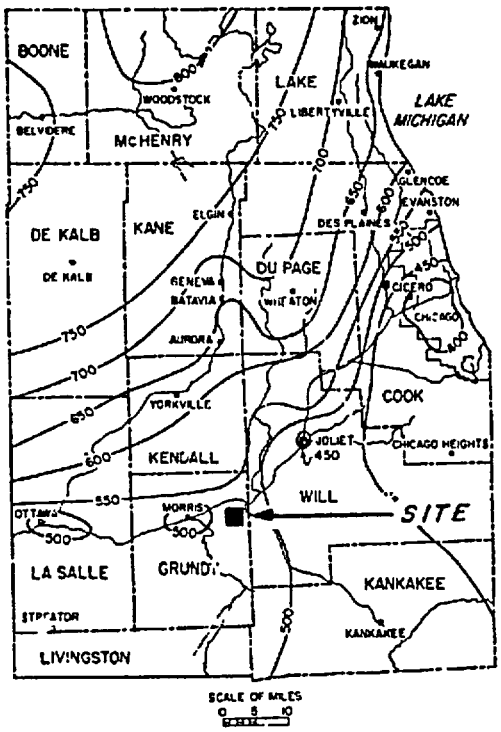
REFERENCE: MODIFIED FROM

BRISTOL, H.M. AND BUSCHBACH, T.C., 1973, ORDOVICIAN GALENA GROUP (TRENTON) OF ILLINOIS-STRUCTURE AND OIL FIELDS; ILLINOIS STATE GEOLOGICAL SURVEY, ILL. PET. 99, PLATE 1.

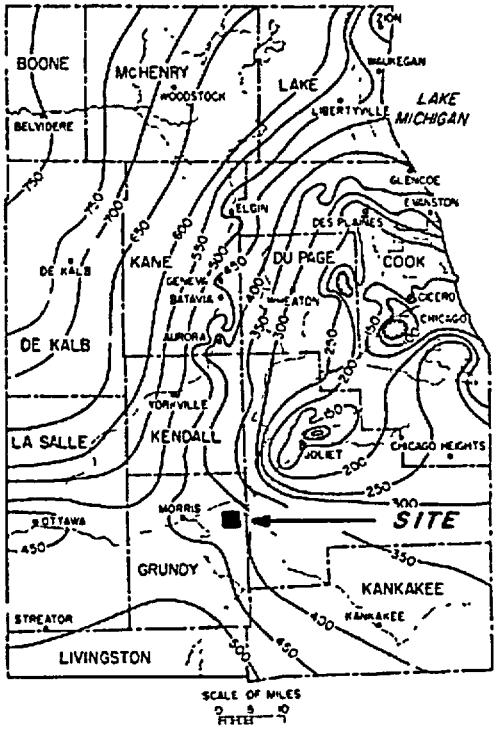
STRUCTURE ON TOP OF GALENA GRO

DAMES & MC

FIGURE 5



POTENTIOMETRIC SURFACE OF CAMBRIAN-ORDOVICIAN AQUIFER ABOUT 1915.



POTENTIOMETRIC SURFACE OF CAMBRIAN-ORDOVICIAN AQUIFER IN 1958.

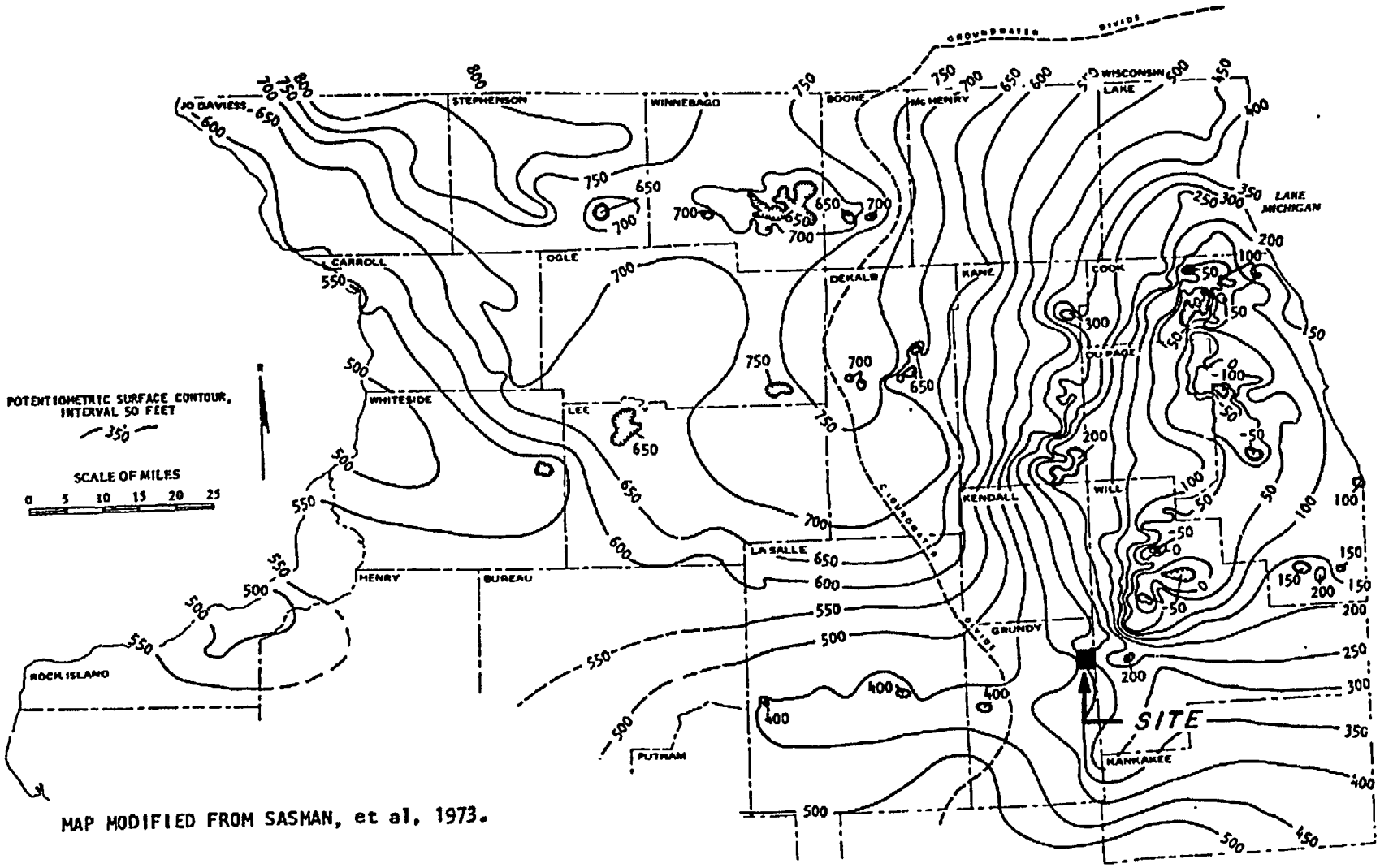
MAPS MODIFIED FROM SUTER, et al, 1959.

1674-101-07

POTENTIOMETRIC SURFACE OF CAMBRIAN-ORDOVICIAN AQUIFER IN 1915 AND 1958

DAMES & MOORE

1674-101-07

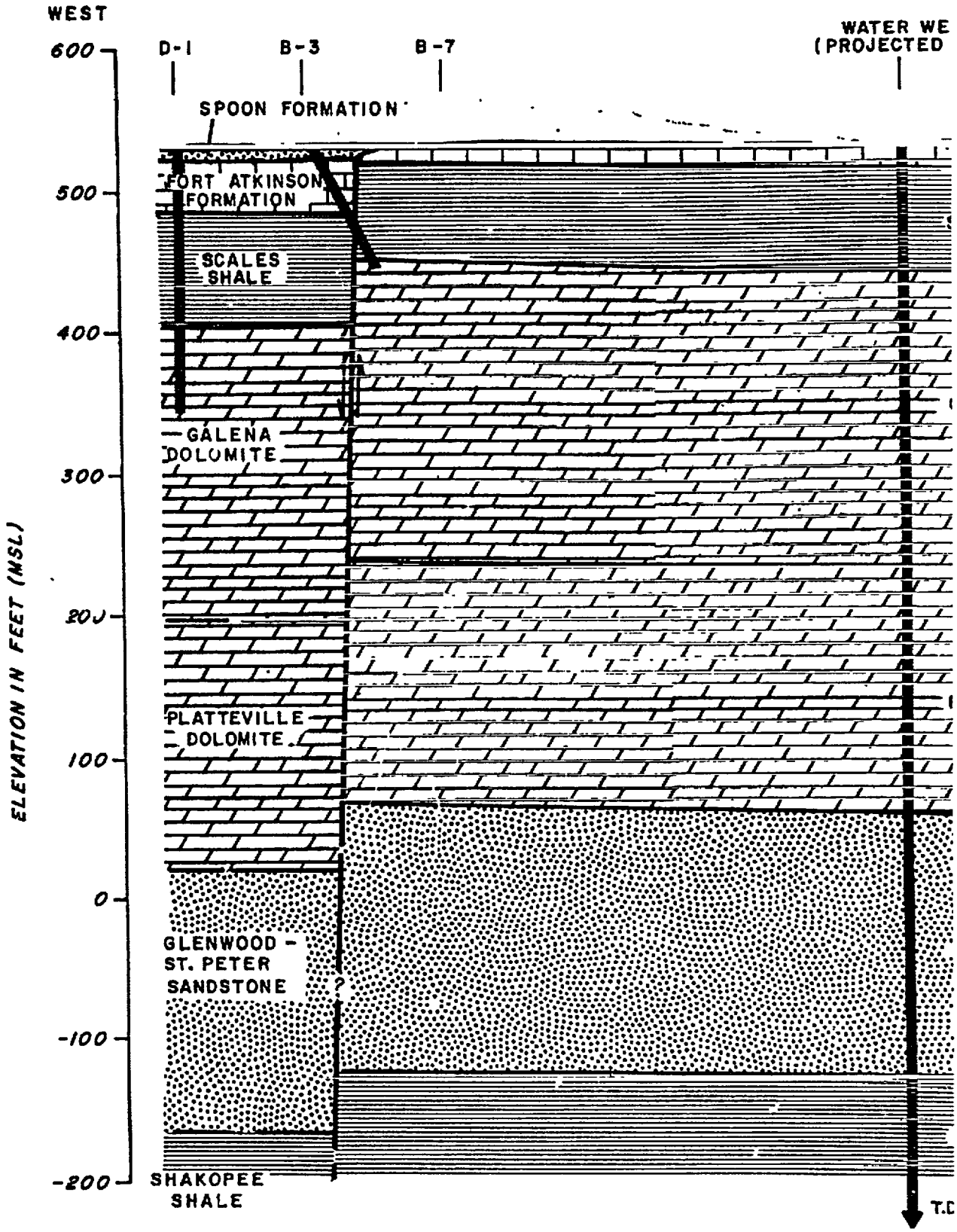


MAP MODIFIED FROM SASMAN, et al, 1973.

POTENTIOMETRIC SURFACE OF CAMBRIAN-ORDOVICIAN AQUIFER IN OCTOBER, 1971

DAMES & MOORE

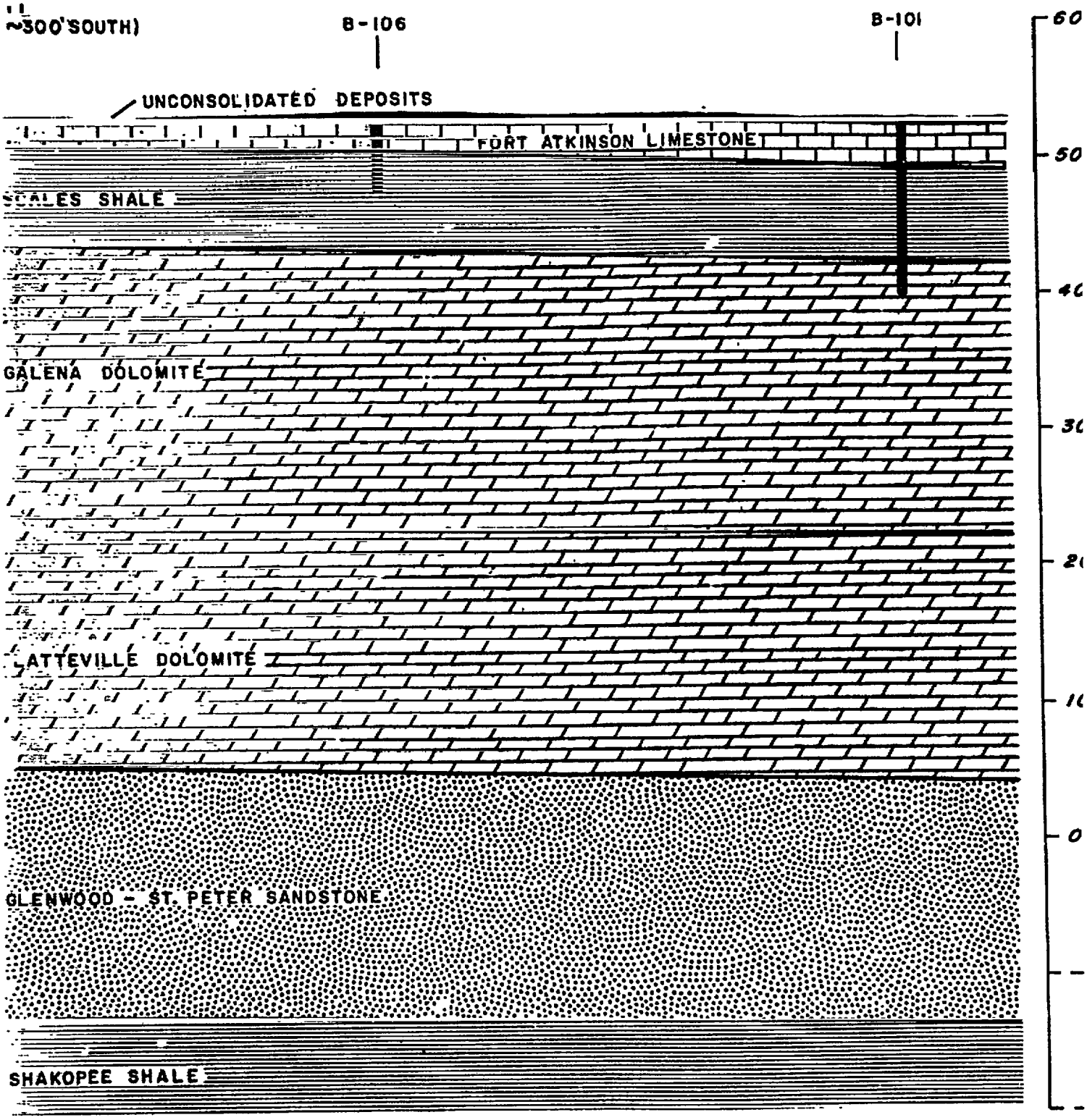
FIGURE 7



NOTES:

1. FOR DETAILS OF FAULT ZONE SEE DAMES & MOORE'S 1977 GEOLOGIC REPORT.
2. STRATIGRAPHY BELOW SCALES SHALE BASED ON LOG FROM GENERAL ELECTRIC'S WATER WELL.
3. SECTION LOCATION PRESENTED ON FIGURE 2 .

1674-101-07



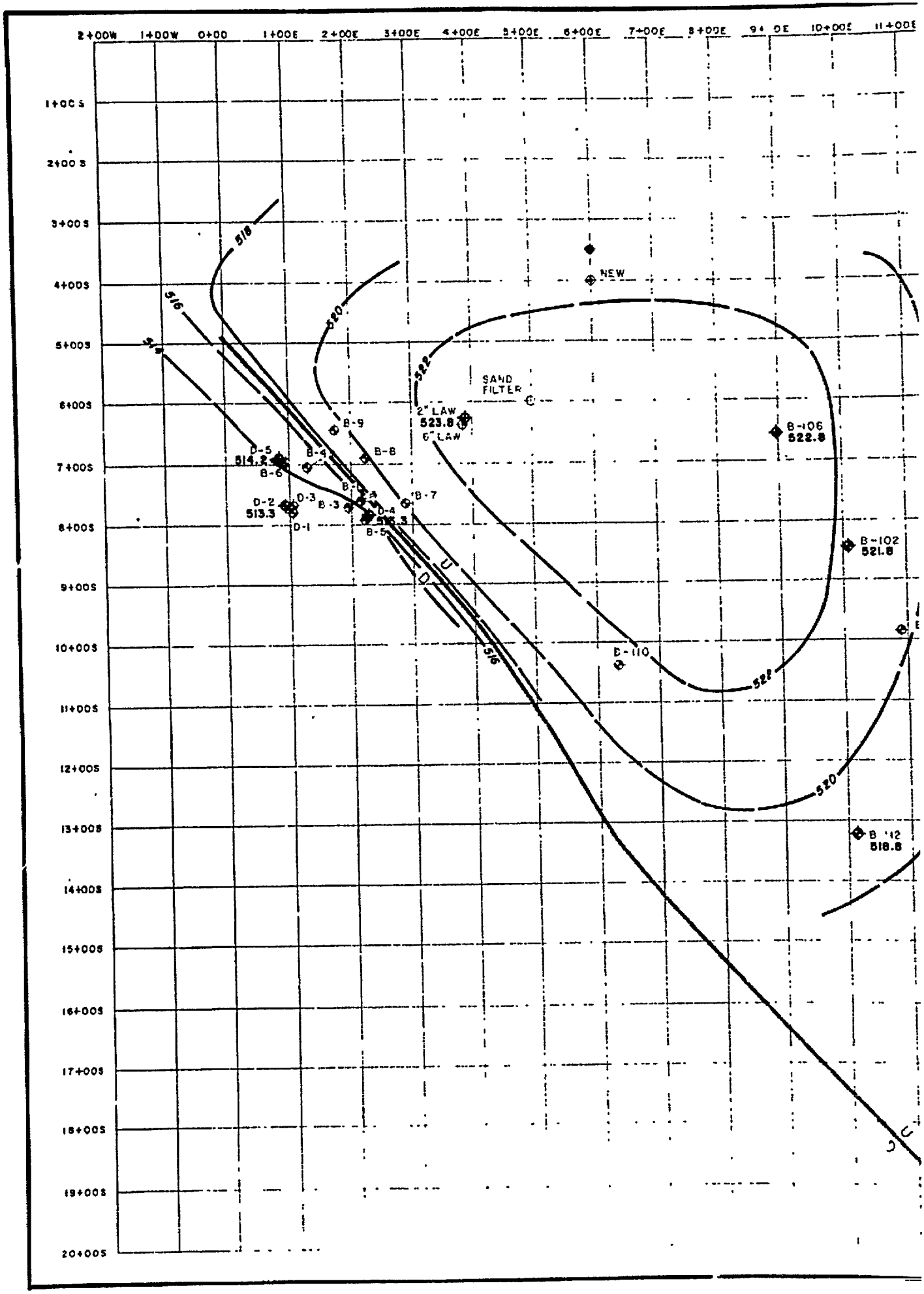
788'

HORIZONTAL SCALE
FEET
0 100

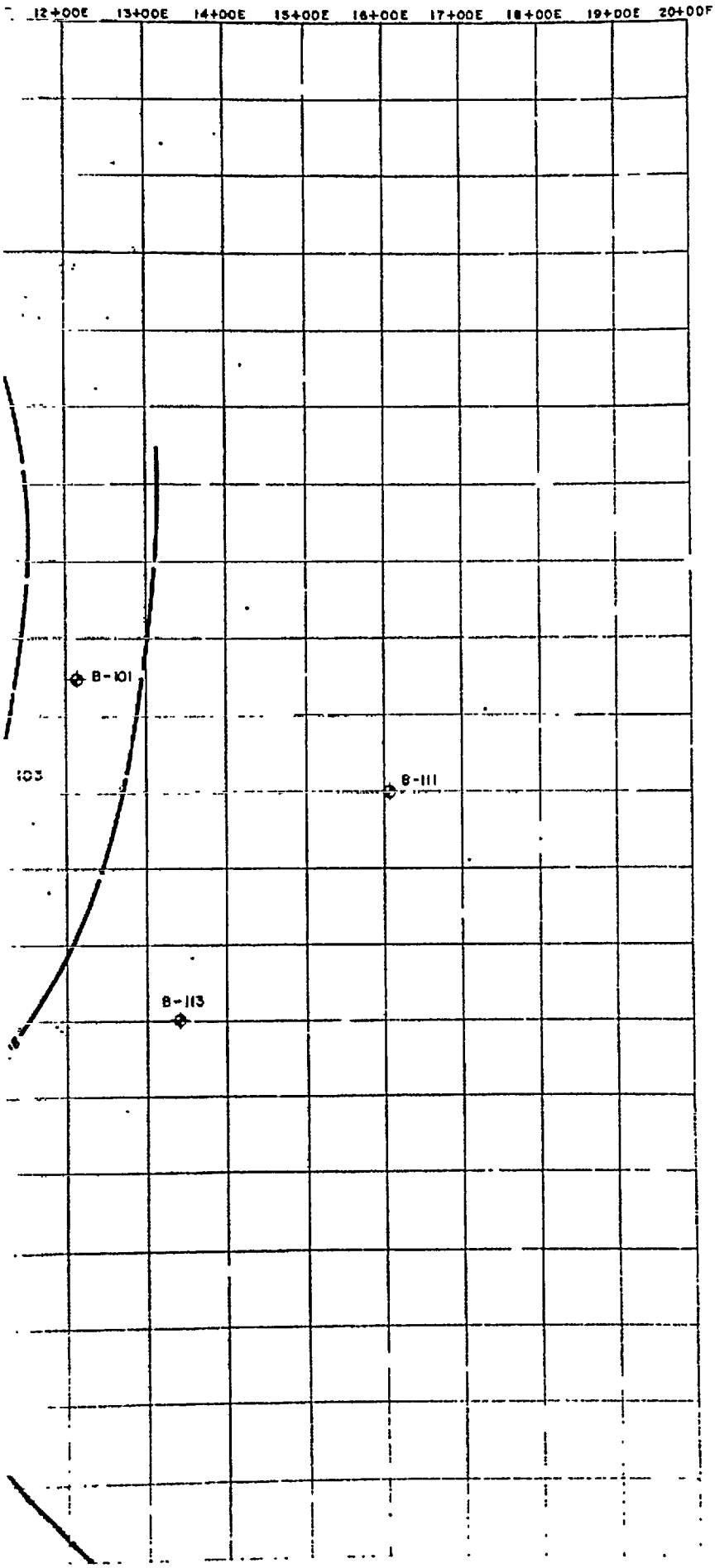
VERTICAL EXAGGERATION

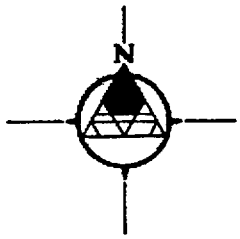
GENERALIZED GEOLOGIC CROSS-SECT

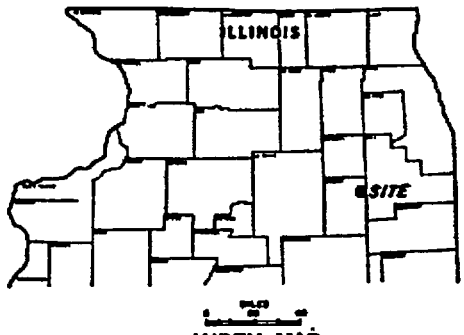
DAMES & M


2+00W
1+00W
0+00
1+00E
2+00E
3+00E
4+00E
5+00E
6+00E
7+00E
8+00E
10+00E
11+00E
1+00S
2+00S
3+00S
4+00S
5+00S
6+00S
7+00S
8+00S
9+00S
10+00S
11+00S
12+00S
13+00S
14+00S
15+00S
16+00S
17+00S
18+00S
19+00S
20+00S
518
516
520
522
NEW
SAND FILTER
2" LAW
523.8
6" LAW
B-9
B-8
B-7
B-4
B-6
D-5
514.2
D-2
513.3
D-3
D-1
B-3
D-4
B-5
B-106
522.8
B-102
521.8
B-110
B-112
518.8

1674-101-07







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- LOCATION OF TEST BORINGS WITH PIEZOMETER FROM DAMES & MOORE'S REPORT DATED SEPTEMBER 3, 1975
- LOCATION OF TEST BORINGS WITH PIEZOMETER FROM THIS INVESTIGATION
- LOCATION OF GENERAL ELECTRIC'S WATER WELL
- U / D — LOCATION OF FAULT ZONE
- 518.8 — WATER LEVEL MEASUREMENT, DECEMBER 12, 1976

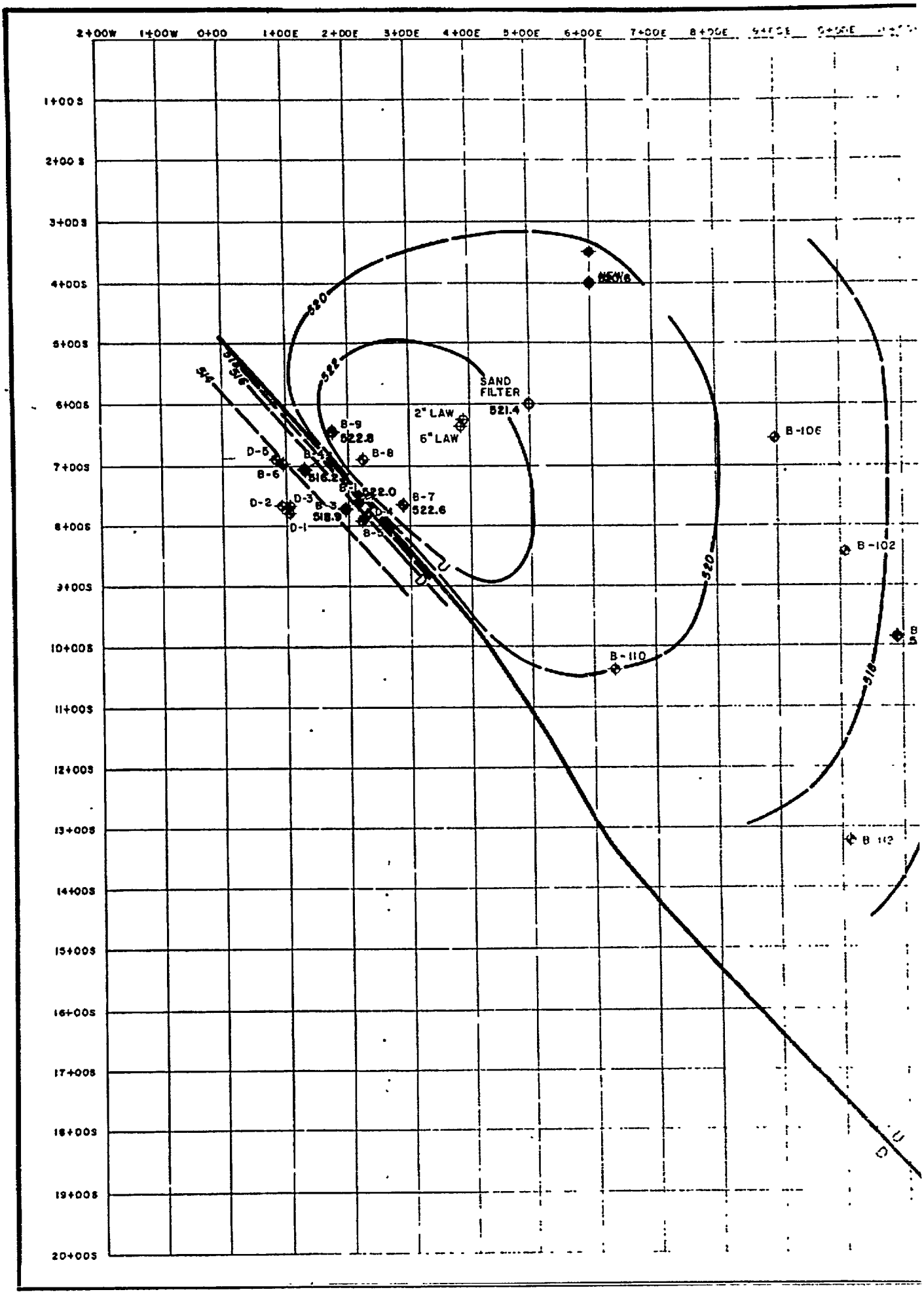
NOTES:

1. POTENTIOMETRIC CONTOURS ARE GENERALIZED BASED ON AVAILABLE DATA.
2. WATER LEVEL MEASUREMENTS MADE BY GENERAL ELECTRIC PERSONNEL.
3. ELEVATIONS REFER TO MEAN SEA LEVEL DATUM.
4. NO PIEZOMETER INSTALLED IN BORING B-8.

SCALE
FEET
100 0 100 200
CONTOUR INTERVAL: 2 FT.

POTENTIOMETRIC SURFACE CONTOU
IN FORT ATKINSON LIMESTONE
DECEMBER 12, 1976

DAMES & MC


2+00W
1+00W
0+00
1+00E
2+00E
3+00E
4+00E
5+00E
6+00E
7+00E
8+00E
1+00S
2+00S
3+00S
4+00S
5+00S
6+00S
7+00S
8+00S
9+00S
10+00S
11+00S
12+00S
13+00S
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15+00S
16+00S
17+00S
18+00S
19+00S
20+00S
520
522
514
516
518
SAND FILTER
521.4
2" LAW
6" LAW
B-9
522.8
B-8
B-106
D-5
B-4
B-6
516.2
B-1
522.0
B-7
522.6
D-2
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518.9
D-4
D-1
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B-102
B-110
B-112
U
D

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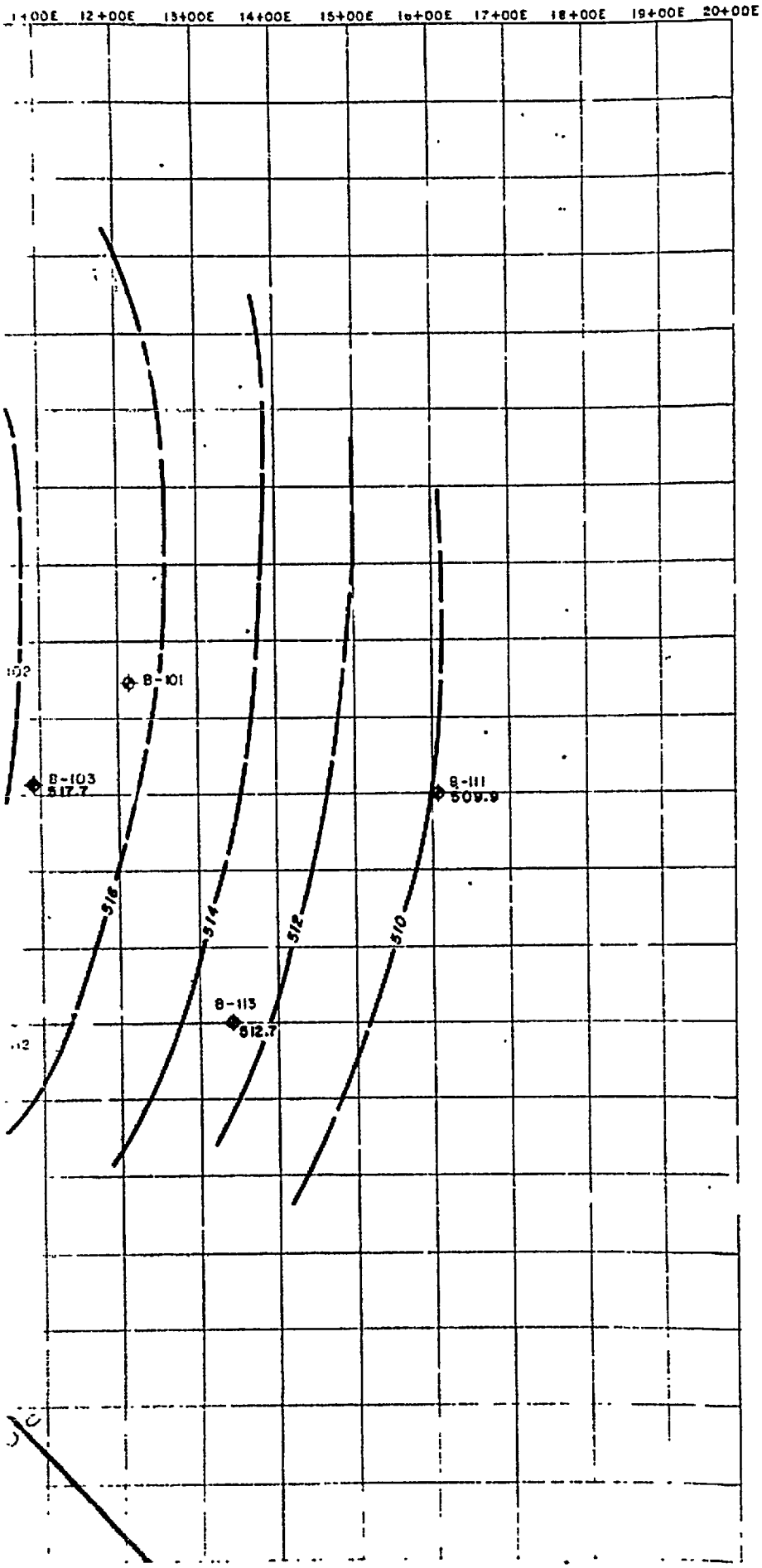

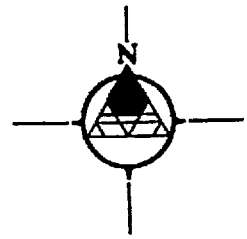

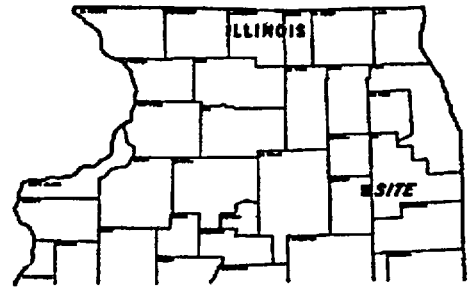

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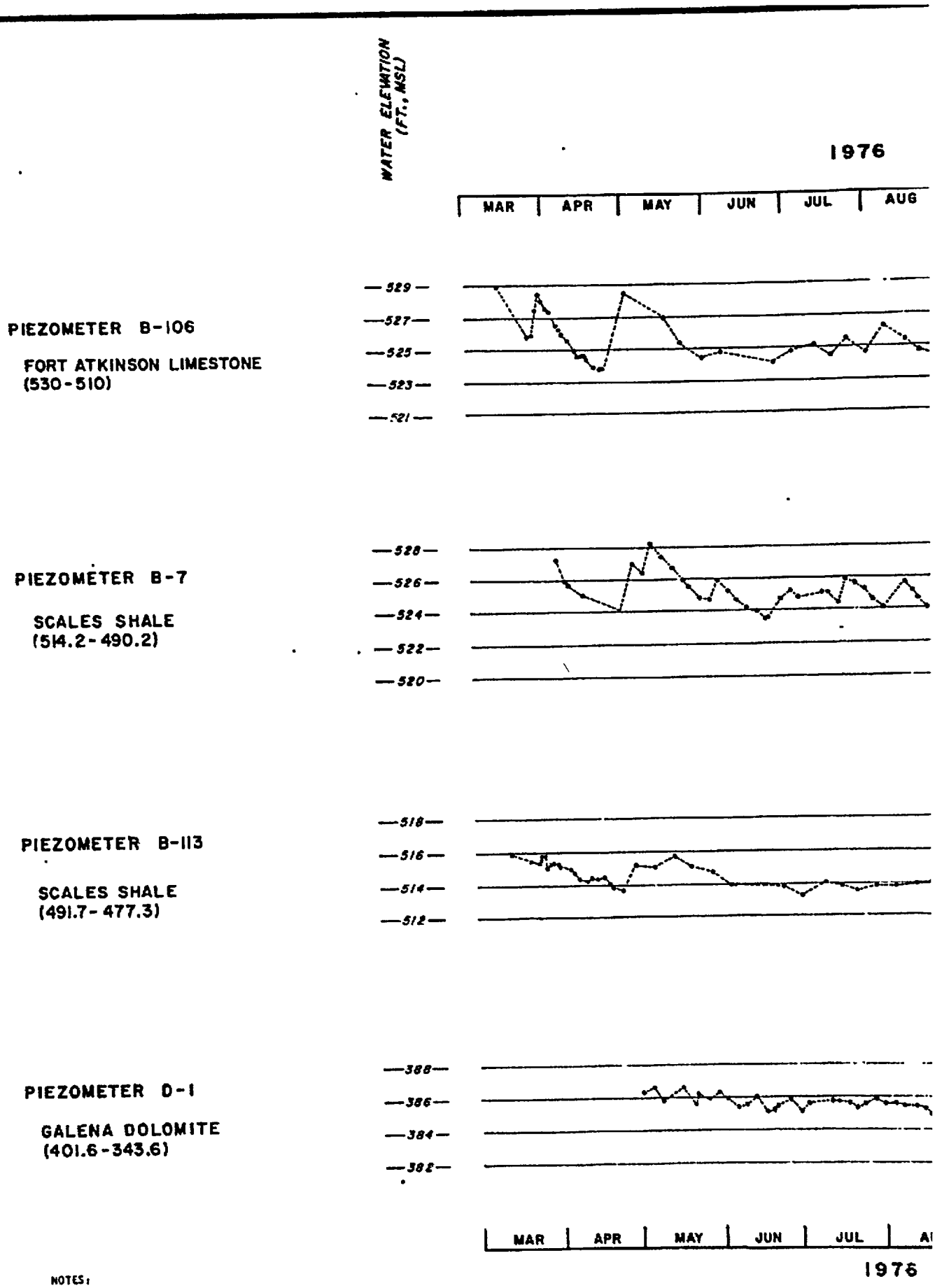
- LOCATION OF GENERAL ELECTRIC'S WATER WE
- U / D LOCATION OF FAULT ZONE
- 512.7 WATER LEVEL MEASUREMENT, DECEMBER 12, 1

NOTES:

1. POTENTIOMETRIC CONTOURS ARE GENERALIZED BAS ON AVAILABLE DATA.
2. WATER LEVEL MEASUREMENTS MADE BY GENERAL ELI PERSONNEL.
3. ELEVATIONS REFER TO MEAN SEA LEVEL DATUM.
4. NO PIEZOMETER INSTALLED IN BORING B-8.

SCALE
FEET
100 0 100 200
CONTOUR INTERVAL 2FT.

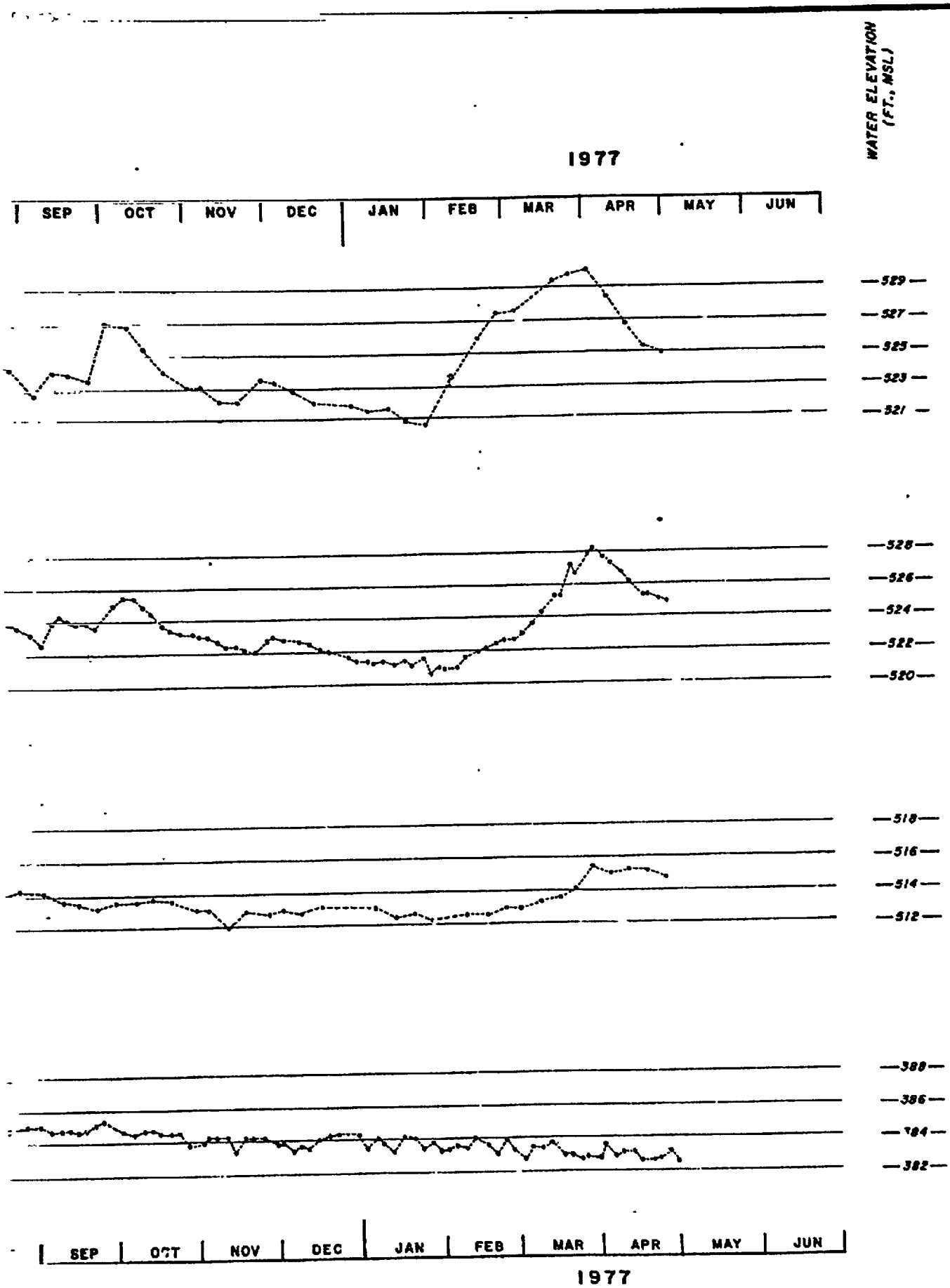
POTENTIOMETRIC SURFACE CONTOU IN SCALES SHALE DECEMBER 12, 1976



NOTES:

1. (530-510) DENOTES INTERVAL TAPPED BY PIEZOMETER.
2. WATER LEVEL MEASUREMENTS MADE BY GENERAL ELECTRIC PERSONNEL.

1674-099-07



GROUND-WATER LEVEL FLUCTUATIO
IN SELECTED PIEZOMETERS

DAMES & MO

FIGURE 11

END

REPORT

GEOPHYSICAL INVESTIGATIONS

PHASE IV FUEL STORAGE CAPACITY EXPANSION
NEAR MORRIS, ILLINOIS

FOR

GENERAL ELECTRIC COMPANY

Prepared By
DAMES & MOORE

July 22, 1977
Job No. 1674-099-07

DAMES & MOORE

July 22, 1977

General Electric Company
Nuclear Energy Division
175 Curtner Avenue
San Jose, California 95125

Attention: Mr. F.H. Shadel
Mail Code 380

Gentlemen:

Re: P.O. 529-JIT-99X
Report
Geophysical Investigations
Project IV - Fuel Storage Capacity Expansion
Near Morris, Illinois
General Electric Company

This letter transmits seven copies of our "Report - Geophysical Investigations Project IV - Fuel Storage Capacity Expansion near Morris, Illinois". This report has been revised to include General Electric's comments and is a partial completion of the work required by Task A, Phase I, charge PGDRX-811-FDX40-M890 of the referenced purchase order. The balance of the reports covered by this charge will be submitted under separate cover.

If there are any questions regarding this report, or any other work being performed for the Morris Facility, please contact us.

Very truly yours,

DAMES & MOORE

Michael L. Kiefer

Michael L. Kiefer
Partner

John S. Trapp

John S. Trapp
Senior Geologist

MLK/JST/br

Enclosure

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NEAR MORRIS, ILLINOIS

FOR

GENERAL ELECTRIC COMPANY

INTRODUCTION

This report presents the results of our geophysical investigations for the Phase IV Fuel Storage Capacity Expansion for the General Electric Company. The purpose of the investigation was to obtain in-situ compressional wave velocities of site materials and to develop attenuation and powder loading factor curves to be used for control of blast vibrations during excavation. The locations at which the studies were performed are shown on Figures 1A, 1B, and 1C.

SCOPE

The scope of the geophysical investigations included:

1. Determining in-situ compressional wave velocities of site materials, to be used with representative values of Poisson's ratio to compute shear wave velocities;

2. Recording blast-induced vibrations to determine attenuation characteristics of site materials; and

3. Establishing powder loading factor curves (charge size versus distance) for design of production excavation blasts.

INVESTIGATION PROCEDURES

UPHOLE COMPRESSIONAL WAVE VELOCITY SURVEYS

Uphole compressional wave velocity measurements were obtained at two locations (Borings B-7 and B-9) as shown on Figure 1B, Plot Plan. Boring B-7, drilled to a depth of 70.0 feet, was surveyed to a depth of 63.0 feet and Boring B-9, drilled to a depth of 70.5 feet, was surveyed to a depth of 64.0 feet.

At both locations, the energy generated by impacting a sledgehammer against the ground surface was detected by a low frequency borehole geophone in the boring being surveyed. The output of the borehold geophone, a Mark products L-1-3Ds, low frequency, 3-component geophone, equipped with an inflatable sidewall packer, was fed to an SIE RS-44, 24-channel refraction seismograph signal conditioner and permanently recorded on an SIE R-6 recording oscillograph onto Kodak direct print linagraph paper.

The borings were surveyed at 5-foot depth intervals. At each recording level, the geophone was locked against the boring wall with the inflatable packer. Vertical hammer impacts were made against a plank placed in the bottom of a shallow trench dug beside the boring. The impact origin time of the sledgehammer was detected by a vertically oriented refraction geophone placed beside

the plank. Two separate recordings were made at each elevation.

In addition to the above surveys, Boring B-9 was also surveyed using electric blasting caps as an energy source. The blasting caps were detonated at various depths in the borehole. The vertically oriented refraction geophone, previously used to indicate sledgehammer impact origin times, was used to detect compressional wave arrivals at the ground surface. Recordings were made with the instrumentation previously described.

The uphole compressional wave velocity survey data from Borings B-7 and B-9 were evaluated by plotting the compressional wave travel time from the impact point to arrival at each geophone position versus the geophone depth. The blasting cap survey data were evaluated as the travel time interval from cap detonation to arrival at the geophone versus cap depth. All travel times were corrected to vertical travel paths. Visual best-fit, straight line segments were constructed through the time-depth data. The slope of the line segments was used to determine the velocity of the individual layers. The resultant time-depth plots are presented on Figures 2, 3, and 4.

BLASTING VIBRATION ATTENUATION STUDY

A series of test blasts was initiated to evaluate the attenuation of ground vibrations produced by blasting.

Only single test blasts were used; no multiple delays were used. The report concerning the dynamic evaluation of the south wall and gate of the existing structure will be submitted at a later date. This report will treat the effects of multiple delay changes. The blasts were recorded using both Sprengnether Engineering Seismographs, Models VS-1200/4 and VS-1200. These two models differ in that the VS-1200/4 has four recorder channels and the VS-1200 has only one. The VS-1200/4 recordings were output on linagraph paper using an Electro-Tech Labs SDW-100 recording oscillograph. The VS-1200 recordings were output on linagraph paper and with the exception of Record No. 17-2 were also input to a Hewlett-Packard, HP 3960A 4-channel magnetic tape recorder monitored with a Tektronix Model 7623 oscilloscope. Each recording location provided three calibrated component directions (transverse, vertical and longitudinal) of ground motion. The records from channel II on the VS-1200/4 were not used in the data analysis because of failure of this channel to satisfy calibration tolerances. Blast charges, consisting of high velocity gelatin dynamite and/or TNT blocks and ranging in size from ½ to 9 pounds, were initiated on single delay periods using instantaneous electric blasting caps.

The individual blast vibration recordings of the test blasting program were analyzed to determine the maximum ground motion (either in terms of particle velocity or acceleration) produced by each blast. This analysis was accomplished by measuring the trace excursions from zero or

null values to peak amplitudes on all of the three component traces at a common record time. The individual component trace amplitudes were adjusted for gain values and then summed vectorially to obtain the maximum ground motion for each recording.

The test blasting program was conducted as a five-phase study. In Phases 1 and 2, recordings were made in the particle velocity mode for each blast. In Phases 3, 4 and 5, the recordings were made in the acceleration mode.

In Phase 1, eight blasts were initiated at a location over 1000 feet from the existing structures (Figure 1A) to develop preliminary particle velocity attenuation data for use in designing the Phase 2 program. The distant test site was selected so that the vibrations resulting from the test blasts would not damage the existing structures. Phase 2 was conducted in the area of the proposed facility at the location shown on Figure 1B to develop particle velocity attenuation data for the proposed construction. This phase consisted of a total of 7 blasts.

Phase 3, which consisted of 7 blasts, was conducted at the same location as Phase 2 to develop acceleration attenuation data. Phase 4 consisted of 3 separate blasts conducted in the area of the excavation haul road that was used and backfilled during previous construction, as shown on Figure 1C. The purpose of this series of test blasts was to evaluate the effects of removal of the backfill on acceleration

attenuation to simulate the effects of removal of backfill adjacent to the existing facility during construction of the proposed storage basin. To accomplish this purpose, the three blast configurations shown on Figure 1C were used. The first blast was recorded with the haul road backfill material in place. A second blast was recorded at the same location following removal of the backfill. The final blast was recorded with the monitor located at the base of the excavated haul road.

In Phase 5, two additional recordings of the blast-induced particle accelerations were obtained at recording locations on the east and west sides of the existing water storage basin gate. In both cases, the seismograph was placed on the basin wall adjacent to the gate and small (½ pound) charges were detonated in holes located approximately 47 feet away. A plan view of these conditions is presented on Figure 1C. Both records were obtained from shots consisting of ½ pound of dynamite detonated at a depth of 6 feet. These tests provided data on motion amplification, the natural periods of in-situ wall vibration, and damping characteristics of the walls adjacent to the gates.

DISCUSSION OF RESULTS

UPHOLE COMPRESSIONAL WAVE VELOCITY SURVEY

The results of the uphole surveys conducted in Borings B-7 and B-9 (Figures 2, 3, and 4) indicate that the Fort Atkinson Formation exhibits compressional wave

velocities of approximately 5000 to 7000 feet per second. The upper Scales Formation exhibited compressional wave velocities of 4300 to 5500 feet per second. The compressional wave velocity values obtained suggest that significant disturbance and/or weathering may have taken place. The Scales Formation below a depth of approximately 30 to 35 feet (18 to 13 feet elevation*) exhibits a velocity of approximately 7900 to 8800 feet per second. This appears to represent fresh shale.

The low velocity above elevation 13 to 18 feet can probably be attributed to a combination of factors. Examination of core samples, trench faces and photographs of previous excavations indicates that significant disturbance of this zone has occurred partially as a result of construction blasting. Both borings surveyed during this study are located near areas that were previously blasted.

In addition to the disturbed materials, the core samples also indicated that significant weathering has occurred in the upper portions of the borings. Based on core sample examination and the evaluation of the uphole velocity survey data, it appears that the change from weathered to unweathered material is gradational.

The foundation grades for the existing storage basin and the proposed expansion are near the elevation at which unweathered shale is indicated on the time-depth plots. The engineering properties of the subsurface materials

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*These elevations refer to Plant Datum. Elevation 0.0 Plant Datum equals 485.0 U.S.G.S. Mean Sea Level Datum (MSL).

(see our letter dated May 12, 1977, Re: Evaluation of Foundation Recommendation) were conservatively estimated since the exact contact cannot be ascertained until the foundation excavation is complete.

Based on an evaluation of data obtained from similiar materials, Poisson's ratios were estimated and corresponding shear wave velocities were computed from compressional wave velocity data obtained during the uphole surveys. The Poisson's ratio estimated for the Fort Atkinson Formation takes into consideration the observed low compressional wave velocities and the highly fractured condition of the rock. Values estimated for the Scales Formation were selected to reflect the variation in weathering.

Blast particle velocities of the subsurface rock formations obtained in this study are presented in Table 1; Figures 2, 3, and 4 show seismic velocities.

BLASTING VIBRATION ATTENUATION STUDY

Particle Velocity Studies

The generally accepted maximum safe vibration level, as recommended by the U.S. Bureau of Mines, is a particle velocity of 2.0 inches per second measured on any of the three orthogonal component directions at any time in the record (Nicholls et al., 1971). This value was based on damage (cracking of plaster) to residential-type structures.

Dames & Moore evaluates blast vibrations by defining the maximum particle velocity as the vector sum of all three orthogonal components at a common record time. This practice assures that the measured particle velocity is equal to or greater than any value determined from a single component. In addition, the following maximum particle velocity limits have commonly been utilized on nuclear related projects:

2.0 inches per second - for concrete less than 28 days old

4.0 inches per second - for concrete greater than 28 days old

Considering that 4.0 inches per second represents a vector sum, it should be noted that this is approximately equivalent to 2.0 inches per second determined from a single component direction. Also since the existing basin is considerably more substantial than a residential building, the above vibration limits are considered conservative. The magnitude of ground motion resulting from a blast is affected simultaneously by distance and charge size. Therefore, a normalizing value termed the scaled distance factor (SDF) is used to incorporate these effects. SDF is computed by the following relationship:

$$\text{SDF} = \frac{\text{distance from blast (feet)}}{\sqrt{\text{maximum charge size (pounds) delay}}}$$

The monitored ground motions for each blast recorded during Phases 1 and 2 of this study are summarized in Table 2 and are presented graphically on Figure 5. On Figure 5, the maximum ground motion is plotted against the corresponding SDF. A line representing the theoretical upper bound of

the vibration attenuation envelope is presented on the figure. The SDF values representing the vector sum particle velocity limits of 2.0 and 4.0 inches per second were obtained from the upper bound curve on Figure 5 and are 29 and 19, respectively. These SDF values were then used to prepare powder loading factor curves (Figure 6) where the maximum allowable charge size per delay is related to the distance from the blast.

The maximum allowable charge size per delay and the distance from the blast to a structure are related in a manner that limits vibrations to levels below the maximum safe limits. The loading factors presented on Figure 6 show that at a distance of 100 feet from a blast to an existing structure, approximately 11 pounds of explosives can be detonated on any single delay with the resultant vector sum of 2.0 inches per second limit.

Maximum charge size must be considered as charge size per individual delay because of the additive nature of vibrations produced by simultaneous detonations. The ground vibration and attenuation characteristics observed during this study though generated by single delay period blasts are considered to be representative of those that would result from multiple delay blasting for bedrock excavation provided a delay period of 8 milliseconds or greater between detonations is used (U.S. Army Corps of Engineers, 1972).

Acceleration Studies

The purpose of the acceleration studies was primarily to obtain input data for the dynamic evaluation of the south wall and gate of the existing structure (Task C as defined in Purchase Order 529-J1T-99X). To accomplish this objective, the effects of blasting were also recorded both on paper and on magnetic tape for input into the computer analysis.

The following paragraphs provide a general discussion of the acceleration data obtained. A more complete discussion and evaluation of this data will be presented in the structural dynamic evaluation report, which will be submitted at a later date.

The blast-induced particle acceleration data obtained during Phases 3, 4, and 5 of this study were evaluated in the same manner as were the velocity data.

The acceleration data, which was obtained primarily from Phase 3, is summarized in Table 3 and presented graphically on Figure 7.

The observed acceleration value can be approximately related to the velocity values by the following equation:

$$v = \frac{a}{2\pi f}$$

v = particle velocity

a = particle acceleration

f = frequency of vibration.

Frequencies generated during this study were in the range

of approximately 30 to 90 hertz.

The data obtained during Phase 4 of this program consisted of a set of three blasts to evaluate the effect of the removal of backfill adjacent to the existing basin prior to excavation blasting. This set of blasts was performed across the area where the abandoned excavation haul road for the existing facility was located, as shown on Figure 1C. Blast records were obtained for three conditions:

Case A (Shot 4-1)	Shot hole and seismograph were located on opposite sides of the haul road at ground level. Haul road backfill was in-place.
Case B (Shot 4-2)	Shot hole and seismograph were located on opposite sides of the haul road at ground level. Haul road backfill was removed.
Case C (Shot 4-3)	Shot hole was located at ground level, with seismograph located in the haul road on the side opposite the shot hole. Backfill was removed.

All three blasts consisted of 1-pound charges buried at a depth of 6 feet.

The acceleration records obtained from each of the cases are presented on Figure 8. As can be noted on this figure, the greatest vector sum particle acceleration was obtained for the case where the haul road was not excavated. Following excavation, a reduction in acceleration was observed.

Phase 5 consisted of two blasts initiated approximately 47 feet from the south wall of the existing basin. The monitor was located on the south wall west of

the existing expansion gate for Shot 5-1 and east of the expansion gate for Shot 5-2, as shown on Figure 1C.

For the two blasts monitored, the basin wall west of the expansion gate was subjected predominately to longitudinal motion while the basin wall east of the gate was subjected to motion with a more intense transverse component. The difference in motion is as expected based on the configuration of the basin walls, relative to the blast locations. The acceleration records obtained from this phase are presented on Figure 9.

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The attached tables and figures complete this report.

Respectfully submitted,

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Michael L. Kiefer

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Partner

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TABLE 1

WAVE VELOCITIES OF SUBSURFACE ROCK

Unit	Compressional Velocity (fps)	Poisson's Ratio[a]	Shear Velocity (fps)[b]
Fort Atkinson Fm.	5000 to 7000	0.35	2400 to 3350
Upper Scales Fm. (Above Plant Elevation 13)[c]	4300 to 5500	0.43	1500 to 1900
Lower Scales Fm. (Below Plant Elevation 13)	7900 to 8800	0.35	3800 to 4200

[a]Assumed.
[b]Computed using assumed Poisson's ratio.
[c]Elevations refer to Plant Datum, Elevation 0.0 Plant Datum equals 485.0 U.S.G.S., MSL.

TABLE 2

PARTICLE VELOCITY BLAST MONITORING SUMMARY

Record Number	Shot Number[a]	Charge Size (lbs)	Distance (feet)	Scale Distance Factor (SDF)	Maximum[d] Particle Velocity (inches/sec.)
13-1 MSS[b]	1-1	1	186.5	186.5	0.036
13-1 MSS	1-1	1	42.0	42.0	0.341
13-2 VS[c]	1-2	1	10.0	10.0	4.15
13-2 MSS	1-2	1	186.5	186.5	0.037
13-2 MSS	1-2	1	42.0	42.0	0.260
13-2 MSS	1-2	1	25.0	25.0	0.303
13-3 VS	1-3	4	10.0	5.0	14.22
13-3 MSS	1-3	4	196.2	98.1	0.245
13-3 MSS	1-3	4	46.1	23.1	0.810
13-3 MSS	1-3	4	20.6	10.3	2.68
13-4 VS	1-4	2	10.0	7.1	13.95
13-4 MSS	1-4	2	207.4	146.7	0.150
13-4 MSS	1-4	2	57.3	40.5	0.594
13-4 MSS	1-4	2	32.0	22.6	1.024
13-5 VS	1-5	½	12.5	17.7	3.11
13-5 MSS	1-5	½	219.9	311.0	0.041
13-5 MSS	1-5	½	72.4	102.4	0.122
13-5 MSS	1-5	½	49.2	69.6	0.244
13-6 VS	1-6	1	20.0	20.0	1.92
13-6 MSS	1-6	1	617.3	617.3	0.0094
13-6 MSS	1-6	1	120.2	120.2	0.0757
13-6 MSS	1-6	1	72.4	72.4	0.16

[a]The first number refers to the Phase. The second to the Shot, thus 2-3 is the third Shot in the second Phase.

[b]MSS - VS1200/4

[c]VS - VS1200

[d]Maximum Particle Velocity is equal to the vectoral sum of all the orthoganal components at a common record line.

TABLE 2 (Cortinued)

PARTICLE VELOCITY BLAST MONITORING SUMMARY

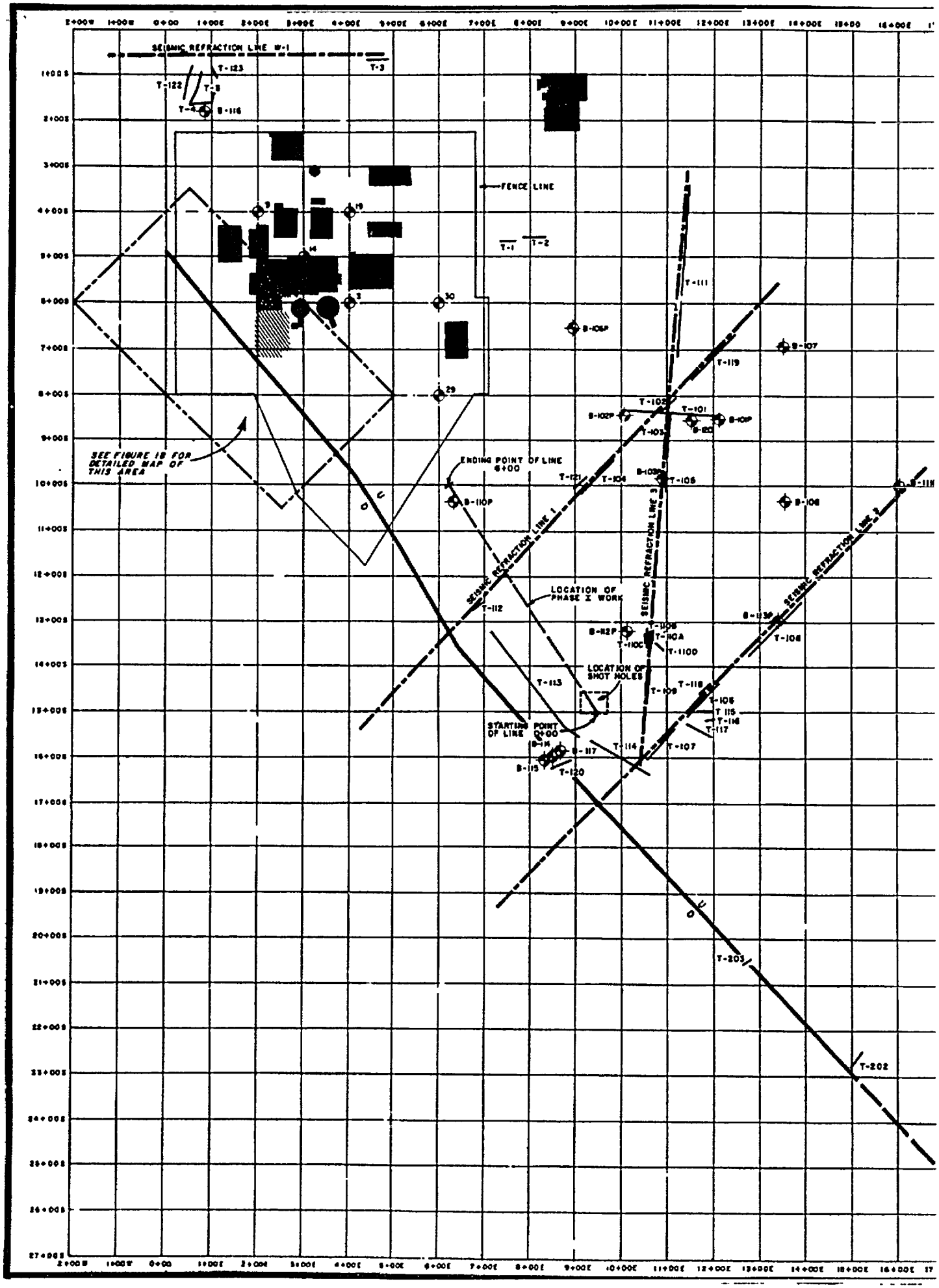
Record Number	Shot Number[a]	Charge Size (lbs)	Distance (feet)	Scale Distance Factor (SDF)	Maximum Particle Velocity (inches/sec.)
13-7 VS	1-7	4	20.0	10.0	2.73
13-7 MSS	1-7	4	601.2	300.6	0.031
13-7 MSS	1-7	4	107.4	53.7	0.291
13-7 MSS	1-7	4	63.0	31.5	0.67
13-8 VS	1-8	9	44.8	14.9	2.32
13-8 MSS	1-8	9	589.4	196.5	0.037
13-8 MSS	1-8	9	92.0	30.7	0.50
17-3 VS	2-1	1	13.2	13.2	2.7
17-3 MSS	2-1	1	250.0	250.0	0.042
17-3 MSS	2-1	1	50.2	50.2	0.673
17-4 VS	2-2	1	57.8	57.8	0.334
17-4 MSS	2-2	1	251.5	251.5	0.022
17-4 MSS	2-2	1	57.8	57.8	0.251
17-4 MSS	2-2	1	39.1	39.1	0.33
17-8 VS	2-3	3	271.6	156.8	0.068
17-8 MSS	2-3	3	75.5	43.6	0.054
17-8 MSS	2-3	3	54.0	31.2	0.91
17-9 VS	2-4	1	115.5	115.5	0.124
17-9 MSS	2-4	1	260.2	260.2	0.023
17-9 MSS	2-4	1	60.4	60.4	0.40
17-9 MSS	2-4	1	36.7	36.7	0.39
17-11 MSS	2-5	3	47.2	27.3	0.70
17-11 MSS	2-5	3	67.7	39.1	0.44
17-13 MSS	2-6	3	50.0	28.9	1.58
17-13 VS	2-6	3	105.0	60.6	0.688
17-18 MSS	2-7	9	884.0	294.7	0.015
17-18 MSS	2-7	9	860.0	286.7	0.016
17-18 MSS	2-7	9	1083.0	361.0	0.013

TABLE 3

PARTICLE ACCELERATION BLAST MONITORING SUMMARY

Record Number	Shot Number[a]	Charge Size (lbs)	Distance (feet)	Scale Distance Factor (SDF)	Maximum Acceleration (gravity)
17-2 VS[b]	3-1	1	10.0	10.0	0.234
17-2 MSS[c]	3-1	1	250.0	250.0	0.013
17-2 MSS	3-1	1	25.0	25.0	0.649
17-5 VS	3-2	1	62.4	62.4	0.426
17-5 MSS	3-2	1	260.0	260.0	0.010
17-5 MSS	3-2	1	62.4	62.4	0.356
17-5 MSS	3-2	1	40.3	40.3	0.338
17-6 VS	3-3	3	53.5	30.9	1.72
17-6 MSS	3-3	3	250.8	144.8	0.0376
17-6 MSS	3-3	3	53.5	30.9	1.03
17-6 MSS	3-3	3	32.3	18.6	0.89
17-7 VS	3-4	3	270.8	156.3	0.0242
17-7 MSS	3-4	3	72.1	41.6	0.73
17-7 MSS	3-4	3	49.0	28.3	0.66
17-10 MSS	3-5	1	266.0	266.0	0.015
17-10 MSS	3-5	1	65.5	65.5	0.56
17-10 MSS	3-5	1	41.2	41.2	0.346
17-12 VS	3-6	3	117.7	68.0	0.382
17-12 MSS	3-6	3	261.7	151.1	0.025
17-12 MSS	3-6	3	63.6	36.7	1.19
17-12 MSS	3-6	3	41.2	23.8	1.03
17-19 MSS	3-7	9	1068.0	356.0	0.004
17-19 MSS	3-7	9	869.0	289.7	0.0068
17-19 MSS	3-7	9	845.0	281.7	0.0047
17-1 VS	4-1	1	32.0	32.0	0.684
17-14 VS	4-2	1	31.5	31.5	0.587
17-15 VS	4-3	1	28.0	28.0	0.572
17-16 VS	5-1	½	47.0	66.5	0.106
17-17 VS	5-2	½	47.0	66.5	0.194

[a]The first number refers to the Phase. The second to the Shot, thus 2-3 is the third Shot in the second Phase.
[b]VS = VS1200
[c]MSS = VS1200/4


SEISMIC REFRACTION LINE W-1
T-123
T-122
T-3
T-4
B-116
FENCE LINE
T-1
T-2
T-111
B-105P
B-107
T-119
T-102
T-101
B-102P
B-101P
B-103
B-120
SEE FIGURE 18 FOR DETAILED MAP OF THIS AREA
ENDING POINT OF LINE 6+00
T-121
T-104
B-109
T-105
B-110P
B-108
SEISMIC REFRACTION LINE 1
SEISMIC REFRACTION LINE 3
SEISMIC REFRACTION LINE 2
LOCATION OF PHASE I WORK
T-112
B-112P
T-110A
T-110C
T-110D
T-108
LOCATION OF SHOT HOLES
T-113
T-109
T-118
T-106
T-115
T-116
T-117
STARTING POINT OF LINE 0+00
B-114
B-117
B-115
T-120
T-114
T-107
T-203
T-202

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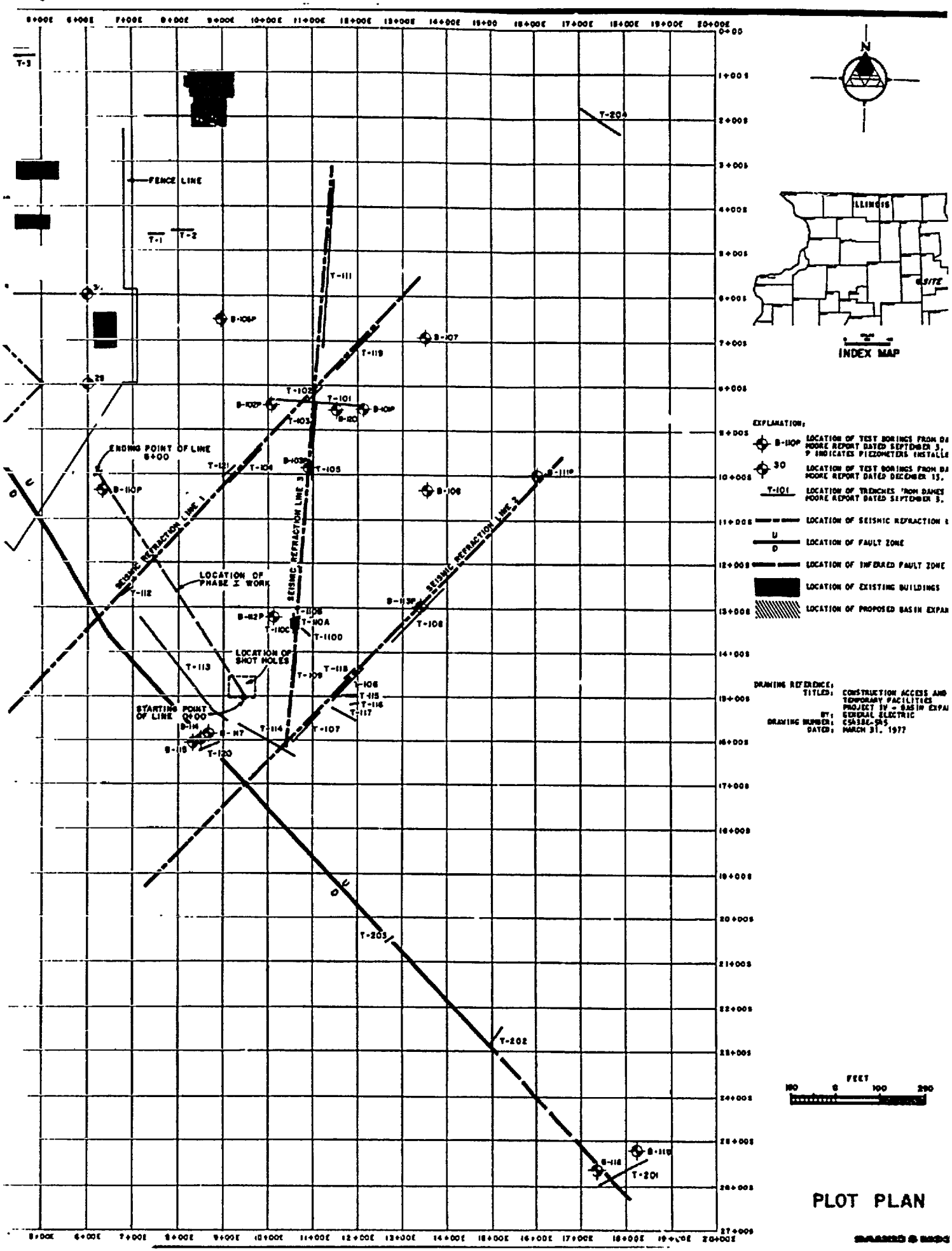

FENCE LINE
ENDING POINT OF LINE 8+00
STARTING POINT OF LINE 0+00
LOCATION OF PHASE I WORK
LOCATION OF SHOT HOLES
SEISMIC REFRACTION LINE 1
SEISMIC REFRACTION LINE 2
SEISMIC REFRACTION LINE 3
T-204
T-111
T-119
T-102
T-101
T-103
T-121
T-104
T-105
T-112
T-113
T-109
T-115
T-116
T-117
T-114
T-107
T-108
T-203
T-202
T-201
B-107
B-108
B-110P
B-120
B-114
B-117
B-118
B-119
N
ILLINOIS
SITE
INDEX MAP
EXPLANATION:
B-110P LOCATION OF TEST BORINGS FROM DA MOORE REPORT DATED SEPTEMBER 3, P INDICATES PIEZOMETERS INSTALLE
30 LOCATION OF TEST BORINGS FROM DA MOORE REPORT DATED DECEMBER 15,
T-101 LOCATION OF TRENCHES FROM DAMES MOORE REPORT DATED SEPTEMBER 3,
LOCATION OF SEISMIC REFRACTION L
U D LOCATION OF FAULT ZONE
LOCATION OF INFERRED FAULT ZONE
LOCATION OF EXISTING BUILDINGS
LOCATION OF PROPOSED BASIN EXPAN
DRAWING REFERENCE:
TITLE: CONSTRUCTION ACCESS AND TEMPORARY FACILITIES PROJECT IV - BASIN EXPA
BY: GENERAL ELECTRIC
DRAWING NUMBER: C5A38E-9A5
DATED: MARCH 31, 1977
FEET
100 0 100 200

PLOT PLAN

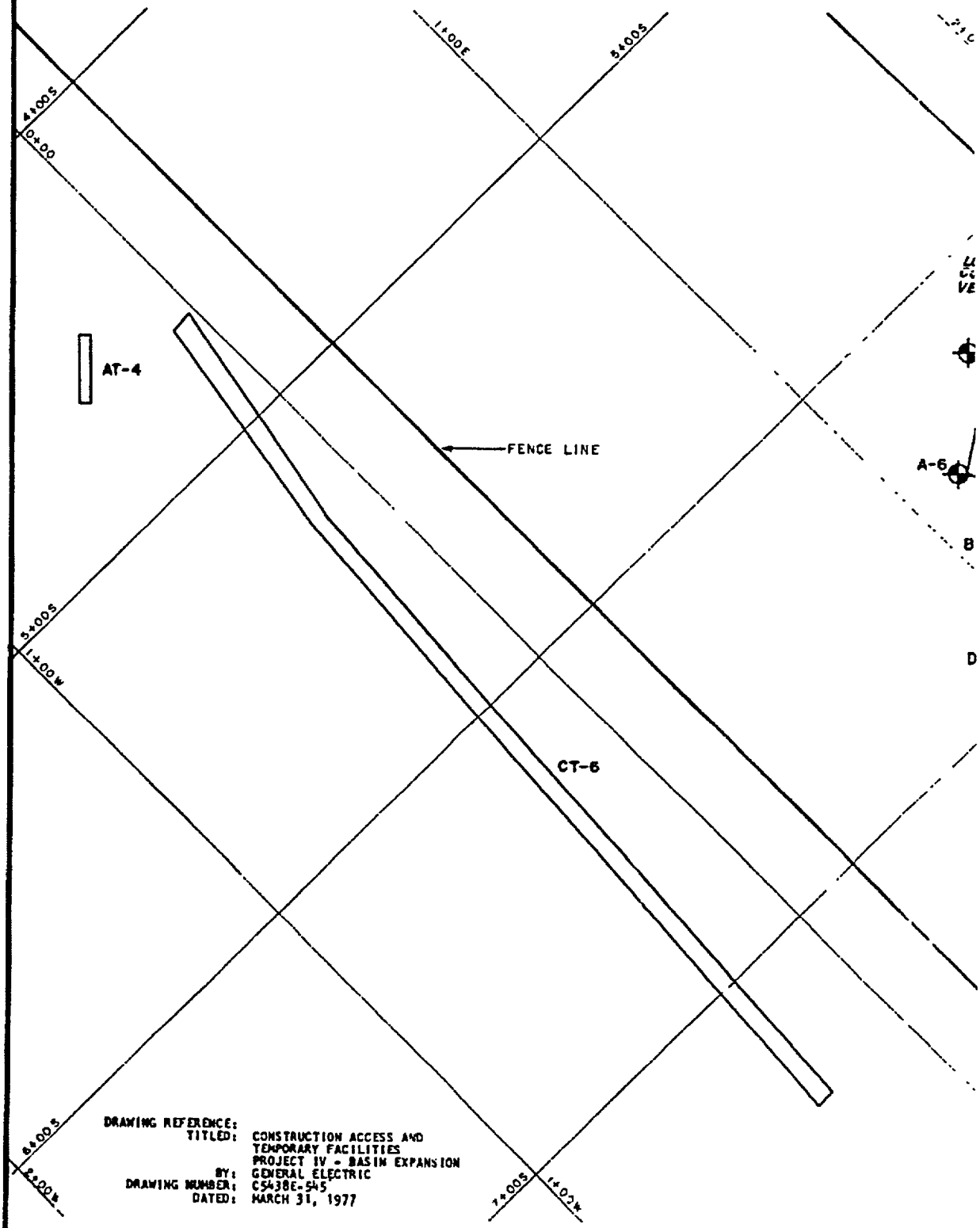
EXPLANATION:

- B-9 — LOCATION OF TEST BORINGS, DRILLED 1976; THIS INVESTIGATION
- D-3 — LOCATION OF GROUNDWATER OBSERVATION WELLS, DRILLED 1976; THIS INVESTIGATION
- A-1 — LOCATION OF TEST BORINGS FROM DAMES & MOORE REPORT DATED OCTOBER 1, 1974
- 5 — LOCATION OF TEST BORINGS FROM DAMES & MOORE REPORT DATED DECEMBER 13, 1967
- AT-1 — LOCATION OF TRENCHES FROM DAMES & MOORE REPORT DATED OCTOBER 1, 1974
- BT-1 — LOCATION OF TRENCHES, EXCAVATED 1976; THIS INVESTIGATION
- CT-1 — LOCATION OF TRENCHES, EXCAVATED 1977; THIS INVESTIGATION

N

FEET 20 0 20

NOTE: SEE FIGURE 1A FOR GENERA
OF STUDY AREA.



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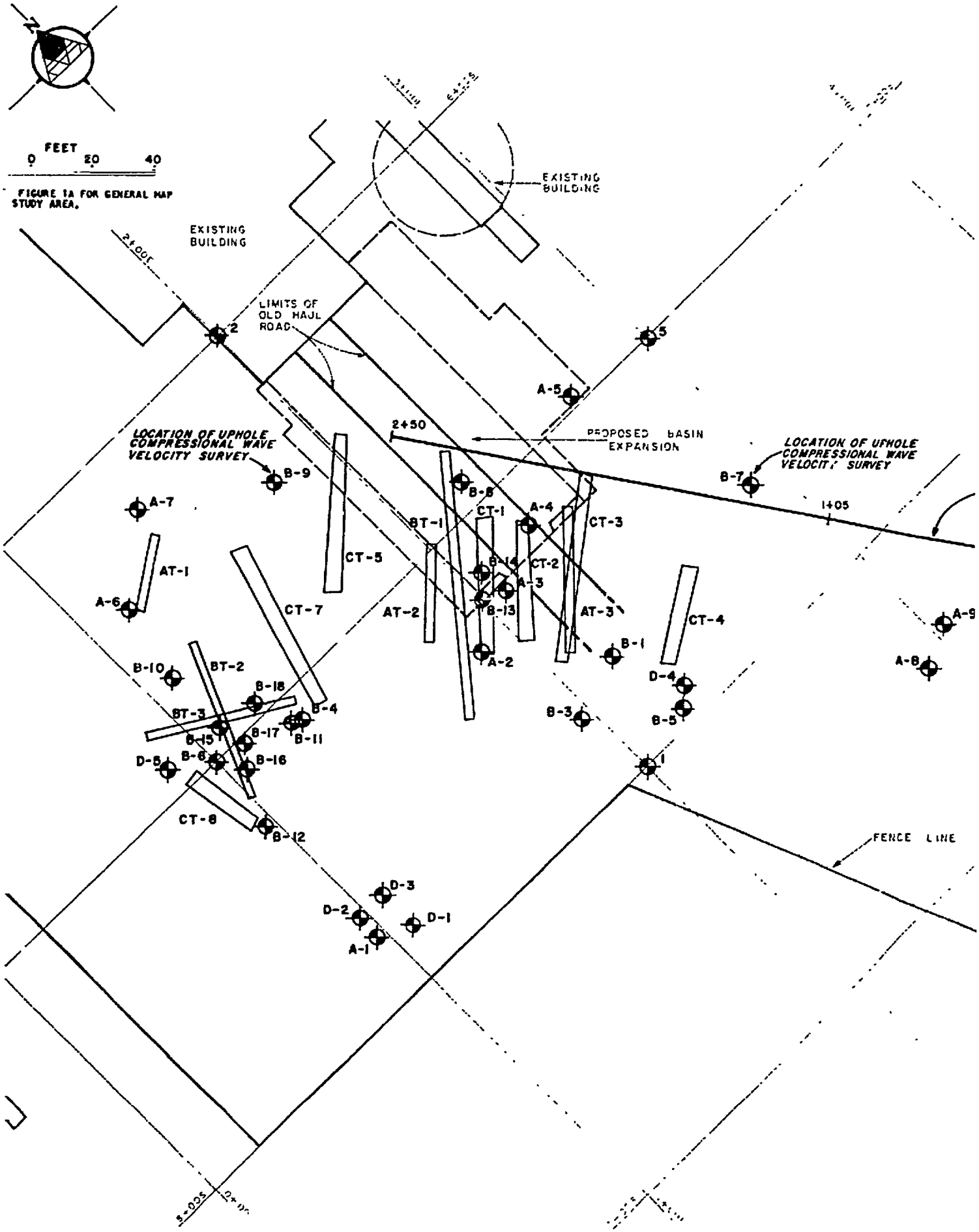
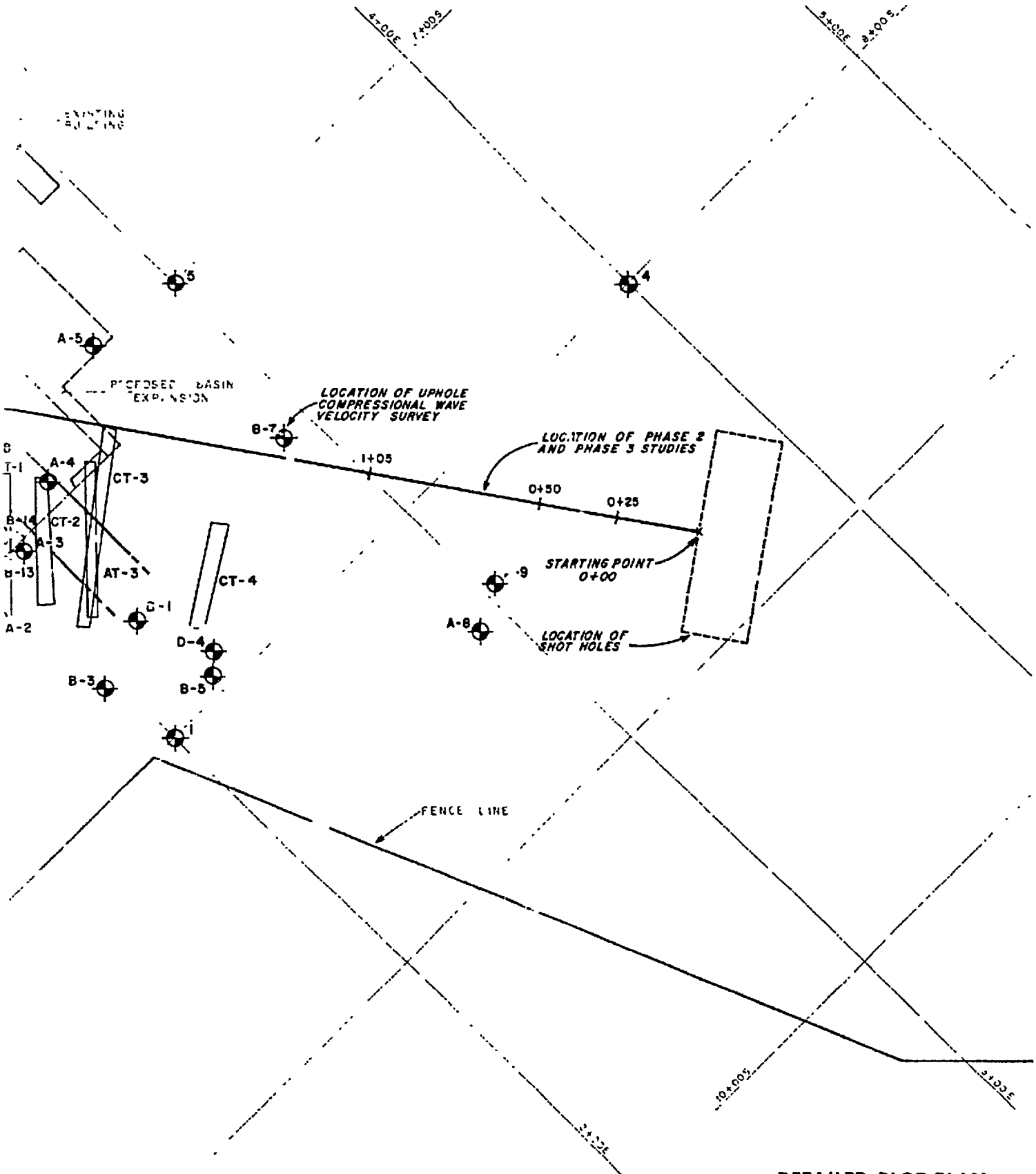
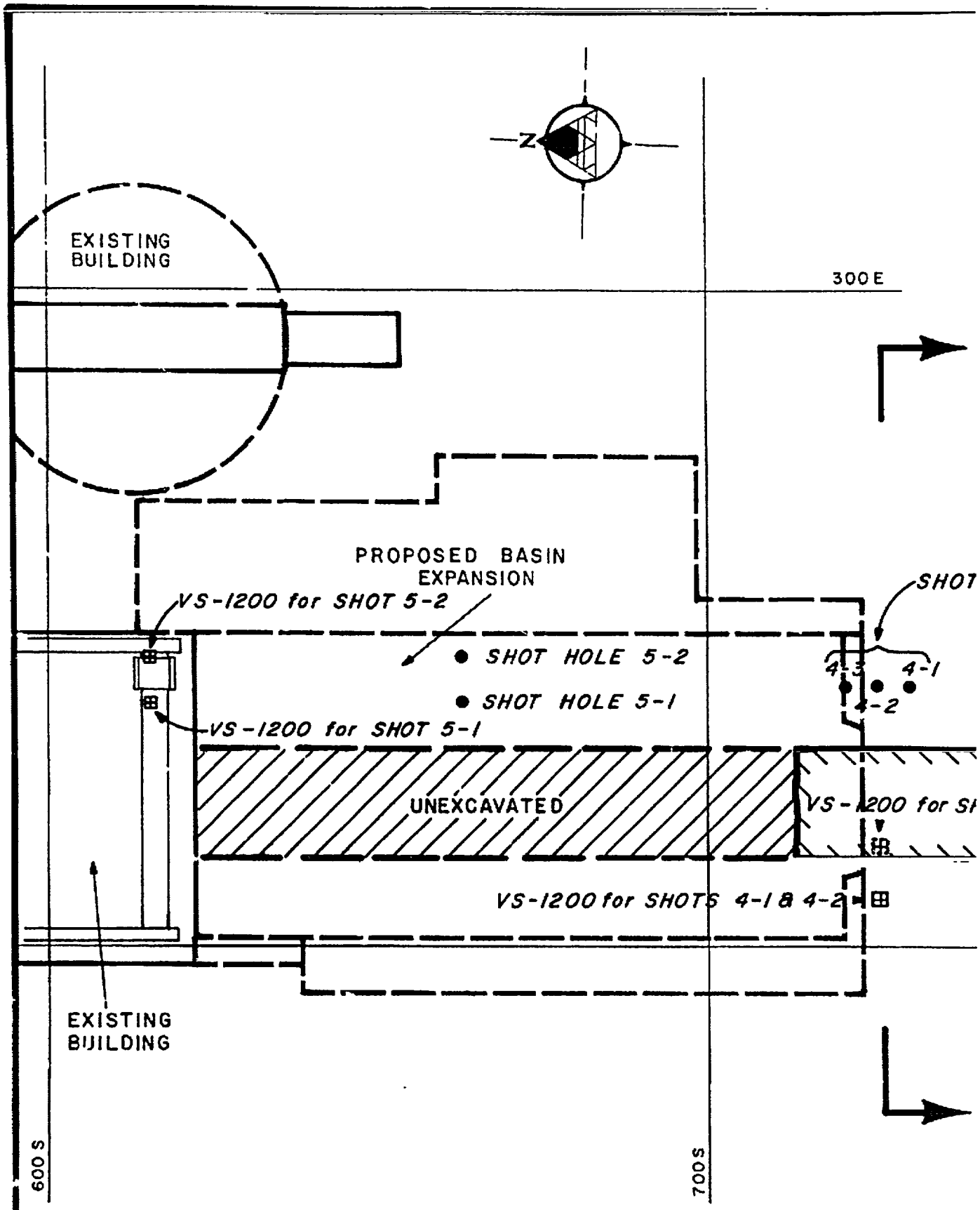

FEET
0 20 40
FIGURE 1A FOR GENERAL MAP STUDY AREA.
EXISTING BUILDING
EXISTING BUILDING
LIMITS OF OLD HAUL ROAD
LOCATION OF UPHOLE COMPRESSIONAL WAVE VELOCITY SURVEY
LOCATION OF UPHOLE COMPRESSIONAL WAVE VELOCITY SURVEY
PROPOSED BASIN EXPANSION
2+50
1+05
FENCE LINE
2
5
A-5
B-9
B-8
B-7
A-7
A-4
BT-1
CT-1
CT-3
CT-5
B-14
CT-2
A-3
AT-1
A-6
CT-7
AT-2
B-13
AT-3
CT-4
A-9
B-1
A-2
A-8
B-10
BT-2
B-18
D-4
BT-3
B-4
B-3
B-5
B-15
B-17
B-11
D-5
B-6
B-16
1
CT-8
B-12
D-3
D-2
D-1
A-1



DETAILED PLOT PLAN
PROPOSED BASIN EXPANSION A

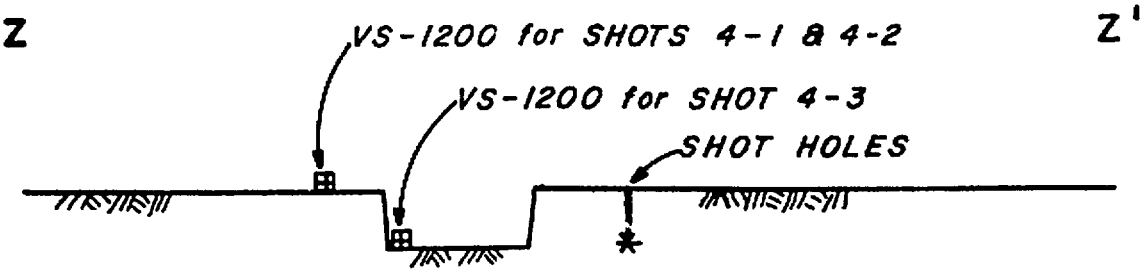
DAMES & MC

FIGURE 1



DRAWING REFERENCE:
TITLED: EXCAVATION PLAN
PROJECT IV - BASIN EXPANSION
BY: GENERAL ELECTRIC
DRAWING NUMBER: C 5438E-543 (PRELIMINARY)
DATED: MARCH 31, 1977

1674-099-07



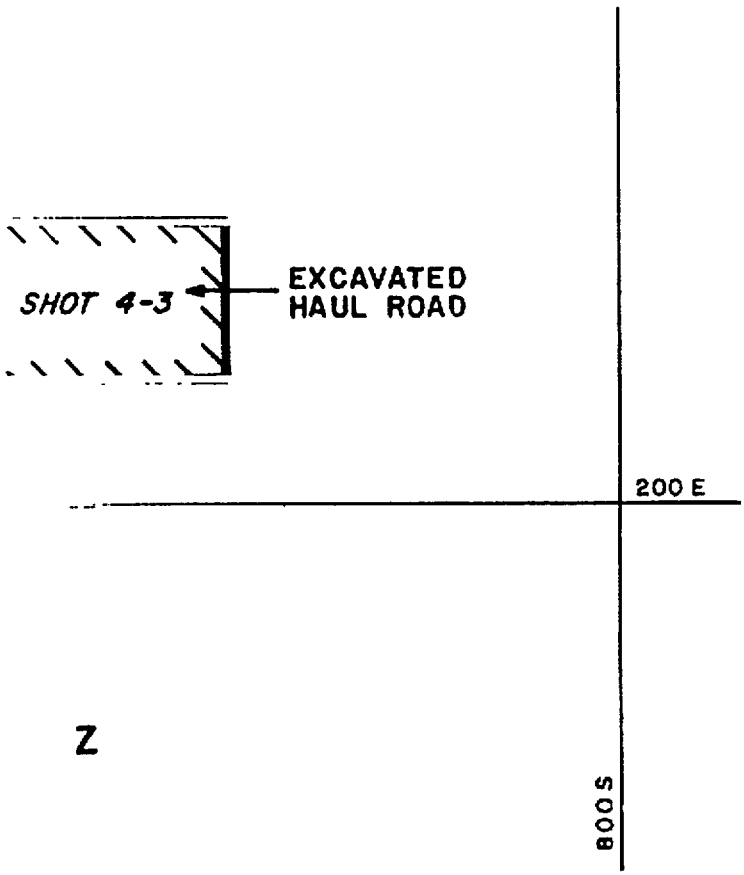
Z'

SECTION Z-Z'

FEET

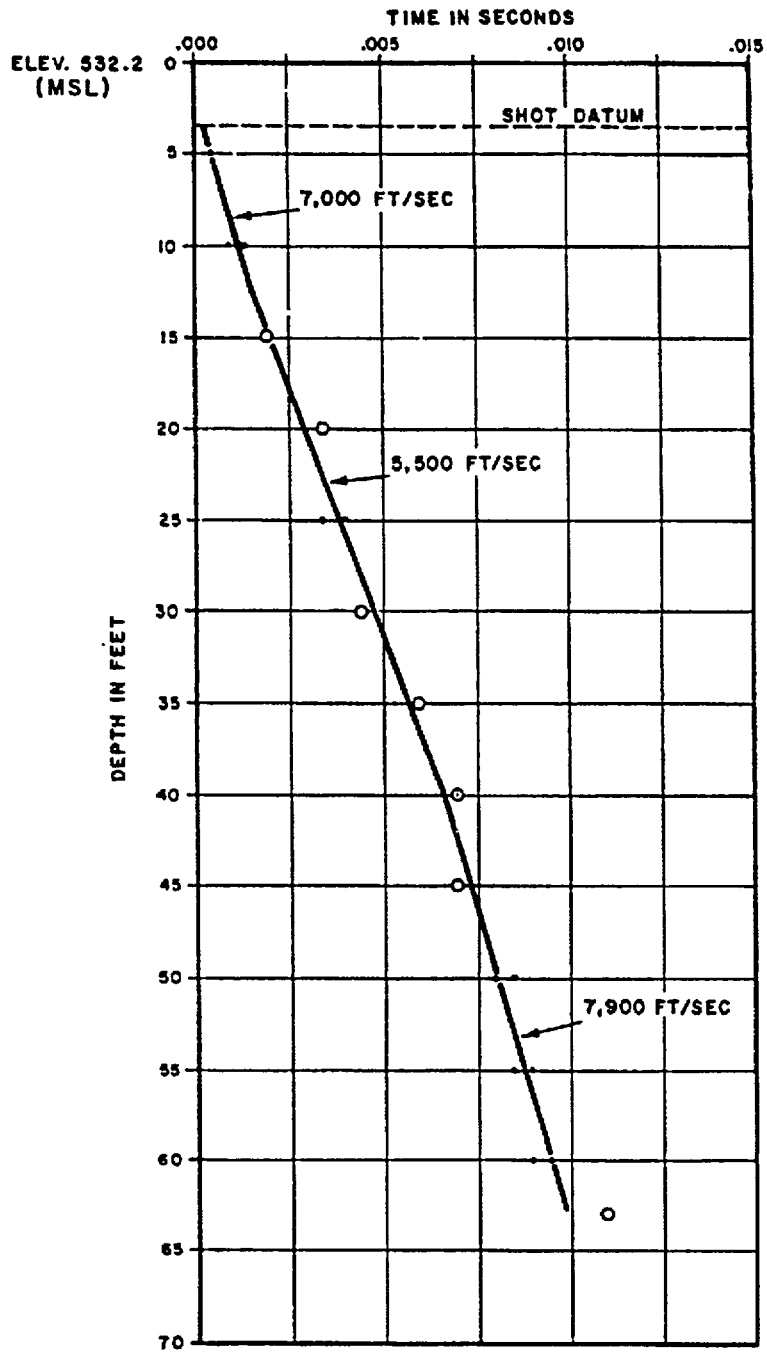
20 0 20

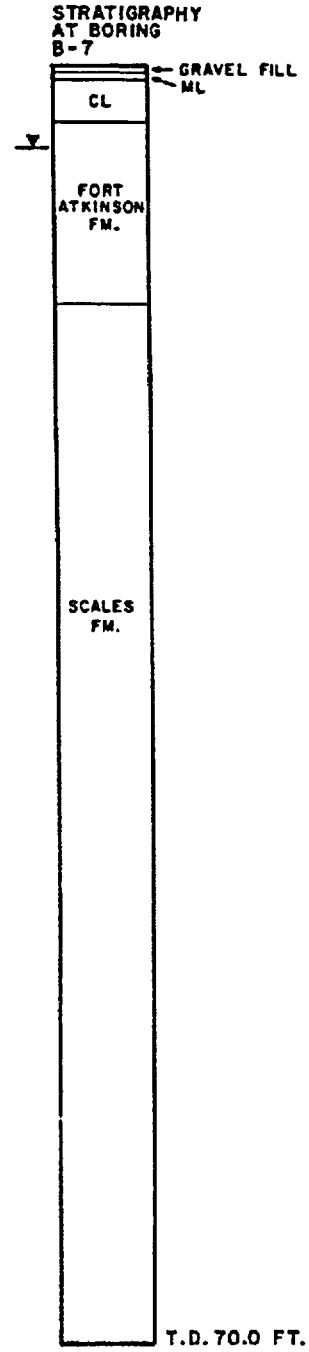
'OT HOLES



LOCATION OF PHASE 4 AND PHASE 5

DAMES





NOTE:

SLEDGE HAMMER USED FOR ENERGY GENERATION.

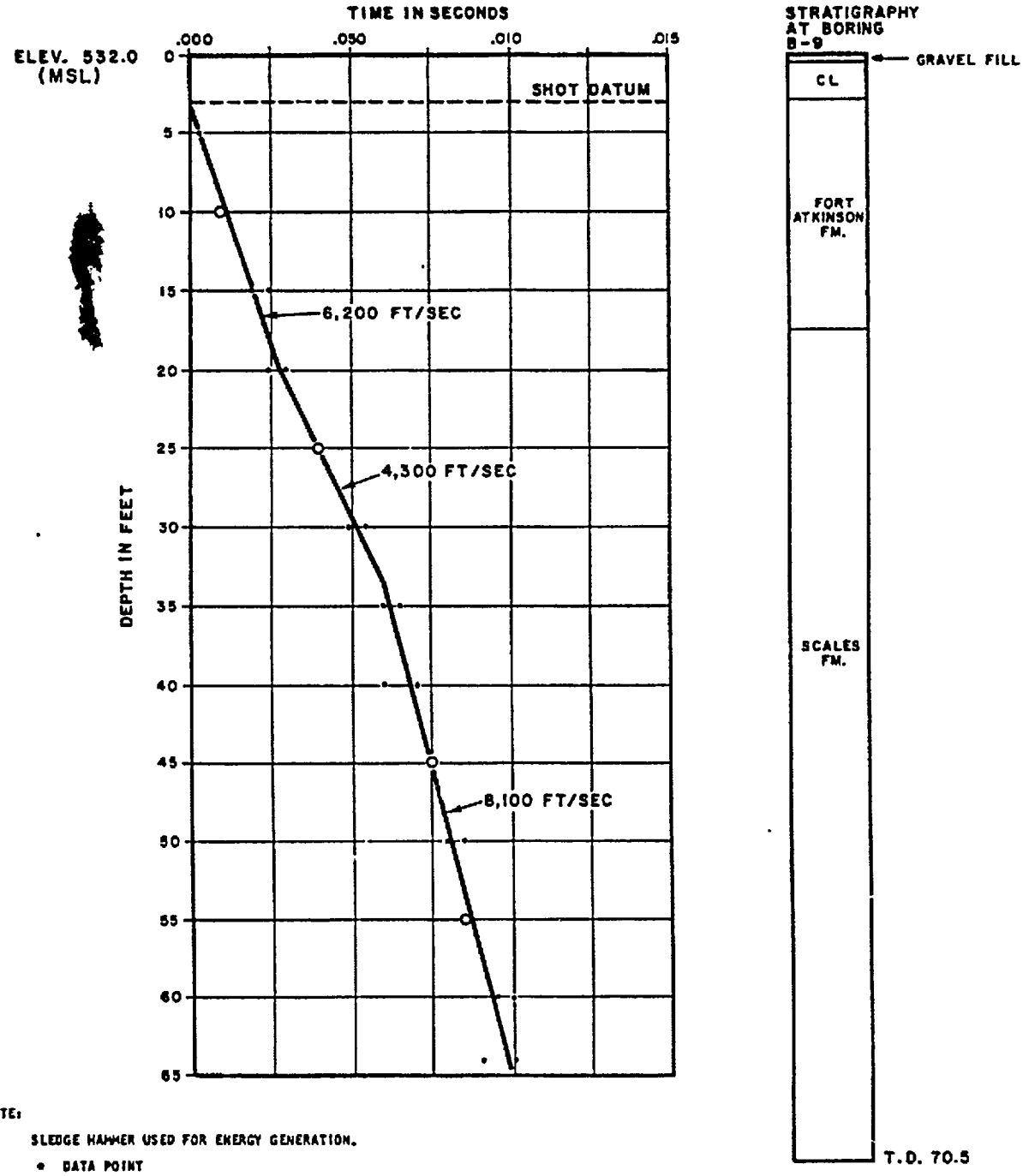
• DATA POINT

O COINCIDENT DATA POINTS

UPHOLE COMPRESSIONAL WAVE VELOCITY SURVEY BORING B-7

DAMES & MOORE

1674-099-07



NOTE:

SLEDGE HAMMER USED FOR ENERGY GENERATION.

• DATA POINT

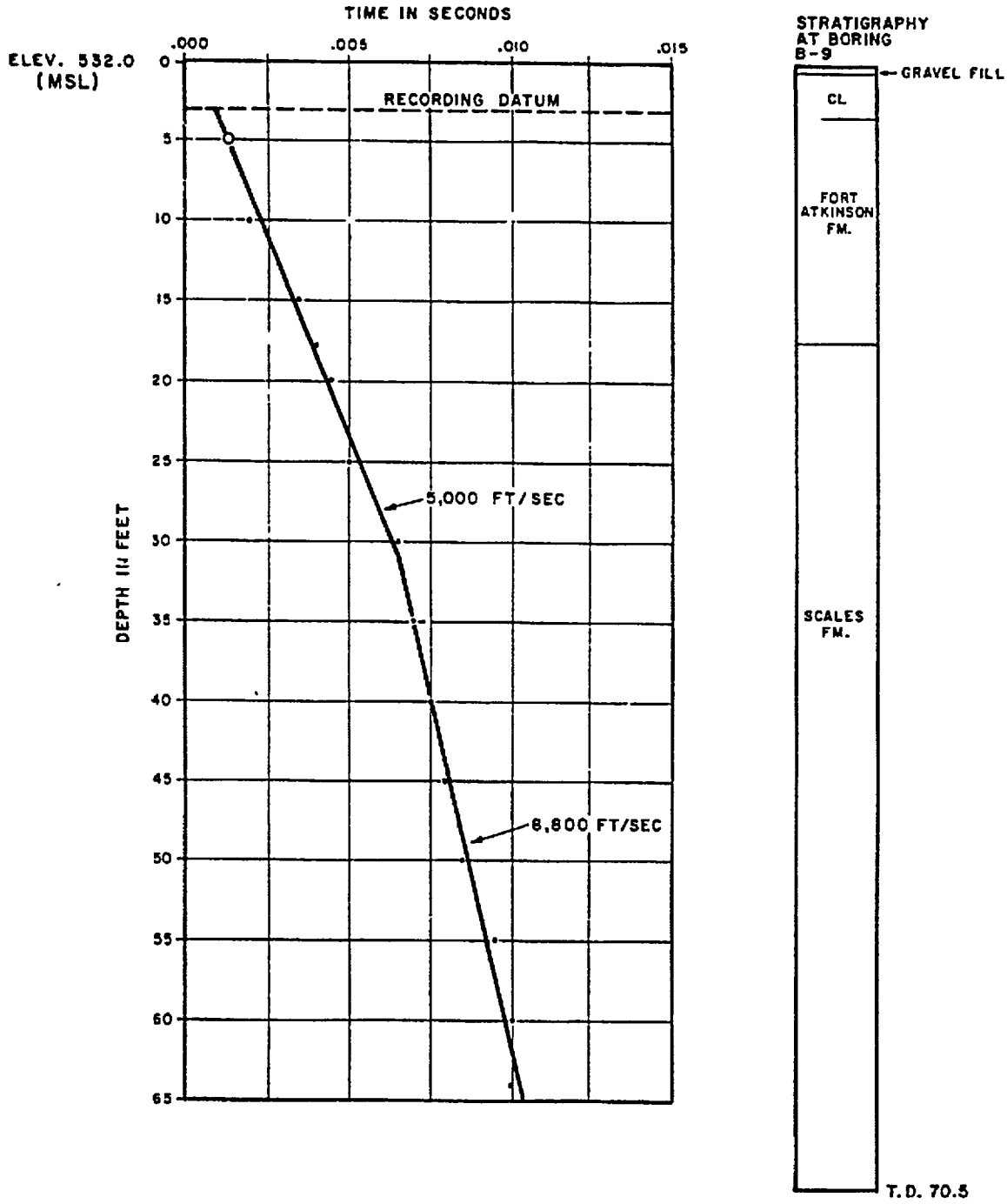
O COINCIDENT DATA POINTS

1674-099-07

UPHOLE COMPRESSIONAL WAVE
VELOCITY SURVEY
BORING B-9

DAMES & MOORE

FIGURE 3



NOTE:

ELECTRIC BLASTING CAP USED FOR ENERGY GENERATION.

• DATA POINT

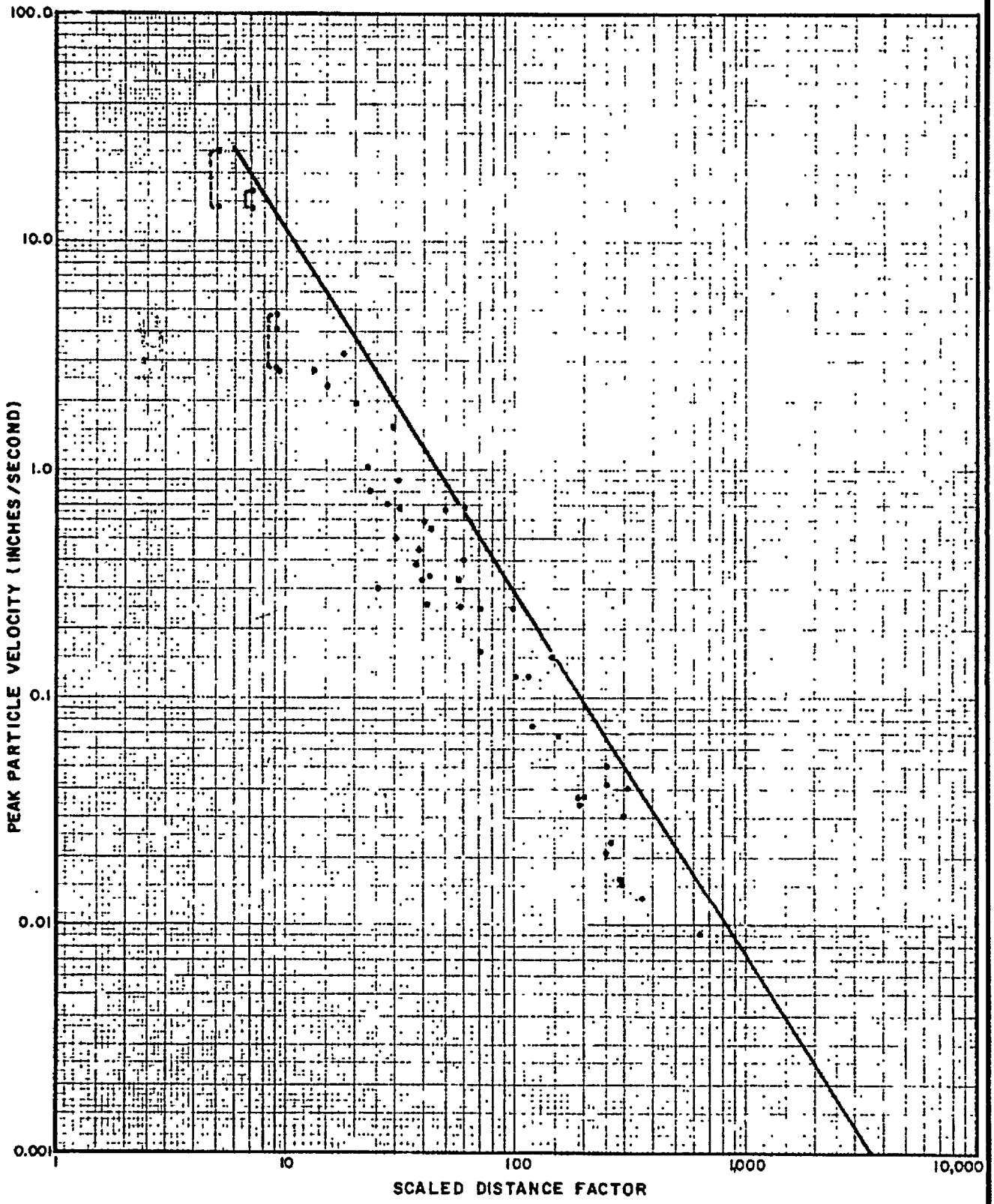
O COINCIDENT DATA POINTS

UPHOLE COMPRESSIONAL WAVE
VELOCITY SURVEY
BORING B-9

DAMES & MOORE

FIGURE 4

1674-099-07



$$\text{SCALED DISTANCE FACTOR} = \text{SDF} = \frac{\text{DISTANCE (FT.)}}{\sqrt{\text{MAXIMUM CHARGE / DELAY (LBS.)}}}$$

EXPLANATION:

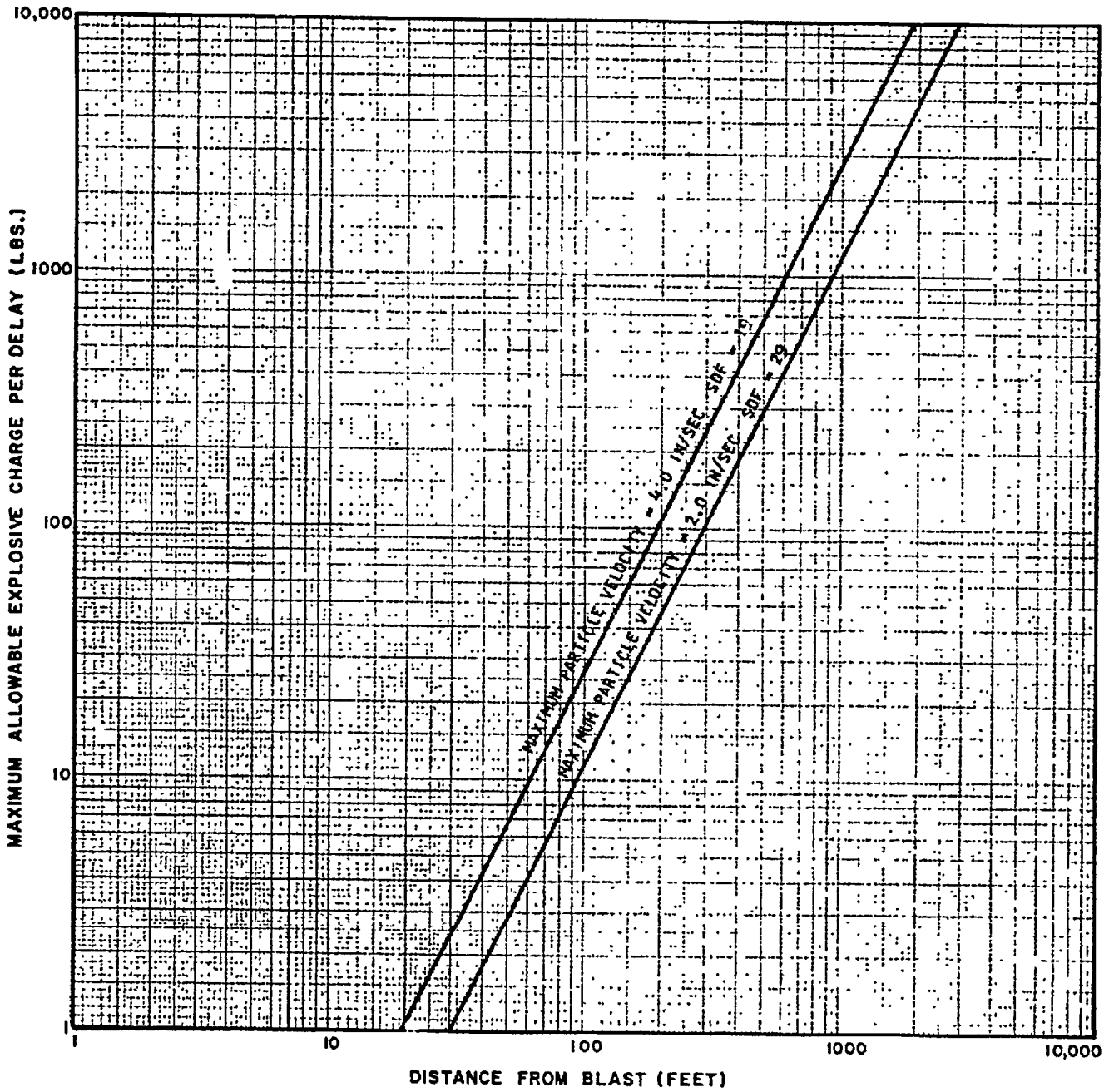
- • DATA POINTS
- ESTIMATED RANGE FROM RECORDS IN WHICH TRACE WENT OFF RECORD

PARTICLE VELOCITY ATTENUATION CURVE

DAMES & MOORE

FIGURE 5

1674-099-07

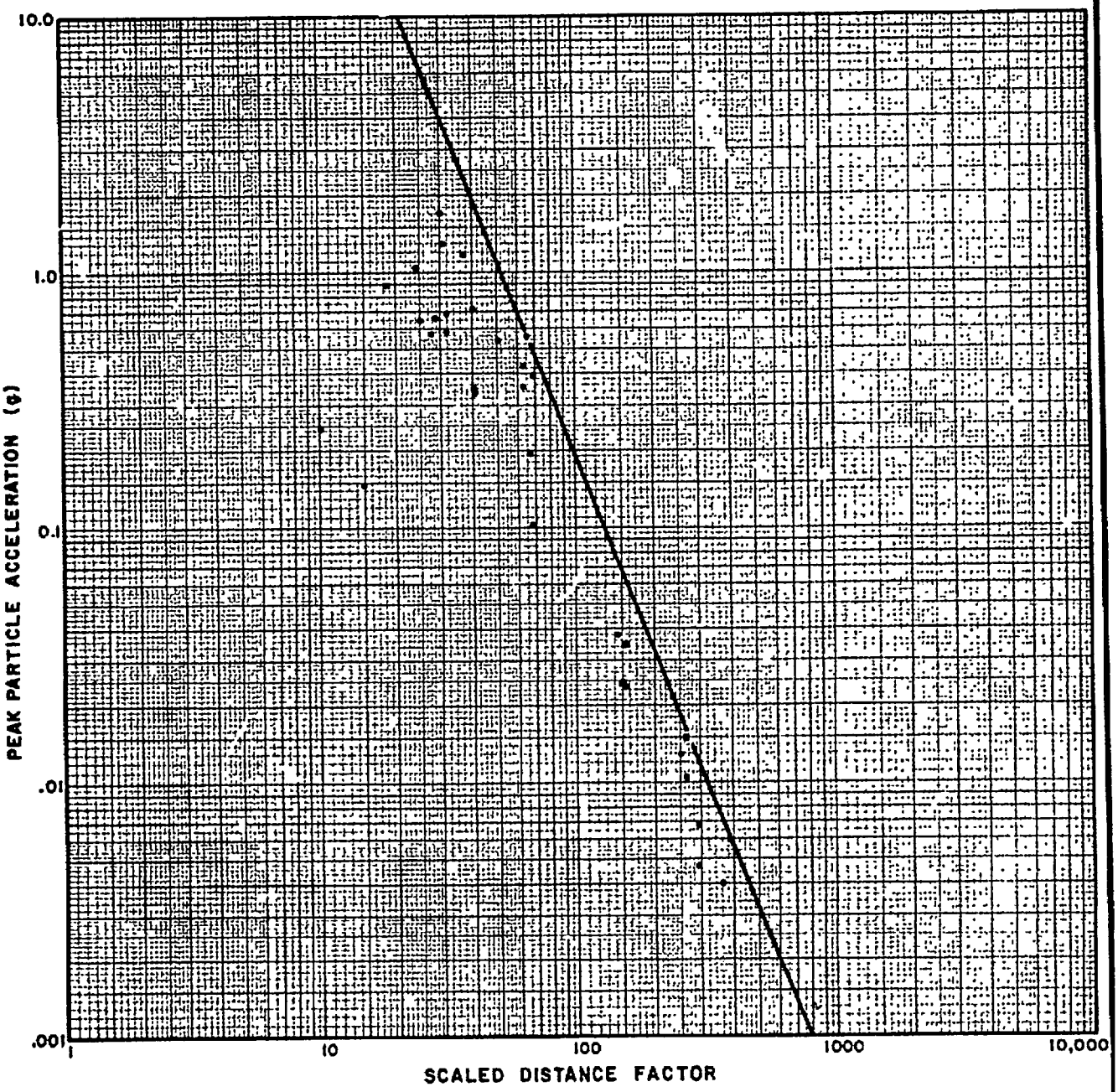


1674-099-07

MAXIMUM CHARGE SIZE PER DELAY VS DISTANCE

DAMES & MOORE

FIGURE 6



$$\text{SCALED DISTANCE FACTOR} = \text{SDF} = \frac{\text{DISTANCE (FT.)}}{\sqrt{\text{MAXIMUM CHARGE / DELAY (LBS.)}}}$$

1874-099-07

EXPLANATION:

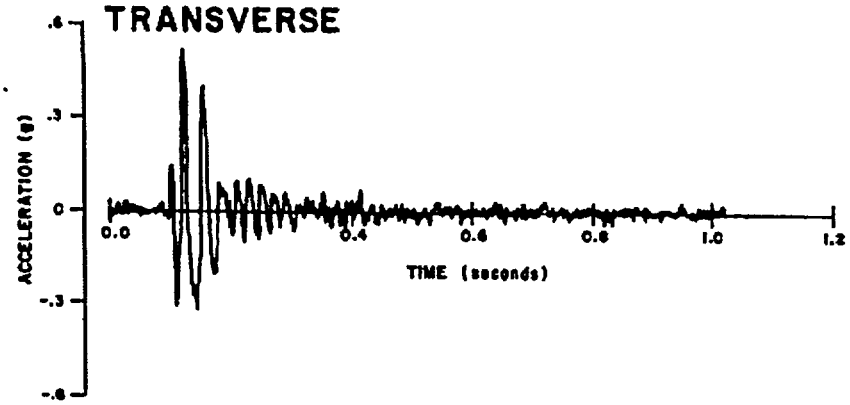
• DATA POINTS

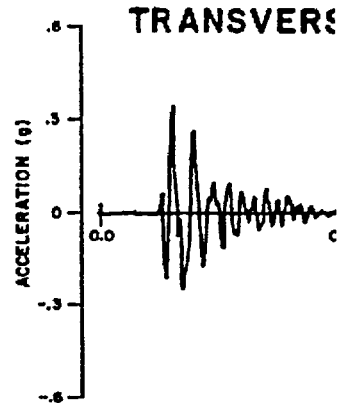
PARTICLE ACCELERATION ATTENUATION CURVE

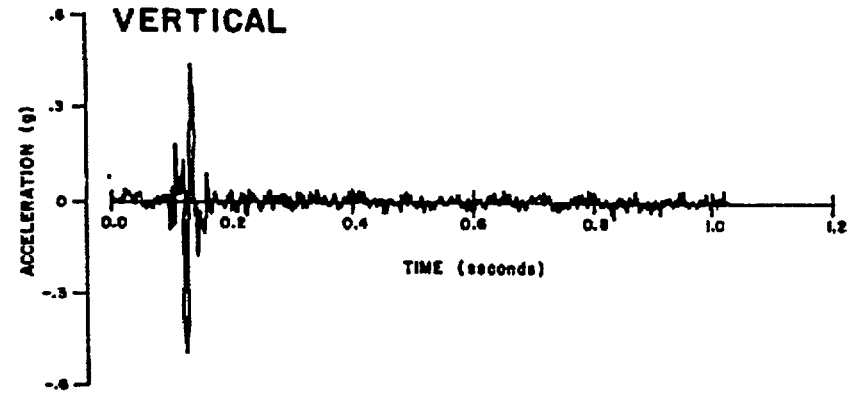
DAMES & MOORE

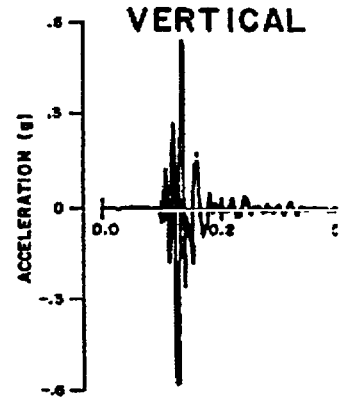
FIGURE 7

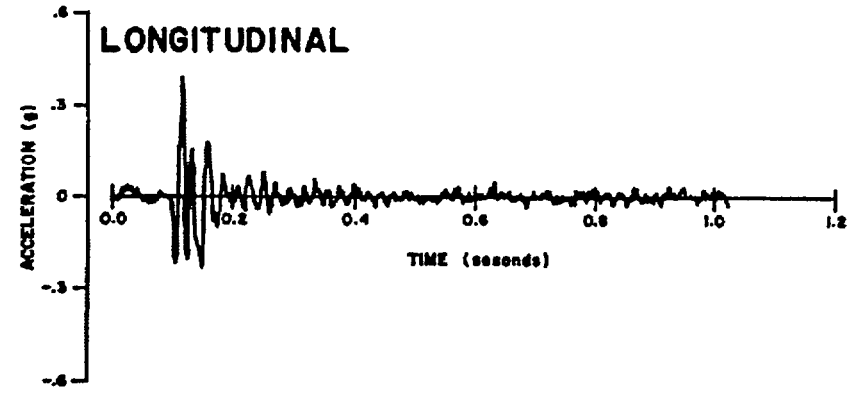
CASE I
(SHOT 4-I)

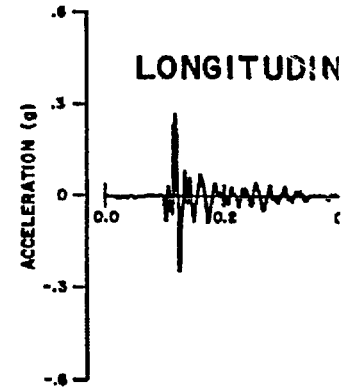












VECTOR SUM: .684 g

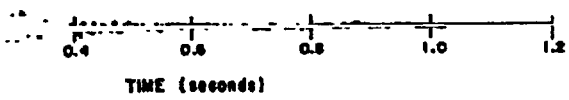
VECTOR SUM:

1674-099-07

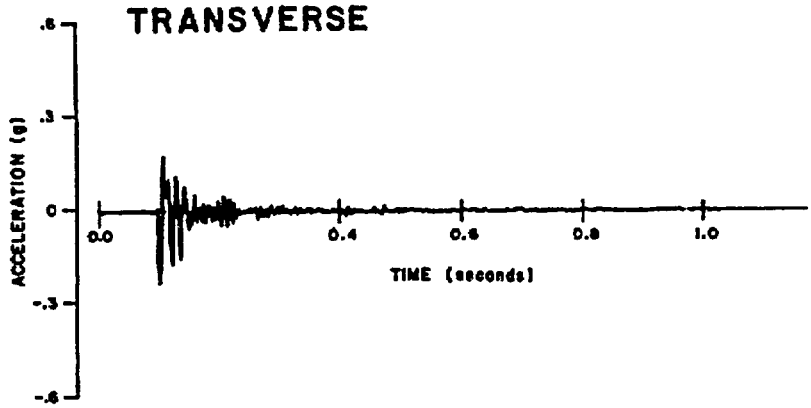
CASE 2
(SHOT 4-2)

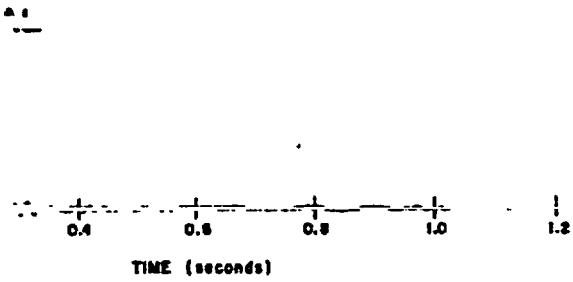
CASE 3
(SHOT 4-3)

ERSE

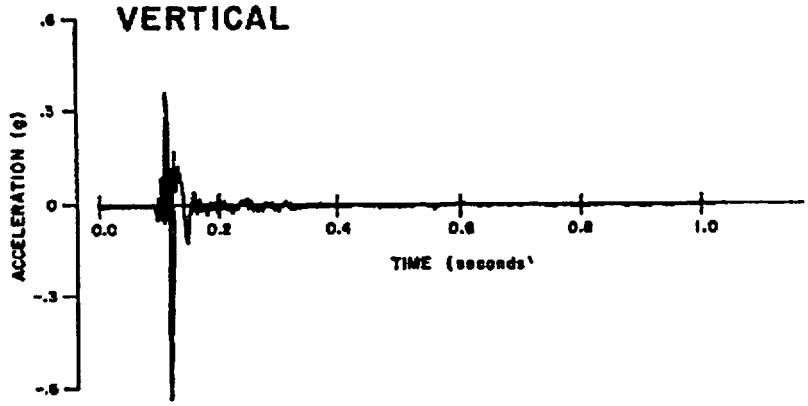


TRANSVERSE

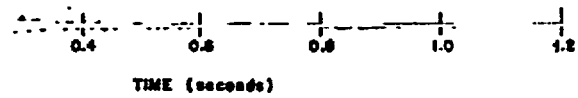




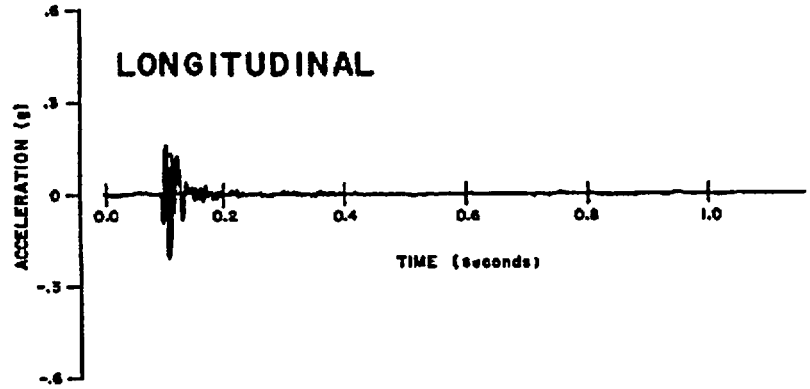
VERTICAL



IDINAL



LONGITUDINAL



.587 g

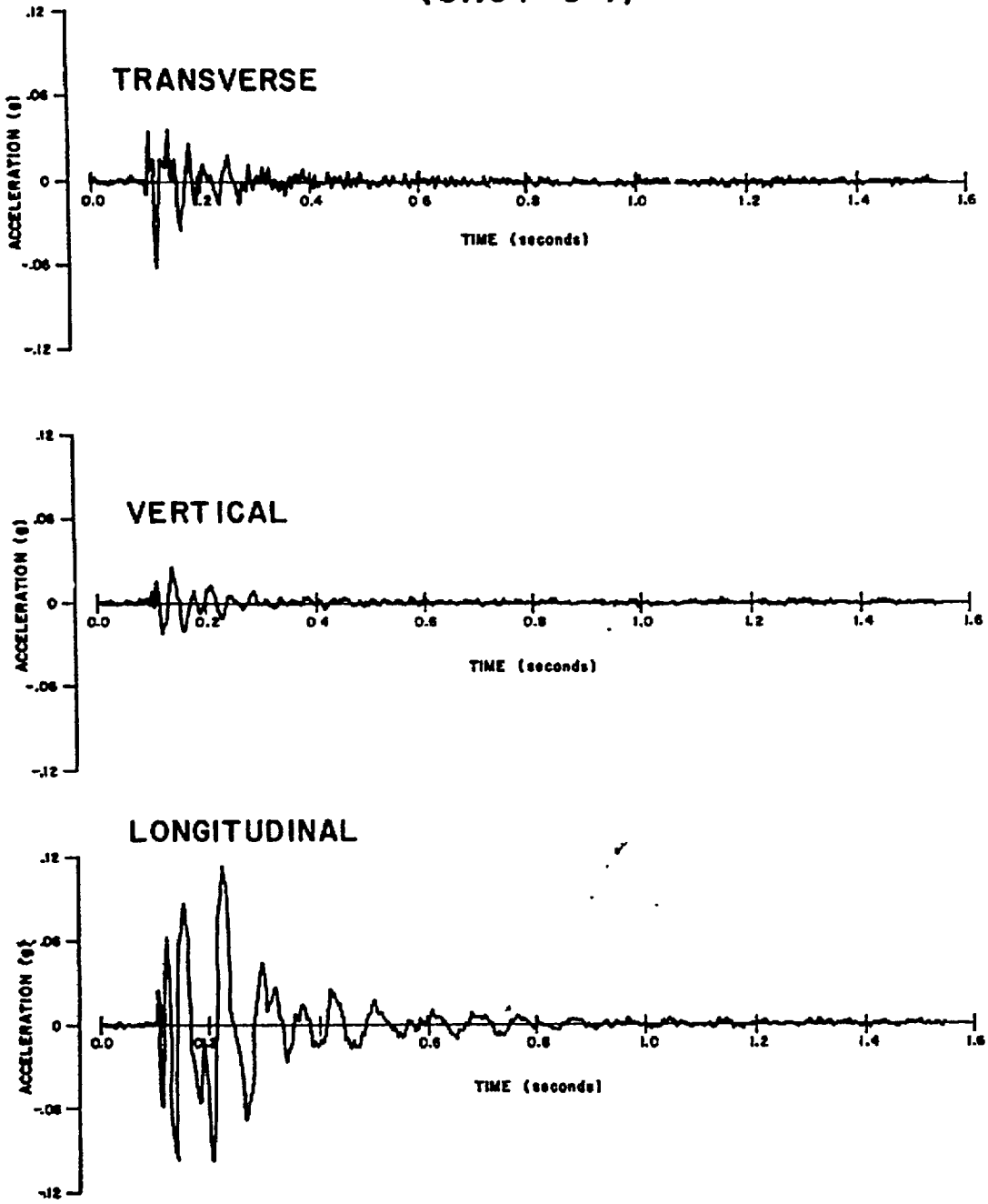
VECTOR SUM: .572 g

BLAST RECORDS PHASE 4

FIGURE

WEST SIDE OF GATE

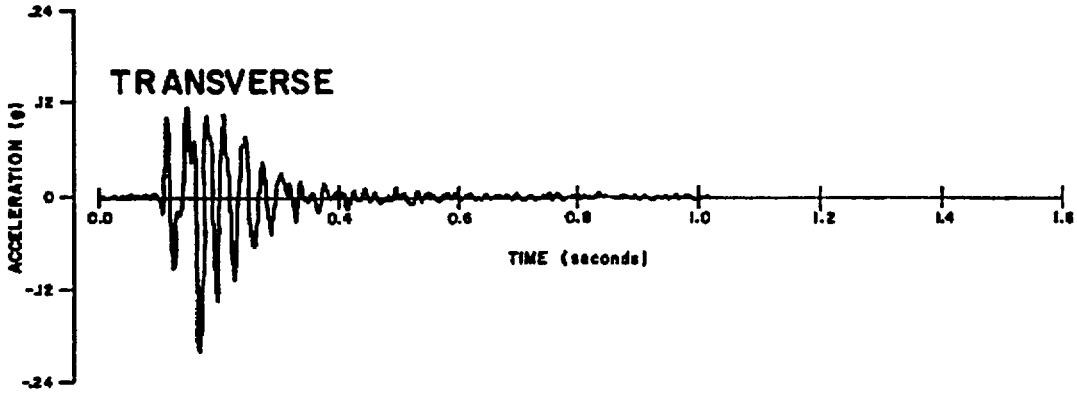
(SHOT 5-1)

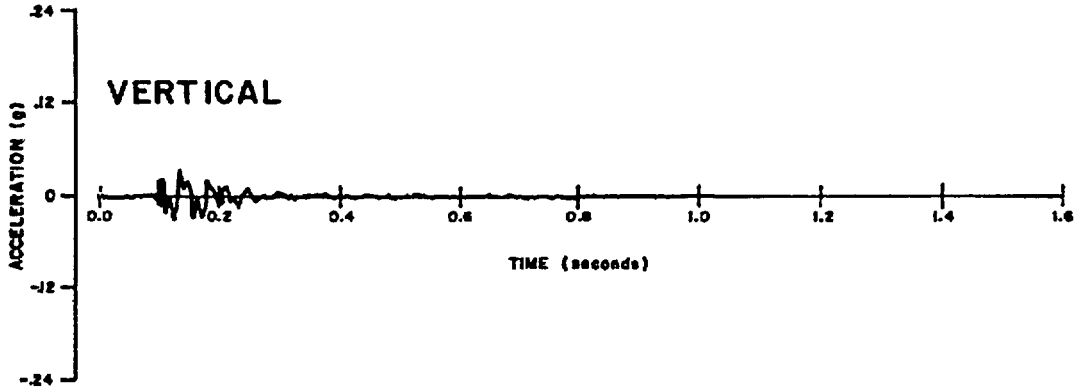


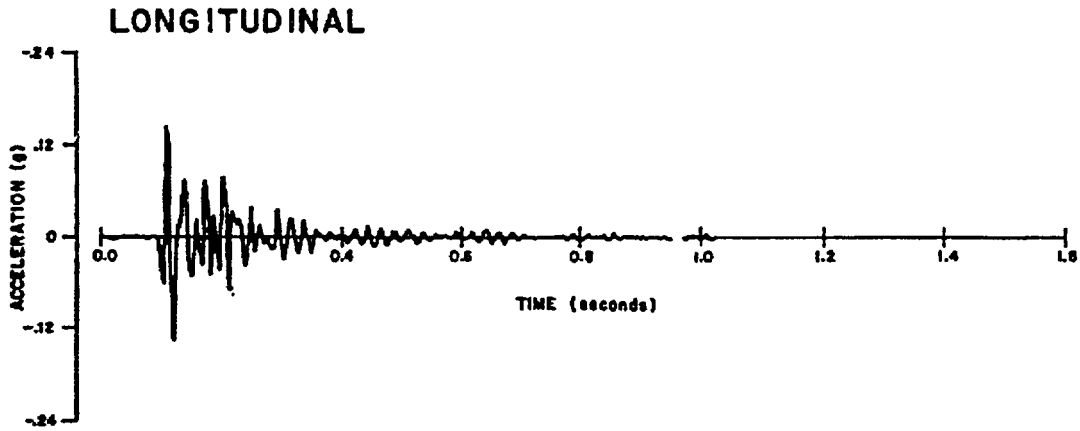
VECTOR SUM = .106 g

1674-069-07

EAST SIDE OF GATE
(SHOT 5-2)







VECTOR SUM: .194g

END

DAMES & MOORE

Copies to
EAG
DMD
WRK
G Kingle

May 12, 1977

General Electric Company
Nuclear Energ Division
175 Cutner Avenue
San Jose, California 95125

Attention: Mr. F. H. Shadel

Gentlemen:

Re: Purchase Order No. 529-J1T-99X, Rev. 2
Evaluation of Foundation Recommendations
Project IV - Fuel Storage Capacity Expansion
Near Morris, Illinois
General Electric Company

In 1967, Dames & Moore submitted a report to General Electric entitled "Report of Foundation Investigation, Proposed FPO Plant Project", near Morris, Grundy County, Illinois. This report contained foundation recommendations based on the data which was then available for the site. Since 1967, several additional geotechnical investigations have been conducted at the site. It was the purpose of this investigation to review the data presented in the 1967 report to determine its applicability to the proposed project IV Expansion and to make the required changes in recommendations based on data which has become available since our submittal of the 1967 report. Based on analysis of all work which has been performed to date, the enclosed table has been prepared that summarizes our recommendations. It is anticipated that settlement from the imposed foundation loads will be negligable.

If there are any questions regarding this information, please contact us.

Very truly yours,

DAMES & MOORE

Michael L. Kiefer
Michael L. Kiefer
Partner

RECEIVED
MAY 1 1 1977
F. H. SHADEL

MLK:pb
Enclosure

Three copies submitted

RECOMMENDED DESIGN PARAMETERS
FUEL STORAGE CAPACITY EXPANSION
GENERAL ELECTRIC COMPANY

	Fort Atkinson Limestone	Scales Shale (above plant grade elevation 13)	Scales Shale (below plant grade elevation 13)
Dynamic Modulus of Elasticity (PSI)*	$5.5\text{-}11.0 \times 10^5$	$2.0\text{-}3.4 \times 10^5$	11.0×10^5
Dynamic Modulus of Rigidity (PSI)*	$2.0\text{-}4.0 \times 10^5$	$0.7\text{-}1.2 \times 10^5$	4.0×10^5
Poisson Ratio **	.35	.43	.35
Allowable Bearing Pressure (PSF)***	10,000	10,000	70,000
Allowable Passive Resistance (PSF)***	2000	2000	10000
Coefficient of Friction	.25	.25	.25

* Static elastic properties may be taken as 40% of the dynamic values.

** Estimated value.

*** These values include a factor of safety against failure of the rock in excess of three.

Dames & Moore
May 12, 1977