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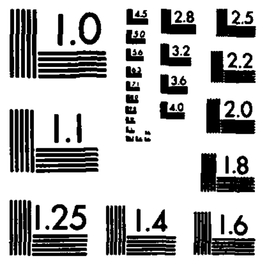
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This report is a reevaluation of the Stability of the existing Onondaga Dam which is located near the city of Syracuse, NY. This is an earth and rockfill dam and provides flood protection for the city of Syracuse which is downstream of the dam. This evaluation includes a seismic evaluation (Attachment 2) and a stability analysis based upon current Corps criteria. This document contains a Main Report, six appendices (A-F), and two attachments. The Main Report contains the local and regional geology at the project site and summarizes the results of the stability analysis. Appendix A contains pertinent data (Cont'd)

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about Onondaga Dam. Appendix B contains the rationale for the selected soil parameters used in the analysis. Appendix C contains hand calculations of the critical slip surfaces. Appendix D contains the computer input files and sampl output for the slip circle analysis. Appendix E contains the wave runup analys for the storage pool. Appendix F contains the slope protection calculations. Attachment No. 1 is the Concrete Spillway Stability analysis and Attachment No. 2 is the seismic evaluation.

ONONDAGA DAM, NY

REPORT ON SEISMIC STABILITY
ONONDAGA DAM, NY
ATTACHMENT NO. 2

U.S. Army Corps of Engineers, Buffalo District
1776 Niagara Street
Buffalo, NY

PREFACE

This study was conducted by H & A of New York and was authorized by the Department of the Army, Buffalo District, Corps of Engineers under Contract No. DACW 49-81-D-0011, Work Orders No. 2 and No. 3, dated October 13, 1981 and June 15, 1982, respectively.

The work was accomplished and the report written by Thomas X. Grasso, Staff Geologist, with assistance on seismologic evaluations provided by Dr. Edward F. Chiburis, Consultant, and Dr. Edward B. Kinner of Haley & Aldrich, Inc. All work was performed under the general technical supervision of Joseph J. Rixner, Manager of H & A of New York.

This work order was performed under the technical administration of the Buffalo District, Corps of Engineers, Geotechnical Section.

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GEOLOGICAL AND SEISMOLOGICAL INVESTIGATIONS AT ONONDAGA DAM, NEW YORK

PART I: INTRODUCTION

Purpose and Scope

1. The purpose of this study was to investigate and evaluate the potential earthquake hazard at Onondaga Dam located in Central New York. This study was conducted in compliance with ER1110-2-1806 "Earthquake Design and Analysis for Corps of Engineers Dams" (by the Office of the Chief of Engineers, dated April 1977).

2. The study included geological, seismological, and subsurface investigations, and geotechnical engineering analyses. The study consisted of the following elements:

- a. an evaluation of the regional and local geology,
- b. performance of subsurface explorations and laboratory testing to further define the nature and density of soil deposits,
- c. an evaluation of the regional and local tectonic history with respect to structural deformation including faults,
- d. a review of historical regional seismicity,
- e. the determination of the maximum earthquake that will effect the site,
- f. an assessment of earthquake effects on Onondaga Dam, including an evaluation of liquefaction potential of the subsurface soils.

General Description of Onondaga Dam

3. Onondaga Dam is located on Onondaga Creek, a tributary to the Seneca River in Onondaga County, New York (Figure 1). It is about four miles southwest of the southern limits of the City of Syracuse, New York and about 3,000 feet south of N.Y. Route 80.

4. Onondaga Dam is a flood control structure consisting of a rolled earth fill embankment with a concrete overflow side channel spillway on the right (east) abutment. The overall length of the rolled fill embankment is 1,780 feet and the maximum height is 67 feet. An 1,100 ft. long spillway channel has been cut into rock along the right abutment. Rock cuts, ranging from about 15 to 40 ft. high, are exposed along the spillway channel.

5. The dam was completed in August 1949. It was designed and constructed by the Syracuse District of the U.S. Army Corps of Engineers.

PART II: GEOLOGY

Physiography

6. Figure 2 shows the physiographic provinces of New York State. Onondaga Dam is located in the northern part of the Allegheny (Appalachian) Plateau Physiographic Province. The physiographic province immediately north of the site is the Lake Plain Physiographic Province.

Lake Plain Province

7. Bordering Lakes Erie and Ontario is a region of low relief known as the Lake Plain Province. This plain is underlain by sedimentary rocks of Late Ordovician to Devonian age that dip gently southward at 30 to 50 feet per mile. Refer to Table I for a geologic time scale. This province is bordered on the South by the Appalachian Plateau with a more or less abrupt boundary.

8. Three escarpments or "cuestas" strike east-west across the Lake Ontario portion of the plain, especially west of Rochester to the Niagara Peninsula. They are, from north to south:

a. Medina Escarpment - Formed in the resistant Grimsby and Thorold Sandstones. This ridge is of minor topographic relief being only some 30 to 50 feet high. Wherever streams cross this feature, waterfalls result such as those at Medina, Albion and Holley. The escarpment cannot be recognized east of the Genesee River. The line of the Barge Canal rests atop this escarpment from Spencerport to Lockport.

b. Lockport or Niagara Escarpment - This ridge is the most prominent bedrock controlled topographic feature on the Lake Ontario Plain. The Lockport Dolostone forms the caprock of this "mountain ridge", the crest of which lies about 300 feet above Lake Ontario. Niagara Falls, the Upper Falls of the Genesee at Rochester, and many other minor falls in between are also formed on the Lockport Dolostone.

c. Onondaga Escarpment - The southernmost escarpment is about 50 feet in height, trending eastward from Buffalo through Batavia to Auburn. This escarpment is formed of resistant Onondaga Limestone. A line of abandoned and existing quarries marks its trace across the state, along with relatively small waterfalls on the numerous streams that cross the escarpment.

9. The remainder of the Lake Plain is underlain predominantly by shales, with a few relatively thin sandstone and carbonate interbeds forming the prominent east-west escarpments described above.

10. In general, the rocks are structurally simple, dipping gently southward and forming the north-northwest flank of the Appalachian (Allegheny) Synclinorium or Basin. This singly-dipping, homoclinal structure is interrupted locally by a few faults and a few minor low, open folds. The most significant of these is the Clarendon-Linden Fault, which strikes southwestward from Lake Ontario across northwest Monroe County and southeast Orleans County, through Batavia in eastern Genesee County and to Attica in central Wyoming County. It is a nearly vertical fault system, downthrown to the west, cutting the Precambrian basement, and having a displacement ranging from about 30 to 90 meters (100 to 275 ft.), (Hutchinson, et al. 1979).

11. A local fault structure of perhaps significant proportions occurs in northern Cayuga County but mainly in the subsurface, although one or more of these faults are thought to have a surface expression. Not much is known about this structure at present. A new gas field, the Blue Tail Rooster, is producing from traps in this structure. A well-developed, nearly vertical joint system of two sets, one essentially north-south and the other east-west is the only major, regional, geologic structure. Locally, a third set of joints may be present in places.

12. The Paleozoic rocks of the Lake Plain are mantled by a substantial thickness of glacial deposits. The most dramatic of these is the drumlin field of glacial till lying between Rochester and Syracuse. Several morainal deposits and glacial lake shoreline deposits, such as the offshore bar of Lake Iroquois are also present. Ridge Road (Rt. 104) runs along this bar.

Allegheney (Appalachian) Plateau

13. The Allegheny Plateau covers nearly a third of the entire State, as shown on Figure 2, and is its largest physiographic province. It is a region of moderate to high relief with summits at Elevations 2000 to 4000 feet above sea level. The Catskill Mountains make up the eastern portion of the plateau while the remainder is often referred to as the Southern Tier. The entire region is underlain by Devonian shales, siltstones, and sandstones. However, the tops of the hills, south of Olean, expose sandstones and conglomerates of Mississippian and Pennsylvanian age (Figure 2 and Table 1). The eastern border of this province is the Catskill Front, an escarpment composed of Middle Devonian, massive, red sandstone of the Catskill Delta. The entire Catskill region is held up by these coarse deltaic sandstones. The Helderberg Escarpment of Lower Devonian Limestones stretches from the Albany area westward to Syracuse forming the northern and eastern boundary. West of Syracuse, in the Finger Lakes and Genesee region, the boundary with the Lake Plain province is not abrupt, but more gradual, occurring in the northern portion of the Finger Lakes across the Middle Devonian Hamilton Group. In western New York and southeast of Lake Erie, the Portage Escarpment of Upper Devonian siltstones and sandstones forms the western border.

14. The strata of the Allegheney Plateau dip gently southward at about 50 to 80 feet per mile. In south central New York, gentle warping of the Devonian rocks occurred and produced several gentle open folds along with minor faulting. Deep wells and geophysical seismic surveys, penetrating through the Upper Silurian in this region, do not reveal

the large surface anticlines at depth. This suggests that the Upper Silurian salt beds may have "absorbed" the deformation. Aside from the Clarendon-Linden structure, no major faults are known in the Allegheny Plateau. A few small reverse faults of minor displacement are known in central New York, one in particular being the Portland Point Fault north of Ithaca along Cayuga Lake. Several thin, ultrabasic, peridotite dikes are known in central New York near Ithaca and Syracuse. These dikes have migrated upward along joint planes, are of Mesozoic age, and are of limited extent. The joint system is extremely regular, especially in Central New York, and comprises a north-south set and an east-west set. A third set is well developed only in the southwestern part of the province. Most of the streams in the bedrock gorges are controlled by the north-south and east-west joints.

15. Glacial deposits are relatively thin on the upland portions of this province, but the north-south valleys are normally deep U-shaped glacial troughs that are partially filled by thick moraine, lacustrine, and glacial outwash deposits. Some of the glacial troughs are plugged at both ends, thereby forming Finger Lakes, while other valleys have subsequently drained. A major east-west trending divide in drainage between the north flowing St. Lawrence and the south flowing Susquehanna systems occurs along the Valley Heads Moraine, which loops across the province at the southern extremities of the Finger Lakes and neighboring valleys.

16. In the Onondaga (Tully) Valley, the Tully Moraine, south of the site and west of the Village of Tully, is the local development of the Valley Heads Moraine. Onondaga Creek flows north off the moraine toward Lake Ontario and the Tioughnioga River flows south through Cortland to the Susquehanna River.

Drainage

17. The major drainage system through the site is Onondaga Creek, consisting of two branches; the west branch rising in the vicinity of Cedarville Village and the main branch rising at the Tully Moraine. Both branches join just south of the Onondaga Dam (Figures 3 and 4) and flow north past the dam into Onondaga Lake, a tributary of the Seneca River and part of the St. Lawrence System.

18. Onondaga Creek occupies a deep U-shaped glaciated valley that once impounded a finger lake in the waning stages of glaciation. Therefore the valley contains glaciofluvial sand and gravel as terraces on both sides probably representing hanging deltas. Lacustrine deposits floor the valley in the vicinity of the site and probably underlie the sands and gravels of the hanging deltas.

19. The highest delta terrace is approximately at El. 800 feet, just southeast of Nichols Corners, while the lowest is approximately at El. 520 feet near Nedrow.

Central New York Stratigraphy

20. The rock formations of central New York are structurally simple and abundantly fossiliferous, thereby lending themselves to detailed stratigraphic studies over the last 100 years. The stratigraphic sequence dips gently southward at approximately 40 to 50 feet per mile such that the oldest units are exposed in the north and progressively younger formations are exposed southward.

21. Table II presents the generalized stratigraphic column for central New York. Figure 3 is a geologic map of the central New York region.

22. A brief description of the various rock formations in central New York is contained in the following paragraphs. A more detailed discussion of thicknesses, lithologies, and relationships of the various series, groups and formations noted on Table II is presented in Appendix A.

Upper Ordovician System

23. The oldest stratigraphic unit in central New York, exposed along the south shore of Lake Ontario, is the Queenston Formation. It encompasses a maximum of 700 feet of red, crumbly shale and red siltstone and sandstone in this region. The coarser beds increase in thickness eastward and southward.

Silurian System

24. Silurian rocks surround the Appalachian Plateau on the north and are found in the Lake Ontario Plain, and on the east in the westernmost Hudson Valley Province. The older units of the Silurian sequence consist of the Grimsby Sandstone and Clinton and Lockport Groups of the Albion and Niagaran Series. These units are overlain by shales, dolomites and limestones of the Cayugan Series.

Devonian System

25. Devonian rocks are by far the most extensively exposed in New York State. Devonian strata underlie all of the Allegheny Plateau and regions adjacent to it, such as the Lake Erie Plain, southern Lake Ontario Plain, and the westernmost Hudson Valley Province.

26. Carbonates dominate the Lower Devonian and lower part of the Middle Devonian while clastic deposits predominate in the remainder of the section. The clastics are fine-textured marine rocks at the bottom, grading upward to coarse, red continental sandstones. These deposits, are known as the Catskill Delta and are a wedge of clastic sediments that thicken and become coarser to the east. The New York Devonian is subdivided into the Ulsterian Series (Lower Devonian), Erian Series (Middle Devonian) and Senecan and Chautauquan Series (Upper Devonian).

Onondaga Dam Site Stratigraphy

27. The stratigraphic sequence in the vicinity of the dam belongs to the Lower and Middle Devonian System described on Table II. A more detailed stratigraphic column along the Syracuse Meridian in the vicinity of the dam is summarized on Table III, and Figure 4 is a geologic map of the area surrounding the dam.

28. Older Silurian units are exposed to the north of the dam in Syracuse and younger Upper Devonian units cap the hills south of the dam, and form the valley sides and floor south of the Village of Tully.

29. A brief description of the stratigraphy exposed at the location of the dam is contained in the following paragraphs. Appendix B presents an expanded discussion of this stratigraphy, along with a discussion of the underlying or surrounding stratigraphy in the general vicinity of the dam site, as shown on Figure 4.

Lower Devonian - Ulsterian Series

Helderberg Group

30. The Helderberg group is composed of two formations; the Manlius Formation overlying the Rondout Formation (Chrysler Dolostone).

31. The Manlius Formation is subdivided, from older to younger, into the Olney Limestone Member, the Elmwood A, B, and C Dolostone Members, the Clark Reservation Limestone Member, and the Jamesville Limestone Member.

- a. The Olney Member is approximately 30 ft. of fine-grained, even bedded limestones; thin bedded in the lower portion, somewhat more thickly bedded in the upper portion.
- b. The Elmwood Member overlies the Olney and consists of a series of dolostones, waterlimes, and limestones. It is subdivided into three units. Elmwood A is a drab yellowish-brown, thin-bedded and mud cracked waterlime approximately 6 ft. thick. Elmwood B is a fine-grained,

blue limestone, approximately 3 ft. thick. Elmwood C, the uppermost unit, is approximately 4 ft. thick, and is a waterlime similar to Elmwood A.

c. The Clark Reservation Limestone Member overlies the Elmwood and consists of a fine-grained, white weathering limestone characterized by a diagonal fracture system. It is approximately 5 ft. thick.

d. The Jamesville Limestone Member overlies the Clark Reservation Member. It is approximately 25 ft. of fine-grained, dark blue, brittle limestone in thin even beds. It is exposed in the lower 12 ft. of the rock exposed in the spillway cut at the east end of the dam.

Tristates Group

32. The Oriskany Sandstone is the only formation of this group exposed in Central New York. It is not well developed in the vicinity of the dam. Only a few inches of reddish-orange, sandy layers of this unit are exposed at the base of the Onondaga Limestone in the spillway cut.

Middle Devonian - Erian Series

Onondaga Limestone

33. The Onondaga Limestone is the lowest Middle Devonian formation within the Syracuse area. It is a series of light bluish-gray semi-crystalline limestones in even continuous layers from 1 inch to 2 feet thick, separated by thin seams of dark calcarerous shale. Flattened nodules of dark blue or black chert, sometimes in continuous sheets or beds, are unevenly distributed throughout the formation, but occur mainly in the upper part of the formation. The total formation thickness is approximately 70 ft.

34. The Onondaga is comprised of five members which, from older to younger, are the Edgecliff Member, the Nedrow Member, the Moorehouse Member, the Tioga Bentonite Member, and the Seneca Member.

a. The Edgecliff Member is a coarse, crystalline limestone with abundant fossils. The base of the member is a disconformity; i.e., it was deposited over an erosion surface that had removed previously deposited rock strata. The Member is approximately 15 ft. thick and may be seen in the spillway cut.

b. The Nedrow Member is characterized by thin-bedded, shaley limestone. It is medium gray, very fine-grained, and contains a little chert unevenly distributed at top. It is approximately 10 ft. thick and is gradational with the overlying Moorehouse Member. Both the Nedrow and the Moorehouse units are exposed in the spillway cut.

c. The Moorehouse Member is a medium gray, very fine-grained limestone, with 2-in. to 5-ft. thick beds separated in many places by thin shaley partings. Total thickness of the deposit is approximately 25 ft. Chert is common in the Member, but varies in amount.

d. The Tioga Bentonite Member is a volcanic ash layer 6 to 9 inches thick separating the Moorehouse and Seneca Members. Neither the Tioga nor the overlying Seneca Member were observed in the spillway cut.

e. The Seneca Member is similar in lithology to the upper portion of the Moorehouse Member, but is characterized by a slightly different fossil assemblage. Chert is less common in the upper part of the Member and the limestone beds become darker gray. The Member is approximately 25 ft. thick.

35. The Onondaga Limestone is overlain by the Hamilton Group which includes, from older to younger, the Marcellus Formation, the Skaneateles Formation, the Ludlowville Formation, and the Moscow Formation. These formations are approximately 1,100 ft. thick in total and are comprised

mostly of silty shales and siltstones. Refer to Appendix B for further details. The formations of the Hamilton Group are generally exposed in ravines and gullys on the sides of the Onondaga Valley at elevations above the spillway.

Depositional History

36. In general, the sedimentary rocks of central New York, and at the site in particular, were deposited in a shallow sea that flooded most of New York State. The sea was bounded on the east by a landmass that occupied the Hudson Valley region. This landmass was uplifted into a region of high relief during the Late Ordovician and once again in the Middle and Late Devonian Periods. These are discussed further in Part III of this report. Between these periods of uplift the landmass was an area of low relief and may even have been flooded by shallow seas from time to time. The material comprising the shales, siltstones and sandstones, such as the Hamilton Group, was sediment being transported off this landmass by westward flowing streams. When this landmass was high, coarse-grained clastics such as sandstones reached central New York, when it was low, fine-grained clastics such as shale were deposited. When this area was very low or even flooded, the sea cleared allowing for the deposition of carbonates such as the Helderberg Group and the Onondaga Limestone.

37. The abundance and diversity of organic remains attests to normal marine conditions prevailing during deposition. The sea was probably warm, shallow, well lighted, and of normal salinity and oxygen content. Notable exceptions to this would be conditions represented by the Queenston and Grimsby Formations, Salina Group, and the black and dark shales of the Marcellus Formation.

Glaciation

38. During the Pleistocene Epoch, the study area was covered by glacial ice approximately 2 miles thick. The erosional effect of the ice was to deeply scour the Valley of Onondaga Creek into a deep U-shaped trough.

39. As the ice waned northward, its margin paused momentarily south of the site, depositing the Tully Moraine, near Tully, New York. With continued northward withdrawal of the ice, a thin veneer of ground moraine or glacial till was laid down on top of bedrock. The ice margin then paused along the northern edge of the Allegheny Plateau causing a proglacial lake to form south of the ice front and north of the Tully Moraine. Since the ice acted as a dam, the impounded waters were forced to flow eastward to the adjacent north-south valley (Butternut Creek Valley) across the sharp ridge between the two. Therefore, a dramatic series of west to east meltwater channels were carved across the highland ridge between the Onondaga Valley on the west and the Butternut Creek Valley on the east. As the ice margin slowly withdrew northward, successively lower channels were cut across the northerly sloping face of the Helderberg-Onondaga Escarpment marking the northern rim of the Allegheny Plateau. One of the more spectacular of these is the extinct waterfall of Clark Reservation State Park west of Jamesville. A large horseshoe shaped rim of a once high waterfall and plunge basin below (Green Lake) is all that remains of this meltwater channel.

40. As lower meltwater channels were carved, the lake in the Onondaga Valley was lowered until the ice finally pulled back from the rim of the Allegheny Plateau allowing the pent up waters to escape eastward to the Mohawk River draining the lake from the Onondaga Valley.

41. When the lake was present in the valley south of Syracuse, and as it gradually receded, it received meltwater from waters discharging eastward from Marcellus, through Pumpkin Hollow, to Cedervale (Figure 3). As the lake received meltwaters from the west, a dramatic series of glacial lake deltas were deposited in the vicinity of the site. These are the nearly flat terraces so pronounced in the immediate vicinity

of the dam, as well as at Gwills Corners, South Onondaga, Nichols Corners and Ironsides on the south side of the valley. They are known as hanging deltas and are shown on Figure 4. The west end of the dam is tied into one of the largest hanging deltas in the Onondaga Valley having a surface elevation of approximately 620 feet. The hanging deltas are excellent sources of coarse sand and gravel and are being actively quarried northwest of South Onondaga. Many smaller hanging deltas occur at lower elevations north of the site on both sides of the valley.

42. The surfaces of the hanging deltas correspond favorably with the threshold elevations of the various west to east meltwater channels, described above, leading eastward to Butternut Creek Valley. Therefore, the surface elevation of the lowering proglacial lake can be mapped and recognized.

43. At the dam, the soil profile, based on the geologic history, should reflect till above bedrock with lacustrine deposits above till in the middle of the valley but coarser deltaic deposits on the sides of the valley. Above this should be coarse deltaic sand and gravel as the deltas came closer to the site as a result of the lowering lake. Finally, overbank deposits and organic peat from Onondaga Creek should cap the section. A detailed discussion of the soil profile beneath the dam is presented in a later section of this report.

PART III: FIELD AND LABORATORY INVESTIGATIONS

Subsurface Exploration Program

44. Subsurface conditions in the vicinity of the dam were investigated prior to dam construction. Nine test borings, Nos. DH-1 through DH-4, DH-6, DH-8, DH-10, DH-11, and DH-16, were drilled approximately along the dam centerline as shown on Figure 5, Site and Subsurface Exploration Plan. A subsurface profile along the dam centerline, prepared by the Corps of Engineers, is shown on Figure C-1, Profile Along Dam Centerline, contained in Appendix C. Strata lines and geologic descriptions were added to Figure C-1 by H & A of New York.

45. The logs of the original test borings generally indicate compact foundation soils. However, near-surface soil and one deeper strata in DH-3, are noted to be semi-compact. The criteria used in the design phase explorations for the dam to evaluate the relative density of the soils is not known. Therefore, no specific quantitative data relative to soil density, such as blow counts, were available to make evaluations of the liquefaction susceptibility of the subsurface soils. Such data is required to assess liquefaction susceptibility and foundation stability under design earthquake loadings.

46. For these reasons, H & A of New York recommended that a limited subsurface exploration program be conducted to obtain relative density data in order to conduct liquefaction susceptibility analyses. It was recommended that three test borings be made from the dam crest, through the embankment and into the foundation soils. Standard penetration test results would be obtained and split spoon soil samples recovered for laboratory soil testing. By drilling the borings from the dam crest, data on soil type and density for the embankment materials could be obtained and added to the permanent record for the dam.

47. The three test borings, Nos. D82-101 through D82-103, were conducted during the period 28 July through 27 August 1982 by Parratt-Wolff, Inc. of East Syracuse, New York. These test borings were drilled generally in accordance with Corps of Engineers "Specifications for Subsurface Drilling Sampling and Testing". H & A of New York field

personnel monitored the test borings, described soil and rock samples, and prepared written test boring logs in accordance with standard Corps of Engineers procedures. Completed test boring logs are contained in Appendix D. As-drilled locations and ground surface elevations are shown on Figure 6. They were surveyed by Rowell and Associates, P.C., of North Syracuse, New York, using base information contained in "Plans for Onondaga Dam, Onondaga Creek, Syracuse, N.Y.", dated 1947. Elevations are referenced to Mean Sea Level Datum (MSL).

48. The test borings were drilled with truck-mounted Mobile Drill B-56, CME 55 and/or CME 75 drill rigs. Hollow stem augers with 3-3/4 in. inside diameters were used to drill through the dam embankment materials. Augers were fitted with a properly sized plug to prevent soils from entering the augers during drilling. Split spoon samples were obtained through the augers. After the augers were advanced to a depth of 60 to 78 ft., NW-size (3-3/16-in. I.D.) flush-joint casing was then set within the augers and the boring continued by driving the NW casing with a 350-lb. hammer. The casing was driven to the depth at which a sample was to be obtained and washed out using a fishtail bit. Split spoon samples were obtained below the bottom of the casing. When driving of the NW casing became difficult, BW size (2.75-in. I.D.) flush joint casing was set within the NW casing and the boring continued by driving the BW casing. In D82-103, driving of the BW casing became difficult at a depth of 150 ft. This hole was completed from this depth using an open hole filled with drilling fluid consisting of bentonite powder manufactured by N.L. Baroid. The test boring logs in Appendix A contain notes relative to the specific steps taken to advance each of the test borings.

49. Split spoon samples were taken in all test borings. When soils containing an appreciable gravel content were encountered in the embankment, a 2-7/8-in. I.D. by 3.5-in. O.D. split spoon was used. It was driven into the soil with a 350-lb. hammer free falling 18 inches. This large diameter spoon could only be used through the hollow stem augers. When sampling in all other instances, a standard 1-3/8-in. I.D. by 2.0-in. O.D. split spoon, was used. It was driven by a 140-lb. safety hammer free falling 30 inches. All split spoons were generally

driven 24 inches unless refusal was encountered. Refusal was defined as 50 blows of either hammer with less than 0.5 ft. of spoon penetration. Boulder or cobble obstructions were occasionally encountered and were removed by means of fishtail bits or tricone roller bits. The test boring logs contain notes relative to specific sampling procedures and obstruction removal procedures used for each of the test borings.

50. Sampling was conducted continuously in each of the test borings from the bottom of the embankment soils to a depth of 150 ft. or to the bottom of the hole as in D82-101. Continuous sampling was also conducted through the embankment materials in D82-102. At depths below 150 ft. and through the embankment materials in D82-101 and D82-103, sampling was conducted at 5-ft. intervals. Test boring D82-101 was terminated at a depth of 105.7 ft., D82-102 at 173.0 ft., and D82-103 at 184.8 ft.

51. When sampling below the subsurface water level, efforts were taken to generally maintain a positive head of water within the casing to prevent the soils below the casing from running into the casing. Running conditions were still encountered, however, within D82-102 at a depth of 63.0 ft.

52. Bedrock was encountered in D82-101 at a depth of 103.3 ft. During core drilling operations, it was discovered that the bottom portion of the casing had become bent when the bedrock was encountered, and only 1.9 ft. of rock was cored before a BX-size (1.375-in. I.D.) core barrel was sheared off within the hole. The core barrel was later retrieved and the hole terminated.

53. Upon completion of each test boring, the hole was filled with grout from the bottom of the hole to the top of the embankment. The casing was removed as the grout was placed. The grout consisted of a cement and bentonite mixture containing a small amount of sand.

Laboratory Testing Program

54. Laboratory soil tests were performed on selected samples obtained from the test borings in order to assist in classification of the samples. Natural water contents, Atterberg Limits, and grain size distribution tests were performed. Grain size distributions were obtained by means of mechanical sieve analyses and/or hydrometer analyses. All tests were conducted in accordance with accepted practice, generally as recommended by ASTM.

55. A total of five natural water contents and five Atterberg Limits determinations were made on fine-grained soils exhibiting some degree of plasticity (i.e., containing clay). Four of the samples tested were from the uppermost natural soil strata and one was from a cohesive layer within the lacustrine deposits found in D82-103. In addition, a hydrometer analysis was performed on each of these samples. A total of thirteen mechanical sieve analyses were performed. Four of the samples were from the embankment materials and nine from underlying natural soil strata. Representative samples were selected from most of the major soil strata.

56. Laboratory test results for all of the above tests are contained in Appendix E.

PART IV: SUBSURFACE CONDITIONS ALONG DAM CENTERLINE

57. The recent test borings were designated, from east to west, D82-101, D82-102, and D82-103 as shown on Figure 6. They encountered five significant soil deposits and bedrock. These were as follows:

- Dam Embankment Materials
- Fluvial Overbank Deposits
- Deltaic Deposits
- Lacustrine Deposits
- Glacial Till
- Bedrock

58. Bedrock was encountered in the eastern-most boring only, D82-101. Not all soil deposits were encountered in each test boring. A subsurface profile along the dam centerline developed from both the recent test borings and the original design test borings is shown on Figure 6. The following paragraphs describe the major soil deposits encountered in the recent borings, beginning with the embankment materials and progressing downward. Refer to Paragraphs 38 through 43 for a discussion of the geologic origin of the deposits.

Dam Embankment Materials

59. The dam embankment materials may generally be described as brown, silty coarse to fine SAND, little gravel, to coarse to fine sandy GRAVEL, little silt, with an occasional layer of medium to fine SAND, trace gravel, trace silt.

a. Embankment materials were encountered to depths of 55.0, 65.5, and 65.5 ft. in borings D82-101, D82-102, and D82-103, respectively.

b. Penetration resistance values were generally obtained with a 2-7/8 in. I.D. by 3.5-in. O.D. split spoon sampler driven by a 350-lb. hammer falling freely

18 inches. Blow counts for one foot of penetration ranged from 19 to refusal, defined as 50 blows with less than 0.5 ft. penetration. Generally, measured penetration resistances exceeded 50 blows/ft. A granular soil of this average penetration resistance can be described as very compact.

c. Grain size distribution curves of typical embankment samples are contained in Appendix E as Test Nos. 1, 4, 5 and 9. For the samples tested, the embankment materials consisted of 34 to 56% gravel, 31 to 39% sand, and 13 to 28% silt.

d. As a result of the above visual descriptions and laboratory test results, the dam embankment materials would be classified as GM, SM, or SP soils according to the Unified Soils Classification System (USCS).

Fluvial Overbank Deposits

60. The fluvial overbank deposits consist of gray and brown, fine sandy SILT, little clay, to silty CLAY, with an occasional layer of silty fine SAND. Small amounts of organic material are also present. They occur immediately below the embankment material, and are the original near-surface soils of the valley bottom.

a. The deposit was 11.0, 6.5, and 5.0 ft. thick in borings D82-101, D82-102, and D82-103, respectively.

b. Penetration resistance values were generally obtained with a 1-3/8-in. I.D. by 2.0-in. O.D. standard split spoon driven by a 140-lb. safety hammer falling freely 30 inches. Standard penetration resistance values of 1.0 ft. of penetration ranged from 17 to 34, with an average of 24. A cohesive soil of this average penetration resistance can be described as stiff; a granular soil as medium compact.

d. As a result of the above visual descriptions and laboratory test results, the deltaic deposits would be classified as GM, GW, SM, and SP soils according to the USCS.

Lacustrine Deposits

62. Lacustrine sediments underly the deltaic deposits. These sediments consist of red-brown, silty fine SAND, trace coarse to medium sand and fine gravel, to silty CLAY, trace coarse to fine sand, with occasional layers of coarse to fine SAND, little gravel, little silt.

a. The lacustrine deposit was encountered in D82-102 from a depth of 120.5 to 154.0 ft. and in D82-103 from 101.5 to 181.0 ft. It was not encountered in D82-101. The deposit was 33.5 and 79.5 ft. thick in D82-102 and D82-103, respectively.

b. Samples were recovered with a standard split spoon sampler. Standard penetration resistance values ranged from 32 to 128 blows/ft. with an average of 77 blows/ft. A granular soil with this average penetration resistance would be described as hard.

c. Grain size distributions of representative samples of coarser portions of this deposit (silty fine SAND) are contained in Appendix E as Test Nos. 8, 12, and 13. These soils contained 60 to 72% fine sand and 28 to 40% silt. Atterberg Limits No. A-5 and hydrometer analysis H-5 reported in Appendix E were performed on a sample of silty clay soil recovered in D82-103 from the uppermost portion of the deposit. This sample had a natural water content of 13.6%, a plastic limit of 12.9%, and a liquid limit of 21.7%, and consisted of 10% sand, 30% silt, and 60% clay.

d. As a result of the above visual descriptions and laboratory test results, the lacustrine deposits would be classified as SM, SP, ML, and CL soils according to the USCS.

Glacial Till

63. Glacial till underlies the lacustrine deposit. Descriptions of recovered samples range from gray, gravelly, coarse to fine SAND, little silt, to brown, fine sandy SILT, little coarse to medium sand and gravel. Numerous cobbles and boulders were indicated during casing advance and sampling.

- a. This deposit was penetrated 19.0 and 3.8 ft. by D82-102 and D82-103, respectively. These borings terminated within this deposit. Glacial till was not encountered in D82-101.
- b. Standard penetration resistance values ranged from 71 blows/ft. to refusal. A granular soil of this penetration resistance can be described as very compact.
- c. No grain size distributions of this deposit were obtained.
- d. As a result of the above visual descriptions, the glacial till would be described as SM, GM and GW soils according to the USCS.

Bedrock

64. Bedrock was encountered in only one test boring; D82-101 at a depth of 103.3 ft. Attempts to core the rock met with limited success due to bent casing at the bottom of the hole. A run of 1.9 ft. was made using a BXM double tube core barrel with 1.6 ft. of rock core recovered. The recovered rock core has been described as a dark gray, slightly weathered, moderately hard, dense to finely crystalline, flat-lying LIMESTONE, with a few stylolites. It has been identified as the Manlius Limestone, Olney Member.

Subsurface Water

65. At the time of the dam construction, a series of piezometers and settlement gages were installed. The settlement gages were constructed such that subsurface water level readings could also be obtained. Readings have been obtained at semi-regular intervals since the dam was constructed. These readings indicate a subsurface water level of approximately EL 460± to 465±, closely corresponding to the original ground surface. During the recent subsurface exploration program, regular water level observations were made during drilling operations and the water level in adjacent settlement gages was measured. These levels, noted on the subsurface profile on Figure 6, also correspond closely with the original ground surface.

Subsurface Profile

66. The subsurface conditions along the centerline of the dam are quite variable. The previous subsurface explorations reveal that the soils of the east and west dam abutments are deltaic deposits. These deltaic deposits form the terraces rising above the Onondaga Creek flood plain. However, the recent test borings along with the previous test borings show that, within the limits of the original flood plain beneath the dam, a deposit of fluvial overbank sediments overlie deltatic deposits, which in turn overlie lacustrine deposits. Glacial till and bedrock lie below the lacustrine deposits. The depths and thicknesses of these deposits vary from east to west.

a. The silt and clay overbank deposits were encountered between test borings DH-6 and DH-2. The overbank sediments are approximately 5 to 13 ft. thick at test boring locations, within the flood plain, and pinch out to the east and west at the valley sides.

b. Sand and gravel deltaic deposits underlie the obervank deposits in the central portion of the dam and make up the east and west abutments. At the test boring locations, the deltaic sediments beneath the dam appear to vary in thickness from approximately 30 to 55 ft. This deposit thins to the east where the bedrock surface rises. The deltaic deposits of the west abutment consist of two units; a coarse-grained upper portion and a fine-grained lower portion. The deltaic deposits of the east abutment are predominantly granular and overlie bedrock.

c. Underlying the deltaic deposit, along approximately the western one-half of the dam centerline, is a lacustrine deposit consisting of silt and fine sand. Based on test boring results, it appears the deposit thickens to 80 ft. and extends beneath the terrace at the west abutment. Towards the east it pinches out due to the rising bedrock surface.

d. Underlying the lacustrine deposit, is a deposit of glacial till, a homogeneous mixture of silt, sand, and gravel. The top of the glacial till deposit slopes to the west as shown by the test borings and is probably closely underlain by bedrock.

e. Test borings along approximately the eastern one-third of the dam and the east abutment encountered limestone bedrock immediately beneath the deltaic deposit. The bedrock surface appears to drop off sharply to the west, as rock was not encountered west of boring DH-2. It is H & A of New York's opinion that the rock cored in the bottom of DH-3 is a boulder in the till.

PART V: TECTONIC HISTORY

Orogenies

67. Orogenic events, or mountain building episodes, have not occurred per se in central New York. However, orogenies have occurred within and outside the state boundaries that have effected the depositional and structural history of the region.

The orogenic events are as follows:

a. Taconic Orogeny - This is the earliest mountain building episode to strike the state and took place in the Late Ordovician and Early Silurian Periods (Table I). It resulted from compressive forces that became established as ancestral Africa and Europe began to move closer to ancestral North America. These compressive forces folded and thrust faulted the area of eastern New York and western New England forming the Taconic Mountains of New York, Berkshire Hills of Massachusetts, and the Green Mountains of Vermont. Streams flowing westward of this mountainous highland (sometimes called Vermontia) deposited a westward migrating delta or clastic wedge across the state. It is known as the Queenston Delta and the Queenston and Grimsby Formation represent the terrestrial uppermost portion of this delta.

b. Acadian Orogeny - The Acadian Orogeny took place during Middle and Late Devonian times immediately after the deposition of the Onondaga Limestone. It continued into the succeeding Mississippian Period as well. The Acadian Orogeny struck the same general area as the earlier Taconic Orogeny. However, from the amount of clastic sediment shed from the highland area and other data, this orogeny was larger than the Taconic. It came about as a result of the collision of ancestral Africa and Europe with northeastern North America. This orogeny was the climax of the Appalachian Mountains uplift in the north. Another delta of clastic wedge was shed westward off the Acadian Landmass known as the Catskill Delta. It begins with the clastic sedimentation of the Hamilton Group and continues into the Upper Devonian (Table II). By the end of the Devonian Period this delta had prograded westward across the entire state or nearly so.

c. Appalachian Orogeny - This orogeny struck mostly the southern Appalachian chain as ancestral Africa rotated to collide with southeastern North America. This took place primarily during the Late Paleozoic Era, the Pennsylvanian and Permian Periods. The effect on central New York from this orogeny was to impart to the strata a dip of 40 to 50 feet per mile to the south. In addition, the joint system was formed at this time as well as the minor faults and folds discussed below.

d. Mesozoic Events - After the Appalachian Orogeny the present Atlantic began to open as Europe and Africa rifted from North America and drifted gradually eastward. Tensional forces resulting from this breakup formed the downfaulted Triassic Lowland Province of southeastern New York (Figure 2). In addition, upward migrating magmas formed the Palisades Sill of the Hudson and also may have been responsible for the many small dikes that occur throughout central New York. These dikes are shown on Figure 3, and discussed below.

Structural Deformation

68. Superimposed on the regional dip approximately 1/2° to the south are local folds, consisting of low amplitude anticlines and synclines, and faults of low displacement.

Folds

69. A broad anticline and syncline is exposed in the Chittenango Member of the Marcellus Formation on the east side of N.Y. Route 173 just south of its intersection with Slate Hill Road, south of Marcellus.

70. Along the east side of Interstate 81, south of the junction of Interstate 481, there are a series of gentle anticlines and synclines. The height of these folds is approximately 30 feet. They are a few hundred feet wide and expose the Manlius Formation (Olney, Elmwood, Clark Reservations and Jamesville Members).

71. A gentle anticline is exposed in the spillway cut at the dam. The Manlius-Onondaga contact rises to a maximum of 12 feet above the floor of the valley from the spillway northward, then descends further northward such that it is near creek level at the northern extremity of the exposure.

72. A monocline in the Onondaga Limestone is exposed on the south side of the Seneca Turnpike (NY Route 173) at Fillmore Corner, which is at the intersection of Sweet Road, about 2.5 miles east of Jamesville. The Onondaga is horizontal on each side of the monocline but is bent nearly vertical within the structure. The Onondaga is some 23 feet lower on the downside of the monocline. Outside of the Onondaga Valley region, a broad anticline is exposed along Cayuga Lake north of Ithaca, known as the Portland Point anticline.

73. The folds in the Syracuse and Central New York region are related either to mild compression as a result of the Appalachian Orogeny or to removal of salt and gypsum in the Salina and Bertie Groups due to migrating ground water. Thus some of the smaller folds may be subsidence structures and not uplift structures formed by compression.

Faults

74. A number of small faults occur in the Syracuse - Central New York region as revealed by a search of the literature augmented by field work. All of these are small in lateral extent and displacement or offset. Further, they strike approximately N70°W, dip mainly southward, are mostly thrust faults that form due to compression, and therefore, are probably Late Paleozoic Appalachian Orogeny structures (approximately 220 million years old). Overlying glacial deposits are not offset indicating that no motion has taken place on these faults at least since the last retreat of the ice, approximately 14,000 years ago.

75. A small thrust fault of 3 feet vertical displacement occurs in the Old Malley quarries south of Marcellus and a few hundred yards north of the anticline described above in the Chittenango Shale Member. The fault cuts the Onondaga Limestone.

76. A thrust fault, with a throw of about 5 feet, in the Onondaga Limestone and extending into the overlying Union Springs Member can be seen in the drainage ditch on the east side of U.S. Route 11, south of the Nedrow interchange to Interstate 81 at the intersection of Kennedy-Camping Road. The Union Springs Shale Member is highly contorted and tightly folded, apparently absorbing the fault motion. This fault is the closest thrust fault to the dam, a distance of approximately 2.5 miles, and cannot be traced beyond this one exposure.

77. A thrust fault in the Jamesville Quarry on the east side of the Butternut Creek Valley, north of Jamesville, has a vertical displacement of 16.5 feet in the Onondaga Limestone. This structure probably grades eastward into the monocline described above, exposed at Fillmore Corner.

78. One of the largest faults in the Syracuse area formerly was exposed in the old Russell's Quarry, now buried near the junction of N.Y. 173 and LaFayette Road in the southeast corner of the Syracuse West quadrangle. The fault plane dips south 20° and displaces the Manlius and Onondaga limestones 42 feet. South of Jamesville, on the east side of the Butternut Creek Valley, in the Onondaga County Penitentiary Quarry, a thrust fault of about 31 feet may be the same fault as the one

formerly exposed in Russell's Quarry. If so, the fault is approximately 3.5 miles long parallel to strike.

79. Four small thrust faults with throws of 2 to 4 feet cut the Bertie Group in the Fiddlers Green Gorge at Jamesville. Three thrust faults of comparable strike, dip, and displacement to those described above have been discovered on the Manlius Quadrangle to the east.

80. A series of small normal faults, down thrown to the north, can be seen along the southwest side of the Tully Valley in Lords Hill Ravine and Cass Hill Ravine, south (upstream) of U.S. Route 20, having a total displacement of approximately 45 feet. The fault planes strike N60°W, and are nearly vertical. The Staghorn Point and Joshua Submembers are cut by the faults.

81. The unusual thickness of the Pompey Member in Bare Mountain Ravine may also be due to normal faulting, but the lack of outstanding key beds makes this hypothesis difficult to test.

Joints

82. The joint system in the Syracuse region contains two main sets, one nearly north-south and the other nearly east-west. Most of the joints in these sets are vertical or nearly so. Two minor sets that strike northeast and northwest are also present.

83. Inclined joints that strike about N70° to 75°W and dip 30° to 80° either north or south are locally developed in the limestones in the Syracuse area. Some of the inclined joints are continuous for many tens of feet while others are limited to a single bed or group of beds and end against a shaley parting. They are well developed in parts of the Manilus Formation such as the Clark Reservation Limestone Member and the Onondaga Limestone, especially the Nedrow Member.

Dikes

84. In central New York, small dikes from a few inches to a few feet wide occupy the North-South joint set. They are composed of kimberlite

and alnoite, a high temperature, ultra-basic, igneous rock, high in iron and magnesium silicates and low in aluminum silicates such as potash feldspars.

85. One dike occurs in North Syracuse near Schiller Park, one at the DeWitt Reservoir 3 miles east of Syracuse, and another near Otisco Lake, 15 miles southwest of Syracuse. A relatively large number are exposed in Ithaca and on both sides of Cayuga Lake north of Ithaca to Taughannock Falls State Park.

PART VI: EARTHQUAKE ACTIVITY

Historic Earthquakes

86. More than 330 earthquakes with a maximum Modified Mercalli Intensity (I_0) greater than II are known to have occurred in New York State between 1720 and 1980 (Mitronovas, 1981). Figure 7 is a seismicity map for the northeast U.S. and adjacent Canada, showing all known historical and recorded events of maximum intensity greater than or equal to III for the time period 1534 to 1977. Figure 7A is a seismic zone map for the contiguous United States and Puerto Rico with the corresponding location of the dam site. An abbreviated form of the Modified Mercalli scale is shown on Figure 8, along with approximate relationships between intensity, Richter magnitude, and peak horizontal ground acceleration.

87. All earthquakes with a maximum intensity greater than or equal to IV that have occurred within 200 kilometers of the Onondaga site are listed in Table IV in order of decreasing epicentral intensity.

Geographic Distribution of Earthquakes

88. As discussed by Mitronovas (1981) and shown on Figure 9, New York State can be subdivided into three areas of relatively high seismic activity, separated by a large area of very low or no activity in the center of the State (which includes the Onondaga Dam site). These regions were designated A, B, C, and D by Mitronovas. Over 90 percent of all seismic events, and all events of maximum intensity greater than V, fall into regions A, B, and C, which have a combined area of less than 60 percent of that of the State. Table V gives a chronological list of earthquakes within New York State of maximum intensity VI or greater. The following discussions of the seismicity of the four regions of New York State are taken from Mitronovas (1981).

89. Region A is an area of moderate seismic activity. It contains the Ramapo fault system, which has been associated with recent seismic activity. One of the earliest documented large earthquakes in New York (I_0 = VII) occurred in Region A near New York City on 18 or 19 December 1737.

90. The Adirondack area, region B, is the most seismically active region of the state. It is part of a larger seismic area which trends northwest-southeast and extends well into Canada. There is evidence that the Adirondacks are undergoing doming, or upward movement (Isachsen, 1975). The doming may be linked to the seismic activity of the area, but this is not known for certain. The largest known earthquake within New York State (I_o = VIII) occurred in this region near Massena, New York on 5 September 1944.

91. The number of known earthquakes within region C is smaller than in either of regions A or B. However, one of the two largest earthquakes in the state, near Attica, occurred in region C on 12 August 1928. The general location of this event suggests that it was associated with the southern end of the Clarendon-Linden fault system. Past and present seismicity of region C is not restricted to this fault system alone, however.

92. The central part of the state, region D, has very little seismic activity, both at present and historically. This large aseismic area separates the seismically active areas of the state into three distinct regions.

93. The available data (Mitronovas, 1981) indicates secular variation, or periodicity over time, in seismic activity in New York since 1920. Periods of greater activity, in terms of total number of events per unit of time, between 1760 and 1790, 1830 and 1880, and 1910 through the present, are separated by periods of less activity between 1790 and 1830 and 1880 and 1910. An increase since 1910 is consistent with the improvement in detection capability. Chiburis (1981) has indicated that the Adirondack region has exhibited a decreased seismic activity since 1925. The reasons for time-dependent seismicity in the northeast U.S. are not known.

PART VII: EVALUATION FOR ACTIVE FAULTS

94. Earlier sections of this report have established that mapped faults in the site vicinity are ancient ones which date back to the Appalachian Orogeny of Late Paleozoic time (over 220 million years ago). Glacial overburden and urban construction have made it all but impossible to trace faults for any great distances. The evidence indicates that all the faults are inactive at the present time and are small local occurrences of limited extent.

Assocation of Earthquakes with Tectonism and Faults

95. The earthquake distribution in New York State bears little or no proven relationship to known active or inactive faults. In region A, there is some activity that corresponds to the Ramapo fault system, but not all activity is confined to this system. In region B, the relationship to known faults or other tectonic features is not clear. The correlation between epicenters and known surface faults or other brittle structures still remains to be determined. In region C, the past and present seismicity is not restricted to the Clarendon-Lindon fault system alone. Indeed, although the seismicity extends both east and west of the fault system, it does not extend northward along the fault system, which is known to extend into Lake Ontario. The relationship of most of the epicenters in region C to tectonic structures is, as in region B, not yet known.

96. The Attica seismic region (region C) has produced several events for which some possible fault types and orientations have been obtained, based on seismological data. Hermann (1978) determined similar focal mechanisms for both the 1 January 1966 and 13 June 1967 events. A plane striking NNE parallels the trend of the Clarendon-Linden fault structure. If this is indeed the fault plane, then the motion along this plane has approximately equal components of right-lateral strike slip and reverse

faulting. Composite fault-plane solutions obtained by Fletcher and Sykes (1977) for Attica events between 1972 and 1975 have one plane also oriented NNE, but their solution indicates predominantly reverse faulting.

Lineations

97. Lineations or linear features, are those that are found in tonal changes in satellite imagery, and in the alignment of rivers, terrace boundaries, etc. They may be the result of a multitude of causes and may be unrelated to faults.

98. The Brittle Structures Map of New York State, compiled by Isachsen & McKendree (1977) was reviewed to note locations of any lineations in the site vicinity. Several lineations were noted. An attempt was made to check these in the field but nothing could be discerned. They appear to be unrelated to faults but may be due to jointing or glacial erosion and deposition. None of the faults or linears show any evidence of activity in the area of the project.

PART VIII: INTENSITY OF EARTHQUAKE SHAKING AT ONONDAGA DAM

Earthquake Intensities and Attenuation

99. All earthquakes with a maximum intensity greater than or equal to IV that have occurred within 200 kilometers (km) of the site are shown in Table IV. Because larger earthquakes at distances greater than 200 km may produce significant site intensities, all 2705 events in the Chiburis (1981) earthquake catalog have been attenuated to the Onondaga site. The attenuation relation used was that of Cornell and Merz (1975):

$$I = I_o + 3.211 - 1.3 \ln (\text{distance in km})$$

100. Table VI shows the specific events which produce site intensities greater than or equal to IV when attenuated to the site.

101. As the data clearly show, the maximum shaking intensity experienced at the Onondaga Dam site has been IV to V. (Intensities noted in Table VI are in arabic numerals because of fractional values). The peak horizontal ground acceleration was therefore in the range of 1 to 3 percent of the acceleration due to gravity (0.01g to 0.03g). The event that produced the highest intensity at the site was the 1663 La Malbaie earthquake (I_o = X) at a distance of about 700 km from the site. Because of the early occurrence at this event, the assigned intensity of X, based on historical accounts (written or otherwise) is at best only an estimate. Of more concern would be the Attica and Massena earthquakes, recorded in 1929 and 1944, at distances of 180 km and 250 km from the site, respectively. The magnitude of the Massena event was reported to be 5.9, whereas the magnitude of the Attica event was estimated from historical records to range from 5.5 to 5.9 (Chiburis, 1981). However, the attenuated intensities at the dam are still only on the order of IV. A possible faulting mechanism for the Attica region was discussed earlier in this report (para. 96).

102. Isoseismals from the 1 March 1925 intensity IX event centered in La Malbaie, Quebec are shown in Figure 10. This event resulted in

intensity IV shaking at the site, and would have caused rattling of dishes and windows and disturbance of doors and cars near the site. The reduction in five levels of intensity from La Malbaie to central New York for the 1925 event is consistent with the attenuation of the 1663 La Malbaie earthquake discussed in the previous paragraph.

103. It is concluded that earthquakes with epicentral intensity greater than IV will not have epicenters near the Onondaga site. The nearest regions of concern are the Attica and Massena regions, which may produce intensities of IV to V at the site. The focal mechanism of the Attica region is most probably reverse or thrust faulting with north-easterly trending fault planes.

Frequency of Earthquake Occurrence and Seismic Risk

104. A seismic risk analysis was performed to aid in the selection of a level of earthquake shaking for use in assessing the seismic stability of Onondaga dam. The analysis was used to estimate the probability of exceeding various levels of earthquake shaking within a specified time period. These calculated probabilities allow for selection of an "analysis" earthquake that is consistent in terms of seismic risk with other similar structures.

105. The procedure used to calculate the probability of exceedence of specific levels of earthquake shaking at the site was to first divide the northeastern United States and adjacent areas into more than 50 zones or potential sources of seismic activity. Each zone has its own assigned level of seismic activity based on historical seismicity. The zones are quadrilateral in shape and are based on the regionalization given in Chiburis (1981). It is assumed that the locations of potential earthquake point sources (epicenters) are randomly distributed with each zone. In addition to the specific zones, a low-level "background" seismicity was assumed, randomly distributed over the entire northeast area. This allows for the possibility of earthquakes occurring at any location, not just in zones where historic seismicity is relatively concentrated.

106. The probability of occurrence of intensity $i \geq I_1$ shaking at the site was calculated based on the "Total Probability Theorem" as

$$P\,(i \geq I_1) = \sum_{\substack{\text{all}\\ \text{source}\\ \text{zones}}} \sum_{m} P\,(i \geq I \mid m)\;\; P(m)$$

in which:

$P\,(i \geq I_1)$ denotes the probability of the occurrence of intensity $i \geq I_1$ at the site;

$P\,(m)$ denotes the probability of occurrence of an earthquake of magnitude m or greater in a source zone;

$P\,(i \geq I_1 \mid m)$ denotes the probability of occurrence of intensity $i \geq I_1$ at site given the occurrence of a magnitude m event in the source zone.

107. The probability calculations were performed on a computer using a program developed by McGuire (1977). The procedures used to calculate the needed parameters for each zone are described in the following two paragraphs.

108. The probability of occurrence of an earthquake of magnitude m or greater within a source zone, P (m), is determined from the assigned recurrence relationship for each zone. The recurrence relationship is of the form:

$$\log N = A - Bm$$

in which N is the average number of events per year of magnitude m or greater for each specific source zone, and A and B are constants for the zone. The probability of occurrence of an earthquake of magnitude m or greater is determined by numerical integration of the above recurrence relationship for each zone. The "B" parameter was assumed to be equal for all zones except La Malbaie, which exhibits much more seismic activity than other areas in the northeast. The "A" parameter was determined from historical seismic activity for each zone.

109. The probability of intensity i shaking at the site given a magnitude m event in a source zone, $P(i \geq I_1 | m)$, is related to the attenuation relationship for the site area. Attenuation is assumed to follow a normal probability distribution. The mean value of the distribution was based on Cornell and Merz (1975) as presented in paragraph 99. Chiburis (1979) compared the Cornell and Merz relationship to observed attenuation for six northeastern events, as shown on Figure 11. The relationship compares well with the observed data in the near and far fields, although it is not as good in the intermediate range. To account for the variability in the observed attenuation in the analysis, a standard deviation of 0.4 was assumed. This is more conservative than the 0.2 value used by Cornell and Merz.

110. The probability of exceedence results calculated with the computer program are based on a one-year time period. The probability of exceedence of a specified intensity I_1 in T years can be calculated from the following:

$$P(i \geq I_1) = 1 - e^{-\lambda T}$$

in which λ is the mean number of events per year of intensity I_1. For the levels of seismic risk considered herein, λ is also equal to the probability of exceedence of intensity I_1 in one year.

111.. Figure 12 depicts the results of the analysis, that is, the probability that specified earthquake intensities and corresponding peak horizontal ground accelerations will be exceeded at the site in a 50-year period. Intensity was converted to peak horizontal ground acceleration in rock using the relationship shown on Figure 8. The following is a brief summary of selected results:

PEAK HORIZONTAL GROUND ACCELERATION IN ROCK	INTENSITY	PROBABILITY OF EXCEEDENCE IN 50 YEARS
0.02g	V	7.0%
0.05g	VI	1.0%
0.10g	VII	0.8%

On the average, intensity V, VI and VII shaking would be expected to recur at the site every 650, 4,400 and 65,000 years, respectively.

PART IX: ASSESSMENT OF EARTHQUAKE EFFECTS ON ONONDAGA DAM

112. Based on the results of the seismic risk analysis and current engineering practice, the peak horizontal ground accelerations in rock recommended for use in assessing the seismic stability of the Onondaga Dam is 0.05g. This acceleration corresponds to an intensity of shaking of VI, which is one intensity level higher than the site is known to have experienced historically. The probability that this level of shaking would be exceeded in a 50-year period is 1.0 percent based on the analysis performed.

113. The duration of strong motion in an earthquake is often defined as the time interval between the times that a 0.05g acceleration is first and last achieved. This definition would result in a duration of zero for Onondaga Dam. Nuttli (1979) has defined duration as the time interval between the times that one-half the "sustained maximum" (third highest acceleration peak) acceleration is first and last achieved. This definition leads to longer durations for small earthquakes. Using this definition of duration and considering that the epicenter of the causative earthquake is likely to be more than 100 km from the site, the recommended duration of shaking is approximately 30 seconds.

114. The recommended level of earthquake shaking could only cause embankment or spillway instability, if a marginal static stability condition exists for either the embankment dam or concrete spillway. Based on the calculations presented in the U.S. Engineer Office Design Analysis for the dam (Ref. 17), the static stability of the embankment and spillway appears adequate. Significant settlement or liquefaction of foundation soils could only occur if the foundation soils are cohesionless and very loose to loose in relative density. In addition, for liquefaction to occur, the foundation soils must be saturated. The logs of the design phase (1945) borings indicate that foundation soils at the dam are predominantly compact to very compact, saturated cohesionless soils, but the criteria used to evaluate the relative density

of the soils is not known. No penetration test results or quantitative data of any kind were available. The recent test borings were undertaken as part of this study in order to provide such data. Engineering studies relative to the seismic stability of the dam were then performed using the data obtained from the borings.

115. The subsurface conditions along the dam centerline are shown on Figure 6 and have been summarized in paragraphs 57 to 66. As noted in paragraph 65, subsurface water levels are generally between El. 460 to 465.

116. A plot of Standard Penetration Resistance (N-value) versus sample depth below the top of the embankment for the recent test borings is provided in Figure 13. N-values obtained by means of standard methods, 1-3/8 in. I.D. 2.0-in. O.D. split spoon driven by a 140-lb. hammer free falling 30 inches, are shown on the plot without correction. N-values obtained by means of the large split spoon, 2.875-in. I.D. 3.5-in. O.D. driven by a 350-lb. hammer free falling 18 inches, have been converted to standard values for use on the plot. The conversion has been made on the basis of sampler-hammer ratios which take into account sampler size, hammer weight, and drop height by the following equations:

$$R_s = (D_o^3 - D_i^3)/WH\ (144)\ \text{ft.}^2/\text{lb. for granular soils}$$

$$R_s = (D_o^2 - D_i^2)/WH\ (12)\ \text{ft./lb. for cohesive soils}$$

where;

R_s = Sampler - Hammer Ratio

D_o = Outside Diameter of Sampler (in.)

D_i = Inside Diameter of Sampler Shoe (in.)

W = Weight of Hammer (lb.)

H = Height of Drop (in.)

Calculations of the sampler-hammer ratios and the conversion charts used are contained in Appendix F.

117. In addition, projected N-values have been used for samples which encountered refusal before reaching the required one foot of

penetration. In these cases the recorded penetration resistance values were projected by direct proportion to the one foot standard for use on the plot.

118. The liquefaction potential of the saturated cohesionless foundation soils was analyzed in accordance with the methodology of Seed and Idriss (1981). The calculations performed for the assessment of liquefaction potential are provided in Appendix F. A summary of the analytical procedure is as follows:

1. Calculate the effective ($\bar{\sigma}_{vo}$) and total (σ_{vo}) overburden pressures below the crest and toe of the dam.

2. Calculate the seismic shear stresses (τ) imposed by the earthquake on the foundation soils and obtain the seismic shear stress ratio, $\tau / \bar{\sigma}_{vo}$, as a function of depth below the toe and crest of dam.

3. Correct Standard Penetration Resistance values to N_1 values, the N-value at an effective overburden pressure of one ton per sq. ft. (tsf.)

4. Plot $\tau / \bar{\sigma}_{vo}$ versus N_1 and compare to data obtained from previous earthquakes for known cases of liquefaction and nonliquefaction.

119. To determine the seismic shear stress as a function of depth, it is necessary to estimate the amplification of the bedrock earthquake motions as cuased by the presence of the overburden soils. The amplification by the dense soils at the site was estimated by taking the ratio of the response spectra peak for "stiff" soil conditions to the peak for "rock", for the spectra shown on Figure 14. The ratio of the "stiff" soil peak to the "rock" peak was 1.16. An amplification factor of 1.2 was assumed in the analysis, resulting in a peak horizontal ground acceleration of 0.06g at the natural ground surface.

120. The results of the liquefaction analysis are shown on Figures 15 and 15A, which shows the plot of $\tau / \bar{\sigma}_{vo}$ versus N_1 for the dam foundation soils. The figures show that even the lowest N_1 values ooygained at the site lie

to the "safe" side of the boundary line separating regions of observed liquefaction from nonliquefaction. Therefore, liquefaction of the foundation soils is not believed to be possible under the recommended levels of earthquake shaking.

121. It should be noted that the N_1 range shown on Figures 15 and 15A is the range of the lowest N_1 values encountered at the site. The average N_1 for the foundation soils would be significantly greater than the highest end of the range shown.

122. The embankment soils were disclosed by the borings to be medium compact to very compact, as noted earlier. In addition, these soils were found to be partially saturated. The results of the foregoing analyses provide a basis for concluding that the embankment soils would not be liquefaction-susceptible for the recommended level of shaking if they were to become saturated due to an impoundment.

PART X: CONCLUSISONS

123. The Onondaga Dam is located in a region of exposed gentle, southerly sloping Lower and Middle Devonian limestones and shales of the Helderberg Group, Onondaga Limestone and Hamilton Group. Superimposed on the dip are some minor, small faults and folds of Late Paleozoic age. Therefore, the dam is situated in an area that is structurally simple and tectonically stable.

124. The region has been glaciated, and the valley in which the dam is located is a U-shaped glacial trough. Upon retreat of the ice, large, hanging delta terraces of sand and gravel were deposited in the valley in a gradually receding proglacial lake that escaped eastward through meltwater channels.

125. The dam is located in an area that historically can be described as nearly aseismic. The intensity of ground shaking recommended for use in assessing the seismic stability of the dam and its foundations is VI, with a corresponding peak horizontal ground acceleration of 0.05g in rock and 0.06g at the surface of natural ground where the dam overlies soil deposits. The average length of time between occurrences of this degree of shaking at the site is 4,400 years, based on probability analyses. The calculated probability that the above intensity will be exceeded at the site in a 50-year period is 1.0 percent. Possible sources of earthquakes which might produce this degree of shaking are the Attica and Massena, New York areas and the La Malbaie, Quebec area.

126. To obtain qualitative and quantitative data for use in the assessment of the stability of the dam under earthquake shaking, three test borings were drilled from the crest of the embankment into the foundation soils as a part of this study.

127. The approximately 65-ft. high embankment consists of medium compact to very compact sands and gravels that were not saturated at the time of this study. Immediately below the embankment is a relatively thin layer of saturated, stiff to hard, clayey silt and silty clay.

Below this layer, foundation soils consist primarily of saturated, medium compact to very compact sand with varying amounts of gravel and silt, to a depth of approximately 35 to 65 ft. below the base of the dam. Below this granular deposit is a medium compact to very compact fine grained deposit of variable thickness overlying glacial till. On the east side, bedrock is relatively close to the bottom of the embankment.

128. The static stability of the embankment and foundation soils is adequate based on the type and relative density of the soils present and the geometry of the dam. Likewise, the stability of the concrete spillway, which bears on rock, also appears to be adequate.

129. The liquefaction susceptibility of the soils at the site was analyzed for an earthquake producing 0.06g peak acceleration at the surface of natural ground. The embankment and foundation soils are not considered to be susceptible to liquefaction for this level of earthquake shaking. Minor seismically-induced settlement of the embankment and subsoils may occur, but the settlement will not be detrimental to the performance of the structure.

130. As a result of the analyses conducted, it is the opinion of H & A of New York that a more in-depth analysis of the stability of the dam due to liquefaction or other earthquake effects is not warranted.

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ONONDAGA DAM, NEW YORK

TABLES

U. S. Army Engineer District, Buffalo
1776 Niagara Street
Buffalo, New York 14207

TABLE I

GEOLOGIC TIME SCALE

ERA	PERIOD	EPOCH	BEGINNING (TIME BEFORE PRESENT, MILLIONS OF YEARS)	DURATION (TIME BEFORE PRESENT, MILLIONS OF YEARS)
CENOZOIC	Quarternary	Holocene (recent)	0.01	
		Pleistocene	3±	2.99
	Tertiary	Pliocene	5	2±
		Miocene	25	20
		Oligocene	34	9
		Eocene	49	15
		Paleocene	64	15
MESOZOIC	Cretaceous		130	66
	Jurassic		180	50
	Triassic		220	40
PALEOZOIC	Permian		270	50
	Pennsylvanian		325	55
	Mississippian		355	30
	Devonian		410	55
	Silurian		430	20
	Ordovician		500	70
	Cambrian		600	100
PRECAMBRIAN				
FORMATION OF THE EARTH			4,600	

NOTE: Table derived from various geologic sources.

TABLE I

TABLE II

GENERALIZED STRATIGRAPHIC COLUMN - CENTRAL NEW YORK

	SYSTEM	SERIES	GROUP	FORMATION	APPROXIMATE THICKNESS IN FEET
DEVONIAN	Upper Devonian	Chautauquan	Conewango Conneaut Canadaway	(Many formations recognized in each group)	3000
		Senecan	West Falls Sonyea Genesee		2600 670 to 800 900 to 1450
				Tully Ls.	15 to 100
	Middle Devonian	Erian	Hamilton	Moscow Ludlowville Skaneateles Marcellus	160 to 240 300 300 to 500 100 to 500
				Onondaga Ls.	70 to 100
	Lower Devonian	Ulsterian	Tristates	Oriskany Ss.	0 to 10
			Helderberg	Manlius Ls. Chrysler Dol.	0 to 200 15
SILURIAN	Upper Silurian	Cayugan		Chrysler Dol. Cobleskill Ls.	15 10
			Bertie	Williamsville Dol. Scajaquada Dol. Fiddlers Green Dol.	50
			Salina	Camillus Sh. Syracuse Sh. Vernon Sh.	200 200 600
	Middle Silurian	Niagaran	Lockport Clinton	Scondondoa Ls. (Many formations)	80 to 150 320
	Lower Silurian	Albion	Medina	Grimsby Ss.	30
	Upper Ordovician			Queenston Sh.	700

TABLE II

TABLE III

DETAILED DEVONIAN STRATIGRAPHIC COLUMN
SYRACUSE MERIDIAN - ONONDAGA DAM VICINITY

SYSTEM	SERIES	GROUP	FORMATION	MEMBER	APPROXIMATE THICKNESS IN FEET
Upper Devonian	Senecan		Tully Ls.		30
Middle Devonian	Erian	Hamilton	Moscow	Windom Sh.	165
				Portland Point Ls.	12
			Ludlowville	Owasco Ss.	2
				Spafford Sh.	27
				Ivy Point Ss.	37
				Otisco Sh.	209
				Centerfield Ls. & Ss.	25
			Skaneateles	Butternut Sh.	135
				Pompey Sh. & Siltst.	60
				Delphi Station Sh. & Siltst.	125
				Mottville Ls. & Sh.	6
			Marcellus	Cardiff Sh.	180
				Chittenango Bl. Sh.	80
				Cherry Valley Ls.	3
				Union Springs Bl. Sh.	12
			Onondaga Limestone	Seneca Ls.	25
				Tioga Bentonite	.4
				Moorehouse Ls*	25
				Nedrow Ls*	10
				Edgecliff Ls*	15
Lower Devonian	Ulsterian	Tristates	Oriskany Ss*		0 to .2
		Helderberg	Manlius	Jamesville Ls*	25
				Clark Reserv. Ls.	5
				Elmwood Dol.	10
				Olney Ls.	30
			Rondout	Chrysler Dol.	30

* = Exposed in spillway of dam.

TABLE IV

EARTHQUAKES WITHIN 200 KM OF ONONDAGA DAM SITE

Year	Date	Location Lat(N)	Location Long(W)	Maximum* Intensity	Richter Magnitude	Location
1929	Aug. 12	42.9	78.4	VIII	5.8	Attica, NY
1954	Feb. 21	41.2	75.9	VII		Wilkes-Barre, PA
1840	Jan. 16	43.0	75.0	VI		Herkimer, NY
1853	Mar. 12	43.7	75.5	VI		Lowville, NY
1857	Oct. 23	43.2	78.6	VI		Buffalo, NY
1954	Feb. 24	41.2	75.9	VI		Wilkes-Barre, PA
1966	Jan. 1	42.8	78.2	VI	4.7	Attica, NY
1966	Jun. 13	42.9	78.2	VI	3.9	Attica, NY
1916	Feb. 2	42.9	74.0	V		Mohawk Valley, NY
1916	Feb. 3	43.0	74.0	V		Mohawk Valley, NY
1922	Dec. 8	44.4	75.1	V		S. of Canton, NY
1929	Dec. 2	42.8	78.3	V		Attica, NY
1952	Aug. 25	43.0	74.5	V		Johnstown, NY
1955	Jan. 21	43.0	73.8	V		Malta, NY
1955	Aug. 16	42.9	78.3	V		Attica, NY
1971	May 23	43.8	74.5	V	3.9	Blue Mt. Lake, NY
1971	May 23	43.9	74.5	V	3.6	Blue Mt. Lake, NY
1971	Jul. 10	43.9	74.5	V	3.4	Blue Mt. Lake, NY
1907	Jan. 24	42.8	74.0	IV		Schenectady, NY
1927	Mar. 14	44.6	75.4	IV		Canton, NY
1929	Dec. 3	42.8	78.3	IV		Attica, NY
1933	Oct. 29	43.0	74.7	IV		St. Johnsville, NY
1946	Oct. 28	41.5	76.6	IV	3.6	LaPorte, PA
1946	Nov. 10	42.9	77.5	IV	3.1	Canandaigua, NY
1950	Mar. 20	41.5	75.8	IV	3.3	NW of Scranton, PA
1954	Jan. 31	42.9	77.3	IV		Canandaigua, NY
1954	Feb. 1	43.0	76.7	IV	3.3	Montezuma, NY
1958	May 6	42.7	73.8	IV		Albany, NY
1960	Jan. 22	41.5	75.5	IV	3.4	Carbondale, PA
1963	Mar. 2	41.5	75.7	IV	3.4	Scranton, PA
1963	Jul. 2	42.6	73.8	IV	3.3	Albany, NY
1965	Jul. 16	43.0	78.1	IV	3.2	Attica, NY
1965	Aug. 27	43.0	78.1	IV	3.1	Attica, NY
1969	Aug. 13	43.3	78.2	IV	2.8	Albion, NY
1971	Jun. 21	43.9	74.5	IV	3.3	Blue Mt. Lake, NY
1973	Jul. 15	43.9	74.4	IV	3.4	Blue Mt. Lake, NY
1973	Jul. 15	43.9	74.4	IV	3.2	Blue Mt. Lake, NY
1973	Jul. 16	43.8	74.5	IV	3.3	Blue Mt. Lake, NY
1975	Nov. 3	43.9	74.6	IV	3.9	Raquette Lake, NY

* Modified Mercalli Intensity

Ref.: Chiburis (1981)

TABLE V

CHRONOLOGICAL LIST OF SIGNIFICANT ($I_o \geq$ VI) EARTHQUAKES WITHIN NEW YORK

Year	Date	Location Lat (N)	Location Long (W)	Region (1)	I_o (2)	M (3)
1737	Dec. 18	40.8	74.0	A	VII	
1775	July 6	43.5	73.5	B	VI	
1853	Mar. 12	43.7	75.5	B	VI	
1857	Oct. 23	43.2	78.6	C	VI	
1867	Dec. 18	44.7	75.2	B	VI	
1877	Nov. 4	45.3	74.0	B	VII	
1884	Aug. 10	40.6	74.0	A	VII	
1897	May 27	44.5	73.5	B	VI	
1929	Aug. 12	42.9	78.3	C	VIII	5.9
1931	Apr. 20	43.4	73.7	B	VII	5.0
1944	Sept. 5	45.0	74.9	B	VIII	5.9
1944	Sept. 5	45.0	74.9	B	-	4.6
1957	Mar. 23	41.6	74.8	A	VI	4.8
1966	Jan. 1	42.8	78.2	C	VI	4.7
1967	Jun. 13	42.9	78.2	C	VI	3.9
1974	Jun. 7	41.6	73.9	A	-	3.3
1975	Jun. 9	44.9	73.6	B	-	4.2

1. See Figure 6.
2. I_o = Maximum Intensity (Modified Mercalli Scale)
3. M = Generalized Magnitude

Ref.: Mitronovas (1981)

TABLE VI

LIST OF EARTHQUAKES HAVING ATTENUATED INTENSITIES GREATER THAN OR EQUAL TO IV AT THE ONONDAGA DAM SITE

EVENT	REGION	AT EPICENTER Intensity[1]	AT EPICENTER Magnitude	DISTANCE FROM SITE (KM)	ATTENUATED INTENSITY[2]
Feb. 5, 1663	La Malbaie, Quebec	10		705	4.7
Aug. 12, 1929	Attica, N. Y.	8	5.8	182	4.4
Sept. 5, 1944	Massena, N. Y.	8	5.9	252	4.0
Oct. 20, 1870	Baie-St.-Paul, Quebec	9		668	3.8
Mar. 1, 1925	La Malbaie, Quebec	9	6.6	705	3.7
June 11, 1638	La Malbaie, Quebec	9		707	3.7
1534	Les Eboulements, Quebec	9		713	3.7
Nov. 18, 1929	Grand Banks, NF	10	7.2	1608	3.6
Sept. 16, 1732	Montreal, Quebec	8		352	3.6

(1) Modified Mercalli Intensity

(2) At Dam Site

Ref: Chiburis (1981)

ONONDAGA DAM, NEW YORK

FIGURES

U. S. Army Engineer District, Buffalo
1776 Niagara Street
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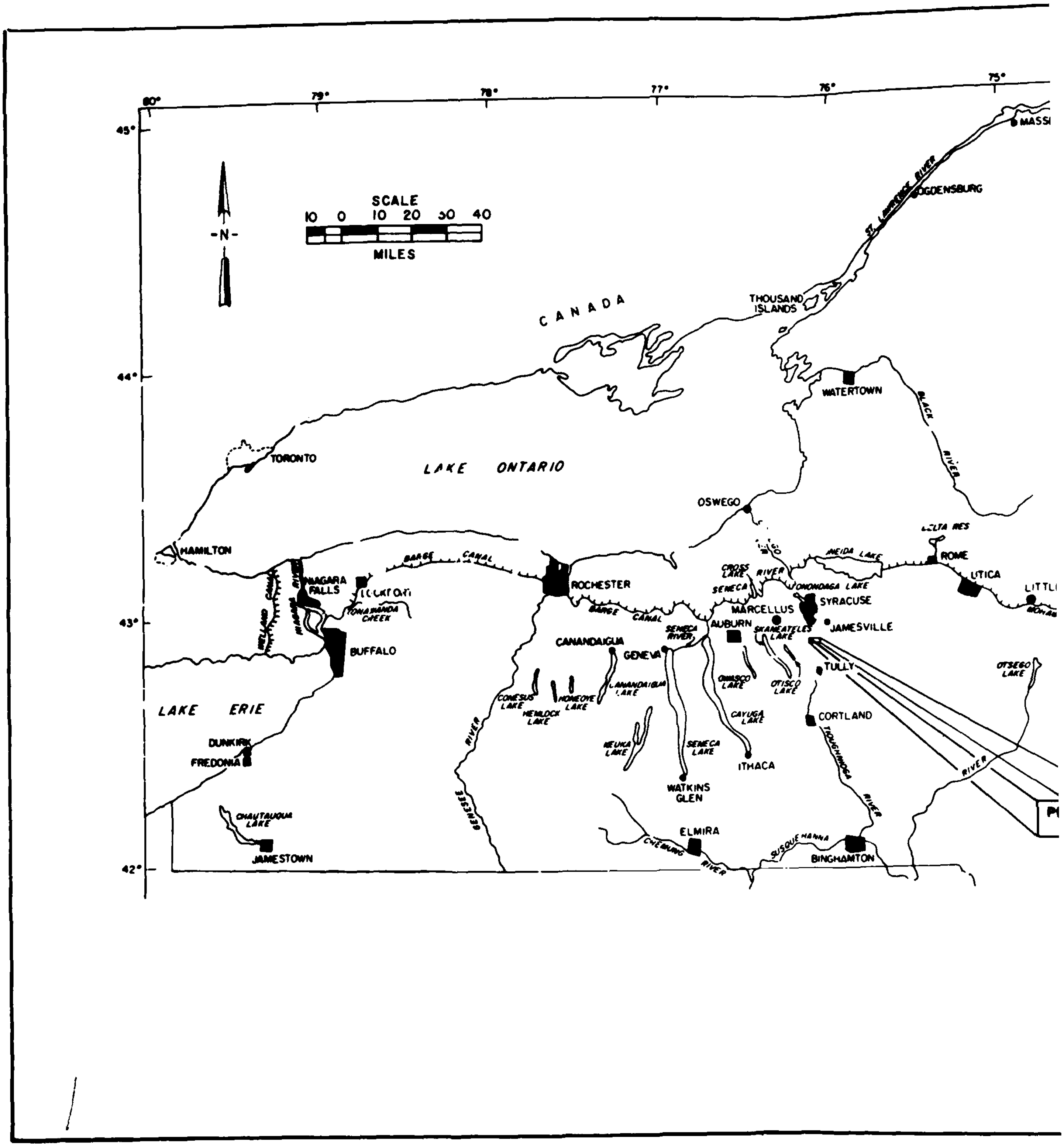
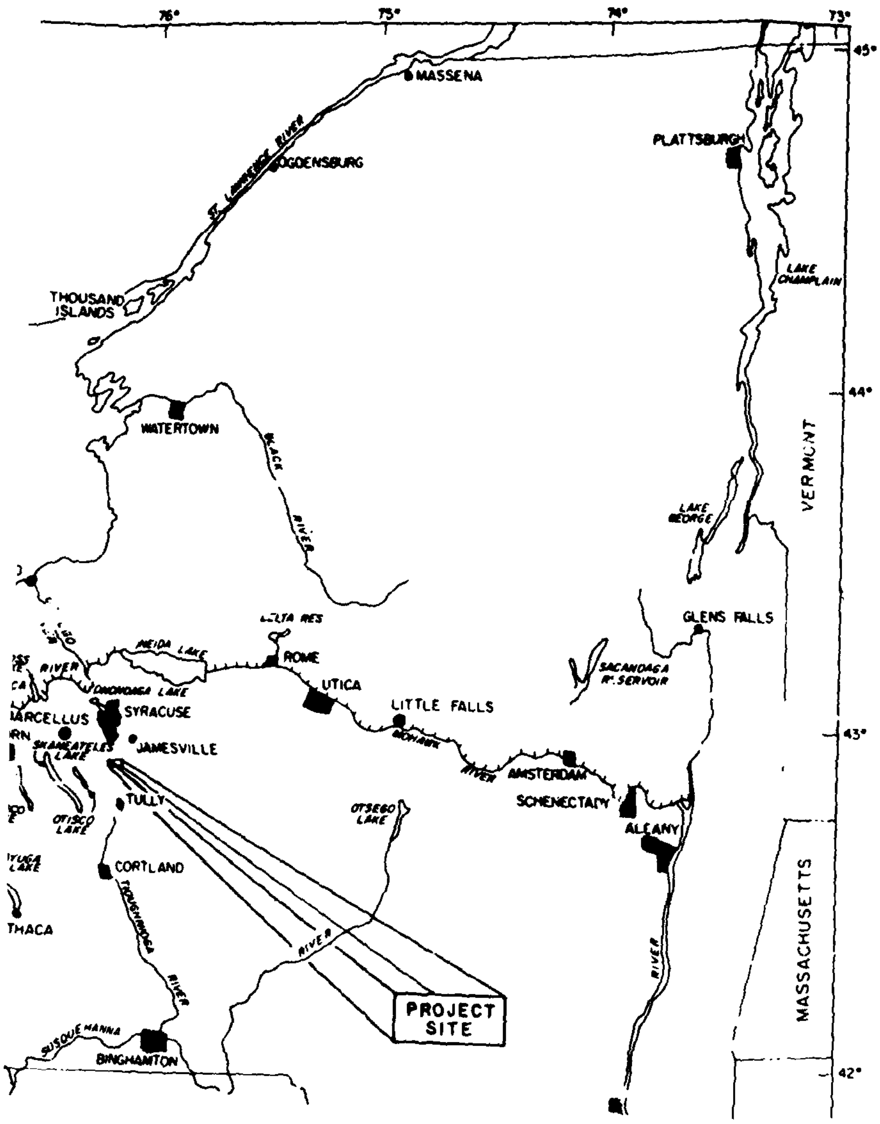


80°
79°
78°
77°
76°
75°
45°
44°
43°
42°
-N-
SCALE
10 0 10 20 30 40
MILES
CANADA
LAKE ONTARIO
LAKE ERIE
TORONTO
HAMILTON
NIAGARA FALLS
LOCKPORT
TONAWANDA CREEK
BUFFALO
DUNKIRK
FREDONIA
CHAUTAUQUA LAKE
JAMESTOWN
BARGE CANAL
ROCHESTER
GENESEE RIVER
CANANDAIGUA
CANANDAIGUA LAKE
CONESUS LAKE
HEMLOCK LAKE
HONEOYE LAKE
KEUKA LAKE
GENEVA
SENECA RIVER
SENECA LAKE
WATKINS GLEN
ELMIRA
CHEMUNG RIVER
AUBURN
OWASCO LAKE
CAYUGA LAKE
ITHACA
MARCELLUS
SKANEATELES LAKE
OTISCO LAKE
SYRACUSE
JAMESVILLE
TULLY
CORTLAND
TIOUGHNIOGA RIVER
SUSQUEHANNA RIVER
BINGHAMTON
CROSS LAKE
SENECA RIVER
ONONDAGA LAKE
ONEIDA LAKE
OSWEGO
ROME
UTICA
OTSEGO LAKE
WATERTOWN
BLACK RIVER
THOUSAND ISLANDS
ST. LAWRENCE RIVER
OGDENSBURG



ONONDAGA DAM, NEW YORK

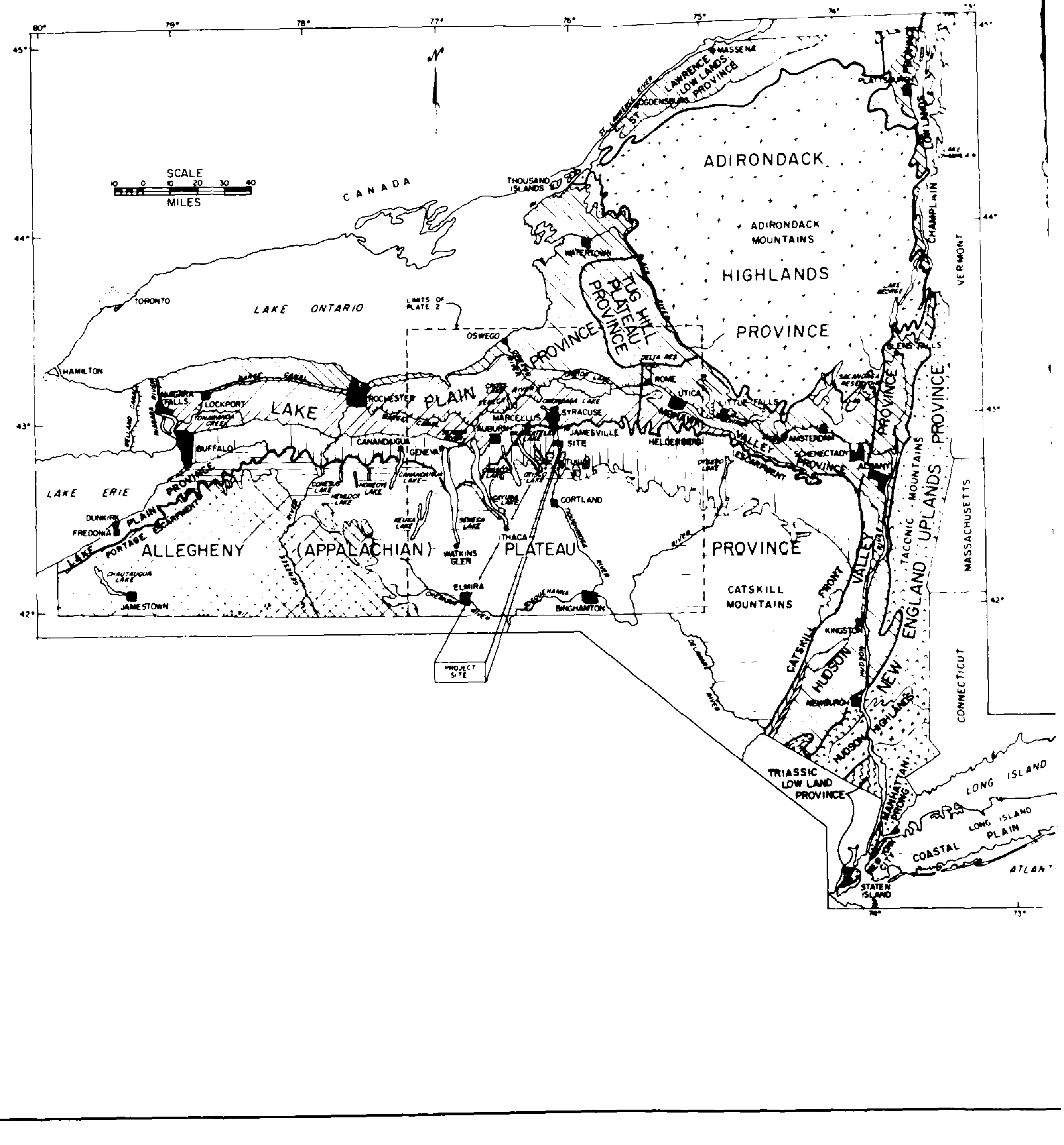
PROJECT LOCUS

U.S. ARMY ENGINEER DISTRICT BUFFALO

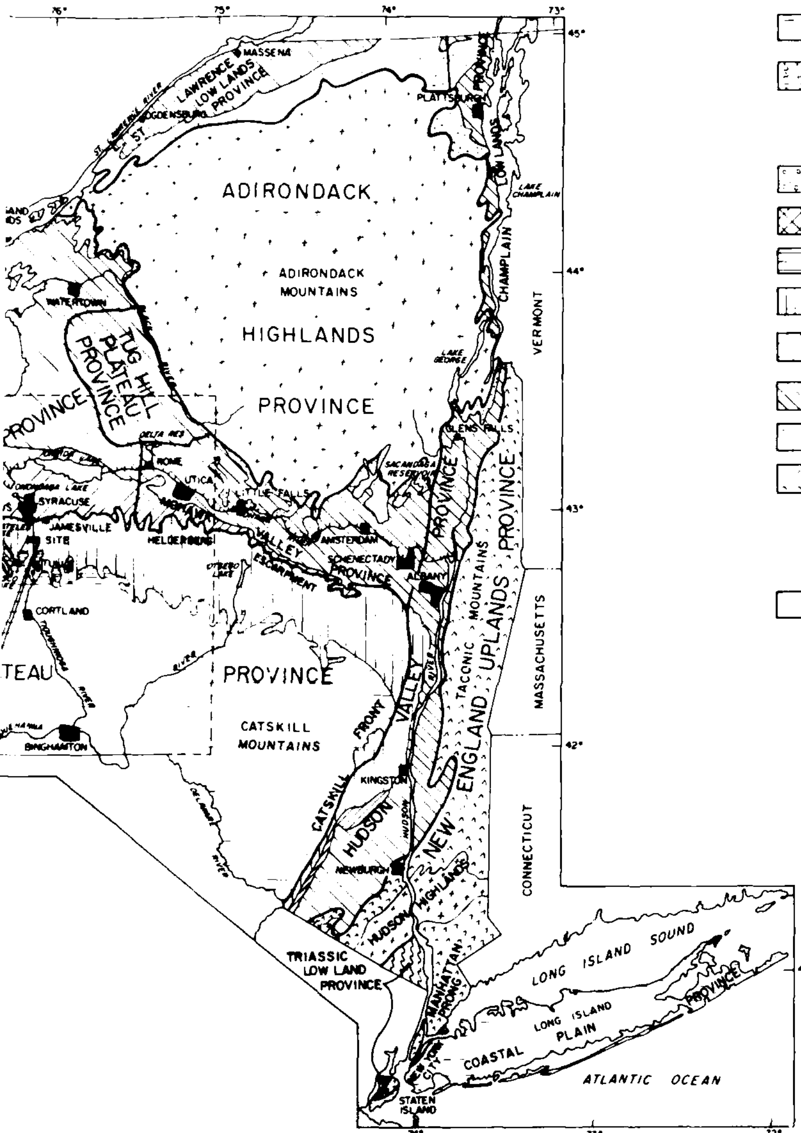
TO ACCOMPANY PHASE I, SEISMIC STABILITY INVESTIGATION

DATED: AUGUST 1982

FIGURE 1



SCALE
MILES
CANADA
LAKE ONTARIO
TORONTO
HAMILTON
LIMITS OF PLATE 2
LAKE ERIE
ADIRONDACK
ADIRONDACK MOUNTAINS
HIGHLANDS
PROVINCE
TUG HILL PLATEAU PROVINCE
ST. LAWRENCE LOW LANDS PROVINCE
THOUSAND ISLANDS
WATERTOWN
OSWEGO
LAKE PLAIN PROVINCE
ROCHESTER
LOCKPORT
BUFFALO
SYRACUSE
MARCELLUS
JAMESVILLE SITE
AUBURN
GENEVA
CANANDAIGUA
ROME
UTICA
SCHENECTADY
ALBANY
AMSTERDAM
ALLEGHENY (APPALACHIAN) PLATEAU PROVINCE
PORTAGE ESCARPMENT
DUNKIRK
FREDONIA
JAMESTOWN
WATKINS GLEN
ITHACA
CORTLAND
ELMIRA
BINGHAMTON
PROJECT SITE
CATSKILL MOUNTAINS
CATSKILL FRONT
HUDSON VALLEY PROVINCE
KINGSTON
NEWBURGH
HUDSON HIGHLANDS
NEW ENGLAND UPLANDS PROVINCE
TACONIC MOUNTAINS
TRIASSIC LOW LAND PROVINCE
MANHATTAN PRONG
STATEN ISLAND
LONG ISLAND
COASTAL PLAIN
VERMONT
MASSACHUSETTS
CONNECTICUT
PLATTSBURGH
MASSENA
OGDENSBURG



LEGEND:

APPROXIMATE BOUNDARY OF PHYSIOGRAPHIC PROVINCES

MESOZOIC ERA

- CRETACEOUS (UPPER) CLAY, SAND AND GRAVEL (UNCONSOLIDATED BEDROCK)
- TRIASSIC (UPPER) RED SANDSTONE, SHALE, AND CONGLOMERATE, INTRUDED BY PALISADES SILL

PALEOZOIC ERA

- PENNSYLVANIAN AND MISSISSIPIAN CONGLOMERATE
- DEVONIAN (LATE UPPER) SHALE, SILTSTONE, SANDSTONE
- DEVONIAN (EARLY UPPER): SHALE, SILTSTONE, SANDSTONE
- DEVONIAN (LOWER AND MIDDLE): LIMESTONE OVERLAIN BY SHALE, SILTSTONE AND SANDSTONE
- SILURIAN: DOLOSTONE, LIMESTONE, SHALE, SALTBEDS, SANDSTONE, CONGLOMERATE IN SOUTHEASTERN PART OF STATE
- ORDOVICIAN MAINLY SHALE AND SANDSTONE IN UPPER PART, LIMESTONE AND DOLOSTONE IN LOWER
- CAMBRIAN SANDSTONE AND QUARTZOSE DOLOSTONE
- PRECAMBRIAN, CAMBRIAN, ORDOVICIAN: INTENSELY FOLDED AND THRUST-FAULTED, SLATE, PHYLLITE, SCHIST, GNEISS, GRAYWACKE, SERPENTINE ON STATEN ISLAND, ALSO SHALES, LIMESTONE AND MARBLE

PRECAMBRIAN

- METAMORPHIC AND IGNEOUS ROCKS, STRUCTURALLY COMPLEX

NOTES:

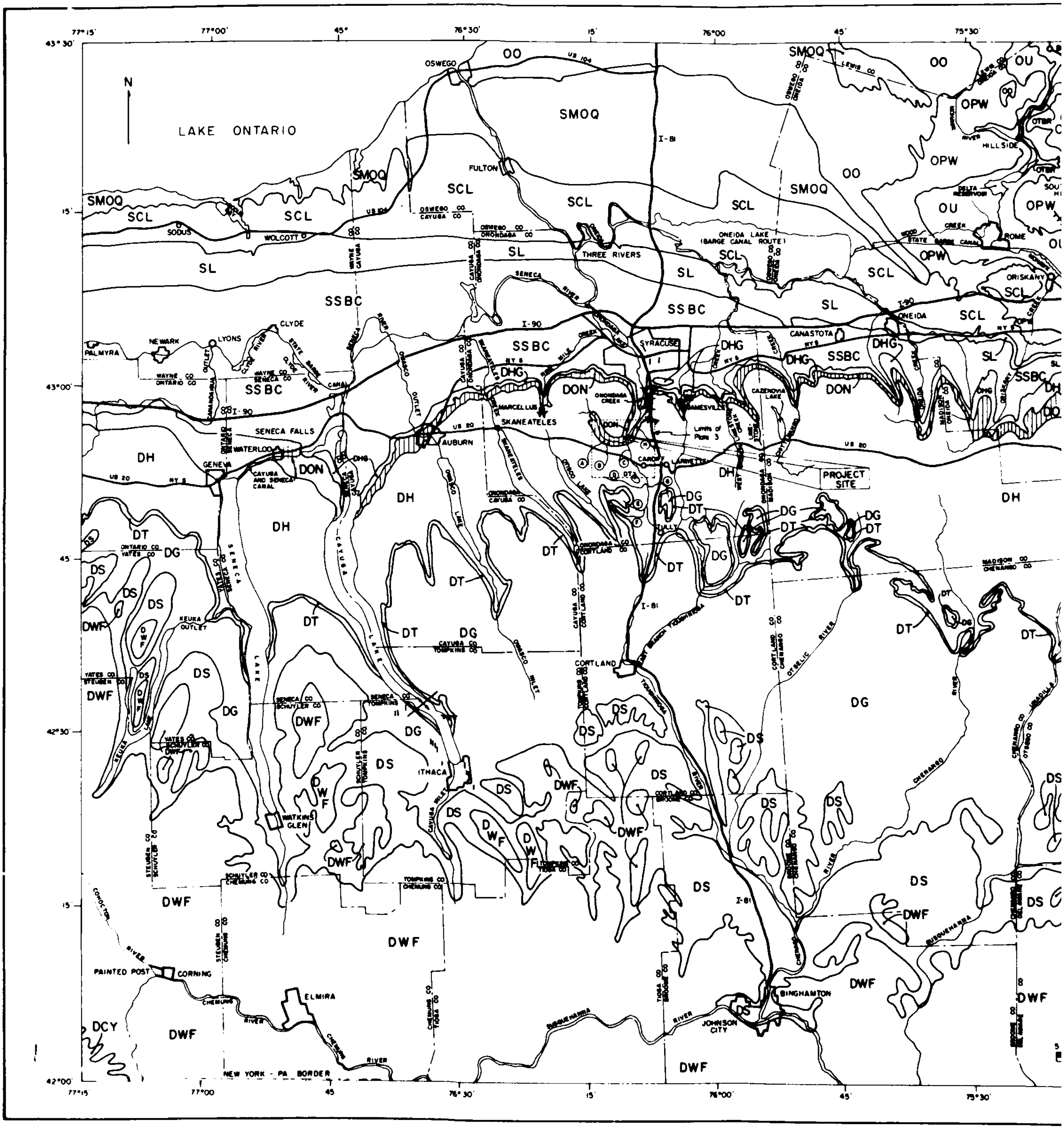
1. BOUNDARIES OF PHYSIOGRAPHIC PROVINCES APPROXIMATE
2. SEE TABLE I FOR GEOLOGIC TIME SCALE.
3. SEE TEXT AND TABLES II AND III FOR DETAILS ON STRATIGRAPHY AND BEDROCK GEOLOGY OF CENTRAL NEW YORK
4. SEE FIGURE 3, GEOLOGIC MAP OF CENTRAL NEW YORK AND FIGURE 4, SITE GEOLOGIC MAP FOR ADDITIONAL INFORMATION ON BEDROCK GEOLOGY AND STRUCTURE

ONONDAGA DAM, NEW YORK

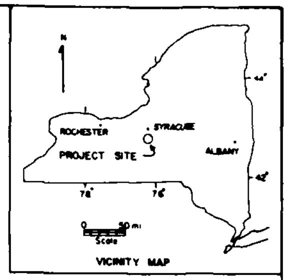
PHYSIOGRAPHIC PROVINCES AND GENERAL BEDROCK GEOLOGY OF NEW YORK STATE

US ARMY ENGINEER DISTRICT BUFFALO
TO ACCOMPANY PHASE I, SEISMIC STABILITY INVESTIGATION
DATED NOVEMBER 1982

FIGURE 2



LAKE ONTARIO
N
OSWEGO
FULTON
SODUS
WOLCOTT
THREE RIVERS
SYRACUSE
ONEIDA LAKE (BARGE CANAL ROUTE)
CANASTOTA
ONEIDA
ROME
ORISKANY
DELTA RESERVOIR
PALMYRA
NEWARK
LYONS
CLYDE
SENECA FALLS
WATERLOO
GENEVA
AUBURN
MARCELLUS
SKANEATELES
CAZENOVIA LAKE
PROJECT SITE
Limits of Plate 3
TULLY
CORTLAND
ITHACA
WATKINS GLEN
PAINTED POST
CORNING
ELMIRA
BINGHAMTON
JOHNSON CITY
NEW YORK - PA BORDER
CAYUGA LAKE
SENECA LAKE
KEUKA LAKE
US 104
US 20
I-90
I-81
SMOQ
SCL
SL
SSBC
OO
OU
OPW
DH
DHG
DON
DT
DG
DS
DWF
DCY
43°30'
43°00'
42°30'
42°00'
77°15'
77°00'
76°30'
76°00'
75°30'



LEGEND

QUATERNARY	Q	ALLUVIAL AND GLACIAL SURFACE DEPOSITS - UNDERLYING BEDROCK GEOLOGY UNKNOWN
UPPER DEVONIAN	DCY	CANADAWAY GROUP - SHALE, SILTSTONE, SANDSTONE
	DWF	WEST FALLS GROUP - SHALE, SILTSTONE, SANDSTONE
	DS	SONYEA GROUP - SHALE, SILTSTONE
	DG	GENESEE GROUP - LIMESTONE, SHALE, SILTSTONE
	DT	TULLY LIMESTONE
MIDDLE DEVONIAN	DH	HAMILTON GROUP - LIMESTONE, SHALE, SANDSTONE
	DON	ONONDAGA LIMESTONE
LOWER DEVONIAN	DHG	HELDERBERG GROUP - LIMESTONE, DOLOSTONE
UPPER SILURIAN	SSBC	SALINA GROUP, BERTIE FORMATION, COBBLESKILL LIMESTONE - LIMESTONE, DOLOSTONE, SHALE, GYPSUM, SALT
	SL	LOCKPORT GROUP - LIMESTONE, DOLOSTONE
LOWER SILURIAN	SCL	CLINTON GROUP - LIMESTONE, SHALE, SANDSTONE
	SMOQ	QUEENSTON FORMATION AND MEDINA GROUP - SHALE, SILTSTONE, SANDSTONE
UPPER ORDOVICIAN	OO	OSWEGO SANDSTONE
	OPW	PULASKI, WHETSTONE GULF FORMATIONS - SHALE, SILTSTONE
	OF	FRANKFORT FORMATION - SHALE, SILTSTONE
MIDDLE ORDOVICIAN	OU	UTICA SHALE
	OTBR	TRENTON AND BLACK RIVER GROUPS - LIMESTONE
UPPER CAMBRIAN	CLF	LITTLE FALLS FORMATION - DOLOSTONE
PRE-CAMBRIAN	PC	PRECAMBRIAN METASEDIMENTARY AND METAMORPHIC ROCKS

NORMAL FAULT - HACHURES ON RELATIVELY DOWNTHROWN SIDE

THRUST FAULT - SAWTEETH ON RELATIVELY OVERTHRUST BLOCK

ANTICLINE / SYNCLINE - ARROWS INDICATE DIRECTION OF DIP

MESOZOIC INTRUSIVE ROCKS (DIKES)

NOTES

1. CONTACTS BETWEEN ROCK UNITS APPROXIMATE
2. SEE TABLE I FOR GEOLOGIC TIME SCALE
3. SEE TEXT AND TABLES II AND III FOR DETAILS OF STRATIGRAPHY AND BEDROCK GEOLOGY OF CENTRAL NEW YORK STATE
4. SEE FIGURE 2, PHYSIOGRAPHIC PROVINCES AND GENERAL BEDROCK GEOLOGY OF NEW YORK STATE, AND FIGURE 4, SITE GEOLOGIC MAP, FOR ADDITIONAL BEDROCK GEOLOGY AND STRUCTURE
5. ONONDAGA CREEK TRIBUTARIES DESIGNATED THUS Ⓐ PEPPER-MILL GULF, Ⓑ LORDS HILL RAVINE, Ⓒ CASE HILL RAVINE, Ⓓ BARE MT RAVINE, Ⓔ EMERSON GULF, Ⓕ FELLOWS FALLS RAVINE, Ⓖ RAINBOW CREEK, Ⓗ HEMLOCK CREEK

ONONDAGA DAM, NEW YORK

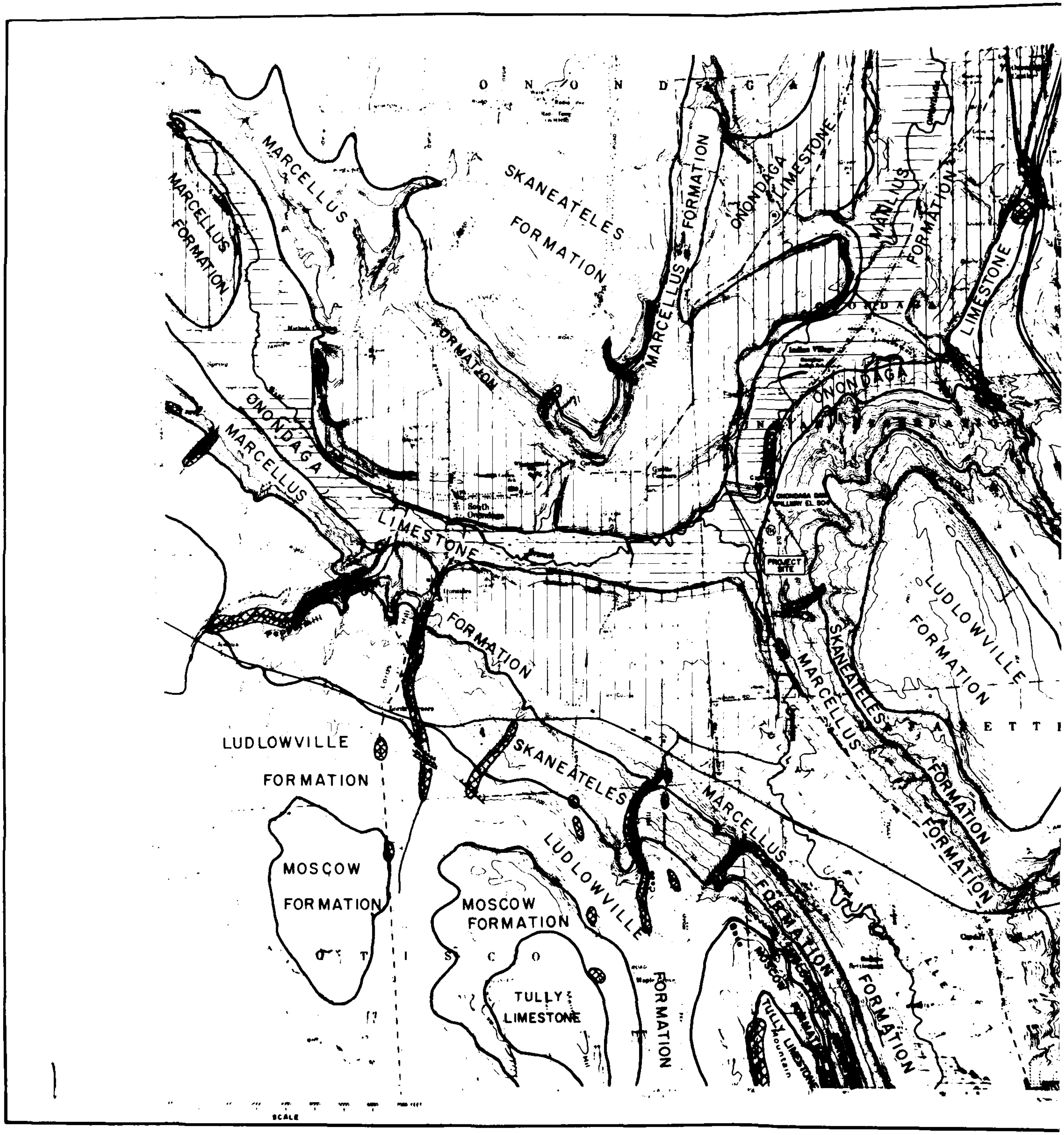
GEOLOGIC MAP OF CENTRAL NEW YORK STATE

US ARMY ENGINEER DISTRICT BUFFALO

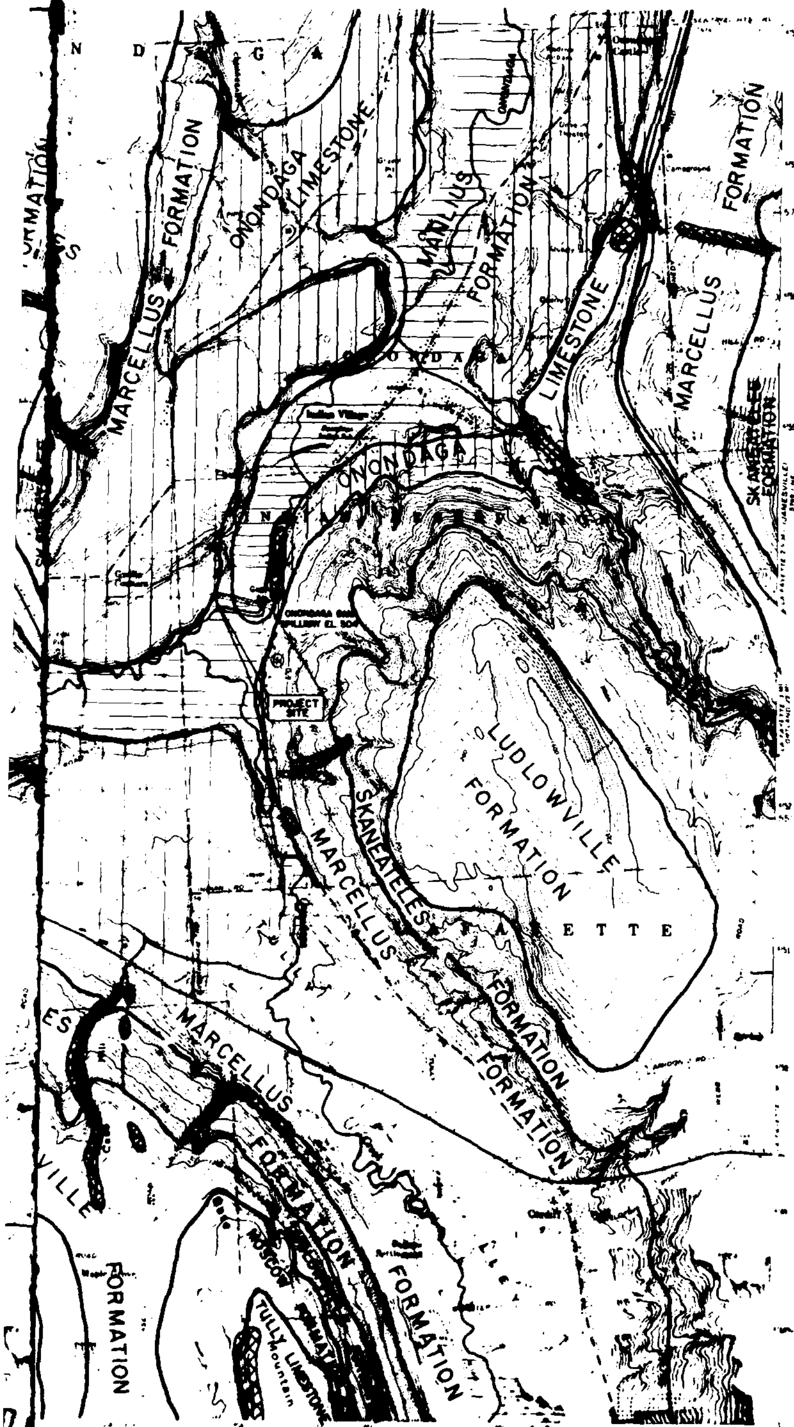
TO ACCOMPANY PHASE I, SEISMIC STABILITY INVESTIGATION

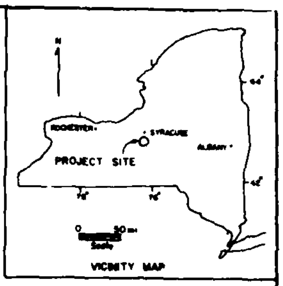
DATED NOVEMBER 1982

FIGURE 3



O N O N D A G A
MARCELLUS FORMATION
MARCELLUS
SKANEATELES FORMATION
MARCELLUS FORMATION
ONONDAGA LIMESTONE
MANLIUS FORMATION
LIMESTONE
ONONDAGA
MARCELLUS
ONONDAGA
LIMESTONE
FORMATION
FORMATION
PROJECT SITE
LUDLOWVILLE FORMATION
SKANEATELES
MARCELLUS
LUDLOWVILLE FORMATION
SKANEATELES
MARCELLUS
FORMATION
FORMATION
MOSCOW FORMATION
LUDLOWVILLE
MOSCOW FORMATION
TULLY LIMESTONE
FORMATION
FORMATION
FORMATION
TULLY LIMESTONE
SCALE





LEGEND:

- CONTACT BETWEEN BEDROCK FORMATIONS
- APPROXIMATE EXTENT OF MAJOR BEDROCK EXPOSURES
- APPROXIMATE AXIS OF BROAD, GENTLE ANTICLINE
- APPROXIMATE LOCATION OF THRUST FAULT. SAWTEETH ON RELATIVELY OVERTHRUST BLOCK
- NORMAL FAULT – HACHURES ON RELATIVELY DOWNTHROWN SIDE

GEOLOGIC FORMATIONS:

QUATERNARY

- ONONDAGA CREEK OVERBANK DEPOSITS
- PLEISTOCENE SAND AND GRAVEL TERRACES (HANGING DELTAS)

UPPER DEVONIAN
TULLY LIMESTONE

MIDDLE DEVONIAN
HAMILTON GROUP
MOSCOW FORMATION - SHALE
LUDLOWVILLE FORMATION - SILTY SHALE, SILTSTONE
SKANEATELES FORMATION - DARK GRAY TO BLACK SHALE AND SILTSTONE
MARCELLUS FORMATION - DARK GRAY AND BLACK SHALE
ONONDAGA LIMESTONE

LOWER DEVONIAN
ORISKANY SANDSTONE - HORIZON AT BASE OF ONONDAGA LIMESTONE
HELDERBERG GROUP:
MANLIUS FORMATION - LIMESTONE, DOLOSTONE

NOTES:

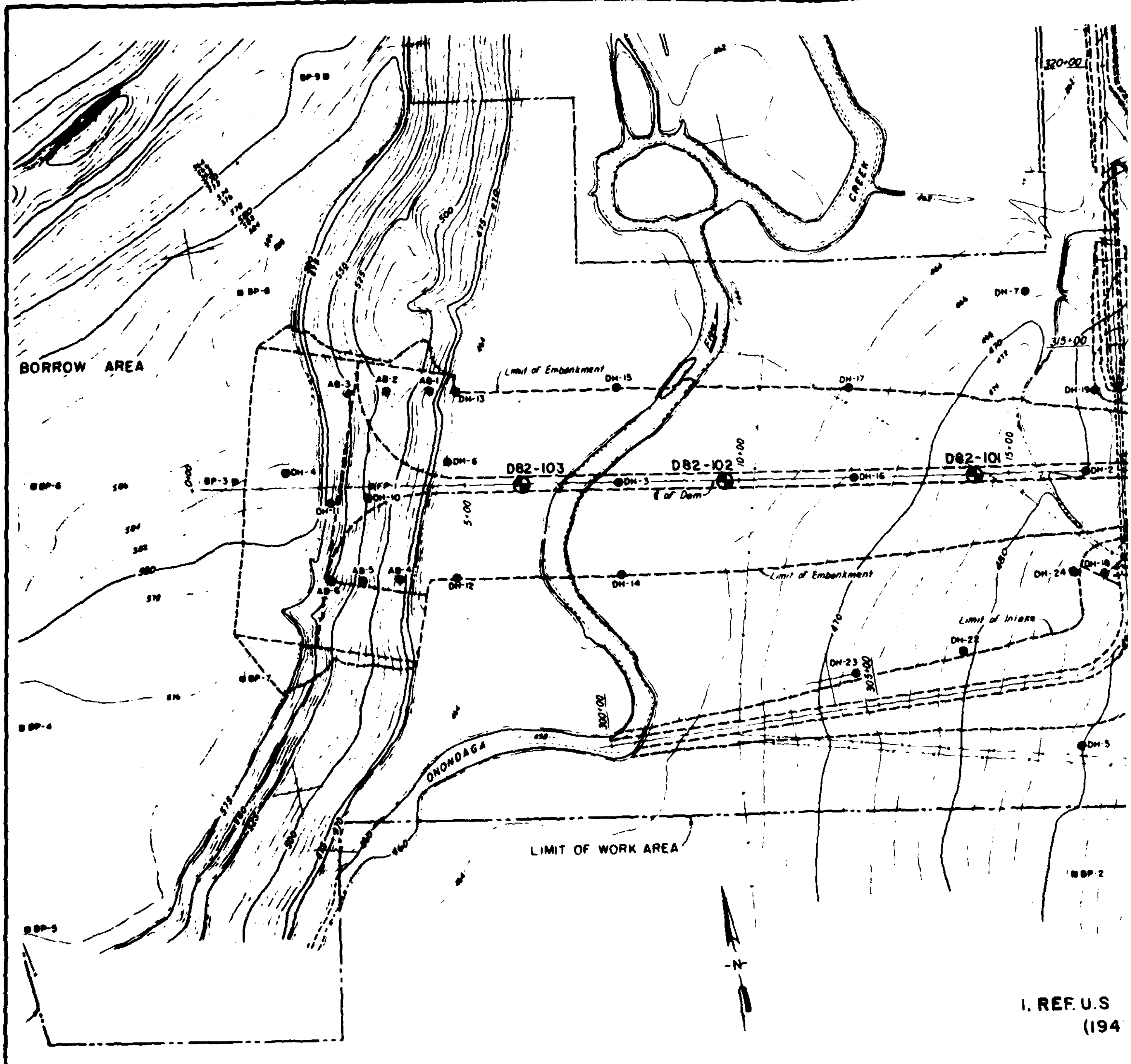
1. SEE TEXT FOR DETAILED DESCRIPTIONS OF GEOLOGIC UNITS INCLUDING ROCK FORMATIONS AND ASSOCIATED MEMBERS AND SUBMEMBERS
2. SEE TABLE I, GEOLOGIC TIME SCALE FOR RELATIVE AGES OF ROCK UNITS
3. BEDROCK CONTACT LINES AND LOCATIONS OF QUATERNARY DEPOSITS ARE APPROXIMATE AND BASED ON GEOLOGIC LITERATURE REVIEW AND FIELD MAPPING BY H & A OF NEW YORK PERSONNEL DURING THE FALL OF 1981
4. CONTACT LINES FOR THE ONONDAGA LIMESTONE AND MANLIUS FORMATION ARE GENERALLY BURIED BENEATH QUATERNARY DEPOSITS AND ARE THEREFORE INFERRED FROM AVAILABLE GEOLOGIC INFORMATION AND OBSERVATIONS
5. CONTACT LINES FOR UNITS ABOVE THE ONONDAGA LIMESTONE ARE EITHER OBSERVED OR CLOSELY APPROXIMATED AS MANY SMALLER EXPOSURES OF THESE UNITS EXIST ALONG THE VALLEY WALLS BETWEEN THE MAJOR BEDROCK EXPOSURES
6. THE TOPS AND SIDES OF HILLS ARE GENERALLY BEDROCK OVERLAIN BY A MANTLE OF GLACIAL TILL
7. BASE MAP OBTAINED FROM USGS QUADRANGLE SOUTH ONONDAGA, NEW YORK

ONONDAGA DAM, NEW YORK

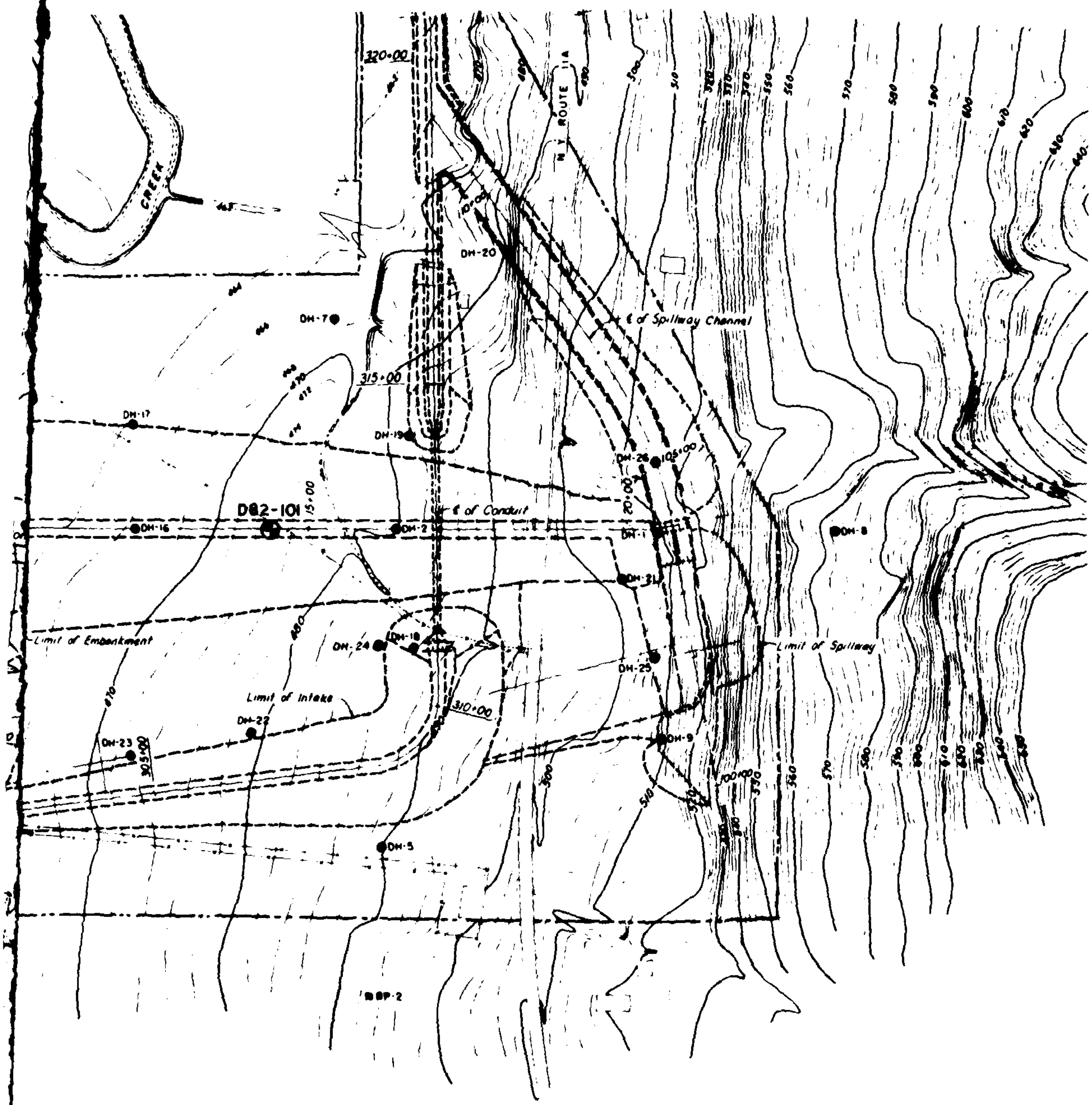
SITE GEOLOGIC MAP

US ARMY ENGINEER DISTRICT BUFFALO
TO ACCOMPANY PHASE I, SEISMIC STABILITY INVESTIGATION
DATED NOVEMBER 1982

FIGURE 4



NOTE: SEE FIGURE 6 FOR EXPLORATION DETAILS.



1. REF. U.S ARMY CORPS OF ENGINEERS. (1947)

2

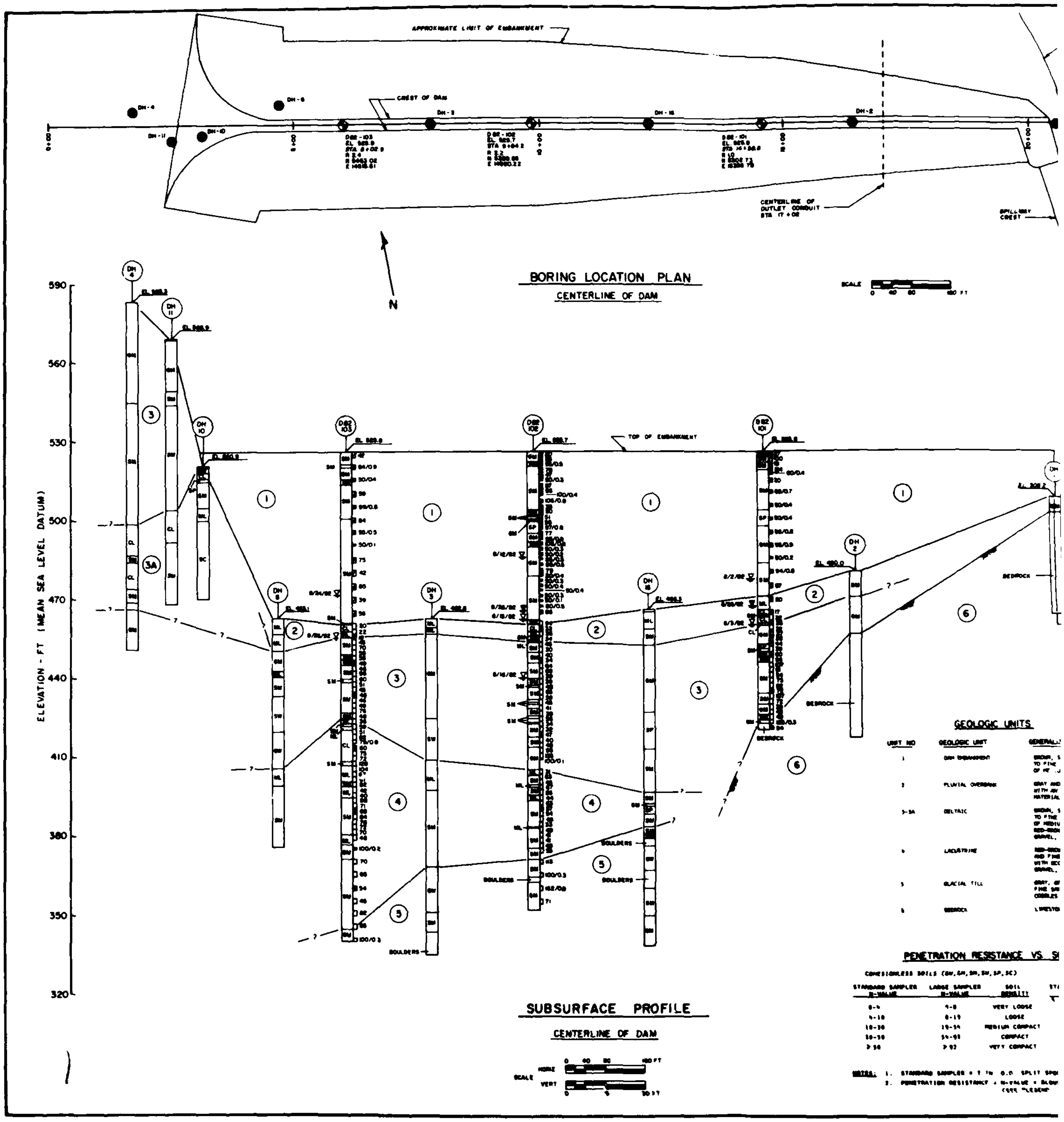
ONONDAGE DAM, NEW YORK

SITE AND SUBSURFACE EXPLORATION PLAN

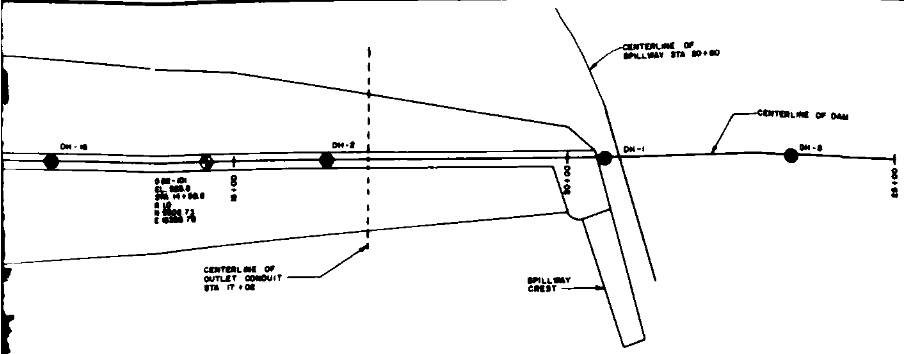
U.S. ARMY ENGINEER DISTRICT BUFFALO

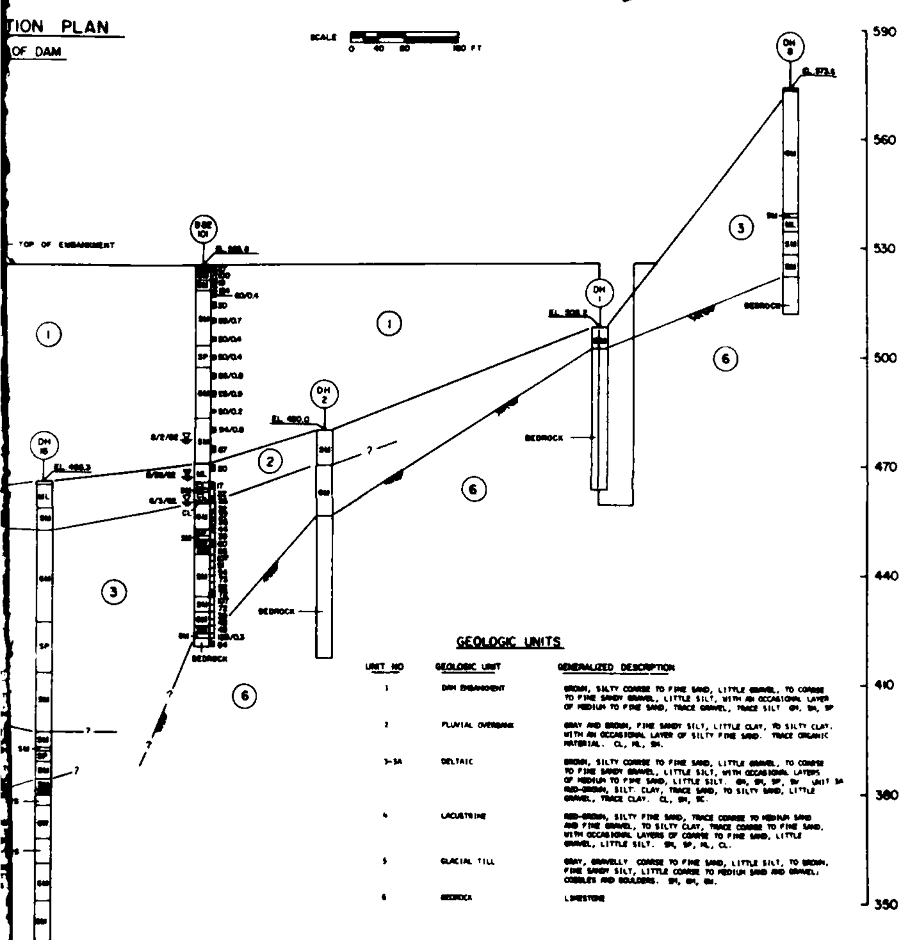
TO ACCOMPANY PHASE I, SEISMIC STABILITY INVESTIGATION DATED AUGUST [illegible]

FIGURE 5



APPROXIMATE LIMIT OF EMBANKMENT
CREST OF DAM
CENTERLINE OF OUTLET CONDUIT STA 17+02
SPILLWAY CREST
BORING LOCATION PLAN
CENTERLINE OF DAM
N
TOP OF EMBANKMENT
ELEVATION - FT (MEAN SEA LEVEL DATUM)
590
560
530
500
470
440
410
380
350
320
BOULDERS
BEDROCK
GEOLOGIC UNITS
UNIT NO
GEOLOGIC UNIT
DAM EMBANKMENT
FLUVIAL OVERBANK
DELTAIC
LACUSTRINE
GLACIAL TILL
BEDROCK
PENETRATION RESISTANCE VS. S
SUBSURFACE PROFILE
CENTERLINE OF DAM
SCALE
HORIZ
VERT





LEGEND: SUBSURFACE EXPLORATION PLAN

D82-102 EL 525.7 STA 9+84.2 R 2.2 N 5389.85 E 4890.22 — LOCATION, NUMBER, GROUND SURFACE ELEVATION, DAM CENTERLINE STATION, OFFSET (R 2.2), AND COORDINATES OF 1982 TEST BORING

DH-16 — LOCATION AND NUMBER OF 1946 DESIGN PHASE TEST BORING

NOTES:

1. TEST BORING NOS D82-101 THROUGH D82-105 DRILLED BY PARRATT-WOLFF, INC, UNDER H&A OF NEW YORK OBSERVATION DURING THE PERIOD 28 JULY TO 27 AUGUST 1982
2. SUBSURFACE EXPLORATION LOCATIONS AND GROUND SURFACE ELEVATIONS OF 1982 TEST BORINGS PROVIDED BY ROWELL & ASSOCIATES, PC, USING BASE INFORMATION OBTAINED IN "PLANS FOR ONONDAGA DAM, ONONDAGA CREEK, SYRACUSE, N.Y." DATED 1947 DATUM USGS-MSL
3. SUBSURFACE PROFILE IS ORIENTED ALONG CENTERLINE OF DAM
4. TEST BORINGS DH-1 THROUGH DH-4, DH-6, DH-8, DH-10, DH-11, AND DH-16 WERE DRILLED FOR DESIGN OF DAM. LOCATIONS AND ELEVATIONS OBTAINED FROM A PLAN ENTITLED "PLAN OF FOUNDATION EXPLORATION" BY US ENGINEER OFFICE, SYRACUSE DISTRICT, SYRACUSE, N.Y., DATED 25 AUGUST 1945. RECOVERED SOIL AND ROCK SAMPLES, SAMPLE LOCATIONS AND BLOW COUNT OR CORE RECOVERY DATA WERE NOT AVAILABLE. SEE APPENDIX C FOR DETAILED SOIL LOGS AND ORIGINAL SUBSURFACE PROFILE
5. SOIL AND ROCK STRATIFICATION LINES ARE GRADATIONAL AND INTERPOLATED FROM SOIL AND ROCK CONDITIONS REVEALED AT SUBSURFACE EXPLORATIONS. ACTUAL CONDITIONS BETWEEN EXPLORATIONS MAY VARY
6. UNIFIED SOIL CLASSIFICATION SYSTEM SYMBOL BASED ON SOIL DESCRIPTIONS OF ORIGINAL TEST BORINGS, AND VISUAL DESCRIPTIONS AND LABORATORY TEST RESULTS OF RECENT TEST BORINGS
7. SEE ACCOMPANYING REPORT FOR ADDITIONAL INFORMATION

LEGEND: SUBSURFACE PROFILE

- D82-101 — SUBSURFACE EXPLORATION NUMBER
- EL 525.6 — GROUND SURFACE ELEVATION - DATUM USGS MEAN SEA LEVEL
- 30 — LOCATION OF SOIL SAMPLE OBTAINED BY 3.5-IN O.D. BY 2.875-IN I.D. SPLIT SPOON SAMPLER. PARTIALLY CLOSED SYMBOL INDICATES SAMPLE USED FOR LABORATORY TESTING. NUMBER IS THE BLOWS OF A 300 LB HAMMER FALLING FREELY FOR 18 IN TO DRIVE THE SAMPLER 1.0 FT
- ML — UNIFIED SOIL CLASSIFICATION SYSTEM SYMBOL
- 22 — LOCATION OF SOIL SAMPLE OBTAINED BY 2.0-IN O.D. BY 1.375-IN I.D. SPLIT SPOON SAMPLER. CLOSED SAMPLE INDICATES SAMPLE USED FOR LABORATORY TESTING. NUMBER IS THE BLOWS OF A 140 LB HAMMER FALLING FREELY FOR 30 IN TO DRIVE THE SAMPLER 1.0 FT
- 85/0.3 — NUMBER OF BLOWS AS DESCRIBED ABOVE FOR INDICATED PENETRATION IN FEET
- APPROXIMATE SOIL STRATIFICATION LINE. QUESTION MARKS INDICATE HIGH DEGREE OF UNCERTAINTY
- 8/26/82 — WATER LEVEL RECORDED IN ADJACENT OBSERVATION WELL. OPEN SYMBOL INDICATES WATER LEVEL OBSERVED IN BOREHOLE DURING DRILLING OF TEST BORING. DATE OF OBSERVATION INDICATED
- APPROXIMATE TOP OF BEDROCK
- 84 — LOCATION OF ROCK CORE RUN. NUMBER INDICATES THE PERCENT CORE RECOVERY

GEOLOGIC UNITS

UNIT NO	GEOLOGIC UNIT	GENERALIZED DESCRIPTION
1	DAM EMBANKMENT	BROWN, SILTY COARSE TO FINE SAND, LITTLE GRAVEL, TO COARSE TO FINE SANDY GRAVEL, LITTLE SILT, WITH AN OCCASIONAL LAYER OF MEDIUM TO FINE SAND, TRACE GRAVEL, TRACE SILT. GM, SM, SP
2	FLUVIAL OVERBANK	GRAY AND BROWN, FINE SANDY SILT, LITTLE CLAY, TO SILTY CLAY, WITH AN OCCASIONAL LAYER OF SILTY FINE SAND. TRACE ORGANIC MATERIAL. CL, ML, SM.
3-3A	DELTAIC	BROWN, SILTY COARSE TO FINE SAND, LITTLE GRAVEL, TO COARSE TO FINE SANDY GRAVEL, LITTLE SILT, WITH OCCASIONAL LAYERS OF MEDIUM TO FINE SAND, LITTLE SILT. GM, SM, SP, SW. UNIT 3A RED-BROWN, SILTY CLAY, TRACE SAND, TO SILTY SAND, LITTLE GRAVEL, TRACE CLAY. CL, SM, SC.
4	LACUSTRINE	RED-BROWN, SILTY FINE SAND, TRACE COARSE TO MEDIUM SAND AND FINE GRAVEL, TO SILTY CLAY, TRACE COARSE TO FINE SAND, WITH OCCASIONAL LAYERS OF COARSE TO FINE SAND, LITTLE GRAVEL, LITTLE SILT. SM, SP, ML, CL.
5	GLACIAL TILL	GRAY, GRAVELLY COARSE TO FINE SAND, LITTLE SILT, TO BROWN, FINE SANDY SILT, LITTLE COARSE TO MEDIUM SAND AND GRAVEL, COBBLES AND BOULDERS. SM, GM, ML.
6	BEDROCK	LIMESTONE

PENETRATION RESISTANCE VS. SOIL DENSITY/CONSISTENCY

COHESIONLESS SOILS (GW,GM,SM,SW,SP,SC)			COHESIVE SOILS (CL,ML)		
STANDARD SAMPLER N-VALUE	LARGE SAMPLER N-VALUE	SOIL DENSITY	STANDARD SAMPLER N-VALUE	LARGE SAMPLER N-VALUE	SOIL CONSISTENCY
0-4	0-8	VERY LOOSE	0-2	0-2	VERY SOFT
4-10	8-19	LOOSE	2-4	2-4	SOFT
10-30	19-54	MEDIUM COMPACT	4-8	4-9	MEDIUM STIFF
30-50	54-92	COMPACT	8-15	9-17	STIFF
> 50	> 92	VERY COMPACT	15-30	17-36	VERY STIFF
			> 30	> 30	HARD

NOTES:
1. STANDARD SAMPLER = 2 IN. O.D. SPLIT SPOON; LARGE SAMPLER = 3.5 IN. O.D. SPLIT SPOON
2. PENETRATION RESISTANCE = N-VALUE = BLOWS REQUIRED TO DRIVE SAMPLER 1.0 FT. (SEE "LEGEND: SUBSURFACE PROFILE" FOR ADDITIONAL DETAILS.)

ONONDAGA DAM, NEW YORK

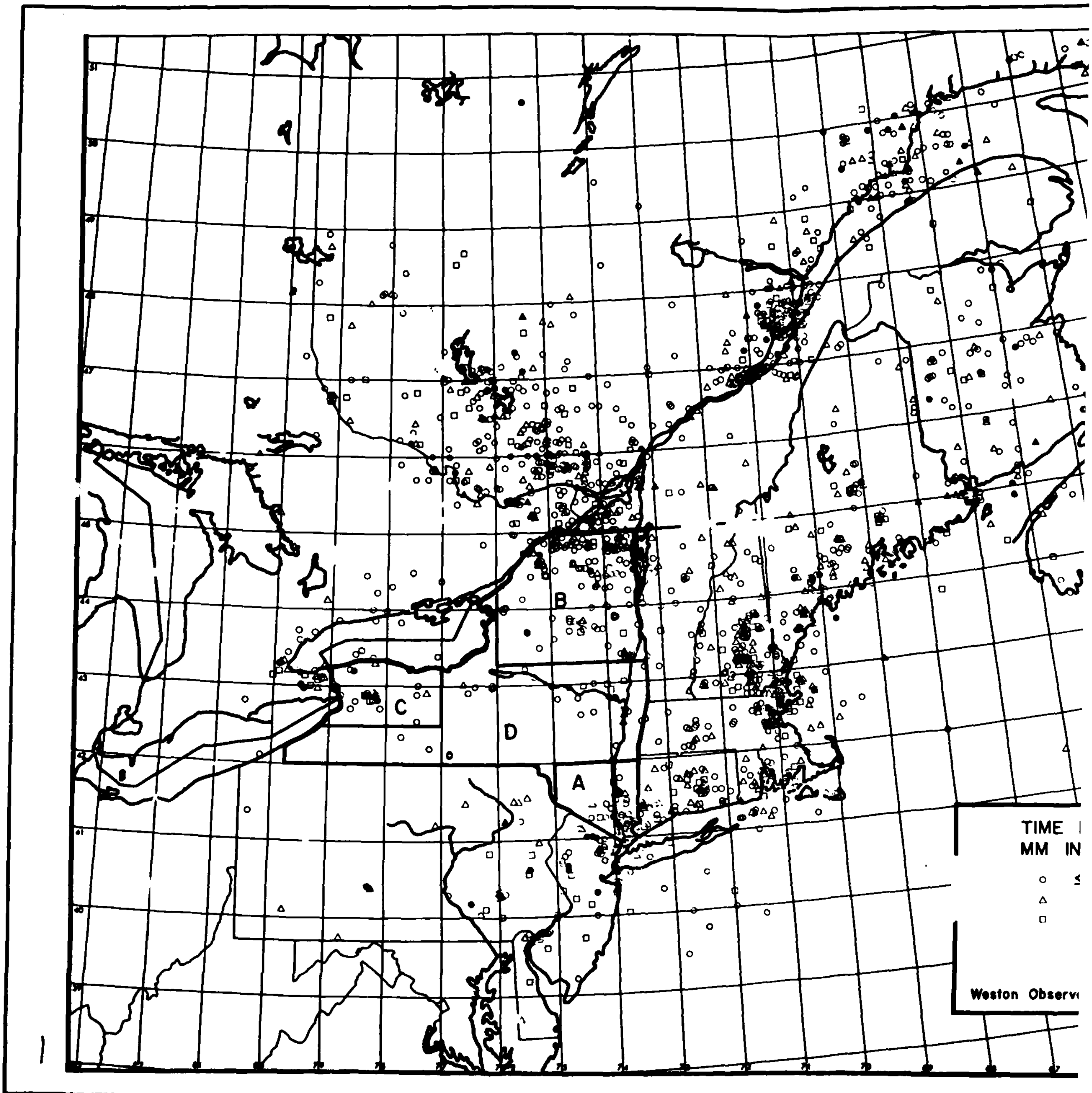
BORING LOCATION PLAN AND SUBSURFACE PROFILE

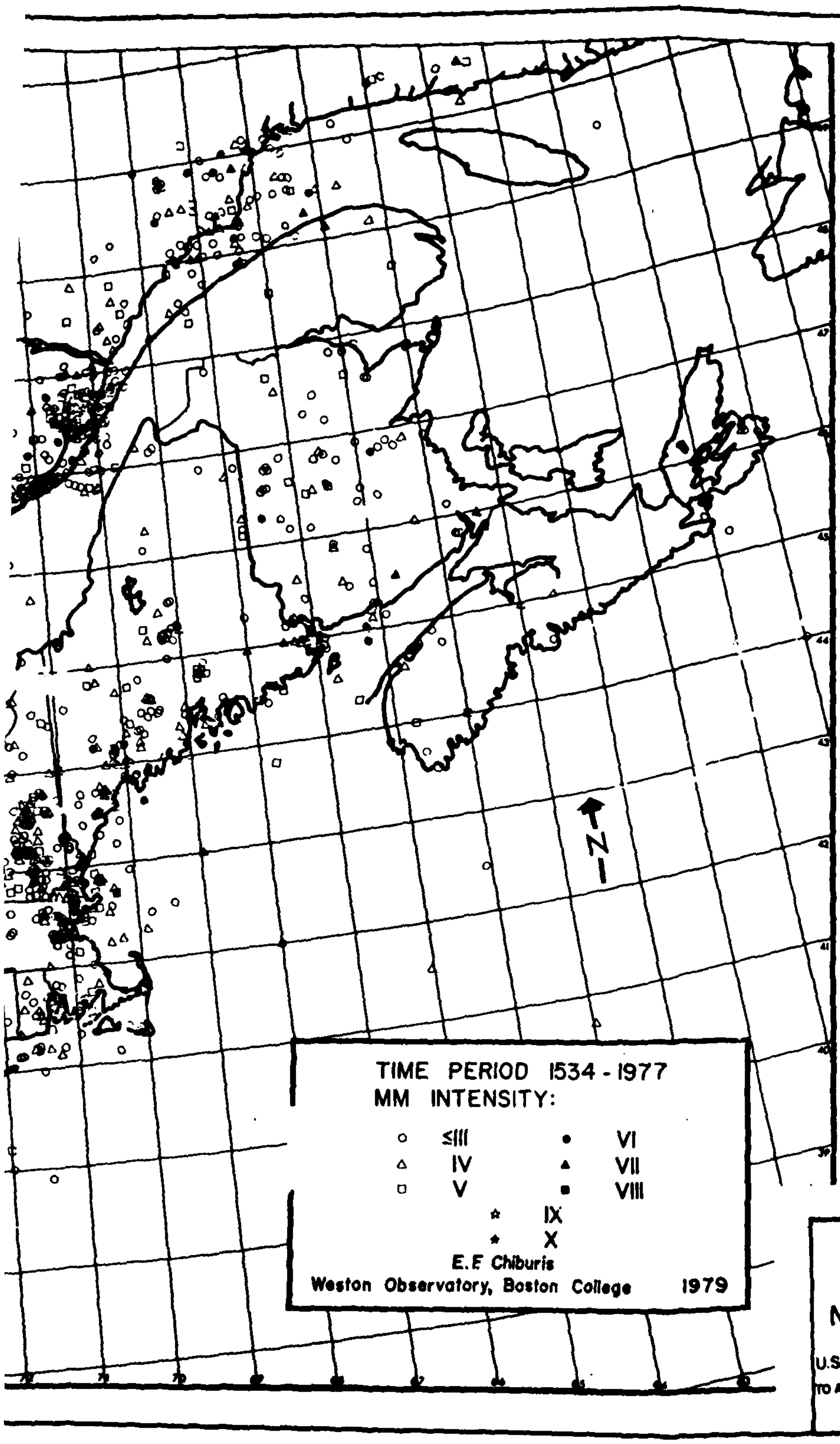
US ARMY ENGINEER DISTRICT BUFFALO

TO ACCOMPANY PHASE I, SEISMIC STABILITY INVESTIGATION

DATED NOVEMBER 1982

FIGURE 6


B
C
D
A
TIME
Weston



NOTE: ZONES A, B, C AND D OBTAINED FROM MITRONOVAS (1981)

REF: Chiburis, et al (1979)

2

ONONDAGA DAM, NEW YORK

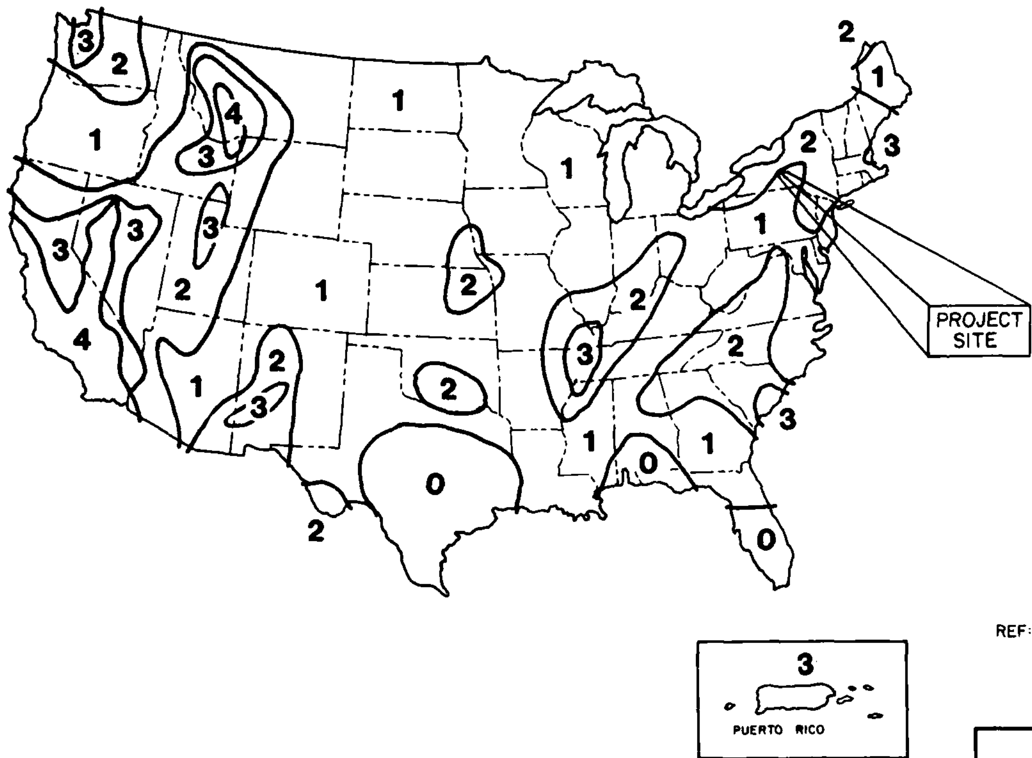
SEISMICITY EPICENTERS
NORTHEASTERN U.S. VICINITY

U.S. ARMY ENGINEER DISTRICT BUFFALO

TO ACCOMPANY PHASE I, SEISMIC STABILITY INVESTIGATION

DATED: AUGUST 1982

FIGURE 7



ZONE	DAMAGE	COEFFICIENT
0	NONE	0.00
1	MINOR	0.05
2	MODERATE	0.10
3	MAJOR	0.15
4	GREAT	0.20

REF: ER1110-2-1806
16 MAY 1983

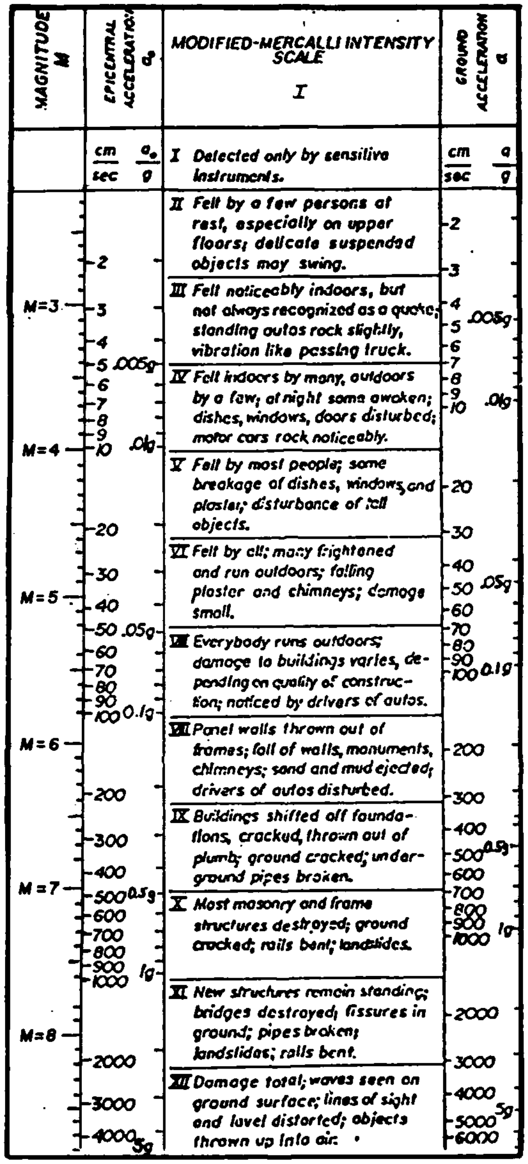
ONONDAGA DAM, NEW YORK

SEISMIC ZONE MAP OF THE CONTIGUOUS STATES AND PUERTO RICO

U.S. ARMY ENGINEER DISTRICT BUFFALO
TO ACCOMPANY PHASE I SEISMIC STABILITY INVESTIGATION DATED NOVEMBER 1982

FIGURE 7A

FIGURE 7A



REF: Nuclear Reactors and Earthquakes (1963)

ONONDAGA DAM, NEW YORK

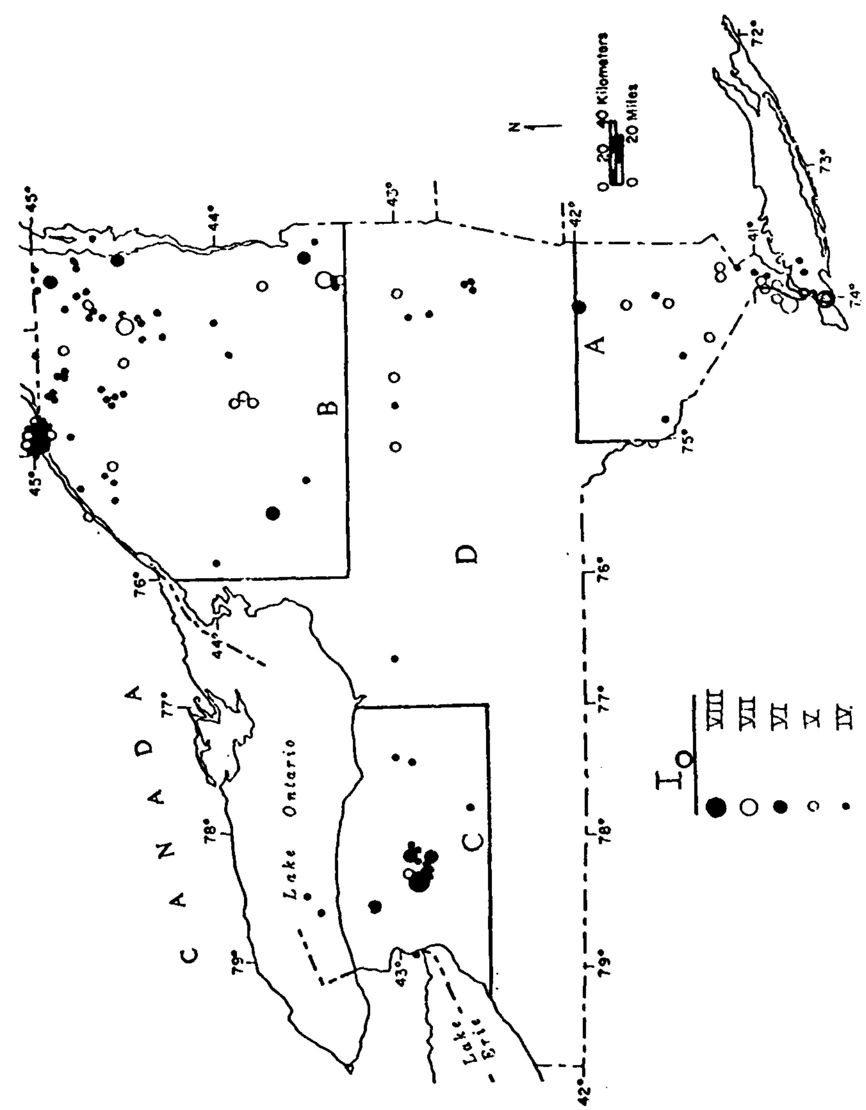
INTENSITY, MAGNITUDE AND ACCELERATION RELATIONSHIP

U.S. ARMY ENGINEER DISTRICT BUFFALO

TO ACCOMPANY PHASE I, SEISMIC STABILITY INVESTIGATION

DATED: AUGUST 1982

FIGURE 8



REF: Mitronovas (1981)

ONONDAGA DAM, NEW YORK

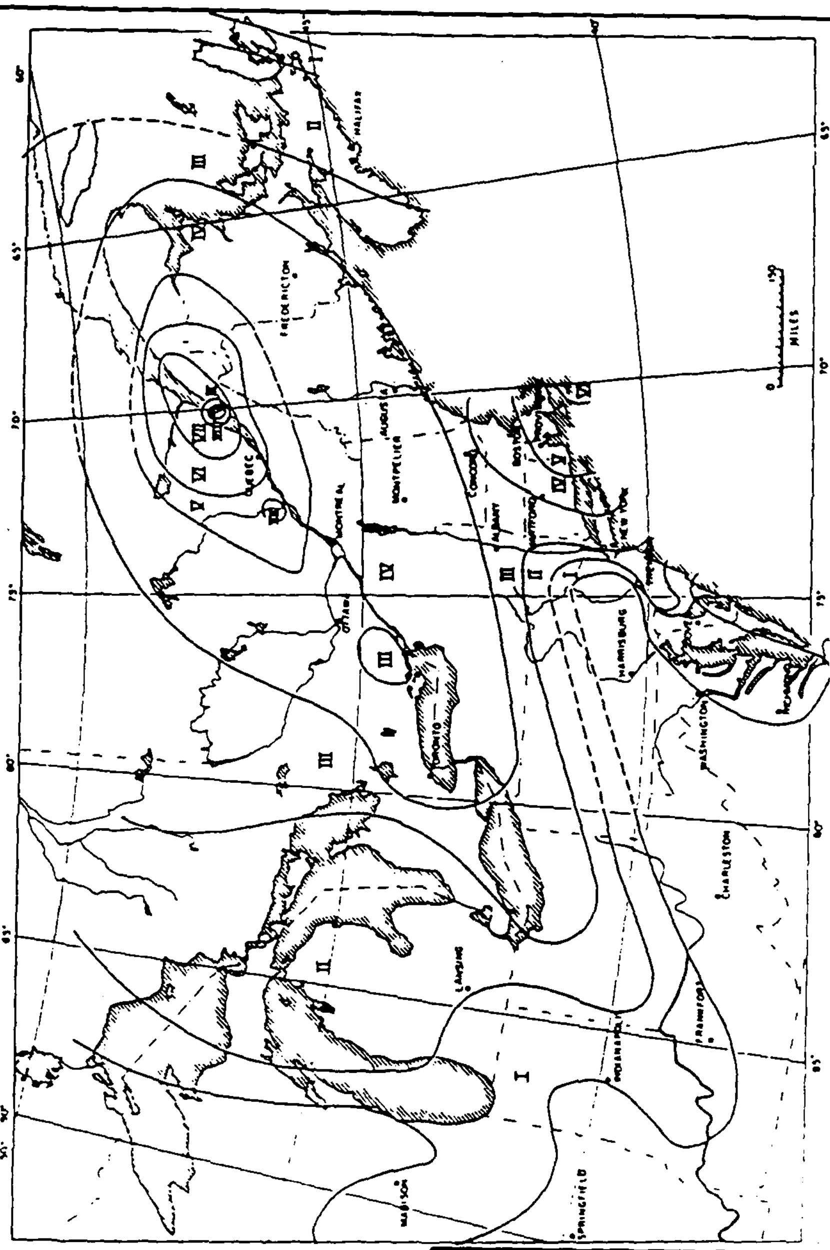
NEW YORK STATE SEISMICITY ZONES

U.S. ARMY ENGINEER DISTRICT BUFFALO

TO ACCOMPANY PHASE I, SEISMIC STABILITY INVESTIGATION

DATED: AUGUST 1982

FIGURE 9



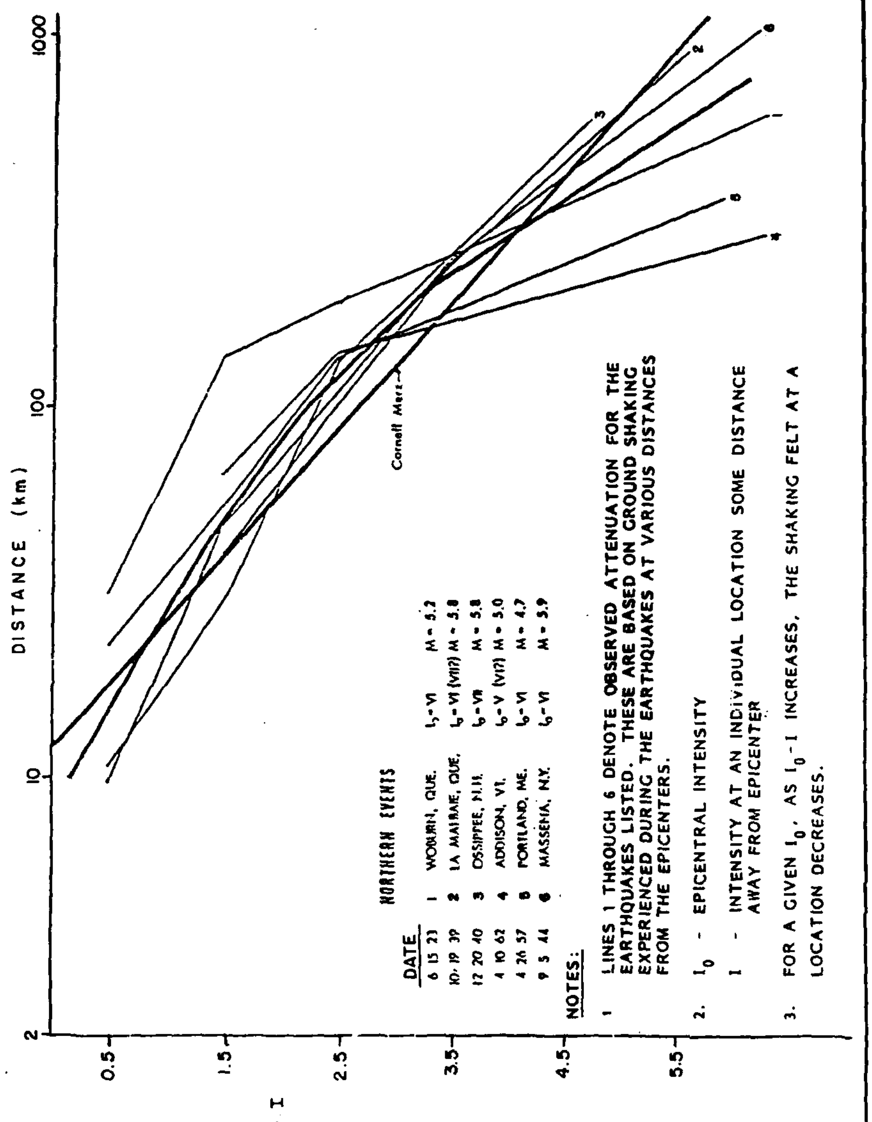
REF.: Krinitzsky and Patrick (1977)
NOTE: ISOSEISMALS ARE FOR 1 MARCH 1925 EVENT

ONONDAGA DAM, NEW YORK

ISOSEISMALS FOR I_0= IX EVENT, LA MALBAIE, QUEBEC

U.S. ARMY ENGINEER DISTRICT BUFFALO
TO ACCOMPANY PHASE I, SEISMIC STABILITY INVESTIGATION
DATED: AUGUST 1982

FIGURE 10



REF: Chiburis (1979)

ONONDAGA DAM, NEW YORK

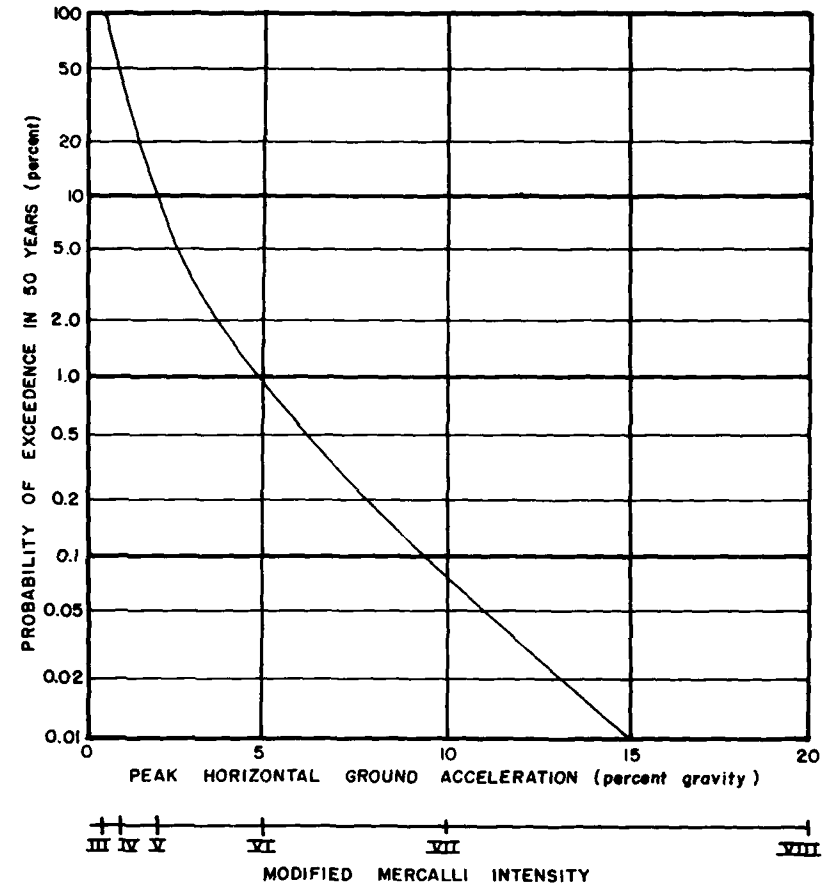
ATTENUATION RELATIONSHIPS

U.S. ARMY ENGINEER DISTRICT BUFFALO

TO ACCOMPANY PHASE I, SEISMIC STABILITY INVESTIGATION

DATED: AUGUST 1982

FIGURE 11



NOTE:

BASED ON CORNELL AND MERZ (1975)
ATTENUATION ANALYSES USING
STANDARD DEVIATION OF 0.4

ONONDAGA DAM, NEW YORK

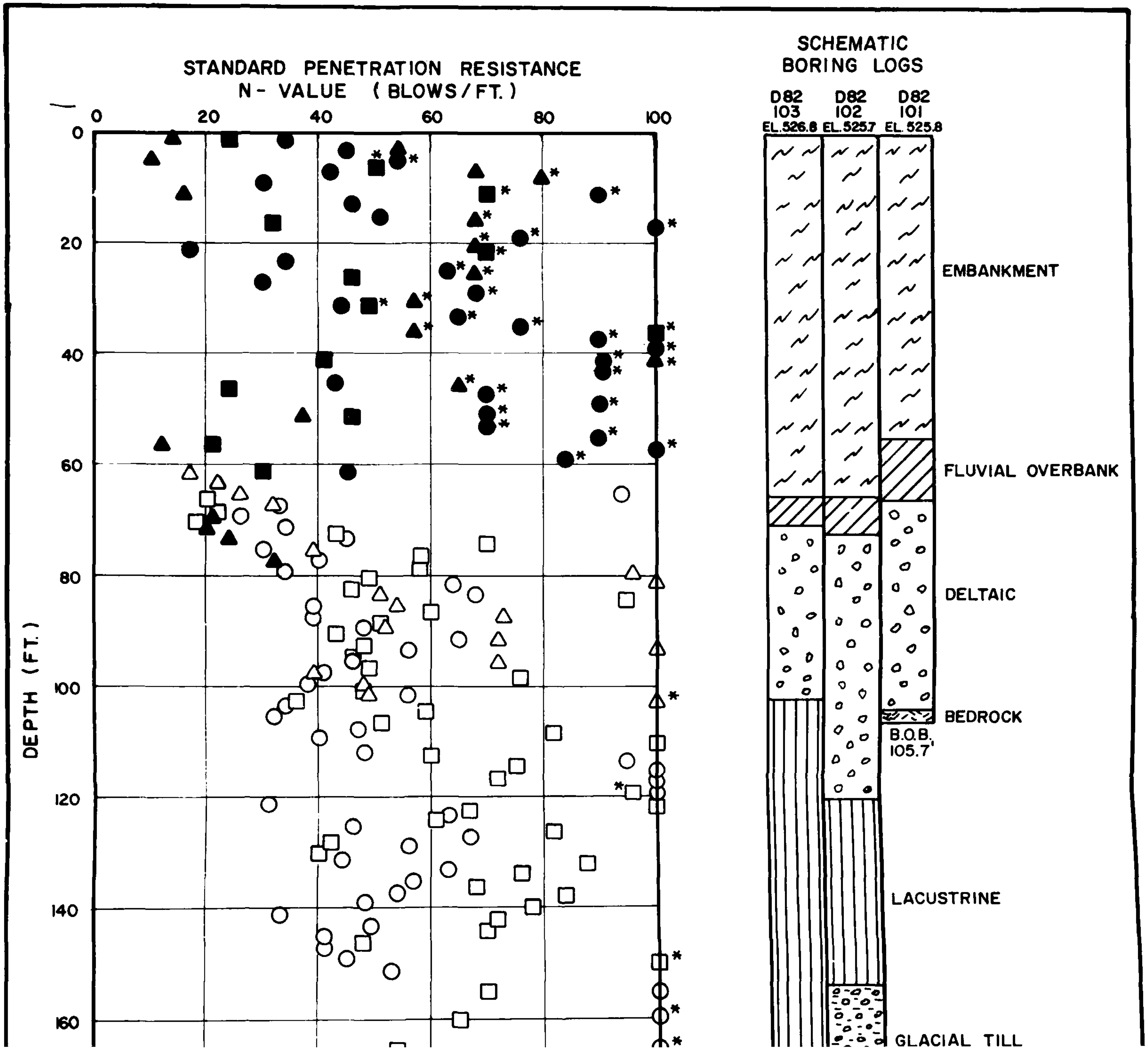
PROBABILITY OF EXCEEDENCE FOR PEAK HORIZONTAL GROUND ACCELERATIONS

U.S. ARMY ENGINEER DISTRICT BUFFALO

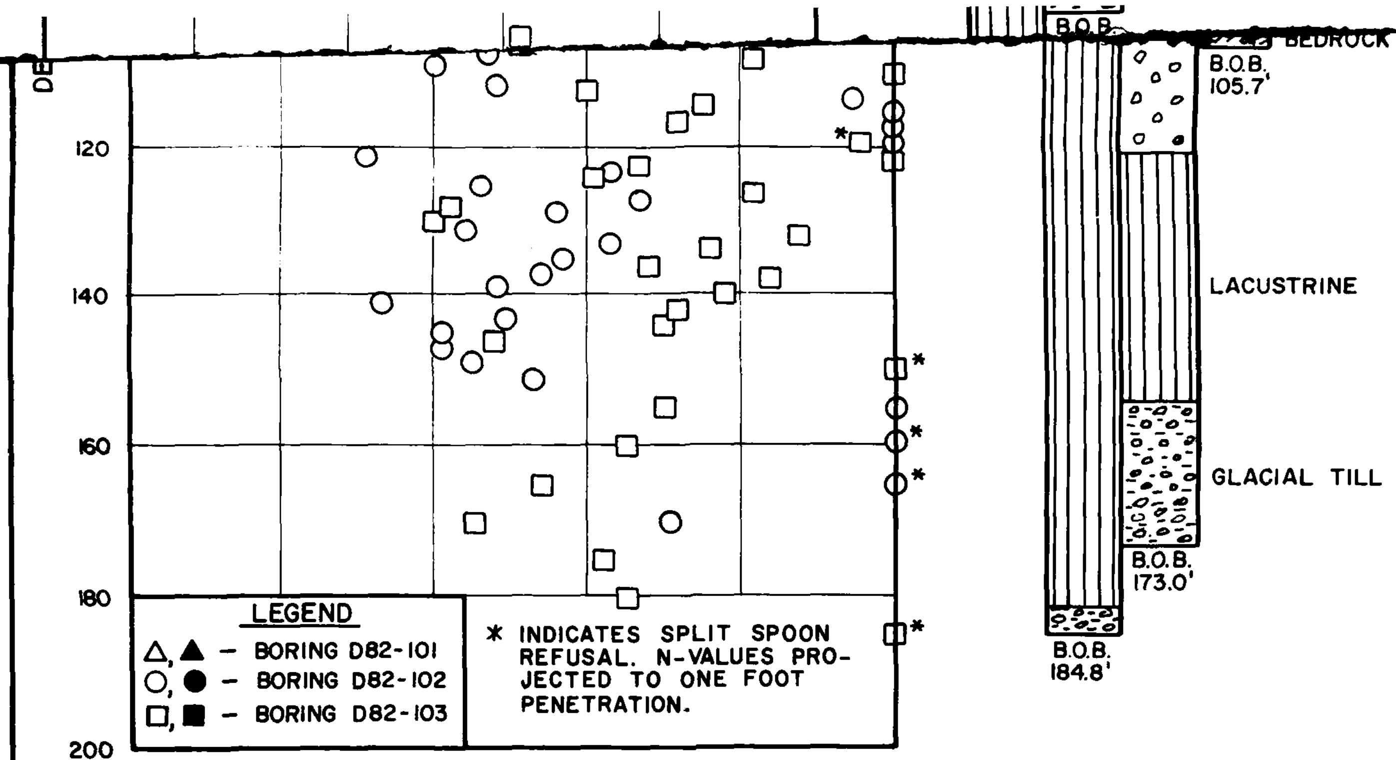
TO ACCOMPANY PHASE I, SEISMIC STABILITY INVESTIGATION

DATED: AUGUST 1982

FIGURE 12



STANDARD PENETRATION RESISTANCE
N- VALUE (BLOWS/FT.)
DEPTH (FT.)
SCHEMATIC BORING LOGS
D82 103 EL. 526.8
D82 102 EL. 525.7
D82 101 EL. 525.8
EMBANKMENT
FLUVIAL OVERBANK
DELTAIC
BEDROCK
B.O.B. 105.7'
LACUSTRINE
GLACIAL TILL



NOTES:

1. OPEN SYMBOL INDICATES USE OF 1-3/8 IN. I.D. x 2.0 IN. O.D. STANDARD SPLIT SPOON SAMPLER DRIVEN BY 140-LB. HAMMER FALLING FREELY 30 INCHES.
2. CLOSED SYMBOL INDICATES USE OF 2-7/8 IN. I.D. x 3.5 IN. O.D. SPLIT SPOON SAMPLER DRIVEN BY 350-LB. HAMMER FALLING FREELY 18 INCHES. N-VALUES HAVE BEEN CONVERTED TO EQUIVALENT STANDARD N-VALUE (SEE APPENDIX F).
3. N-VALUES GREATER THAN 100 HAVE BEEN PLOTTED AT 100 ON THE CHART.
4. SEE TEXT FOR DESCRIPTION OF SOIL DEPOSITS.

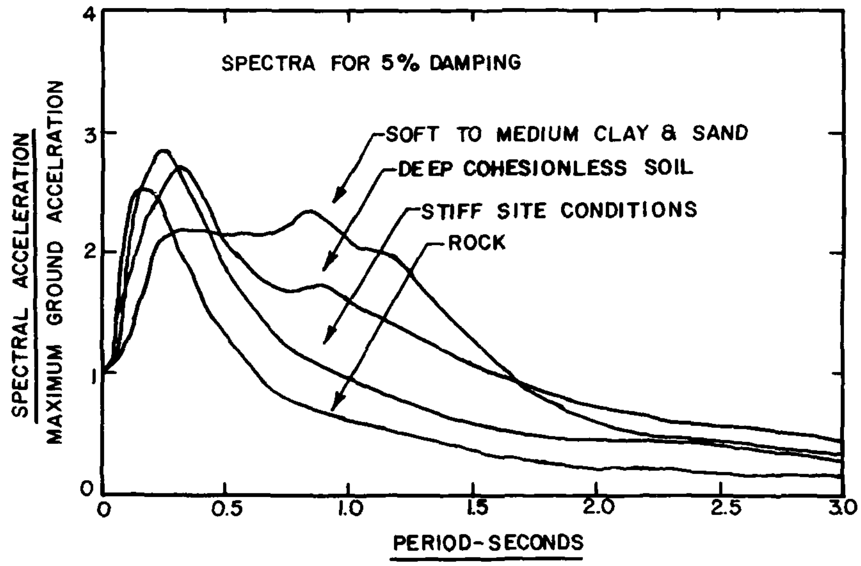
FIGURE 13

ONONDAGA DAM, NEW YORK

STANDARD PENETRATION RESISTANCE VS. DEPTH

U.S. ARMY ENGINEER DISTRICT BUFFALO
TO ACCOMPANY PHASE I, SEISMIC STABILITY INVESTIGATION
DATED: SEPTEMBER 1982

FIGURE 13



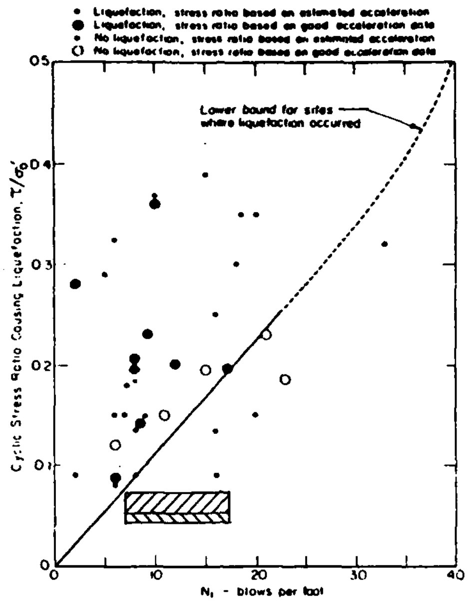
REF: APPLIED TECHNOLOGY COUNCIL
(PUBLICATION ATC 3-06, 1978)

ONONDAGA DAM, NEW YORK

AVERAGE ACCELERATION
SPECTRA FOR DIFFERENT
SITE CONDITIONS

U.S. ARMY ENGINEER DISTRICT, BUFFALO
TO ACCOMPANY PHASE I, SEISMIC STABILITY
INVESTIGATION. DATED: NOVEMBER 1982

FIGURE 14



LEGEND:

SOILS BELOW TOE OF DAM

SOILS BELOW CREST OF DAM

REF: SEED AND IDRISS (1981)

FILE NO. 7450 03

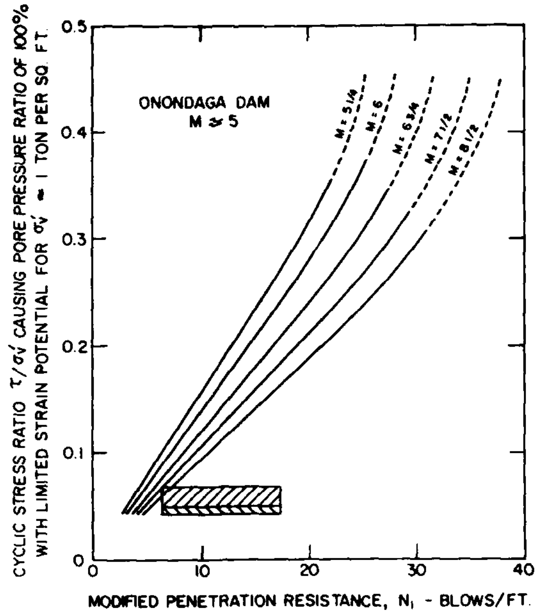
ONONDAGA DAM, NEW YORK

LIQUEFACTION POTENTIAL OF DAM FOUNDATION SOILS

U.S. ARMY ENGINEER DISTRICT BUFFALO

TO ACCOMPANY PHASE I, SEISMIC STABILITY INVESTIGATION DATED: AUGUST 1982

FIGURE 15



LEGEND:

SOILS BELOW TOE OF DAM

SOILS BELOW CREST OF DAM

REF: SEED AND IDRISS (1981)

ONONDAGA DAM, NEW YORK

LIQUEFACTION POTENTIAL OF DAM FOUNDATION SOILS CORRELATED TO DIFFERENT EARTHQUAKE MAGNITUDES

U.S. ARMY ENGINEER DISTRICT BUFFALO
TO ACCOMPANY PHASE I, SEISMIC STABILITY INVESTIGATION DATED: NOVEMBER 1982

FIGURE 15A

[illegible]

[illegible]

[illegible]

[illegible]

APPENDIX A

CENTRAL NEW YORK STRATIGRAPHY

A1. Table II presents the generalized stratigraphic column for central New York and Figure 3 is a geologic map of the central New York Region.

A2. As shown on Table II, the rocks in central New York range in age from Late Ordovician along the south shore of Lake Ontario to Late Devonian at the New York-Pennsylvania border. Refer to Table I for the geologic time scale.

Upper Ordovician System

A3. The oldest stratigraphic unit in central New York, exposed along the south shore of Lake Ontario, is the Queenston Formation. It encompasses a maximum of 700 feet of red, crumbly shale and red siltstone and sandstone in this region. The coarser beds increase in thickness eastward and southward.

Silurian System

A4. Silurian rocks surround the Appalachian Plateau on the north and are found in the Lake Ontario Plain, and on the east in the westernmost Hudson Valley Province. In the Helderberg region in the northeast corner of the Allegheny Plateau, Lower Devonian rocks rest upon the Middle Ordovician and the normally intervening Silurian strata are entirely missing.

A5. For convenience, the New York Silurian can be subdivided into three parts. A lower portion, mainly of red sandstone beds (Medina Group); a middle part consisting of shales and carbonates (Clinton and Lockport Groups); and an upper division of more unusual strata, mostly hypersaline evaporites and brackish lagoonal deposits (Salina and Bertie Groups).

A6. Complexities in the Silurian rocks include numerous facies changes from west to east, the presence of many depositional breaks (disconformities), and poor exposures especially in the Upper Silurian section. Small fossils called conodonts and ostracods have been used to develop refined correlations in the Silurian Sy em of New York State, and individual strata can now be identified from rock core of exploratory borings. These rocks have a simple geologic structure, dipping gently southward at 40 to 50 feet per mile (65 to 80 feet in the subsurface) south of Lake Ontario.

Albion Series (Lower Silurian)

A7. Lower Silurian rocks are exposed in a narrow east-west belt parallel to the south shore of Lake Ontario and just south of the exposure belt of Queenston rocks, pinching out by unconformity east of the Oswego River. The line of Barge Canal eastward from Lockport to Spencerport follows the outcrops of this unit.

A8. The Medina Group is the sole Albion-aged unit in New York State. It is made up of, in the Niagara region, the Whirlpool Sandstone (25 feet thick) below, Power Glen Formation (30 feet thick) and the Grimsby Formation or Red Medina Sandstone above (50 to 70 feet thick). East of Lockport, the Whirlpool and Power Glen rocks pass by facies change into the lower Grimsby Formation. At Rochester, the Grimsby Formation rests directly on the Queenston Formation.

A9. The Grimsby Formation consists of red, crossbedded, medium bedded to massive, medium to coarse, locally conglomeritic, arkosic sandstone with some red silty shale. East of Holly and Medina, the massive sands become thin and interbedded with finer silty shales. To the west, the silty shales become thicker.

Niagaran Series (Middle Silurian)

A10. Niagaran rocks are exposed in an east-west belt from the Niagara River through Rochester to the Helderberg region and in a northeast-southwest belt in the western Hudson Valley Province from the Kingston area to Port Jervis. Niagaran rocks are missing around the Northeast perimeter of the Allegheny Plateau. On the Lake Ontario Plain, the Niagaran Series embraces the Clinton Group below and the Lockport Group above.

A11. The Clinton Group is a complex suite of lithologies and facies changes, with numerous disconformities. Therefore, no Clinton formation traverses the state without some change in character. In general, coarse clastic sedimentary rocks dominate this section in east central New York, with fine shales and carbonates being restricted to western New York. The section is about 120 feet thick at Niagara, 180 feet in the Rochester Gorge, 320 feet in the Oneida Lake region, and some 220 feet at its easternmost outcrops in Oneida and Herkimer Counties. It can be divided into a lower, middle and upper part based on fossil zones.

A12. Lower Clinton rocks represent a transgressive sequence of rock types, including the basal Kodak (Thorold) Sandstone (six feet thick), Oneida conglomerate (12 to 50 feet), the Neahga (six feet), Maplewood (20 feet), Bear Creek (10 feet), and Sodus (60 feet) shales, and finally terminating upward with Reynales (7 to 17 feet) and Wolcott Limestone (20 feet).

A13. Middle Clinton formations are restricted to central and east central New York, none being found west of the Sodus Bay - Seneca Lake meridian. The Sauquoit Formation is the sole Middle Clinton unit (0 to 80 feet), consisting of shales with interbedded sandstone and siltstones. The Sauquoit strata change eastward into the Otsquago Sandstone (100 to 130 feet). At the top of the Sauquoit, the fourth Clinton iron ore bed is found, the Westmoreland, south of Rome and Utica. The Otsquago and the eastern and coarsest Sauquoit beds have yielded several gas and salt water shows in Madison and Otsego Counties.

A14. Upper Clinton rocks, unlike the Middle Clinton units, are found across New York, east to west. The Irondequoit Limestone (18 to 30 feet), Williamson Black Shale (0 to 30 feet) and Willowvale Shale

(0 to 80 feet) are all facies of one another comprising the lowermost portion. In eastern New York, the Kirkland Hematite rests on top of the Dawes Dolostone (ten feet), the uppermost Clinton iron ore. The most significant portion of the Upper Clinton is made up of the Rochester Shale and its eastern facies, the Herkimer Sandstone. Rochester rocks are relatively thick, gray to dark gray, calcareous, dolomitic, silty shale containing numerous limestone and dolostone beds and lenses, especially in the upper portion. In the Genesee region, an upper dolostone is so prominent that a separate mappable unit, the Gates Dolostone, is recognized. The Rochester Shale is about 90 feet thick in the west and increases to 140 feet thick in central New York, north of Syracuse.

A15. The Herkimer Sandstone is 70 feet of gray calcareous, thin-bedded sandstone, interbedded with dark gray sandy and silty shale, and is found only in the Oneida-Utica region. To the east, this sandstone becomes a coarse, medium-bedded, gray and red sandstone with minor shale partings.

A16. The Lockport Group is a thick (75 to 200 feet, east to west) sequence of dolostones and sandy dolostones with lesser amounts of limestone. The Lockport rocks are extremely resistant and form the Niagara or Lockport Escarpment, a major topographic feature extending from Rochester to the Niagara Gorge. East of the Rome meridian, the Lockport passes into the Ilion Formation of shales with interbedded dolostones.

Cayugan Series (Upper Silurian)

A17. Rocks of Late Silurian age belong essentially to the Salina and Bertie Groups. Exposures of the Salina Group are relatively rare as it is composed primarily of weak shales and was, therefore, usually stripped by glacial erosion. The Bertie rocks are more resistant carbonates, and therefore overlying glacial deposits are thin. The Salina Group is about 300 feet thick near Buffalo, increasing to about 950 to 1000 feet near Syracuse, thereafter thinning rapidly to a featheredge near Richfield

Springs in Otsego County. Three formations are included in the Salina Group: Vernon Shale, salt of the Syracuse Formation, and the Camillus Formation.

A18. The Vernon Shale is composed of variegated red and green shale and siltstone totalling 300 to 400 feet in thickness. The base of the Vernon is Late Niagaran in age in eastern and central New York, and becomes progressively younger westward.

A19. The Syracuse Formation consists of three to four hundred feet of shale, dolostone and anhydrite which thicken rapidly southward to about 1,300 feet beneath Schuyler and Chemung Counties. With distance to the south, numerous salt beds occur, some reaching a maximum thickness of 400 feet. These salt beds rarely, if ever, outcrop at the surface, but the updip limit of the major salt beds is nearest the surface at Syracuse. This limit then strikes southwestward across the state, meaning that salt lies considerably deeper below the Genesee Valley than below Syracuse.

A20. Overlying the Syracuse Formation are 100 to 200 feet of shales, dolostones, and shaley dolostones of the Camillus Formation, containing a large quantity of interbedded anhydrite and gypsum.

A21. The remainder of the Cayugan Series above the Salina Group is composed of the Bertie Group dolostones (50 feet), Akron or Cobleskill limestones and dolostone (10 feet), and lower Chrysler Dolostone (30 feet). The Silurian-Devonian boundary occurs in the middle of the Chrysler Formation. Caverns, caves and other solution features are also common in these units.

Devonian System

A22. Devonian rocks are by far the most extensively exposed in New York State. Devonian strata underlie all of the Allegheny Plateau and regions adjacent to it, such as the Lake Erie Plain, southern Lake Ontario

Plain, and westernmost Hudson Valley Province. In addition, the beds are generally structurally simple, and the abundant fossil fauna in such rocks have led to a detailed stratigraphic description over the last fifty years.

A23. Carbonates dominate the Lower Devonian and lower part of the Middle Devonian while clastic deposits predominate in the remainder of the section. The clastics are fine-textured marine rocks at the bottom, grading upward to coarse, red continental sandstones. These deposits, are known as the Catskill Delta, and are a wedge of clastic sediments that thicken and become coarser to the east. The New York Devonian is subdivided into the Ulsterian Series (Lower Devonian), Erian Series (Middle Devonian) and Senecan and Chautauquan Series (Upper Devonian).

Ulsterian Series (Lower Devonian)

A24. Lower Devonian exposures are confined to the area west of Seneca Lake, along the north edge of the Allegheny Plateau and south along the north edge of the Allegheny Plateau and south along its eastern perimeter to Port Jervis. This largely carbonate sequence is divided into the Helderberg Group below and the Tristates Group above.

A25. The Helderberg Group is a complex of intertonguing carbonate facies. Lagoonal dolostones with minor evaporites pass eastward into an offshore shelf facies dominated by limestones, some with reefs. The Helderberg Group is about 240 feet thick in the Helderberg Mountains southwest of Albany, increasing southward to some 450 feet at Port Jervis near the New Jersey border. Westward the group thins to about 100 feet near Syracuse and is absent west of Geneva. Solution features and caverns (e.g. Howe Caverns) are common in the Helderberg Group.

A26. The Helderberg Group is succeeded in an upward direction by the Tristates Group of which the Oriskany Sandstone is the lowest unit. This formation is, in turn, succeeded by the Esopus Shale, Carlisle Center

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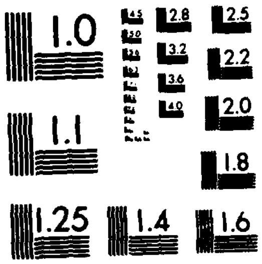


MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

Shale and Schoharie Limestone in eastern New York only. The Tristates Group is about 160 feet thick in the Albany region, thickening southward to about 750 feet at Port Jervis, and except for isolated patches of Oriskany, disappears west of Richfield Springs.

A27. The Oriskany Sandstone is the most important formation in the Tristates Group. It underlies much of the Allegheny Plateau, except in the southwest part of the state, and is 0 to 50 feet of quartzose sandstone, with calcite and silica cement. This sandstone is porous and permeable in siliceous zones and tight where calcareous. In the west, it is a prolific gas producer. Eastward in the Allegheny Plateau, there is no known gas production in the Oriskany Sandstone.

Erian Series (Middle Devonian)

A28. Two stratigraphic units make up the Middle Devonian in New York State, the Onondaga Limestone and the Hamilton Group. They are exposed across the entire state, in a continuous belt, from Lake Erie on the west to the New Jersey border near Port Jervis in the southeast.

A29. The Onondaga Limestone is a regional, blanket carbonate deposit, thinning from about 175 feet at Buffalo to only some 70 feet at Syracuse, but thickens eastward again to about 250 feet at Catskill and 300 feet at Port Jervis. It is a thin to medium bedded, medium to coarse textured, gray limestone, often containing bedded chert and chert nodules. Onondaga rocks are extensively quarried across the state.

A30. The Hamilton Group is a clastic wedge (Catskill Delta) deposited by westward flowing streams from a rising mountainous region to the east and southeast of the present Catskill region. The group is about 265 feet thick in western New York, 1,100 feet in central New York and 2,500 to 3,000 feet thick in the Catskills. At the toe of the delta complex, in an ocean basin in what is now western New York, fine-grained, bituminous, dark to black Hamilton shales were deposited. Uppermost Hamilton beds in western New York are gray calcareous shales. The shales pass eastward into coarse, silty shales and sandstones. These, in turn, grade eastward and interfinger with mostly terrestrial, crossbedded, red and green sandstones, shales and siltstones.

A31. Three thin but persistent carbonate units (key beds) pierce the clastic wedge and were deposited over the delta at times of low sediment influx. These serve to subdivide the Hamilton into four formations, the Marcellus, Skaneateles, Ludlowville, and Moscow. The carbonate beds are from oldest to youngest, Mottville Member, Centerfield Member and Portland Point Member.

Combined Senecan and Chautauquan Series (Upper Devonian)

A32. The Upper Devonian sequence is a continuation of the Catskill Delta which was migrating westward during deposition. The same general Middle Devonian facies continue but persistent key beds are black shale tongues, not carbonate units, except for the lowest formation, the Tully Limestone. The black shales subdivide the Upper Devonian into a number of groups, totalling some 3,300 feet of thickness in southwest New York, 7,000 feet in south central New York, and 7,700 feet in the Catskills. The Upper Devonian is exposed throughout the southern tier region of the Allegheny Plateau, however the Chatauquan Series is present only in the western part, as it has been removed further eastward by erosion.

Senecan Series

A33. The Tully Limestone is the basal formation of the Senecan Series. It reaches a maximum thickness of 100 feet in east central New York and changes eastward into the Gilboa Shale and sandstone. The Tully is approximately 30 feet thick in the Syracuse region and is not present west of Canandaigua Lake due to its being removed by erosion prior to deposition of overlying units.

A34. Overlying the Tully is the Genesee, Sonyea and West Falls Groups. They are black shales in the west and red beds in the east, although each facies is found further westward in the West Falls Group.

Chautaquan Series

A35. The Chautauquan Series is made up of the Canadaway, Conneaut, and Conewango Groups. The Canadaway and Conneaut Groups contain several fresh water aquifers as well as the major oil producing sands of SW New York. They have been penetrated by numerous borings but records of many of the early wells have now been lost. Much of the oil is trapped along axis of the broad anticlinal structures that characterize the southwest portion of the Allegheny Plateau. If salt water is not present, the oil may also be found along the synclinal axes.

APPENDIX B

ONONDAGA DAM SITE STRATIGRAPHY

B1. Older Silurian units are exposed to the north of the dam in Syracuse and younger Upper Devonian units cap the hills south of the dam, and form the valley sides and floor south of the Village of Tully.

B2. Table III presents the detailed stratigraphic column along the Syracuse Meridian in the vicinity of the dam. Figure 4 is a geologic map of the area surrounding the dam. A description of the stratigraphy summarized on Table III and Figure 4 follows.

Lower Devonian - Ulsterian Series

Helderberg Group

B3. The Helderberg Group in the Onondaga Valley region is composed of two formations which, in ascending order, are the Rondout Formation (Chrysler Dolostone) and the Manilus Formation (Table III). The Rondout is poorly exposed in this area, however, a limited outcrop is exposed in the base of the rock cuts on Interstate 81, just south of the junction with Interstate 481.

B4. The Manilus Formation is subdivided from older to younger, into the Olney Limestone Member, Elmwood A, B and C Dolostone Member, Clark Reservation Limestone Member and the Jamesville Limestone Member.

a. Olney Member - Named for Olney Station on the now abandoned Auburn and Syracuse Electric Railroad, is approximately 30 feet of fine-grained, even bedded limestones. The lower portion is thin-bedded; the upper portion is somewhat more thickly bedded, although both may have laminated beds. Fossils are neither abundant nor well diversified. The Olney underlies the spillway cut at the east end of the dam and is exposed in road cuts on Interstate 81 south of the junction with Interstate 481.

b. Elmwood Member - Overlies the Olney Member and consists of a series of dolostones, waterlimes, and limestones. The name is derived from Elmwood Park near Onondaga Hill in the southwestern part of Syracuse. It is subdivided into 3 units known as Elmwood A, B, and C in ascending order. Elmwood A is a drab yellowish brown, thin-bedded and mud cracked waterlime, barren of fossils and about 6 feet thick. Elmwood B is a fine-grained, blue limestone, 3 feet thick, locally known as the "Diamond blue". This is overlain by 4 feet of waterlime, similar to Elmwood A, and known as Elmwood C. The Elmwood is exposed on the west side of the Onondaga Valley in Sweet's Quarry and Split Rock Quarry, in the roadcuts along Interstate 81 south of Interstate 481 junction, at Clark Reservation State Park, and in the vicinity of the Village of Jamesville. It underlies the spillway rock cut at the east edge of the flood control structure.

c. Clark Reservation Limestone Member - Lies above the Elmwood and consists of a bed of fine-grained, dark blue, white-weathering limestone characterized by a diagonal fracture system. The name comes from Clark Reservation State Park, one mile west of Jamesville, where the type section is located. It is approximately 5 feet thick and in addition to the type locality it is exposed at Onondaga Hill on the west side of the valley and in the rock cuts along Interstate 81 mentioned above. It is also exposed at the base of the exposure on the east side of U. S. 11 just north of the Nedrow interchange to Interstate 81.

d. Jamesville Limestone Member - Lies between the Clark Reservation and the Onondaga Limestone. It is approximately 25 feet of fine-grained, dark blue, brittle, limestone in thin, even beds at its type exposure in Clark Reservation State Park. It makes up the lower 12 feet of the rock exposure in the spillway cut at the east edge of the dam. The lowest 2.5 feet of the Jamesville exposed at this location is a stromatroporoid biostrome which is a layer composed of enormous numbers of stromatroporoids, perhaps a type of fossil sponge. A complete section of the Jamesville is exposed on U.S. 11 just north of the Nedrow interchange to Interstate 81, and in the rock cuts on Interstate 81 south of the junction of Interstate 481.

Tristates Group

B5. The Oriskany Sandstone, the only formation of this group exposed in central New York, is not well developed in the vicinity of the dam and Onondaga Valley in general. A few inches of reddish-orange, sandy layers at the base of the Onondaga Limestone represent this unit in the spillway rock cut.

Middle Devonian - Erian Series

Onondaga Limestone

B6. The Middle Devonian sequence begins with the Onondaga Limestone which attains a thickness of approximately 70 feet in the Syracuse area. It is a series of light bluish-gray semi-crystalline limestones in even continuous layers from 1 inch to 2 feet in thickness, separated by thin seams of dark, calcareous shale. Flattened nodules of dark blue or black chert, sometimes in continuous sheets or beds are unevenly distributed throughout the Onondaga but mainly in the upper part.

B7. The Onondaga is comprised of five members as shown on Table III and discussed below:

a. Edgecliff Member - The lowest member of the Onondaga is distinguished by its coarser, more pronounced, crystalline texture and abundant fossils. The base of the Edgecliff is a disconformity, meaning it was deposited over an erosion surface that had removed previously deposited rock strata. The member is approximately 15 ft. thick and is exposed in the spillway cut.

b. Nedrow Member - Just above the Edgecliff, is characterized by thin-bedded, shaley limestone, marked in the lower part by abundant snail fossils. It is a medium gray, very fine-grained, argillaceous limestone containing little chert unevenly distributed at the top. It is approximately 10 ft. thick, is gradational with the overlying Moorehouse Member, and rests with a sharp contact on the Edgecliff. Both the Nedrow and the overlying Moorehouse Member occur in the spillway cut.

c. The Moorehouse Member - Consists of 20 to 25 feet of medium gray, very fine grained limestone beds which are separated in many places by thin shaley partings ranging from 2 inches to 5 feet thick. Dark gray chert is common in this member but varies in amount. It is more common in the upper part of the member and occurs as more or less continuous strata.

d. Tioga Bentonite Member - Occurs in the upper part of the Onondaga as a volcanic ash layer, 6 to 9 inches thick. It separates the underlying Moorehouse Limestone Member from the overlying Seneca Limestone Member. Neither the Tioga nor the Seneca Member were observed in the spillway cut.

e. Seneca Member - Although lithologically similar to the upper Moorehouse, is characterized by a slightly different fossil assemblage. Also chert is less common in the upper part of the Seneca Member and the limestone beds are darker gray. This Member is approximately 25 feet thick.

B8. The Onondaga Limestone is exposed in the upper 50 feet of the spillway cut on the east side of the dam. Other exposures in the vicinity of the dam include Hemlock Creek northeast of Indian Village, abandoned quarries along Quarry Road on the Indian Reservation, road cuts on U.S. 11 at the Nedrow interchange to Interstate 81, road cuts on Interstate 81 north of the Nedrow exit, along the west branch of Onondaga Creek 3 miles northwest of South Onondaga and near Cedarvale. Additional exposures occur along the northern margin of the Allegheny Plateau from Jamesville through southern Syracuse and the famous quarries at Split Rock.

Hamilton Group

B9. The Hamilton Group in the Tully Valley consists of approximately 1,100 feet of mostly silty shales and siltstones lying above the Onondaga Limestone and below the Tully Limestone. Three thin carbonate beds serve to define the formational boundaries. The succession of units, their lithologies and thicknesses are shown on Table III.

B10. The Hamilton is the rock unit exposed in the dam vicinity except for the spillway cut at the dam itself. The Hamilton forms the sides of the Onondaga Valley north and south of the dam and also the floor of the valley south of the dam (Figures 3 and 4).

B11. The Hamilton rocks in the Tully Valley dip S25°W at approximately 48 feet per mile, based upon the Centerfield Member as a datum. Formations included in the Hamilton Group are described below, in ascending order.

Marcellus Formation

B12. The Marcellus Formation is divided into four members. The lower three are composed of black shales and limestone, while the upper member is dominantly a transition from black to gray shale. The lower contact of this formation with the Onondaga Limestone is fairly sharp throughout the area and is overlain by the Mottville Member of the Skaneateles Formation with a sharp contact.

a. Union Springs Member - In the vicinity of the dam, the Union Springs Member is 10 feet thick. It is an alternation of black, sooty, carbonaceous, calcareous shale with thin bands and lenses of black bituminous limestone. The limestone beds range from less than 1 inch to 6 inches in thickness. Pyrite is dissemminated throughout the Union Springs, many fossils being replaced by it. The contact with the overlying Cherry Valley Member is sharp.

b. Cherry Valley Member - The Cherry Valley Limestone is a hackly, black, bituminous limestone with an orange-red stain that fills cavities, stains the surface, and coats some of the fossils. It is approximately 3 ft. thick.

c. Chittenango Member - This member consists of about 80 feet of unfossiliferous, jet black, non-calcareous, bituminous shale that contains abundant pyrite. It is extremely thin bedded and displays excellent rectangular jointing. Wherever it is exposed it breaks into paper-thin flakes that are usually stained a rusty color. Calcareous, unfossiliferous, septarian concretions up to 6 or more feet in diameter are common in this member, as are also smaller non-septarian concretions. These shales grade upward into the overlying Cardiff.

d. Cardiff Member - This member is named for exposures around the Village of Cardiff in the Tully Valley. It is a noncalcareous, dark gray to grayish black, medium-bedded shale at its base and grades upward into a slightly coarser shale of medium dark gray color. Toward the top, particularly the uppermost 4 feet, small, round, calcareous, nonseptarian, unfossiliferous concretions are present. They range from 1 inch to 8 inches in diameter. As defined here, the Cardiff is approximately 180 feet thick and is overlain by the Mottville Member of the Skaneateles Formation.

B13. The Marcellus Formation is exposed in the immediate vicinity of the dam. It makes up the lower slopes of the valley north of the dam, and south of the dam to a point south of Rattlesnake Gulf (Bare Mountain Ravine) approximately 6 miles south of dam. It is also exposed on the lower slopes of the valley along the west branch of Onondaga Creek westward through Pumpkin Hollow to the Village of Marcellus, the type section. Streams cascading down the sides of the Tully Valley notch ravines in which the Marcellus Formation is exposed in the lower reaches. Peppermill Gulf and Lords Hill Ravine near Ironsides are two excellent exposures, as well as ravines flowing down the east side of the valley south of the dam. Road cuts on Route 11A south of the dam expose Marcellus to a point a few miles south of Cardiff. The lower part of the formation, the Union Springs and Cherry Valley Limestone Members, are best exposed north of the dam. Two localities would be Hemlock Creek and a road cut on Interstate 81 just north of the Nedrow exit on the east side of the highway.

Skaneateles Formation

B14. In the Tully Valley, the Skaneateles Formation, with the exception of the Mottville Member, represents the intertonguing of a black shale facies to the west with a silty shale facies more fully developed to the east. Three tongues of dark shale, which are the eastern elongations of the Levanna Member of Cayuga Lake, extend into the silty facies and thereby provide the basis for subdividing this formation, above the Mottville, into three members. Each member begins with a dark, relatively unfossiliferous shale that passes upward into coarser, lighter colored, more fossiliferous beds. These are in turn sharply overlain by the next dark shale of the member above.

a. Mottville Member - In the Tully Valley, the Mottville Member is about 5 to 6 feet thick. It is highly fossiliferous, calcareous, medium gray shale containing one or two thin limestone beds.

b. Delphi Station Member - At most localities this member is about 125 feet thick, except at Rainbow Creek where 145 feet is measured. It is a dark gray shale in its lower portions containing abundant irregularly shaped, calcareous, non-septarian, unfossiliferous concretions from 1 to 5 inches in diameter. The dark shales pass upward into slightly calcareous siltstones abounding in bivalves (clams). The contact with the overlying Pompey is sharp.

c. Pompey Member - The Pompey Member is 60 feet thick, with the exception of the exposure in Bare Mountain Ravine, where it is about 114 feet thick, probably due to faulting. It is a dark gray to grayish black shale at its base grading upward to silty shale and finally siltstone at the top. Concretions occur more or less throughout the section, but are especially conspicuous in the upper 5 feet. Most of them are small, rounded, non-septarian and calcareous, and less than 4 or 5 inches in diameter. Although some fossils may be found on the periphery of the concretions, few are fossiliferous internally. The upper 20 feet of the Pompey contains abundant pyrite as nodules and disseminated particles

d. Butternut Member - The characteristic feature of the lower and middle Butternut is that it is a "paper shale", i.e., it splits into thin flakes, a distinct change from the underlying Pompey Member. Upward, this lithology is gradually replaced by silty shales interbedded with thin siltstone bands and lenses. The lenses vary in size from 3 feet long with maximum thickness of 1 inch, to 24 feet long with a maximum thickness of 6 inches. The lenses are cross-bedded at their bases only. Higher in the section, the silty shale gradually gives way to siltstone and the uppermost 4 or 5 feet of the Butternut is a calcareous flaggy siltstone. The contact with the overlying Centerfield Member is transitional and difficult to place. The Member is approximately 135 feet thick.

B15. The Skaneateles formation is exposed in virtually all the ravines mentioned above for the Marcellus, only in the middle and upper reaches of these ravines, usually above the first waterfall, which is held up by the Mottville Member. Therefore, it forms the middle slopes of the valley sides in the vicinity of the dam.

Ludlowville Formation

B16. The Ludlowville Formation is the most fossiliferous formation in the Tully Valley. It consists of intertonguing silty shales and siltstones and, on the basis of these, can be divided, above the Centerfield Member, into four members.

a. Centerfield Member - In the Tully Valley area, the Centerfield Member is a coarse siltstone about 25 feet thick. The lower and upper 10 feet are flaggy but the middle portion is massive. Only the middle portion is highly calcareous and fossiliferous. The siltstone beds in the flaggy parts are about 1 inch thick and at some localities crossbedded. The contact with the overlying Otisco is sharp.

b. Otisco Member - This unit is a soft, thinly bedded, slightly calcareous, silty, medium-gray to medium-dark-gray shale, which is interbedded toward the top with thin siltstone beds. The contact with the Ivy Point Member, about 165 feet above the Centerfield, is sharp. This member is especially interesting for two coral biostromes which have been given submember status by Oliver (1951). The lower, designated the Staghorn Point Submember, is about 7 feet thick in the Tully Valley. The Staghorm Point occurs about 50 feet above the top of the Centerfield and rests on a massive calcareous siltstone platform about 3 feet thick. The upper biostrome, named the Joshua Submember, varies from 0 to 55 feet in thickness in the Tully Valley. It covers some 40 square miles, less extensive than the Staghorn Point Submember.

c. Ivy Point Member - This member is about 36 to 37 feet thick and is dominantly a flaggy, slightly calcareous, gray siltstone, that weathers to a distinct yellowish-brown color. Most of the siltstone beds are approximately 1 inch thick. Spheriodal, calcareous, nonseptarian, unfossiliferous concretions 3 to 18 inches in diameter are present in the lower 20 feet.

d. Spafford Member - The Spafford Member consists of 27 feet of thin-bedded, gray to dark gray shale and silty shale sharply overlying the coarse Ivy Point Member. Although the Spafford becomes coarser upward, the upper 3 feet are very fine-grained.

e. Owasco Member - This is a calcareous, massive siltstone bed 2 feet thick.

B17. The Ludlowville Formation makes up the upper slopes of the Tully Valley and is best exposed in Lords Hill Ravine, and in Emerson Gulf and Fellow Falls Ravines south of Bare Mountain Ravine.

Moscow Formation

B18. Exposures of the lower 70 feet of the Moscow Formation are difficult to find in the Tully Valley. Even where this portion crops out in a ravine, the exposure is poor and incomplete. Therefore, this interval could not be examined thoroughly and much of the remarks pertaining to the Portland Point and lower and middle Windom Members were derived from the study of a single section. The upper 80 feet of this formation is well exposed as it occurs in high waterfalls capped by the resistant Upper Devonian Tully Limestone.

a. Portland Point Member - The upper and lower contacts of the Portland Point Member are sharp. A basal crinoidal, shelly limestone about 1 foot thick is succeeded by 11 feet of gray, silty shale, interbedded with thin, crinoidal, shelly limestone bands 2 inches thick or less and about 8 inches apart. The silty shales are not very fossiliferous.

b. Windom Member - The Windom Member is a thin-bedded, gray to medium-gray shale grading upward to medium-gray silty shale to a point 20 feet below the Tully. Here a sharp lithologic change to a medium-gray to dark gray or grayish black, non-calcareous, pyritiferous shale takes place and this is in turn sharply overlain by the Tully Limestone. This dark shale appears as a reddish orange zone beneath the Tully due to the weathering of the pyrite.

B19. The Windom is 163 feet thick in the Tully Valley. The Moscow Formation is exposed at the tops of the hills south of U.S. Route 20 such as Bare Mountain. It is well exposed in the vicinity of the Village of Tully in ravines and road cuts.

Upper Devonian - Senecan & Chautaquan Series

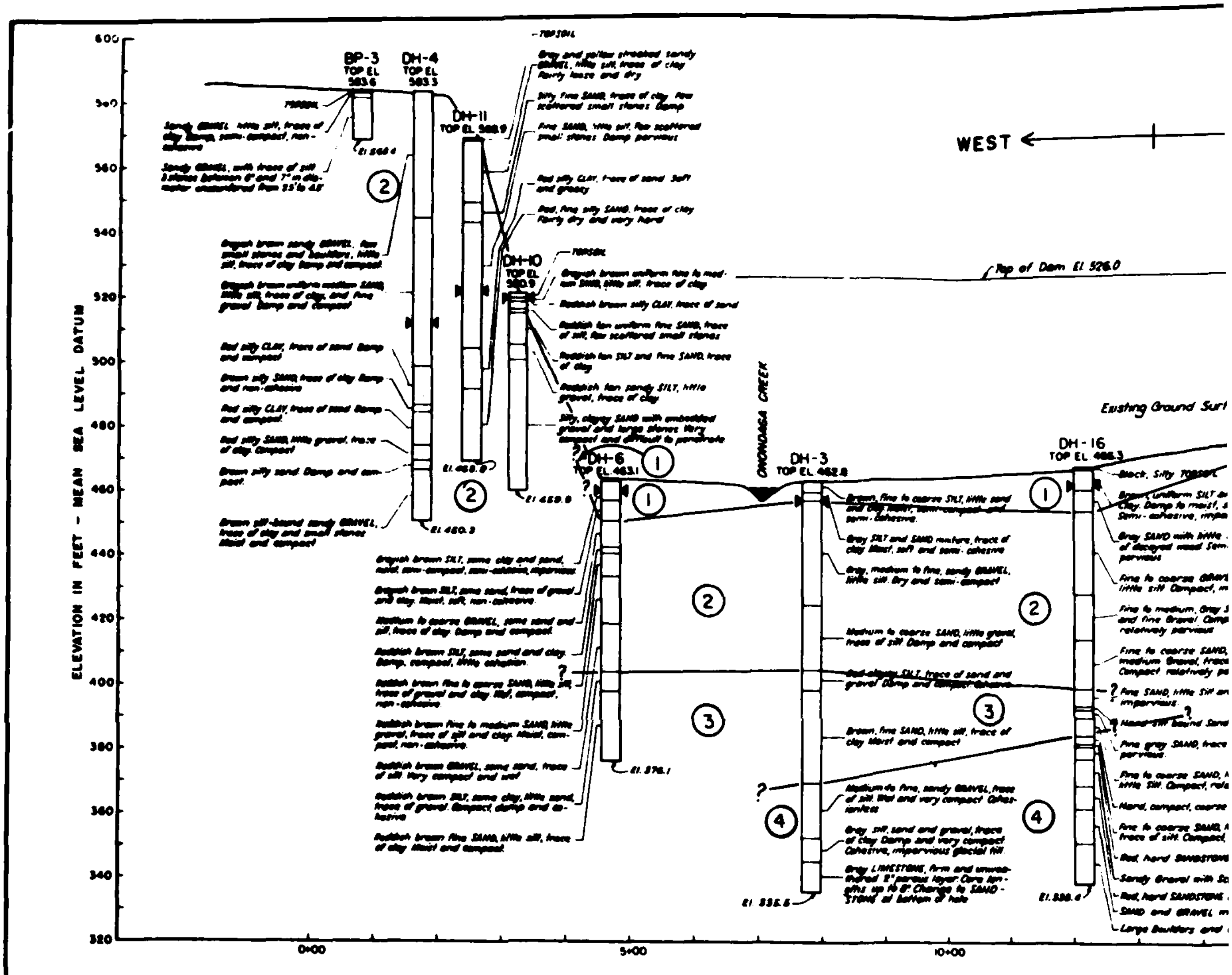
B20. The Upper Devonian sequence begins with the Tully Limestone exposed at the tops of the highest hills, at about El. 1,600 feet just south of the dam such as at Bare Mountain. However, the well developed and best exposed Upper Devonian does not occur until south of the village of Tully. The Upper Devonian is judged to be relatively far removed from the site and therefore no details of the stratigraphy will be given other than those shown on Table II and in Appendix A.

[illegible]

[illegible]

[illegible]

[illegible]



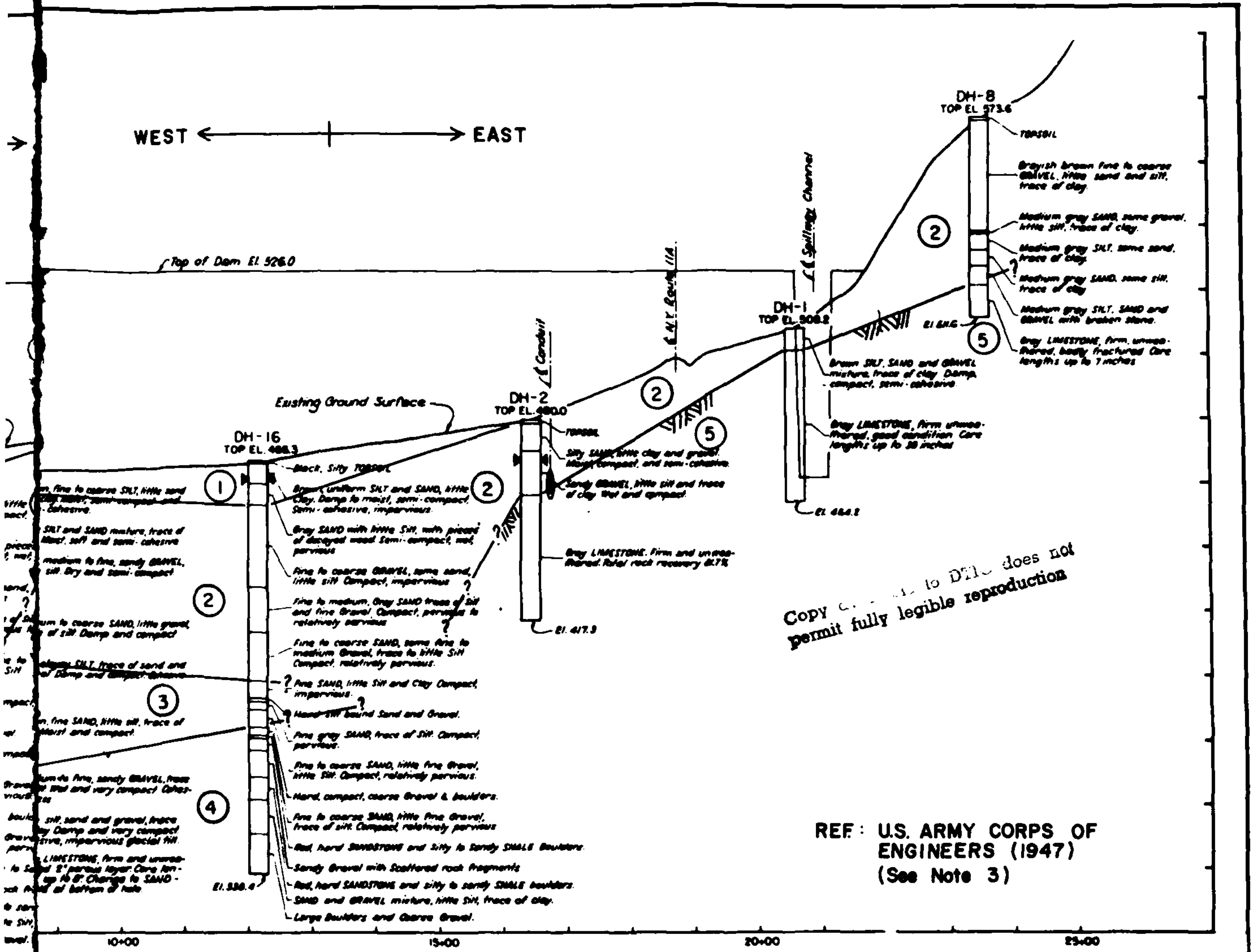
PROFILE ALONG ℄ DA

GEOLOGIC LEGEND:

STRATUM NO.	GENERALIZED GEOLOGIC DESCRIPTION
(1)	FLUVIAL OVERBANK
(2)	DELTAIC
(3)	LACUSTRINE
(4)	GLACIAL TILL
(5)	BEDROCK

NOTES:

1. STRATA LINES ARE GR FROM SUBSURFACE CO LOCATIONS. ACTUAL C MAY VARY. QUESTION OF UNCERTAINTY.
2. SEE TEXT FOR DISCUS
3. INDIVIDUAL SOIL DESCRIF CORP OF ENGINEERS PLA STRATA LINES AND GEOLC OF NEW YORK, MARCH 19



PROFILE ALONG ℄ DAM

NOTES:

1. STRATA LINES ARE GRADATIONAL AND INTERPOLATED FROM SUBSURFACE CONDITIONS AT EXPLORATION LOCATIONS. ACTUAL CONDITIONS BETWEEN EXPLORATIONS MAY VARY. QUESTION MARKS INDICATE A HIGH DEGREE OF UNCERTAINTY.

2. SEE TEXT FOR DISCUSSION OF SUBSURFACE CONDITIONS.

3. INDIVIDUAL SOIL DESCRIPTIONS OBTAINED FROM U.S. ARMY CORP OF ENGINEERS PLANS FOR ONONDAGA DAM DATED 1947. STRATA LINES AND GEOLOGIC DESCRIPTIONS ADDED BY H&A OF NEW YORK, MARCH 1982.

ONONDAGA DAM, NEW YORK

PROFILE ALONG DAM CENTERLINE

U.S. ARMY ENGINEER DISTRICT BUFFALO

TO ACCOMPANY PHASE I, SEISMIC STABILITY INVESTIGATION

DATED: AUGUST 1982

FIGURE C-1

APPENDIX B

TEST BORING LOGS [illegible]-101 THROUGH [illegible]-103

Hole No. D82-101

DRILLING LOG	DIVISION: NORTH CENTRAL	INSTALLATION: BUFFALO DISTRICT	SHEET 1 of 7 SHEETS

1. PROJECT: ONONDAGA DAM	10. SIZE AND TYPE OF BIT: —
2. LOCATION (Coordinates or Station): STA H+28.8 R 10 COORD N 5302.73 E 13356.78	11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
3. DRILLING AGENCY: PARRAT-WOLFF INC.	12. MANUFACTURER'S DESIGNATION OF DRILL: MOBIL DRILL D-56 SER 621674
4. HOLE NO. (As shown on drawing title and file number): D82-101	13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 42; UNDISTURBED —
5. NAME OF DRILLER: A.J. BECK	14. TOTAL NUMBER CORE BOXES: 1
6. DIRECTION OF HOLE: [X] VERTICAL [ ] INCLINED ___ DEG. FROM VERT.	15. ELEVATION GROUND WATER: —
7. THICKNESS OF OVERBURDEN: 103.3 ft	16. DATE HOLE: STARTED 28 JULY 1982; COMPLETED 6 AUGUST 1982
8. DEPTH DRILLED INTO ROCK: 2.4 ft	17. ELEVATION TOP OF HOLE: 525.8 ft
9. TOTAL DEPTH OF HOLE: 105.7 ft	18. TOTAL CORE RECOVERY FOR BORING: — %
	19. SIGNATURE OF INSPECTOR: (illegible signature) (H.F.A of NEW YORK)

ELEVATION (a)	DEPTH (b)	LEGEND (c)	CLASSIFICATION OF MATERIALS (Description) (d)	% CORE RECOVERY (e)	BOX OR SAMPLE NO. (f)	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) (g)
525.8	0	SET, 8, 19, 24	Coarse to fine sandy GRAVEL, little silt, medium dense, dry, brown GM — 2.0	BAG 1 — 2.0	JAR 1 — 2.0	ADVANCE BORING W/3.75 IN ID HOLLOW STEM AUGERS W/PLUG. MFG CME. DRIVE 3.0 x 3.5 x 38 IN SPLIT SPOON W/300 HAMMER FALLING FREE 18 IN. DRIVE 2.0 ft REC 1.6 ft LOSS 0.4 ft
523.8	2	SET, 48, 52, 31	Gravelly coarse to fine SAND, little silt, very dense, dry, brown SM — 4.0	BAG 2 — 4.0	JAR 2 — 4.0	DRIVE 2.0 ft REC 2.0 ft LOSS 0.0 ft
521.8	4	SET, 9, 10, 34	Silty coarse to fine SAND, little gravel, medium dense, damp, brown SM	BAG 3	JAR 3 — 6.0	DRIVE 2.0 ft REC 2.0 ft LOSS 0.0 ft
	6	SET, 57	— 6.8	6.8	JAR 4 — 6.8	DRIVE 1.9 ft REC 1.9 ft LOSS 0.0 ft
519.0	7	67, 103	Gravelly SAND, little silt, very dense, damp, brown SM	BAG	JAR 5 — 7.9	
	8	[illegible], 60	Gravelly SAND, little silt, very dense, damp, brown SM	G 4 — 8.9	JAR 6 — 8.9	DRIVE 1.0 ft REC 1.0 ft LOSS 0.0 ft
	9				NS	WATER READING 29 JUL 82 AM. BOTTOM OF HOLE 8.6, CSG 8.0, DEPTH TO WATER - DRY
	10					

ENG FORM 1836 MAR 71 PREVIOUS EDITIONS ARE OBSOLETE. (TRANSLUCENT)

PROJECT: ONONDAGA DAM — HOLE NO. D82-101

DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE: 525.8 ft MSL | Hole No. D82-101

PROJECT: ONONDAGA DAM | INSTALLATION: BUFFALO DISTRICT | SHEET 2 of 9 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	10	SET 13 17 28	Gravelly coarse to fine SAND little silt, medium dense damp, brown SM	10.0	10.0 JAR 7 12.0	ADVANCE BORING w/ 3.75 IN ID HOLLOW STEM AUGER MFG. CME DRIVE 2.0 REC 2.0 ft LOSS 0.0 ft 3.0x3.5x38 SPLIT SPOON DRIVEN w/ 350 lb HAMMER
	12–15			BAG 5	NS	ADVANCE BORING TO 15.0 ft w/ 3.75 IN ID HOLLOW STEM AUGER w/PLUG. MFG-CME
	15	SET 38 50	Gravelly coarse to fine SAND, little silt, very dense, damp, brown SM		15.0 JAR 8 16.2	DRIVE 1.2 ft REC 1.2 ft LOSS 0.0 ft NOTE: LARGE GRAVEL PARTICLE IN NOSE OF SPOON
	16–20			BAG 5	NS	ADVANCE BORING TO 20.0 ft w/ 3.75 IN ID HOLLOW STEM AUGER w/PLUG. MFG-CME
	20	SET 50	Gravelly coarse to fine SAND little silt, very dense damp, brown SM	20.9	20.0 JAR 9 20.9	DRIVE 0.9 ft REC 0.9 ft LOSS 0.0 ft
	21–22				NS	

ENG FORM 1836-A | PROJECT: ONONDAGA DAM | HOLE NO. D82-101

DRILLING LOG (Cont Sheet) ELEVATION TOP OF HOLE 525.8 ft MSL **Hole No.** D82-101

PROJECT ONONDAGA DAM INSTALLATION BUFFALO DISTRICT SHEET 3 OF 9 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
503.3	22		Gravelly coarse to fine SAND, little silt, very dense, damp brown SM 22.5		NS	ADVANCE BORING TO 25.0 ft w/ 3.75 IN ID HOLLOW STEM AUGER w/PLUG MFG-CME SAMPLING CONDUCTED w/ 3.0 x 3.5 x 38 IN SPLIT SPOON DRIVEN BY 350 lb HAMMER FALLING FREE 18 IN
	25	SET 50	Fine to medium SAND, trace gravel, trace silt very compact, damp, brown SP	25.0 BAG 6 25.9	25.0 JAR 10 25.9	DRIVE 0.9 ft REC 0.9 ft LOSS 0.0 ft
497.3	26–29		28.5		NS	DRILLER NOTES MATR LESS DENSE @ APPROX 27 ft. AT APPROX 28.5 ft MATR BECOMES MORE DENSE. ADVANCE BORING TO 30.0 ft w/ 3.75 IN ID HOLLOW STEM AUGER w/PLUG MFG-CME DRILLER NOTES HARD MATL ENCOUNTERED FROM APPROX 29 to 30 ft
	30	SET 36 50	Coarse to fine sandy GRAVEL little silt, very dense, damp brown - GM	30.0 BAG 7	30.0 JAR 11 31.3	DRIVE 1.3 ft REC 1.3 ft LOSS 0.0 ft
	31–34					

ENG FORM 1836-A

PROJECT ONONDAGA DAM HOLE NO. D82-101

DRILLING LOG (Cont Sheet) — ELEVATION TOP OF HOLE: 525.8 ft MSL — Hole No. D82-101

PROJECT: ONONDAGA DAM — INSTALLATION: BUFFALO DISTRICT — SHEET 4 OF 9 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	34					ADVANCE BORING TO 35.0 ft w/3.75 IN ID HOLLOW STEM AUGER W/PLUG MFG CME
	35	SET / 45 / 50	Coarse to fine sandy GRAVEL, little silt, very dense, damp, brown GM	BAG 7	35.0 JAR 12 36.4	DRIVE 1.4 ft REC 1.4 ft LOSS 0.0 ft
	36–40				NS	ADVANCE BORING TO 40.0 ft w/ 3.75 IN ID HOLLOW STEM AUGER W/PLUG MFG-CME SAMPLING CONDUCTED w/ 3.0 x 3.5 x 38 IN SPLIT SPOON DRIVEN BY 350 lb HAMMER FALLING FREE 18 IN. MATL APPEARS TO BE MORE DENSE AT APPROX 37 ft.
	40	SET / 50	Coarse to fine sandy GRAVEL, little silt, very dense damp, brown GM	40.7	40.0 JAR 13 40.7	DRIVE 0.7 ft REC 0.7 ft LOSS 0.0 ft
483.3	42.5		42.5		NS	MATL APPEARS TO BE MORE DENSE AT APPROX 42.5 ft ADVANCE BORING TO 45.0 ft w/3.75 IN ID HOLLOW STEM AUGER W/PLUG MFG-CME
	45	SET / 44	Gravelly, coarse to fine SAND, little silt, very dense, damp, brown SM	45.0 BAG 8	45.0 JAR 14	DRIVE 1.3 ft REC 1.3 ft LOSS 0.0 ft
	46					

ENG FORM 1836-A — PROJECT: ONONDAGA DAM — HOLE NO. D82-101

DRILLING LOG (Cont Sheet) ELEVATION TOP OF HOLE 525.8 ft MSL — Hole No. D82-101

PROJECT: ONONDAGA DAM — INSTALLATION: BUFFALO DISTRICT — SHEET 5 OF 9 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	46	50	Gravelly coarse to fine SAND, little silt, very dense, damp, brown SM		46.3	
	47, 48, 49			BAG 8	NS 50.0	ADVANCE BORING TO 50.0 ft W/ 3.75IN ID HOLLOW STEM AUGER W/PLUG MFG-CME SAMPLING CONDUCTED BY 3.0x3.5x3.5IN DRIVEN W/ 350 lb HAMMER FALLING FREE 18IN. 30 JULY 82 AM DEPTH TO BOTTOM OF CSG 50.0 ft DEPTH TO WATER 46.8 ft
	50, 51	SET 30 37 45	Gravelly coarse to fine SAND, little silt, very dense, moist, brown SM	52.0	JAR 15 52.0	DRIVE 2.0 ft REC 1.7 ft LOSS 0.3 ft
	52, 53, 54		55.0	55.0	NS 55.0	ADVANCE BORING TO 55.0 ft W/ 3.75IN ID HOLLOW STEM AUGER W/PLUG MFG-CME
470.8	55, 56	SET 10 10 13	Fine sandy SILT, little clay, medium dense, moist, brown, ML	BAG 9 57.0	JAR 16 57.0	DRIVE 2.0 ft REC 1.8 ft LOSS 0.2 ft
	57, 58				NS	ADVANCE BORING TO 60.0 ft W/3.75IN ID HOLLOW STEM AUGER W/PLUG MFG-CME

DRILLING LOG (Cont Sheet) ELEVATION TOP OF HOLE 525.8 ft MSL Hole No. DB2-101

PROJECT ONONDAGA DAM INSTALLATION BUFFALO DISTRICT SHEET 6 of 9 SHEETS

ELEVATION (a)	DEPTH (b)	LEGEND (c)	CLASSIFICATION OF MATERIALS (Description) (d)	% CORE RECOV-ERY (e)	BOX OR SAMPLE NO. (f)	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) (g)
	58 – 60		60.0		NS 60.0	ADVANCE BORING TO 60.0 ft W/3.75 IN ID HOLLOW STEM AUGER W/PLUG MFG CME. DRIVE 1 3/8 x 2.0 x 27 1/2 IN STANDARD SPLIT SPOON W/140 lb SAFETY HAMMER FALLING FREE 30 IN
465.8	60 – 62	SET 9 8 8	Fine sandy SILT & CLAY trace fine gravel & coarse to medium sand in layers, medium dense, moist, brown CL 62.0		JAR 17 62.0	DRIVE 2.0 ft REC 1.2 ft LOSS 0.8 ft
463.8	62	SET	Silty fine SAND, loose, moist, brown SM 62.5		JAR 18 62.5	DRIVE 2.0 ft REC 2.0 ft LOSS 0.0 ft
463.3	62.5 – 64	9 13 17	Silty CLAY, little fine sand, trace organics, hard, moist, brown CL		JAR 19 64.0	
	64 – 65.5	SET 11 15	Silty CLAY, little fine sand, trace organics, hard, moist, brown CL 65.5		JAR 20 65.5	DRIVE 2.0 ft REC 1.7 ft LOSS 0.3 ft
460.3	65.5 – 66	24	Silty CLAY little coarse to fine sand, hard, moist, brown CL 66.0		JAR 21 66.0	
459.8	66 – 68	SET 19 13 17	Coarse to fine sandy GRAVEL, little silt, medium dense, moist, brown GM	68.0	JAR 22 68.0	DRIVE 2.0 ft REC 0.8 ft LOSS 1.2 ft
	68 – 70	SET 15 22 21	Coarse to fine sandy GRAVEL, little silt, medium dense, moist, brown GM	B 4 6 10	JAR 23 70.0	DRIVE 3.0 x 3.5 x 38" SPLIT SPOON WITH 340 lb HAMMER FREE FALLING 18 IN. DRIVE 2.0 ft REC 1.8 ft LOSS 0.2 ft

ENG FORM 1836-A PROJECT ONONDAGA DAM HOLE NO. DB2-101

DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE: 525.8 ft MSL | Hole No. D82-101

PROJECT: ONONDAGA DAM | INSTALLATION: BUFFALO DISTRICT | SHEET 7 OF 9 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g	CSG BLOWS PER FOOT
	70 – 72.0	SET, 18, 18, 25	Coarse to fine sandy GRAVEL, little silt, medium dense, wet, brown. GM	BAG 10	70.0; JAR 24; 72.0	DRIVE 3.0 x 3.5 x 38" SPLIT SPOON W/ 350 lb HAMMER FALLING FREE 18 IN. DRIVE 2.0 ft, REC 2.0 ft, LOSS 0.0 ft	
	72 – 73.0	SET, 19	Coarse to fine sandy GRAVEL, little silt, medium dense, wet, brown. GM (73.0)	72.0	72.0; JAR 25; 73.0	DRIVE 2.0 ft, REC 1.0, LOSS 1.0	
452.8	73 – 75.0	25, 30, SET, 18	Medium to fine SAND, trace coarse sand, trace silt, dense, wet, brown. SP (75.0)		JAR 26; 74.0; JAR 27; 75.0	WATER INTRODUCED INTO BOREHOLE IN ORDER TO RETAIN HYDROSTATIC HEAD. DRIVE 1 3/8 x 2.0 x 27 1/2" STANDARD SPLIT SPOON W/ 140 lb SAFETY HAMMER FALLING FREE 30 IN	
450.8	75 – 76.0	21, 25	Coarse to fine SAND, little gravel, little silt, dense, moist, brown. SM (76.0)	76.0	JAR 28; 76.0	DRIVE 2.0 ft, REC 0.7 ft, LOSS 1.3 ft	
449.8	76 – 78.0	SET, 31, 29, 32	Coarse to fine sandy GRAVEL, trace silt, very dense, wet, brown. GW (78.0)	BAG 11; 78.0	JAR 29; 78.0	DRIVE 3.0 x 3.5 x 38" SPLIT SPOON W/ 350 lb HAMMER FALLING FREE 18 IN. DRIVE 2.0 ft, REC 2.0 ft, LOSS 0.0 ft	
447.8	78 – 80.0	SET, 53, 43, 44	Silty coarse to fine SAND, little gravel, very dense, damp, brown. SM (80.0)		JAR 30; 80.0	2 AUGUST 1982 AM. DEPTH TO BOTTOM OF CSG 78.0 ft. DEPTH TO WATER 47.0 ft. CONTRACTOR HAS [illegible] CME 55 TRUCK MOUNTED ROTARY RIG SERIAL # 146605 PULL AUGERS BACK TO 75 ft SET NW CSG 3 3/16 IN ID AT 77.7 ft DRIVE CASING TO 78.0 ft W/ 350 lb HAMMER FALLING FREE 24 IN. CASING CLEANED OUT W/ TRI-CONE ROLLER BIT [illegible] TO SAMPLING. DRIVE 2.0 REC 0.5 LOSS 1.5	42, 64
445.8	80 – 82	SET, 48, 59, 40	Gravelly coarse to fine SAND, little silt, very dense, wet, brown. SM		JAR 31; 82.0	DRIVE 1 3/8 x 2.0 x 27 1/2 IN STANDARD SPLIT SPOON W/ 140 lb SAFETY HAMMER FALLING FREE 30 IN. DRIVE 2.0 ft, REC 1.2 ft, LOSS 0.8 ft	40, 63

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 525.8 ft. MSL	Hole No. D82-101
PROJECT ONONDAGA DAM	INSTALLATION BUFFALO DISTRICT	SHEET 8 OF [illegible] SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g	CSG BLOWS PER FT
	82 – 84	SET, 33, 18, 17	Gravelly coarse to fine SAND, little silt, very dense, wet, brown SM		82.0 JAR 32 84.0	3 AUGUST [illegible] AM CSG @ 82.0 DEPTH TO WATER 65.1 ft BOREHOLE ADVANCED w/ CME 75 TRUCK MOUNTED ROTARY SERIAL # 154115 ADVANCE BOREHOLE BY DRIVING NW CASING w/ 350 lb HAMMER FALLING FREE 24 IN BOREHOLE WASHED PRIOR TO SAMPLING W/ TRICONE ROLLER BIT. DRIVE 2.0 REC 0.8 LOSS 1.2	35, 47
	84 – 86	SET, 28, 26, 24	Gravelly coarse to fine SAND, little silt, very dense, wet, brown SM		JAR 33 86.0	DRIVE 1 3/8 x 2.0 x 27 1/2 IN STANDARD SPLIT SPOON W/ 140 lb SAFETY HAMMER FALLING FREE 30 IN DRIVE 2.0 ft REC 0.7 ft LOSS 1.3 ft	22, 52
	86 – 88	SET, 38, 35, 30	Gravelly coarse to fine SAND, little silt, very dense, wet, brown SM		JAR 34 88.0	DRIVE 2.0 ft REC 0.8 ft LOSS 1.2 ft	29, 49
	88 – 90	SET, 26, 26, 29	Gravelly coarse to fine SAND, little silt, very dense, wet, brown SM		JAR 35 90.0	DRIVE 2.0 ft REC 0.5 ft LOSS 1.5 ft	19, 37
433.8	90 – 92	SET, 34, 38, 29	Gravelly coarse to fine SAND, little silt, very dense, wet, brown SM 92.0		JAR 36 92.0	DRIVE 2.0 ft REC 0.5 ft LOSS 1.5 ft NOTE: LARGE GRAVEL PIECES OFTEN FOUND LODGED IN SPOON, SAMPLES FROM 78.0 TO 96.0 ft	28, 45
	92 – 94	SET, 80, 27, 37	silty coarse to fine SAND little gravel, very dense wet, brown SM		JAR 37 94.0	DRIVE 2.0 ft REC 0.5 ft LOSS 1.5 ft	18, 51

ENG FORM 1836-A

PROJECT ONONDAGA DAM HOLE NO. D82-101

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE: 525.8 ft MSL	Hole No. DB2-101
PROJECT: ONONDAGA DAM	INSTALLATION: BUFFALO DISTRICT	SHEET 9 of 9 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g	CSG BLOWS PER FOOT
429.8	94–96	SET / 35 / 37 / 34	Silty coarse to fine SAND, little gravel, very dense, wet, brown SM 96.0		94.0 JAR 38 96.0	DRIVE 1 3/8 x 2 x 27 1/2" STANDARD SPLIT SPOON w/140 lb SAFETY HAMMER FALLING FREE 30 IN. ADVANCE BOREHOLE w/ NX CASING DRIVEN w/ 350 lb HAMMER FALLING FREE 24 IN. DRIVE 2.0 ft REC 0.3 ft LOSS 1.7 ft	33, 74
	96–98	SET / 14 / 25 / 27	Coarse to fine sandy GRAVEL, little silt, dense wet, brown GM		JAR 39 98.0	DRIVE 2.0 ft REC 0.7 ft LOSS 1.3 ft	26, 37
425.8	98–100	SET / 22 / 26 / 24	Coarse to fine sandy GRAVEL, little silt dense, wet, brown GM 100.0		JAR 40 100.0	DRIVE 2.0 ft REC 0.8 ft LOSS 1.2 ft	33, 37
423.8	100–102	SET / 26 / 23 / 24	Silty coarse to fine SAND, little gravel, dense, wet, brown SM 102.0		JAR 41 102.0	DRIVE 2.0 ft REC 0.6 ft LOSS 1.4 ft	31, 38
422.8	102–103	SET / 25 / 100	Coarse to fine sandy GRAVEL, little silt, very dense, wet, brown GM APPROXIMATE TOP OF ROCK 103.3	103.3	JAR 42 103.3	DRIVE 1.3 ft REC 0.4 ft LOSS 0.9 ft SPOON REFUSAL 103.3 ft. ADVANCE CASING TO 103.2 ft w/350 lb HAMMER	45, 151
420.4	103–106		MANLIUS LIMESTON, OLNEY MEMBER LIMESTONE moderately hard, dense to finely crystalline flat lying, few stylolites, slightly weathered, solid, dark gray. Frequent fractures in the core are mechanical in nature caused by drilling. PULL #1 RAN 1.9 ft REC 1.6 ft UNACCOUNTABLE LOSS 0.3 ft BOTTOM OF BORING @ 105.7 ft		NS 103.8 PULL 1 105.7	FALLING FREE 18 IN. USED TRI-CONE ROLLER BIT TO 103.8 ft TO CLEAR PRESUMED OBSTRUCTION. CUTTINGS INDICATED ROCK. ATTEMPTED TO CORE w/ NX DOUBLE TUBED BARREL (2 1/8 in ID) BUT WAS UNABLE, DUE TO BENT CASING AT BOTTOM OF CASING. ATTEMPTED TO CORE w/ BXM DOUBLE TUBE BARREL (1 5/8 in ID) DRILLED 1.9 ft BEFORE CORE BARREL BROKE OFF. DRILLING TIME WAS 6 MIN/FT. HOLE WAS TERMINATED AND CORE BARREL RECOVERED AT A LATER DATE. BORE HOLE GROUTED TO SURFACE. BAG SIZE CASING @ 103.2 ft WATER 65.2 ft	

ENG FORM 1836-A

PROJECT: ONONDAGA DAM | HOLE NO. DB2-101

Hole No. D82-102

DRILLING LOG	DIVISION: NORTH CENTRAL	INSTALLATION: BUFFALO DISTRICT	SHEET 1 of 15 SHEETS

1. PROJECT: ONONDAGA DAM
2. LOCATION (Coordinates or Station): STA 9+84.2 R 2.2 COORD N5389.85 E 8690.22
3. DRILLING AGENCY: PARRATT-WOLFF INC.
4. HOLE NO. (As shown on drawing title and file number): D82-102
5. NAME OF DRILLER: W. RICE / A.J. BECK
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED ___ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: NOT FULLY PENETRATED
8. DEPTH DRILLED INTO ROCK: NOT ENCOUNTERED
9. TOTAL DEPTH OF HOLE: 123.0 ft
10. SIZE AND TYPE OF BIT: —
11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
12. MANUFACTURER'S DESIGNATION OF DRILL: CME 75 SERIAL NO 154115
13. TOTAL NO. OF OVER-BURDEN SAMPLES TAKEN: DISTURBED 98; UNDISTURBED
14. TOTAL NUMBER CORE BOXES: —
15. ELEVATION GROUND WATER: —
16. DATE HOLE: STARTED 5AUG82; COMPLETED 15AUG82
17. ELEVATION TOP OF HOLE: 525.7
18. TOTAL CORE RECOVERY FOR BORING: — %
19. SIGNATURE OF INSPECTOR: [signature] (U/A OF NEW YORK)

ELEVATION	DEPTH	LEGEND	CLASSIFICATION OF MATERIALS (Description)	% CORE RECOVERY	BOX OR SAMPLE NO.	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant)
525.7	0	SET, 13, 37, 27	Coarse to fine sandy GRAVEL, little silt, very dense, dry, brown GM	0.0	0.0 JAR 1 2.0	ADVANCE BORING w/ 3.75 IN ID HOLLOW STEM AUGER w/ PLUG - MFG CME. DRIVE 2.0 x 2.5 x 38 SPLIT SPOON w/ 350 lb HAMMER FALLING FREE 18 IN. DRIVE 2.0 ft REC 1.5 ft LOSS 0.5 ft
	2	SET, 35, 50, 50	Coarse to fine sandy GRAVEL, little silt, dense, dry, brown GM (4.0)	BAG 1	JAR 2 3.7	DRIVE 1.7 ft REC 1.7 ft LOSS 0.0 ft
					NS	ADVANCE BORING TO 4.0 ft w/ 3.75 IN ID HOLLOW STEM AUGER w/ PLUG MFG-CME
521.7	4	SET, 43, 50	Silty coarse to fine SAND, little gravel, very dense, dry, brown SM (5.4)	5.4	4.0 JAR 3 5.4	DRIVE 1.4 REC 1.4 LOSS 0.0
520.3				6.0	NS 6.0	ADVANCE BORING TO 6.0 ft w/ 3.75 IN ID HOLLOW STEM AUGER w/ PLUG MFG-CME.
	6	SET, 42, 36, 32	Gravelly coarse to fine SAND, little silt, dense, damp, brown SM	BAG 2	JAR 4 8.0	DRIVE 2.0 ft REC 2.0 ft LOSS 0.0 ft
	8	SET, 20, 27, 50	Gravelly coarse to fine SAND, little silt, dense, damp, brown SM		JAR 5 9.9 NS	DRIVE 1.9 ft REC 1.9 ft LOSS 0.0 ft
	10					

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PROJECT: ONONDAGA DAM | HOLE NO. D82-102

DRILLING LOG (Cont Sheet) ELEVATION TOP OF HOLE 525.7 ft MSL **Hole No.** D82-102

PROJECT: ONONDAGA DAM — INSTALLATION: BUFFALO DISTRICT — SHEET 2 OF 15 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	10	SET 50	Gravelly coarse to fine SAND, little silt, very dense, damp, brown SM	BAG 2 10.8	10.0 JAR 6 10.8	DRIVE 0.8 ft REC 0.8 ft LOSS 0.0 ft
	11			12.0	NS 12.0	ADVANCE BORING TO 12.0 ft W/3.75 IN HOLLOW STEM AUGER W/PLUG MFG-CME. DRIVE 3.0×3.5×38 IN SPLITSPOON W/350 lb HAMMER FREE FALL 18 IN
	12 13	SET 37 50 50	Gravelly coarse to fine SAND, little silt, very dense, damp, brown SM	BAG 3	JAR 7 13.9	DRIVE 1.9 ft REC 1.9 ft LOSS 0.0 ft
	14 15	SET 48 48 37	Gravelly coarse to fine SAND, little silt very dense, damp, brown SM		14.0 JAR 8 16.0	DRIVE 2.0 ft REC 2.0 ft LOSS 0.0 ft 6 AUG 1982 CONTRACTOR SWITCHED TO CME-55 SERIAL # 139795
	16	SET	Gravelly coarse to fine SAND, little silt, very dense, dry, brown SM		JAR 9 16.4	DRIVE 0.4 ft REC 0.4 LOSS ... ft SPOON REFUSAL 50 BLOWS/0.4 ft
	17				NS	ADVANCE BORING TO 18.0 ft W/ 3.75 IN ID HOLLOW STEM AUGER W/PLUG MFG-CME
	18 19	SET 56 50	Gravelly coarse to fine SAND, little silt, very dense, damp, brown SM		18.0 JAR 10 19.3	DRIVE 1.3 ft REC 1.3 ft LOSS 0.0 ft
					NS	ADVANCE BORING TO 20.0 ft W/3.75 IN ID HOLLOW STEM AUGER W/ PLUG MFG-CME
	20 21	SET 12 21 34	Gravelly coarse to fine SAND, little silt, dense, moist, brown SM		20.0 JAR 11	DRIVE 2.0 ft REC 1.3 ft LOSS 0.7 ft
503.7	22		22.0	22.0	22.0	

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PROJECT: ONONDAGA DAM — HOLE NO. D82-102

DRILLING LOG (Cont Sheet) ELEVATION TOP OF HOLE 525.7 ft MSL | Hole No. D82-102 | SHEET 3 OF 5 SHEETS

PROJECT: ONONDAGA DAM | INSTALLATION: BUFFALO DISTRICT

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
503.7	22	SET, 24, 26, 30	22.0 Coarse to fine sandy GRAVEL, little silt, dense, damp, brown GM 24.0	22.0 BAG 4 24.0	22.0 JAR 12 24.0	ADVANCE BORING w/ 3.75 IN ID HOLLOW STEM AUGER w/PLUG MFG-CME. DRIVE 3.0x3.5x38" SPLIT SPOON w/ 350 lb HAMMER FALLING FREE 18 IN. DRIVE 2.0 ft REC 2.0 ft LOSS 0.0 ft
501.7	24	SET	Medium to fine SAND, little silt, trace gravel, medium dense, damp, brown SM 24.5		JAR 13 24.5	DRIVE 1.7 ft REC 1.7 ft LOSS 0.0 ft
501.2	25	21, 30	Gravelly coarse to fine SAND, little silt, very dense, damp, brown SM 25.4		JAR 14 25.4	
500.3		50	Medium to fine SAND, little silt very dense, damp, brown SM 26.0		JAR 15 25.7 NS 26.0	ADVANCE BORING TO 26.0 ft w/ 3.75 IN HOLLOW STEM AUGER w/ PLUG MFG-CME
499.7	26	SET	Coarse to fine sandy GRAVEL, little silt dense, damp, brown GM 26.5	26.5	JAR 16 26.5	DRIVE 2.0 ft REC 2.0 ft LOSS 0.0 ft
499.2	27	31, 24, 35	Medium to fine SAND, trace silt, trace gravel, very dense, damp, brown SP	BAG	JAR 17 28.0	
	28	SET, 47, 50	Medium to fine SAND trace to little silt, trace gravel, very dense, damp brown SP	5	JAR 18 29.3	DRIVE 1.3 ft REC 1.3 ft LOSS 0.0 ft
	29				NS	ADVANCE BORING TO 30.0 ft w/ HOLLOW STEM AUGER w/ PLUG MFG-CME
	30	SET, 32	Medium to fine SAND, trace silt, trace gravel very dense, damp, brown SP 30.8	30.8	30.0 JAR 19 30.8	DRIVE 2.0 ft REC 2.0 ft LOSS 0.0 ft
494.9	31	45, 44	Coarse to fine sandy GRAVEL little silt, very dense, damp brown GM	BAG	JAR 20 32.0	
	32	SET, 45, 50	Coarse to fine sandy GRAVEL, little silt, very dense, damp, brown GM	6 33.3	JAR 21 33.3	DRIVE 1.3 ft REC 1.3 ft LOSS 0.0 ft
	33				NS	ADVANCE BORING TO 34.0 ft w/ 3.75 IN ID HOLLOW STEM AUGER w/ PLUG MFG-CME
491.7	34		34.0			

DRILLING LOG (Cont Sheet) — ELEVATION TOP OF HOLE: 525.7 ft MSL — Hole No. DB2-102

PROJECT: ONONDAGA DAM — INSTALLATION: BUFFALO DISTRICT — SHEET 4 OF 15 SHEETS

ELEVATION (a)	DEPTH (b)	LEGEND (c)	CLASSIFICATION OF MATERIALS (Description) (d)	% CORE RECOVERY (e)	BOX OR SAMPLE NO. (f)	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) (g)
491.7	34	SET 56 50	34.0 Coarse to fine SAND, some gravel, little silt, very dense, damp, brown SM	34.0	34.0 JAR 22 35.3	DRIVE 1.3 ft REC 1.3 ft LOSS 0.0 ft
	35			35.3	NS	ADVANCE BORING TO 36.0 ft w/ 3.75 IN ID HOLLOW STEM AUGER w/ PLUG MFG-CME
489.7	36	SET 50	36.0 Coarse to fine sandy GRAVEL, little silt, very dense, damp, brown GM	36.0	36.0 JAR 23 36.8	DRIVE 0.8 ft REC 0.8 ft LOSS 0.0 ft
	37			BAG 8	NS 38.0	ADVANCE BORING TO 38.0 ft w/ HOLLOW STEM AUGER w/ PLUG MFG-CME 9 AUGUST 1982 AM DEPTH TO BOTTOM OF CSG 38.0 ft DEPTH TO WATER - DRY
	38	SET 50	Coarse to fine sandy GRAVEL, little silt, very dense, damp, brown GM		JAR 24 38.7	DRIVE 0.7 ft REC 0.7 ft LOSS 0.0 ft
	39				NS 40.0	ADVANCE BORING TO 40.0 ft w/ 3.75 IN ID HOLLOW STEM AUGER w/ PLUG - MFG CME
	40	SET	Coarse to fine sandy GRAVEL, little silt, very dense, damp, brown GM		JAR 25 40.5	DRIVE 0.5 ft REC 0.3 ft LOSS 0.2 ft
	41				NS 42.0	SPOON REFUSAL @ 40.5 ft 85 BLOWS/0.5 ft ADVANCE BORING TO 42.0 ft w/ 3.75 IN ID HOLLOW STEM AUGER - NO PLUG CLEAN BOREHOLE w/ TRI-CONE ROLLER BIT TO 42.0 ft AND CONTINUE SAMPLING w/ 3.0 x 3.5 x 3E" SPLIT SPOON DRIVEN w/ 350 lb HAMMER FALLING FREE 18 IN.
	42	SET 85	Coarse to fine sandy GRAVEL, little silt, very dense, damp, brown GM		JAR 26 43.0	DRIVE 1.0 ft REC 0.3 ft LOSS 1.7 ft
	43		GM	BAG	NS 44.0	ADVANCE BORING TO 44.0 ft w/ 3.75 IN ID HOLLOW STEM AUGER w/ PLUG. MFG-CME NOTE: AUGERING DIFFICULT
	44	SET 41 38 50	Coarse to fine sandy GRAVEL, little silt, very dense, wet, brown GM	8	JAR 27 45.8	[illegible] AUGERS TO CHECK BIT, REPLACED 1 TOOTH. ADVANCED BORING TO 44.0 ft w/ HOLLOW STEM AUGERS w/o PLUG. CLEANED OUT AUGERS w/ TRI-CONE ROLLER BIT RESUME SAMPLING @ 44.0 ft DRIVE 1.8 REC 1.3 LOSS 0.5
	46				NS	ADVANCE BORING TO 46.0 ft

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PROJECT: ONONDAGA DAM — HOLE NO. DB2-102

DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE: 525.7 ft MSL | **Hole No.** D82-102

PROJECT: ONONDAGA DAM | INSTALLATION: BUFFALO DISTRICT | SHEET 5 OF 15 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	46	SET / 50	Coarse to fine sandy GRAVEL, little silt, very dense, wet, brown GM 46.9	46.9	46.0 JAR 28 46.9	DRIVE 0.9 ft REC 0.5 ft LOSS 0.4 ft
478.8	47				NS 48.0	ADVANCE BORING TO 48.0 ft W/ 3.75 IN ID HOLLOW STEM AUGER W/PLUG DRILLER NOTES DIFFICULT AUGERING
	48	SET / 50	Gravelly coarse to fine SAND, little silt, very dense, wet, brown SM	B A G 9	JAR 29 48.8	DRIVE 0.8 ft REC 0.8 ft LOSS 0.0 ft
	49				NS 50.0	ADVANCE BORING TO 50.0 ft W/ 3.75 IN ID HOLLOW STEM AUGER W/PLUG [illegible] 82 [illegible] DEPTH TO BOTTOM OF [illegible] ft DEPTH TO WATER 48.36
	50	SET / 50	Gravelly coarse to fine SAND, little silt, very dense, wet, brown SM		JAR 30 50.9	DRIVE 0.9 ft REC 0.9 ft LOSS 0.0 ft
	51				NS 52.0	ADVANCE BORING TO 52.0 ft W/ 3.75 IN ID HOLLOW STEM AUGER W/PLUG AND CONTINUE SAMPLING W/ 2.5 x 3.5 x 36 SPLIT SPOON [illegible] W/ 300 lb HAMMER FALLING FREE 18 IN
	52	50	Gravelly coarse to fine SAND, little silt, very dense, wet, brown SM		JAR 31 52.4	DRIVE 0.4 REC 0.4 LOSS 0.0
	53			B	NS 54.0	SPOON REFUSAL @ 52.4 ft 50 BLOWS/0.4 ft ADVANCE BORING TO 54.0 ft W/ 3.75 IN ID HOLLOW STEM AUGER W/PLUG. MFG CME
	54	SET / 50	Gravelly coarse to fine SAND, little silt, very dense, wet, brown SM	A G	JAR 32 54.8	DRIVE 0.8 ft REC 0.6 ft LOSS 0.2 ft
	55			9	NS 56.0	ADVANCE BORING TO 56.0 ft W/ 3.75 IN ID HOLLOW STEM AUGER W/PLUG MFG CME
	56	SET / 50	Gravelly coarse to fine SAND, little silt very dense, wet, brown SM		JAR 33 56.6	DRIVE 0.6 ft REC 0.4 ft LOSS 0.2 ft
	57				NS	ADVANCE BORING TO 58.0 ft W/ 3.75 IN ID HOLLOW STEM AUGER W/PLUG NOTE: AUGERING DIFFICULT
	58					

DRILLING LOG (Cont Sheet) — ELEVATION TOP OF HOLE: 525.7 ft MSL — Hole No. D82-102

PROJECT: ONONDAGA DAM — INSTALLATION: BUFFALO DISTRICT — SHEET 8 of 15 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g	CSG BLOWS PER FOOT
	58	SET	Gravelly coarse to fine SAND, little silt, very dense moist, brown SM		58.0 JAR 34 58.5	DRIVE 0.5 ft REC 0.5 ft LOSS 0.0 ft SPOON REFUSAL @ 58.5 ft 80 BLOWS / .5 ft	
	59			BAG	NS 60.0	ADVANCE BORING TO 60.0 ft w/3.75 IN ID HOLLOW STEM AUGER w/PLUG MFG CME	
	60	SET 50 36 50	Gravelly coarse to fine SAND, little silt, very dense, moist, brown SM	9	JAR 35 61.7	DRIVE 1.7 ft REC 1.7 ft LOSS 0.0 ft	
	61						
	62				NS	AUGER w/PLUG 61.7 ft USED CARBIDE TRI-CONE ROLLER BIT FROM 61.7 TO 63.0 ft ADVANCE 3.75 IN ID HOLLOW STEM AUGERS TO 63.0 ft w/ PLUG. 5 ft of RUNNING SAND IN AUGERS. UNABLE TO CLEAN OUT AUGERS w/TRI-CONE ROLLER BIT. PULL AUGERS TO 60.0 ft AND SET NW CASING 3 [illegible] ID TO DRIVE CSG TO 64.0 ft AND RESUME CONVENTIONAL SAMPLING w/1 3/8 x 2.0 x 27 [illegible] IN SPLIT SPOON DRIVEN w/140 lb SAFETY HAMMER [illegible]	35
	63		64.0	64.0	64.0		
461.7	64	SET 50 44	Coarse to fine sandy GRAVEL, little silt, very dense, wet, brown GM 65.5		JAR 36 65.5	DRIVE 2.0 ft REC 1.1 ft LOSS 0.9 ft	25
460.2	65	25	Fine sandy SILT & CLAY very stiff, damp, gray CL		JAR 37 66.0		32
	66	SET 14 15 21	Fine sandy SILT & CLAY very stiff, damp, brown CL 68.0		JAR 38 68.0	DRIVE 2.0 ft REC 2.0 ft LOSS 0.0 ft	39
	67						68
457.7	68	SET 14 12 12	SILT, little clay, trace medium to fine sand, medium dense, wet, brown ML 70.0		JAR 39 70.0	DRIVE 2.0 ft REC 0.4 ft LOSS 1.6 ft NOTE: THE POOR RECOVERY MAY BE DUE TO GRAVEL AND/OR COBBLE BEING DRIVEN AHEAD BY THE SPOON	35
455.7	70						62

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 525.7 ft MSL	Hole No. DB2-102
PROJECT: ONONDAGA DAM	INSTALLATION: BUFFALO DISTRICT	SHEET 7 OF 15 SHEETS

ELEVATION (a)	DEPTH (b)	LEGEND (c)	CLASSIFICATION OF MATERIALS (Description) (d)	% CORE RECOVERY (e)	BOX OR SAMPLE NO. (f)	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) (g)	CSG BLOWS PER FT
455.7	70 – 71	SET, 15, 19	Silty fine SAND, trace organics, wood & shell fragments, dense, moist, gray SM (70.0)		70.0 JAR 40	DRIVE 2.0 ft REC 2.0 ft LOSS 0.0 ft	60
454.2	71.5	14	Coarse to fine sandy GRAVEL, little silt, trace organics, stiff, moist, gray GM (71.5 – 71.7)		71.5 JAR 41		86
454.0	71.7		Clayey SILT, little fine sand, trace fine gravel, trace organics, stiff, moist, gray ML (71.7 – 72.0)		71.7 JAR 42		
453.7	72 – 74	SET, 17, 28, 18			72.0 JAR 43 74.0	DRIVE 2.0 ft REC 1.6 ft LOSS 0.4 ft. BORING ADVANCED WITH NW CASING 3 3/16 IN ID DRIVEN W/ 350 lb HAMMER FALLING FREE 24 IN. SAMPLING CONDUCTED W/ 1 3/8 x 2.0 x 27 1/2 IN STANDARD SPLITSPOON DRIVEN W/ 140 lb SAFETY HAMMER FALLING FREE 30 IN	56, 58
	74 – 76	SET, 15, 15, 25	Silty coarse to fine SAND, trace gravel, dense, wet, gray SM (76.0)		JAR 44 76.0	DRIVE 2.0 ft REC 1.1 ft LOSS 0.9 ft	56, 195
449.7	76 – 78	SET, 25, 15, 13	Gravelly coarse to fine SAND, little silt, dense, wet, gray SM		JAR 45 78.0	Drive 2.0 ft REC 1.1 ft LOSS 0.9 ft	72, 63
	78 – 80	SET, 18, 16, 15	Gravelly coarse to fine SAND, little silt, trace wood fragments, medium dense, wet, gray SM (80.0)		JAR 46 80.0	DRIVE 2.0 ft REC 0.8 ft LOSS 1.2 ft	50, 78
445.7	80 – 82	SET, 31, 33, 28	Silty coarse to fine SAND, little gravel, very dense, wet, brown SM		JAR 47 82.0	DRIVE 2.0 ft REC 0.8 ft LOSS 1.2 ft	75, 195

DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE: 525.7 ft MSL | Hole No. D82-102

PROJECT: ONONDAGA DAM | INSTALLATION: BUFFALO DISTRICT | SHEET 8 of 15 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g	CSG BLOWS PER FOOT
	82	SET, 38, 30, 24	Silty coarse to fine SAND, little gravel, very dense, wet, brown SM		82.0 JAR 48 84.0	Drive 2.0 ft REC 1.8 ft LOSS 0.2 ft	88, 115
	83–84	SET, 20, 19, 24	Silty coarse to fine SAND, little gravel, dense, wet, brown SM 86.0		JAR 49 86.0	DRIVE 2.0 ft REC 1.1 ft LOSS 0.9 ft. BORING ADVANCED BY NW CASING 3 3/16 IN ID DRIVEN W/ 350 lb HAMMER FALLING FREE 24 IN. SAMPLING CONDUCTED W/ 1 3/8 x 2.0 x 27 1/2 IN STANDARD SPLIT SPOON DRIVEN W/ 140 lb SAFETY HAMMER FALLING FREE 30 IN	86, 118
439.7	86	SET, 21, 18, 15	Gravelly coarse to fine SAND, little silt, dense, wet, brown SM		JAR 50 88.0	DRIVE 2.0 ft REC 1.1 ft LOSS 0.9 ft	47, 77
	88	SET	Gravelly coarse to fine SAND, little silt, dense, wet, brown - SM 88.5		JAR 51	DRIVE 2.0 ft REC 1.2 ft LOSS 0.8 ft	95
437.2	88.5	22	Silty medium to fine SAND trace gravel & coarse sand, wet, brown - SM 89.0		JAR 52 89.0		
436.7	89	26, 26	Gravelly coarse to fine SAND, little silt, very dense, wet, brown SM		JAR 53 90.0		95
	90	SET, 36, 29, 28	Gravelly coarse to fine SAND, little silt, very dense, wet, brown SM		JAR 54 92.0	DRIVE 2.0 ft REC 1.4 ft LOSS 0.6 ft	25, 71
	92	SET, 29, 27, 19	Gravelly coarse to fine SAND, little silt, very dense, wet, gray SM 94.0		JAR 55 94.0	12 AUG 82 AM DEPTH TO BOTTOM OF CSG 92.0 DEPTH TO WATER 41.3 DRIVE 2.0 ft REC 1.1 ft LOSS 0.9 ft	82, 108
431.7	94						

ENG FORM 1836-A

PROJECT: ONONDAGA DAM | HOLE NO. D82-102

DRILLING LOG (Cont Sheet) ELEVATION TOP OF HOLE: 525.7 ft MSL — Hole No. DB2-102

PROJECT: ONONDAGA DAM — INSTALLATION: BUFFALO DISTRICT — SHEET 9 OF 15 SHEETS

ELEVATION (a)	DEPTH (b)	LEGEND (c)	CLASSIFICATION OF MATERIALS (Description) (d)	% CORE RECOVERY (e)	BOX OR SAMPLE NO. (f)	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) (g)	CSG BLOW PER FOOT
431.7	94	SET 21	94.0 Silty coarse to fine SAND trace gravel, dense, wet gray SM 95.0		94.0 JAR 56	DRIVE 2.0ft REC 1.1ft LOSS 0.9ft	87
430.7	95	25	Medium to fine SAND, little silt, trace coarse sand, dense wet, gray SM 95.5		95.0 JAR 57 95.5		165
430.2		25	Silty fine SAND, trace coarse to medium sand, dense, wet, gray SM		JAR 58 96.0		
	96	SET 21	Silty fine SAND, trace coarse to medium sand, dense wet, gray SM 97.0		JAR 59 97.0	BORE HOLE ADVANCED w/ NW CASING 3 7/16 IN ID w/ 350 lb HAMMER FALLING FREE 24 IN SAMPLING CONDUCTED w/ 1 3/8" x 2.0" x 27 1/2" STANDARD SPLIT SPOON SAMPLER DRIVEN w/ 140 lb SAFETY HAMMER FALLING FREE 30 IN.	54
428.7	97	20 20	Coarse to fine SAND, little gravel, little silt, dense, wet, gray SM		JAR 60 98.0	DRIVE 2.0ft REC 1.2ft LOSS 0.8ft	67
	98 99	SET 20 18 15	Coarse to fine SAND, little silt, little gravel, dense, wet, gray SM 100.0		JAR 61 100.0	DRIVE 2.0ft REC 1.1ft LOSS 0.9ft	57 65
425.7	100	SET 27	Medium to fine SAND, little silt, dense, wet, gray SM 101.0		JAR 62 101.0	DRIVE 2.0ft REC 1.4ft LOSS 0.6ft	81
424.7	101	29 46	Gravelly coarse to fine SAND, little silt, very dense, wet, gray SM 102.3		JAR 63 102.0 JAR 64 102.3		154
423.4	102	SET	Silty medium to fine SAND, medium dense, wet, gray SM 102.6		JAR 65 102.6	DRIVE 2.0ft REC 1.1ft LOSS 0.9ft	65
423.1	103	17 17 15	Coarse to fine SAND, little silt, little gravel, medium dense, wet, gray SM		JAR 66 104.0		56
	104 105 106	SET 14 18 25	Coarse to fine SAND, little silt, little gravel SM		JAR 67 106.0	DRIVE 2.0ft REC 1.4ft LOSS 0.6ft	47 82

DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE: 525.7 ft MSL | Hole No. D82-102

PROJECT: ONONDAGA DAM | INSTALLATION: BUFFALO DISTRICT | SHEET 10 OF 15 SHEETS

ELEVATION (a)	DEPTH (b)	LEGEND (c)	CLASSIFICATION OF MATERIALS (Description) (d)	% CORE RECOVERY (e)	BOX OR SAMPLE NO. (f)	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) (g)	CSG BLOWS PER FOOT
	106–108	SET / 21 / 26 / 28	Coarse to fine SAND, little gravel, little silt, dense, wet, gray SM — 108.0		106.0 JAR 68 108.0	DRIVE 2.0 ft REC 1.3 ft LOSS 0.7 ft. SAMPLING CONDUCTED BY 1 3/8 x 2.0 x 27 1/2 IN STANDARD SPLIT SPOON DRIVEN w/ 140 lb SAFETY HAMMER FALLING FREE 30 IN	110, 117
417.7	108–110	SET / 18 / 22 / 31	Silty fine SAND, trace coarse to medium sand, trace gravel, dense, wet, gray SM		JAR 69 110.0	DRIVE 2.0 ft REC 1.4 ft LOSS 0.6 ft	74, 68
	110–112	SET / 19 / 29 / 30	Silty fine SAND, trace gravel, trace coarse to medium sand, dense, wet, gray SM — 112.0		JAR 70 112.0	DRIVE 2.0 ft REC 1.3 ft LOSS 0.7 ft	63, 52
413.7	112–114	SET / 74 / 21 / 20	Coarse to fine sandy GRAVEL, little silt, very dense, wet, gray GM		JAR 71 114.0	13 AUG 82 AM DEPTH TO BOTTOM OF CSG 110.0 DEPTH TO BOTTOM OF HOLE 112.0 DEPTH TO TOP OF WATER 63.4 ft. DRIVE 2.0 REC 0.5 LOSS 1.5	90, 165
	114–116	SET / 60 / 75 / 75	Coarse to fine sandy GRAVEL, little silt, very dense, wet, gray GM		JAR 72 116.0	DRIVE 2.0 ft REC 1.1 ft LOSS 0.9 ft. ROLLER BIT USED TO CLEAR POSSIBLE OBSTRUCTION. CASING ADVANCED TO 116.0 ft	325, 228
	116–116.6	SET / [illegible]	Coarse to fine sandy GRAVEL, little silt, very dense, wet, gray GM		JAR 73 116.6	DRIVE 0.6 ft REC 0.6 ft LOSS 0.0 ft	141
	116.6–118				NS	USED TRI-CONE ROLLER BIT TO 118.0 ft AND RESUMED SAMPLING.	343

ENG FORM 1836-A JAN 67 | PROJECT: ONONDAGA DAM | HOLE NO. D82-102

DRILLING LOG (Cont Sheet)

Elevation Top of Hole: 525.7 ft MSL | Hole No. D82-102 | Sheet 11 of 15 sheets

Project: ONONDAGA DAM | Installation: BUFFALO DISTRICT

Elevation (a)	Depth (b)	Legend (c)	Classification of Materials (Description) (d)	% Core Recovery (e)	Box or Sample No. (f)	Remarks (Drilling time, water loss, depth of weathering, etc., if significant) (g)	CSG Blow per Foot
	118	SET			118.0	DRIVE 2.0 ft	145
		77			NS	REC 0.0 ft	
	119	88				LOSS 2.0 ft	150
		25			120.0	NOTE: COBBLE DRIVEN AHEAD OF SPOON. TRI-CONE ROLLER BIT WAS USED TO ADVANCE CASING TO 120.0 ft.	
	120	SET	Coarse to fine sandy GRAVEL, little silt, very dense, wet, gray GM 120.5		JAR 74 120.5	6 AUG 1982 AM DEPTH TO BOTTOM OF CSG 120.0 ft DEPTH TO WATER 85.5 ft	160
405.2		21	Fine sandy SILT, dense, wet, red-brown ML		JAR 75	DRIVE 2.0 ft REC 1.2 ft LOSS 0.8 ft	
	121	10					95
		4			122.0		
	122	SET	Fine sandy SILT, trace medium sand, very stiff, damp, red-brown ML 122.5		JAR 76 122.5	DRIVE 2.0 ft REC 1.2 ft LOSS 0.8 in.	87
403.2		27	Silty fine SAND, very dense, wet, red-brown SM		JAR 77	BORING ADVANCED w/ NW FLUSH JOINT CASING. SAMPLING CONDUCTED W/ 1 3/8 x 2.0 x 27 1/2 IN STANDARD SPLIT SPOON SAMPLER DRIVEN W/ 140 lb SAFETY HAMMER FALLING FREE 30 IN	
	123	36					138
		34			124.0		
	124	SET	Silty fine SAND, trace medium sand, w/ occassional silt layers, dense, wet, red-brown SM		JAR 78	DRIVE 2.0 ft REC 1.3 ft LOSS 0.7 ft	94
		22					
	125	24					170
		33	126.0		126.0		
399.7	126	SET	Fine sandy SILT, trace medium sand, dense, wet, red-brown ML 127.0		JAR 79	DRIVE 2.0 ft REC 1.5 ft LOSS 0.5 ft	135
		34			127.0		
398.7	127	33	Silty fine SAND, very dense, wet, red-brown SM		JAR 80		148
		34			128.0		
	128	SET	Silty fine SAND, very dense, wet, red-brown SM		JAR 81	DRIVE 2.0 ft REC 0.5 ft LOSS 1.5 ft	97
		26					
	129	30					213
395.7	130	27	130.0		130.0		

DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE 525.7 ft MSL | Hole No. D82-102

PROJECT: ONONDAGA DAM | INSTALLATION: BUFFALO DISTRICT | SHEET 12 OF 15 SHEETS

ELEVATION (a)	DEPTH (b)	LEGEND (c)	CLASSIFICATION OF MATERIALS (Description) (d)	% CORE RECOVERY (e)	BOX OR SAMPLE NO. (f)	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) (g)	CSG BLOWS PER FOOT
395.7	130	SET 21 23 25	Fine sandy SILT, dense, wet, red-brown ML 130.0 – 132.0		JAR 82 132.0	DRIVE 2.0 ft REC 2.0 ft LOSS 0.0 ft	100 175
393.7	131 132	SET 29 34 39	Silty fine SAND, to fine SAND, little silt, very dense, wet, red-brown SM		JAR 83 134.0	DRIVE 2.0 ft REC 1.6 ft LOSS 0.4 ft	101 79
	133 134	SET 27 30 37	Silty fine SAND, very dense, wet, red-brown SM		JAR 84 136.0	DRIVE 2.0 ft REC 1.5 ft LOSS 0.5 ft BORING ADVANCED w/NW FLUSH JOINT CASING. SAMPLING CONDUCTED w/ 1 3/8 x 2.0 x 27 1/2 SAMPLER DRIVEN BY 140 lb WEIGHT FALLING FREELY 30 IN	78 117
	135 136	SET 25 29 34	Silty fine SAND, very dense, wet, red-brown SM		JAR 85 138.0	DRIVE 2.0 ft REC 1.6 ft LOSS 0.4 ft	67 140
	137 138	SET 23 25 30	Silty fine SAND, dense, wet, red-brown SM		JAR 86 140.0	DRIVE 2.0 ft REC 2.0 ft LOSS 0.0 ft	80 87
	139 140	SET 15 18 28	Silty fine SAND, dense, wet, red-brown with occassional silt layers SM 142.0		JAR 87 142.0	DRIVE 2.0 ft REC 1.6 ft LOSS 0.4 ft	7 17
383.7	141 142						

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE: 525.7 ft MSL	Hole No. D82-102
PROJECT: ONONDAGA DAM	INSTALLATION: BUFFALO DISTRICT	SHEET 13 OF 15 SHEETS

ELEVATION (a)	DEPTH (b)	LEGEND (c)	CLASSIFICATION OF MATERIALS (Description) (d)	% CORE RECOVERY (e)	BOX OR SAMPLE NO. (f)	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) (g)	CSG BLOWS PER FOOT
383.7	142	SET	Clayey SILT, stiff, damp, red-brown ML (142.0–142.5)		SAR 88 (142.5)	16 AUG 1982 SET BX CASING 2.75 IN ID TO 142.0 ft AND RESUME SAMPLING. CASING DRIVEN BY 350 lb HAMMER FALLING FREE 24 IN. CASING CLEANED W/A FISH TAIL BIT WHICH DIRECTS WATER TO THE SIDE.	23
	143	24, 25, 23	Fine to medium SAND, little silt, dense, wet, red-brown SM		SAR 89 (144.0)	DRIVE 2.0 ft REC 1.0 ft LOSS 1.0 ft	28
	144–145	SET, 20, 21, 19	Fine to medium SAND, little silt, trace coarse sand, dense, wet, red-brown SM		SAR 90 (146.0)	DRIVE 2.0 ft REC 1.0 ft LOSS 1.0 ft	15, 23
	146–147	SET, 20, 21, 24	Fine to medium SAND, little silt, trace coarse sand, dense, wet, red-brown. SM		SAR 91 (148.0)	DRIVE 2.0 ft REC 1.1 ft LOSS 0.9 ft	29, 31
	148–149	SET, 22, 23, 21	Fine to medium SAND little silt, dense, wet, red-brown SM (150.0)		SAR 92 (150.0)	DRIVE 2.0 ft REC 1.4 ft LOSS 0.6 ft	9, 14
375.7	150–151	SET, 23, 30, 31	Fine to medium SAND, little silt, trace coarse sand, very dense, wet, gray SM		SAR 93 (152.0)	DRIVE 2.0 ft REC 1.2 ft LOSS 0.8 ft	4, 12
	152–153				NS	ADVANCE BW CASING TO 154.0 ft W/ 350 lb HAMMER FALLING FREE 24 IN. RESUME STANDARD SAMPLING AT 5 ft INTERVALS W/ 1 3/8 x 2.0 x 27 1/2 IN STANDARD SPLIT SPOON DRIVEN BY 140 lb SAFETY HAMMER FALLING FREE 30 IN	25, 35
371.7	154		(154.0)				

ENG FORM 1836-A

PROJECT: ONONDAGA DAM HOLE NO. D82-102

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 525.7 ft MSL	Hole No. D82-102
PROJECT ONONDAGA DAM	INSTALLATION BUFFALO DISTRICT	SHEET 14 OF 15 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g	CSG BLOWS PER FOOT
371.7	154	SET 53 60 51	Silty coarse to fine SAND, little gravel very dense, moist, gray SM (154.0)		154.0 JAR 94 156.0	DRIVE 2.0 ft REC 2.0 ft LOSS 0.0 ft SAMPLING CONDUCTED BY 1 3/8 x 2.0 x 27 1/2 ID STANDARD SPLIT SPOON DRIVEN w/ 140 lb SAFETY HAMMER FALLING FREE 30 IN	8
	155						23
	156				NS	ADVANCE BW CASING TO 159.0 ft w/ 350 lb HAMMER FREE FALLING 24 IN	52
	157						106
	158				159.0		88
	159	SET 100	NOTE: WASH SAMPLE COBBLES & BOULDERS ENCOUNTERED		JAR 95 159.8	DRIVE 0.8 ft REC 0.1 ft LOSS 0.7 ft	46
	160				NS	OBSTRUCTION ENCOUNTERED AT 161.1 ft WHILE ADVANCING BW CASING. OBSTRUCTION COULD NOT BE REMOVED w/ BW FISHTAIL BIT. REMOVED BW CASING AND ADVANCED NW CASING TO 161.1 ft. TRI-CONE ROLLER BIT USED FROM 161.1 TO 162.6 ft THROUGH OBSTRUCTION AND FROM 162.6 TO 164.0 ft THROUGH COBBLES. BW CASING SET TO 164.0 ft AND SAMPLING RESUMED	149
364.6	161		(161.1) BOULDER				13
363.1	162		(162.6)				51
	163				164.0		111
	164	SET 62 100	Silty coarse to fine SAND, w/ embedded gravel, very dense, moist, gray SM COBBLES ENCOUNTERED		JAR 96 165.3 NS	DRIVE 1.3 ft REC 0.2 ft LOSS 1.1 ft SPOON REFUSAL 165.3 ft ROLLER BIT TO 166.8 ft AND ADVANCE CASING TO 169.0 ft w/ 350 lb HAMMER FALLING FREE. RESUME STANDARD SAMPLING AT 169.0 ft	38
	165						61
	166						

ENG FORM 1836-A

PROJECT ONONDAGA DAM HOLE NO. D82-102

DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE: [illegible] MSL | Hole No. DB2-102

PROJECT: ONONDAGA DAM | INSTALLATION: BUFFALO DISTRICT | SHEET 15 OF 15 SHEETS

ELEVATION (a)	DEPTH (b)	LEGEND (c)	CLASSIFICATION OF MATERIALS (Description) (d)	% CORE RECOVERY (e)	BOX OR SAMPLE NO. (f)	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) (g)	CSG BLOWS PER FOOT
	166				JAR 97	UNABLE TO ADVANCE CASING PAST 167.7 ft. FISHTAIL BIT 167.7 ft TO 169.0 ft. COBBLES ENCOUNTERED. ADVANCED BW CASING TO 165.0 ft W/ 350 lb HAMMER. NOTE: JAR 97 IS A WASH SAMPLE FROM 167.7 TO 169.0 ft	77
	167						35
							47
	168						214
	169	SET	Fine sandy SILT trace clay with embedded coarse to medium sand and gravel, very dense, moist to wet, brown ML		169.0	DRIVE 2.0 ft REC 1.2 ft LOSS 0.8 ft	65
		35			JAR 98	SAMPLING CONDUCTED BY 1⅜ x 2.0 x 27½ IN STANDARD SPLIT SPOON DRIVEN W/ 140 lb SAFETY HAMMER FALLING FREE 30 IN	
	170	36					60
		58			171.0		
	171					BW CASING ADVANCED TO REFUSAL @ 173.0 ft REMOVED BW CASING TO CHECK POSSIBLE DAMAGE. 10.0 ft OF BW CASING REMAINING IN BOREHOLE FROM 163.0 TO 173.0 ft.	115
	172						304
352.7	173		BOTTOM OF BORING @ 173.0 ft			BOREHOLE TERMINATED AND GROUTED TO SURFACE.	
	174						
	175						
	176						
	177						
	178						

Hole No. D82-103

DRILLING LOG	DIVISION: NORTH CENTRAL	INSTALLATION: BUFFALO DISTRICT	SHEET 1 of 16 SHEETS

1. PROJECT: ONONDAGA DAM
2. LOCATION (Coordinates or Station): STA 6+02.5 R 2.4 COORD N 5463.02 E 1151.61
3. DRILLING AGENCY: PARRATT-WOLFF INC.
4. HOLE NO. (As shown on drawing title and file number): D82-103
5. NAME OF DRILLER: A. ELLENSWORTH / W. RICE
6. DIRECTION OF HOLE: ☒ VERTICAL ☐ INCLINED ____ DEG. FROM VERT.
7. THICKNESS OF OVERBURDEN: NOT PENETRATED
8. DEPTH DRILLED INTO ROCK: NOT ENCOUNTERED
9. TOTAL DEPTH OF HOLE: 184.8 FT
10. SIZE AND TYPE OF BIT: —
11. DATUM FOR ELEVATION SHOWN (TBM or MSL): MSL
12. MANUFACTURER'S DESIGNATION OF DRILL: CME 75
13. TOTAL NO. OF OVERBURDEN SAMPLES TAKEN: DISTURBED 70 | UNDISTURBED —
14. TOTAL NUMBER CORE BOXES: —
15. ELEVATION GROUND WATER: —
16. DATE HOLE: STARTED 20 AUG 82 | COMPLETED 27 AUG 82
17. ELEVATION TOP OF HOLE: 525.8 ft
18. TOTAL CORE RECOVERY FOR BORING: —
19. SIGNATURE OF INSPECTOR: [signature] (STA OF NEW YORK)

ELEVATION (a)	DEPTH (b)	LEGEND (c)	CLASSIFICATION OF MATERIALS (Description) (d)	% CORE RECOVERY (e)	BOX OR SAMPLE NO. (f)	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) (g)
525.8	0	SET 17 25 27	Gravelly coarse to fine SAND, little silt, dense damp, brown SM	0.0 BAG 1	0.0 JAR 1 2.0	ADVANCE BORING W/ 3.75 IN ID HOLLOW STEM AUGER W/ RIG MFG CME. SAMPLE WILL BE TAKEN EVERY 5 ft IN THE BOREHOLE. SAMPLE TAKEN W/ 3.0 x 3.5 x 38 IN SPLIT SPOON DRIVEN W/ 340 lb HAMMER FALLING FREE 30 IN DRIVE 2.0 ft REC 1.5 ft LOSS 0.5 ft
	1–4				NS	
520.8	5	SET 34	5.0 Silty coarse to fine SAND, little gravel, dense damp, brown SM 6.0	5.0 BAG 2 6.0	5.0 JAR 2 6.0	DRIVE 1.4 ft REC 1.4 ft LOSS 0.0 ft
519.8	6	50	Gravelly coarse to fine SAND, little silt, very dense, damp, brown SM	BAG 1	JAR 3 6.4 NS	SPOON REFUSAL @ 6.4 ft ADVANCE BORING TO 10.0 ft W/ 3.75 IN ID HOLLOW STEM AUGER W/ RIG MFG CME
	7–10					

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PROJECT: ONONDAGA DAM | HOLE NO. D82-103

DRILLING LOG (Cont Sheet) ELEVATION TOP OF HOLE: 525.8 ± MSL — Hole No. DB2-103

PROJECT: ONONDAGA DAM — INSTALLATION: BUFFALO DISTRICT — SHEET 2 of 16 SHEETS

ELEVATION (a)	DEPTH (b)	LEGEND (c)	CLASSIFICATION OF MATERIALS (Description) (d)	% CORE RECOVERY (e)	BOX OR SAMPLE NO. (f)	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) (g)
	10	SET	Gravelly coarse to fine SAND, little silt, dense, damp, brown SM 10.5	BAG 1 10.5	10.0 JAR 4 10.5	DRIVE 0.9 ft REC 0.9 ft LOSS 0.0 ft
515.3		50	Silty coarse to fine SAND, little gravel, very dense, damp, brown SM	BAG 2 10.9	JAR 5 10.9	
	11					ADVANCE BORING TO 15.0 ft W/ 3.75 IN ID HOLLOW STEM AUGER W/PLUG MFG-CME. SAMPLING CONDUCTED BY 3.0x3.5x3 IN STANDARD SPLIT SPOON DRIVEN W/ 350 lb HAMMER FALLING FREE 30 IN.
	12		12.5			
513.3	13				NS	
	14			15.0	15.0	
	15	SET	Coarse to fine SAND, little gravel, trace to little silt, very dense, damp, brown SM	B	JAR 6	DRIVE 2.0 ft REC 2.0 ft LOSS 0.0 ft
		25				
	16	34		A		
		33			17.0	
	17			G		ADVANCE BORING TO 20.0 ft W/ 3.75 IN ID HOLLOW STEM AUGER W/PLUG. MFG CME
	18				NS	
				3		
	19				20.0	
	20	SET	Coarse to fine SAND, little gravel, little silt, very dense, damp, brown SM		JAR 7	DRIVE 1.3 ft REC 1.3 ft LOSS 0.0 ft
		49				
	21	50			21.3	
					NS	ADVANCE BORING TO 25.0 ft W/ 3.75 IN ID HOLLOW STEM AUGER W/PLUG MFG CME
	22					

DRILLING LOG (Cont Sheet) ELEVATION TOP OF HOLE 523.8 ft MSL Hole No. D82-103

PROJECT ONONDAGA DAM INSTALLATION BUFFALO DISTRICT SHEET 5 of 16 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	22–25			BAG 3	NS	
	25	SET	Coarse to fine SAND, little gravel, trace to little silt, very dense, damp, brown SM 25.6	25.6	25.0 JAR 8 25.6	DRIVE 1.7 ft REC 1.7 ft LOSS 0.0 ft
500.2	25.6	34 50 50	Gravelly coarse to fine SAND, little silt, very dense, damp, brown SM		JAR 9 26.7	
	26.7–30			BAG 4	NS	ADVANCE BORING TO 30.0 ft w/ HOLLOW STEM AUGER w/ PLUG, MFG CME. SAMPLING CONDUCTED BY 3.0x3.5x38IN STANDARD SPLIT SPOON DRIVEN BY 350lb HAMMER FALLING FREE 18IN
	30	SET 55	Gravelly coarse to fine SAND, little silt, damp, very dense, brown SM	31.0	30.0 JAR 10 31.0	DRIVE 1.0 ft REC 1.0 ft LOSS 0.0 ft
	31–34				NS	ADVANCE BORING TO 35.0 ft w/ HOLLOW STEM AUGER w/ PLUG MFG-CME

ENG FORM 1836-A PROJECT ONONDAGA DAM HOLE NO. D82-103

DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE 525.8 ft MSL | Hole No. D82-103

PROJECT: ONONDAGA DAM | INSTALLATION: BUFFALO DISTRICT | SHEET 4 of 16 SHEETS

ELEVATION (a)	DEPTH (b)	LEGEND (c)	CLASSIFICATION OF MATERIALS (Description) (d)	% CORE RECOVERY (e)	BOX OR SAMPLE NO. (f)	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) (g)
	34–35					
	35	50				ATTEMPTED TO SAMPLE @ 35.0 ft. SPOON REFUSAL @ 35.1 ft DRIVE 0.1 ft REC 0.0 ft LOSS 0.1 ft
	36–40				NS	ADVANCE BORING TO 40.0 ft w/ 3.75 IN ID HOLLOW STEM AUGER w/PLUG MFG-CME SAMPLING CONDUCTED BY 3.0x3.5x38 IN SPLIT SPOON DRIVEN w/350 lb HAMMER FALLING FREE 18 IN
	40–42	SET 27 48 50	Gravelly coarse to fine SAND, little silt very dense, damp, brown SM	40.0 B A G 5	40.0 JAR 11 42.0	DRIVE 2.0 ft REC 2.0 ft LOSS 0.0 ft
	42–45				NS	ADVANCE BORING TO 45.0 ft w/3.75 IN ID HOLLOW STEM AUGER w/PLUG MFG-CME
	45–46	SET 18	Gravelly coarse to fine SAND, little silt, dense moist, brown SM		45.0 JAR 12	DRIVE 2.0 ft REC 2.0 ft LOSS 0.0 ft

ENG FORM 1836-A (JUN 67)

PROJECT: ONONDAGA DAM | HOLE NO. D82-103

DRILLING LOG (Cont Sheet)	ELEVATION TOP OF HOLE 525.8 ft MSL	Hole No. D82-103
PROJECT ONONDAGA DAM	INSTALLATION BUFFALO DISTRICT	SHEET 5 of 16 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	46	24		BAG 5	JAR 12	
		32		47.0	47.0	
	47 – 50				NS	ADVANCE BORING TO 50.0 ft w/ 3.75 IN ID HOLLOW STEM AUGER w/PLUG MFG-CME SAMPLING CONDUCTED BY 3.0 x 3.5 x 38 IN SPLIT SPOON DRIVEN w/ 350 lb HAMMER FALLING FREE 8 IN,
				50.0	50.0	
	50	SET	Silty coarse to fine SAND, & GRAVEL, very dense, damp to moist, brown SM-GM	BAG 6	JAR 13	DRIVE 2.0 ft REC 1.7 ft LOSS 0.3 ft
		35				
	51	50				
		47		52.0	52.0	
	52 – 55				NS	ADVANCE BORING TO 55.0 ft w/ 3.75 IN ID HOLLOW STEM AUGER w/PLUG. MFG-CME
				55.0	55.0	
	55	SET	Gravelly coarse to fine SAND, little silt, dense, damp, brown SM	BAG 7	JAR 14	DRIVE 2.0 ft REC 1.8 ft LOSS 0.2 ft
		16				
	56	23				
		13			57.0	
	57 – 58				NS	ADVANCE BORING TO 60.0 ft w/ 3.75 IN ID HOLLOW STEM AUGER w/PLUG MFG CME

DRILLING LOG (Cont Sheet) ELEVATION TOP OF HOLE 525.8 ft MSL Hole No. D82-103

PROJECT: ONONDAGA DAM INSTALLATION: BUFFALO DISTRICT SHEET 6 OF 16 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g	CSG BLOWS PER FOOT
	58–60			B A G	NS 60.0		
	60–62	SET 23 33 32	Gravelly coarse to fine SAND, trace silt, damp, very dense, brown SM	7 62.0	JAR 15 62.0	DRIVE 2.0 ft REC 2.0 ft LOSS 0.0 ft SAMPLING CONDUCTED BY 3.0x3.5x38 IN SPLIT SPOON DRIVEN W/ 350 lb HAMMER FALLING FREE 18 IN.	3, 5
	62–65				NS 65.0	SET NW FLUSH JOINT CASING 3 3/16 IN ID @ 60.0 ft. DRIVE TO 65.0 ft. WATER LEVEL CHECKED AFTER SETTING CASING BOREHOLE DRY 20 AUG 1982 PM	12, 65, 90
460.8	65		65.0				
460.3	65–67	SET 8 12 18	Silty coarse to fine SAND, trace gravel, dense, damp, brown SM 65.5		JAR 16 67.0	DRIVE 2.0 ft REC 1.2 ft LOSS 0.8 ft COMMENCE CONTINUOUS SAMPLING USING 1 3/8 x 2.0 x 27 IN STANDARD SPLIT SPOON SAMPLER DRIVEN W/ 140 lb SAFETY HAMMER FALLING FREE 30 IN.	21, 30
	67–68	SET 8	Silty CLAY, very stiff, damp, gray CL 68.0		JAR 17 68.0	DRIVE 2.0 ft REC 1.5 ft LOSS 0.5 ft	27
457.8	68–69	14 18	SILT, little fine sand, little clay, trace organics (wood fragments) dense, damp, gray ML		JAR 18 69.0		55
	69–70	SET 6	SILT, little fine sand, little clay, trace gravel, trace wood fragments, medium dense, damp, gray ML		JAR 19	DRIVE 2.0 ft REC 1.7 ft LOSS 0.3 ft	62

ENG FORM 1836-A

PROJECT: ONONDAGA DAM HOLE NO. D82-102

DRILLING LOG (Cont Sheet) ELEVATION TOP OF HOLE: 525.8 ft MSL — Hole No. D82-103

PROJECT: ONONDAGA DAM — INSTALLATION: BUFFALO DISTRICT — SHEET 7 OF 16 SHEETS

ELEVATION (a)	DEPTH (b)	LEGEND (c)	CLASSIFICATION OF MATERIALS (Description) (d)	% CORE RECOVERY (e)	BOX OR SAMPLE NO. (f)	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) (g)	BLOW PER FOOT
	70	12	Silt, little fine sand, little clay, trace gravel, trace wood fragments and dense, damp, gray ML 70.5		JAR 19 70.5	DRIVE 2.0 ft REC 1.7 ft LOSS 0.3 ft	
455.3		17	Silty coarse to fine SAND, trace gravel SM		JAR 20 71.0		78
	71	SET	Silty coarse to fine SAND, little gravel, very dense, damp, gray SM		JAR 21	DRIVE 2.0 ft REC 0.3 ft LOSS 1.7 ft	105
	72	18, 25, 32			73.0		41
	73	SET	Silty coarse to fine SAND little gravel, very dense, dry, gray SM		JAR 22	DRIVE 2.0 ft REC 0.1 ft LOSS 1.9 ft. BORING ADVANCED BY NW CASING 3 3/16 IN. TO DRIVEN W/350 lb HAMMER FALLING FREE 24 IN. SAMPLING CONDUCTED W/1 3/8 x 2.0 x 17 IN STANDARD SPLIT SPOON DRIVEN BY 140 lb SAFETY HAMMER FALLING FREE 30 IN	65
	74	38, 32, 30			75.0		69
	75	SET	Silty coarse to fine SAND little gravel, very dense damp to wet, gray SM		JAR 23	DRIVE 2.0 ft REC 0.9 ft LOSS 1.1 ft	41
	76	27, 31, 27	77.0		77.0		58
448.8	77	SET	Gravelly coarse to fine SAND, little silt, very dense, wet, gray SM		JAR 24	DRIVE 2.0 ft REC 0.7 ft LOSS 1.3 ft	58
	78	27, 31, 34	79.0		79.0		58
446.8	79	SET	Coarse to fine sandy GRAVEL, little silt, very dense, damp, brown GM		JAR 25	DRIVE 2.0 ft REC 0.6 ft LOSS 1.4 ft	48
	80	19, 30, 41	81.0		81.0		84
444.8	81	SET, 21	Gravelly coarse to fine SAND, little silt, very dense, moist, wet, brown SM		JAR 26	DRIVE 2.0 ft REC 1.2 ft LOSS 0.8 ft	33
	82						

ENG FORM 1836-A JUN 67 — PROJECT: ONONDAGA DAM — HOLE NO. D82-103

DRILLING LOG (Cont Sheet) ELEVATION TOP OF HOLE 525.8 ft MSL Hole No. DE2-103

PROJECT ONONDAGA DAM INSTALLATION BUFFALO DISTRICT SHEET 8 of 16 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g	CSG Blow Pen Ft
	82	25	Gravelly coarse to fine SAND, little silt, very dense moist, to wet, brown SM		JAR 26	DRIVE 2.0 ft REC 1.2 ft LOSS 0.8 ft	55
		35			83.0		
	83	SET	Gravelly coarse to fine SAND, little silt, very dense moist, brown SM		JAR 27	DRIVE 2.0 ft REC 0.1 ft LOSS 1.9 ft BORING ADVANCED BY NW CASING 3 3/16 IN ID DRIVEN W/ 350 lb HAMMER FALLING FREE 24 IN, SAMPLING CONDUCTED W/ 1 3/8 x 2.0 x 27 IN STANDARD SPLIT SPOON DRIVEN BY 140 lb SAFETY HAMMER FALLING FREE 30 IN.	40
		52					
	84	43					44?
		30			85.0		
	85	SET	Gravelly coarse to fine SAND, little silt, very dense moist-wet, gray SM 86.5		JAR 28	DRIVE 2.0 ft REC 0.7 ft LOSS 1.3 ft	34
		32					
	86	28			86.5		45
439.3		25	Silty fine SAND, trace gravel, trace coarse-med sand, dense wet red-brown SM 87.0		JAR 29 87.0		
438.8	87	SET	Silty medium to fine SAND, very dense, wet, red-brown SM		JAR 30	DRIVE 2.0 ft REC 1.1 ft LOSS 0.9 ft	38
		27					
	88	24					46
		23			89.0		
	89	SET	Silty medium to fine SAND, dense, wet red-brown SM		JAR 31	DRIVE 2.0 ft REC 1.1 ft LOSS 0.9 ft	29
		19					
	90	24					42
		30			91.0		
	91	SET	Silty medium to fine SAND, very dense, wet, red-brown SM		JAR 32	DRIVE 2.0 ft REC 1.4 ft LOSS 0.6 ft	33
	92	25					
		23					47?
		24			93.0		
	93	SET	Silty medium to fine SAND, very dense, wet red-brown SM		JAR 33	DRIVE 2.0 ft REC 1.4 ft LOSS 0.6 ft	40
	94	23					

DRILLING LOG (Cont Sheet) ELEVATION TOP OF HOLE 525.8 ft MSL | Hole No. D82-103

PROJECT: ONONDAGA DAM | INSTALLATION: BUFFALO DISTRICT | SHEET 9 OF 16 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g	CSG BLOW PER FOOT
	94	23, 37	Silty medium to fine SAND, very dense, wet, red-brown SM		JAR 33 (95.0)	DRIVE 2.0 ft REC 1.4 ft LOSS 0.6 ft	44
	95, 96	SET, 22, 27, 32	Silty medium to fine SAND, dense, wet, red-brown SM		JAR 34 (97.0)	DRIVE 2.0 ft REC 1.4 ft LOSS 0.6 ft. BORING ADVANCED BY NW CASING 3 3/16 IN ID DRIVEN w/ 350 lb HAMMER FALLING FREE 24 IN, SAMPLING CONDUCTED w/ 1 3/8 x 2.0 x 27 IN (L) STANDARD SPLIT SPOON DRIVEN BY 140 lb SAFETY HAMMER FALLING FREE 30 IN	36, 41
	97, 98	SET, 35, 41, 43	Silty medium to fine SAND, wet, very dense, red-brown SM. NOTE: clayey SILT layer from ≈ 98.5 to 98.8 ft (99.0)		JAR 35 (99.0)	24 AUG 1982 AM CSG @ 97.0 ft Bottom of HOLE 97.0 ft DEPTH TO WATER 53.8 ft. DRIVE 2.0 ft REC 1.3 ft LOSS 0.7 ft	44, 89
426.8	99, 100	SET, 25, 23, 25	Coarse to fine SAND, little silt, wet, dense, red-brown SM		JAR 36 (101.0)	DRIVE 2.0 ft REC 1.2 ft LOSS 0.8 ft	58, 35
	101	SET	Coarse to fine SAND, little silt, trace fine gravel, wet, dense, red-brown SM (101.5)		JAR 37 (101.5)	DRIVE 2.0 ft REC 1.3 ft LOSS 0.7 ft	43
424.3	102	17, 19, 25	SILT, little fine sand, hard, wet, red-brown ML (103.0)		JAR 38 (103.0)		50
422.8	103	SET, 25	Silty fine SAND w/ occassional gray SILT seams, wet, very dense, red-brown SM (104.0)		JAR 39 (104.0)	DRIVE 2.0 ft REC 1.2 ft LOSS 0.8 ft	28
421.8	104, 105	34, 37	SILT, trace gravel, trace coarse to fine sand, trace clay, hard, damp, red-brown ML (105.5)		JAR 40 (105.0); NS	DRILLER NOTES ROLLER BIT ENCOUNTERED BOULDER FROM 104.8 TO 105.5 ft.	84, 62
420.3	106	SET	Silty CLAY, trace embedded gravel, trace coarse to fine sand, hard, damp, red-brown CL		JAR 41	DRIVE 1.5 ft REC 1.2 ft LOSS 0.3 ft	

ENG FORM 1836-A JUN 67 | PROJECT: ONONDAGA DAM | HOLE NO. D82-103

DRILLING LOG (Cont Sheet) ELEVATION TOP OF HOLE: 525.8 ft MSL — Hole No. D82-103

PROJECT: ONONDAGA DAM — INSTALLATION: BUFFALO DISTRICT — SHEET 10 of 16 SHEETS

ELEVATION (a)	DEPTH (b)	LEGEND (c)	CLASSIFICATION OF MATERIALS (Description) (d)	% CORE RECOVERY (e)	BOX OR SAMPLE NO. (f)	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) (g)	CSG BLOWS PER FOOT
	106	36, 54	Silty CLAY, trace coarse to fine sand, hard, damp, red-brown CL		JAR 41 (107.0)	DRIVE 1.5 ft; REC 1.2 ft; LOSS 0.3 ft	132
	107	SET, 35, 47, 50	Silty CLAY, trace coarse to fine sand, hard, damp, red-brown CL		JAR 42 (109.0)	DRIVE 2.0 ft; REC 1.4 ft; LOSS 0.6 ft. BORING ADVANCED BY NW CASING 3 3/16 IN ID DRIVEN W/ 350 lb HAMMER FALLING FREE 24 IN. SAMPLING CONDUCTED W/ 1 3/8 x 2.0 x 27 IN STANDARD SPOON SPOON DRIVEN BY 140 lb SAFETY HAMMER FALLING FREE 30 IN	110, 127
	108						
	109	SET, 29, 50	Silty CLAY, trace coarse to fine sand, hard, damp, red-brown CL		JAR 43 (110.3)	DRIVE 1.3 ft; REC 1.1 ft; LOSS 0.2 ft	112
	110				NS (111.0)	USE TRICONE ROLLER BIT TO CLEAR POSSIBLE OBSTRUCTION TO A DEPTH OF 111.0 ft. ADVANCE NW CASING TO 111.0 ft AND RESUME CONTINUOUS SAMPLING	132
	111	SET, 25, 35, 43	Silty CLAY, trace coarse to fine sand, hard, damp, red-brown CL		JAR 44 (113.0)	DRIVE 2.0 ft; REC 2.0 ft; LOSS 0.0 ft	135, 224
	112						
	113	SET, 35, 40, 54	Silty CLAY, trace coarse to fine sand, hard, damp, red-brown CL		JAR 45 (115.0)	DRIVE 2.0 ft; REC 2.0 ft; LOSS 0.0 ft	135, 231
	114						
	115	SET, 35, 37, 75	Silty CLAY, trace coarse to fine sand, hard, damp, red-brown CL		JAR 46 (117.0)	DRIVE 2.0 ft; REC 1.6 ft; LOSS 0.4 ft. SET BW CASING THROUGH NW CASING TO A DEPTH OF 115.0 ft. DRIVE CASING TO 117.0 ft W/ 350 lb HAMMER FALLING FREE 24 IN AND RESUME CONTINUOUS SAMPLING	23, 47
	116						
	117	SET	Silty CLAY, trace coarse to fine sand, hard, damp, red-brown CL 117.5		JAR 47 (117.5)	DRIVE 2.0 ft; REC 1.9 ft; LOSS 0.1 ft	59
408.5		59	Silty fine SAND, very dense, wet, red-brown SM		JAR 48		
	118						

ENG FORM 1836-A

PROJECT: ONONDAGA DAM — HOLE NO.: D82-103

DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE 525.8 ft MSL | Hole No. D82-103

PROJECT: ONONDAGA DAM | INSTALLATION: BUFFALO DISTRICT | SHEET 11 OF 16 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g	CSG BLOWS PER FT
	118	69 115	Silty fine SAND, very dense, wet, red-brown SM 119.0		JAR 48 119.0	DRIVE 2.0 ft REC 1.9 ft LOSS 0.1 ft	53
406.8	119 120	SET 54 50 78	SILT, little fine sand occassional clayey SILT seams, hard, wet, red-brown ML		JAR 49 121.0	DRIVE 2.0 ft REC 2.0 ft LOSS 0.0 ft BORING ADVANCED BY BW CASING 2.75 IN ID DRIVEN W/ 350 lb HAMMER FALLING FREE 24 IN. SAMPLING CONDUCTED W/ 1 3/8 x 2.0 x 27 IN STANDARD SPLIT SPOON DRIVEN BY 140 lb SAFETY HAMMER FALLING FREE 30 IN	88 189
	121 122	SET 31 36 51	SILT, little fine sand, trace clay, occassional clayey SILT seams, hard, damp to wet, red-brown ML		JAR 50 123.0	25 AUG 1982 BOTTOM OF CASING 119.0 ft BOTTOM OF HOLE 121.0 ft DEPTH TO WATER 66.6 ft DRIVE 2.0 ft REC 1.6 ft LOSS 0.4 ft	85 113
	123 124	SET 22 39 49	SILT, little fine sand, trace clay, with clayey SILT, seams and layers, hard, damp to wet, red-brown ML 125.0		JAR 51 125.0	DRIVE 2.0 ft REC 1.6 ft LOSS 0.4 ft	122 150
400.8	125 126	SET 39 43 54	Silty fine SAND, trace medium to coarse sand, w/ occassional clayey SILT seams, very dense, wet red-brown SM 127.0		JAR 52 127.0	DRIVE 2.0 ft REC 1.4 ft LOSS 0.6 ft	58 14?
398.8	127 128	SET 20 22 25	Clayey SILT, little fine sand (seams), hard moist, red-brown ML		JAR 53 129.0	DRIVE 2.0 ft REC 1.4 ft LOSS 0.6 ft	75 163
	129 130	SET 18	Clayey SILT little fine sand (seams) with occassional layers of silty CLAY, very dense, red-brown		JAR 54	DRIVE 2.0 ft REC 2.0 ft LOSS 0.0 ft	149

DRILLING LOG (Cont Sheet) ELEVATION TOP OF HOLE: 525.8 ft MSL | Hole No. DB2-103

PROJECT: ONONDAGA DAM | INSTALLATION: BUFFALO DISTRICT | SHEET 12 OF 16 SHEETS

ELEVATION (a)	DEPTH (b)	LEGEND (c)	CLASSIFICATION OF MATERIALS (Description) (d)	% CORE RECOVERY (e)	BOX OR SAMPLE NO. (f)	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) (g)	CSG BLOW PER FOOT
	130	22 35	Clayey SILT, little fine sand (~~sandy~~) w/ occassional layers of silty CLAY, very dense, damp, brown ML 131.0		JAR 54 131.0	DRIVE 2.0 ft REC 2.0 ft LOSS 0.0 ft	242
394.8	131 132	SET 37 51 83	Silty fine SAND, very dense, wet, red-brown SM		JAR 55 133.0	DRIVE 2.0 ft REC 1.6 ft LOSS 0.4 ft DUE TO HIGH CASING BLOWS FISHTAIL BIT w/SIDEPORTS UTILIZED FROM 131.0 TO 133.0 ft. CASING ADVANCED TO 133.0 ft, WASHED OUT AND CONTINUOUS SAMPLING RESUMED.	92 94
	133 134	SET 32 39 51	Silty fine SAND, very dense, wet, red-brown SM		JAR 56 135.0	DRIVE 2.0 ft REC 1.5 ft LOSS 0.5 ft BORING ADVANCED BY BW CASING 2.75 IN ID DRIVEN w/ 350 lb HAMMER FALLING FREE 24 IN. SAMPLING CONDUCTED w/ 1 3/8 x 2.0 x 17 IN STANDARD SPLIT SPOON DRIVEN BY 140 lb SAFETY HAMMER FALLING FREE 30 IN	99 177
	135 136	SET 29 39 55	Silty fine SAND, w/ occassional SILT seams very dense, wet, red-brown SM		JAR 57 137.0	DRIVE 2.0 ft REC 1.4 ft LOSS 0.6 ft	121 302
	137 138	SET 33 51 57	Silty fine SAND, very dense, wet, red-brown SM		JAR 58 139.0	DRIVE 2.0 ft REC 1.4 ft LOSS 0.6 ft UTILIZE FISHTAIL BIT w/ SIDEPORTS FROM 137.0 TO 138.7 ft. ADVANCE BW CASING TO 139.0 ft AND RESUME CONTINUOUS SAMPLING.	180 158
	139 140	SET 30 48 62	Silty fine SAND, very dense, wet, red-brown SM		JAR 59 141.0	DRIVE 2.0 ft REC 1.6 ft LOSS 0.4 ft UTILIZE FISHTAIL w/ SIDEPORTS FROM 139.0 TO 140.7 ft. ADVANCE CASING TO 141.0 ft WASHOUT AND RESUME CONTINUOUS SAMPLING	140 157
	141 142	SET 33	Silty fine SAND, very dense, wet, red-brown SM		JAR 60	DRIVE 2.0 ft REC 1.6 ft LOSS 0.4 ft	149

DRILLING LOG (Cont Sheet) | ELEVATION TOP OF HOLE: 525.8 ft MSL | Hole No. DB2-103

PROJECT: ONONDAGA DAM | INSTALLATION: BUFFALO DISTRICT | SHEET 13 OF 16 SHEETS

ELEVATION (a)	DEPTH (b)	LEGEND (c)	CLASSIFICATION OF MATERIALS (Description) (d)	% CORE RECOVERY (e)	BOX OR SAMPLE NO. (f)	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) (g)	CSG BLOWS PER FOOT
	142	39, 43	Silty fine SAND, very dense, wet, red-brown SM		JAR 60 (143.0)	DRIVE 2.0 ft REC 1.6 ft LOSS 0.4 ft	250
	143–144	SET, 33, 37, 50	Silty fine SAND, trace coarse to medium sand, very dense, wet, red-brown SM 145.0		JAR 61 (145.0)	DRIVE 2.0 ft REC 1.9 ft LOSS 0.1 ft BORING ADVANCED BY BW CASING 2.75IN ID DRIVEN w/ 350 lb HAMMER FALLING FREE 24IN, SAMPLING CONDUCTED w/ 1 3/8 x 2.0 x 27IN STANDARD SPLIT SPOON DRIVEN BY 140 lb SAFETY HAMMER, FALLING FREE 30IN	186 300
380.8	145–146	SET, 21, 27, 57	SILT, little fine sand, trace clay, hard, wet, red-brown ML		JAR 62 (147.0)	26 AUG 82 AM CSG @ 143.0 BOTTOM OF HOLE 145.0 ft DEPTH TO WATER 70.3 ft DRIVE 2.0 ft REC 2.0 ft LOSS 0.0 ft	194 222
	147–148		149.0		NS (150.0)	UTILIZED FISHTAIL BIT FROM 145.0 TO 145.5 ft ADVANCE CASING TO 150.0 ft. COMMENCE SAMPLING AT 5 ft INTERVALS USING 1 3/8 x 2.0 x 27IN STANDARD SPLIT SPOON DRIVEN w/ 140 lb SAFETY HAMMER FREE FALLING 30IN	150 173
376.8	149						300
	150	100	Coarse to fine SAND, little gravel, little silt, very dense, wet, red-brown SM		JAR 63 (150.2)	DRIVE 0.2 REC 0.2 LOSS 0.0	
	151–153				NS	UTILIZED BENTONITE MUD IN LIEU OF BW CASING FROM 150.0 ft TO BOTTOM OF BORING. WESTERN BRAND BENTONITE, MFG NL BAROID	
371.8	154		154.0				

ENG FORM 1836-A | PROJECT: ONONDAGA DAM | HOLE NO. DB2-103

DRILLING LOG (Cont Sheet) ELEVATION TOP OF HOLE: 525.8 ft MSL — Hole No. DE2-103

PROJECT: ONONDAGA DAM — INSTALLATION: BUFFALO DISTRICT — SHEET 14 OF 16 SHEETS

ELEVATION (a)	DEPTH (b)	LEGEND (c)	CLASSIFICATION OF MATERIALS (Description) (d)	% CORE RECOVERY (e)	BOX OR SAMPLE NO. (f)	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) (g)
371.8	154	SET 32 38 47	154.0 Silty fine SAND, very dense, wet, red-brown SM		154.0 JAR 64 156.0	DRIVE 2.0 ft REC 1.5 ft LOSS 0.5 ft
	156–159				NS	ADVANCE BOREHOLE TO 159.0 ft w/ FISHTAIL BIT AND DRILLING MUD. RESUME SAMPLING
	159	SET 27 38 47	Silty fine SAND, very dense, wet, red-brown SM		159.0 JAR 65 161.0	DRIVE 2.0 ft REC 1.2 ft LOSS 0.8 ft
	161–164.5				NS	ADVANCE BOREHOLE TO 164.5 ft w/ FISHTAIL BIT AND DRILLING MUD. RESUME SAMPLING.
	164.5	SET 22 32	Silty fine SAND, very dense, wet, red-brown SM		164.5 JAR 66	DRIVE 2.0 ft REC 1.5 ft LOSS 0.5 ft

DRILLING LOG (Cont Sheet) Elevation top of hole: 525.8 ft MSL — Hole No. D82-103

Project: ONONDAGA DAM — Installation: BUFFALO DISTRICT — Sheet 15 of 16 sheets

Elevation a	Depth b	Legend c	Classification of Materials (Description) d	% Core Recovery e	Box or Sample No. f	Remarks (Drilling time, water loss, depth of weathering, etc., if significant) g
	166	37	Silty fine SAND, very dense, wet, red brown SM		JAR 66 (to 166.5)	DRIVE 2.0 ft REC 1.5 ft LOSS 0.5 ft
	167–169				NS	ADVANCE BORING TO 169.5 ft w/ FISHTAIL AND DRILLING MUD. RESUME SAMPLING. DRILLER NOTES GRAVEL AND/OR COBBLES ENCOUNTERED BY FISHTAIL BIT FROM 167.5 TO 168.5 ft
	169.5–171.5	SET, 19, 26, 38	Silty fine SAND, dense, wet, red-brown SM		169.5 JAR 67 171.5	DRIVE 2.0 ft REC 1.1 ft LOSS 0.9 ft
	172–173				NS	ADVANCE BORING TO 174.0 ft w/ FISHTAIL BIT AND DRILLING MUD. RESUME SAMPLING.
	174–176	SET, 24, 38, 42	Silty fine SAND, occassional silt seams very dense, wet, red-brown SM		174.0 JAR 68 176.0	DRIVE 2.0 ft REC 1.2 ft LOSS 0.8 ft
	176–178				NS	ADVANCE BORING TO 179.0 ft w/ FISHTAIL BIT AND DRILLING MUD. RESUME SAMPLING.

ENG FORM 1836-A — Project: ONONDAGA DAM — Hole No. D82-103

DRILLING LOG (Cont Sheet) ELEVATION TOP OF HOLE 525.8 ~~[illegible]~~ Hole No. DBZ-103

PROJECT ONONDAGA DAM | INSTALLATION BUFFALO DISTRICT | SHEET 16 of 16 SHEETS

ELEVATION a	DEPTH b	LEGEND c	CLASSIFICATION OF MATERIALS (Description) d	% CORE RECOVERY e	BOX OR SAMPLE NO. f	REMARKS (Drilling time, water loss, depth of weathering, etc., if significant) g
	178					ADVANCE BOREHOLE w/ FISHTAIL BIT TO 179.0 ft RESUME SAMPLING. DRILLER NOTES GRAVEL AND/OR COBBLES 178.0-178.2 ft
	179	SET 29 36 46	Silty fine SAND, very dense, wet, red-brown SM		179.0 JAR 69	DRIVE 2.0 ft REC 1.7 ft LOSS 0.3 ft
344.8	181		181.0		181.0	
	182				NS	ADVANCE BOREHOLE TO 184.0 ft w/ FISHTAIL BIT AND DRILLING MUD. RESUME SAMPLING. DRILLER NOTES GRAVEL AND/OR COBBLES FROM 181.0 ft TO 184.0 ft
	184	SET 100	Gravelly coarse to fine SAND, little silt, very dense, moist, gray SM		184.0 JAR 70 184.8	DRIVE 0.8 ft REC 0.3 ft LOSS 0.5 ft
341.0	185		BOTTOM OF BORING @ 184.8 ft			BOREHOLE TERMINATED AND GROUTED TO SURFACE.
	186					
	187					
	188					
	189					
	190					

ENG FORM 1836-A JUN 67 | PROJECT ONONDAGA DAM | HOLE NO. DBZ-103

H&A FORM 6 FEB. 74

SUMMARY OF LABORATORY TEST RESULTS

Onondaga Dam
Seismic and Geologic Investigations

FILE NO 745003
SHEET 1 OF 1

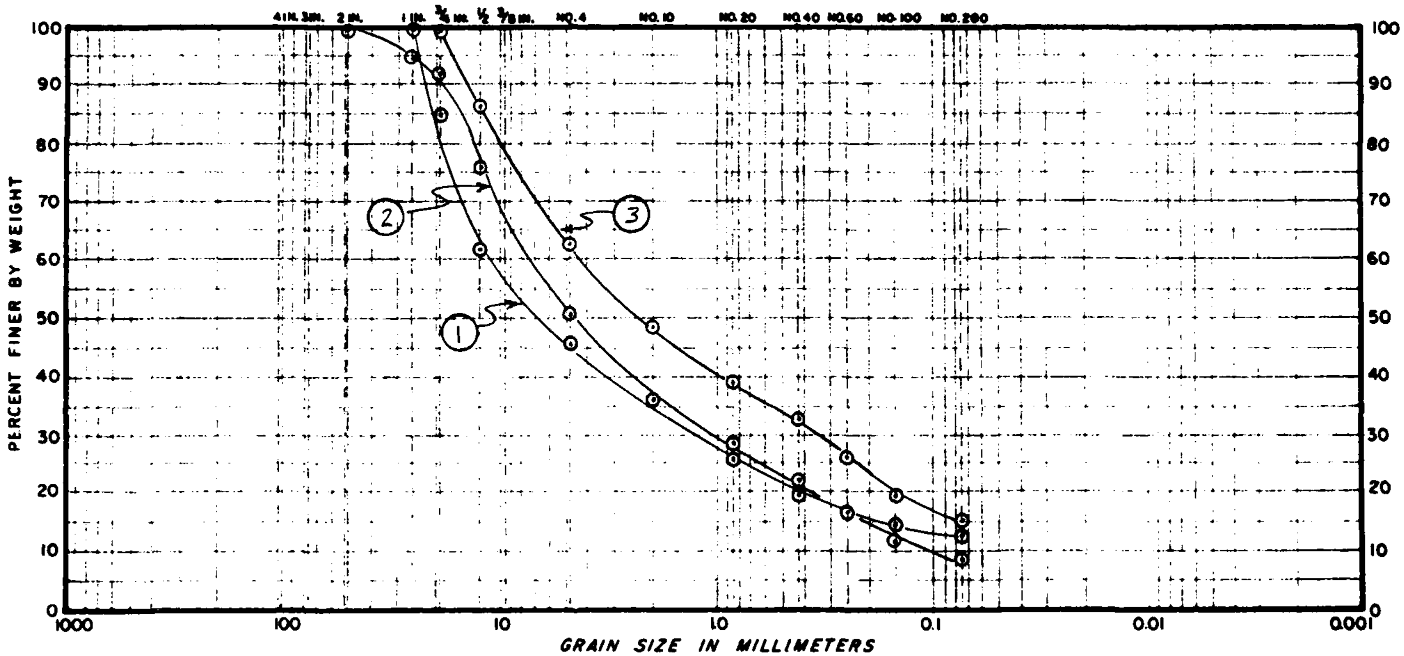
BORING & SAMPLE NUMBER	DESCRIPTION	DEPTH (FEET)	TEST NO.	NATURAL WATER CONTENT %	ATTERBERG LIMITS %		UNIT WEIGHT LB/CU FT	UNCONFINED TEST		CONSOLIDATION		OTHER TESTS
					LL	PL		COMPRESSIVE STRENGTH PSF	STRAIN %	MAX. PAST PRESSURE TON/SQ. FT.	C_c	
D82-101/ S17	Brown, fine sandy SILT and CLAY, trace fine gravel, trace coarse to medium sand. -CL-	60.0-62.0	A-1	19.6	23.4	13.6						Hydrometer H-1
D82-101/ S20	Brown, silty CLAY, little fine sand. -CL-	64.0-65.5	A-2	19.3	38.2	18.1						Hydrometer H-2
D82-102/ S38	Brown, fine sandy SILT and CLAY. -CL-	66.0-68.0	A-3	20.6	27.4	17.0						Hydrometer H-3
D82-103/ S19	Gray, fine sandy SILT and CLAY, trace coarse to medium sand. -ML-CL-	69.0-71.5	A-4	23.1	22.1	16.0						Hydrometer H-4
D82-103/ S44	Red-brown, silty CLAY trace coarse to fine sand. -CL-	110.0-113.0	A-5	13.6	21.7	12.9						Hydrometer H-5

HALEY & ALDRICH, INC.
CONSULTING SOIL ENGINEERS

H&A FORM 40 OCT. 75

GRAIN SIZE DISTRIBUTION

U.S. STANDARD SIEVE SIZE



<table>
<tr><td rowspan="2">COBBLES</td><td colspan="2">GRAVEL</td><td colspan="3">SAND</td><td rowspan="2">SILT OR CLAY</td></tr>
<tr><td>COARSE</td><td>FINE</td><td>COARSE</td><td>MEDIUM</td><td>FINE</td></tr>
</table>

UNIFIED SOIL CLASSIFICATION SYSTEM, CORPS OF ENGINEERS, U.S. ARMY

Test No.	Boring/Sample	Depth (ft.)	Description
1	D82-101/S12	35.0-36.4	Brown, coarse to fine sandy GRAVEL, little silt. -GM-
2	D82-101/S29	76.0-78.0	Brown, coarse to fine sandy GRAVEL, trace silt. -GW-
3	D82-101/S36	90.0-92.0	Brown, gravelly coarse to fine SAND, little silt. -SM-

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FILE NO 745003 DATE August 1982

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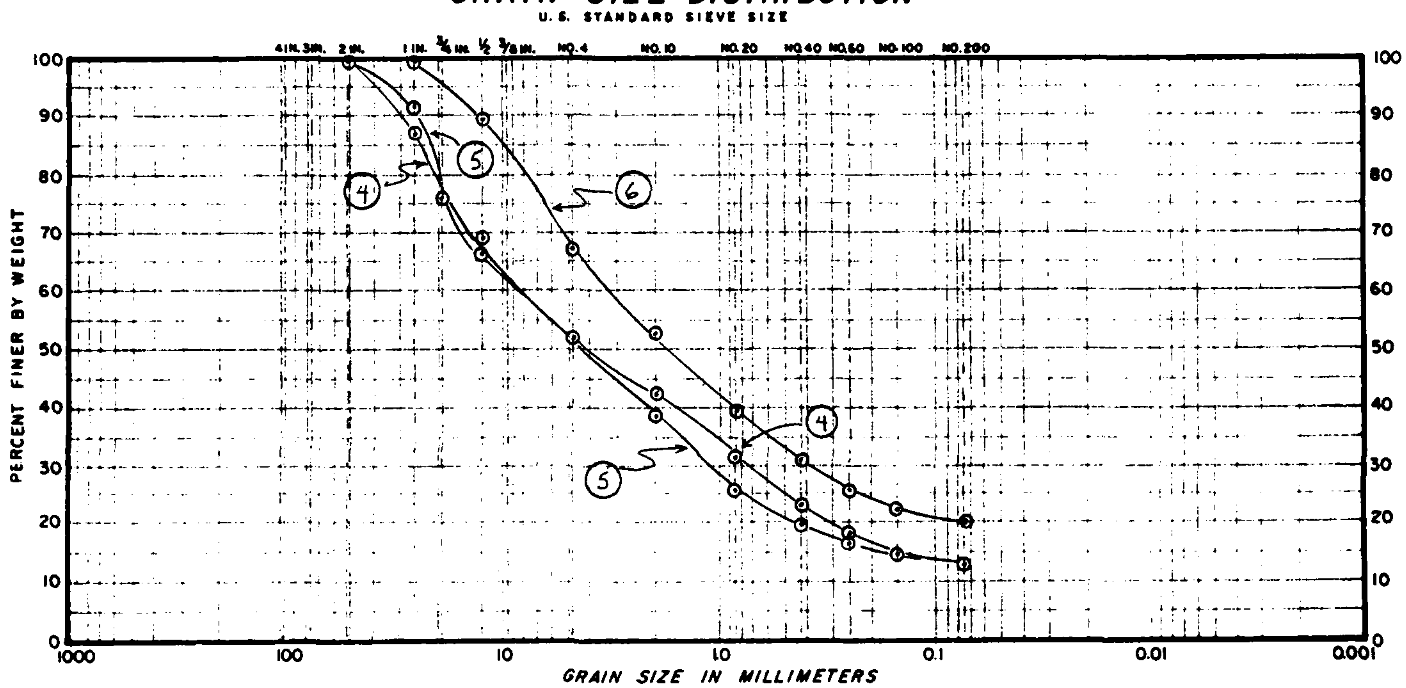
GRAIN SIZE DISTRIBUTION



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

UNIFIED SOIL CLASSIFICATION SYSTEM, CORPS OF ENGINEERS, U.S. ARMY

Test No.	Boring/Sample	Depth (ft.)	Description
4	D82-102/S12	22.0-24.0	Brown, coarse to fine sandy GRAVEL, little silt. -GM-
5	D82-102/S27	44.0-45.8	Brown, coarse to fine sandy GRAVEL, little silt. -GM-
6	D82-102/S46	78.0-80.0	Brown, gravelly coarse to fine SAND, little silt. -SM-

PROJECT Onondaga Dam

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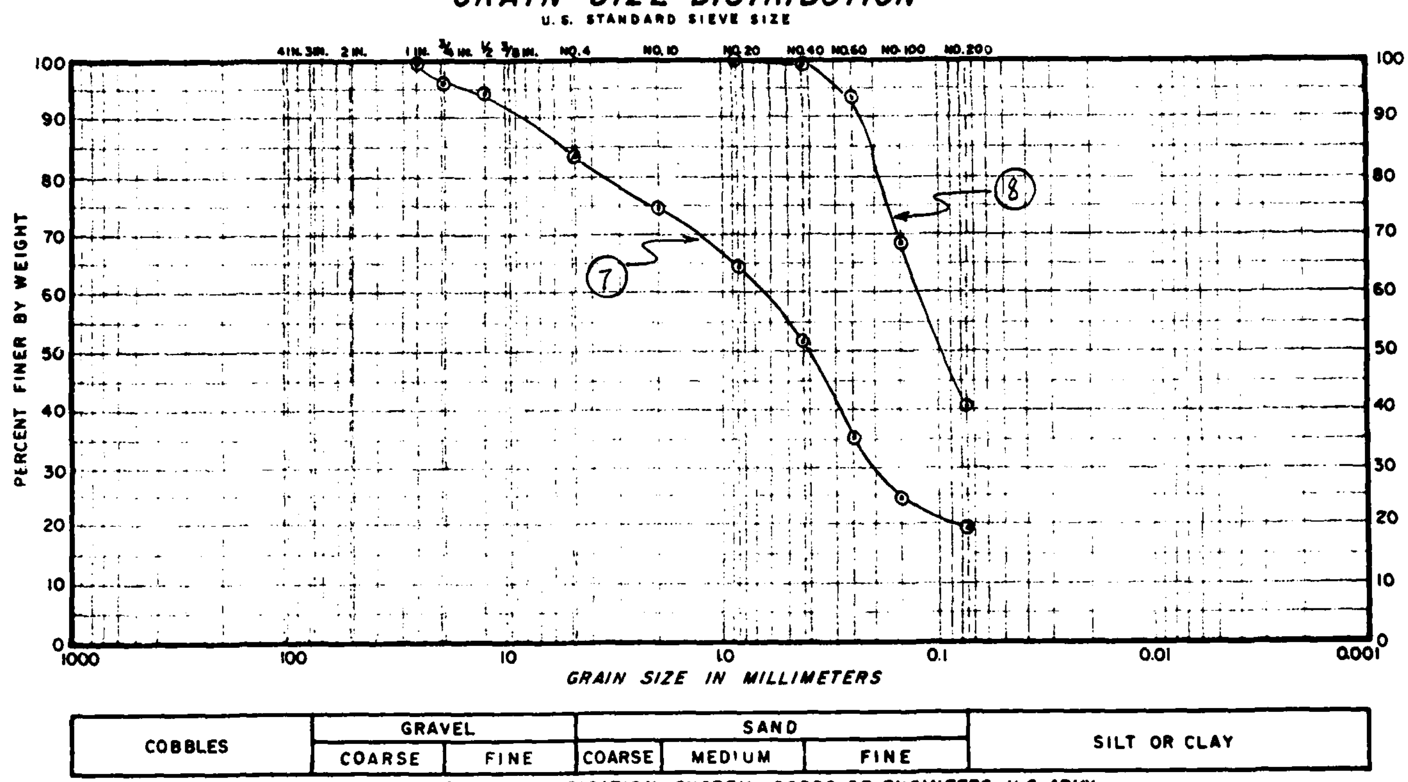

Test No.	Boring/Sample	Depth (ft.)	Description
7	D82-102/S68	106.0-108.0	Gray, coarse to fine Sand, little gravel, little silt. -SM-
8	D82-102/S84	134.0-136.0	Red-brown, silty fine SAND. -SM-

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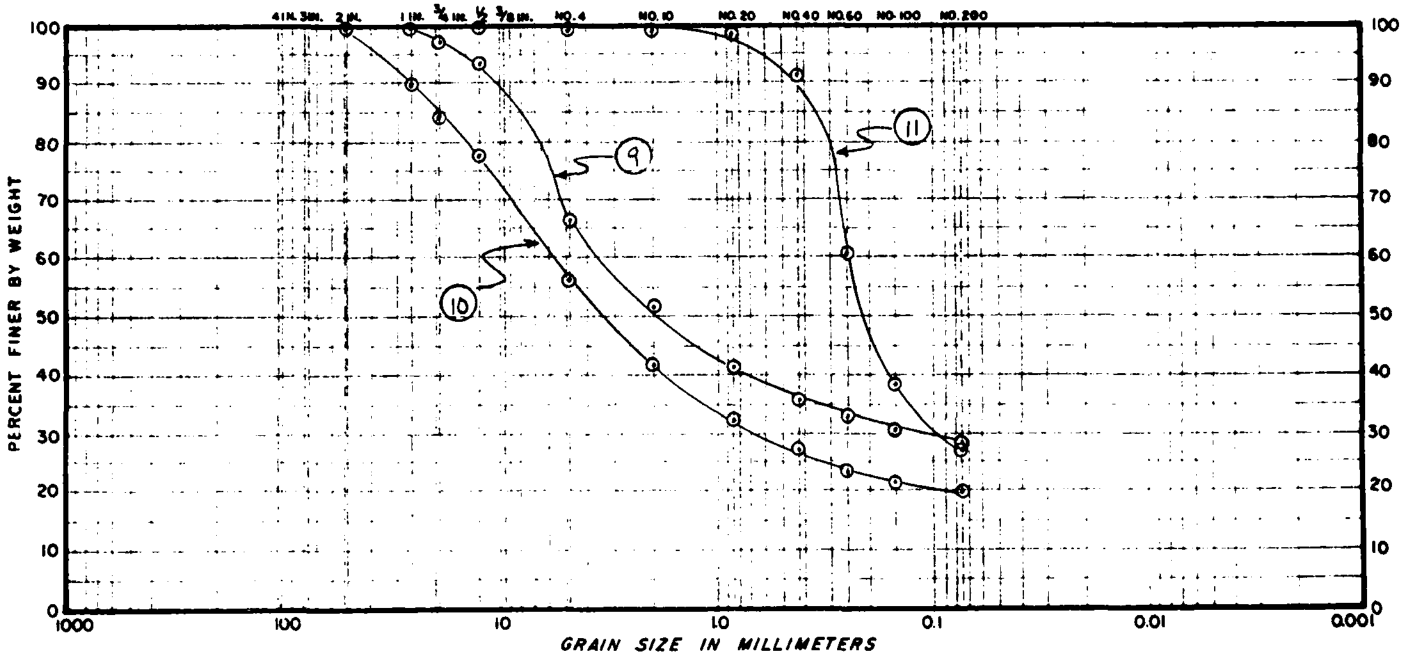
U. S. STANDARD SIEVE SIZE



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

UNIFIED SOIL CLASSIFICATION SYSTEM, CORPS OF ENGINEERS, U.S. ARMY

Test No.	Boring/Sample	Depth (ft.)	Description
9	D82-103/S13	50.0-52.0	Brown, silty coarse to fine SAND and GRAVEL. -SM-GM-
10	D82-103/S25	79.0-81.0	Brown, coarse to fine sandy GRAVEL, little silt. -GM-
11	D82-103/S32	91.0-93.0	Red-brown, silty medium to fine SAND. -SM-

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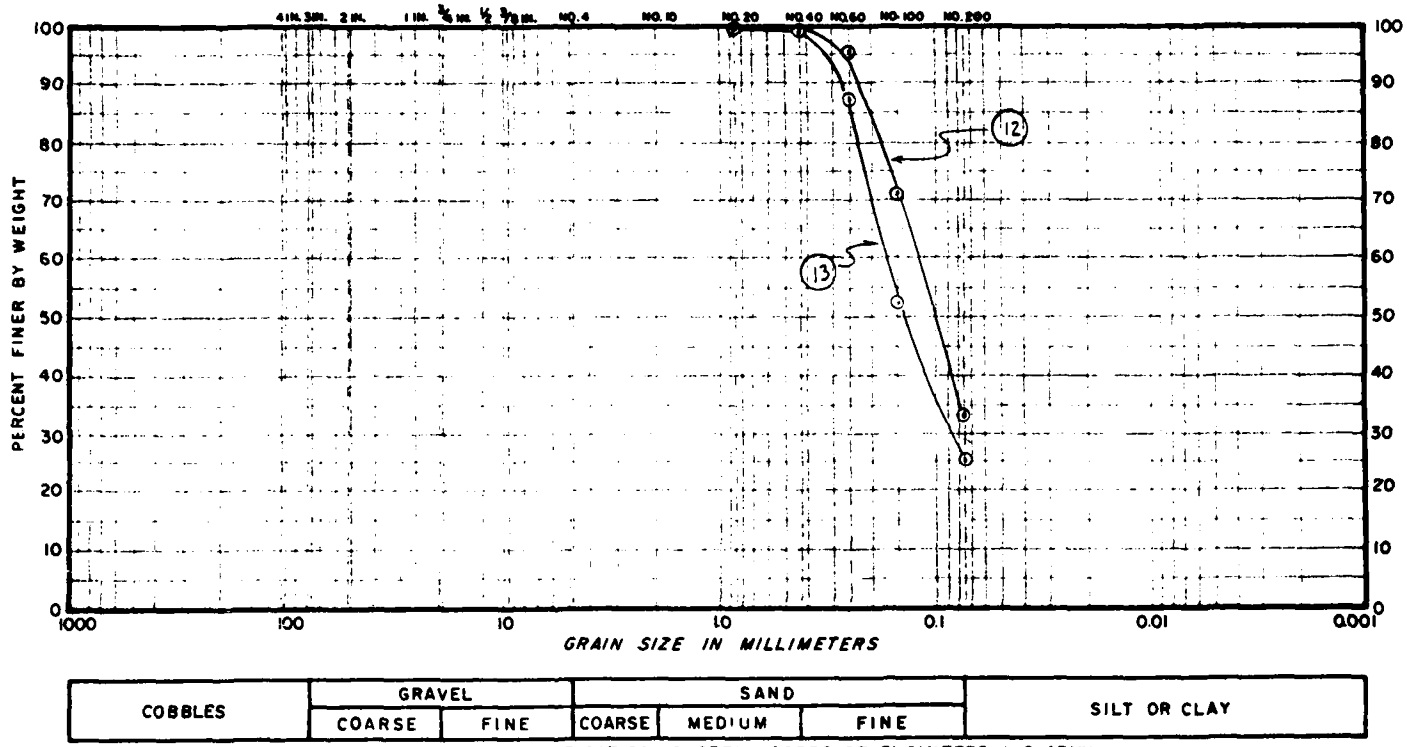

UNIFIED SOIL CLASSIFICATION SYSTEM, CORPS OF ENGINEERS, U.S. ARMY

Test No.	Boring/Sample	Depth (ft.)	Description	
12	D82-103/S57	137.0-139.0	Red-brown, silty fine SAND.	-SM-
13	D82-103/S66	169.5-171.5	Red-brown, silty fine SAND.	-SM-

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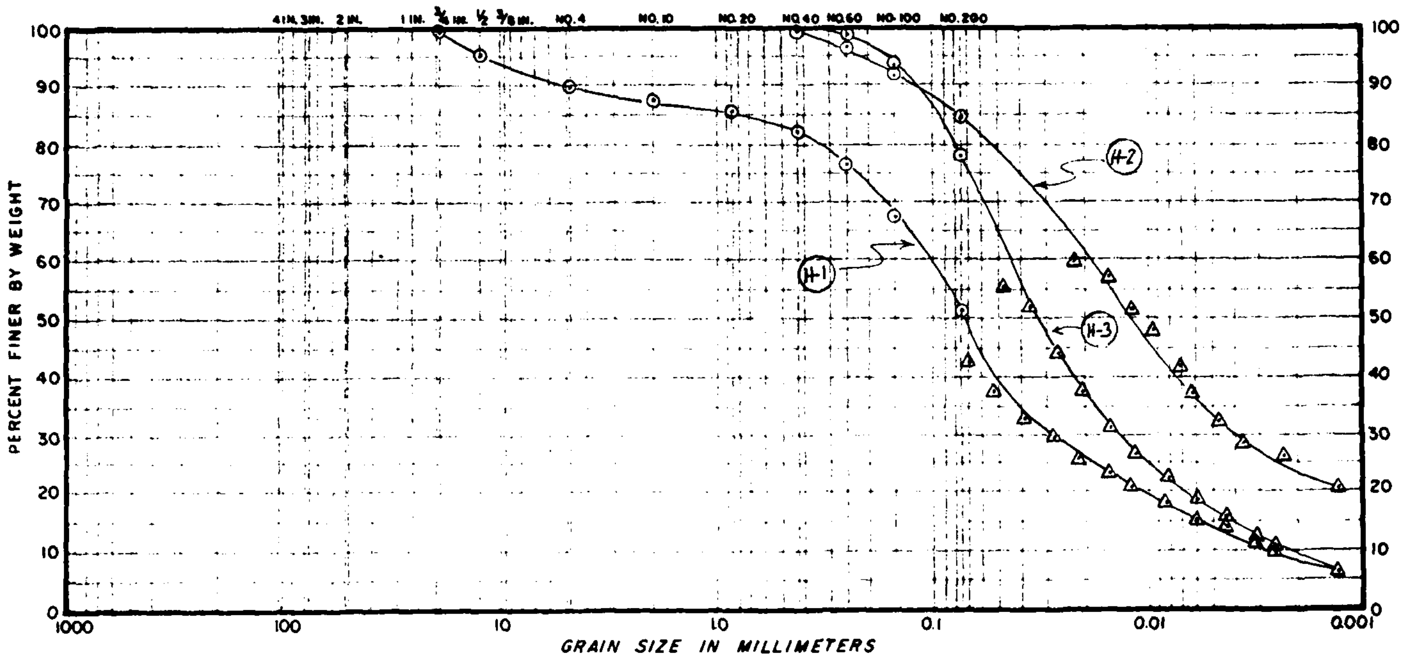
GRAIN SIZE DISTRIBUTION



COBBLES	GRAVEL		SAND			SILT OR CLAY
	COARSE	FINE	COARSE	MEDIUM	FINE	

UNIFIED SOIL CLASSIFICATION SYSTEM, CORPS OF ENGINEERS, U.S. ARMY

Test No.	Boring/Sample	Depth (ft.)	Description
H-1	D82-101/S17	60.0-62.0	Brown, fine sandy SILT and CLAY, trace fine gravel, trace coarse to medium sand. -CL-
H-2	D82-101/S20	64.0-65.5	Brown, silty CLAY, little fine sand. -CL-
H-3	D82-102/S38	66.0-68.0	Brown, fine sandy SILT and CLAY. -CL-

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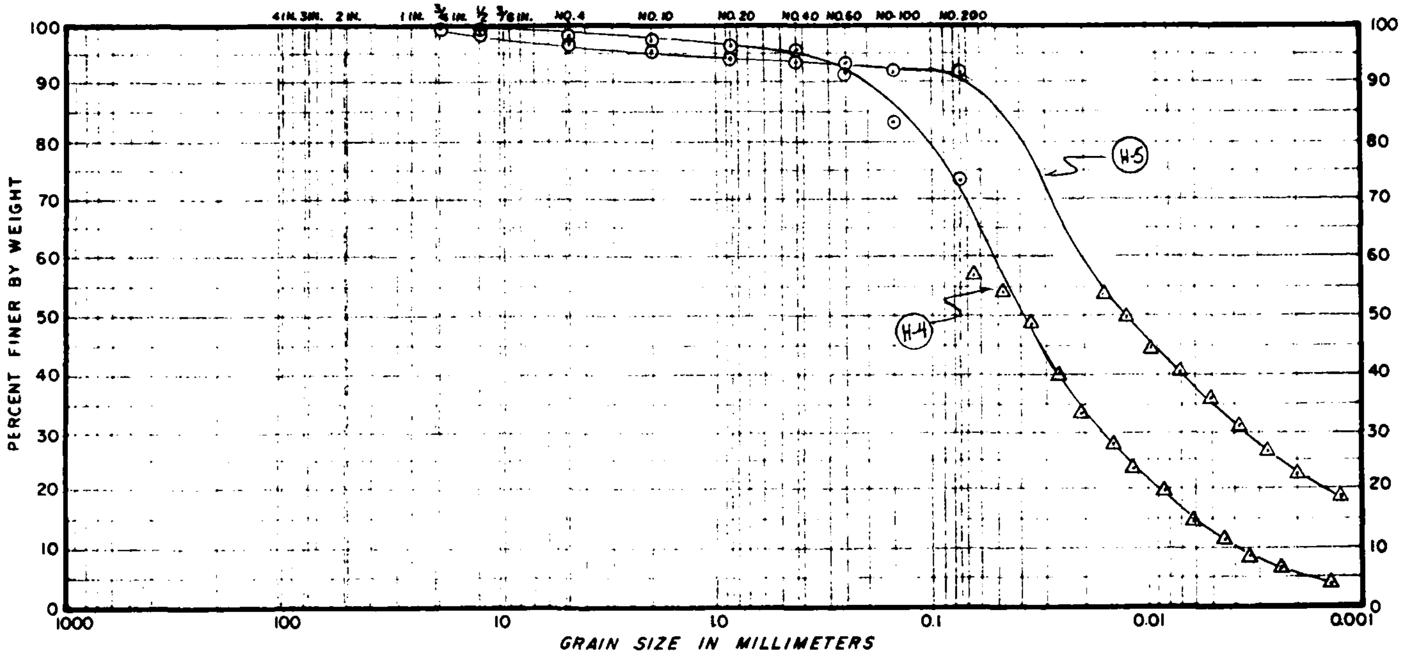

Test No.	Boring/Sample	Depth (ft.)	Description
H-4	D82-103/S19	69.0-70.5	Gray, fine sandy SILT and CLAY, trace coarse to medium sand. ML-CL
H-5	D82-103/S44	111.0-113.0	Red-brown, silty CLAY, trace coarse to fine sand. -CL-

PROJECT Onondaga Dam
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FILE NO 745003 DATE September 1982

HALEY & ALDRICH, INC.

[illegible] DAM, NEW YORK

APPENDIX F

ENGINEERING ANALYSES

. SAMPLER - HAMMER RATIOS

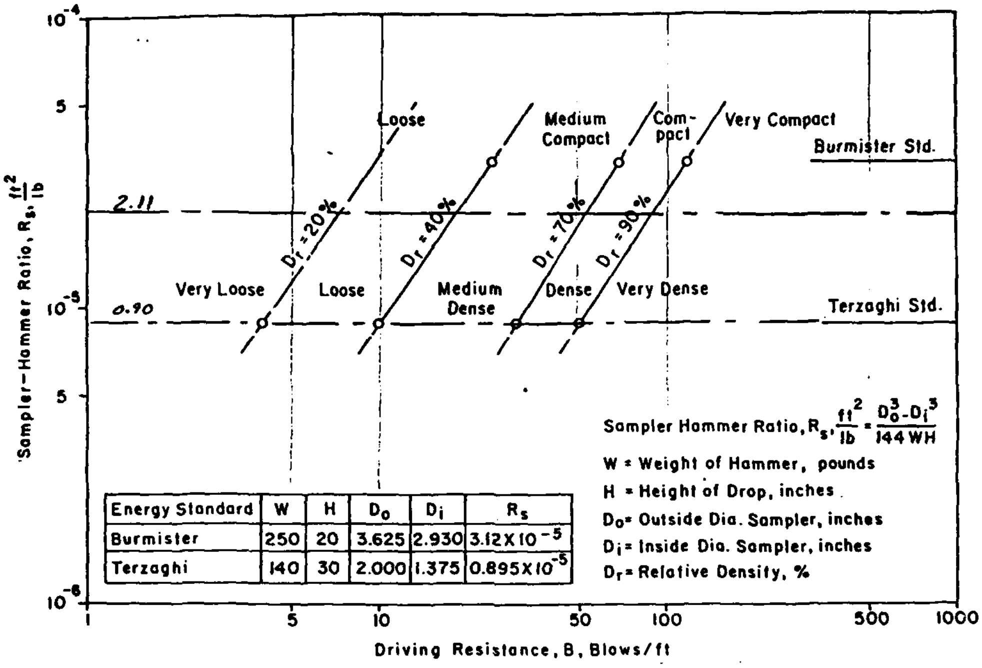
. LIQUEFACTION ANALYSES

[illegible]
[illegible]
[illegible]

SAMPLER-HAMMER RATIOS

HALEY & ALDRICH, INC., Cambridge, Massachusetts

Client	CORPS OF ENGINEERS	File Number	745003
Project	ONONDAGA DAM	Sheet	1 of 2
		Date	Sept 1982
		Computed by	DJS
		Checked by	JOS



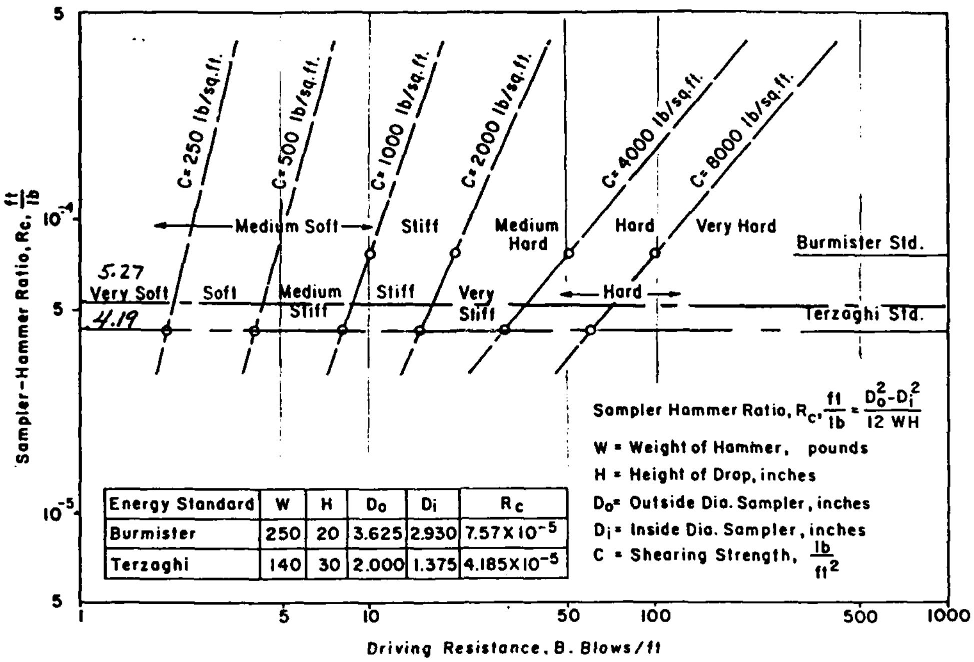
Sampler driving resistance vs compactness-cohesionless sands and silts.

SAMPLER	W (lb)	H (in)	Do (in)	Di (in)	Rs (ft²/lb)
Standard	140	30	2.000	1.375	0.90×10^{-5}
Large	350	18	3.500	2.875	2.11×10^{-5}

HALEY & ALDRICH, INC., Cambridge Massachusetts

Client: CORPS OF ENGINEERS
Project: ONONDAGA DAM

File Number: 745003
Sheet: 2 of 2
Date: Sept 1982
Computed by: DJS
Checked by: JOS



Sampler driving resistance vs consistency-cohesive soils.

SAMPLER	W (lb.)	H (in)	Do (in)	Di (in)	Rs (ft./lb)
Standard	140	30	2.000	1.375	4.19×10^{-5}
Large	350	18	3.500	2.875	5.27×10^{-5}

LIQUEFACTION ANALYSIS

• SUMMARY OF LIQUEFACTION STUDIES FOR ONONDAGA DAM

• SHEAR STRESS/CONFINING STRESS ($\tau/\bar{\sigma}_{vo}$) RATIOS WERE CALCULATED AS: (FROM PROCEDURES BY SEED, 1976)

$\tau/\bar{\sigma}_{vo} = 0.047$ to 0.071 BELOW TOE OF DAM

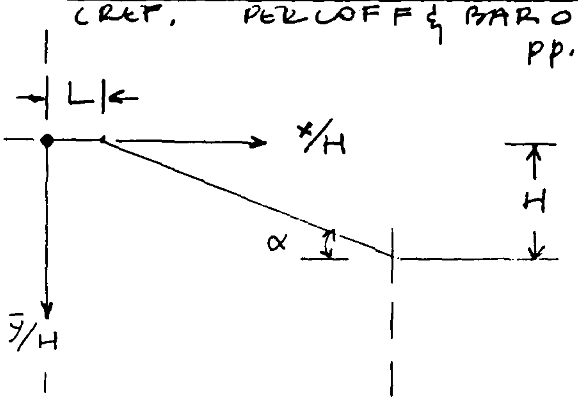
$\tau/\bar{\sigma}_{vo} = 0.040$ to 0.048 BELOW CREST OF DAM

• FROM STUDIES BY SEED (1976) AND OTHERS, THE SPT-BLOW COUNT (CORRECTED TO 1 TSF OVERBURDEN PRESSURE) N_1 MUST BE LESS THAN 4.3 TO 6.5 FOR LIQUEFACTION TO BE A CONCERN FOR SOILS BELOW THE TOE OF THE DAM, AND N_1 MUST BE LESS THAN 3.6 TO 4.4 FOR SOILS BELOW THE CREST OF THE DAM TO BE CONSIDERED POTENTIALLY LIQUEFIABLE.

• ONE VALUE OF N_1 EQUAL TO 6.7 WAS FOUND IN THE FOUNDATION SOILS OF BORING DCC-101 AT 56 FT. BELOW THE DAM CREST ABOVE G.W.L. ALL OTHER VALUES OF N_1 IN THE FOUNDATION SOILS EQUALLED OR EXCEEDED 9.

• THEREFORE, IT IS CONCLUDED THAT THE FOUNDATION SOILS AT THE DAM SITE ARE NOT SUSCEPTIBLE TO LIQUEFACTION.

★ STRESSES DUE TO EMBANKMENT
(REF. PERLOFF & BARON, 1976)
pp. 682-683



- USE: L = 12.5′, H = 60′, L/H ≅ 0.2
- SIDE SLOPES = 2½:1, α = 22°
- ASSUME μ = 0.3

a) CENTER OF EMBANKMENT x/H = 0
b) TOE OF EMBANKMENT x/H = (L + H cot α)/H

$\sigma_y/\gamma H$ (γH = 60(130) = 7800 PSF)

(FT) DEPTH	y/H	CENTER α = 15°		CENTER α = 30°	TOE α = 15°		TOE α = 30°
60	1.00	0.82	(0.76)	0.70	0.0	(0.0)	0.0
75	1.25	-		-	-		-
90	1.50	0.78	(0.70)	0.61	0.07	(0.08)	0.10
105	1.75	-		-	-		-
120	2.00	0.71	(0.62)	0.53	0.11	(0.12)	0.14
135	2.25	-		-	-		-
150	2.50	0.65	(0.55)	0.45	0.14	(0.15)	0.17
165	2.75	-		-	-		-
180	3.00	0.61	(0.50)	0.39	0.16	(0.17)	0.19

- CALCULATE $\Delta\bar{\sigma}_v$ BELOW DAM FROM EMBANKMENT

DEPTH BELOW TOP OF NATURAL GROUND (FT)	$\Delta\bar{\sigma}_v$ (PSF) ℄ 55′ EMB.	$\Delta\bar{\sigma}_v$ (PSF) ℄ 65′ EMB.	$\Delta\bar{\sigma}_v$ (PSF) TOE 55′ EMB.	$\Delta\bar{\sigma}_v$ (PSF) TOE 65′ EMB.
0	5435	6,420 (6190)	0	0
30	5005	5915 (5700)	575	675
60	4435	5240 (5045)	825	1,015
90	3935	4650 (4480)	1,075	1270
120	3575	4230 (4070)	1,215	1,440

↑ GWT @ GS (NATURAL)   ↑ GWT @ EL. 465

HALEY & ALDRICH, INC., Cambridge, Massachusetts

Client: C.O.E.	File Number: 7450-0??
Project: ONONDAGA DAM	Sheet ? of 3
	Date: 8 SEP 82
	Computed by: WAW
	Checked by: CS

* DYNAMIC SHEAR STRESSES

$$\tau = 0.65 \, a_{max} \, r_d \, \sigma_{vo}$$

a_{max} = peak horizontal ground acceleration at ground surface (g)

r_d = depth reduction factor

σ_{vo} = total overburden pressure

* REFER ATC-3 DOCUMENT – FIG. C1-8

- RATIO OF "STIFF SOIL" PEAK TO "ROCK" PEAK :

$$\frac{2.9}{2.5} = 1.16$$

- USE 1.2 AS AMPLIFICATION FACTOR.

- NATURAL GROUND SURFACE ACCELERATION (PEAK HORIZONTAL) = (1.2)(0.05) = 0.06 g

$$a_{max} = 0.06 \, g$$

DEPTH (FT)	σ_{vo} (PSF)	BELOW TOE OF DAM (NATURAL GROUND) r_d	BELOW TOE OF DAM (NATURAL GROUND) τ (PSF)	BELOW CREST OF DAM r_d	BELOW CREST OF DAM τ (PSF)
1	[illegible]	[illegible]	5		
5	[illegible]	1.0	26		
10	[illegible]	0.96	[illegible]		
20	[illegible]	0.93	[illegible]		
30	[illegible]	0.9	140		
40	[illegible]	0.86	[illegible]		
50	[illegible]	[illegible]	[illegible]	1.0	260
75	[illegible]	0.8	316	0.9	351
100	[illegible]	0.8	416	0.8	416
125	[illegible]	0.8	520	[illegible]	520
150	[illegible]	0.8	624		

HALEY & ALDRICH, INC., Cambridge, Massachusetts

Client: C.O.E
Project: ONONDAGA DAM
File Number: 7450-03
Sheet: 2 of 3
Date: 8 SEP 82
Computed by: WAW
Checked by: CS

* $\tau/\bar{\sigma}_{vo}$ RATIOS

BORING	DEPTH BELOW TOP OF DAM (FT)	DEPTH BELOW NATUR. GROUND (FT)	σ_{vo} (PSF) CREST	σ_{vo} (PSF) TOE	$\bar{\sigma}_{vo}$ (PSF) CREST	$\bar{\sigma}_{vo}$ (PSF) TOE	τ (PSF) CREST	τ (PSF) TOE	$\tau/\bar{\sigma}_{vo}$ CREST	$\tau/\bar{\sigma}_{vo}$ TOE	* N	* C_N	N_1
D82-101	56	1	5565	150	5565	150	223	7	0.040	0.017	(20)12	0.558	6.7
GWT@	61	5	6130	895	6065	835	245	35	0.040	0.042	17	0.529	9.0
EL.465	71	16	7205	2385	6600	1705	282	89	0.043	0.052	(36)20	0.506	10.1
(60')	77	22	7980	3280	6925	2225	301	119	0.044	0.054	(60)32	0.488	15.6
	97	42	10,235	6150	7945	3055	361	206	0.045	0.053	39	0.441	17.2
D-82-102	67	2	6645	305	6295	180	266	13	0.042	0.071	33	0.518	17.1
GWT@	69	4	6870	610	6395	360	270	24	0.042	0.068	26	0.512	13.3
EL.465	105	40	10,890	5990	8200	3480	374	201	0.046	0.058	32	0.431	13.8
(60')	121	56	12,610	8250	8940	4740	408	261	0.046	0.055	31	0.400	12.4
	142	77	14,915	11,170	9960	6350	477	357	0.048	0.056	30	0.400	12.0
D-82-103	70	5	6285	765	6450	450	270	30	0.042	0.067	18	0.610	9.2
GWT@	103	38	10,675	5705	8110	3320	370	195	0.046	0.058	36	0.433	15.6
EL.465 (60')	130	65	13,590	9510	9370	5735	435	305	0.046	0.056	40	0.385	15.4

AT NATURAL G.S., σ_{vo} = 6,420 PSF, $\bar{\sigma}_{vo}$ = 6190 PSF (for D-82-102)

* VALUES ADDED BY BUFFALO DIST BY GL 6/6/83

( ) REPRESENTS ACTUAL UNCORRECTED PENETRATION RESISTANCES FOR 3.5IN DIA. SPOON.

END

DATE FILMED

8-86