AD-A169 722 REPORT ON SEISMIC STABILITY ONONDAGA DAM NEW YORK(U) 1/3
CORPS OF ENGINEERS BUFFALO NY BUFFALO DISTRICT MAY 86

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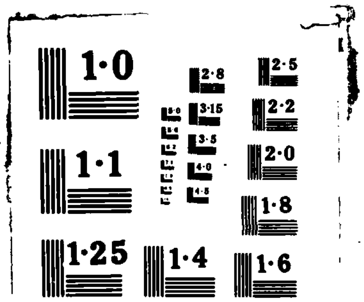

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number)

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.

DISCLAIMER NOTICE

ONONDAGA DAM

STABILITY ANALYSIS

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ONONDAGA DAM
SLOPE STABILITY ANALYSIS

1. INTRODUCTION

1.1 Authority.

Authority for continuing evaluation of a completed civil works structure, whose failure or partial failure would endanger the lives of the public or cause substantial property damage, is contained in ER 1110-2-100. Authority for a seismic investigation is contained in ER 1110-2-1800. This stability investigation has been performed in accordance with these regulations and North Central Division request contained in NCDED-T 1st Indorsement, periodic Inspection Report, Onondaga Dam dated 20 December 1978.

1.2 Scope.

This report includes a stability analysis for a cross section of the embankment (to include an evaluation of the slope protection) stability analysis of the spillway and a seismic stability report.

1.3 Purpose.

The purpose of this investigation is to comply with ER 1110-2-100, "Engineering and Design, Periodic Inspection and Continuing Evaluation of Completed Civil Works Structures," Appendix A, paragraph 6d and ER 1110-2-1806, Engineering and Design, Earthquake Analysis for Corps of Engineers projects. These regulations call for a review of the stability of principle structures based on current criteria and a seismic evaluation of existing projects.

1.4 Background.

The Onondaga Dam Flood Control Project was authorized by the Flood Control Act of 1941 (Public Law 228, 77th Congress, 1st Session). Construction of the Dam was initiated in May 1947 and was completed in August 1949.

1.5 General Description of Onondaga Dam.

Onondaga Dam is located on Onondaga Creek about 4 miles southwest of the southern limits of Syracuse, NY (See Plate 1). The structure consists of a rolled earthfill embankment with a concrete overflow side channel spillway on the right abutment (See Plate 2). The overall length of the rolled fill embankment is 1,782 feet, having a maximum height of 67 feet. A 1,100-foot long spillway channel has been cut into bedrock along the right abutment. For additional pertinent data, see Appendix A.

2. GEOLOGY

2.1 Regional Geology.

2.1.1 Surficial Geology - Onondaga Dam is located in the northern part of the Allegheny Plateau Physiographic Province. The physiographic province, which lies immediately north of the dam, is a region of low relief and is termed the Lakes Plains Province. See Plate 3 for locations of physiographic provinces. The Allegheny Plateau is characterized as a region of moderate to high relief with elevations ranging from about 2,000 to 4,000 feet above sea level. The topography of the region has been produced by erosion of the underlying sedimentary strata and later modified by glacial processes. Glacial deposits are relatively thin on the upland portions of this province; however, the prominent north-south U-shaped valleys have been deeply eroded and filled by extensive moraine, lacustrine, and glacial outwash deposits. Some of the valleys are plugged at both ends by glacial deposits, thereby forming the Finger Lakes, while other valleys have subsequently drained.

2.1.2 Bedrock Geology - The stratigraphy of central New York consists of relatively undeformed, flat-lying sedimentary rocks ranging in age from Upper Ordovician to Upper Devonian. The predominant rock formations of the region consist of interbedded limestone, sandstone, and shale. The stratigraphic sequence dips gently southward at approximately 40 to 50 feet per mile such that the oldest units are exposed to the north with progressively younger formations exposed southward. Devonian rocks are by far the most extensively exposed in central New York. Devonian strata underlie all of the Allegheny Plateau region and much of the regions adjacent to it. Carbonates dominate the Lower to Middle Devonian with shales comprising the remainder of the section.

During the Pleistocene Epoch which began about 3 million years ago, central New York was covered by glacial ice, approximately 2 miles thick. The erosional effect of the ice mass was to deeply scour the valley of Onondaga Creek and other north-south trending valleys. As the ice receded northward, its margin paused south of the Onondaga damsite, depositing the Tully Moraine, near Tully, NY. With continued northward withdrawal of the glacial ice, a thin veneer of ground moraine in the form of glacial till was deposited over the bedrock surface. Glacial lakes formed south of the ice front and filled the valleys north of the Tully Moraine. One of many glacial lakes existed in the valley south of Syracuse. As the lake received meltwater from the west, a dramatic series of glacial lake deltas were deposited. As the glacial ice receded north into the Lake Ontario Basin many of the glacial lakes drained eastward into the Mohawk River. Those which did not drain formed the present day Finger Lakes.

2.1.3 Structural Geology - Generally, the sedimentary rocks in the area are horizontally bedded with a regional dip of approximately 1/2° to the south. Superimposed on this dip are low amplitude anticlines and synclines and faults of low displacement. The folds in the Syracuse and central New York region are related either to mild compression as a result of the Appalacian Orogeny or to removal of salt and gypsum in the Salina and Bertie Groups due to migrating groundwater. Some of the smaller folds may be the result of subsidence. A number of small faults occur in the Syracuse central New York region. They are all small in lateral extent and displacement or offset. Generally, they strike N70°W, dip southward and are thrust faults that form due to compression. The overlying glacial deposits are not offset, indicating that no motion has taken place on these faults since the last ice retreat.

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 nearly vertical. Two minor sets that strike northeast and northwest are also present.

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.

2.1.4 Earthquake Activity - Between 1720 and 1980, more than 330 earthquakes with a maximum Modified Mercalli Intensity (Io) greater than II are known to have occurred in New York State (Mitronovas, 1981). New York State has been subdivided into three areas, a 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).

Details regarding the distribution of earthquakes, the evaluation for active faults and the intensity and effects of earthquake shaking at Onondaga Dam are summarized in "Report on Seismic Stability, Onondaga Dam, New York: Geological and Seismological Investigations at Onondaga Dam, New York" (Attachment 2). This report concludes that the dam is situated in an area that is structurally simple and tectonically stable.

2.2 Site Geology.

2.2.1 Surficial Geology

2.2.1.1 General - Geologic conditions at the dam e have been largely influenced by the advance and waning of continental ice sheets during the Pleistocene. Plate 4 shows the local surficial geology. With recession of the glacial ice, a large terminal moraine was deposited, filling the valley at Tully and blocking drainage to the south. As the ice slowly retreated northward, vast quantities of meltwater flowed eastward along the front of the glacier, ponding a preglacial lake in the valleys south of Syracuse. The eastward-moving currents poured into Onondaga Valley through the well-defined Cedarvale Channel near West Onondaga, carrying large amounts of sediment which were rapidly deposited in a large delta at the point of entry into the lake. As the ice receded further, lake outlet channels to the east were uncovered at progressively lower elevations. This caused the delta to grow outward in a series of descending steps. Finally, the lake waters completely disappeared and the existing drainage, including Onondaga Creek, formed.

At the dam site, Onondaga Creek flows almost due north through a narrow steep-walled, post glacial valley. The valley floor at the dam site consists of a floodplain approximately 600 feet wide.

2.2.1.2 Fluvial Overbank Deposits - The fluvial overbank deposits consist of gray and brown fine sandy silt, clay to silty clay, with an occasional layer of silty fine sand, small amounts of organic material, and are the original near-surface soils of the valley bottom. See Plates 7 and 8 for the extent of this material. Laboratory test results indicate the fluvial overbank deposits consist of 0-10 percent fine gravel, 15 to 37 percent sand, 25-40 percent silt, and 25 to 60 percent clay. As a result of the visual descriptions and laboratory test results, the fluvial overbank deposits would be classified as ML, CL, and SM soils according to the USCS. These are the weakest soils in the dam foundation. Appendix B summarizes the soil strength parameters.

2.2.1.3 Deltaic Deposits - Deltaic deposits underlie the overbank deposit in each of the recent test borings and generally consist of brown, silty, coarse to fine sand, gravel, to coarse to fine, sandy gravel, silt, with occasional layers of medium to fine sand. Plates 7 and 8 show the extent of the deltaic deposits. Grain size distribution curves of this deposit indicate the material consists of 0 to 49 percent gravel, 36 to 73 percent sand, and 9 to 27 percent silt. As a result of the above visual descriptions and laboratory test results, the deltaic deposits would be classified as GM, GW, SW, SM, and SP soils, according to the USCS. For the discussion of soil strength parameters, see Appendix B.

2.2.1.4 Lacustrine Deposits - Lacustrine sediments underly the deltaic deposits. These sediments consist of red-brown, silty fine sand, coarse to medium sand and fine gravel, to silty clay, coarse to fine sand, with occasional layers of coarse to fine sand, gravel, and silt. The extent of the lacustrine deposits are shown on Plates 7 and 8. Grain size distributions of representative samples of coarser portions of this deposit (silty fine sand) contained 60 to 72 percent fine sand and 28 to 40 percent silt. The hydrometer analysis of silty clay consisted of 10 percent sand, 30 percent silt, and 60 percent clay. As a result of the above visual descriptions and laboratory test results, the lacustrine deposits would be classified as SM, SP, ML, and CL, according to the USCS. For the discussion of soil strength parameters, see Appendix B.

2.2.1.5 Glacial Till - Glacial till underlies the lacustrine deposit. Descriptions of recovered samples range from gray, gravelly, coarse to fine sand, silt to brown, fine sandy silt, coarse to medium sand and gravel. Numerous cobbles and boulders were indicated during casing advance and sampling. No grain size distributions of this deposit were obtained. As a result of the above visual descriptions, the glacial till would be described as SM, GM, and GW soils, according to the USCS.

2.2.2 Bedrock Geology

2.2.2.1 Dam - The stratigraphic sequence of rocks exposed in the vicinity of the dam is represented by Lower and Middle Devonian Limestone and shales of the Helderberg Group, Onondaga Limestone, and Hamilton Group. Plate 5 shows the bedrock geology of central New York State. The Onondaga Limestone is exposed in the walls of the spillway cut. In this region, the Onondaga Formation is described as a series of light bluish grey semi-crystalline limestone occurring in even continuous layers from 1 inch to 2 feet thick, separated by thin seams of dark calcareous shales. Flattened nodules of dark blue or black chert, sometimes in continuous sheets or beds, are unevenly distributed throughout the formation, but is predominant in the upper part.

The total thickness of the Onondaga Limestone is approximately 70 feet. The formation, subdivided into five members, from older to younger are: the Edgecliff Member, the Nedrow Member, the Moorehouse Member, the Tioga Bentonite Member, and the Seneca Member. Borings indicate that the top of rock occurs at 117 feet or deeper along the central portion of the dam embankment.

2.2.2.2. Spillway - Both the Nedrow and overlying Moorehouse Members are exposed within the spillway cut at Onondaga Dam. The Nedrow Member is characterized as medium grey, thin bedded, shaly limestone. A small amount of chert is unevenly distributed at the top of the unit. The Nedrow is about 10 feet thick and gradational with the overlying Moorehouse Member. The Moorehouse is described as a medium grey, very fine grained limestone, with 2-inch to 5-foot thick beds separated in many places by thin shale partings. Chert is common, but is variable in amount. The total thickness of the Moorehouse Member is about 25 feet.

Testing of rock was not conducted for the design analysis of the spillway. Strength parameters and permeability were not determined.

Based upon the descriptions of the rock from the 1945 subsurface exploration program, numerous horizontal and vertical seams are present. Generally, the material appears unweathered.

2.2.3 Structural Geology

2.2.3.1 Structural Deformations - Bedrock in the study area exhibits a gentle dip of 1/2° to the south. 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.

2.2.3.2 Joints - The joint system in the study area contains two main sets, one nearly north-south and the other nearly east-west. Most of the joints are nearly vertical. Two minor sets that strike northeast and northwest are also present. The results of the 1945 subsurface exploration program describe the rock core as containing numerous horizontal and vertical seams. Orientations of these defects were not discussed.

2.2.3.3 Faults - A number of small faults occur in the general vicinity of central New York; however, none were identified specifically at the project site.

2.2.3.4 Dikes - Dikes have been identified in isolated locations in central New York. None have been identified at the project site.

2.3 Groundwater.

Borings that were conducted for the original design analysis in 1945 along the dam embankment indicate an artesian flow of sulphur water occurred in the Manlius Limestone. The flow was spontaneous with little pressure after the first run, but increased slightly and became constant after drilling a total of 10 feet into rock. The overflow amounted to 1/2 gallon per minute through a 2-1/2-inch casing. The flow was sealed in the rock with Oakum and Portland cement. Artesian flow of sulphur water from the overburden was also encountered at a depth of 55 feet in one hole and in 105 feet in another hole. These holes were both sealed with Oakum and backfilled after the casing was pulled to prevent seepage.

The left portion of the dam rests against a steeply pitching deltaic terrace. This terrace is capped with a 40-foot layer of pervious sandy gravel underlain by a uniform sand bed averaging 45 feet in thickness. Immediately below, a bed of red silty clay occurs, 20 feet thick, serving as an impervious barrier to groundwater seepage. Plates 7 and 8 show this sequence of sediments. The thick sand beds also serve as a reservoir for subsurface drainage, and a perched water table has been formed with springs issuing from the terrace front. The perched water table was found at a depth of 71.0 feet in the uniform sand above the silty clay stratum. Groundwater was not encountered again after the casing reached the clay stratum. This perched water table probably has seasonal variations and finds outlet in seepage about halfway down the slope. The seepage upstream of the dam flows through the riprap slope protection to a cutoff trench at the base. It then runs to the creek channel. Downstream of the dam, the water runs along the rock toe to the old creek bed and runs northward untill it merges with the creek channel.

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 indicated a subsurface water level of approximately 460± to 465±, closely corresponding to the original ground surface. Plate 7 shows where groundwater was encountered in the 1982 subsurface explorations. During the 1982 subsurface exploration program, regular water level observations were made during drilling operations and the water level in adjacent settlement gages were measured. These levels correspond closely with the original ground surface.

Twelve piezometers were installed to measure the porewater pressures under the downstream toe of the dam. Eight are located in the downstream rock toe of the dam embankment, and four are located behind the east wall of the spillway. The stability of the embankment slope depends on the porewater pressure realized.

Since the construction of the dam, water storage has never exceeded about one-third of the depth below spillway crest. Saturation levels are generally low because of the prevailing low stage. Drainage of the spillway wall backfill is provided by a perforated pipe drain and filter at the heel of the wall. The four piezometers behind the wall have not shown water levels higher than the drain elevation which was also used as the design saturation level.

3. EMBANKMENT STABILITY ANALYSIS

3.1 General.

The stability analysis was performed using EM 1110-2-1902 and WES Slope Stability Program I0009. The WES program utilizes the Modified Swedish Method. In this program, the sliding mass is divided into finite slices and a number of circular failure arcs are investigated to determine which is the most critical. In the Modified Swedish Method, the earth forces acting on the sides of the slice are considered. The direction of these side forces is assumed to be parallel to the average slope of the embankment and are changed to horizontal at the heel and toe. The program conducts a systematic search for the critical slip circle tangent to a specified depth. By varying the tangent elevation and the grid, the minimum factor of safety can be obtained. The grid was generally between 9 and 25 points per tangent elevation in order to insure that the minimum factor of safety was within the inside of the grid. The WES program is also designed to handle all cases outlined in the EM with the exception of Case VI - Surcharge Pool.

3.2 Stability Criteria.

The stability criteria for earth dams is set forth in EM 1110-2-1902. The minimum factor of safety for each case is given in Table 3.1

Table 3.1

Case Number	Design Condition	Minimum Factor of Safety	Remarks
I	End of Construction	1.3	Upstream and Downstream Slopes
II	Sudden Drawdown From Maximum Pool	1.0	Upstream Slope
III	Sudden Drawdown From Spillway Crest	1.2	Upstream Slope
IV	Partial Pool With Steady Seepage	1.5	Upstream Slope
V	Steady Seepage With Maximum Storage Pool	1.5	Downstream Slope
VI	Steady Seepage With Storage Pool	1.4	Downstream Slope
VII	Earthquake (Cases I, IV, and V With Seismic Loading)	1.0	

3.3 Selection of Cross Section.

The cross section used in the analysis is at Station 6+02. This section was selected based on the following:

- It is in the area of maximum embankment height.

- Cross sectional data was readily available.

- It is at a location where a recent subsurface exploration was conducted.

3.4 Selection of Soil Parameters.

The embankment cross section and foundation details are shown on Plate 8. The parameters selected for the analysis are listed in Table 3.4.1. The rationale for these selected parameters is in Appendix B. A detailed description of the foundation materials is in paragraph 2.2.1.

The embankment is primarily made up of random fill materials excavated from borrow areas in the vicinity of the dam. The random fill materials may generally be described as brown, silty coarse to fine sand and gravel with an occasional layer of medium to fine sand and coarse to fine sandy gravel. Samples consist of 34 to 56 percent gravel, 31 to 39 percent sand, and 13 to 28 percent silt. As a result of the above visual descriptions and laboratory test results, the random fill materials would be classified as GM, SM, or SP soils, according to the Unified Soils Classification System (USCS). These materials are considered to be relatively pervious and compact to very compact.

Table 3.4.1

Soil Type	c	Ø	Unit Weight Sat (pcf)
Embankment			
Riprap	0	40°	105
Random Fill	0	36°	145
Impervious	0	34°	145
Foundation			
Fluvial Overbank	0	23°	105
Deltaic Deposit	0	35°	119
Lacustrine	0	27°	124

These parameters are based on test results and boring log descriptions from the original subsurface exploration and testing program, and on a Corps of Engineers subsurface exploration program conducted in July and August 1982.

3.5 Results of the Analysis.

Table 3.5.1 summarizes the results of the analysis. Discussions of individual case are contained in paragraph 3.7.

Table 3.5.1

Case	Condition	Min. F.O.S	Calculated F.O.S
I	As is (No Pool) US Slope	1.3	2.13
	DS Slope	1.3	1.65
II	Sudden Drawdown From Maximum Pool - US Pool	1.0	1.25
III	Sudden Drawdown From Spillway Crest - US Pool	1.2	1.34
IV	Partial Pool With Steady Seepage - US Slope	1.5	1.83
V	Steady Seepage With May Storage Pool - DS Slope	1.5	1.51
VI	Steady Seepage With Surcharge Pool - DS Slope	1.4	NA*
VII	Earthquake Cases I (US, DS) VI, V	1.0	1.8, 1.4, 1.5, 1.3**

* See Paragraph 3.7.6
** See Paragraph 3.7.7

The input data files used in the computer analysis and a sample output run are contained in Appendix D. It should be noted that for the analysis the cross sections were simplified somewhat in order to codify the soil profiles. In general, for the upstream slope cases, the simplifications included:

- elimination of the riprap slope protection and filter layer.
- simplification of the geometry of the impervious layer.
- elimination of downstream slope features (i.e. riprap toe and variable slope).

The downstream slope simplification includes:

- elimination of filter layer.
- simplification of the riprap toe geometry.
- elimination of upstream slope features.

A more detailed discussion is contained in subsequent paragraphs.

3.6 Hand Check of the Results.

The results of the computer analyses were checked by hand using the Simplified Bishops Method. This method was chosen for ease of hand calculation and to provide a check by an alternate stability method. The hand calculation checks were made on the critical slip surfaces obtained by computer. The calculations are contained in Appendix C. Table 4.4.2 summarizes the results.

Table 4.4.2

Case		Min.	Factor of Safety	
			Computer	Hand Check
I	US	1.3	2.13	2.10
I	DS	1.3	1.65	1.68
II		1.0	1.25	1.02
III		1.2	1.34	1.28
IV		1.5	1.83	1.4
V		1.5	1.51	1.37

While the factors of safety for Case IV and V are less than the minimum required, it is not considered to be significant because of the conservativeness of the assumptions and these cases are not considered critical for the dam (see paragraphs 3.7.4 and 3.7.5).

3.7 Discussion of Individual Cases.

3.7.1 Case I -

3.7.1.1 Upstream Slope - The tangent elevation of the slip surface was varied from 424' to 484' (see Figure 1A). The results indicate that the slip surface "walks out" due to the lack of a cohesion value for the materials. The significance is that the lowest factor of safety represents only a very shallow, noncritical, failure surface. Therefore, for this analysis the minimum factor of safety chosen was for the first slip circle that was considered to be "significant" (i.e, that would encompass a significant portion of the embankment, where failure would endanger the structure). The factor of safety for this slip circle is 2.13. The water level was taken to be groundwater only and the elevation used is just above the embankment foundation line.

3.7.1.2 Downstream Slope - The tangent elevations for the slip circles was varied from 422' to 462' (see Figure 1B). The minimum factor of safety obtained was 1.65. "Walking out" was not encountered in this or any other subsequent downstream analysis.

3.7.2 Case II Sudden Drawdown From Maximum Pool - The sudden drawdown case assumes that steady seepage is occurring (the phreatic line is assumed to be horizontal) and the pool is drawn down from a maximum pool elevation of 520.4' to approximately ground level, 470' (see Figure 2). This is the most critical case for Onondaga Dam, which under flood conditions would experience rapid changes in pool elevation. Figures 7 and 8 show that the expected drawdown rate is approximately 80 hours from maximum pool to spillway crest elevation and then 11 days to drawdown the remainder of the pool to normal levels (i.e. no pool). The slip circle again exhibited "walk out" and a failure surface was chosen as in Case I at a point where failure would endanger the embankment. The minimum factor of safety obtained was 1.25.

3.7.3 Case III Sudden Drawdown for Spillway Crest Elevation - This case is the same as Case II. The minimum factor of safety obtained was 1.34 (see Figure 3).

3.7.4 Case IV - Partial Pool with Steady Seepage - The partial pool case examines the upstream slope stability for various pool levels. Steady seepage conditions are assumed and the phreatic line is assumed to be horizontal (see Figure 4). For each failure surface the pool elevation is varied and the minimum factor of safety is chosen. The minimum factor of safety obtained was 1.83 for the failure surface that would endanger the embankment.

3.7.5 Case V Steady Seepage with Maximum Storage Pool - It is unlikely that a condition of steady seepage would occur at the dam because of the rapid rise to and drawdown from maximum pool expected at the site (para. 4.6.2 above). The case was examined however, and a phreatic surface drawn (see Figure 5). The main portion of the dam consists of pervious materials. This portion of the embankment is approximately 300 times more pervious than the sloping impervious core (see Appendix B). The main portion of the dam would, therefore, drain freely to a level equaling the tailwater (see reference 9, Chapter 6). The tailwater at the dam is the result of backwater effects of flow downstream of the embankment (see Figure 7). The minimum factor of safety obtained for this case was 1.51.

3.7.6 Case VI - Steady Seepage with Surcharge Pool - The surcharge pool case assumes that there is a rapid increase in the pool height while the phreatic surface remains constant. In the case of Onondaga this would be a rapid increase from no pool, to maximum storage pool. The weight of the water would be added to that portion of the failure surface that it affects. The critical failure surface for the no pool case does not, however, intersect the upstream slope. An examination of failure surfaces that would intersect the upstream slope reveals relatively high factors of safety (1.8 - 3.9). It can be seen on Figure 6 that the effect of the additional water weight on these failure surfaces would be minimal. This case is, therefore, not critical for the dam. The minimum factor of safety would be the same as that at case I DS, 1.65.

3.7.7 Case VII Earthquake (Cases I, IV, and V) - ETL 1110-2-301 states that this case is no longer valid for embankment dams. It was, however, evaluated using the computer program and the critical slip circles for Cases I, IV, and V. It is included in the analysis for informational purposes only and is not supported by hand computation. For further information on t e seismic stability of the embankment see paragraph 3.5 above and reference 7.

4. SPILLWAY STABILITY ANALYSIS

An evaluation of the stability of the side channel spillway was submitted after the 26 September 1978 Periodic Inspection of Onondaga Dam as an attachment to Period Inspection Report No. 3. It was approved by NCDED-T 1st Indorsement dated 25 March 1979. The analysis is extracted and attached as Attachment 1.

The spillway stability analysis examined the sliding stability of the concrete spillway using EM 1110-2-2200. The analysis examined the structure under a variety of loading and uplift conditions. Two separate failure modes were assumed: one at the concrete bedrock contact and the other along a plane through the rock below the spillway. The following Table 4.4.3 summarizes the results.

Table 4.4.3

Concrete - Rock Sliding Coefficient				
	Allowable	Calculated	Within Middle Third	Remarks
Case I	0.65	0.41	Yes	1. Headwater at MAX Pool, 520.3' 2. Full Hydrostatic pressure against the upstream face. 3. Tailwater at 497.5'. 4. Uplift 100 percent HW at heel to 100 100 percent at Toe.
Case II	0.65	0.43	Yes	1, 2, 3 as above. 4. Uplift 100 percent HW at heel to 0 percent at toe.
Case III	0.65	0.23	Yes	1, 2, 4, as in Case I. 3. TW at 504.5'.

Rock - Rock Sliding Coefficient				
	Allowable	Calculated	Within Middle Third	Remarks
Case I	0.30	0.26	Yes	1, 2, 3, 4, as in Case I above.
Case II	0.30	NA		See Appendix F.
Case III	0.30	0.10	Yes	1, 2, 3, 4. Same as Case III above.
Case IV	0.30	0.28	No*	1, 2, 4. Same as Case I. 3 TW at 485.4'.
Case V	0.30	0.16	Yes	1. HW at 504.5'. 2, 4 Same as Case II. 3. TW=0

*Resultant is .75 feet outside the middle third.

The report concluded that the calculated sliding friction was less than the allowable and the resultant was either within the middle or close to it.

5. SEISMIC STABILITY STUDY

In 1982, a study was conducted to determine the maximum earthquake that would effect the site and to assess the earthquake effects on the dam. The study was performed by Haley & Aldrich of New York under contract number DACW 49-81-D-0011 dated 13 October 1981. This report was submitted by the Buffalo District and approved by NCDED-G 1st Indorsement dated 5 April 1983 subject to minor revisions. Attachment 2 is a copy of this report which includes the recommended revisions. The study included geological, seismological and subsurface investigations, and geotechnical engineering analyses. The study consisted of the following elements:

- An evaluation of the regional and local geology

- Performance of subsurface explorations and laboratory testing to further define the nature and density of soil deposits

- An evaluation of the regional and local tectonic history with respect to structural deformation including faults

- A review of historical regional seismicity

- The determination of the maximum earthquake that will affect the site

- An assessment of earthquake effects on the dam, including an evaluation of liquefaction potential of the subsurface soils

The report concluded that the dam is located in an area that can be described as being nearly aseismic. The maximum earthquake intensity expected is VI (Modified Mercalli Intensity) with a peak horizontal ground acceleration of 0.05g in rock and 0.06g in soil. The report went on to conclude that:

> "...The embankment and foundation soils are not considered to be susceptable to liquification... Minor seismically-induced settlement of the embankment and subsoils may occur, but the settlement will not be detrimental to the performance of the structure."

6. SLOPE PROTECTION EVALUATION

4.1 General.

The upstream slope of Onondaga Dam is protected by a 36-inch thick dumped layer of riprap that was excavated from the spillway channel during construction of the dam. This stone is breaking up thereby reducing the protection that it affords the dam. Reduction in size is estimated to be more than 50 percent. See Figures 10 through 13.

The design gradation curve for the riprap is at Figure 14. The rationale behind this gradation specification is not apparant; however, Sherard (Reference 17) reports that in the mid 1940's it was commonly considered that a dumped riprap layer of 36 inches was satisfactory under any wave action. Therefore, it is assumed that the design was adequate.

An analysis using the current Corps criteria as outlined in EM 1110-2-2300 and ETL 1110-2-120 is necessary for comparison to the original design specifications. An evaluation must then be made to determine the effect of the breakup.

6.2 Wave Analysis.

A wave analysis for Onondaga Dam was performed and is at Appendix E. The recommended maximum wave height for Onondaga Dam is 2 feet.

6.3 Gradation requirements.

Using EM 1110-2-2300, and ETL 1110-2-120, a specific gravity of 2.65, an average value of the slope of the embankment, and a wave height of 2 feet, the following gradation is obtained:

Median rock size W_A = 27.5 lb.
Riprap Thickness T = 12 in.
$W_{MAX} = 4\ W_A$ = 110 lb.
$W_{MIN} = W_A/8$ = 3.4 lb.

Percent Lighter By Weight	Limits of Stone Weight (lbs.)
100	86-35
50	26-17
15	13- 5
10	12- 4

This information is plotted on Figure 14 for comparison with the original design specifications. The actual computations are in Appendix F.

7. CONCLUSION AND RECOMMENDATIONS.

7.1 The embankment, spillway, and foundation of Onondaga Dam have been determined to be statically stable and meet all current Corps criteria. No further analysis is recommended at this time.

7.2 The foundation and embankment soils are not considered to be susceptible to liquefaction and the dam will experience no reduction in its capacity after experiencing the maximum expected earthquake. No further analysis is recommended at this time.

7.3 The rip-rap slope protection original design specification gradation exceeds current Corps criteria. The extent to which the current significant rip rap breakup affects the slope protection is unknown. In order to make a more complete evaluation of current conditions, the existing gradation of the rip rap we need to be established and the effects of future breakup considered. In order to determine the degree of deterioration, in-place gradation test would need to be performed.

8. REFERENCES

1. Corps of Engineers, "Engineering and Design Stability of Earth and Rockfill Dams," EM 1110-2-1903, HQDA, Office, Chief of Engineers, Washington, DC, 1970.

2. Corps of Engineers, "Earth and Rockfill Dams General Design and Construction Consideration," EM 1110-2-2300, HQDA, Office, Chief of Engineers, Washington, DC, 1971.

3. ER 1110-2-100, "Periodic Inspection and Continuing Evaluation of Completed Civil Works Structures," ER 1110-2-100, HQDA, Office, Chief of Engineers, Washington, DC, 1977.

4. ETL 1110-2-301, "Interim Procedure for Specifying Earthquake Motions," ETL 1110-2-301, HQDA, Chief of Engineers, Washington, DC, 1983.

5. Corps of Engineers, "Design Analysis for Onondaga Reservoir, Onondaga Creek, New York," Buffalo District, Buffalo, NY, 1945.

6. Corps of Engineers, "Onondaga Creek Dam and Reservoir Regulation Manual," Buffalo District, Buffalo, NY, 1955.

7. Corps of Engineers, "Seismic Stability: Geological and Seismological Investigations," Buffalo District, Buffalo, NY, 1982 (attached as Attachment 2).

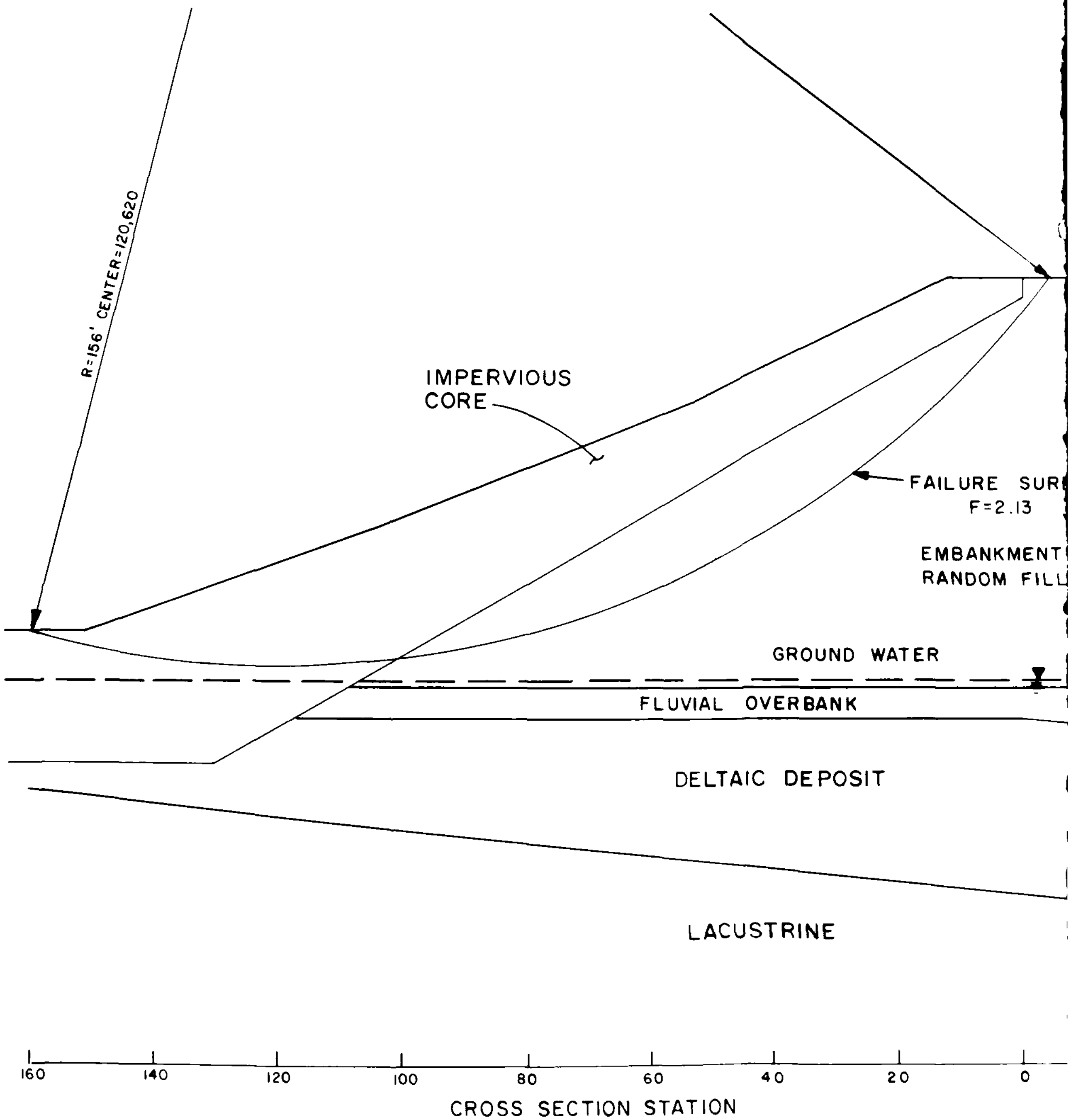
8. Bowles, Foundation Analysis and Design, McGraw Hill, NY, 1977.

9. Cedergren, Seepage, Drainage, and Flow Nets, J. Wiley & Sons, NY, 1967.

10. Hough, Basic Soils Engineering, J. Wiley & Sons, NY, 1969.

11. Mitronovas, W. "Earthquake Statistics in New York State," In Press, 1981.

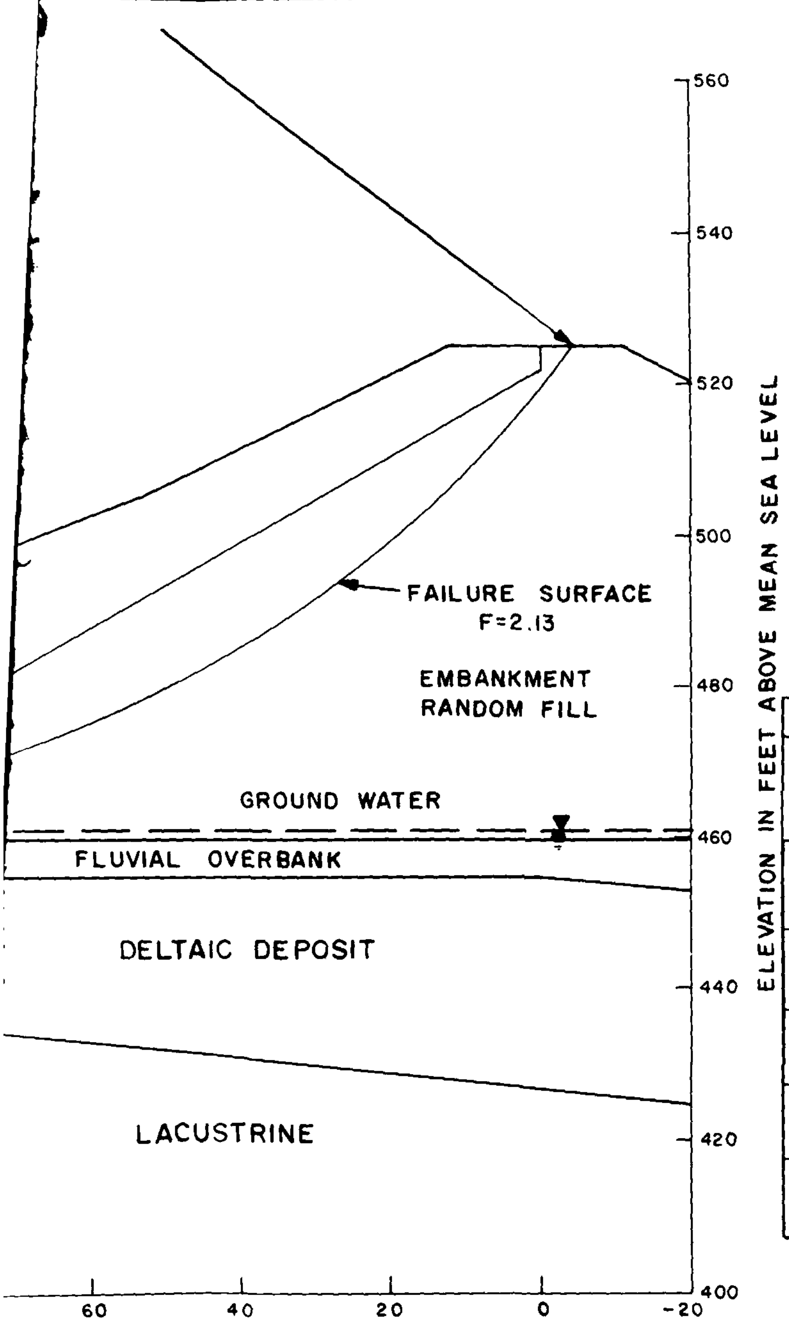
12. Sherard, J.L. etal. Earth and Earth-Rock Dams, J. Wiley & Sons, NY, 1963.



NOTES:

1. FOR RATIONALE OF ADOPTED DESIGN VALUE SELECTION, S

2. FOR COMPUTER INPUT FILES AND SAMPLE OUTPUT LISTINGS



TION STATION

TANGENT EL.	CENTER X	CENTER Y	FACTOR OF SAFETY
424	120	580	2.48
434	120	580	2.36
444	120	580	2.51
454	120	620	2.24
464	120	620	2.13 *
474	160	740	1.69
484	160	780	1.46

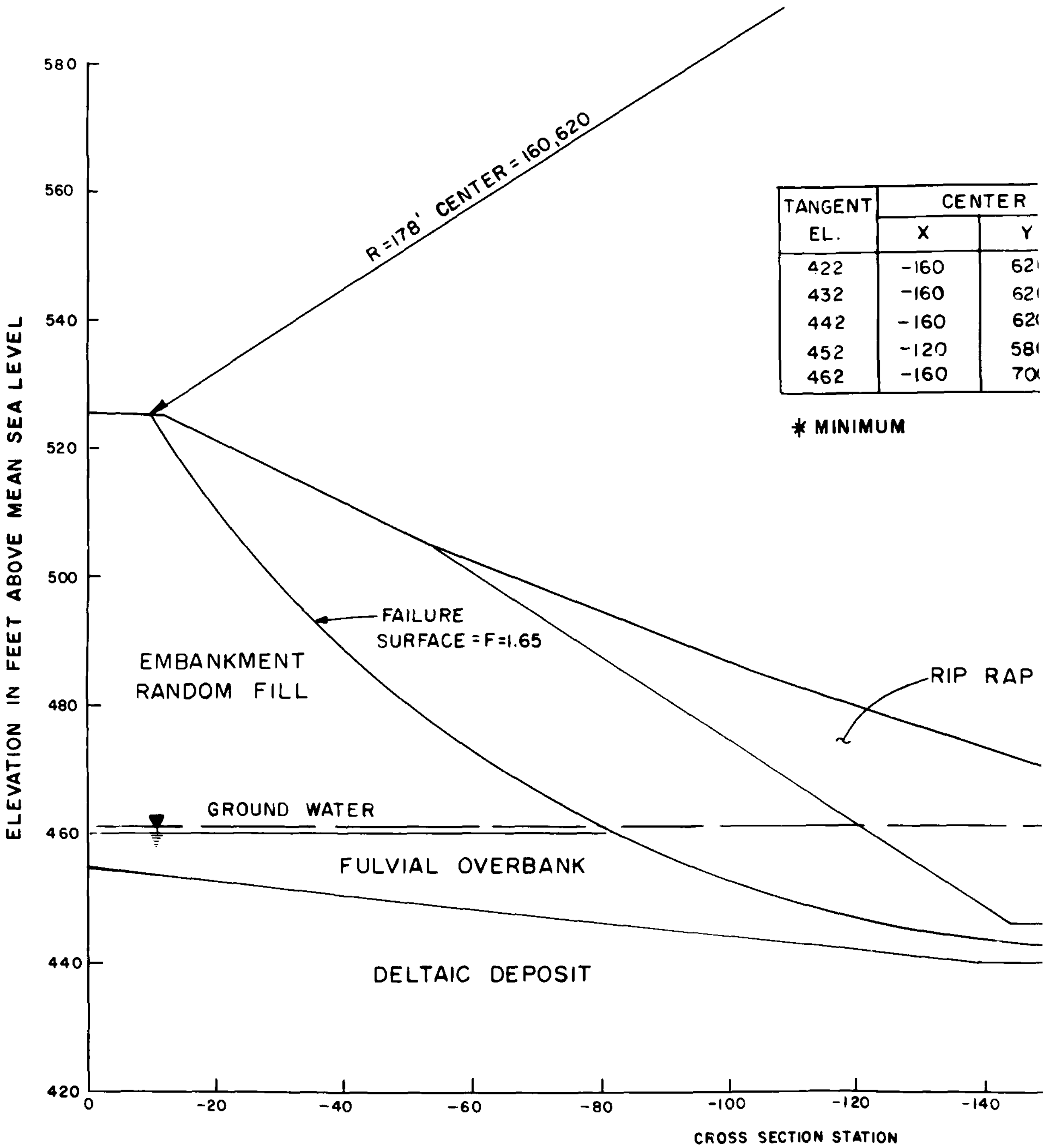
* SELECTED MIN. F.O.S. OTHER FAILURE SURFACES REPRESENTS ONLY SHALLOW NON CRITICAL SURFACES

ADOPTED DESIGN DATA					
MATERIAL TYPE	UNIT WEIGHT		STRENGTH VALUES		
	γ MST (KCF)	γ SAT (KCF)	C (KSF)	Ø DEG.	Ø TAN
IMPERVIOUS CORE (SILTY SANDY GRAVEL)	.139	.145	0	34	.675
EMBANKMENT RANDOM FILL (SM, GM, SP)	.143	.145	0	36	.727
FLUVIAL OVERBANK (ML, CL, SM)	--	.105	0	23	.425
DELTAIC (GM, GW, SW, SM, SP)	--	.119	0	35	.700
LACUSTRINE (SM, SP, ML, CL)	--	.124	0	27	.510

ONALE OF ADOPTED DESIGN VALUE SELECTION, SEE APPENDIX B.
PUTER INPUT FILES AND SAMPLE OUTPUT LISTINGS, SEE APPENDIX D.

ONONDAGA DAM, NEW YORK
STABILITY ANALYSIS CASE I
UPSTREAM SLOPE
STA. 6 + 02
U.S. ARMY ENGINEER DISTRICT BUFFALO
TO ACCOMPANY STABILITY ANALYSIS
DATED: MAY 1986

FIGURE 1A



TANGENT EL.	CENTER X	Y
422	-160	62
432	-160	62
442	-160	62
452	-120	58
462	-160	70

NOTES:

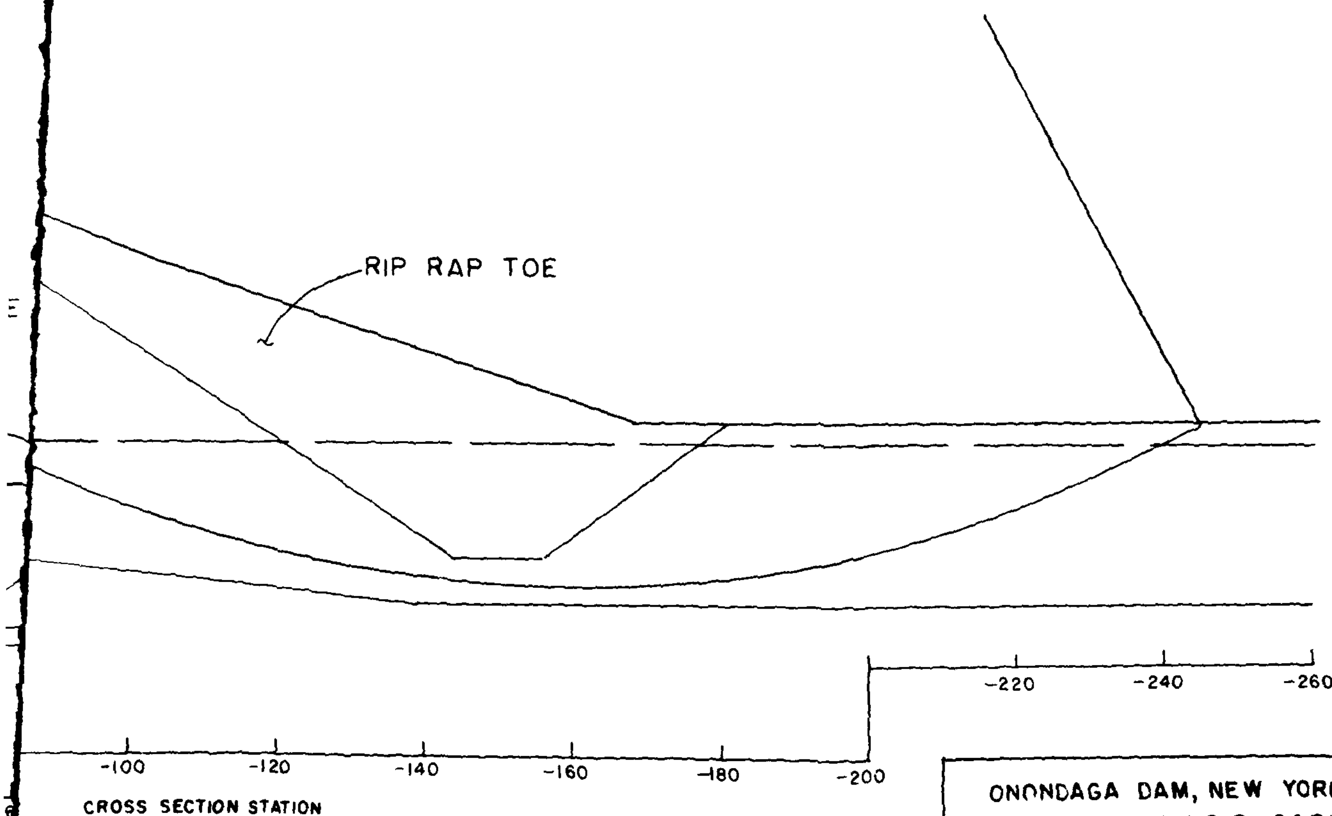
1. FOR RATIONALE OF ADOPTED DESIGN VA
2. FOR LISTINGS OF COMPUTER INPUT FI
SEE APPENDIX D.

TANGENT EL.	CENTER X	CENTER Y	FACTOR OF SAFETY
422	-160	620	2.15
432	-160	620	1.94
442	-160	620	1.65 *
452	-120	580	1.86
462	-160	700	2.02

* MINIMUM

ADOPTED DESIGN DATA

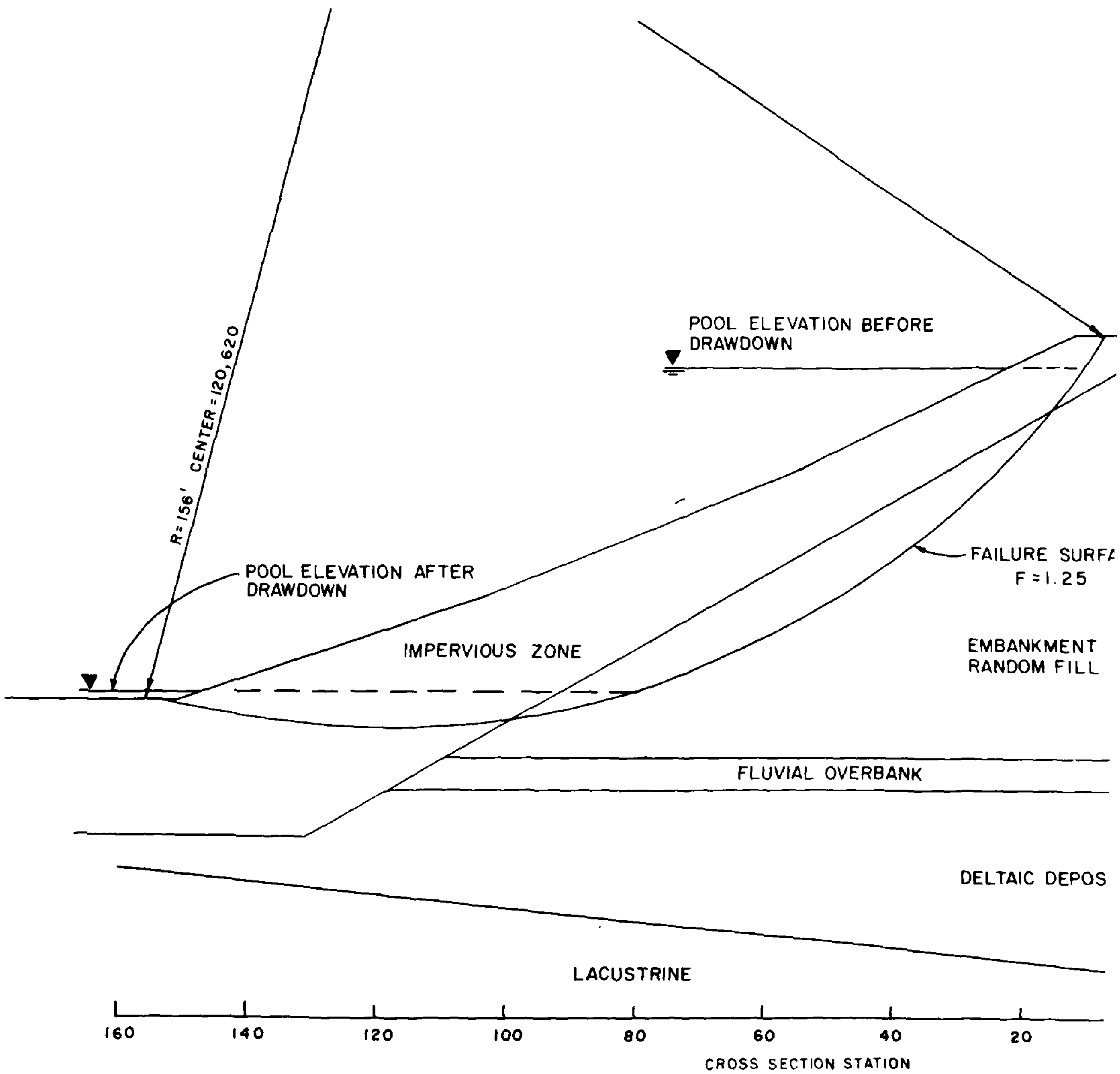
MATERIAL TYPE	UNIT WEIGHT		STRENGTH VALUES		
	γ_{mst} (KCF)	γ_{SAT} (KCF)	C (KSF)	Ø (DEG)	TAN Ø
EMBANKMENT RANDOM FILL (SM, GM, SP)	.143	.145	0	36	.727
RIP RAP TOE	.105	.105	0	40	.839
FLUVIAL OVERBANK (ML, CL, SM)	---	.105	0	26	.488
DELTAIC (GM, GW, SW, SM, SP)	---	.119	0	35	.700



S:
R RATIONALE OF ADOPTED DESIGN VALUES SELECTION, SEE APPENDIX B.
R LISTINGS OF COMPUTER INPUT FILES AND SAMPLE OUTPUT
E APPENDIX D.

ONONDAGA DAM, NEW YORK
STABILITY ANALYSIS CASE I
DOWNSTREAM SLOPE
STA.6+02
U.S. ARMY ENGINEER DISTRICT BUFFALO
TO ACCOMPANY STABILITY ANALYSIS
DATED: MAY 1986

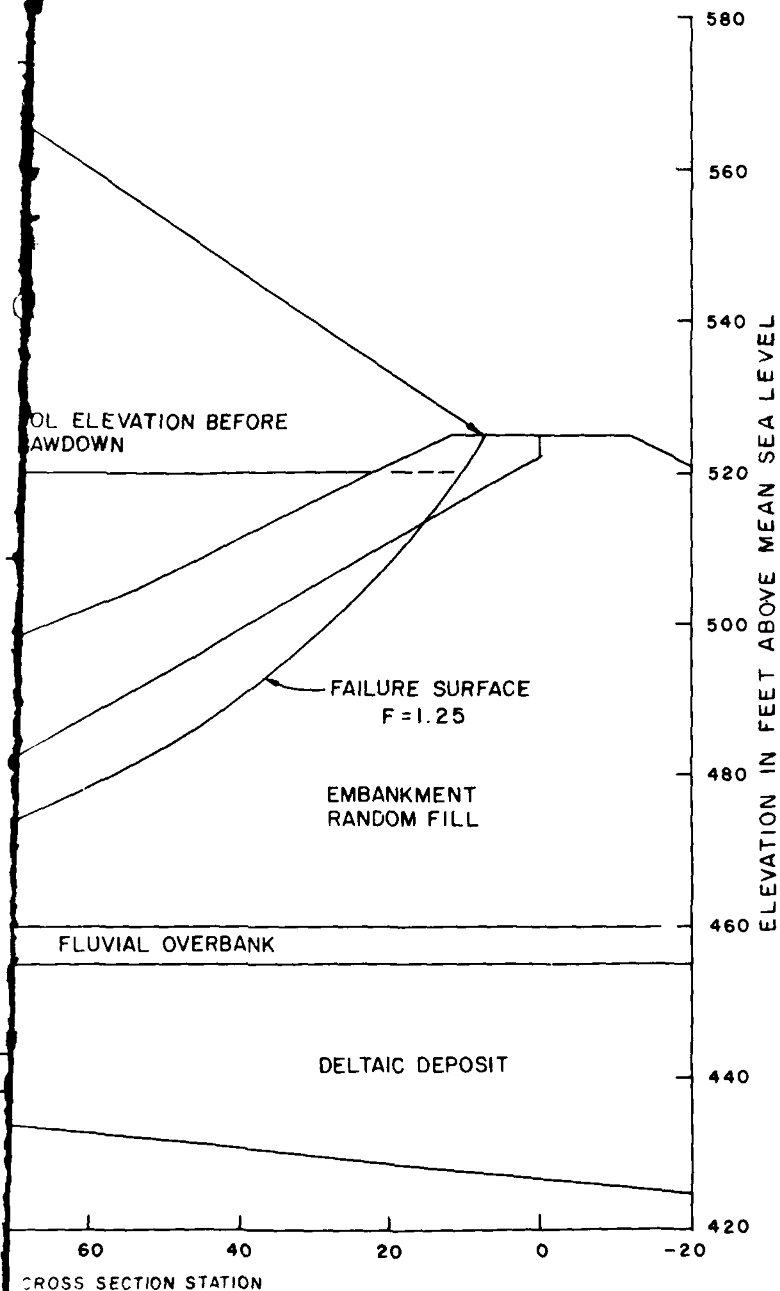
FIGURE 1B



NOTES:

1. FOR RATIONALE OF ADOPTED DESIGN VALUE SELECTION

2. FOR COMPUTER INPUT FILES AND SAMPLE OUTPUT LI



TANGENT EL.	CENTER		FACTOR OF SAFETY
	X	Y	
434	120	580	1.87
444	120	580	1.62
454	120	580	1.35
464	120	620	1.25 *
474	160	700	1.00

* SELECTED MIN F.O.S., OTHER SURFACE REPRESENTS ONLY SHALLOW NON CRITICAL FAILURE SURFACE

ADOPTED DESIGN DATA					
MATERIAL TYPE	UNIT WEIGHT		STRENGTH VALUES		
	γ_{mst} (KCF)	γ_{SAT} (KCF)	C (KSF)	Ø (DEG)	TAN Ø
IMPERVIOUS ZONE (SILTY SANDY GRAVEL)	.139	.145	0	34	.675
EMBANKMENT RANDOM FILL (SM,GM,SP)	.143	.145	0	36	.727
FLUVIAL OVERBANK (ML,CL,SM)	---	.105	0	23	.425
DELTAIC DEPOSIT (GM, GW, SW, SM, SP)	---	.119	0	35	.700
LACUSTRINE (SM,SP,ML,CL)	---	.124	0	27	.510

ADOPTED DESIGN VALUE SELECTION, SEE APPENDIX B.

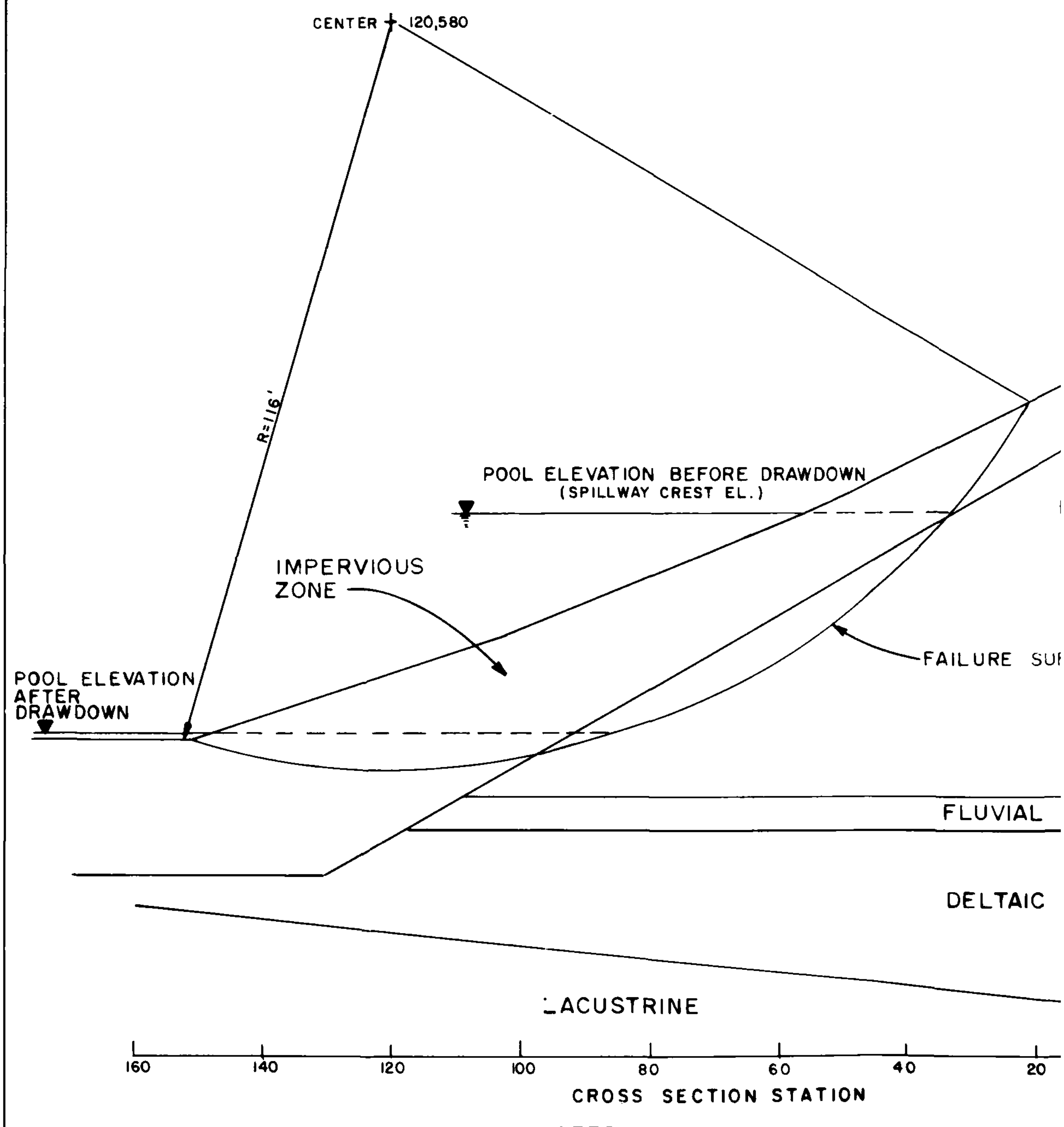
PUT FILES AND SAMPLE OUTPUT LISTING, SEE APPENDIX D.

ONONDAGA DAM, NEW YORK

STABILITY ANALYSIS, CASE II
SUDDEN DRAWDOWN FROM
MAXIMUM POOL
STA.6+02

U.S. ARMY ENGINEER DISTRICT BUFFALO
TO ACCOMPANY STABILITY ANALYSIS
DATED: MAY 1986

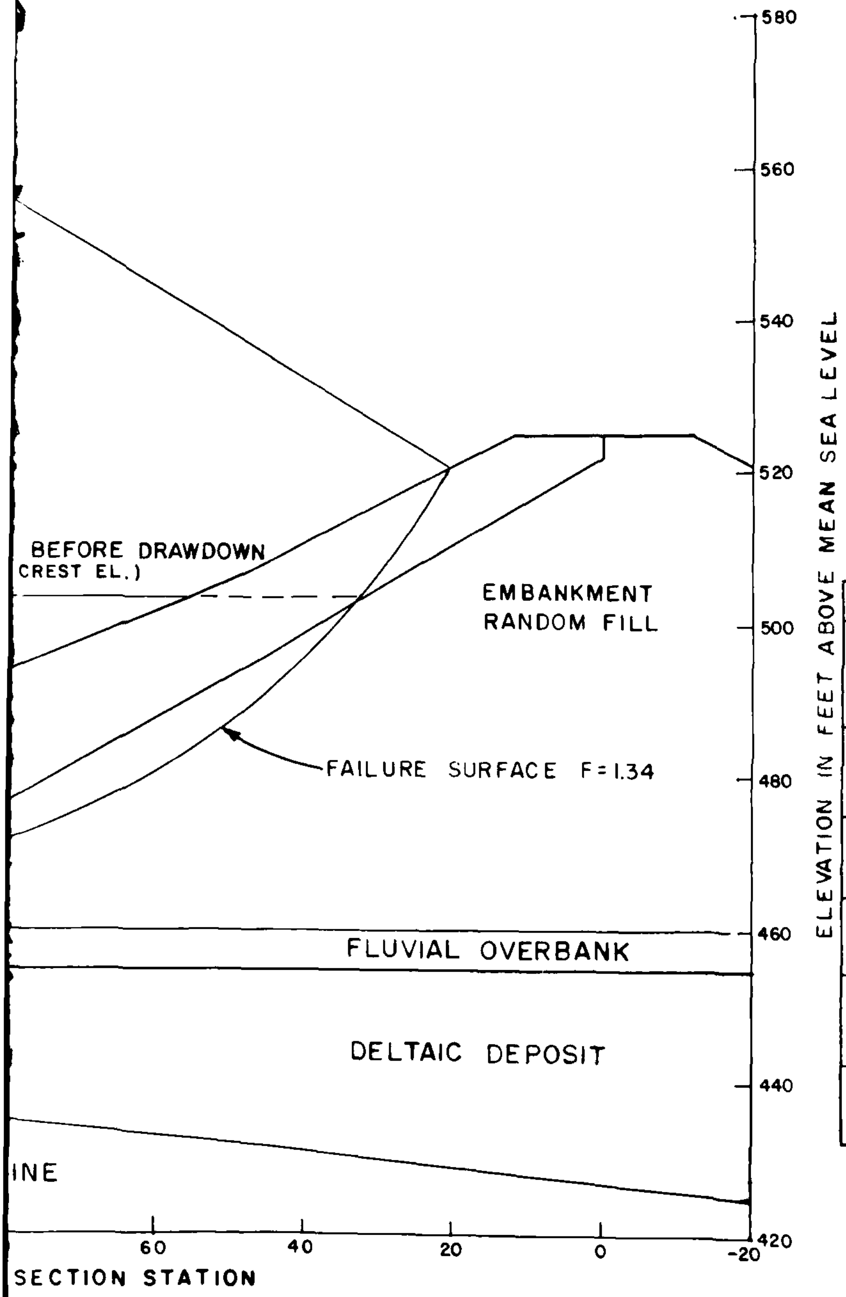
FIGURE 2



NOTES:

1. FOR RATIONALE OF ADOPTED DESIGN VALUE SEL

2. FOR LISTINGS OF COMPUTER INPUT FILES AND S



TANGENT EL.	CENTER		FACTOR OF SAFETY
	X	Y	
434	120	580	2.00
444	120	580	1.73
454	120	580	1.44
464	120	580	1.34 *
474	160	660	1.05

* SELECTED MIN. F.O.S. OTHER SURFACE REPRESENTS ONLY SHALLOW, NON CRITICAL FAILURE SURFACE.

ADOPTED DESIGN DATA					
MATERIAL TYPE	UNIT WEIGHT		STRENGTH VALUES		
	γ MST (KCF)	γ SAT (KCF)	C (KSF)	Ø DEG	TAN Ø
IMPERVIOUS ZONE (SILTY SANDY GRAVEL)	.139	.145	0	34	.675
EMBANKMENT RANDOM FILL (SM, GM, SP)	.143	.145	0	36	.727
FLUVIAL OVERBANK (ML, CL, SM)	– –	.105	0	23	.425
DELTAIC DEPOSIT (GM, GW, SW, SM, SP)	– –	119	0	35	.700
LACUSTRINE (SM, SP, ML, CL)	– –	.124	0	27	.510

ONALE OF ADOPTED DESIGN VALUE SELECTION, SEE APPENDIX B.

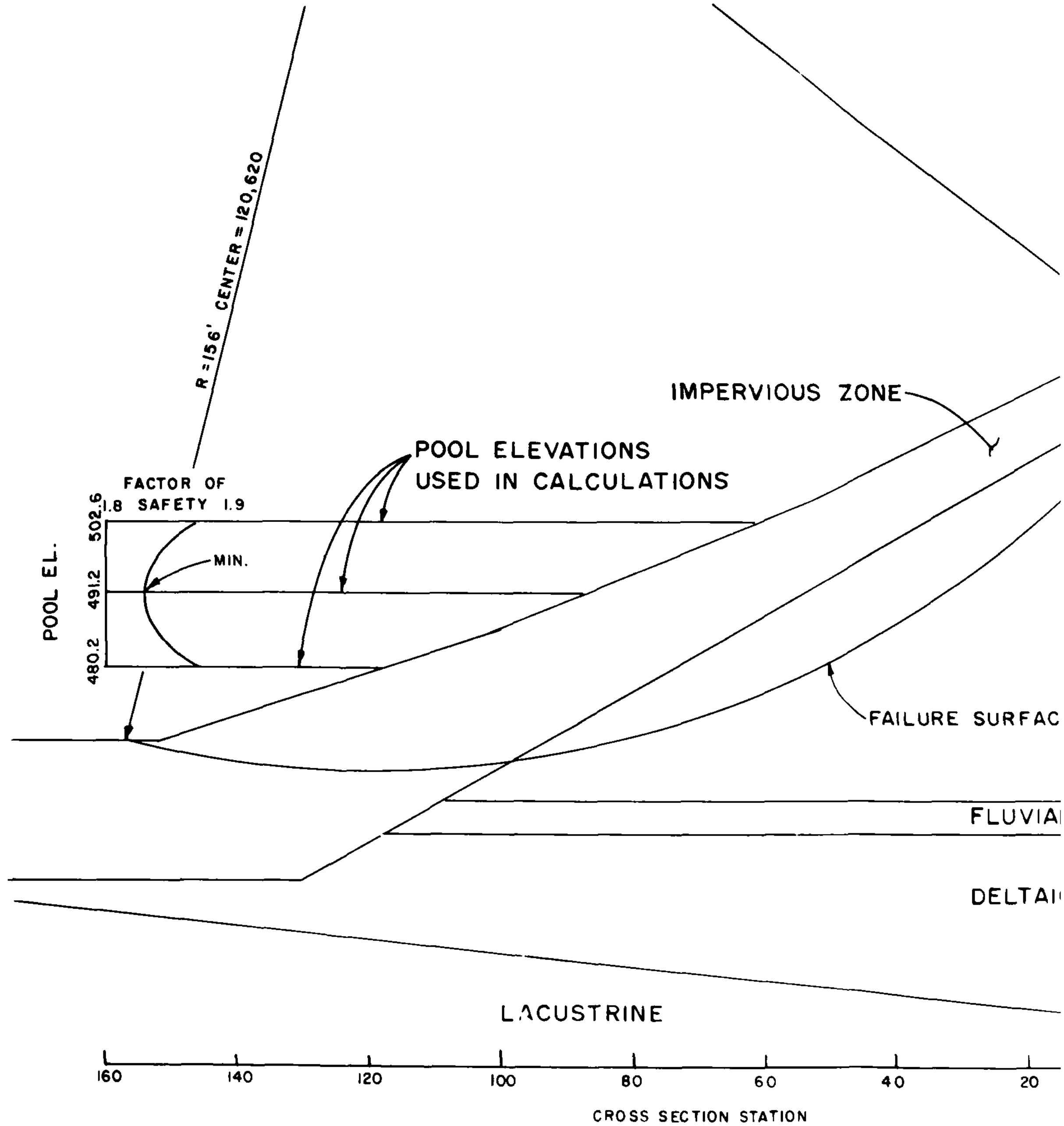
INGS OF COMPUTER INPUT FILES AND SAMPLE OUTPUT, SEE APPENDIX D.

ONONDAGA DAM, NEW YORK

STABILITY ANALYSIS, CASE III
SUDDEN DRAWDOWN FROM
SPILLWAY CREST
STA. 6 + 02

US ARMY ENGINEER DISTRICT BUFFALO
TO ACCOMPANY STABILITY ANALYSIS
DATED: MAY 1986

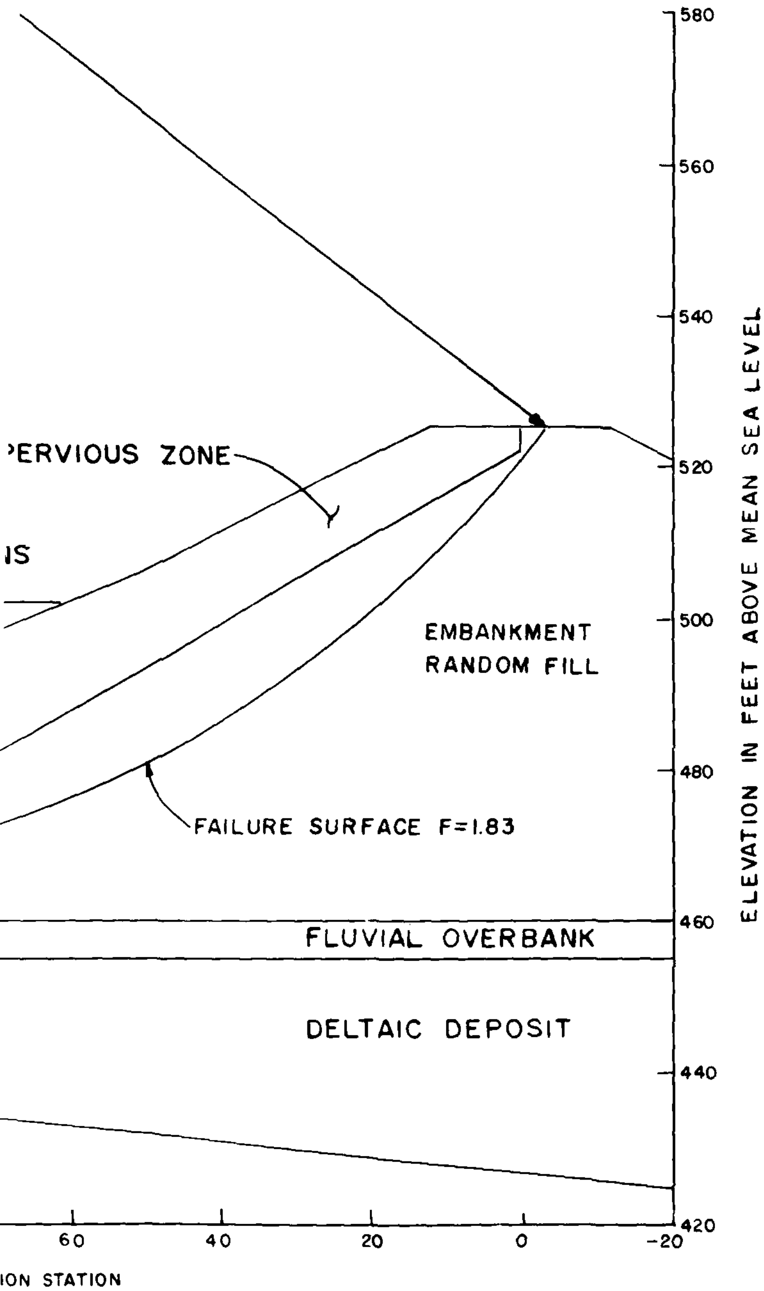
FIGURE 3



NOTES:

1.FOR RATIONALE OF ADOPTED DESIGN VALUE SELEC

2.FOR LISTING OF COMPUTER INPUT FILES AND SAM



TANGENT EL.	CENTER X	CENTER Y	POOL EL.	FACTOR OF SAFETY
434	120	580	475.9 490.9 469.2	2.49 2.60 2.48
444	120	580	480.2 491.4 469.2	2.20 2.30 2.25
454	120	580	480.2 491.4 464.2	1.92 1.99 2.02
46.4	120	620	480.2 491.4 502.6	1.87 1.83 * 1.87

* SELECTED MIN F.O.S.

ADOPTED DESIGN DATA

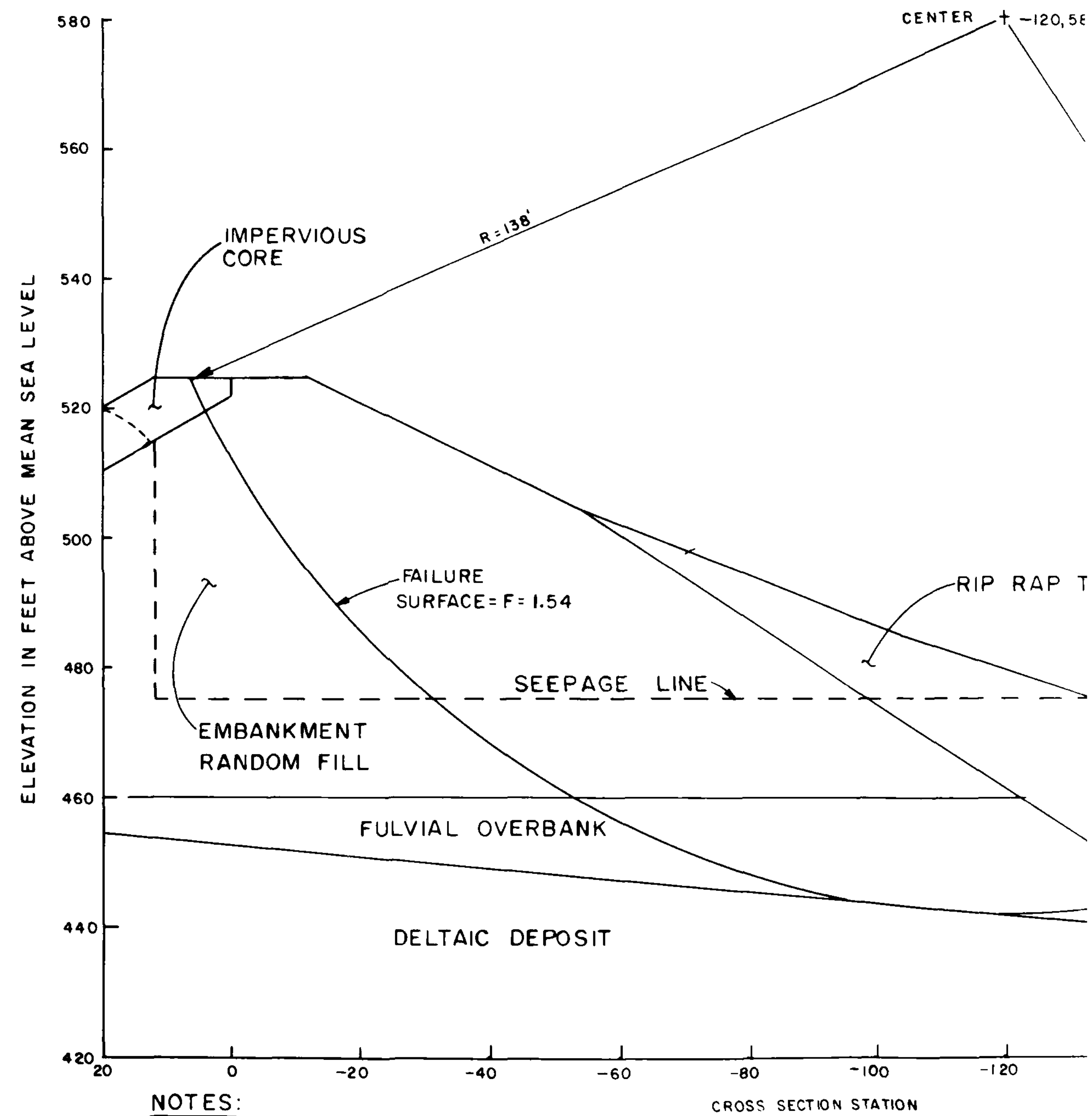
MATERIAL TYPE	UNIT WEIGHT γ_{mst} (KCF)	UNIT WEIGHT γ_{SAT} (KCF)	STRENGTH VALUES C (KSF)	STRENGTH VALUES Ø (DEG)	STRENGTH VALUES TANØ
IMPERVIOUS ZONE (SILTY SANDY GRAVEL)	.139	.145	0	34	.675
EMBANKMENT RANDOM FILL (SM, GM, SP)	.143	.145	0	36	.727
FLUVIAL OVERBANK (ML, CL, SM)	---	.105	0	23	425
DELTAIC DEPOSIT (GM, GW, SW, SM, SP)	---	.119	0	35	.700
LACUSTRINE (SM, SP, ML, CL)	---	.124	0	27	.510

ADOPTED DESIGN VALUE SELECTION, SEE APPENDIX B.

OMPUTER INPUT FILES AND SAMPLE OUTPUT, SEE APPENDIX D.

ONONDAGA DAM, NEW YORK
STABILITY ANALYSIS, CASE IV
PARTIAL POOL WITH
STEADY SEEPAGE
STA. 6+02
U.S. ARMY ENGINEER DISTRICT BUFFALO
TO ACCOMPANY STABILITY ANALYSIS
DATED: MAY 1986

FIGURE 4



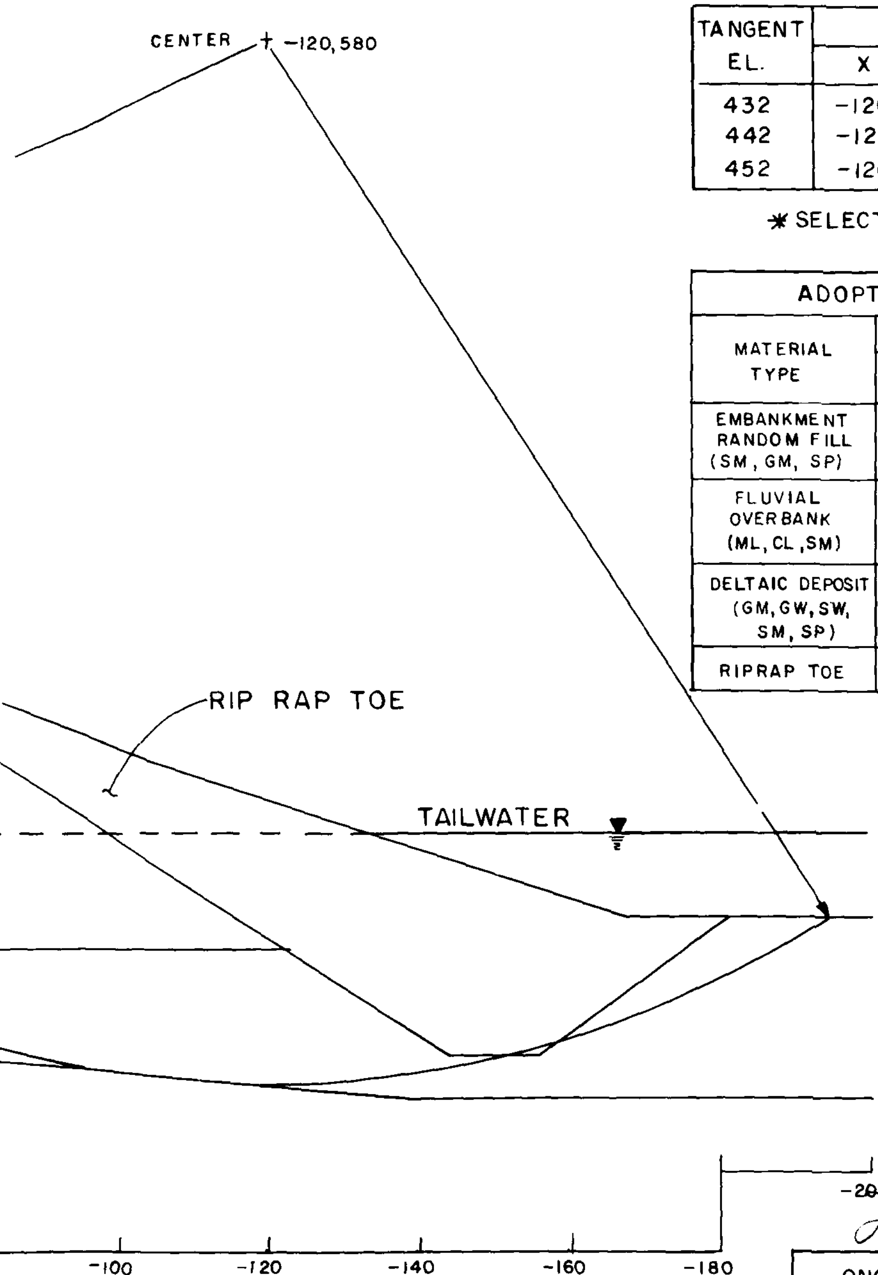
NOTES:

1. TAILWATER IS BACKWATER FROM FLOW RESTRICTIONS DOWNSTREAM OF DAM ASSUME BACK SA

2. SEEPAGE LINE IS NEAR VERTICAL IN EMBANKMENT BECAUSE IT IS APPROXIMATE 300 TIMES

3. FOR RATIONALE OF ADOPTED DESIGN VALUES, SEE APPENDIX B.

4. FOR LISTINGS OF COMPUTER INPUT FILES AND SAMPLE OUTPUT, SEE APPENDIX D.



TANGENT EL.	CENTER X	CENTER Y	FACTOR OF SAFETY
432	-120	580	1.78
442	-120	580	1.54 *
452	-120	580	1.56

* SELECTED MIN. F.O.S.

ADOPTED DESIGN DATA					
MATERIAL TYPE	UNIT WEIGHT		STRENGTH VALUES		
	γmst (KCF)	γSAT (KCF)	C (KSF)	Ø (DEG)	TAN Ø
EMBANKMENT RANDOM FILL (SM, GM, SP)	.143	.145	0	36	.727
FLUVIAL OVERBANK (ML, CL, SM)	---	.105	0	26	.488
DELTAIC DEPOSIT (GM, GW, SW, SM, SP)	---	.119	0	35	.700
RIPRAP TOE	.105	.105	0	40	.839

SECTION STATION

REAM OF DAM ASSUME BACK SATURATION OF EMBANKMENT.

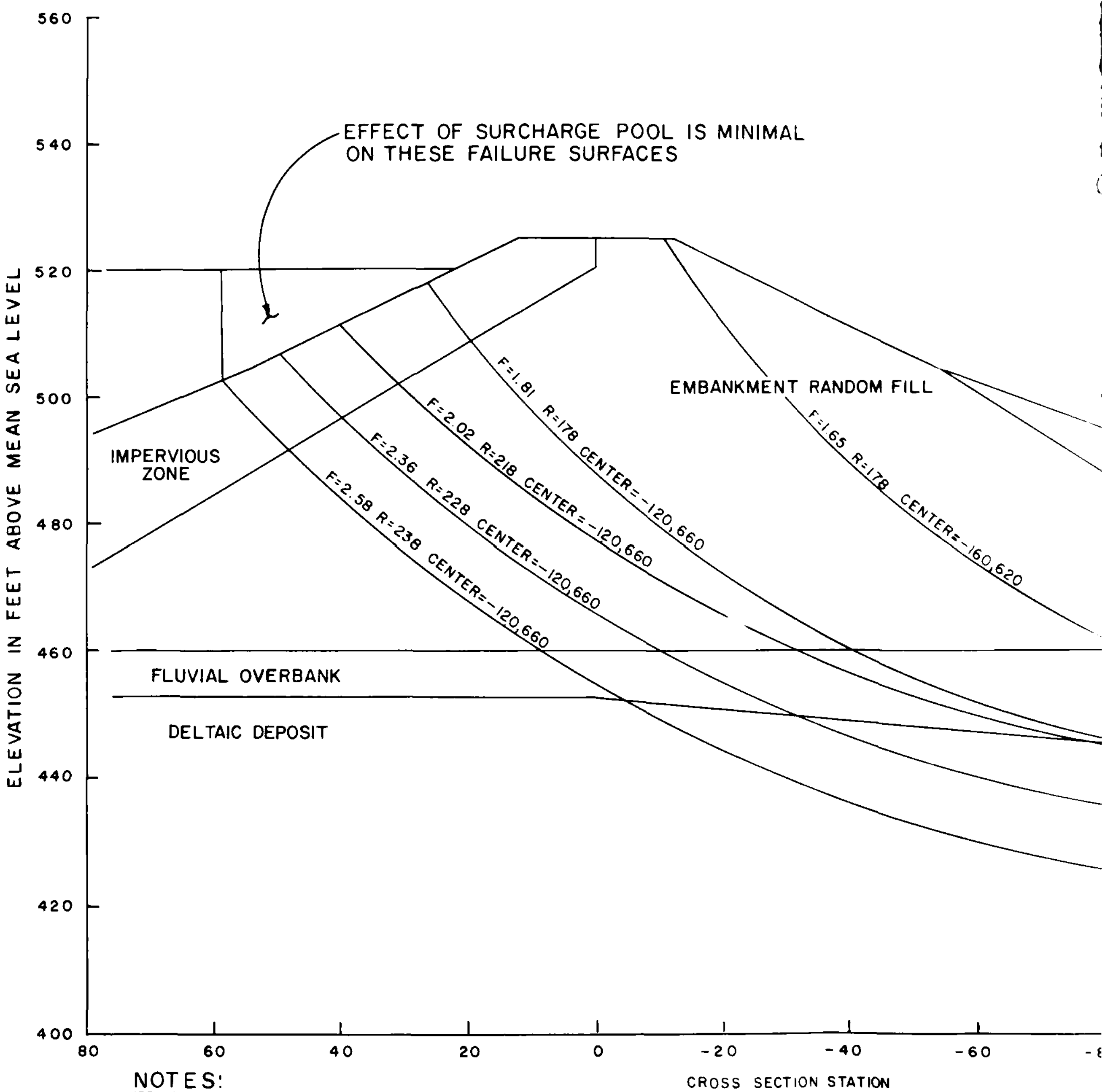
E IT IS APPROXIMATE 300 TIMES MORE PERVIOUS THAN THE CORE.

B.

UT, SEE APPENDIX D.

ONONDAGA DAM, NEW YORK
STABILITY ANALYSIS CASE V
STEADY SEEPAGE FROM
MAXIMUM POOL
STA. 6+02
U.S. ARMY ENGINEER DISTRICT BUFFALO
TO ACCOMPANY STABILITY ANALYSIS
DATED: MAY 1986

FIGURE 5

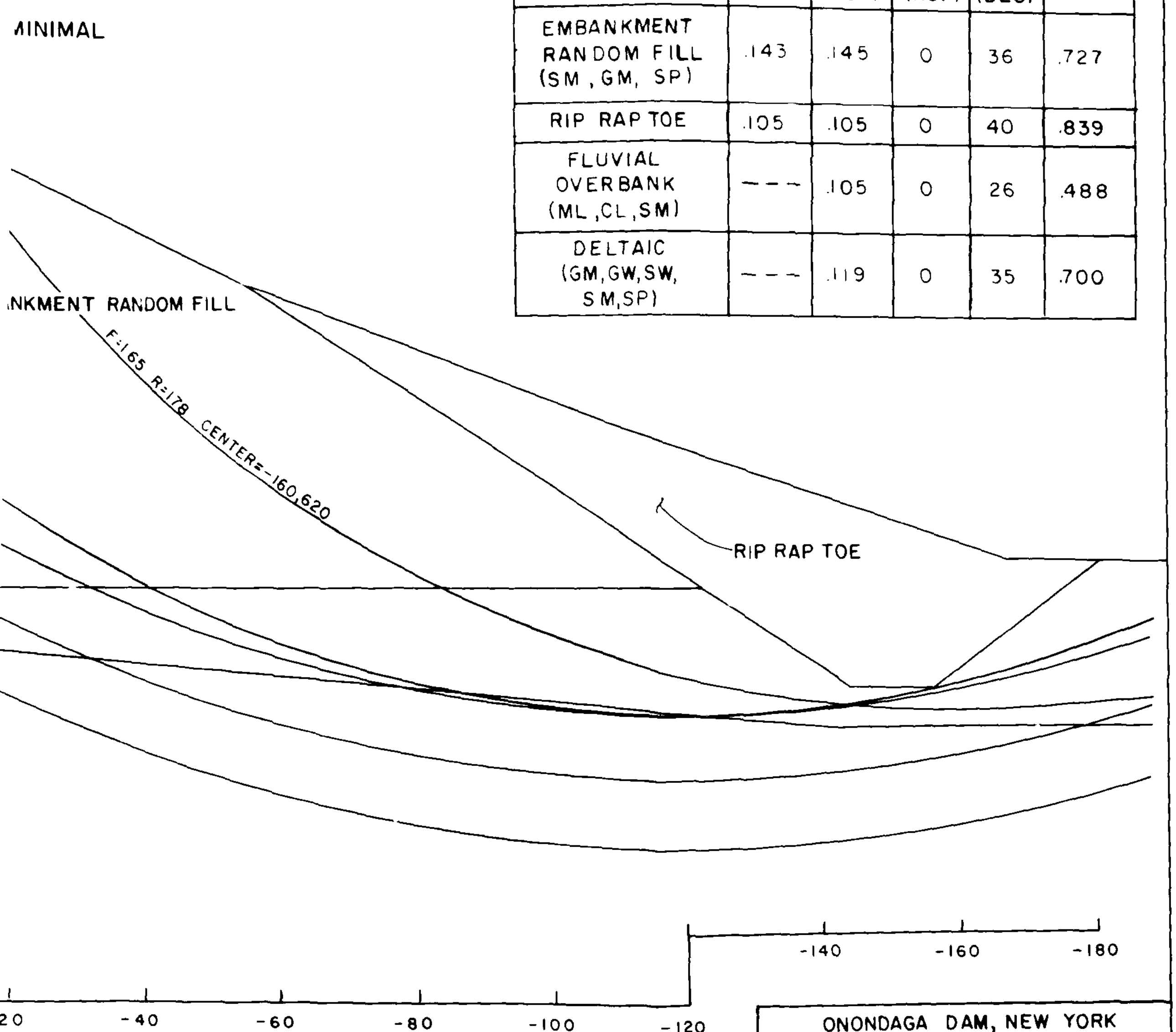


NOTES:

1. FACTORS OF SAFETY (F) ARE PRIOR TO APPLICATION OF THE SURCHARGE POOL.
2. FOR RATIONALE OF ADOPTED DESIGN VALUES, SEE APPENDIX B.
3. FOR LISTINGS OF COMPUTER INPUT FILES AND SAMPLE OUTPUT, SEE APPENDIX D.

MATERIAL TYPE	UNIT WEIGHT		STRENGTH VALUES		
	γ_{mst} (KCF)	γ_{SAT} (KCF)	C (KSF)	Ø (DEG)	TAN Ø
EMBANKMENT RANDOM FILL (SM, GM, SP)	.143	.145	0	36	.727
RIP RAP TOE	.105	.105	0	40	.839
FLUVIAL OVERBANK (ML, CL, SM)	---	.105	0	26	.488
DELTAIC (GM, GW, SW, SM, SP)	---	.119	0	35	.700

ADOPTED DESIGN DATA



SS SECTION STATION

E SURCHARGE POOL.

X B.

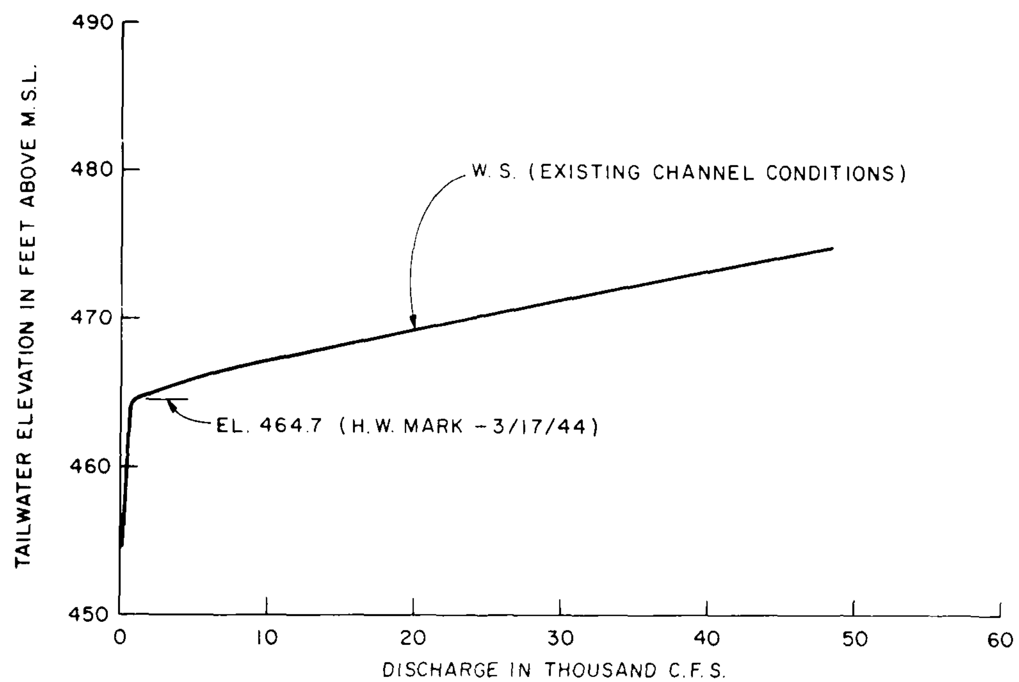
OUTPUT, SEE APPENDIX D.

ONONDAGA DAM, NEW YORK

STABILITY ANALYSIS, CASE VI
SURCHARGE POOL
STA. 6+02

U.S. ARMY ENGINEER DISTRICT BUFFALO
TO ACCOMPANY STABILITY ANALYSIS
DATED: MAY 1986

FIGURE 6



NOTE:

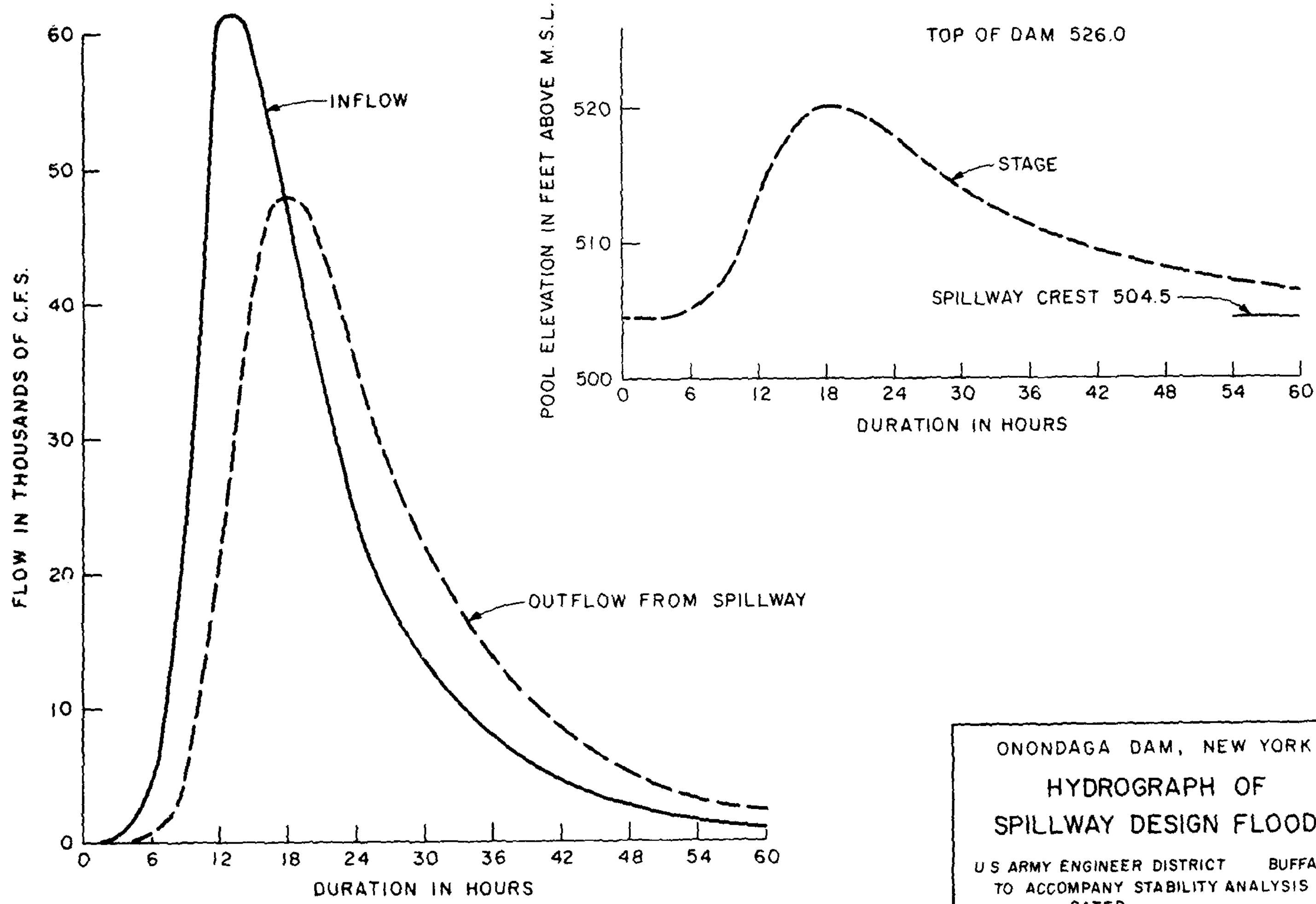
1. CURVE APPLIES 600' BELOW CENTERLINE OF DAM.
2. TAILWATER IS EFFECTIVELY BACKWATER AND NOT DUE TO SEEPAGE THROUGH THE DAM.

ONONDAGA DAM, NEW YORK

TAILWATER RATING CURVE

U S ARMY ENGINEER DISTRICT BUFFALO
TO ACCOMPANY STABILITY ANALYSIS
DATED

FIGURE 7

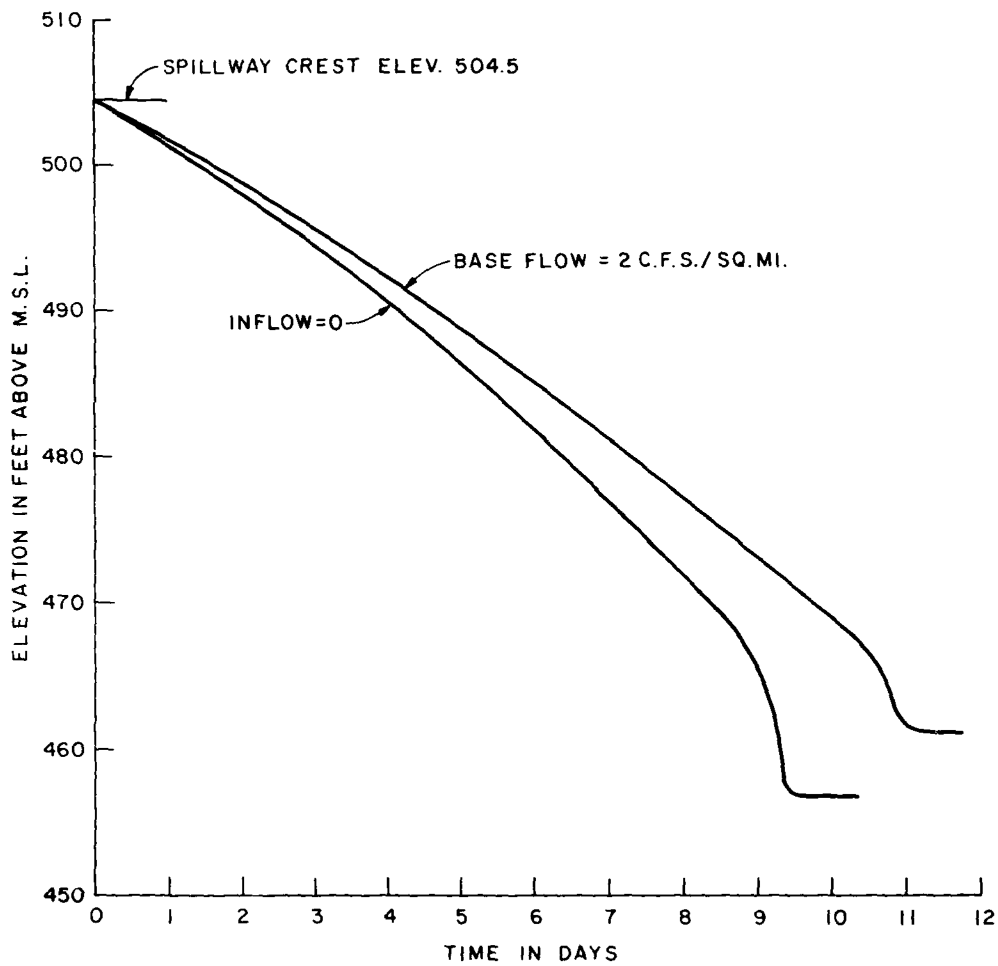


ONONDAGA DAM, NEW YORK

HYDROGRAPH OF
SPILLWAY DESIGN FLOOD

U S ARMY ENGINEER DISTRICT BUFFALO
TO ACCOMPANY STABILITY ANALYSIS
DATED

FIGURE 8



ONONDAGA DAM, NEW YORK

DRAWDOWN CURVES

U S ARMY ENGINEER DISTRICT BUFFALO
TO ACCOMPANY STABILITY ANALYSIS
DATED

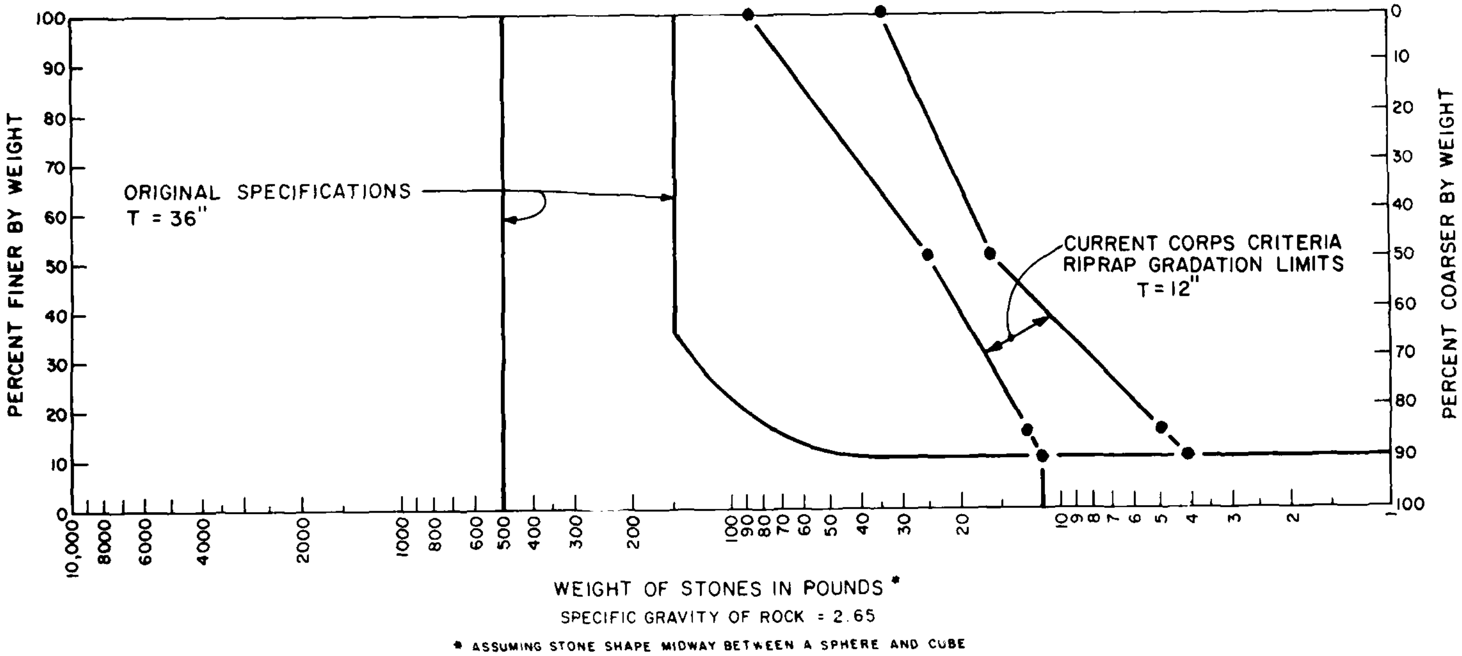
FIGURE 9

Figure 10 - Riprap Disintegration

Figure 11 - Riprap Delamination

Figure 12 - Riprap Size Reduction

Figure 13 - Riprap Size Reduction



ORIGINAL SPECIFICATIONS	
SIZE (lb)	% FINER
500	100
150	0 – 35
35	0 – 10

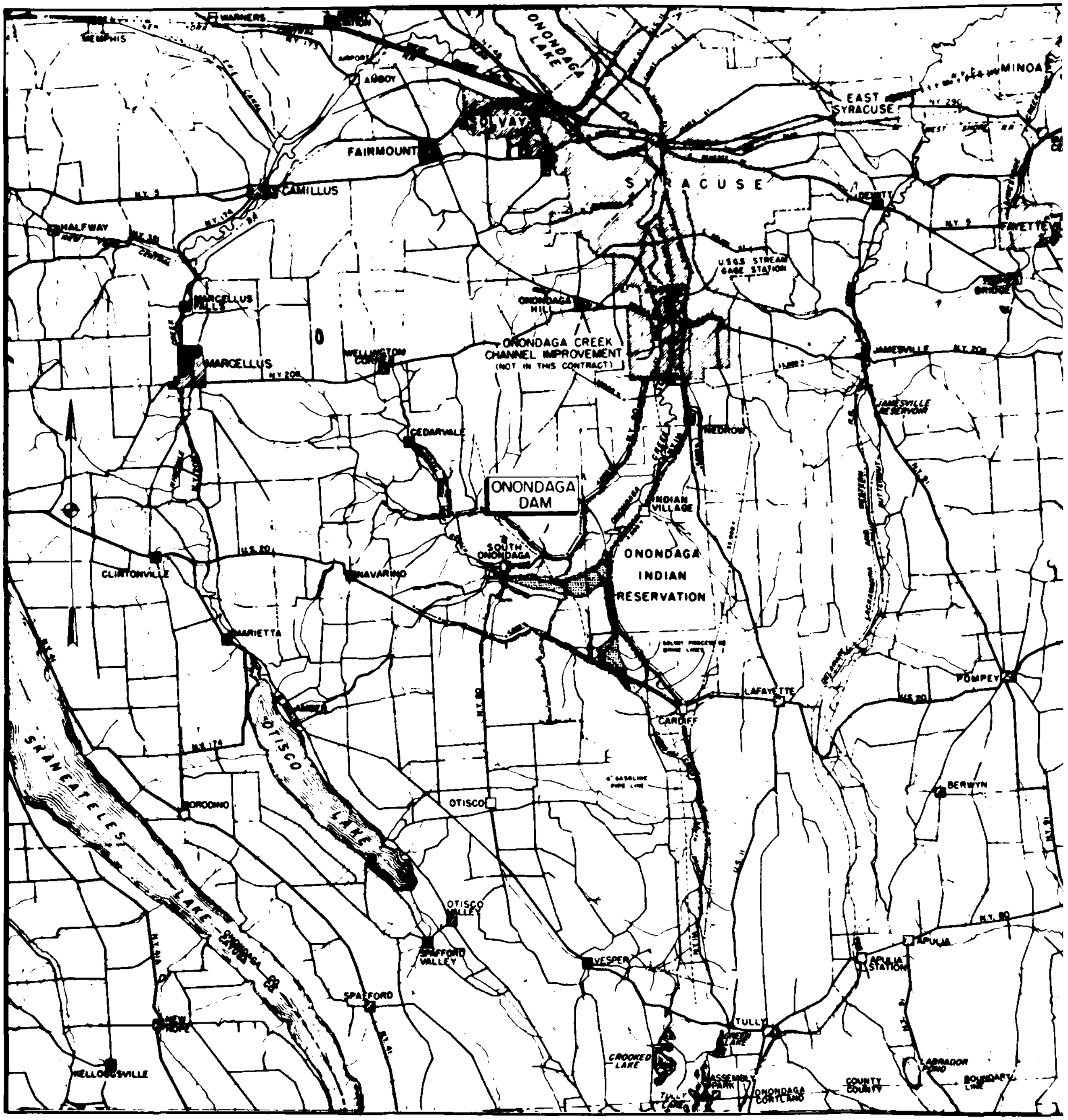
CURRENT CRITERIA	
PERCENT LIGHTER BY WEIGHT	LIMITS OF STONE WEIGHT (lbs)
100	86-35
50	26-17
15	13-5
10	12-4

ONONDAGA DAM, NEW YORK

RIPRAP GRADATION CURVES

U S ARMY ENGINEER DISTRICT BUFFALO
TO ACCOMPANY STABILITY ANALYSIS
DATED

FIGURE 14

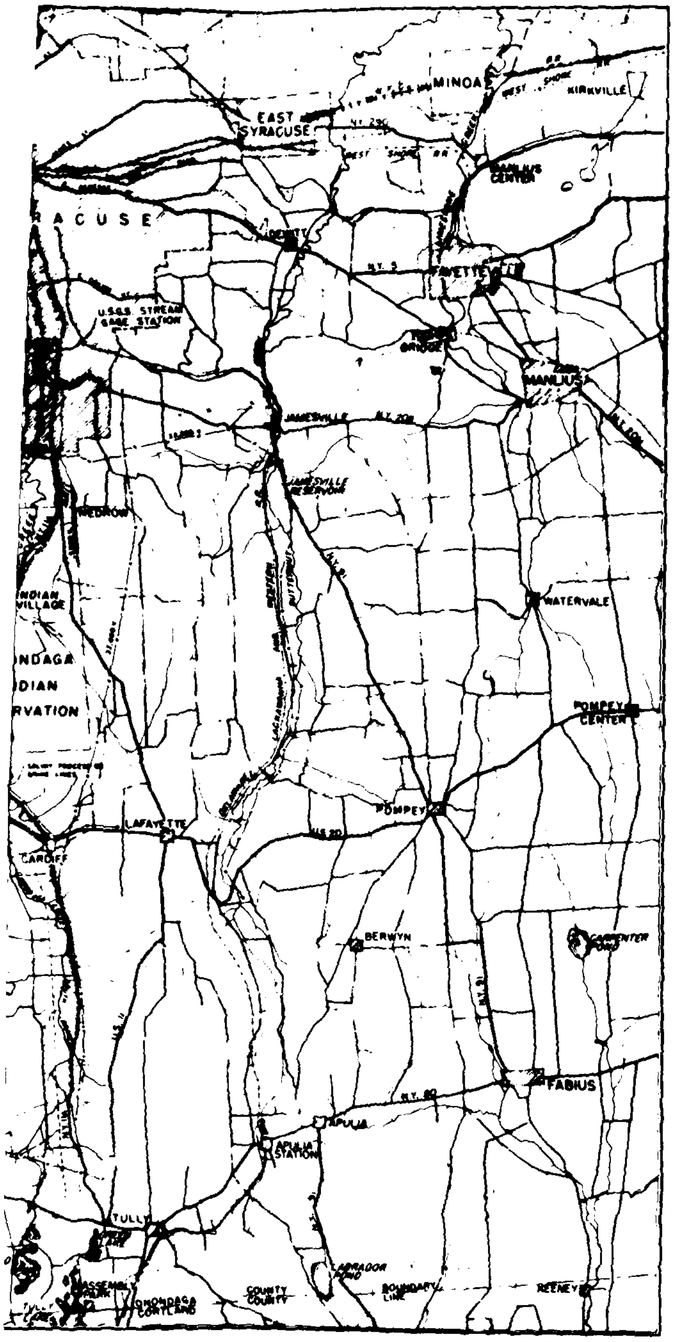


LOCATION MAP

SCALE

0 1 2 MI

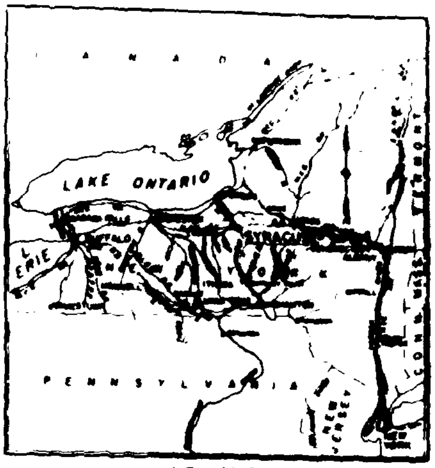
HIGHWAYS
RAILROADS
ELECTRIC POW
TELEPHONE L
RESERVOIR AT
CREST ELEV



MAP

LEGEND

HIGHWAYS
RAILROADS
ELECTRIC POWER LINES
TELEPHONE LINES
RESERVOIR AT SPILLWAY CREST ELEVATION



KEY MAP

SCALE

REF: DESIGN ANALYSIS
FOR ONONDAGA
RESERVOIR (1945)

ONONDAGA DAM NEW YORK

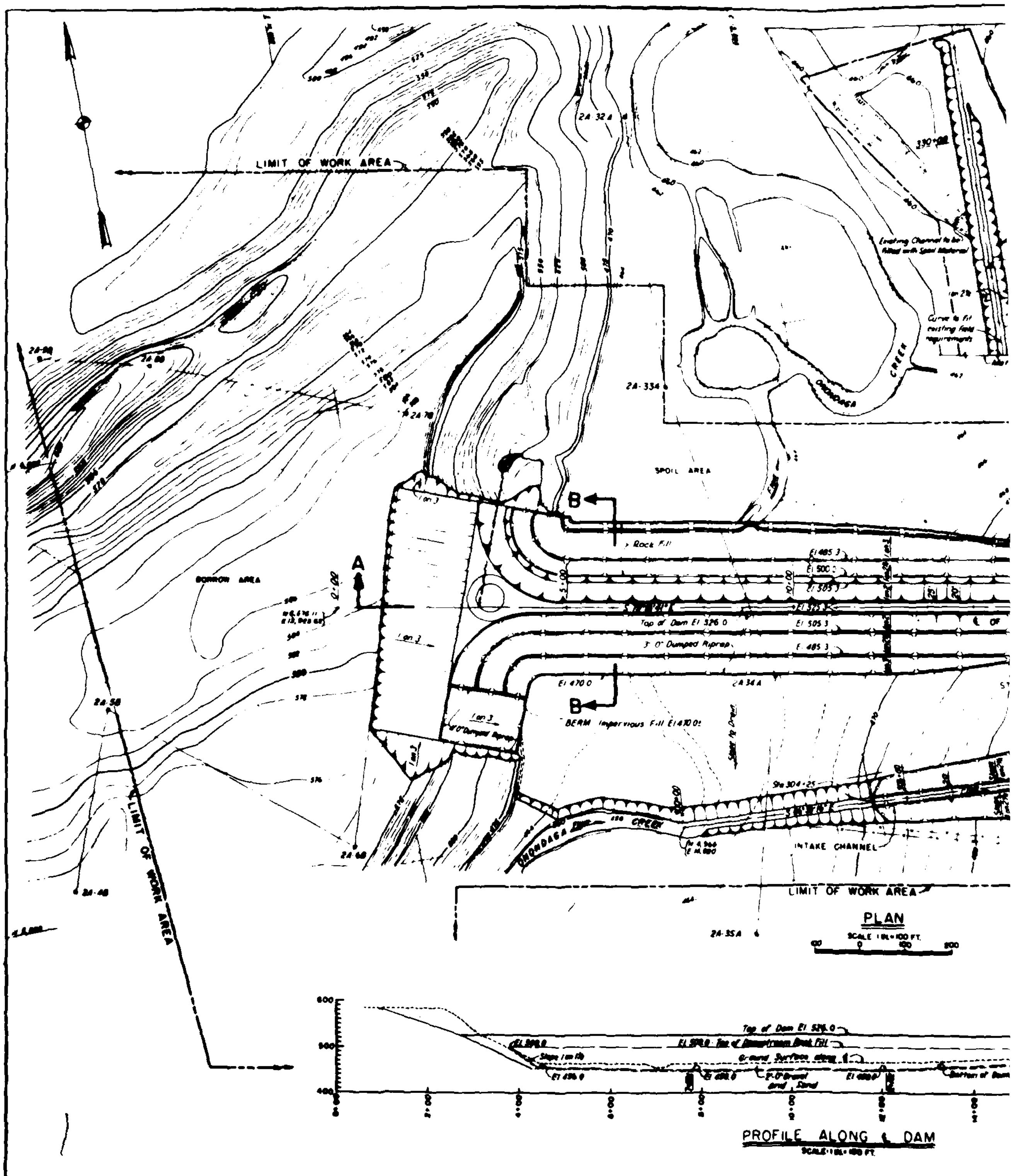
PROJECT LOCATION

US ARMY ENGINEER DISTRICT BUFFALO

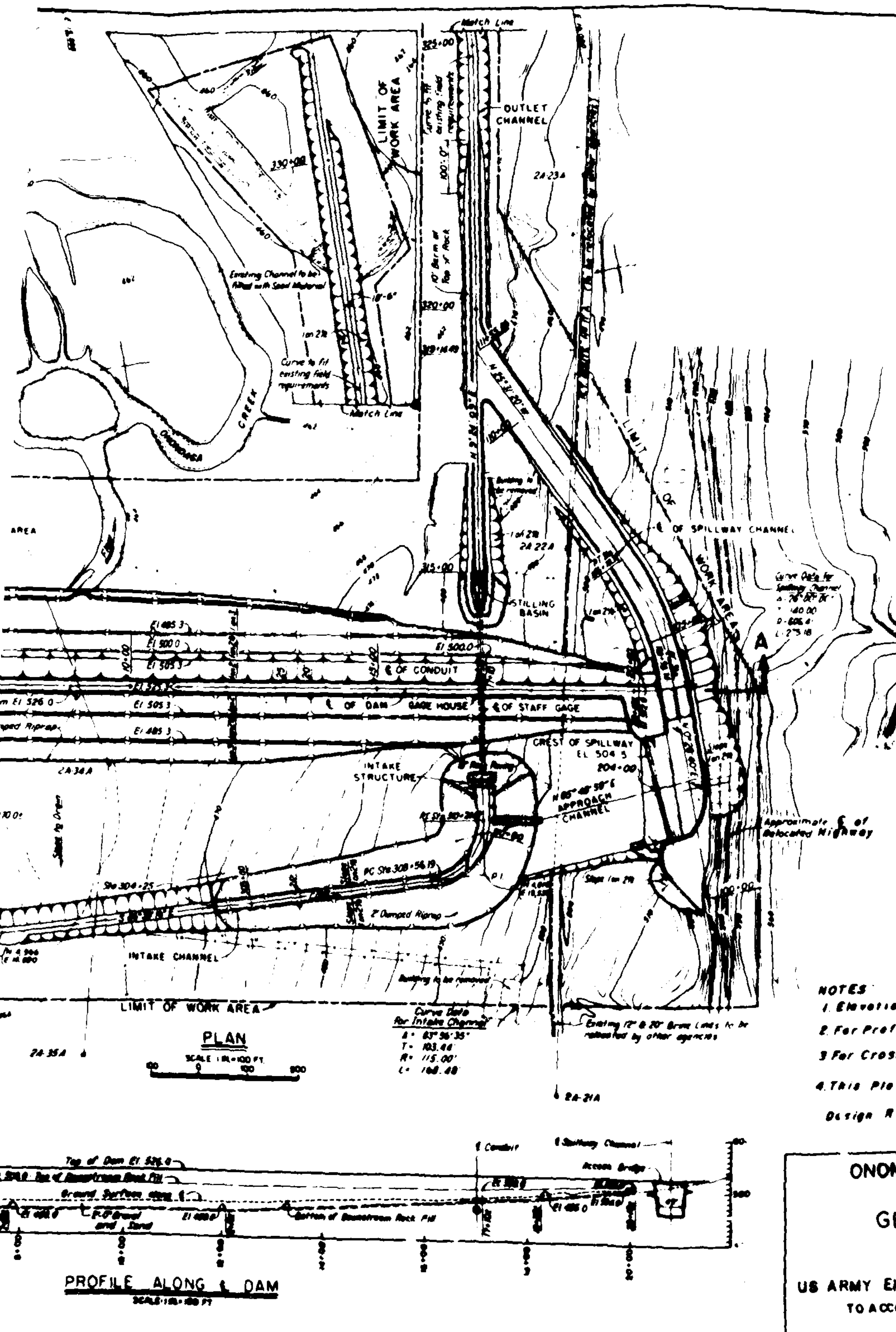
TO ACCOMPANY STABILITY ANALYSIS

DATED: MAY 1986

PLATE I



LIMIT OF WORK AREA
SPOIL AREA
BORROW AREA
Rock Fill
Top of Dam El 526.0
3' 0" Dumped Riprap
BERM Impervious Fill El 470.0
INTAKE CHANNEL
LIMIT OF WORK AREA
PLAN
PROFILE ALONG ℄ DAM



NOTES

1. Elevations refer to mean sea level datum.
2. For Profile A-A see Plate 7.
3. For Cross Section B-B see Plate 8.
4. This Plate obtained from original Design Report 1947.

ONONDAGA DAM, NEW YORK

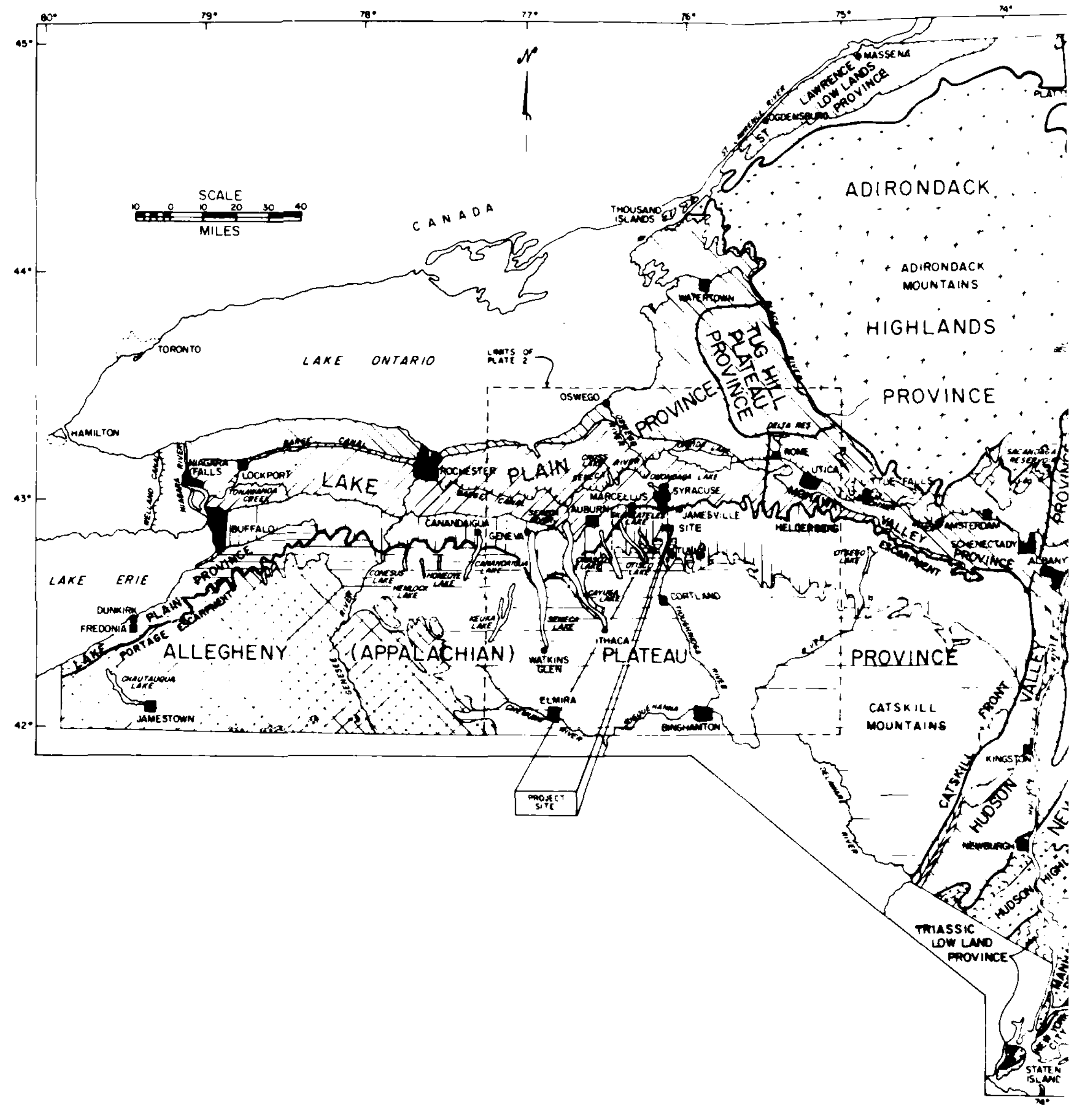
GENERAL PLAN

US ARMY ENGINEER DISTRICT BUFFALO

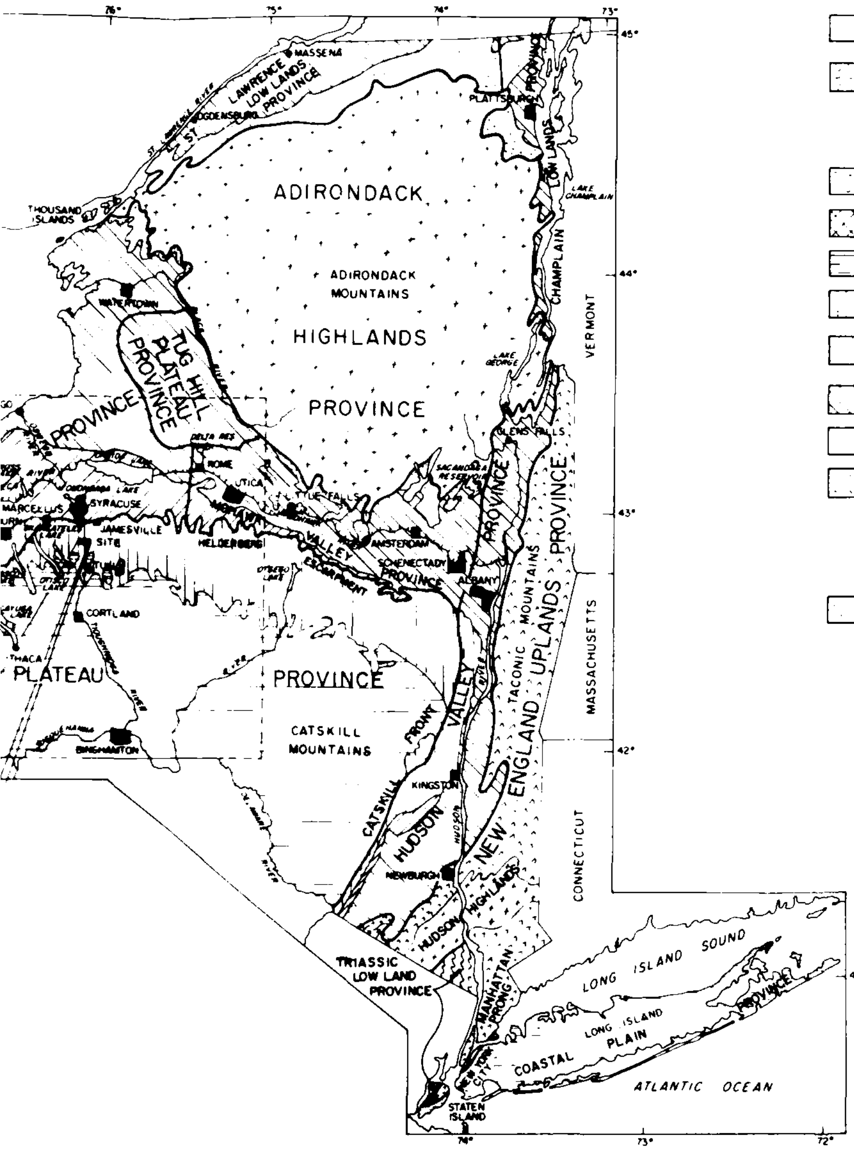
TO ACCOMPANY STABILITY ANALYSIS

DATED MAY 1986

PLATE 2



SCALE
MILES
CANADA
LAKE ONTARIO
LAKE ERIE
TORONTO
HAMILTON
ADIRONDACK
ADIRONDACK MOUNTAINS
HIGHLANDS
PROVINCE
TUG HILL PLATEAU PROVINCE
LAKE PLAIN PROVINCE
ALLEGHENY (APPALACHIAN) PLATEAU PROVINCE
CATSKILL MOUNTAINS
TRIASSIC LOW LAND PROVINCE
PROJECT SITE
JAMESVILLE SITE
OSWEGO
ROCHESTER
BUFFALO
NIAGARA FALLS
LOCKPORT
SYRACUSE
UTICA
ROME
ELMIRA
BINGHAMTON
ITHACA
CORTLAND
AUBURN
GENEVA
CANANDAIGUA
WATKINS GLEN
DUNKIRK
FREDONIA
JAMESTOWN
WATERTOWN
THOUSAND ISLANDS
OGDENSBURG
MASSENA
AMSTERDAM
SCHENECTADY
ALBANY
KINGSTON
NEWBURGH
STATEN ISLAND
MARCELLUS
HELDERBERG



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 APPROXIMATF
2. PLATE FROM ONONDAGA DAM SEISMIC STABILITY INVESTIGATION DATED NOV. 1982

ONONDAGA DAM, NEW YORK

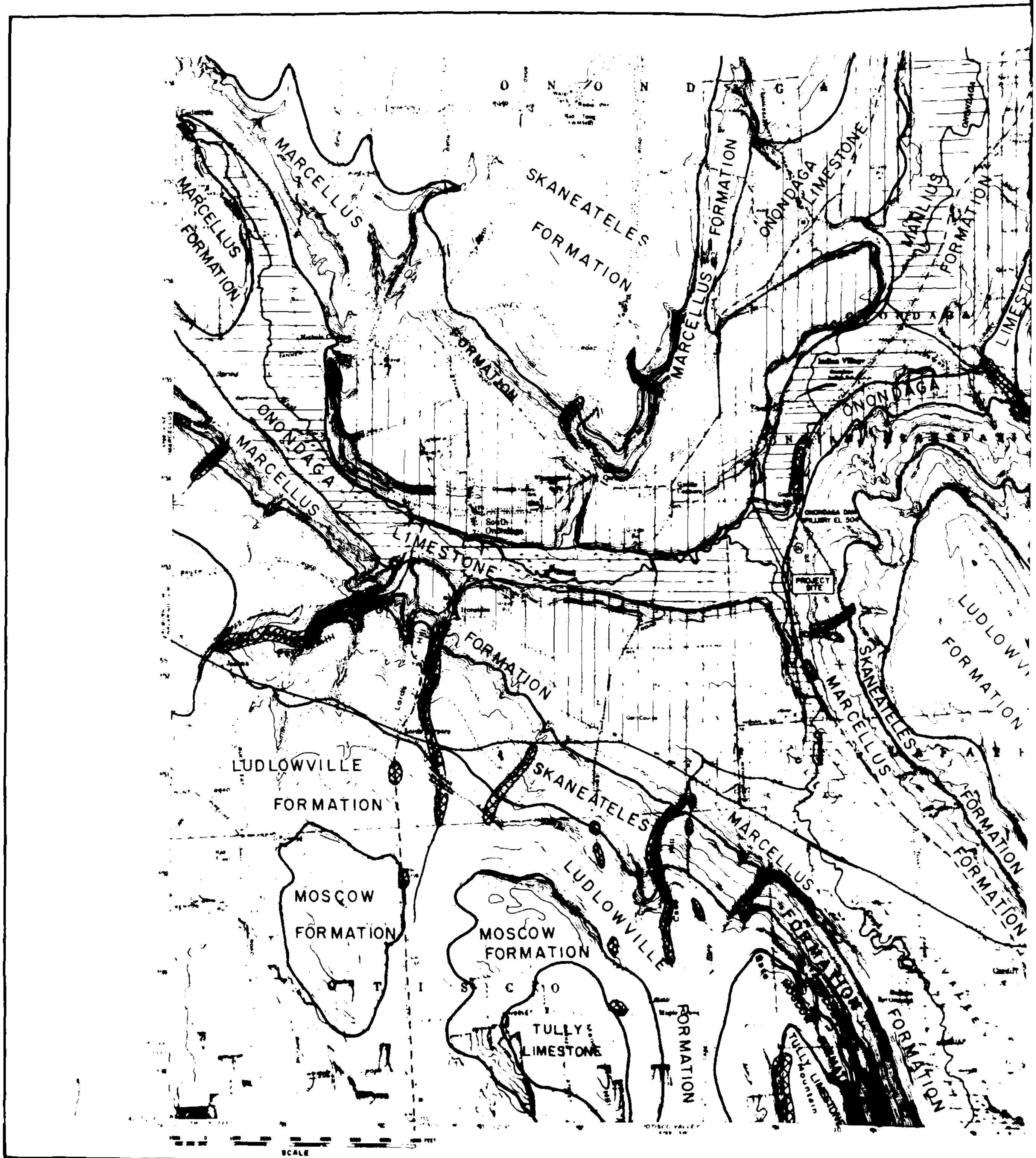
PHYSIOGRAPHIC PROVINCES AND GENERAL BEDROCK GEOLOGY OF NEW YORK STATE

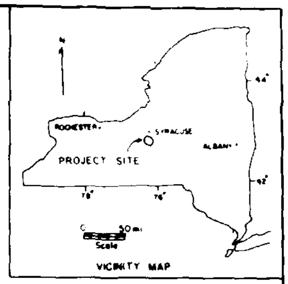
US ARMY ENGINEER DISTRICT BUFFALO

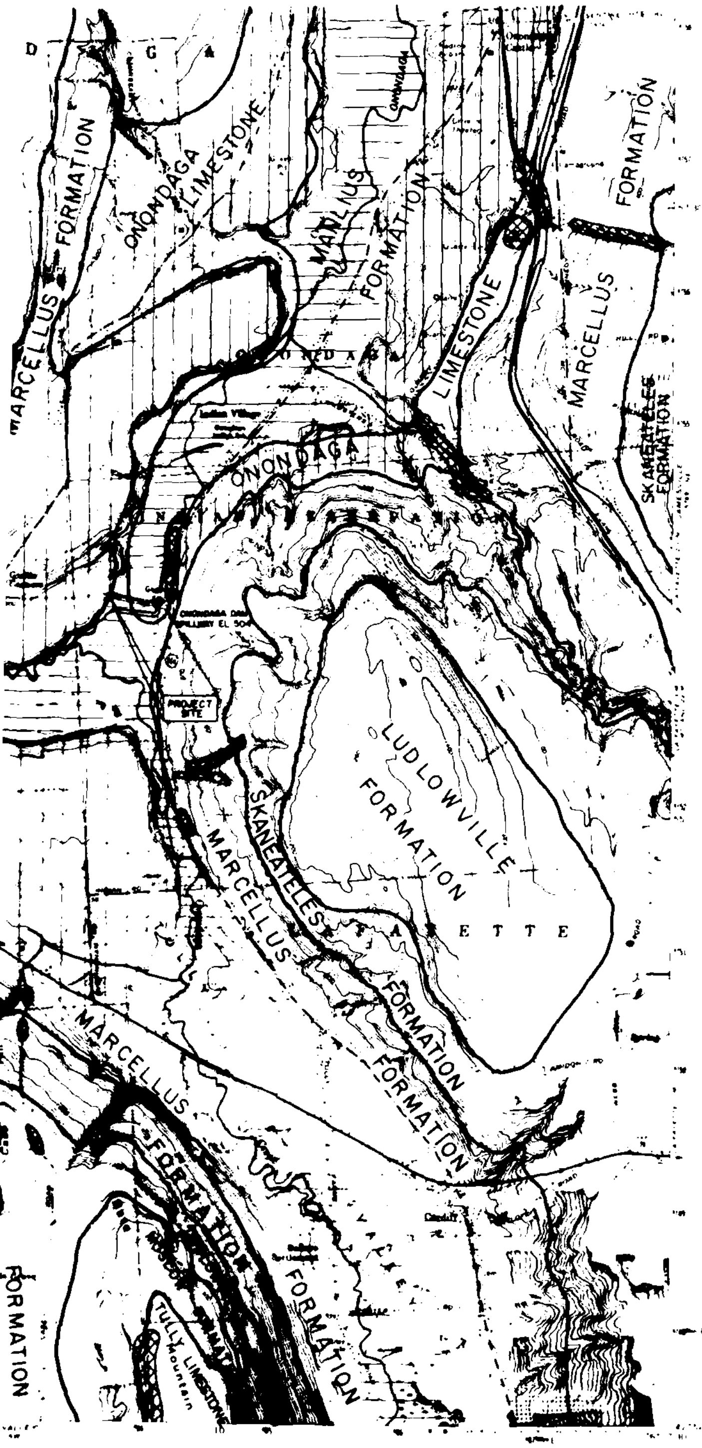
TO ACCOMPANY STABILITY ANALYSIS

DATED. MAY 1986

PLATE 3


O N O N D A G A
MARCELLUS FORMATION
MARCELLUS FORMATION
SKANEATELES FORMATION
MARCELLUS FORMATION
ONONDAGA LIMESTONE
MANLIUS FORMATION
LIMESTONE
ONONDAGA MARCELLUS
ONONDAGA LIMESTONE FORMATION
ONONDAGA
PROJECT SITE
LUDLOWVILLE FORMATION
SKANEATELES FORMATION
MARCELLUS FORMATION
FORMATION
LUDLOWVILLE FORMATION
SKANEATELES
MARCELLUS FORMATION
LUDLOWVILLE FORMATION
MOSCOW FORMATION
MOSCOW FORMATION
T I S C O
TULLY LIMESTONE
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. 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
2. 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
3. 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
4. THE TOPS AND SIDES OF HILLS ARE GENERALLY BEDROCK OVERLAIN BY A MANTLE OF GLACIAL TILL
5. BASE MAP OBTAINED FROM USGS QUADRANGLE SOUTH ONONDAGA NEW YORK
6. PLATE FROM ONONDAGA DAM SEISMIC STABILITY INVESTIGATION DATED NOVEMBER 1982.

ONONDAGA DAM, NEW YORK

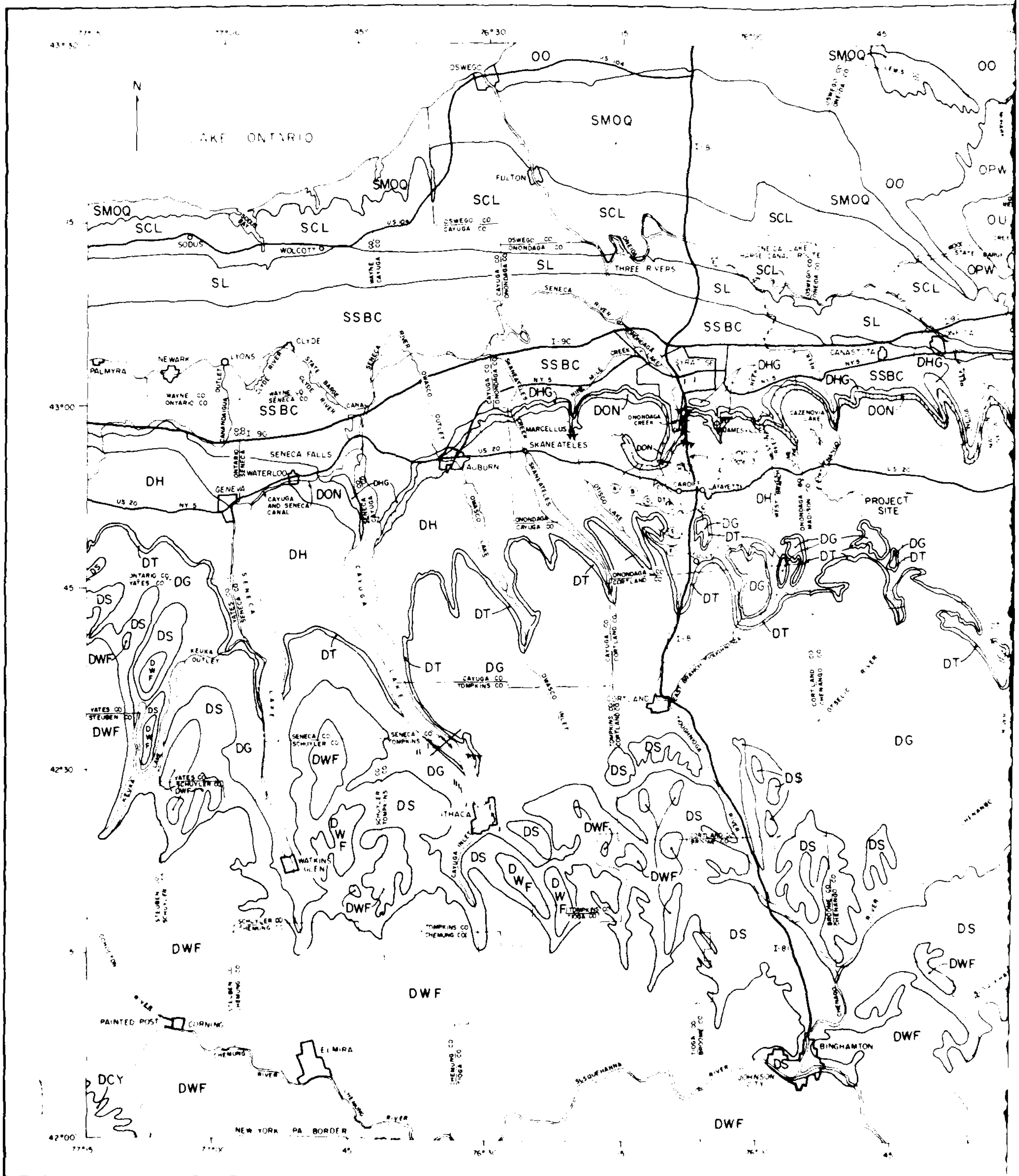
SITE GEOLOGIC MAP

US ARMY ENGINEER DISTRICT BUFFALO

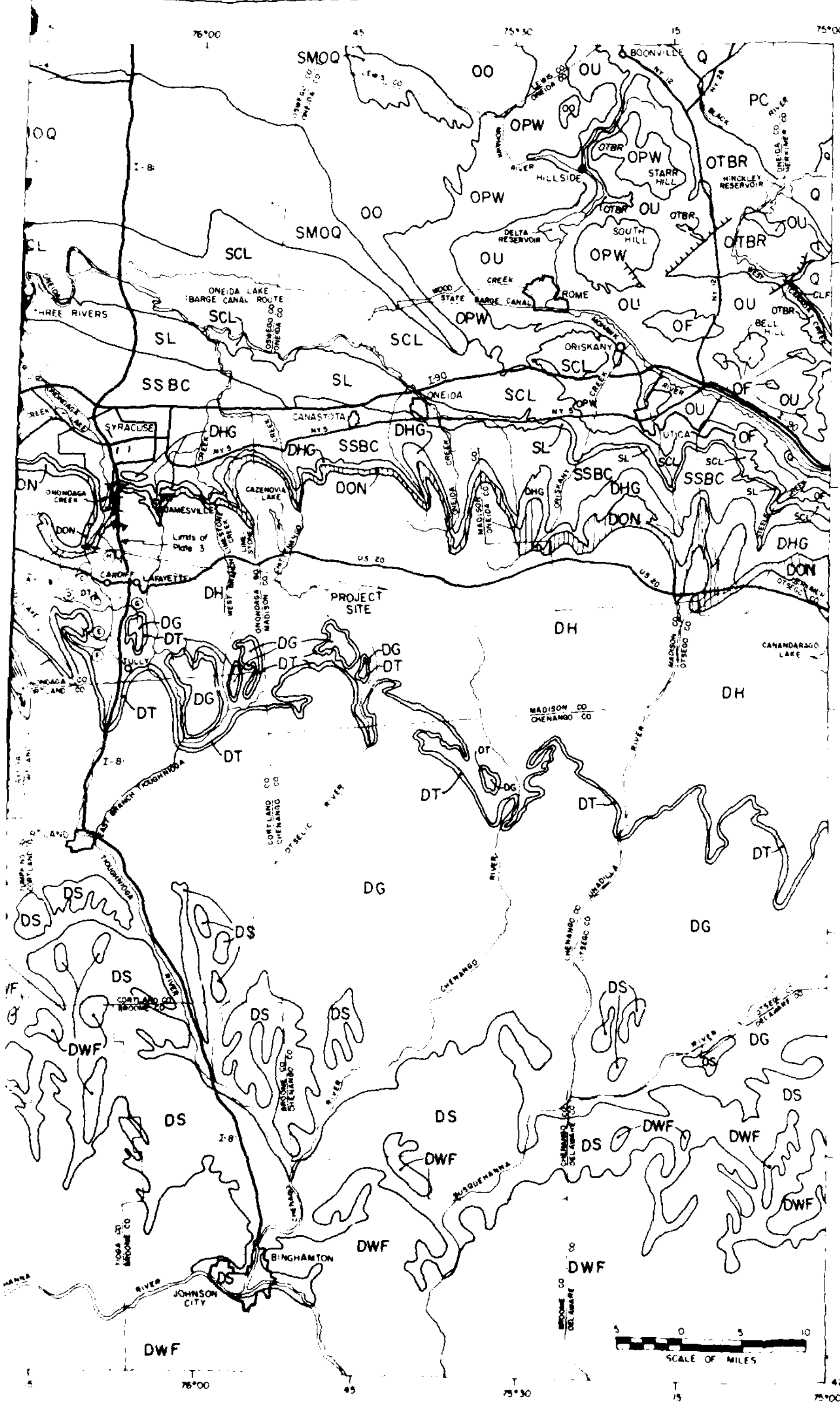
TO ACCOMPANY STABILITY ANALYSIS

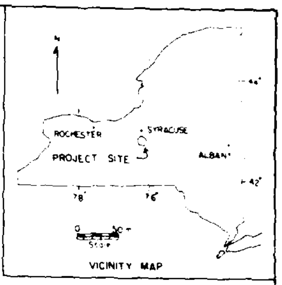
DATED: MAY 1986

PLATE 4



N
LAKE ONTARIO
OO
SMOQ
SCL
SL
SSBC
DHG
DON
DH
DT
DG
DS
DWF
DCY
OPW
OSWEGO
FULTON
SODUS
WOLCOTT
THREE RIVERS
PALMYRA
NEWARK
LYONS
CLYDE
SENECA FALLS
WATERLOO
GENEVA
AUBURN
SKANEATELES
MARCELLUS
PROJECT SITE
CORTLAND
ITHACA
WATKINS GLEN
PAINTED POST
CORNING
ELMIRA
BINGHAMTON
JOHNSON CITY
NEW YORK PA BORDER





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
PRECAMBRIAN	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. PLATE FROM ONONDAGA DAM SEISMIC STABILITY INVESTIGATION DATED NOV. 1982.

ONONDAGA DAM, NEW YORK

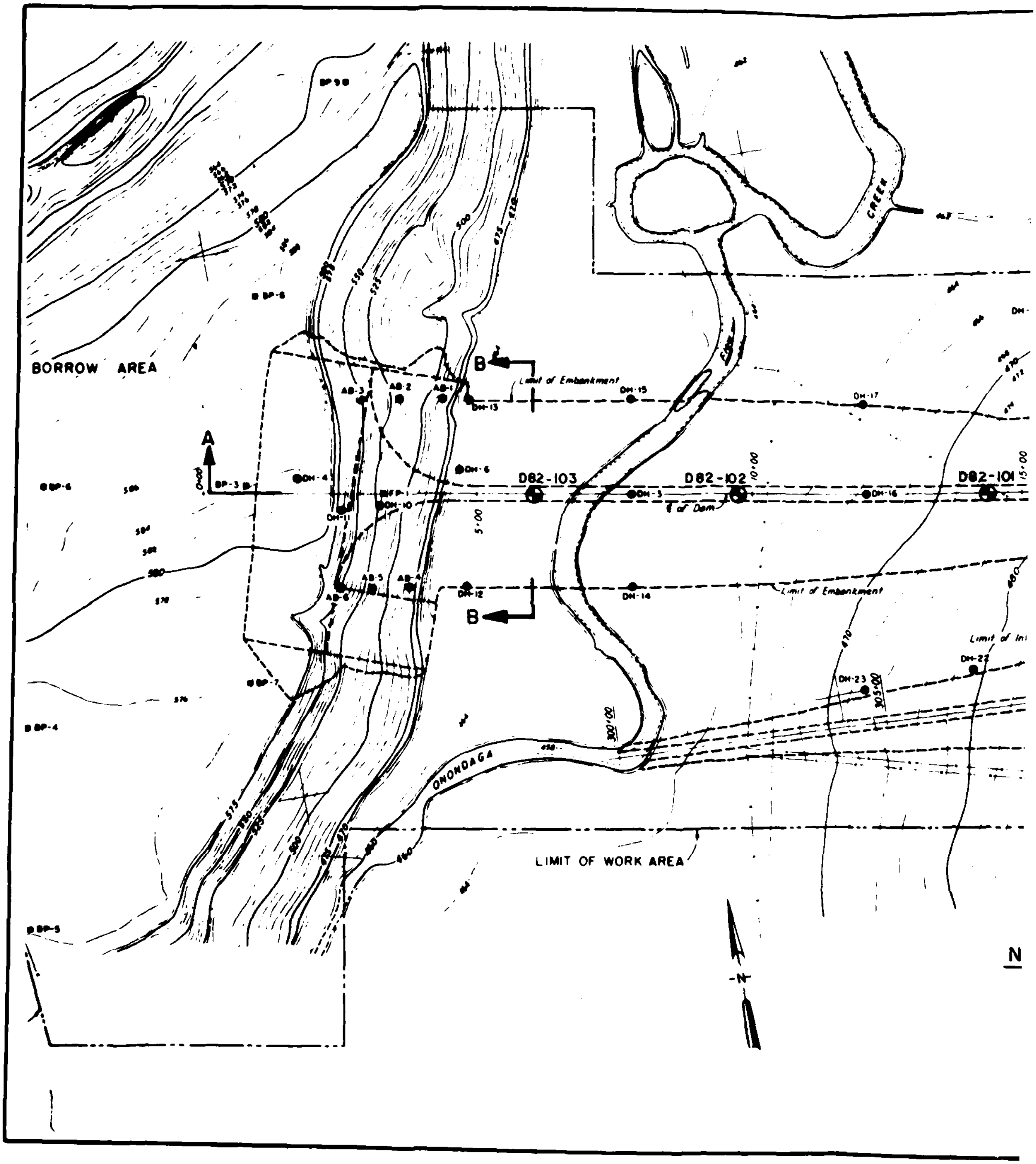
GEOLOGIC MAP OF CENTRAL NEW YORK STATE

U.S. ARMY ENGINEER DISTRICT BUFFALO

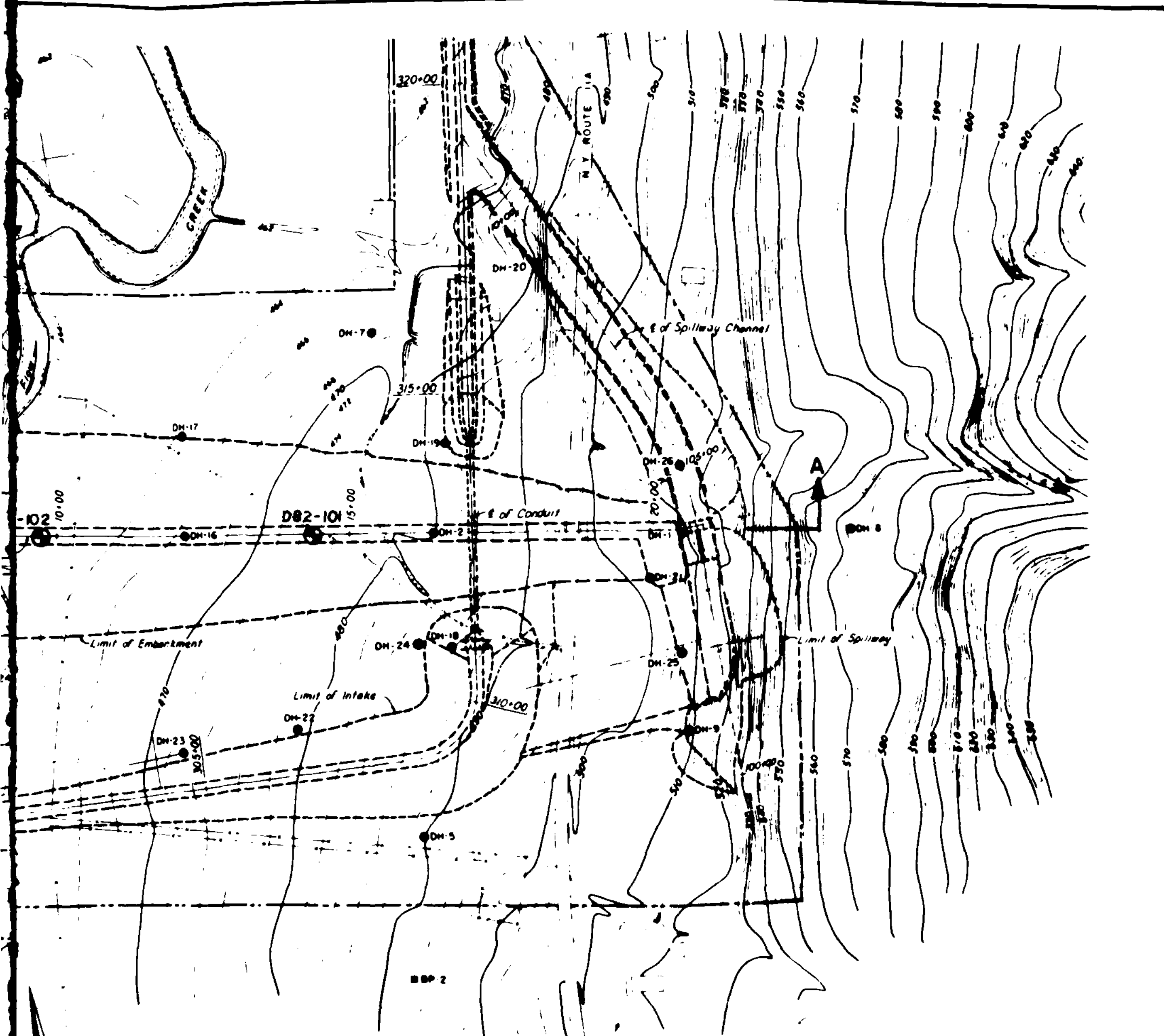
TO ACCOMPANY STABILITY ANALYSIS

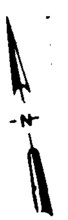
DATED: MAY 1986

PLATE 5



BORROW AREA
A
B
Limit of Embankment
AB-3
AB-2
AB-1
DH-13
DH-15
DH-17
DH-4
DH-6
D82-103
D82-102
D82-101
DH-3
DH-16
DH-11
DH-10
℄ of Dam
AB-5
AB-4
AB-6
DH-12
DH-14
Limit of Embankment
DH-23
DH-22
ONONDAGA
CREEK
LIMIT OF WORK AREA
BP-6
BP-3
BP-7
BP-4
BP-5
BP-8
BP-9
N





NOTES:

1. PLATE FROM ONONDAGA DAM SEISMIC STABILITY INVESTIGATION DATED NOVEMBER 1982.
2. FOR PROFILE A-A SEE PLATE 7.
3. FOR CROSS SECTION B-B SEE PLATE 8.

ONONDAGA DAM, NEW YORK

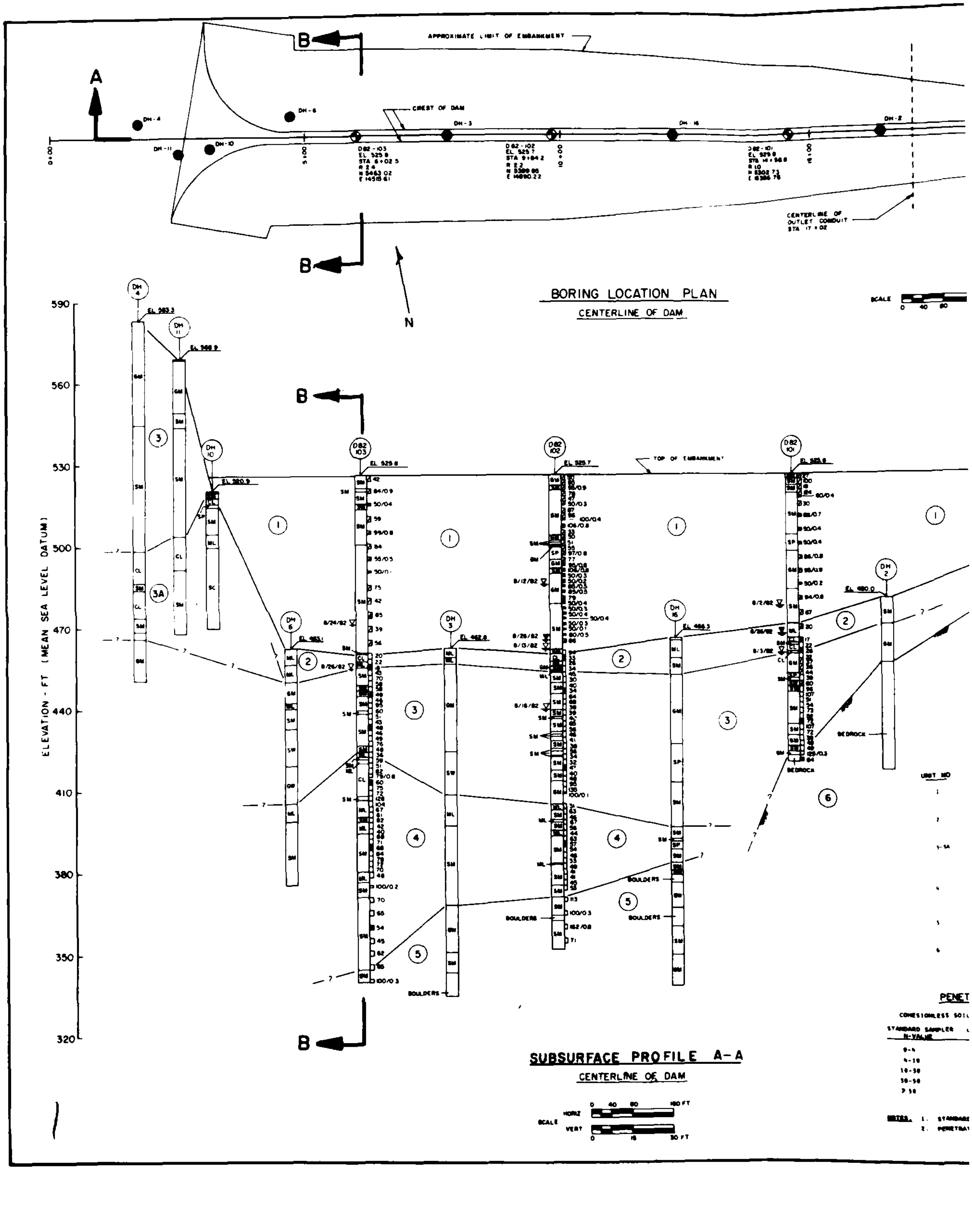
SITE AND SUBSURFACE EXPLORATION PLAN

U.S. ARMY ENGINEER DISTRICT BUFFALO

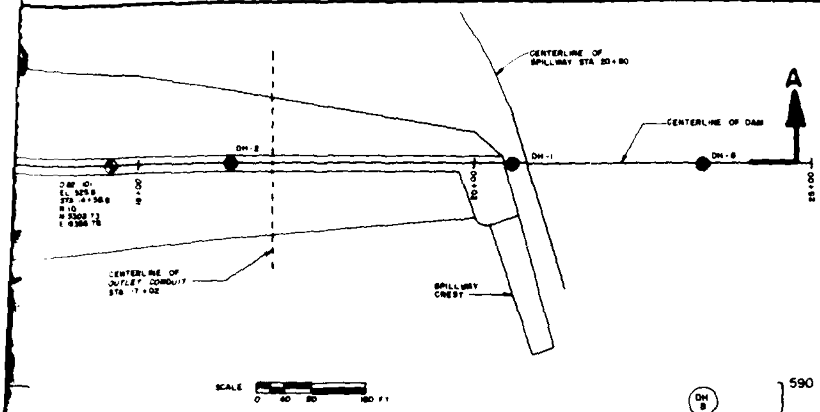
TO ACCOMPANY STABILITY ANALYSIS

DATED: MAY 1986

PLATE 6



APPROXIMATE LIMIT OF EMBANKMENT
CREST OF DAM
DH-4
DH-6
DH-11
DH-10
DH-3
DH-16
DH-2
CENTERLINE OF OUTLET CONDUIT STA 17+02
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
SUBSURFACE PROFILE A-A
CENTERLINE OF DAM
SCALE
HORIZ
VERT
0 40 80 160 FT
0 15 30 FT



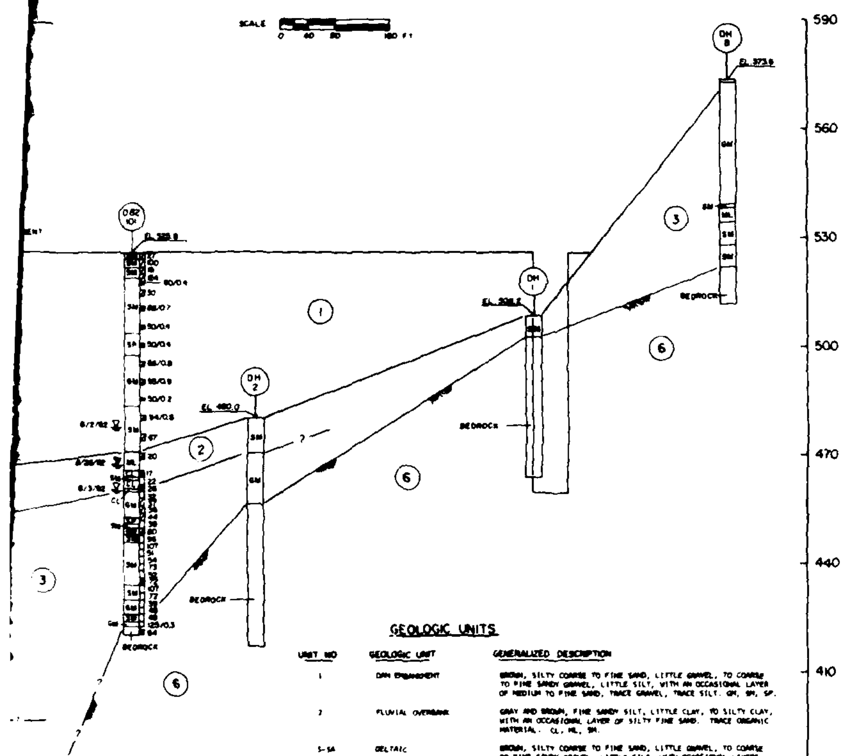
LEGEND: SUBSURFACE EXPLORATION PLAN

D82-102 EL 525.7 STA 9+84.2 R 22 N 538985 E 14890 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 1945 DESIGN PHASE TEST BORING

NOTES:

1. TEST BORING NOS D82-101 THROUGH D82-103 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, NY" 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
8. FOR CROSS SECTION B-B SEE PLATE 8
9. PLATE FROM ONONDAGA DAM SEISMIC STABILITY INVESTIGATION DATED NOVEMBER 1982.



LEGEND: SUBSURFACE PROFILE

SUBSURFACE EXPLORATION NUMBER

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 350 LB HAMMER FALLING FREELY FOR 18 IN TO DRIVE THE SAMPLER 1.0 FT

ML — UNIFIED SOIL CLASSIFICATION SYSTEM SYMBOL (FIELD)

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

125/0.3 — 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

64 — LOCATION OF ROCK CORE RUN. NUMBER INDICATES THE PERCENT CORE RECOVERY

(ML) USCS SYMBOL BASED ON LAB TESTING

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, GW.
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.)

A-A

2

ONONDAGA DAM, NEW YORK

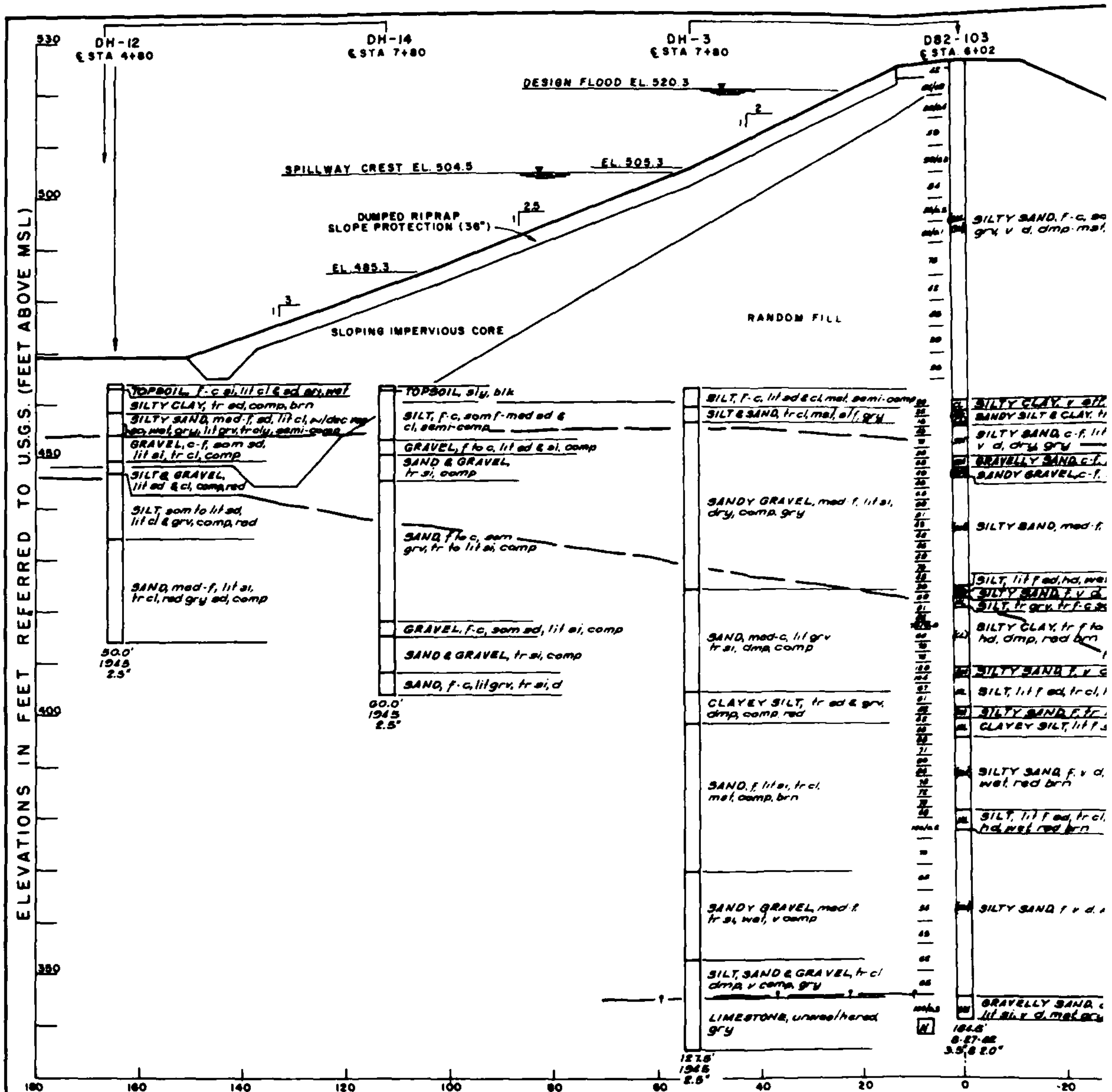
BORING LOCATION PLAN AND SUBSURFACE PROFILE A-A

U.S. ARMY ENGINEER DISTRICT BUFFALO

TO ACCOMPANY STABILITY ANALYSIS

DATED: MAY 1986

PLATE 7



CROSS SECTION B-B RANGE

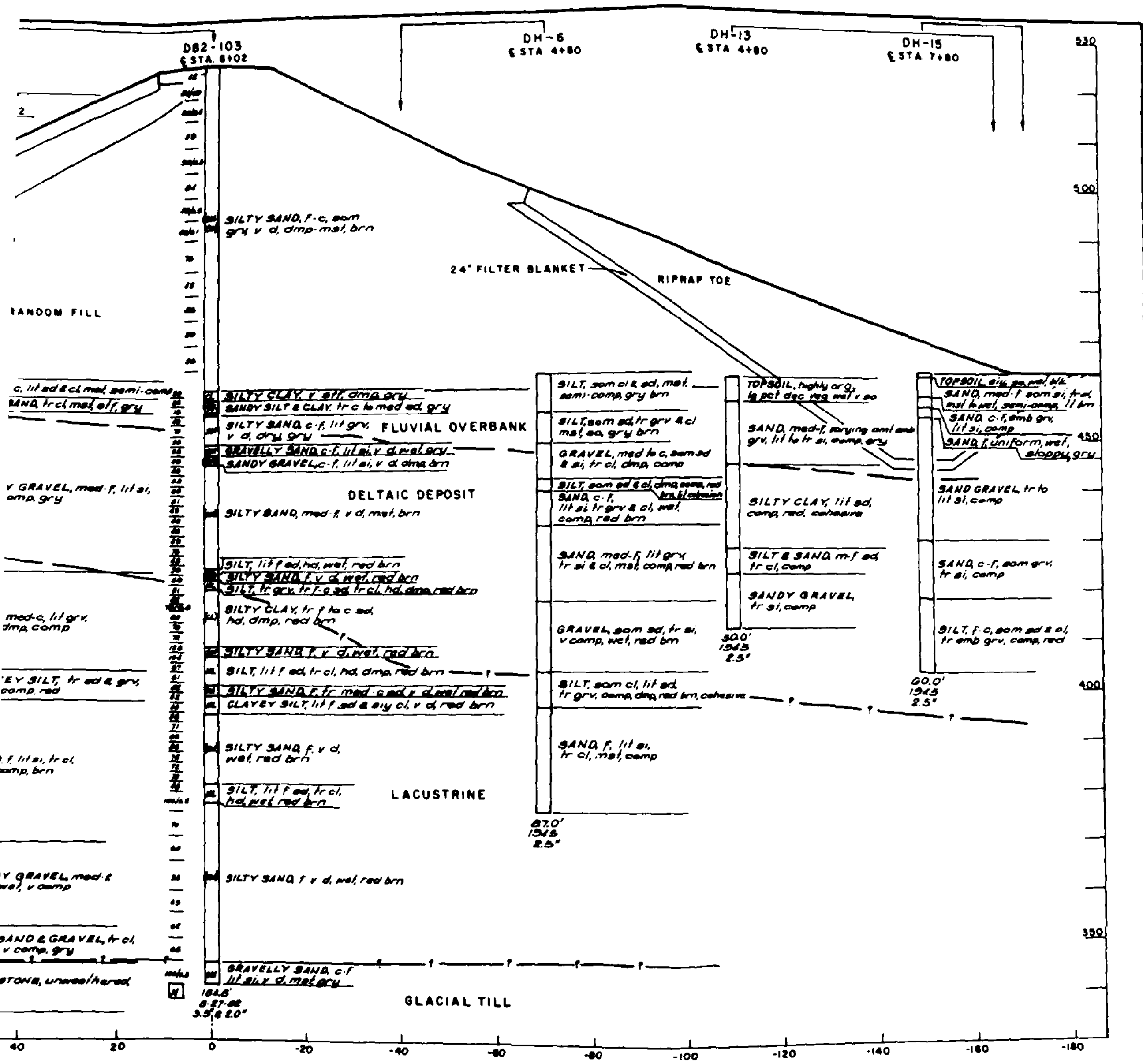
LEGEND (UNIFIED SOIL CLASSIFICATION SYSTEM)

- GW — Well graded gravels gravel sand mixtures, little or no fines.
- GP — Poorly graded gravels or gravel sand mixtures, little or no fines.
- GM — Silty gravels, gravel sand silt mixtures.
- GC — Clayey gravels, gravel sand clay mixtures.
- SW — Well graded sands, gravelly sands, little or no fines.
- SP — Poorly graded sands or gravelly sands, little or no fines.
- SM — Silty sands sand silt mixtures.
- SC — Clayey sands, sand clay mixtures.
- ML — Inorganic silts and very fine sands, rock flour, silty or clayey fine sands or clayey silts w/ slight plasticity
- CL — Inorganic clays of low to medium plasticity, gravelly clays, sandy clays, silty clays, lean clays
- OL — Organic silts and organic silty clays of low plasticity.
- MH — Inorganic silts, micaceous or diatomaceous fine sandy or silty soils, elastic silts.
- CH — Inorganic clays of high plasticity, fat clays.
- OH — Organic clays of medium to high plasticity, organic silts.
- Pt — Peat and other highly organic soils

For details on the Unified Soil Classification System, see Waterways Experiment Sta. Technical Memo. 3-357 dtd. March 1953 and revised in 1960.

ABBREVIATIONS

amt(s)	amount, amounts	lit	little
blk	black	lt	light
brn	brown	lg	large
c	course	med	medium
cl(y)	clay, clayey	mst	moist
comp	compact	org	organic
d	dense	pct	percentage
dec	decayed	sd (y)	sand, sandy
dk	dark	si (y)	silt, silty
dmp	damp	so	soft
		som	some
		stf	stiff
emb	embedded	tr	trace
f	fine	v	very
grv	gravel	veg	vegetation
gry	gray	w/	with
hd	hard		



CROSS SECTION B-B RANGE (FT)

NOTES:

1. For information on exploration notation, see Plate 7.
2. For plan of explorations see Plates 6 & 7.
3. Soil stratification lines are gradational and are interpolated from soil conditions revealed from previous explorations.
4. U.S.B.S. symbols in DB2-103 were assigned by geologist at the time of the boring and on later testing (see Plate 7).

ONONDAGA DAM, NEW YORK

EMBANKMENT ACROSS SECTION B-B
STATION 6+02

U.S. ARMY ENGINEER DISTRICT BUFFALO, N.Y.
TO ACCOMPANY STABILITY ANALYSIS
DATED: SEPTEMBER 1985

PLATE 8

ONONDAGA DAM, NY

PERTINENT DATA

APPENDIX A

STABILITY ANALYSIS

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

APPENDIX A

PERTINENT DATA

ONONDAGA DAM AND RESERVOIR

A1. GENERAL

Purpose - Flood Control

Drainage area above dam - 68.1 sq. mi.

Drainage area, U.S.G.S. gage (Dorwin Ave.) - 88.9 sq. mi.

Drainage area, mouth of Onondaga Creek - 108.9 sq. mi.

A2. DAM

Type - Rolled Earth

Length, feet - 1, 782

Maximum height, feet - 67

Top width, feet - 25

Top elevation, feet above mean sea level - 526

A3. SPILLWAY

Type - Uncontrolled ogee, side channel overflow

Crest length, feet - 200

Crest elevation, feet above mean sea level - 504.5

Surcharge, design flood, feet - 15.8

Capacity at 15.8 feet surcharge - 48,500 cfs

A4. OUTLET

Type - Uncontrolled circular conduit

Number - One

Diameter, feet - 6.5

Length, feet - 329

Location - Under east (right) section of dam

A4. OUTLET (Cont'd)

Invert elevation at intake, feet - 457.0

Invert elevation at outlet, feet - 456.21

Discharge, pool at spillway crest elevation, cfs - 1,270

Minimum time required to empty reservoir from spillway crest elevation, no inflow - with assumed base flow of 2 cfs/sq. mile - 11 days

A5. RESERVOIR

Area, spillway crest elevation (504.5) - 910 acres

Capacity spillway crest elevation (504.5) - 18,200 acre feet

Area, 15.8 feet surcharge - 1,640 acres

Capacity 15.8 feet surcharge - 38,200 acres feet

ONONDAGA DAM, NY

SELECTION OF ANALYSIS

SOIL PARAMETERS

APPENDIX B

STABILITY ANALYSIS

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

APPENDIX B

SELECTION OF ANALYSIS

SOIL PARAMETERS

B1. GENERAL

The parameters used in this stability analysis were based on the test data from the original 1945 Design Analysis (Reference 5) and a subsurface exploration program conducted for the seismic stability analysis done in 1982 (Reference 7). These two programs are discussed in more detail in subsequent paragraphs.

B2. 1945 DESIGN ANALYSIS EXPLORATION PROGRAM

The original design analysis exploration program was carried out in 1944 and 1945. It consisted primarily of 2-1/2-inch diameter holes and test pits at the dam site and at potential borrow areas. The boring log descriptions for holes in the vicinity of the analysis cross section are on Plate 3. The testing program consisted of classification, density, consolidation, direct shear, triaxial shear, permeability and compaction. The results of these tests are at Figures B1 thru B11 and they are summarized in Tables B1 through B3. The direct shear and triaxial tests were consolidated undrained tests (R tests). There is no consolidated drained (S) test data or unconsolidated undrained (Q) test data available for the analysis. Therefore, all strengths used in the analysis are R strengths. In those materials where cohesion was present, it was ignored. This was done to be conservative where cases required a composite strength of envelope (R and S) See Figures B12 and B13.

B3. 1982 EXPLORATION PROGRAM

In 1982, an exploration program was conducted to determine the seismic stability of the dam. The program consisted of three test borings from the dam crest. These borings provide the most recent data available on the dam. The laboratory testing consisted of natural water contents, Atterberg Limits, and grain size distribution. The only information obtained in this program that is relatable to strength is the blow counts (standard penetration test - SPT). The SPT data and boring descriptions are at Plate 7.

B4. DESCRIPTION OF SOILS AND PARAMETER SELECTION

B4.1 Riprap.

The rock used in the slope protection and toe was excavated from the spillway channel. A specific gravity of 2.65 (limestone) an angle of internal friction of 40°, and an average porosity for dumped riprap of 36 percent was assumed (Reference 12). This yields a unit weight of 105 pcf for this riprap.

B4.2 Filter Material.

The filter material was ignored in this analysis due to its similarity to the embankment material and its relatively small size.

B4.3 Impervious Material (Core).

The unit weight and internal angle of friction, 145 pcf and 34° respectively, were obtained from the original design anlaysis and are based on test results conducted on samples taken from borrow areas.

B4.4 Random Fill Embankment Materials.

The unit weight and angle of internal friction, 145 pcf and 36° respectively, were obtained from the original design analysis. The value of ϕ appears to be on the conservative side based on the blow counts obtained for the 1982 exploration program. The blow counts indicate that the material is compact to very compact. According to Bowles (Ref. 8) this indicates an angle of internal friction betwen 38° and 43° and Hough (Ref. 10) indicates that for a compact sand and gravel mixture or coarse sand, the angle of internal friction could be as high as 45°.

B4.5 Fluvial Overbank.

The value of 23° for the angle of internal friction is an average value obtained from the original design analysis. The values in the analysis vary from 19.5° to 32° for the sandy and clayey silts. The unit weight of 105 pcf was the result of modifying the value in the analysis by lowering from 110 pcf to be on the conservative side.

B4.6 Deltaic Deposit.

The value of 35° was assigned based on a range of values obtained in the original design analysis (34-36°) and comparing them to typical values of ϕ based upon blow counts. The value of 35° is conservative. The unit weight of 119 also obtained from the original analysis values of 117-120 pcf.

B4.7 Lacustrine.

The values of 27° and 124 pcf were assigned based on the original analysis.

B4.8 Till.

No values were assigned. The glacial till was considered to be "firm base."

B5 SUMMARY

The values selected in each case are based on test values and blow count information and are considered to be conservative values.

TABLE B-1

PHYSICAL PROPERTIES OF FOUNDATION MATERIALS

Soil Classification	Direct Shear ø	Direct Shear c (t.s.f.)	Triax. Shear ø	Triax. Shear c (t.s.f.)	Coeff. of Perm. (cm./sec.x10^-4)	Unit Wt. (p.c.f.) Wet	Unit Wt. (p.c.f.) Dry
A. LEFT ABUTMENT							
Sandy GRAVEL	35° 15'	0.0	36° 30'	0.0	100-950 (450 Av.)	131	125
Uniform Medium SAND	32° 30'	0.0	36° 40'	0.0	1-10	135	108
Silty CLAY			15° 30'	0.35	0.0001	127	99
Silty SAND With embedded Gravel	*34° 00'	0.0			*1		
Silt-bound Sandy GRAVEL			*36° 00'	0.0	*15		
B. LEFT ABUTMENT SLOPE							
Silty, Sandy GRAVEL			*36° 00'	0.0			
Fine SAND	*32° 00'	0.0			**4.21 (Hor.) 2.36 (Vert.) 31.2 (Hor.) 128.3 (Vert.)	 116 106	 97 94
SAND & SILT	*30° 00'	0.0			**14.2 (Hor.) 2.42 (Vert.)	 118	 97
Sandy SILT	**30° 30'	0.0			** 2.91 (Hor.) 1.60 (Vert.)	 119	 96
Silty CLAY	**16° 40'	0.22	**16° 00'	0.20	** 0.0001	122	94

* Value assigned from tests on similar materials from the site

** Undisturbed samples

B-1

TABLE (CONTINUED)

PHYSICAL PROPERTIES OF FOUNDATION MATERIALS

Soil Classification	Direct Shear ø	Direct Shear C (t.s.f.)	Triax. Shear ø	Triax. Shear C (t.s.f.)	Coeff. of Perm. (cm./sec.x10-4)	Unit Wt. (p.c.f.) Wet	Unit Wt. (p.c.f.) Dry
C. VALLEY FLOOR							
Silty CLAY (At Surface)	19° 30'	0.0					
Silty CLAY (At Depth)	26° 00'	0.02					
Clayey SILT	**28° 10' 23° 10'	0.1 0.19				112	95
Sandy SILT	**32° 00'	0.05			0.001	110	78
Fine to Coarse SAND	31° 30'	0.0	37° 30'	0.0	3-75		
Fine to Coarse SAND with embedded Gravel	34° 10'	0.0			13-43		
Coarse SAND With embedded Gravel			38°-40°	0.0	200-900		
Silty GRAVEL			27°-31°	0.00	0.3-5		
Sandy GRAVEL			*36° 00'	0.00	15-200		
D. ALLUVIAL FAN							
Clayey Silt & SAND	**22°-28°	0.15			0.2	116	95
Silty, Sandy GRAVEL	33° 45'	0.0			1.0		
Sandy GRAVEL			36° 00'	0.00	25-70		117-120
E. RIGHT ABUTMENT							
Silty, Sandy GRAVEL			*36° 00'	0.00	1.0		

* Value assigned from tests on similar materials from the site

** Undisturbed samples

TABLE B-2

PHYSICAL PROPERTIES OF BORROW MATERIALS

Soil Classification	Direct Shear ø	Direct Shear C (t.s.f.)	Coeff. of Permeability (cm./sec.x10-4)	Compaction Max. (p.c.f.) (Dry Wt.)	Compaction Opt. W (Percent Dry Wt.)	Dry Unit Wt. (p.c.f.)
			A. LEFT ABUTMENT			
Sandy GRAVEL	36° 30'	0.0	100-950	130	9	124
			B. LEFT ABUTMENT SLOPE			
Silty Sandy GRAVEL	*36° 00'	0.0	*1.0	*127	10	
Uniform Fine SAND	*32° 00'	0.0	1-10			94-97
SAND & SILT	*30° 00'	0.0	*0.1			97
Silty CLAY	16° 00'	0.2	0.0001			94
			C. ALLUVIAL FAN			
Clayey SILT & SAND	22°-28°	0.15	0.2			95
Silty, Sandy GRAVEL	36° 00'	0.0	1.0	127	10	
Sandy GRAVEL	36° 00'	0.0	25-70	131	9	
			D. RIGHT ABUTMENT			
Silty, Sandy GRAVEL	36° 00'	0.0	1.0	127	10	

* Value assigned from tests on similar materials from the site

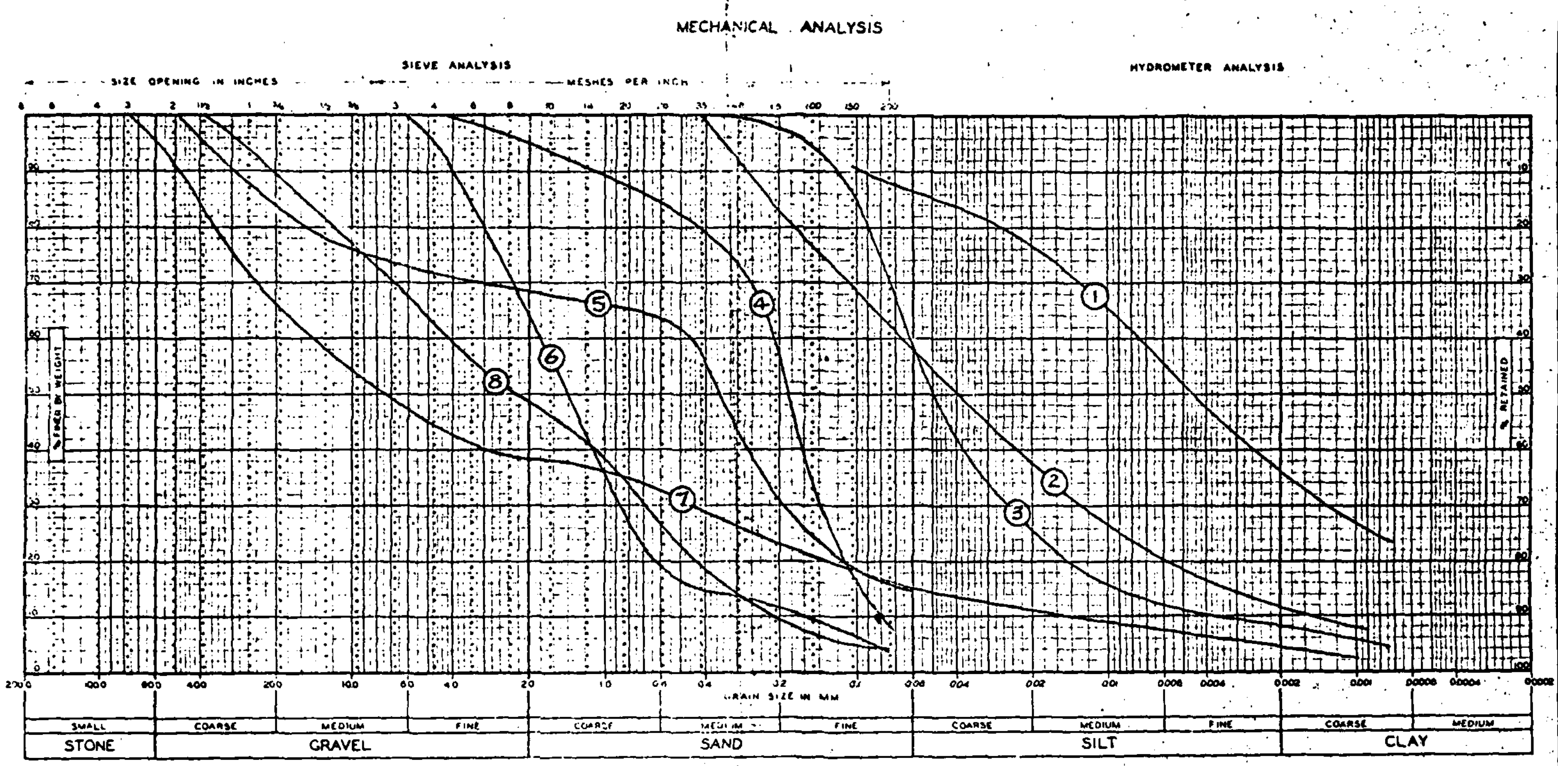
TABLE 8-3

PHYSICAL PROPERTIES USED IN DESIGN

Soil Classification	Shear ø		Shear c (t.s.f.)	Coeff. of Permeability (cm./sec.x10^{-4}) Hor.	Vert.	Unit Wt. (p.c.f.) Wet	Dry
A. PERVIOUS SECTION OF DAM EMBANKMENT							
Sandy GRAVEL	36°	00'	0.0	*900	300	145	140
B. IMPERVIOUS SECTION OF DAM EMBANKMENT							
Silty Sandy GRAVEL	34°	00'	0.0	*3.0	1.0	145	133
C. FOUNDATION							
Silty CLAY (at surface)	19°	30'	0.0				95
Silty CLAY (at depth)	26°	00'	0.02				*100
Clayey SILT	23°	00'	0.10				95
Sandy SILT	32°	00'	0.05	*0.003	0.001		78
Fine to Coarse SAND	36°	00'	9.0	*150	50		*100
Fine to Coarse SAND with embedded Gravel	36°	00'	0.0	*120	40		*100
Coarse SAND with embedded Gravel	38°	30'	0.0	*1500	500		*100
Silty GRAVEL	30°	00'	0.0	*15	5		*100
Sandy GRAVEL	36°	00'	0.0	*600	200		*100

* Value assumed

WAR DEPARTMENT — CORPS OF ENGINEERS



CURVE NUMBER	SAMPLE	HOLE	DEPTH	[illegible]	REMARKS
1	S. Bag 6	D.H. 13	20.0' - 22.0'	Silty CLAY	
2	S. Bag 3	D.H. 12	5.0' - 7.0'	Sandy Clayey SILT	
3	S. Bag 9	D.H. 13	35.0' - 37.0'	Do	
4	S. Bag 4	D.H. 13	10.0' - 12.0'	SAND	
5	S. Bag 2	D.H. 15	5.0' - 7.0'	SAND with embedded Gravel	
6	S. Bag 11	D.H. 13	48.0' - 50.0'	Coarse SAND with emb. Gravel	
7	S. Bag 3	D.H. 18	15.0' - 16.0'	Silty Sandy GRAVEL	
8	S. Bag 6	D.H. 15	25.0' - 27.0'	Sandy GRAVEL	

GRAIN SIZE
DISTRIBUTION CURVES

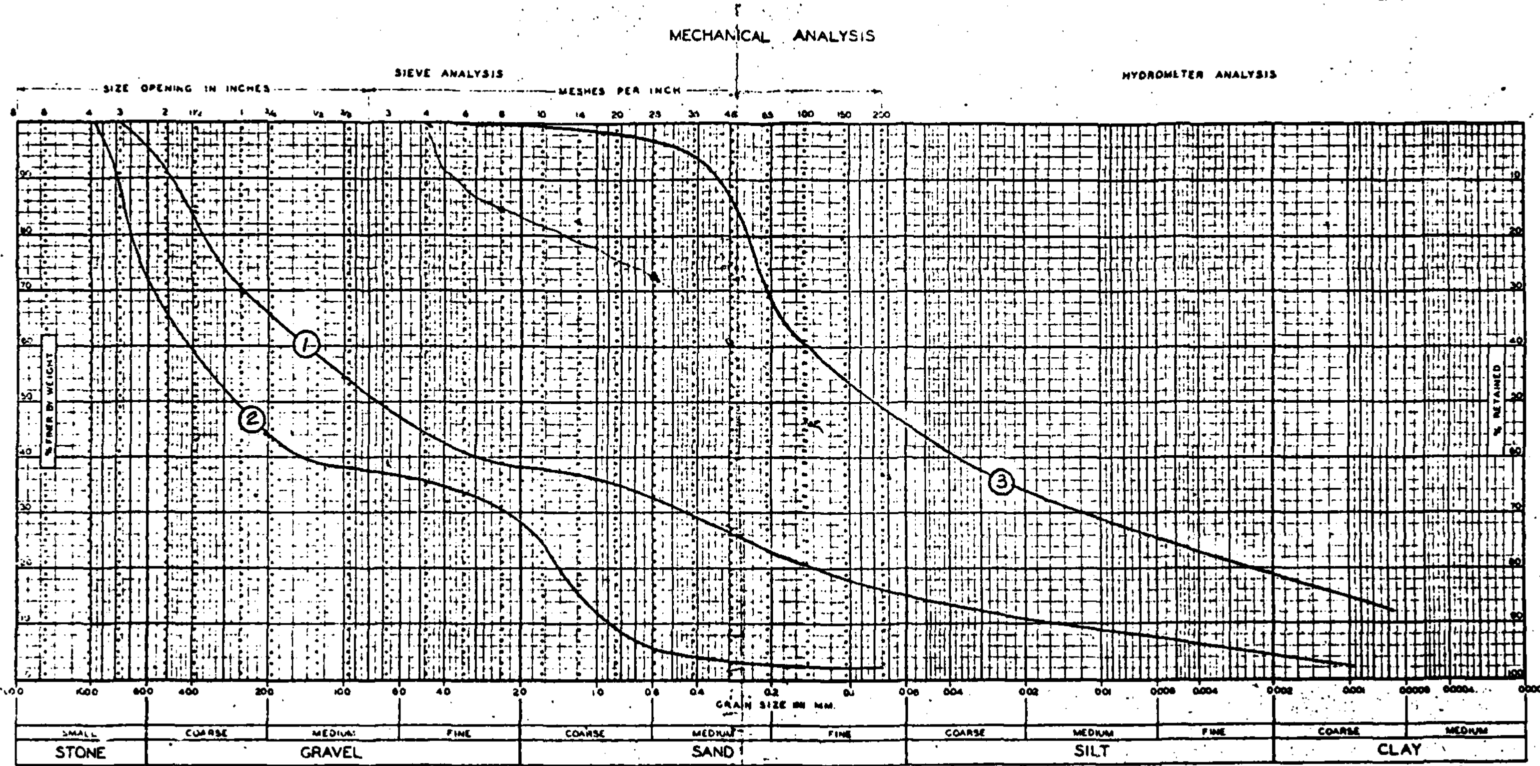
SITE Dam Site 2A
Representative Curves for Foundation Materials
HOLE
PLOTTER V.R.B. DATE 22 July, 1945

20

FIGURE B-1

WAR DEPARTMENT

CORPS OF ENGINEERS



CURVE NUMBER	SAMPLE	Hole [redacted]	Depth [redacted]		REMARKS
1	S. Bag 3	D.H. 18	15.0'-16.0'	Silty Sandy Gravel	
2	L. Bag 4	B.P. 7	5.0'-10.0'	Sandy Gravel	
3	Cyl. 2	D.H. 2	4.0'-5.0'	Clayey Silt & Sand	

GRAIN SIZE
DISTRIBUTION CURVES

SITE Dam Site 2A
Representative Curves For
Borrow Materials
HOLE
PLOTTER V.R.B. DATE 23 July, 1945

FIGURE
B-2

WAR DEPARTMENT CORPS OF ENGINEERS

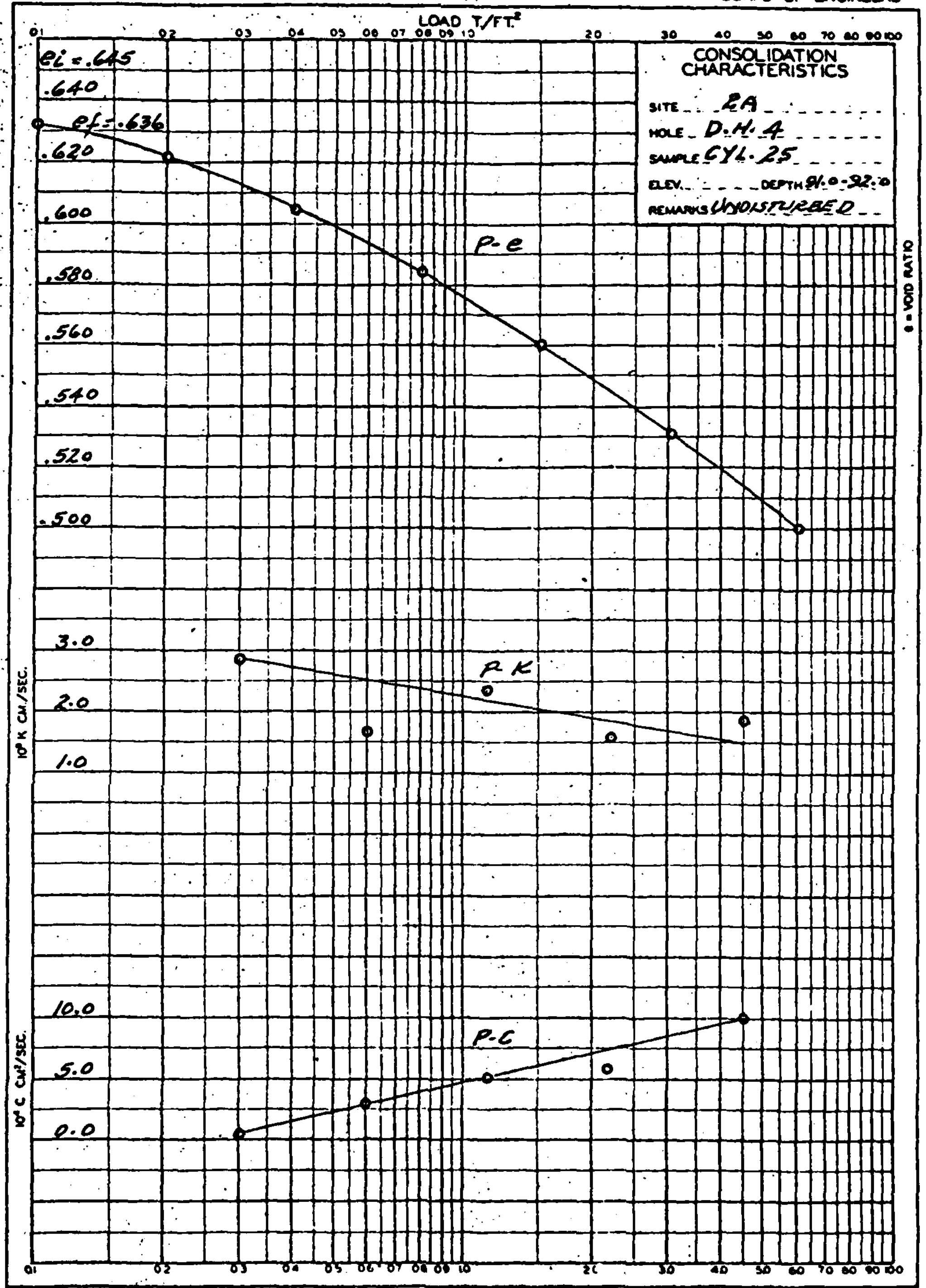


FIGURE B3

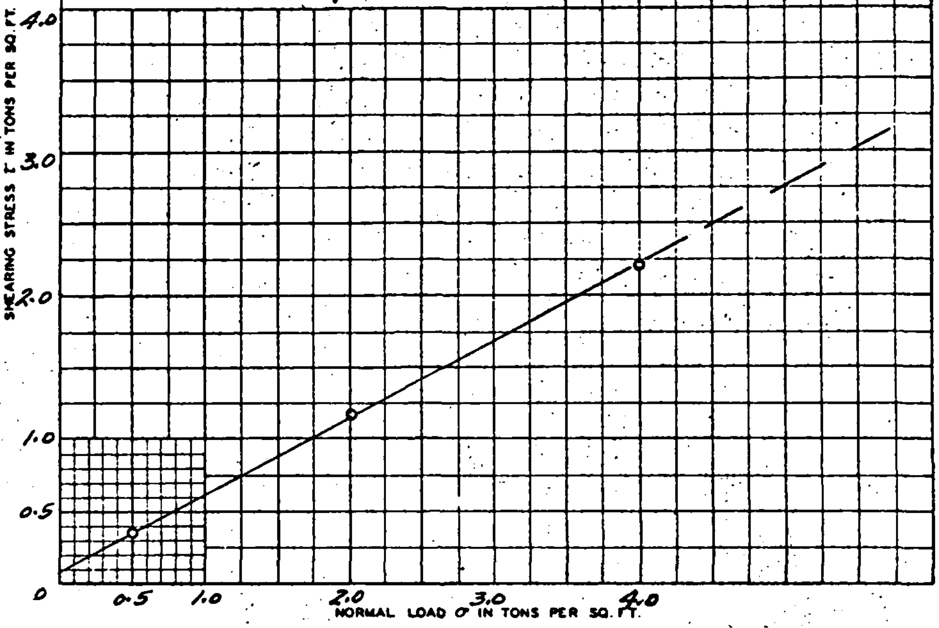
WAR DEPARTMENT — CORPS OF ENGINEERS, U. S. ARMY

DIRECT SHEAR CHARACTERISTICS

SITE 2A — HOLE D.H. 3
SAMPLE CYL. 1 — DEPTH 1.0-2.5 FT.
PLOTTER A. R. A.
REMARKS Sandy Clayey SILT. Worm Holes in Sample.

UNDISTURBED ~ CONSOLIDATED ~ SUBMERGED.

C = 0.08 — φ = 28°-10'



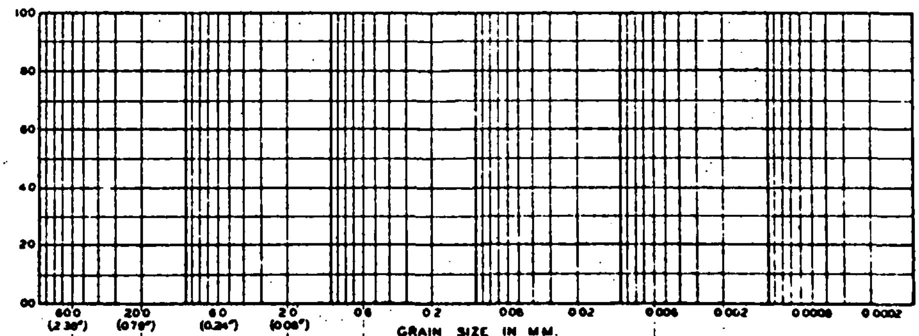


FIGURE B-4

WAR DEPARTMENT — CORPS OF ENGINEERS, U. S. ARMY

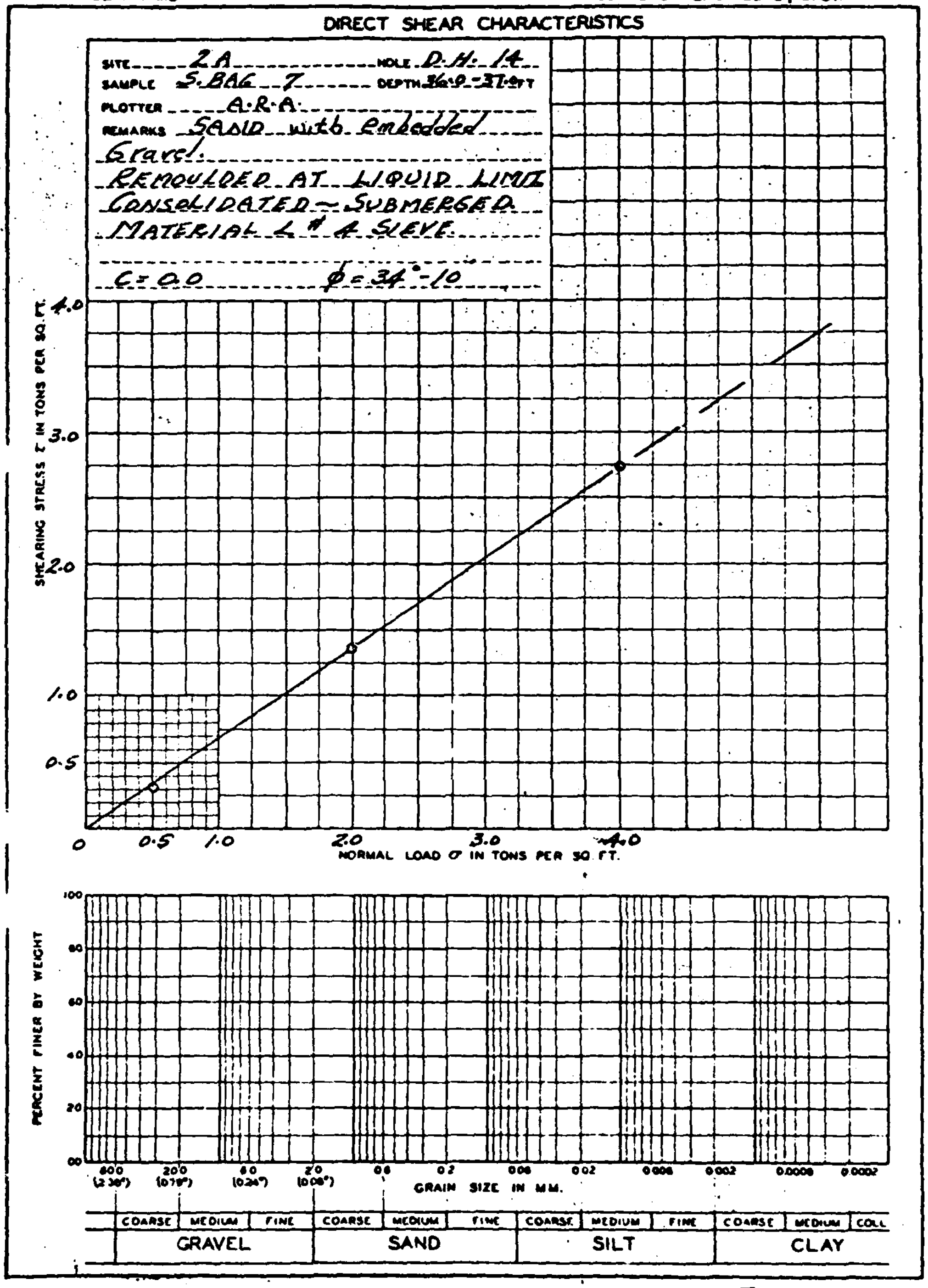


FIGURE B-5

WAR DEPARTMENT | CORPS OF ENGINEERS, U. S. ARMY

DIRECT SHEAR CHARACTERISTICS

SITE 2A HOLE D.H. 23

SAMPLE S. BAG 9 DEPTH 49.0-50.0 FT.

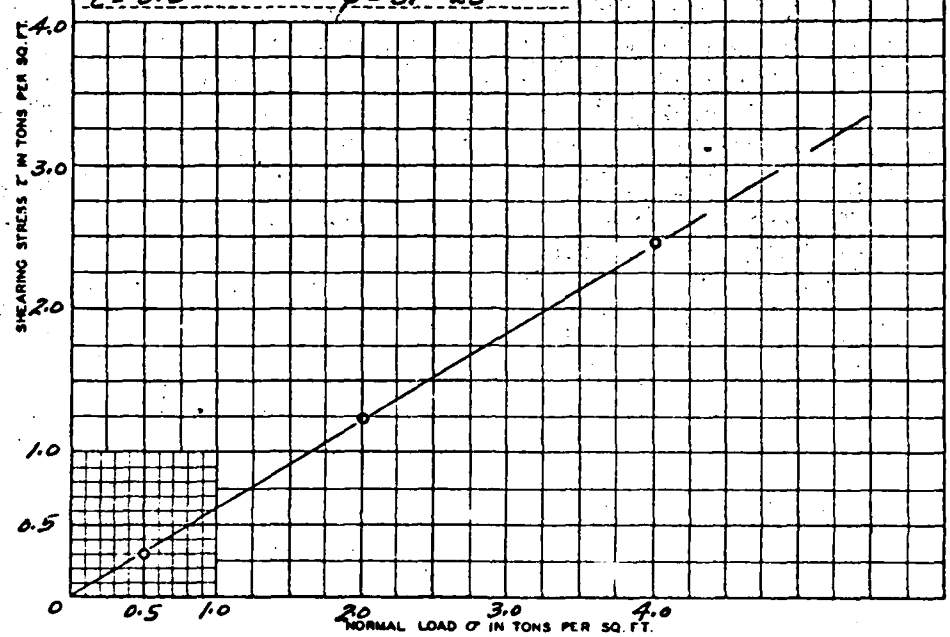
PLOTTER A.R.A.

REMARKS Fine to Coarse SAND

REMOULDED AT LIQUID LIMIT

CONSOLIDATED ~ SUBMERGED

C = 0.0 ϕ = 31°-25'



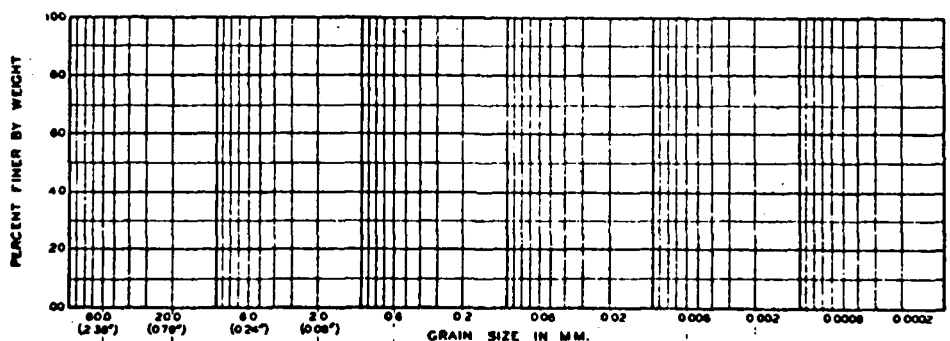


FIGURE B-6

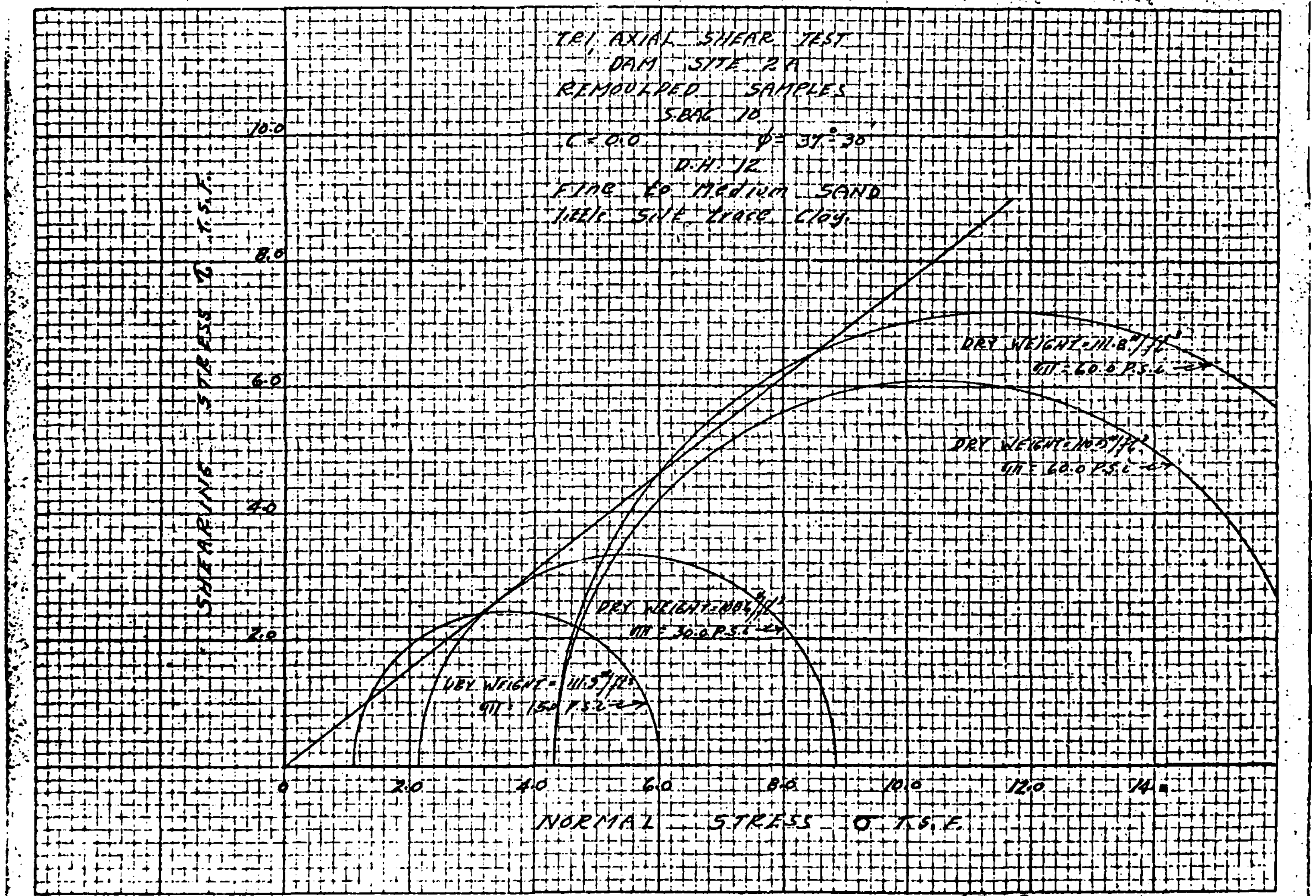
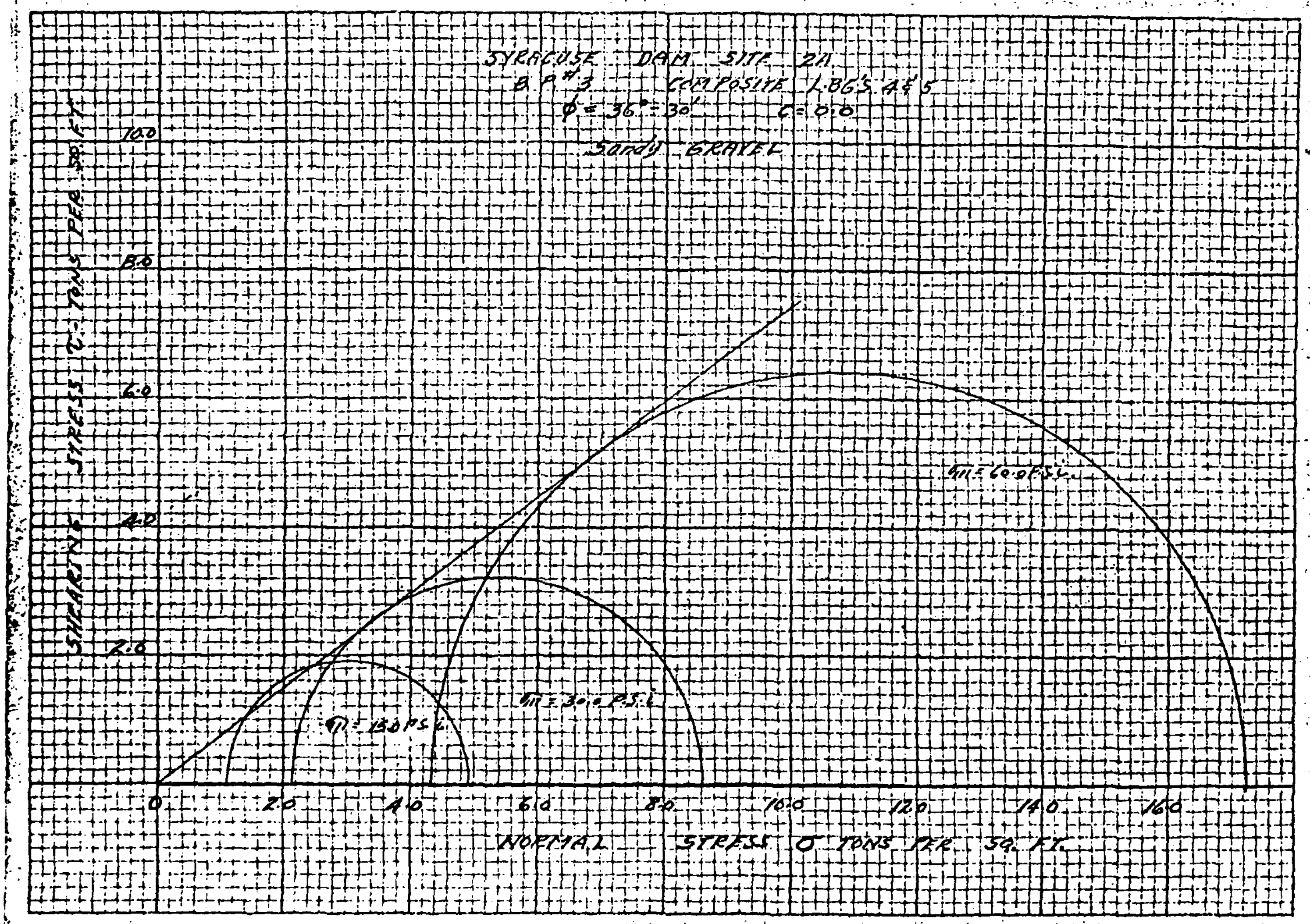
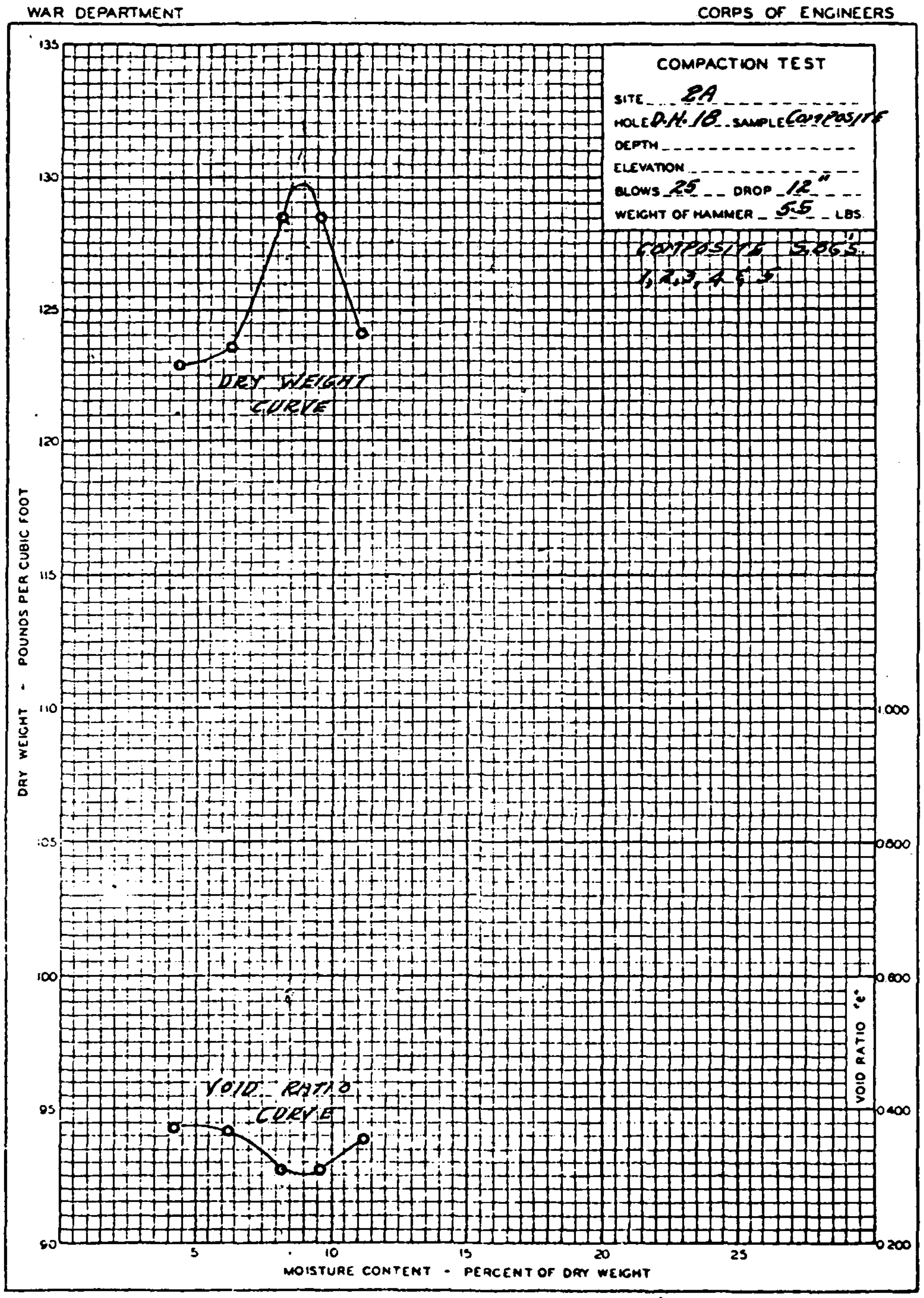

TRI AXIAL SHEAR TEST
DAM SITE 2A
REMOULDED SAMPLES
S.BAG 10
C=0.0 ϕ=37°30'
D.H. 12
Fine to medium SAND
little silt trace clay.
DRY WEIGHT = 111.8#/ft³
σIII = 60.0 P.S.I.
DRY WEIGHT = 110.0#/ft³
σIII = 60.0 P.S.I.
σIII = 30.0 P.S.I.
σIII = 15.0 P.S.I.
SHEARING STRESS τ T.S.F.
NORMAL STRESS σ T.S.F.
0
2.0
4.0
6.0
8.0
10.0
12.0
14.0

FIGURE B-7



SYRACUSE DAM SITE 2A
B.P. #3 COMPOSITE LBGS. 4 & 5
φ = 36° - 30' C = 0.0
Sandy GRAVEL
σIII = 15.0 P.S.I.
σIII = 30.0 P.S.I.
σIII = 60.0 P.S.I.
SHEARING STRESS τ - TONS PER SQ. FT.
NORMAL STRESS σ TONS PER SQ. FT.
0
2.0
4.0
6.0
8.0
10.0
12.0
14.0
16.0

FIGURE B-A



WAR DEPARTMENT
CORPS OF ENGINEERS
COMPACTION TEST
SITE 2A
HOLE D.H. 18 SAMPLE COMPOSITE
DEPTH
ELEVATION
BLOWS 25 DROP 12"
WEIGHT OF HAMMER 5.5 LBS.
COMPOSITE S.BG'S.
1,2,3,4 & 5
DRY WEIGHT CURVE
VOID RATIO CURVE
DRY WEIGHT - POUNDS PER CUBIC FOOT
MOISTURE CONTENT - PERCENT OF DRY WEIGHT
VOID RATIO "e"

FIGURE B-9

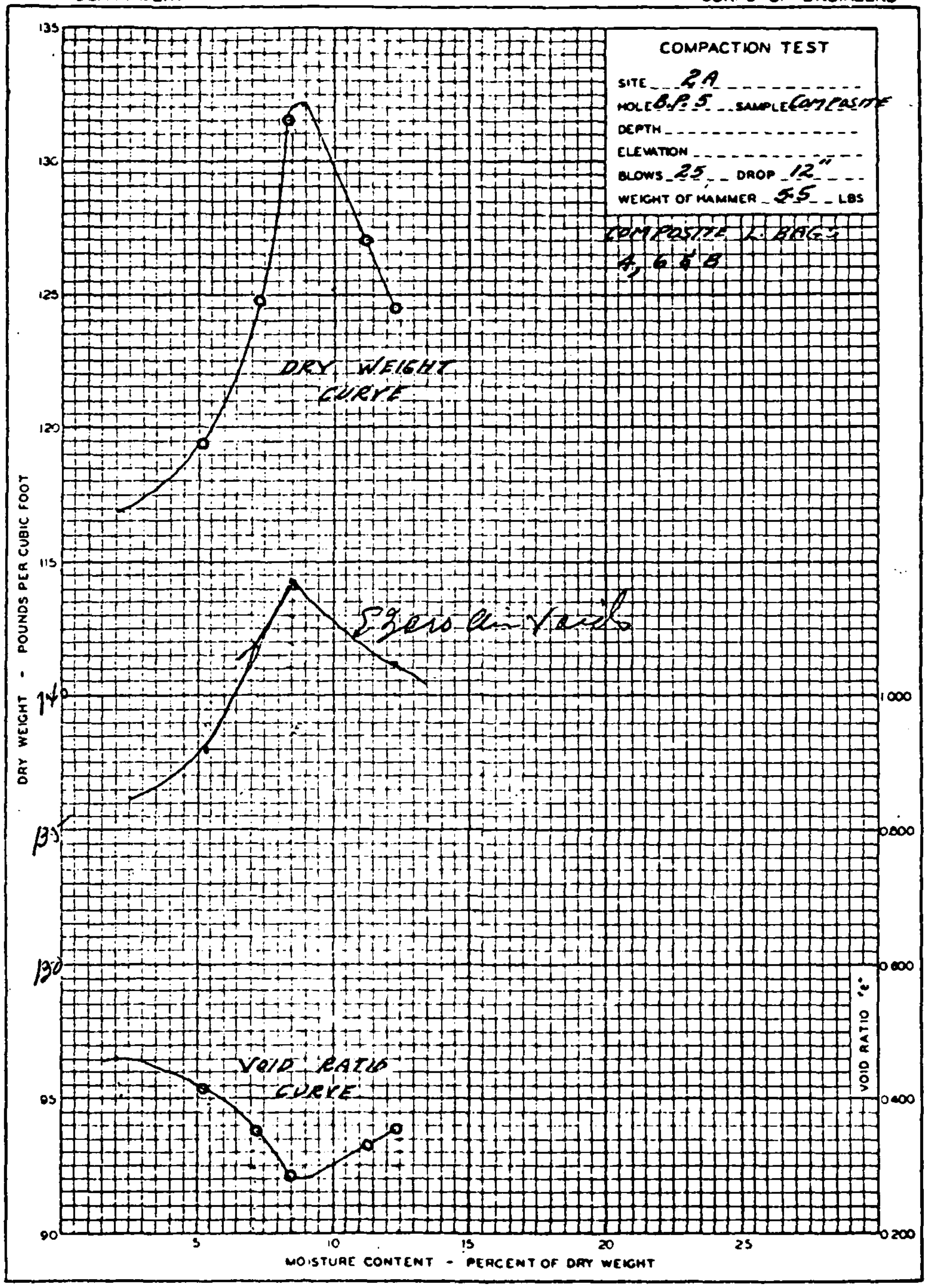

COMPACTION TEST
SITE 2A
HOLE B.P. 5 SAMPLE COMPOSITE
DEPTH
ELEVATION
BLOWS 25 DROP 12"
WEIGHT OF HAMMER 5.5 LBS
COMPOSITE 1. BAGS 4, 6 & 8
DRY WEIGHT CURVE
Zero air voids
VOID RATIO CURVE
DRY WEIGHT - POUNDS PER CUBIC FOOT
VOID RATIO "e"
MOISTURE CONTENT - PERCENT OF DRY WEIGHT
135
130
125
120
115
110
105
100
95
90
140
135
130
1.000
0.800
0.600
0.400
0.200
5
10
15
20
25

FIGURE 8-10

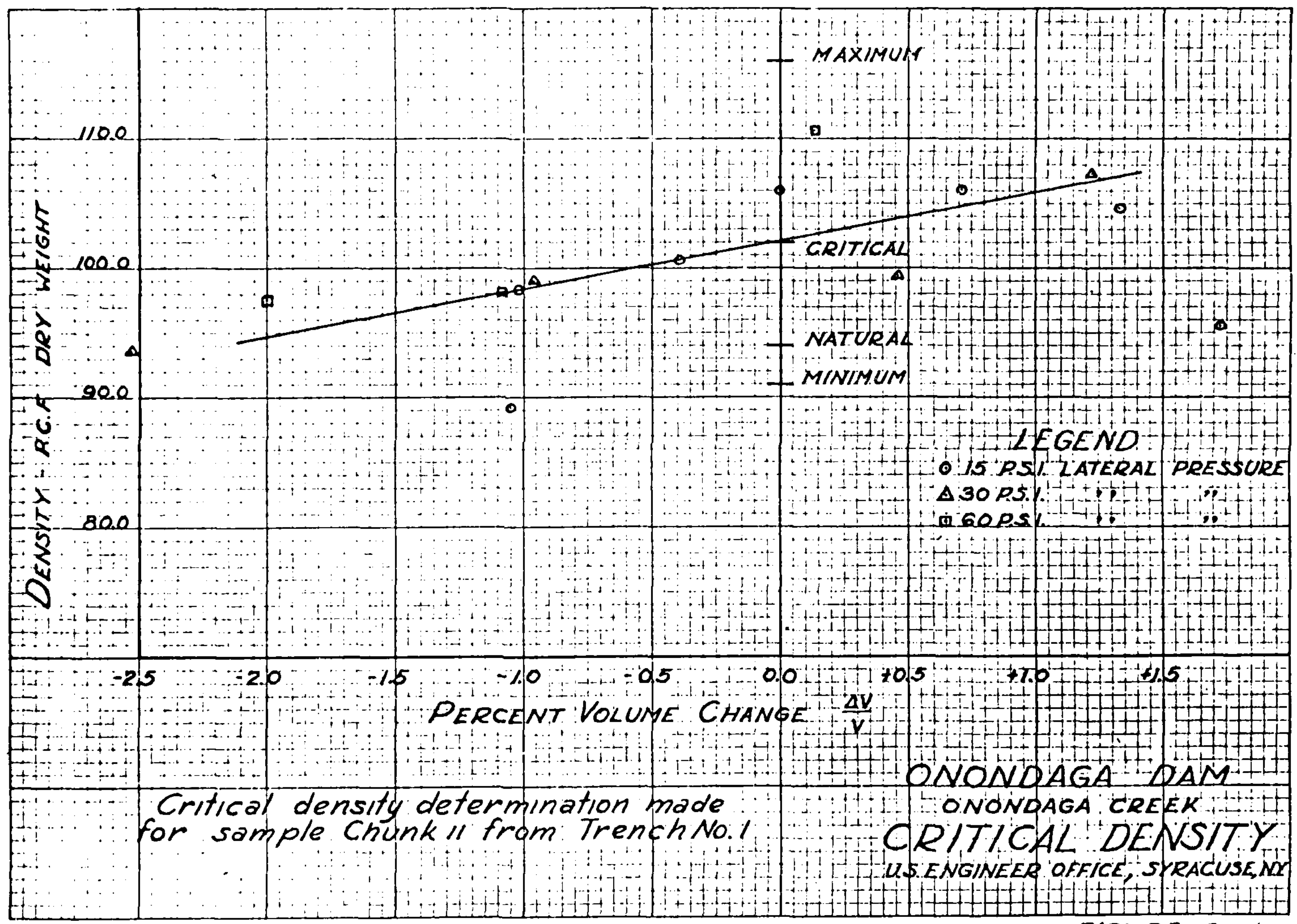

MAXIMUM
CRITICAL
NATURAL
MINIMUM
110.0
100.0
90.0
80.0
DENSITY - R.C.F. DRY WEIGHT
-2.5
-2.0
-1.5
-1.0
-0.5
0.0
+0.5
+1.0
+1.5
PERCENT VOLUME CHANGE ΔV/V
LEGEND
○ 15 P.S.I. LATERAL PRESSURE
△ 30 P.S.I. " "
□ 60 P.S.I. " "
Critical density determination made
for sample Chunk 11 from Trench No. 1
ONONDAGA DAM
ONONDAGA CREEK
CRITICAL DENSITY
U.S. ENGINEER OFFICE, SYRACUSE, N.Y.

FIGURE B-11

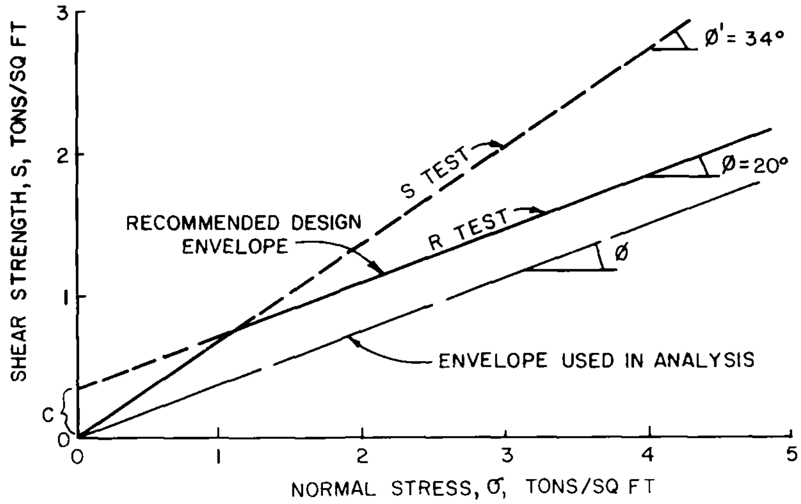


FIGURE B-12. DESIGN ENVELOPE FOR CASES II AND III

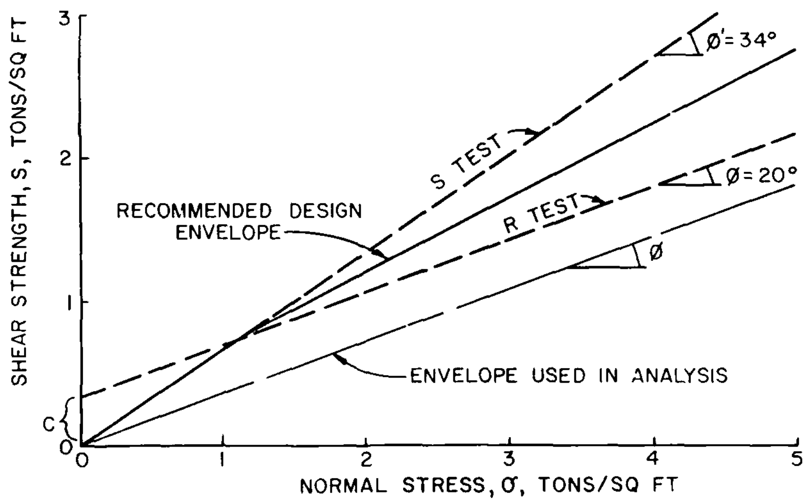


FIGURE B-13. DESIGN ENVELOPE FOR CASES IV, V, AND VI

ONONDAGA DAM, NY

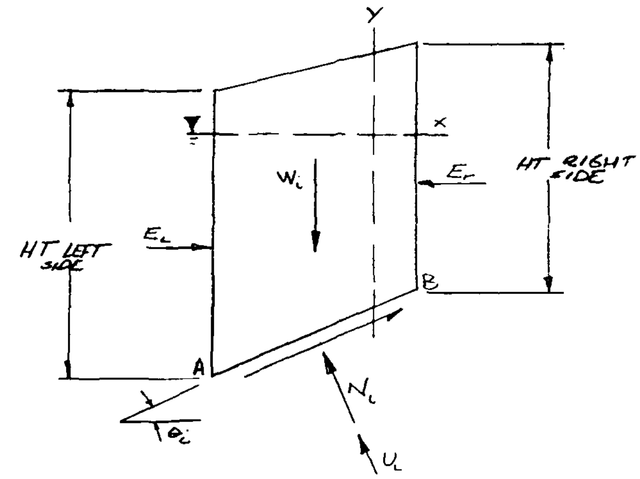
HAND COMPUTATIONS

APPENDIX C

STABILITY ANALYSIS

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

THE SIMPLIFIED BISHOPS METHOD ASSUMES THAT THE FORCES ACTING ON THE SIDES OF THE SLICE ARE HORIZONTAL. THEREFORE THEY HAVE ZERO RESULTANT IN THE VERTICAL DIRECTION AND CAN BE ELIMINATED BY SUMMING THE FORCES IN THE VERTICAL DIRECTION. THE FORCES ACTING ON A TYPICAL SLICE ARE:



THE FACTOR OF SAFETY IS GIVEN BY:

$$F = \frac{\sum_{i=1}^{n} \left[c\Delta x_i + (W_i - u_i \Delta x_i) \tan\phi \right] \left[1 / M_i(\theta) \right]}{\sum_{i=1}^{n} W_i \sin\theta_i}$$

$$M_i(\theta) = \cos\theta_i \left[1 + \frac{\tan\theta_i \tan\phi}{F} \right]$$

WHERE

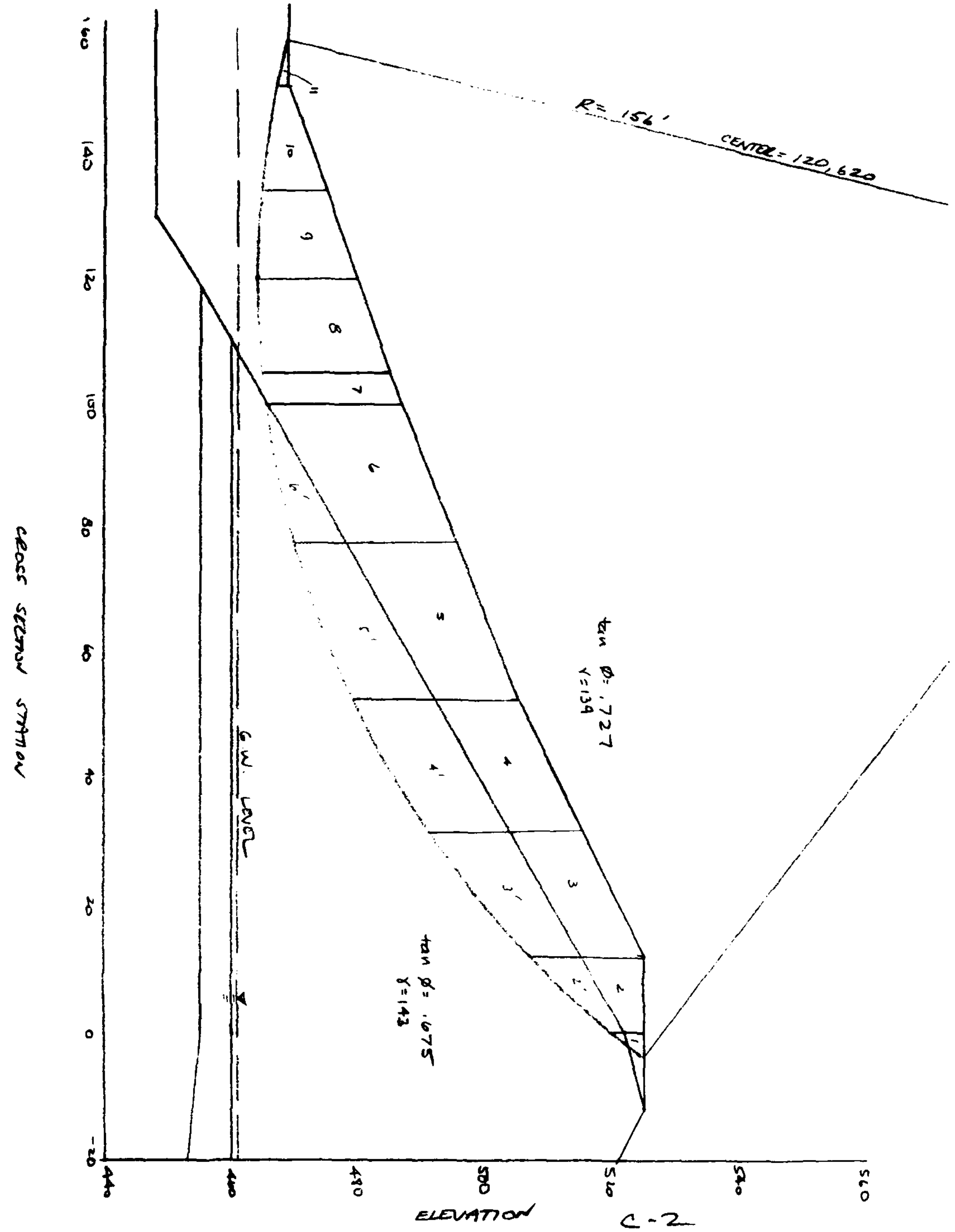
F = FACTOR OF SAFETY
C = COHESION
W_i = TOTAL WEIGHT
θ = ANGLE OF CHORD A-B
i = SLICE NUMBER
n = NUMBER OF SLICES
N = NORMAL FORCE
U = WATER FORCES
T = RESISTING FORCES
ϕ = ANGLE OF INTERNAL FRICTION (AT BASE OF SLICE)

NOTE: IN FOLLOWING TABLES THE TERM $(W_i - u_i \Delta x_i)$ IS ANNOTATED AS W_i' (THE EFFECTIVE WEIGHT) W_b AND W_s BUOYANT AND SATURATED WEIGHT RESPECTIVELY

FOR EASE OF CALCULATION THE ABOVE EQUATION IS REDUCED TO TABULAR FORM. AS CAN BE NOTED, THE FACTOR OF SAFETY APPEARS ON BOTH SIDES OF THE EQUATION THEREFORE IT MUST BE ASSUMED TO CALCULATE Mi(θ) AND THEN THE CALCULATED FOS IS COMPARED WITH THE ASSUMED VALUE, THIS IS DONE SEVERAL TIMES UNTIL THE FOS IS "BRACKETED". THEN THEY CAN BE PLOTTED TO OBTAIN THE FOS.

BY GGK DATE 11 DEC 84 SUBJECT ONONDAGA STABILITY - HAND COMP CASE I UPSTREAM SLOPE SIMPLIFIED BISHOPS METHOD SHEET NO. 1 OF 6

CHKD. BY JB DATE 1/3/85 JOB NO.



BY GGK DATE 11/22/84 SUBJECT .... SHEET NO. 2 OF 6
CHKD. BY JB DATE 1/3/85 .... JOB NO. ....
CASE I CONT

SLICE NO.	Δ X (FT)	HT LS (FT)	HT RS (FT)	$\overline{HT}$ (FT)	AREA (FT²)	W_i (KIPS) SECTION	TOT	θ_i (°)
1	4	5	0	2.5	10.0	1.4	1.4	53
2	12	10	3	6.5	78	10.5	19.4	47
2'	12	8	2	5	60	8.6		
3	20	11.5	10	10.75	215	29.9	59.2	39
3'	20	12.5	8	10.25	205	29.3		
4	21	13	11.5	12.25	257.3	35.8	74.1	30
4'	21	13	12.5	12.75	267.8	38.3		
5	25	18	13	15.5	387.5	53.9	91.4	20.5
5'	25	8	13	10.5	262.5	37.5		
6	22	21	18	19.5	429	59.6	72.4	11.5
6'	22	0	8	4	88	12.8		
7	5	20	21	20.5	102.5	14.2	14.2	7
8	15	16	20	18	270	37.5	37.5	3.5
9	14	10	16	13	182	25.3	25.3	-3.5
10	17	2	10	6	102	14.2	14.2	-8
11	7	0	2	1	7	1.0	1.0	-14.5

SLICE NO	$W_i \times \sin\theta_i$	tan Ø	$W_i \times$ tan Ø	$M_i(\theta)$ F=1.5	F=2.0	F=2.2	$W_i \tan Ø \div M_i$ F=1.5	F=2.0	F=2.2
1	1.1	.727	1.0	.99	.89	.87	1.01	1.1	1.2
2	14.2	.727	14.2	1.04	.95	.92	13.6	14.9	15.3
3	37.3	.727	43.0	1.08	1.0	.99	39.7	43.0	43.7
4	37.1	.727	53.9	1.11	1.05	1.03	48.7	51.4	52.3
5	32.0	.727	66.4	1.11	1.06	1.05	60.0	62.4	63.1
6	14.4	.727	52.6	1.08	1.05	1.05	48.9	50.0	50.3
7	1.7	.675	9.6	1.05	1.03	1.03	9.2	9.3	9.3
8	2.3	.675	25.3	1.03	1.02	1.02	24.7	24.8	24.9
9	-1.5	.675	17.1	.97	.98	.98	17.6	17.5	17.5
10	-2	.675	9.0	.93	.94	.95	10.3	10.2	10.1
11	-.3	.675	0.7	.86	.88	.89	0.8	.8	.8
	136.3						274.5	285.4	288.5

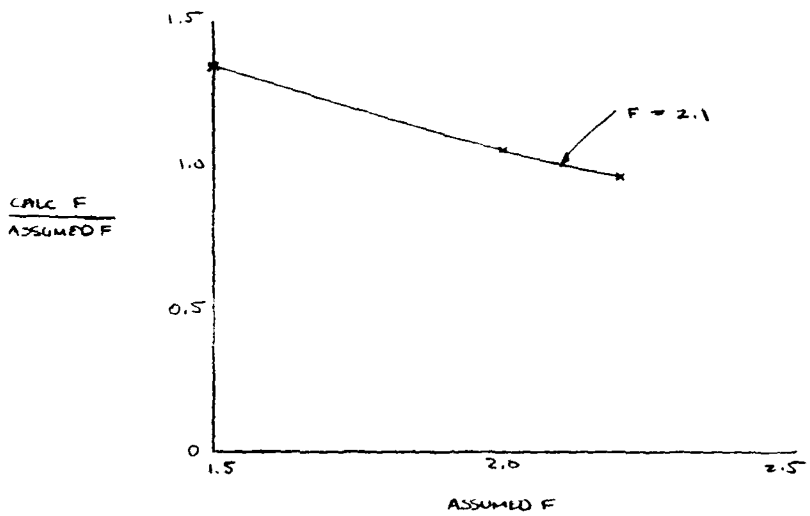
FS = 1.5 $F = \frac{274.5}{136.3} = 2.01$

FS = 2.0 $F = \frac{285.4}{136.3} = 2.09$

F = 2.2 $F = \frac{288.5}{136.3} = 2.12$

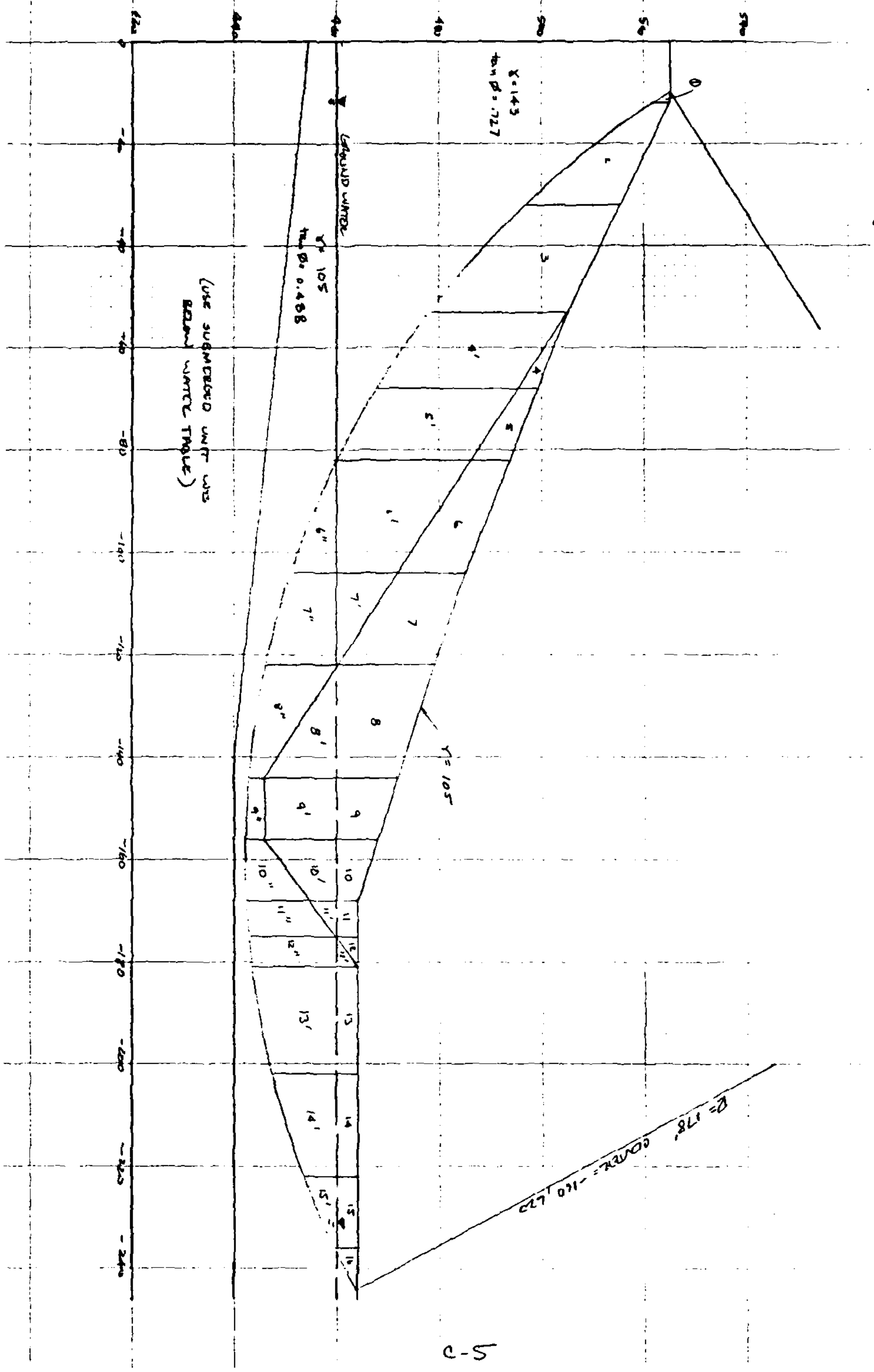
CASE I CONT

① ASSUMED F	② CALCULATED F	② ÷ ①
1.5	2.01	1.34
2.0	2.09	1.05
2.2	2.12	0.96



BY EGL 11 DEC 84

ONONDAGA DAM STABILITY HAND COMP CASE I DOWNSTREAM



BY GGK DATE 11 DEC 84 SUBJECT .... SHEET NO. 5 OF 6
CHKD. BY JB DATE 1/3/85 JOB NO. ....
CASE I CONT

SLICE NO	Δx (FT)	SLICE HT (L) FT	SLICE HT (R) FT	$\overline{HT}$ FT	AREA FT^2	W_s	W_b	W_i	W_i'
1	2	0	3	1.5	3.0	0.5		0.5	0.5
2	20	3	19	11	220	31.5		31.5	31.5
3	21	19	27	23	483	69.1		69.1	69.1
4	15	0	4	2	30	2.2			
4'		27	27.5	27.25	408.8	58.5		61.7	61.7
5	14	4	8	6	84	8.8			
5'		27.5	26	26.75	374.5	53.6		62.4	62.4
6		8	13	10.5	231	24.3			
6'	22	26	12	19	418	59.8		94.5	88.4
6"		0	9	4.5	99	10.4	4.3		
7		13	19	16	288	30.2			
7'	18	12	0	6	108	15.4		67.3	54.5
7"		9	14	11.5	207	21.7	8.9		
8		19	12	15.5	341	35.8			
8'	22	0	14	7	154	16.2	6.6	71.6	50.4
8"		14	3	8.5	187	19.6	8.0		
9		12	8	10	120	12.6			
9'	12	14	14	14	168	17.6	7.2	34.6	21.6
9"		3	4	3.5	42	4.4	1.8		
10		8	4	6	72	7.6			
10'	12	14	5	9.5	114	12	4.9	29.7	16.6
10"		4	12	8	96	10.1	4.1		
11		4	4	4	28	2.9			
11'	7	5	0	2.5	17.5	1.8	0.8	15.4	8.1
11'		12	17	14.5	101.5	10.7	4.4		
12		4	0	2	12	1.3			
12'	6	0	4	2	12	1.3	0.5	13.2	6.1
12"		17	16.5	16.75	100.5	10.6	4.3		
13	21	4	4	4	84	8.8			
13'		16.5	12.5	14.5	304.5	.32	13.1	40.8	21.9
14	20	4	4	4	80	8.4			
14'		12.5	6	9.25	185	19.4	8.0	27.8	16.4
15	15	4	4	4	60	6.3			
15'		6	0	3	45	4.7	1.9	11.0	8.4
16	7	4	0	2	14	1.5		1.5	1.5

BY GGK DATE 11 [illegible] 84 SUBJECT ______ SHEET NO. 6 OF 6

CHKD. BY JB DATE 1/3/85 ______ JOB NO. ______

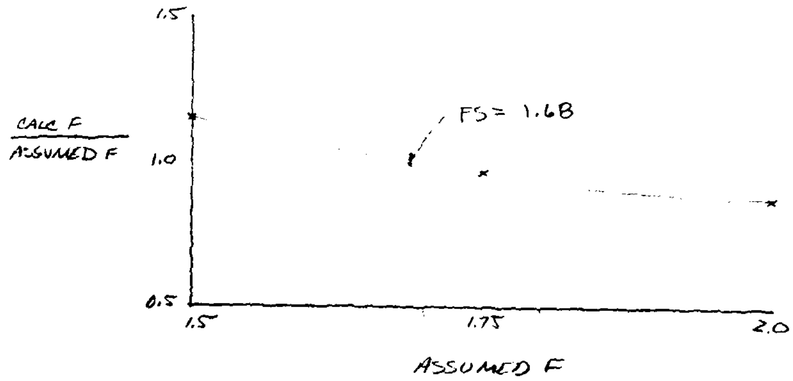
CASE I CONT

SLICE No	θ_i	$W_i \sin\theta_i$	$W_i' \times \tan\phi$	$M_i(\theta)$			$W_i' \tan\phi \div M_i(\theta)$		
				F=1.5	F=2.0	F=1.75	F=1.5	F=2.0	F=1.75
1	57	0.4	.4	.95	.85	.89	.4	.5	.5
2	51	24.5	22.4	1.01	.91	.95	22.8	25.1	24.1
3	41.5	45.8	50.2	1.07	.99	1.02	46.9	50.7	49.0
4	34.5	34.9	44.9	1.10	1.03	1.06	40.9	43.6	42.4
5	29	30.3	45.4	1.11	1.05	1.08	40.9	43.2	42.2
6	22	34.5	43.1	1.05	1.02	1.03	41.1	42.3	41.8
7	15.5	18.0	26.6	1.05	1.03	1.04	25.3	25.9	25.6
8	8	10.0	24.6	1.04	1.02	1.03	34.8	24.0	23.9
9	3.5	2.1	10.5	1.02	1.01	1.02	10.3	10.4	10.3
11	-1	-.5	8.1	.99	1.00	.99	8.2	8.1	8.1
11	-3.5	-.9	4.0	.98	.98	.98	4.1	4.1	4.1
12	-6.5	-1.5	3.0	.96	.97	.96	3.1	3.1	3.1
13	-10.5	-7.4	10.7	.92	.94	.93	11.6	11.4	11.5
14	-17.5	-8.4	8.0	.86	.88	.87	9.4	9.1	9.2
15	-23	-4.3	4.0	.79	.83	.81	5	4.9	4.9
16	-28	-.7	0.7	.73	.77	.75	1	.9	.9
		Σ= 176.8					305.8	307.3	301.6

F=1.5 $F = \frac{305.8}{178.8} = 1.73$ $\frac{1.73}{1.5} = 1.15$

F=2.0 $F = \frac{307.3}{178.8} = 1.74$ $\frac{1.74}{2.0} = .87$

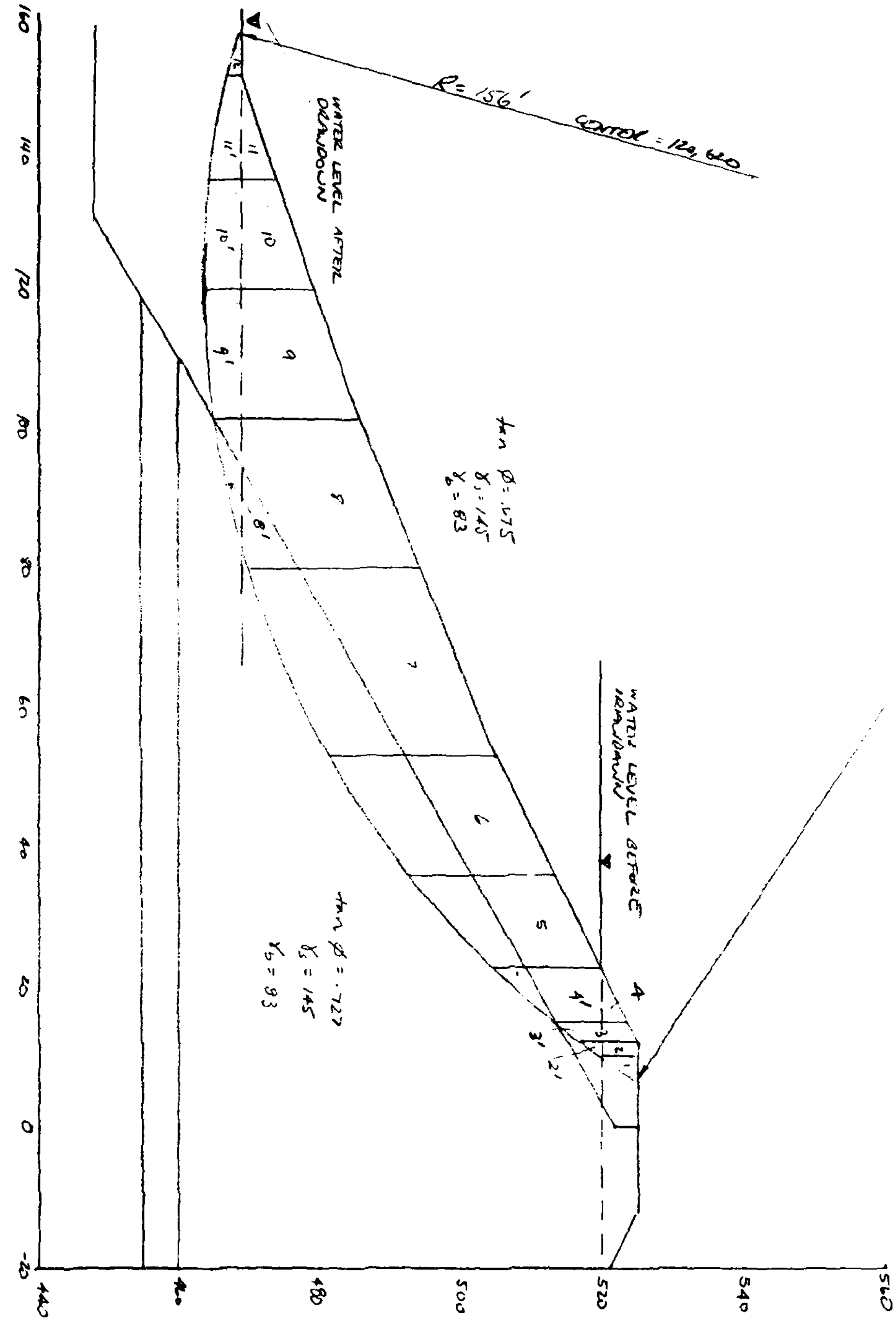
F=1.75 $F = \frac{301.6}{176.8} = 1.71$ $\frac{1.70}{1.75} = .97$



BY GCK DATE 12/?/84 SUBJECT ONONDAGA DAM STABILITY SHEET NO. 1 OF 3

CHKD. BY [illegible] DATE 1/3/85 CASE II SIMPLIFIED BISHOPS METHOD JOB NO.

RAPID DRAWDOWN FROM MAX POOL



BY CGK DATE 12.08.84 SUBJECT SHEET NO. 2 OF 3
CHKD. BY JB DATE 1/3/85 JOB NO.
CASE II CONT

SLICE NO	ΔX	HT LS	HT RS	$\overline{HT}$	AREA	W_{SAT}	W_B *	W_L'	W_L
1	3.5	5	0	2.5	8.8	1.3	—	1.3	1.3
2	2.0	5	5	5	10	1.5	—		
2'	2.0	3	0	1.5	3	.4	.2	1.7	1.9
3	2.5	4	5	4.5	11.3	1.6	—		
3'	2.5	6	3	4.5	11.3	1.6	.9	2.5	3.2
4	8	0	4	2	16	2.3	—		
4'	8	15	6	10.5	84	12.2	6.7	9.0	14.5
5	13	21	15	18	234	33.9	18.7	18.7	33.9
6	17	24	21	22.5	382.5	55.5	30.6	30.6	55.5
7	27	24	24	24	648	94	51.8	51.8	94
8	21	17	24	20.5	430.5	62.4	34.4		
8'	21	4	0	2	42	6.1	3.4	37.8	68.5
9	18.5	11	17	14	259	37.6	20.7		
9'	18.5	5	4	4.5	83.3	12.1	6.7	27.4	49.7
10	16	5	11	8	128	18.6	10.2		
10'	16	4	5	4.5	72	10.4	5.8	16.0	29.0
11	15	0	5	2.5	37.5	5.4	3.0		
11'	15	2	4	2	30	4.4	2.4	5.4	9.8
12	6	0	2	1	6	0.9	.5	.5	0.9

* NOTE USED γ_b = 80 INSTEAD OF 83 HAS NO EFFECT ON ANSWER

BY GGK DATE 12 DEC 84 SUBJECT SHEET NO. 3 OF 3

CHKD. BY JB DATE 1/3/85 JOB NO.

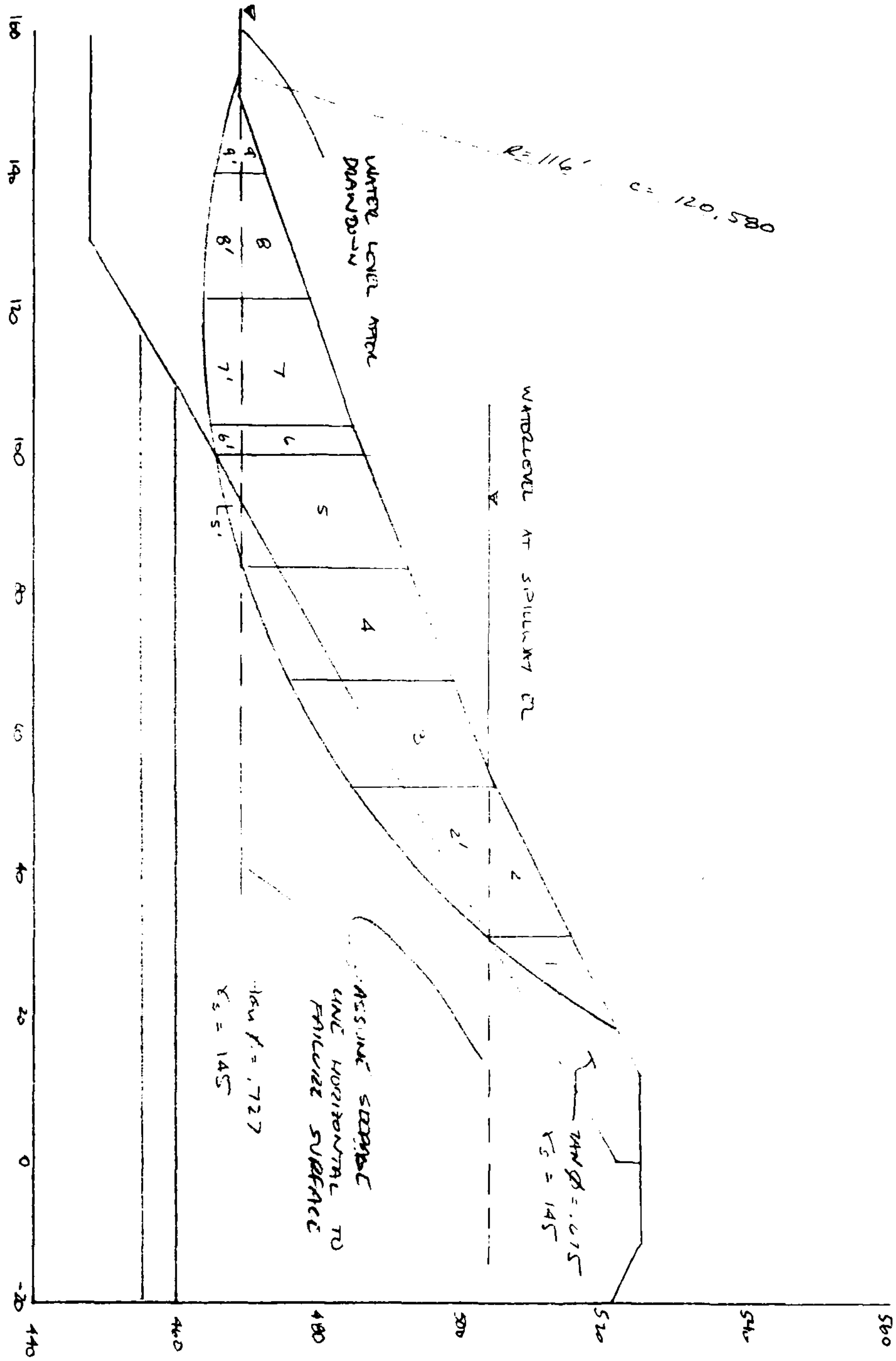
CASE II CONT

SLICE NO	θ_i	$W_i \sin\theta$	$W_i' \tan\phi$	$M_i(\theta)$			$W_i' \tan\phi - M_i(\theta)$		
				F=1.0	F=1.5	F=1.25	F=1.0	F=1.5	F=1.25
1	56	1.1	.9	1.12	.93	1.01	.8	1.0	0.9
2	53	1.5	1.2	1.14	.96	1.03	1.1	1.3	1.2
3	51	2.5	1.7	1.15	.98	1.05	1.5	1.7	1.6
4	49	10.9	6.5	1.20	1.02	1.09	5.4	6.4	5.9
5	42.5	22.9	13.6	1.23	1.06	1.13	11.1	12.8	12.0
6	34	31.0	22.3	1.24	1.10	1.15	18.1	20.3	19.3
7	23.5	37.5	37.7	1.21	1.11	1.15	31.2	34.0	32.8
8	13.5	16.0	27.5	1.14	1.09	1.11	24.1	25.3	24.8
9	5	4.3	18.5	1.06	1.04	1.04	17.5	17.9	17.7
10	-25	-1.3	10.8	.97	0.98	.98	11.1	11	11.1
11	-10	-1.7	3.7	.87	0.91	.89	4.3	4.1	4.2
12	-18	-.3	0.3	.74	0.81	.78	.4	.4	0.4
		Σ = 124.4					126.6	136.2	131.90

FOR F = 1.0 $F = \frac{126.6}{124.4} = 1.02$

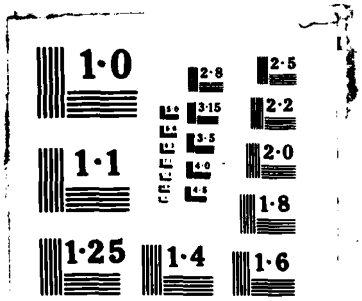
TAKE F = 1.0

BY GGK DATE 13 DEC 84 SUBJECT ONONDAGA DAM STABILITY SHEET NO. 17 OF 2
CHKD. BY GB DATE 1/3/85 CASE III - SIMPLIFIED BISHOPS METHOD JOB NO.
RAPID DRAWDOWN FROM SPILLWAY EL



AD-A169 722 REPORT ON SEISMIC STABILITY ONONDAGA DAM NEW YORK(U) CORPS OF ENGINEERS BUFFALO NY BUFFALO DISTRICT MAY 86 2/3

UNCLASSIFIED F/G 13/2 NL


1·0
1·1
1·25
1·4
1·6
1·8
2·0
2·2
2·5
2·8
3·15
3·5
4·0

BY CCY DATE 13 DEC 84 SUBJECT SHEET NO. 2 OF 2
CHKD. BY JB DATE 1/3/85 JOB NO.

CASE III CONT

SLICE NO	Δx	HT LS	HT RS	$\overline{HT}$	AREA	W_{SAT}	W_B	W_i'	W_i
1	13	11.5	0	5.8	75.4	10.9	—	10.9	10.9
2	21	0	11.5	5.8	121.8	17.7	—	34.3	46.6
2'	21	19	0	9.5	199.5	28.9	16.6		
3	15	23	19	21	315	45.7	26.2	26.2	45.7
4	16	23	23	23	368	53.4	30.5	30.5	53.4
5	16	17	23	20	320	46.4	26.6	29.4	51.0
5'	16	4	0	2	32	4.6	2.7		
6	4	16	17	16.5	66	9.6	5.5	6.8	11.9
6'	4	4	4	4	16	2.3	1.3		
7	18	9	16	12.5	225	32.6	18.7	26.2	45.7
7'	18	6	4	5	90	13.1	7.5		
8	18	4	9	6.5	117	17	9.7	17.2	30.1
8'	18	4	6	5	90	13.1	7.5		
9	11	0	4	2	22	3.2	1.8	4.1	7.3
9'	14	0	4	2	28	4.1	2.3		

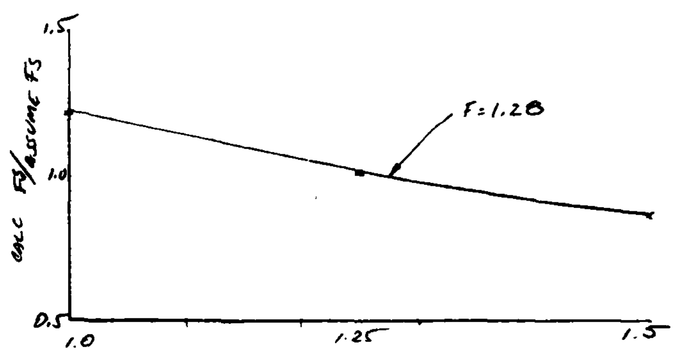
SLICE NO	θ_i	$W_i \sin\theta_i$	$W_i' \tan\phi$	$M_i(\theta)$			$W_i' \tan\phi \div M_i(\theta)$		
				F=1.5	F=1.0	F=1.25	F=1.5	F=1.0	F=1.25
1	55	8.9	7.4	0.94	1.13	1.02	7.9	6.6	7.3
2	42	31.2	24.9	1.07	1.23	1.13	23.3	20.3	22.0
3	30	22.9	19.1	1.11	1.23	1.16	17.2	15.5	16.5
4	22	20.0	22.2	1.11	1.20	1.15	20.0	18.5	19.4
5	14	12.3	21.4	1.09	1.15	1.11	19.7	18.7	19.3
6	11	2.3	4.6	1.07	1.11	1.08	4.3	4.1	4.2
7	3	2.4	17.7	1.02	1.03	1.03	17.3	17.1	17.2
8	-4	-2.1	11.6	.97	.95	.96	12.0	12.2	12.1
9	-15	-1.9	2.8	.85	.79	.83	3.3	3.5	3.4
		96.0					125.0	116.5	121.4

FOR F = 1.5 $F = \frac{125.0}{96} = 1.30$

FOR F = 1.0 $F = \frac{116.5}{96} = 1.21$

FOR F = 1.25 $F = \frac{121.4}{96} = 1.26$

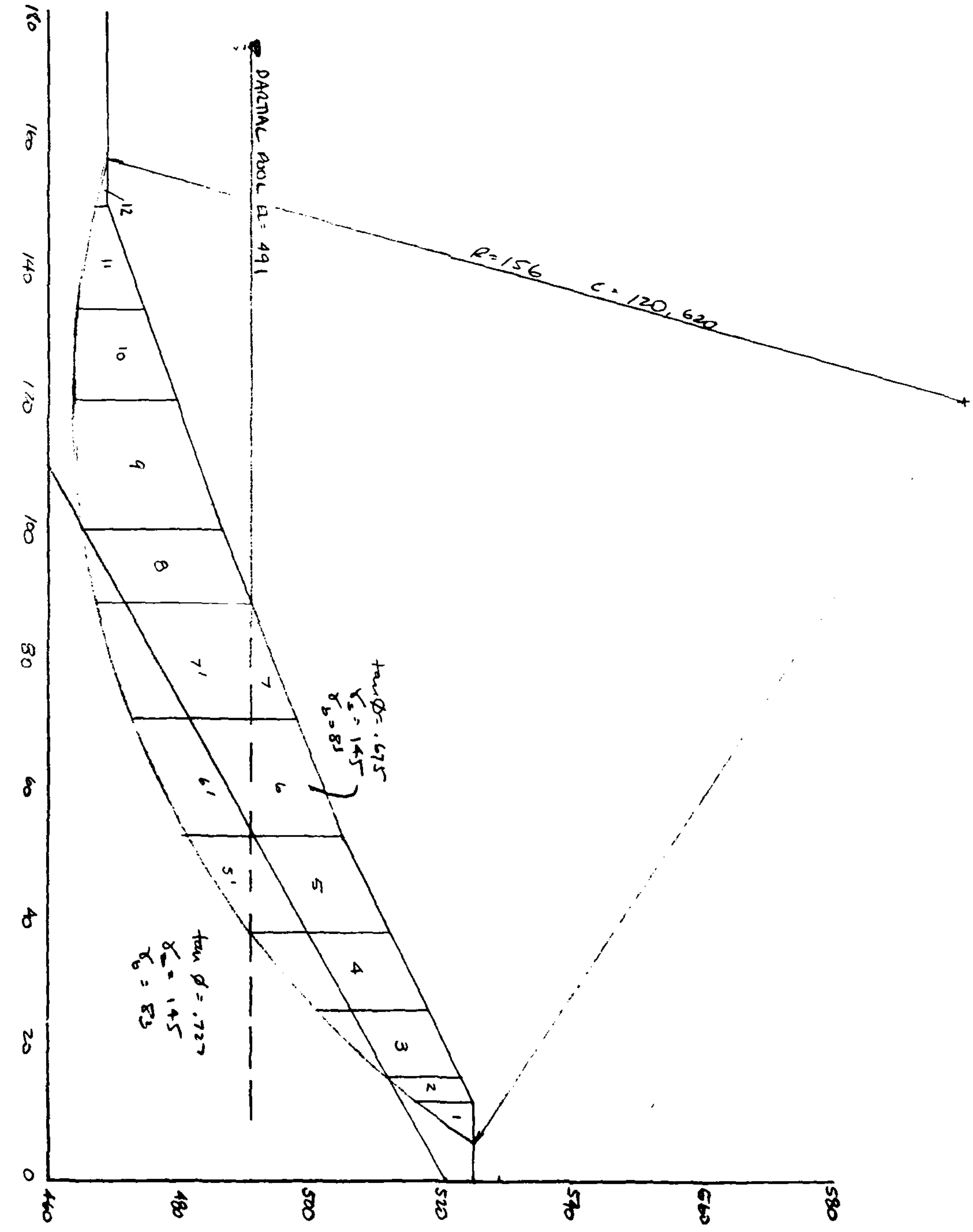
F_{CALC}/F_{ASSUME}	F_{ASSUME}
0.87	1.5
1.21	1.0
1.01	1.25



BY GGK DATE 13 DEC 84 SUBJECT ONONDAGA DAM STABILITY SHEET NO. 1 OF 3

CHKD. BY JB DATE 1/3/85 CASE IV SIMPLIFIED BISHOPS METHOD JOB NO.

PARTIAL POOL W/STEADY SEEPAGE



BY GGK DATE 13 DEC 84 SUBJECT .... SHEET NO. 2 OF 3
CHKD. BY GB DATE 1/3/85 JOB NO. ......

CASE IV CONT.

SLICE NO	Δx	HT RS	HT LS	$\overline{HT}$	AREA	W_s	W_L	W_i'	W_L
1	6	0	8	4	24	3.5	—	3.5	3.5
2	4	8	11	9.5	38	5.5	—	5.5	5.5
3	10	11	17	14	140	20.3	—	20.3	20.3
4	12	17	21	19	228	33.1	—	33.1	33.1
5	15	21	14	17.5	262.5	38.1	—	44.3	49.0
5'	15	0	10	5	75	10.9	6.2		
6	18	14	7	10.5	189	27.4	—	48.3	63.9
6'	18	10	18	14	252	36.5	20.9		
7	18	7	0	3.5	63	9.1	—	40.5	63.9
7'	18	18	24	21	378	54.8	31.4		
8	11	24	21	22.5	247.5	35.9	20.5	20.5	35.9
9	20	21	16	18.5	370	53.7	30.7	30.7	53.7
10	14	16	10	13	182	26.4	15.1	15.1	26.4
11	16	10	2	6	96	13.9	8.0	8.0	13.9
12	7	2	0	1	7	1.0	0.6	0.6	1.0

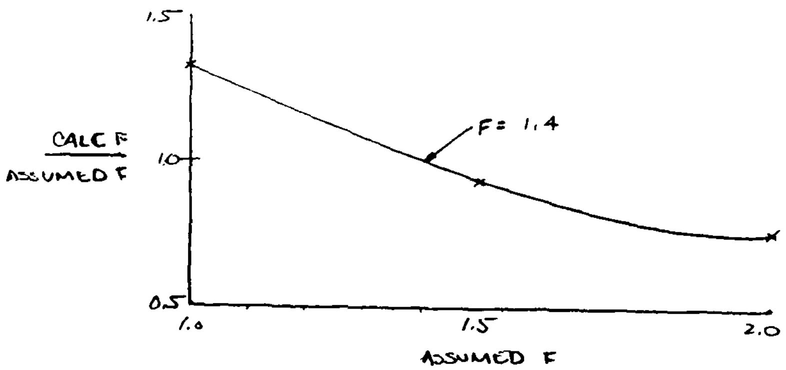
SLICE NO.	θ_i	$W_i \sin\theta_i$	$W_i \tan\phi$	$M_i(\theta)$			$W_i \tan\phi \div M_i(\theta)$		
				F=1.5	F=2.0	F=1.00	F=1.5	F=2.0	F=1.00
1	55.5	2.9	2.4	0.94	0.84	1.12	2.6	2.8	2.1
2	51	4.3	3.7	0.98	0.89	1.15	3.8	4.2	3.2
3	47	14.9	14.8	1.04	0.95	1.21	14.3	15.6	12.2
4	41	21.7	24.1	1.07	0.99	1.23	22.5	24.3	19.6
5	34	27.4	22.2	1.10	1.03	1.24	29.3	31.2	26.1
6	25	27.0	35.1	1.11	1.06	1.21	31.6	33.1	28.9
7	17.5	19.2	29.4	1.10	1.06	1.17	26.7	27.7	25.1
8	11	6.9	14.9	1.07	1.05	1.12	13.9	14.2	13.3
9	5	4.7	20.7	1.04	1.03	1.06	20.0	20.2	19.6
10	−2	−.9	10.2	0.98	.99	.98	10.4	10.3	10.5
11	−9	−8.2	5.4	0.92	.93	.88	5.9	5.8	6.1
12	−15	−.3	0.4	0.85	.88	.79	0.5	0.5	0.5
		125.6					181.5	189.9	167.2

FOR F = 1.5 $F = \frac{181.5}{125.6} = 1.45$

FOR F = 2.0 $F = \frac{189.9}{125.6} = 1.51$

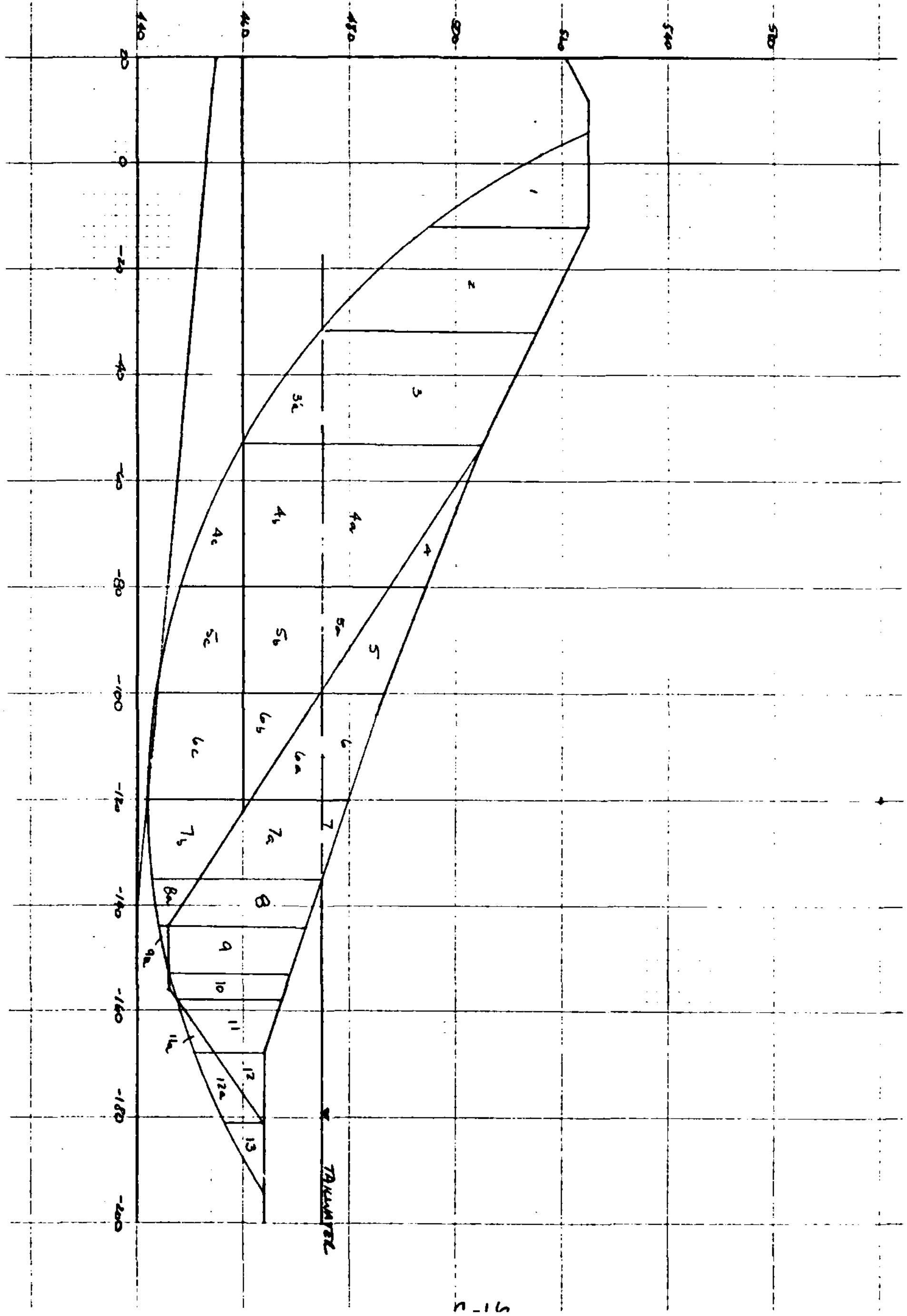
FOR F = 1.0 $F = \frac{167.2}{125.6} = 1.33$

ASSUMED F	CALC/ASSUMED F
1.0	1.33
1.5	0.94
2.0	0.76



BY CGK 14 OCT 84

ONONDAGA STABILITY ANALYSIS
SIMPLIFIED BISHOPS METHOD
CASE V STEADY SEEPAGE FROM
MAX POOL



BY GGK DATE 14 DEC 84 SUBJECT

CHKD. BY JB DATE 1/3/85

CASE V UNIT

JOB NO.

SLICE NO	HT LS	HT RS	$\overline{HT}$ FT	Δx FT	AREA FT^2	W_{SAT}	W_b	W_i'	W_i	θ_i
1	0	30	15	18	270	39.2	–	39.2	39.2	59
2	30	40	35	20	700	101.5	–	101.5	101.5	46
3	40	30	35	21	735	106.6	–	119.7	129.4	35
3a	0	15	7.5		157.5	22.8	13.1			
4	0	7	3.5		94.5	9.9	–			
4a	30	12.5	21.3		575.1	83.4	–			
4b	15	15	15	27	405	58.7	33.6	140.4	169.	24
4c	0	12	6		162	17.0	13.5			
5	7	12	9.5		190	20.0	–			
5a	12.5	0	6.3		126	18.3	–			
5b	15	15	15	20	300	43.5	29.7	86.4	111.2	13
5c	12	16	14		280	29.4	23.2			
6	12	5	7.5		150	15.8	–			
6a	0	13	6.5		130	13.7	5.6			
6b	15	0	7.5	20	150	21.8	6.5	42.5	87	5
6c	16	18	17		340	35.7	14.6			
7	5	0	2.5		37.5	3.9	–			
7a	13	23	18	15	270	28.4	11.6	24.2	53.6	-4
7b	18	9	13.5		202.5	21.3	8.7			
8	23	26	24.5		220.5	23.2	9.5			
8a	9	2	5.5	9	49.5	5.2	2.1	11.6	28.4	-9
9	26	23	24.5		2205	23.2	9.5			
9a	2	0	1	9	9	1.0	0.4	9.9	24.2	-13
10	23	19	21	5	105	11.0	4.5	4.5	11.0	-18
11	19	9	14		140	14.7	6.0			
11a	0	4	2	10	20	2.1	0.9	6.9	16.8	-20
12	9	0	4.5		58.5	6.1	2.5			
12a	4	7	5.5	13	71.5	7.5	3.1	5.6	13.6	-25
13	7	0	3.5	13	45.5	4.8	2.0	2.0	4.8	-31

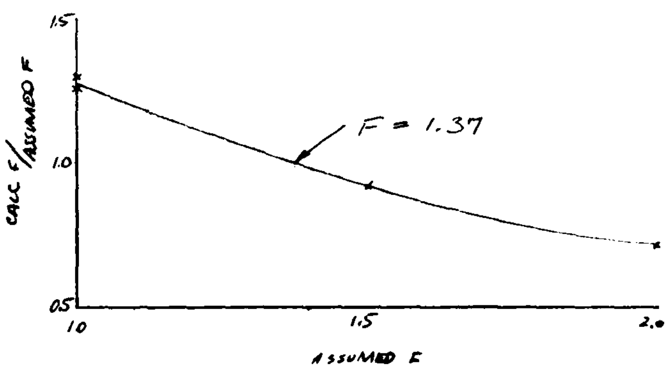
SLICE NO	$W_i \sin\theta$	$\tan\phi$	$W_i \tan\phi$	$M_i(\theta)$ F=2.0	F=1.0	F=1.5	$W_i \tan\phi - M_i(\theta)$ F=2.0	F=1.0	F=1.5
1	22.6	.727	28.5	.83	1.14	0.93	34.5	25.0	30.6
2	73.0	.727	73.8	.96	1.22	1.04	77.2	60.6	70.7
3	74.2	.727	87.0	1.03	1.24	1.10	84.7	70.4	79.3
4	68.7	.488	68.5	1.01	1.11	1.05	67.6	61.6	65.5
5	25.0	.488	42.2	1.03	1.08	1.05	41.0	38.9	40.3
6	7.6	.488	20.7	1.02	1.04	1.02	20.3	19.9	20.2
7	-3.7	.488	11.8	0.98	0.96	0.97	12.0	12.3	12.1
8	-4.4	.488	5.7	0.95	0.91	0.94	6.0	6.3	6.1
9	-5.4	.488	4.8	0.92	0.86	0.90	5.2	5.6	5.3
10	-3.4	.839	3.8	0.82	0.69	0.78	4.6	5.5	4.9
11	-5.8	.488	3.4	0.86	0.77	0.83	4.0	4.4	4.1
12	-5.8	.488	2.7	0.80	0.70	0.77	3.4	3.9	3.5
13	-2.5	.488	1.0	0.73	0.61	0.69	1.4	1.7	1.5
	251.1						361.9	316.1	344.1

FOR F = 2.0 $F = \frac{361.9}{251.1} = 1.44$

FOR F = 1.0 $F = \frac{316.1}{251.1} = 1.26$

FOR F = 1.5 $F = \frac{344.1}{251.1} = 1.37$

ASSUMED F	CALC F / ASSUMED F
1.0	1.26
1.5	0.91
2.0	0.72



BY CGK   DATE 14 DEC 84   SUBJECT ONONDAGA DAM STABILITY   SHEET NO. 1 OF 1
CHKD. BY   DATE   CASE VI: STEADY SEEPAGE W/   JOB NO.
SURCHARGE POOL

STEADY SEEPAGE W/ SURCHARGE POOL IS NOT APPLICABLE TO ONONDAGA DAM. THE CASE OF STEADY SEEPAGE WITH A POOL LOWER THAN MAX POOL YIELDS FAILURE SURFACES THAT DO NOT INTERSECT THE UPSTREAM SLOPE. SINCE THE EMBANKMENT IS 300 TIMES MORE PERVIOUS THAN THE IMPERVIOUS SECTION, CHANGES IN POOL EL. HAD A MINIMAL EFFECT ON THE DOWNSTREAM SLOPE AND THE CRITICAL FAILURE SURFACES

ONONDAGA DAM, NY

COMPUTER INPUT FILES

AND SAMPLE OUTPUT

APPENDIX D

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

COMPUTER INPUT FILES

AND SAMPLE OUTPUT

APPENDIX D

D1. This appendix contains a copy of all input data files used to compute the slope stability factor of safety in this analysis. Pages D2-6 are copies of the input instructions outlined in the User's Manual for WES Program I0009. Pages D7-16 are the input files and pages D17-49 are an example output for Case I Upstream Slope. The other output files are on file in the Geotechnical Section, Buffalo District.

D2. Input files are labeled according to the different cases set forth in EM 1110-2-1902.

Table 1

Detailed Input Instructions
SAVA104 Time Sharing Program for
Modified Swedish Method of Slope Stability Using Circular Arc

Variable Name	Definitions and Instructions for Executing Analyses	Reference Fig. No.	Reference Example Problem
	Input for Basic Data Files		
PROJE	Identification of your analysis		
NGRID	NGRID = 1, Grid system used for calculation of a factor of safety NGRID = 0, Nongrid analysis for a factor of safety If NGRID = 0, then DEL, XBG, YBG, XEND, YEND, TGLOWY, WL, and KOUTER = 0		
DEL	Increment (feet) in grid system (positive number)		
XBG	Abscissa of lower right grid point		
YBG	Ordinate of lower right grid point		
XEND	Abscissa of upper left grid point		
YEND	Ordinate of upper left grid point		
TGLOWY	Tangent elevation for base of circle		
WL	For EOC, WL = groundwater el (may be fictitious value lower than the ground level) SD, WL = pool el (before drawdown Two-force polygon scheme, WL = drawdown pool el for one-force polygon scheme SS, WL = tailwater el PP, WL = 0		
KOUTER	Number of embankment profile intersecting the groundwater level (WL); number of uppermost embankment profile for partial pool case Zero if WL is a fictitious value		
KST	Number of soil types including firm base		
KBASE	Number of last soil profile (firm base)		
BETAU	Angle of earth forces acting on the sides of slices measured clockwise from the positive x axis Zero if downstream analysis only		
BETAD	Angle of earth forces acting on the sides of slices measured counterclockwise from the negative x axis (US Analyses)		
BMAX	Selected maximum slice width; the program will locate slice boundaries at each break in the geometry of the embankment, additional boundaries are added so that the slices will have the selected BMAX		
NKB	Enter the number 1		
SOIL	Name of soil type		
KS	Number of soil type: KS = 1, first soil in the profile, KS = 2, second soil in profile, etc.		
GAMA(KS, 1)	Moist unit weight of soil, kips/cu ft		

Table 1 (con't)

Variable Name	Definitions and Instructions for Executing Analyses	Reference Fig. No.	Reference Example Problem
GAMA(KS, 2)	Saturated unit weight of soil, kips/cu ft		
QC2	Unit cohesion from the second segment of the Q strength envelope or equal to QC		
QTG2	Tan Ø from the second segment of the Q strength envelope or equal to QTG		
QC	Unit cohesion from the first segment of the Q strength envelope, kips/sq ft		
QTG	Tan Ø from the first segment of the Q strength envelope		
RC	Unit cohesion from the R strength envelope, kips/sq ft		
RTG	Tangent Ø from the R strength envelope		
SC	Unit cohesion from the S strength envelope, kips/sq ft		
STG	Tan Ø from the S strength envelope		
	Note: Repeat data groups D andE (see Table 2) for each soil type except the firm base. Soil data are not entered for the firm base.		
K	Number of embankment profile		
KPS	Number of soil type immediately under above profile		
NN1	Number of coordinate points required to define profile		
XP, YP	The abscissa and ordinate of the first point on the uppermost embankment profile. Continue with as many points as needed to define the first embankment profile.		
	Note: Repeat data groups F and G (see Table 2) to completely define all other profiles in the embankment from top to firm base		
	Input for Arc Data File		
NSLOP	Code number of slope analyzed NSLOPE = 1, upstream slope NSLOPE = 2, downstream slope		
NCASE	Code number for case analyzed NCASE = 1, end of construction NCASE = 2, sudden drawdown NCASE = 3, partial pool NCASE = 4, steady seepage		
NLEVEL	Code number for phreatic line in embankment NLEVEL = 1, horizontal line NLEVEL = 2, nonhorizontal line (steady seepage and sudden drawdown cases for a one force polygon scheme)		

Table 1 (con't)

Variable Name	Definitions and Instructions for Executing Analyses	Reference Fig. No.	Reference Example Problem
NPORE	Code number for source of pore pressure NPORE = 1, phreatic surface (horizontal or nonhorizontal) NPORE = 2, other sources (generally a flownet)		
NBETA	Enter the number 1 or 3 NBETA = 1, fixed direction of all side earth forces (the direction will be given in data group C, Table 1) NBETA = 3, vary direction of side earth forces (in embankment zone)		
EQCOE	Seismic coefficient for earthquake EQCOE = 0, no earthquake effects		
WLAFT	Drawdown pool elevation for sudden drawdown WLAFT = 0, all other cases		
KAFT	Code number of outer soil profile intersecting the water level (drawdown pool elevation, WLAFT) in the sudden drawdown case KAFT = 0, all other cases		
NW	Number of points required to define phreatic surface (NLEVEL = 2) NW = 0, for horizontal phreatic surface (i.e., NLEVEL = 1)		
NWAFT	NWAFT = 1, sudden drawdown case after the drawdown with one force polygon scheme (the phreatic line must be nonhorizontal) NWAFT = 0, all other cases		
DESCRI	Name of case analyzed (30 spaces for input)		
	Note: Data group J (Table 2) describe the direction of the side earth forces by specifying zones of varying direction (NBETA = 3 must have been entered in data group H, Table 2). OMIT data group J for all other cases.		
ZONEXI	Abscissa of first boundary		
BEI	Direction of side earth forces in zone specified by ZONEXI		
ZONEX2	Abscissa of the second boundary		
BE2	Direction of side earth forces in zone specified by ZONEX2		
XW, YW	Abscissa and ordinate, respectively, of the first point to define a nonhorizontal phreatic surface. Always enter points from right to left. All other points required to fully define the nonhorizontal phreatic surface should follow. OMIT for a horizontal phreatic surface.		
	Note: Data group L (Table 2) is used only for a nongrid system calculation of a factor of safety.		
M	Identification number of a trial arc (positive nonzero number). Use only for a nongrid case (NGRID = 0). OMIT for a grid system calculation of a factor of safety (NGRID = 1)		

Table 1 (con't)

Variable Name	Definitions and Instructions for Executing Analyses	Reference Fig. No.	Reference Example Problem
XOT, YOT	Abscissa and ordinate, respectively, of the center of the trial arc OMIT for a grid system calculation of a factor of safety (i.e., NGRID = 1)		
XTOET YTOET	Abscissa and ordinate of the exit point of the circle or XTOET = 0 and YTOET = tangent elevation for the circle		
WL	WL = goundwater level for the end of construction case WL = pool elevation before drawdown for the sudden drawdown case with a two force polygon scheme (i.e., horizontal phreatic surface) WL = drawdown pool elevation for the one force polygon scheme WL = pool elevation or the number 9999 for the partial pool case (i an actual pool elevation is entered, the analysis will be run for that pool elevation only; if the number 9999 is entered, the program will vary the pool level and search out the pool level which results in the lowest factor of safety for the particular circle being run)		
KOUTER	Code number of outer soil profile intersecting the water level entered in WL above; or the code number of the uppermost embankment profile for the partial pool case; or if WL is a fictitious value, KOUTER = 0		
M	Enter the number -1		

Table 2

Order of Input
SAVA104 Time Sharing Program for
Modified Swedish Method of Slope Stability Using Circular Arc

Data Group	Line No. Series* for Example Problems	Variables in Free-Field Input Data Files
		Basic Data File
A	100-199	PROJE
B	200-299	NGRID, DEL, XBG, YBG, XEND, YEND, TGLOWY, WL, KOUTER
C	300-399	KST, KBASE, BETAU, BETAD, BMAX, NKB
D**	400-499	SOIL
E**		KS, GAMA(KS, 1), GAMA(KS, 2), QC2, QTG2, QC, QTG, RC, RTG, SC, STG
F	500-599	K, KPS, NN1
G		XP, YP
		Arc Data File
H	700-799	NSLOP, NCASE, NLEVEL, NPORE, NBETA, EQCOE, WLAFT, KAFT, NW, NWAFT
I		DESCRI
J	800-899	ZONEX1, BE1, ZONEX2, BE2
K		XW, YW
L		M, XOT, YOT, XTOET, YTOET, WL, KOUTER
M	1000	M

* Suggested line numbering for free field input is consistent in all illustrations for ease in locating input variables in the input instructions and example problems.

** Repeat data groups D and E for each soil type except the firm base. Soil data are not entered for the firm base.

5 of 5

```
OLD,GGKUS1

/LIST
100  ONONDAGA DAM STABILITY CASE I US
200  1 40 40 540 200 700 424 461 0
300  6 6 338 338 20 1
400  IMPERVIOUS ZONE
402  1 .139 .145 0 .675 0 .675 0 .675 0 .675
410  PERVIOUS FILL
412  2 .143 .145 0 .727 0 .727 0 .727 0 .727
420  FLUVIAL OVERBANK
422  3 .105 .105 0 .425 0 .425 0 .425 0 .425
430  DELTAIC DEPOSIT
432  4 .119 .119 0 .7 0 .7 0 .7 0 .7
440  LACUSTRINE
442  5 .124 .124 0 .51 0 .51 0 .51 0 .51
500  1 1 6
502  -12 525 12 525 53 505 104 485 151 469 500 469
510  2 2 8
512  -168 464 -104 485 -53 505 -12 525 0 522 110 460 130 448 500 448
520  3 3 7
522  -500 464 -168 464 -122 460 110 460 118 455 130 448 500 448
530 4 4 6
533  -500 430 -140 430 0 455 118 455 130 448 500 448
540 5 5 6
542  -500 374 -260 373 -40 404 0 435 165 445 500 445
550  6 6 2
552  -500 345 500 345


/OLD,ADFF
/LIST
400 1,1,1,1,3,0,0,0,0,0
410 CASE I US
415 12 360 151 360
420 -1
```

```
OLD,GGKDS1

/LIST

100  ONONDAGA DAM STABILITY CASE I DS
200  1 40 -240 580 -80 740 422 461 0
300  6 6 0 338 20 1
400  RANDOM PERVIOUS
402  1 .143 .145 0 .727 0 .727 0 .727 0 .727
410  RIP RAP TOE
412  2 .105 .105 0 .839 0 .839 0 .839 0 .839
420  RANDOM PERVIOUS
422  3 .143 .145 0 .727 0 .727 0 .727 0 .727
430  FLUVIAL OVERBANK
432  4 .105 .105 0 .488 0 .488 0 .488 0 .488
440  DELTAIC
442  5 .119 .119 0 .7 0 .7 0 .7 0 .7
500  1 1 7
502  -181 464 -168 464 -104 485 -53 505 -12 525 12 525 151 469
510  2 2 4
512  -181 464 -168 464 -104 485 -53 505
520  3 3 4
522  -181 464 -156 446 -144 446 -53 505
530  4 4 6
532  -500 464 -181 464 -156 446 -144 446 -122 460 151 460
540  5 5 4
542  -500 440 -140 440 0 455 151 455
550  6 6 4
552  -500 374 -260 373 -40 404 500 404
/
OLD,ADFDS1

/LIST

400 2 1 1 1 3 0 0 0 0 0
410 CASE I DS
415 -168 360 -12 360
420 -1
/
```

```
/OLD,GGKSD1

/LIST
100  ONONDAGA DAM STABILITY CASE II SDD FROM MAX POOL
200  1 40 40 540 200 700 444 520.3 1
300  6 6 338 338 20 1
400  IMPERVIOUS ZONE
402  1 .139 .145 0 .675 0 .675 0 .675 0 .675
410  PERVIOUS FILL
412  2 .143 .145 0 .727 0 .727 0 .727 0 .727
420  FLUVIAL OVERBANK
422  3 .105 .105 0 .425 0 .425 0 .425 0 .425
430  DELTAIC DEPOSIT
432  4 .119 .119 0 .7 0 .7 0 .7 0 .7
440  LACUSTRINE
442  5 .124 .124 0 .51 0 .51 0 .51 0 .51
500  1 1 6
502  -12 525 12 525 53 505 104 485 151 469 500 469
510  2 2 8
512  -168 464 -104 485 -53 505 -12 525 0 522 110 460 130 448 500 448
520  3 3 7
522  -500 464 -168 464 -122 460 110 460 118 455 130 448 500 448
530 4 4 6
533  -500 440 -140 440 0 455 118 455 130 448 500 448
540 5 5 6
542  -500 374 -260 373 -40 404 0 435 165 445 500 445
550  6 6 2
552  -500 345 500 345


/OLD,ADFSD2

/LIST
400  1 2 1 1 3 0 470 1 0 0
410  CASE II SDD FROM MAX POOL
415  12 360 151 360
420  -1
```

```
/OLD,GGKSD2

/LIST
100  ONONDAGA DAM STABILITY CASE III SDD FROM SPILLWAY EL
200  1 40 40 540 200 700 464 504.5 1
300  6 6 338 338 20 1
400  IMPERVIOUS ZONE
402  1 .139 .145 0 .675 0 .675 0 .675 0 .675
410  PERVIOUS FILL
412  2 .143 .145 0 .727 0 .727 0 .727 0 .727
420  FLUVIAL OVERBANK
422  3 .105 .105 0 .425 0 .425 0 .425 0 .425
430  DELTAIC DEPOSIT
432  4 .119 .119 0 .7 0 .7 0 .7 0 .7
440  LACUSTRINE
442  5 .124 .124 0 .51 0 .51 0 .51 0 .51
500  1 1 6
502  -12 525 12 525 53 505 104 485 151 469 500 469
510  2 2 6
512  -168 464 -104 485 -53 505 -12 525 0 522 110 460
520  3 3 7
522  -500 464 -168 464 -122 460 110 460 118 455 130 448 500 448
530 4 4 6
533  -500 440 -140 440 0 455 118 455 130 448 500 448
540 5 5 6
542  -500 374 -260 373 -40 404 0 435 165 445 500 445
550  6 6 2
552  -500 345 500 345


/OLD,ADFSD3

/LIST
400  1 2 1 1 3 0 470 1 0 0
410  CASE III SDD FROM SPILLWAY EL
415  12 360 151 360
420  -1
```

```
/OLD,GGKPP

/LIST
100  ONONDAGA DAM STABILITY CASE  IV PP (SS)
200  1 40 40 540 200 700 434  0 1
300  6 6 338 338 20 1
400  IMPERVIOUS ZONE
402  1 .139 .145 0 .675 0 .675 0 .675 0 .675
410  PERVIOUS FILL
412  2 .143 .145 0 .727 0 .727 0 .727 0 .727
420  FLUVIAL OVERBANK
422  3 .105 .105 0 .425 0 .425 0 .425 0 .425
430  DELTAIC DEPOSIT
432  4 .119 .119 0 .7 0 .7 0 .7 0 .7
440  LACUSTRINE
442  5 .124 .124 0 .51 0 .51 0 .51 0 .51
500  1 1 6
502  -12 525 12 525 53 505 104 485 151 469 500 469
510  2 2 8
512  -168 464 -104 485 -53 505 -12 525 0 522 110 460 130 448 500 448
520  3 3 7
522  -500 464 -168 464 -122 460 110 460 118 455 130 448 500 448
530 4 4 6
533  -500 440 -140 440 0 455 118 455 130 448 500 448
540 5 5 6
542  -500 374 -260 373 -40 404 0 435 165 445 500 445
550  6 6 2
552  -500 345 500 345

/OLD,ADFPP

/LIST
400 1 3 1 1 3 0 0 0 0 0
410 CASE IV PP (SS)
415 12 360 151 360
420 -1
```

```
OLD,GGKSS1

/LIST

100  ONONDAGA DAM STABILITY CASE V SS MAX POOL DS
200  1 40 -160 540 -80 620 442 475 1
300  6 6 0 338 20 1
400  RANDOM PERVIOUS
402  1 .143 .145 0 .727 0 .727 0 .727 0 .727
410  RIP RAP TOE
412  2 .105 .105 0 .839 0 .839 0 .839 0 .839
420  RANDOM PERVIOUS
422  3 .143 .145 0 .727 0 .727 0 .727 0 .727
430  FLUVIAL OVERBANK
432  4 .105 .105 0 .488 0 .488 0 .488 0 .488
440  DELTAIC
442  5 .119 .119 0 .7 0 .7 0 .7 0 .7
500  1 1 7
502  -181 464 -168 464 -104 485 -53 505 -12 525 12 525 151 469
510  2 2 4
512  -181 464 -168 464 -104 485 -53 505
520  3 3 4
522  -181 464 -156 446 -144 446 -53 505
530  4 4 6
532  -500 464 -181 464 -156 446 -144 446 -122 460 151 460
540  5 5 4
542  -500 440 -140 440 0 455 151 455
550  6 6 4
552  -500 374 -260 373 -40 404 500 404
/
OLD,ADFSS1

/LIST

400 2 4 2 1 3 0 0 0 5 0
410 CASE V SS MAX POOL DS
415 -168 360 -12 360
417  -500 475 12 475  12 515 17 520 500 520
420 -1
/
```

```
OLD,GGKEQIA


/LIST
100  ONONDAGA DAM STABILITY CASE I US EQ LOAD
200  1 40 120 620 120 620 464 461 0
300  6 6 338 338 20 1
400  IMPERVIOUS ZONE
402  1 .139 .145 0 .675 0 .675 0 .675 0 .675
410  PERVIOUS FILL
412  2 .143 .145 0 .727 0 .727 0 .727 0 .727
420  FLUVIAL OVERBANK
422  3 .105 .105 0 .425 0 .425 0 .425 0 .425
430  DELTAIC DEPOSIT
432  4 .119 .119 0 .7 0 .7 0 .7 0 .7
440  LACUSTRINE
442  5 .124 .124 0 .51 0 .51 0 .51 0 .51
500  1 1 6
502  -12 525 12 525 53 505 104 485 151 469 500 469
510  2 2 8
512  -168 464 -104 485 -53 505 -12 525 0 522 110 460 130 448 500 448
520  3 3 7
522  -500 464 -168 464 -122 460 110 460 118 455 130 448 500 448
530 4 4 6
533  -500 440 -140 440 0 455 118 455 130 448 500 448
540 5 5 6
542  -500 374 -260 373 -40 404 0 435 165 445 500 445
550  6 6 2
552  -500 345 500 345


/OLD,ADFEQIA


/LIST
400 1,1,1,1,3,.05,0,0,0,0
410 CASE I US EQ CASE
415 12 360 151 360
420 -1
```

```
OLD,GGKEQIB

/LIST

100  ONONDAGA DAM STABILITY CASE I DS EQ LOAD
200  1 40 -160 620 -160 620 442 461 0
300  6 6 0 338 20 1
400  RANDOM PERVIOUS
402  1 .143 .145 0 .727 0 .727 0 .727 0 .727
410  RIP RAP TOE
412  2 .105 .105 0 .839 0 .839 0 .839 0 .839
420  RANDOM PERVIOUS
422  3 .143 .145 0 .727 0 .727 0 .727 0 .727
430  FLUVIAL OVERBANK
432  4 .105 .105 0 .488 0 .488 0 .488 0 .488
440  DELTAIC
442  5 .119 .119 0 .7 0 .7 0 .7 0 .7
500  1 1 7
502  -181 464 -168 464 -104 485 -53 505 -12 525 12 525 151 469
510  2 2 4
512  -181 464 -168 464 -104 485 -53 505
520  3 3 4
522  -181 464 -156 446 -144 446 -53 505
530  4 4 6
532  -500 464 -181 464 -156 446 -144 446 -122 460 151 460
540  5 5 4
542  -500 440 -140 440 0 455 151 455
550  6 6 4
552  -500 374 -260 373 -40 404 500 404
/
 OLD,ADFEQIB

/LIST

400 2 1 1 1 3 .05 0 0 0 0
410 CASE I DS EQ CASE
415 -168 360 -12 360
420 -1
/
```

```
/OLD,GGKPPEQ


/LIST
100  ONONDAGA DAM STABILITY CASE  IV PP (SS) EQ LOAD
200  1 40 120 620 120 620 464  0 1
300  6 6 338 338 20 1
400  IMPERVIOUS ZONE
402  1 .139 .145 0 .675 0 .675 0 .675 0 .675
410  PERVIOUS FILL
412  2 .143 .145 0 .727 0 .727 0 .727 0 .727
420  FLUVIAL OVERBANK
422  3 .105 .105 0 .425 0 .425 0 .425 0 .425
430  DELTAIC DEPOSIT
432  4 .119 .119 0 .7 0 .7 0 .7 0 .7
440  LACUSTRINE
442  5 .124 .124 0 .51 0 .51 0 .51 0 .51
500  1 1 6
502  -12 525 12 525 53 505 104 485 151 469 500 469
510  2 2 8
512  -168 464 -104 485 -53 505 -12 525 0 522 110 460 130 448 500 448
520  3 3 7
522  -500 464 -168 464 -122 460 110 460 118 455 130 448 500 448
530 4 4 6
533  -500 440 -140 440 0 455 118 455 130 448 500 448
540 5 5 6
542  -500 374 -260 373 -40 404 0 435 165 445 500 445
550  6 6 2
552  -500 345 500 345


/OLD,ADFPPEQ


/LIST
400 1 3 1 1 3 .05 0 0 0 0
410 CASE IV PP (SS)EQ LOAD
415 12 360 151 360
420 -1
```

```
/OLD,GGKSSEQ


/LIST
100  ONONDAGA DAM STABILITY CASE V SS MAX POOL DS EQ LOAD
200  1 40 -120 580 -120 580 442 475 1
300  6 6 0 338 20 1
400  RANDOM PERVIOUS
402  1 .143 .145 0 .727 0 .727 0 .727 0 .727
410  RIP RAP TOE
412  2 .105 .105 0 .839 0 .839 0 .839 0 .839
420  RANDOM PERVIOUS
422  3 .143 .145 0 .727 0 .727 0 .727 0 .727
430  FLUVIAL OVERBANK
432  4 .105 .105 0 .488 0 .488 0 .488 0 .488
440  DELTAIC
442  5 .119 .119 0 .7 0 .7 0 .7 0 .7
500  1 1 7
502  -181 464 -168 464 -104 485 -53 505 -12 525 12 525 151 469
510  2 2 4
512  -181 464 -168 464 -104 485 -53 505
520  3 3 4
522  -181 464 -156 446 -144 446 -53 505
530  4 4 6
532  -500 464 -181 464 -156 446 -144 446 -122 460 151 460
540  5 5 4
542  -500 440 -140 440 0 455 151 455
550  6 6 4
552  -500 374 -260 373 -40 404 500 404


/OLD,ADFSSEQ


/LIST
400 2 4 2 1 3 .05 0 0 5 0
410 CASE V SS MAX POOL DS EQ LOAD
415 -168 360 -12 360
417  -500 475 12 475  12 515 17 520 500 520
420 -1
```

```
GET,CORPS/UN=CECELB
/BEGIN,,CORPS,I0009

****************************
* CORPS PROGRAM # I0009    *
*      VERSION # 83/10/01 *
****************************

 INPUT,NAME OF BASIC DATA FILE
? GGKUS1
PERM FILE GGKUS1  COPIED TO LOCAL FILE TAPE1
PROJECT    ONONDAGA DAM STABILITY CASE I US
 INPUT,NAME OF THE ARC DATA FILE
? ADFF
PERM FILE ADFF    COPIED TO LOCAL FILE TAPE1


* * * ARC    1 * * *
ARC NO.=   1   CENTER(X,Y)=  40.00, 540.00   EXIT(X,Y)= 135.57, 474.25
RAD.= 116.00   LOWEST Y= 424.00     SLICE NO.= 19        WL= 461.00
 CASE I US

FS=   7.942,  E.C.=    -.00


* * * ARC    2 * * *
ARC NO.=   2   CENTER(X,Y)=  80.00, 540.00   EXIT(X,Y)= 171.73, 469.00
RAD.= 116.00   LOWEST Y= 424.00     SLICE NO.= 19        WL= 461.00
 CASE I US

FS=   3.215,  E.C.=    -.01


* * * ARC    3 * * *
ARC NO.=   3   CENTER(X,Y)= 120.00, 540.00   EXIT(X,Y)= 211.73, 469.00
RAD.= 116.00   LOWEST Y= 424.00     SLICE NO.= 21        WL= 461.00
 CASE I US

FS=   2.805,  E.C.=     .01


* * * ARC    4 * * *
ARC NO.=   4   CENTER(X,Y)= 160.00, 540.00   EXIT(X,Y)= 251.73, 469.00
RAD.= 116.00   LOWEST Y= 424.00     SLICE NO.= 20        WL= 461.00
 CASE I US

FS=   3.765,  E.C.=    -.02
```

```
* * * ARC    5 * * *
ARC NO.=   5   CENTER(X,Y)= 200.00, 540.00   EXIT(X,Y)= 291.73, 469.00
RAD.= 116.00    LOWEST Y= 424.00    SLICE NO.= 16        WL= 461.00
 CASE I US

FS=  8.340,  E.C.=    -.00


* * * ARC    6 * * *
ARC NO.=   6   CENTER(X,Y)=  40.00, 580.00   EXIT(X,Y)= 149.97, 469.35
RAD.= 156.00    LOWEST Y= 424.00    SLICE NO.= 21        WL= 461.00
 CASE I US

FS=  6.700,  E.C.=    -.00


* * * ARC    7 * * *
ARC NO.=   7   CENTER(X,Y)=  80.00, 580.00   EXIT(X,Y)= 189.61, 469.00
RAD.= 156.00    LOWEST Y= 424.00    SLICE NO.= 22        WL= 461.00
 CASE I US

FS=  3.095,  E.C.=    -.05


* * * ARC    8 * * *
ARC NO.=   8   CENTER(X,Y)= 120.00, 580.00   EXIT(X,Y)= 229.61, 469.00
RAD.= 156.00    LOWEST Y= 424.00    SLICE NO.= 22        WL= 461.00
 CASE I US

FS=  2.480,  E.C.=     .07


* * * ARC    9 * * *
ARC NO.=   9   CENTER(X,Y)= 160.00, 580.00   EXIT(X,Y)= 269.61, 469.00
RAD.= 156.00    LOWEST Y= 424.00    SLICE NO.= 21        WL= 461.00
 CASE I US

FS=  2.962,  E.C.=     .05


* * * ARC   10 * * *
ARC NO.=  10   CENTER(X,Y)= 200.00, 580.00   EXIT(X,Y)= 309.61, 469.00
RAD.= 156.00    LOWEST Y= 424.00    SLICE NO.= 20        WL= 461.00
 CASE I US

FS=  5.549,  E.C.=    -.06
```

```
* * * ARC  11 * * *
ARC NO.=  11   CENTER(X,Y)=  40.00, 620.00   EXIT(X,Y)= 164.96, 469.00
RAD.= 196.00   LOWEST Y= 424.00    SLICE NO.= 23       WL= 461.00
 CASE I US

FS=  7.153,  E.C.=   -.03


* * * ARC  12 * * *
ARC NO.=  12   CENTER(X,Y)=  80.00, 620.00   EXIT(X,Y)= 204.96, 469.00
RAD.= 196.00   LOWEST Y= 424.00    SLICE NO.= 22       WL= 461.00
 CASE I US

FS=  3.430,  E.C.=    .04


* * * ARC  13 * * *
ARC NO.=  13   CENTER(X,Y)= 120.00, 620.00   EXIT(X,Y)= 244.96, 469.00
RAD.= 196.00   LOWEST Y= 424.00    SLICE NO.= 24       WL= 461.00
 CASE I US

FS=  2.707,  E.C.=    .00


* * * ARC  14 * * *
ARC NO.=  14   CENTER(X,Y)= 160.00, 620.00   EXIT(X,Y)= 284.96, 469.00
RAD.= 196.00   LOWEST Y= 424.00    SLICE NO.= 24       WL= 461.00
 CASE I US

FS=  2.666,  E.C.=    .00


* * * ARC  15 * * *
ARC NO.=  15   CENTER(X,Y)= 200.00, 620.00   EXIT(X,Y)= 324.96, 469.00
RAD.= 196.00   LOWEST Y= 424.00    SLICE NO.= 22       WL= 461.00
 CASE I US

FS=  4.220,  E.C.=   -.01


* * * ARC  16 * * *
ARC NO.=  16   CENTER(X,Y)=  40.00, 660.00   EXIT(X,Y)= 178.62, 469.00
RAD.= 236.00   LOWEST Y= 424.00    SLICE NO.= 25       WL= 461.00
 CASE I US

FS=  7.040,  E.C.=   -.01
```

```
* * * ARC  17 * * *
ARC NO.=  17   CENTER(X,Y)=  80.00, 660.00   EXIT(X,Y)= 218.62, 469.00
RAD.= 236.00   LOWEST Y= 424.00     SLICE NO.= 24        WL= 461.00
 CASE I US

FS=  3.849,  E.C.=     .00


* * * ARC  18 * * *
ARC NO.=  18   CENTER(X,Y)= 120.00, 660.00   EXIT(X,Y)= 258.62, 469.00
RAD.= 236.00   LOWEST Y= 424.00     SLICE NO.= 26        WL= 461.00
 CASE I US

FS=  2.955,  E.C.=     .08


* * * ARC  19 * * *
ARC NO.=  19   CENTER(X,Y)= 160.00, 660.00   EXIT(X,Y)= 298.62, 469.00
RAD.= 236.00   LOWEST Y= 424.00     SLICE NO.= 25        WL= 461.00
 CASE I US

FS=  2.707,  E.C.=     .00


* * * ARC  20 * * *
ARC NO.=  20   CENTER(X,Y)= 200.00, 660.00   EXIT(X,Y)= 338.62, 469.00
RAD.= 236.00   LOWEST Y= 424.00     SLICE NO.= 25        WL= 461.00
 CASE I US

FS=  3.444,  E.C.=     .04
ANALYSES ABOVE ARE STORED IN LOCAL FILE TAPE7


* * * ARC  21 * * *
ARC NO.=  21   CENTER(X,Y)=  40.00, 700.00   EXIT(X,Y)= 191.05, 469.00
RAD.= 276.00   LOWEST Y= 424.00     SLICE NO.= 26        WL= 461.00
 CASE I US

FS=  8.745,  E.C.=    -.05


* * * ARC  22 * * *
ARC NO.=  22   CENTER(X,Y)=  80.00, 700.00   EXIT(X,Y)= 231.05, 469.00
RAD.= 276.00   LOWEST Y= 424.00     SLICE NO.= 27        WL= 461.00
 CASE I US

FS=  4.293,  E.C.=     .01
```

```
* * * ARC   23 * * *
ARC NO.=   23   CENTER(X,Y)= 120.00, 700.00   EXIT(X,Y)= 271.05, 469.00
RAD.= 276.00    LOWEST Y= 424.00     SLICE NO.= 26        WL= 461.00
 CASE I US

FS=   3.222,  E.C.=     .07


* * * ARC   24 * * *
ARC NO.=   24   CENTER(X,Y)= 160.00, 700.00   EXIT(X,Y)= 311.05, 469.00
RAD.= 276.00    LOWEST Y= 424.00     SLICE NO.= 26        WL= 461.00
 CASE I US

FS=   2.878,  E.C.=    -.09


* * * ARC   25 * * *
ARC NO.=   25   CENTER(X,Y)= 200.00, 700.00   EXIT(X,Y)= 351.05, 469.00
RAD.= 276.00    LOWEST Y= 424.00     SLICE NO.= 27        WL= 461.00
 CASE I US

FS=   3.163,  E.C.=    -.01


LIST OF ARC/FS FOR LOWEST Y=  424.00,  NO.OF ARC/FS
   1/ 7.942,   2/ 3.215,   3/ 2.805,   4/ 3.765,   5/ 8.340,   6/ 6.700,   7/ 3.095,   8/ 2.480,   9/ 2.962,  10/ 5.549,
  11/ 7.153,  12/ 3.430,  13/ 2.707,  14/ 2.666,  15/ 4.220,  16/ 7.840,  17/ 3.849,  18/ 2.955,  19/ 2.707,  20/ 3.444,
  21/ 8.745,  22/ 4.293,  23/ 3.222,  24/ 2.878,  25/ 3.163,

THE MIN FS IS 2.480,  AT CENTER NO.   8

ANALYSES ABOVE ARE STORED IN LOCAL FILE TAPE8
 CODE: 1:NEW ARC FILE.  2:RERUN AN ARC.  3:MODIFY GRID.  4:STOP
? 3
 READ NEW GRID, 8 VAR. :
 DEL,XBC,YBC,XEND,YEND,TGLOWY,WL,KOUTER
? 40 40 540 200 700 434 461 0


* * * ARC    1 * * *
ARC NO.=    1   CENTER(X,Y)=  40.00, 540.00   EXIT(X,Y)= 125.70, 477.61
RAD.= 106.00    LOWEST Y= 434.00     SLICE NO.= 17        WL= 461.00
 CASE I US

FS=   7.272,  E.C.=    -.03
```

```
* * * ARC    2 * * *
ARC NO.=    2   CENTER(X,Y)=  80.00, 540.00   EXIT(X,Y)= 158.71, 469.00
RAD.= 106.00    LOWEST Y= 434.00     SLICE NO.= 18        WL= 461.00
 CASE I US

FS=   3.154,  E.C.=    -.04


* * * ARC    3 * * *
ARC NO.=    3   CENTER(X,Y)= 120.00, 540.00   EXIT(X,Y)= 198.71, 469.00
RAD.= 106.00    LOWEST Y= 434.00     SLICE NO.= 18        WL= 461.00
 CASE I US

FS=   2.663,  E.C.=    -.01


* * * ARC    4 * * *
ARC NO.=    4   CENTER(X,Y)= 160.00, 540.00   EXIT(X,Y)= 238.71, 469.00
RAD.= 106.00    LOWEST Y= 434.00     SLICE NO.= 17        WL= 461.00
 CASE I US

FS=   3.815,  E.C.=    -.03


* * * ARC    5 * * *
ARC NO.=    5   CENTER(X,Y)= 200.00, 540.00   EXIT(X,Y)= 278.71, 469.00
RAD.= 106.00    LOWEST Y= 434.00     SLICE NO.= 13        WL= 461.00
 CASE I US

FS=  12.562,  E.C.=    -.01


* * * ARC    6 * * *
ARC NO.=    6   CENTER(X,Y)=  40.00, 580.00   EXIT(X,Y)= 139.31, 472.98
RAD.= 146.00    LOWEST Y= 434.00     SLICE NO.= 19        WL= 461.00
 CASE I US

FS=   6.483,  E.C.=    -.06


* * * ARC    7 * * *
ARC NO.=    7   CENTER(X,Y)=  80.00, 580.00   EXIT(X,Y)= 174.84, 469.00
RAD.= 146.00    LOWEST Y= 434.00     SLICE NO.= 19        WL= 461.00
 CASE I US

FS=   2.915,  E.C.=     .02
```

* * * ARC 8 * * *
ARC NO.= 8 CENTER(X,Y)= 120.00, 580.00 EXIT(X,Y)= 214.84, 469.00
RAD.= 146.00 LOWEST Y= 434.00 SLICE NO.= 21 WL= 461.00
CASE I US

FS=
2.362, E.C.= .00

* * * ARC 9 * * *
ARC NO.= 9 CENTER(X,Y)= 160.00, 580.00 EXIT(X,Y)= 254.84, 469.00
RAD.= 146.00 LOWEST Y= 434.00 SLICE NO.= 19 WL= 461.00
CASE I US

FS= 3.047, E.C.= .02

* * * ARC 10 * * *
ARC NO.= 10 CENTER(X,Y)= 200.00, 580.00 EXIT(X,Y)= 294.84, 469.00
RAD.= 146.00 LOWEST Y= 434.00 SLICE NO.= 15 WL= 461.00
CASE I US

FS= 6.657, E.C.= -.01

* * * ARC 11 * * *
ARC NO.= 11 CENTER(X,Y)= 40.00, 620.00 EXIT(X,Y)= 149.37, 469.55
RAD.= 186.00 LOWEST Y= 434.00 SLICE NO.= 19 WL= 461.00
CASE I US

FS= 6.691, E.C.= -.10

* * * ARC 12 * * *
ARC NO.= 12 CENTER(X,Y)= 80.00, 620.00 EXIT(X,Y)= 188.60, 469.00
RAD.= 186.00 LOWEST Y= 434.00 SLICE NO.= 20 WL= 461.00
CASE I US

FS= 3.310, E.C.= .01

* * * ARC 13 * * *
ARC NO.= 13 CENTER(X,Y)= 120.00, 620.00 EXIT(X,Y)= 228.60, 469.00
RAD.= 186.00 LOWEST Y= 434.00 SLICE NO.= 21 WL= 461.00
CASE I US

FS= 2.499, E.C.= .01

```
* * * ARC  14 * * *
ARC NO.=  14  CENTER(X,Y)= 160.00, 620.00  EXIT(X,Y)= 268.60, 469.00
RAD.= 186.00  LOWEST Y= 434.00    SLICE NO.= 22       WL= 461.00
 CASE I US

FS=  2.658,  E.C.=   -.01


* * * ARC  15 * * *
ARC NO.=  15  CENTER(X,Y)= 200.00, 620.00  EXIT(X,Y)= 308.60, 469.00
RAD.= 186.00  LOWEST Y= 434.00    SLICE NO.= 20       WL= 461.00
 CASE I US

FS=  4.786,  E.C.=   -.01
ANALYSES ABOVE ARE STORED IN LOCAL FILE TAPE11


* * * ARC  16 * * *
ARC NO.=  16  CENTER(X,Y)=  40.00, 660.00  EXIT(X,Y)= 160.81, 469.00
RAD.= 226.00  LOWEST Y= 434.00    SLICE NO.= 21       WL= 461.00
 CASE I US

FS=  7.115,  E.C.=   -.01


* * * ARC  17 * * *
ARC NO.=  17  CENTER(X,Y)=  80.00, 660.00  EXIT(X,Y)= 200.81, 469.00
RAD.= 226.00  LOWEST Y= 434.00    SLICE NO.= 23       WL= 461.00
 CASE I US

FS=  3.653,  E.C.=    .00


* * * ARC  18 * * *
ARC NO.=  18  CENTER(X,Y)= 120.00, 660.00  EXIT(X,Y)= 240.81, 469.00
RAD.= 226.00  LOWEST Y= 434.00    SLICE NO.= 23       WL= 461.00
 CASE I US

FS=  2.767,  E.C.=    .05


* * * ARC  19 * * *
ARC NO.=  19  CENTER(X,Y)= 160.00, 660.00  EXIT(X,Y)= 280.81, 469.00
RAD.= 226.00  LOWEST Y= 434.00    SLICE NO.= 25       WL= 461.00
 CASE I US

FS=  2.621,  E.C.=    .01
```

* * * ARC 20 * * *
ARC NO.= 20 CENTER(X,Y)= 200.00, 660.00 EXIT(X,Y)= 320.81, 469.00
RAD.= 226.00 LOWEST Y= 434.00 SLICE NO.= 23 WL= 461.00
CASE I US

FS= 3.831, E.C.= -.09

* * * ARC 21 * * *
ARC NO.= 21 CENTER(X,Y)= 40.00, 700.00 EXIT(X,Y)= 171.89, 469.00
RAD.= 266.00 LOWEST Y= 434.00 SLICE NO.= 24 WL= 461.00
CASE I US

FS= 7.798, E.C.= -.04

* * * ARC 22 * * *
ARC NO.= 22 CENTER(X,Y)= 80.00, 700.00 EXIT(X,Y)= 211.89, 469.00
RAD.= 266.00 LOWEST Y= 434.00 SLICE NO.= 23 WL= 461.00
CASE I US

FS= 4.016, E.C.= .01

* * * ARC 23 * * *
ARC NO.= 23 CENTER(X,Y)= 120.00, 700.00 EXIT(X,Y)= 251.89, 469.00
RAD.= 266.00 LOWEST Y= 434.00 SLICE NO.= 25 WL= 461.00
CASE I US

FS= 3.111, E.C.= .00

* * * ARC 24 * * *
ARC NO.= 24 CENTER(X,Y)= 160.00, 700.00 EXIT(X,Y)= 291.89, 469.00
RAD.= 266.00 LOWEST Y= 434.00 SLICE NO.= 25 WL= 461.00
CASE I US

FS= 2.743, E.C.= .00

* * * ARC 25 * * *
ARC NO.= 25 CENTER(X,Y)= 200.00, 700.00 EXIT(X,Y)= 331.89, 469.00
RAD.= 266.00 LOWEST Y= 434.00 SLICE NO.= 25 WL= 461.00
CASE I US

FS= 3.279, E.C.= .02

```
LIST OF ARC/FS FOR LOWEST Y=  434.00,  NO.OF ARC/FS
   1/ 7.272,   2/ 3.154,   3/ 2.663,   4/ 3.815,   5/12.562,   6/ 6.483,   7/ 2.915,   8/ 2.362,   9/ 3.047,  10/ 6.657,
  11/ 6.691,  12/ 3.310,  13/ 2.499,  14/ 2.658,  15/ 4.786,  16/ 7.115,  17/ 3.653,  18/ 2.767,  19/ 2.621,  20/ 3.831,
  21/ 7.788,  22/ 4.016,  23/ 3.111,  24/ 2.743,  25/ 3.279,

THE MIN FS IS 2.362,  AT CENTER NO.   8


ANALYSES ABOVE ARE STORED IN LOCAL FILE TAPE12
 CODE: 1:NEW ARC FILE.  2:RERUN AN ARC.  3:MODIFY GRID.  4:STOP
? 3
 READ NEW GRID, 8 VAR. :
 DEL,XBC,YBC,XEND,YEND,TGLOWY,WL,KOUTER
? 40 40 540 200 700 444 461 0


* * * ARC    1 * * *
ARC NO.=   1   CENTER(X,Y)=  40.00, 540.00   EXIT(X,Y)= 115.73, 481.01
RAD.=  96.00    LOWEST Y= 444.00     SLICE NO.= 15        WL= 461.00
 CASE I US

FS=  6.483,  E.C.=   -.02


* * * ARC    2 * * *
ARC NO.=   2   CENTER(X,Y)=  80.00, 540.00   EXIT(X,Y)= 146.32, 470.59
RAD.=  96.00    LOWEST Y= 444.00     SLICE NO.= 14        WL= 461.00
 CASE I US

FS=  3.155,  E.C.=   -.01


* * * ARC    3 * * *
ARC NO.=   3   CENTER(X,Y)= 120.00, 540.00   EXIT(X,Y)= 184.61, 469.00
RAD.=  96.00    LOWEST Y= 444.00     SLICE NO.= 14        WL= 461.00
 CASE I US

FS=  2.900,  E.C.=   -.02


* * * ARC    4 * * *
ARC NO.=   4   CENTER(X,Y)= 160.00, 540.00   EXIT(X,Y)= 224.61, 469.00
RAD.=  96.00    LOWEST Y= 444.00     SLICE NO.= 16        WL= 461.00
 CASE I US

FS=  4.062,  E.C.=   -.00
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```
* * * ARC   5 * * *
ARC NO.=   5   CENTER(X,Y)= 200.00, 540.00   EXIT(X,Y)= 264.61, 469.00
RAD.=  96.00   LOWEST Y= 444.00     SLICE NO.= 10        WL= 461.00
 CASE I US

FS=  25.671,  E.C.=    -.04


* * * ARC   6 * * *
ARC NO.=   6   CENTER(X,Y)=  40.00, 580.00   EXIT(X,Y)= 128.44, 476.68
RAD.= 136.00   LOWEST Y= 444.00     SLICE NO.= 17        WL= 461.00
 CASE I US

FS=   6.269,  E.C.=    -.01


* * * ARC   7 * * *
ARC NO.=   7   CENTER(X,Y)=  80.00, 580.00   EXIT(X,Y)= 158.58, 469.00
RAD.= 136.00   LOWEST Y= 444.00     SLICE NO.= 17        WL= 461.00
 CASE I US

FS=   3.078,  E.C.=     .00


* * * ARC   8 * * *
ARC NO.=   8   CENTER(X,Y)= 120.00, 580.00   EXIT(X,Y)= 198.58, 469.00
RAD.= 136.00   LOWEST Y= 444.00     SLICE NO.= 19        WL= 461.00
 CASE I US

FS=   2.507,  E.C.=     .01


* * * ARC   9 * * *
ARC NO.=   9   CENTER(X,Y)= 160.00, 580.00   EXIT(X,Y)= 238.58, 469.00
RAD.= 136.00   LOWEST Y= 444.00     SLICE NO.= 18        WL= 461.00
 CASE I US

FS=   3.389,  E.C.=    -.01


* * * ARC  10 * * *
ARC NO.=  10   CENTER(X,Y)= 200.00, 580.00   EXIT(X,Y)= 278.58, 469.00
RAD.= 136.00   LOWEST Y= 444.00     SLICE NO.= 12        WL= 461.00
 CASE I US

FS=  10.308,  E.C.=    -.03
ANALYSES ABOVE ARE STORED IN LOCAL FILE TAPE11
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```
* * * ARC  11 * * *
ARC NO.=  11  CENTER(X,Y)=  40.00, 620.00  EXIT(X,Y)= 137.42, 473.55
RAD.= 176.00  LOWEST Y= 444.00    SLICE NO.= 18     WL= 461.00
 CASE I US

FS=  6.710,  E.C.=   -.00


* * * ARC  12 * * *
ARC NO.=  12  CENTER(X,Y)=  80.00, 620.00  EXIT(X,Y)= 170.42, 469.00
RAD.= 176.00  LOWEST Y= 444.00    SLICE NO.= 18     WL= 461.00
 CASE I US

FS=  3.443,  E.C.=    .04


* * * ARC  13 * * *
ARC NO.=  13  CENTER(X,Y)= 120.00, 620.00  EXIT(X,Y)= 210.42, 469.00
RAD.= 176.00  LOWEST Y= 444.00    SLICE NO.= 19     WL= 461.00
 CASE I US

FS=  2.557,  E.C.=    .03


* * * ARC  14 * * *
ARC NO.=  14  CENTER(X,Y)= 160.00, 620.00  EXIT(X,Y)= 250.42, 469.00
RAD.= 176.00  LOWEST Y= 444.00    SLICE NO.= 19     WL= 461.00
 CASE I US

FS=  2.894,  E.C.=   -.01


* * * ARC  15 * * *
ARC NO.=  15  CENTER(X,Y)= 200.00, 620.00  EXIT(X,Y)= 290.42, 469.00
RAD.= 176.00  LOWEST Y= 444.00    SLICE NO.= 13     WL= 461.00
 CASE I US

FS=  6.514,  E.C.=   -.00


* * * ARC  16 * * *
ARC NO.=  16  CENTER(X,Y)=  40.00, 660.00  EXIT(X,Y)= 144.78, 471.12
RAD.= 216.00  LOWEST Y= 444.00    SLICE NO.= 19     WL= 461.00
 CASE I US

FS=  7.320,  E.C.=   -.01
```

```
* * * ARC   17 * * *
ARC NO.=   17   CENTER(X,Y)=  80.00, 660.00   EXIT(X,Y)= 180.87, 469.00
RAD.= 216.00    LOWEST Y= 444.00      SLICE NO.= 19         WL= 461.00
 CASE I US

FS=   3.734,  E.C.=     .02


* * * ARC   18 * * *
ARC NO.=   18   CENTER(X,Y)= 120.00, 660.00   EXIT(X,Y)= 220.87, 469.00
RAD.= 216.00    LOWEST Y= 444.00      SLICE NO.= 20         WL= 461.00
 CASE I US

FS=   2.789,  E.C.=     .02


* * * ARC   19 * * *
ARC NO.=   19   CENTER(X,Y)= 160.00, 660.00   EXIT(X,Y)= 260.87, 469.00
RAD.= 216.00    LOWEST Y= 444.00      SLICE NO.= 22         WL= 461.00
 CASE I US

FS=   2.716,  E.C.=     .08


* * * ARC   20 * * *
ARC NO.=   20   CENTER(X,Y)= 200.00, 660.00   EXIT(X,Y)= 300.87, 469.00
RAD.= 216.00    LOWEST Y= 444.00      SLICE NO.= 18         WL= 461.00
 CASE I US

FS=   4.880,  E.C.=    -.02


* * * ARC   21 * * *
ARC NO.=   21   CENTER(X,Y)=  40.00, 700.00   EXIT(X,Y)= 150.61, 469.13
RAD.= 256.00    LOWEST Y= 444.00      SLICE NO.= 20         WL= 461.00
 CASE I US

FS=   7.975,  E.C.=    -.02


* * * ARC   22 * * *
ARC NO.=   22   CENTER(X,Y)=  80.00, 700.00   EXIT(X,Y)= 190.34, 469.00
RAD.= 256.00    LOWEST Y= 444.00      SLICE NO.= 22         WL= 461.00
 CASE I US

FS=   4.108,  E.C.=     .03
```

```
* * * ARC   23 * * *
ARC NO.=   23   CENTER(X,Y)= 120.00, 700.00   EXIT(X,Y)= 230.34, 469.00
RAD.= 256.00   LOWEST Y= 444.00     SLICE NO.= 20        WL= 461.00
 CASE I US

FS=  3.064,  E.C.=    .02


* * * ARC   24 * * *
ARC NO.=   24   CENTER(X,Y)= 160.00, 700.00   EXIT(X,Y)= 270.34, 469.00
RAD.= 256.00   LOWEST Y= 444.00     SLICE NO.= 22        WL= 461.00
 CASE I US

FS=  2.764,  E.C.=    .04


* * * ARC   25 * * *
ARC NO.=   25   CENTER(X,Y)= 200.00, 700.00   EXIT(X,Y)= 310.34, 469.00
RAD.= 256.00   LOWEST Y= 444.00     SLICE NO.= 22        WL= 461.00
 CASE I US

FS=  3.941,  E.C.=    .02


LIST OF ARC/FS FOR LOWEST Y=  444.00,  NO.OF ARC/FS
   1/ 6.483,  2/ 3.155,   3/ 2.900,   4/ 4.062,   5/25.671,   6/ 6.269,   7/ 3.078,   8/ 2.507,   9/ 3.389,  10/10.308,
  11/ 6.710,  12/ 3.443,  13/ 2.557,  14/ 2.894,  15/ 6.514,  16/ 7.320,  17/ 3.734,  18/ 2.789,  19/ 2.716,  20/ 4.880,
  21/ 7.975,  22/ 4.188,  23/ 3.064,  24/ 2.764,  25/ 3.941,

THE MIN FS IS 2.507,  AT CENTER NO.   8


ANALYSES ABOVE ARE STORED IN LOCAL FILE TAPE12
 CODE: 1:NEW ARC FILE.  2:RERUN AN ARC.  3:MODIFY GRID.  4:STOP
? 3
 READ NEW GRID, 8 VAR. :
 DEL,XBC,YBC,XEND,YEND,TCLOWY,WL,KOUTER
? 40 40 540 200 700 454 461 0


* * * ARC    1 * * *
ARC NO.=    1   CENTER(X,Y)=  40.00, 540.00   EXIT(X,Y)= 105.64, 484.44
RAD.=  86.00   LOWEST Y= 454.00     SLICE NO.= 12        WL= 461.00
 CASE I US

FS=  5.817,  E.C.=   -.08
```

```
* * * ARC    2 * * *
ARC NO.=    2   CENTER(X,Y)=  80.00, 540.00   EXIT(X,Y)= 135.48, 474.28
RAD.=  86.00    LOWEST Y= 454.00      SLICE NO.= 13         WL= 461.00
 CASE I US

FS=  2.758,  E.C.=    -.00


* * * ARC    3 * * *
ARC NO.=    3   CENTER(X,Y)= 120.00, 540.00   EXIT(X,Y)= 168.53, 469.00
RAD.=  86.00    LOWEST Y= 454.00      SLICE NO.= 12         WL= 461.00
 CASE I US

FS=  2.584,  E.C.=    -.01


* * * ARC    4 * * *
ARC NO.=    4   CENTER(X,Y)= 160.00, 540.00   EXIT(X,Y)= 208.53, 469.00
RAD.=  86.00    LOWEST Y= 454.00      SLICE NO.=  7         WL= 461.00
 CASE I US

FS=  4.163,  E.C.=    -.04


* * * ARC    5 * * *
ARC NO.=    5   CENTER(X,Y)= 200.00, 540.00   EXIT(X,Y)= 248.53, 469.00
RAD.=  86.00    LOWEST Y= 454.00      SLICE NO.=  5         WL= 461.00
 CASE I US
THE RESULTS ARE NOT CORRECT--ERROR OF CLOSURE NOT CONVERGED DUE TO THE INTER SLICE TENSILE FORCE EXISTS.

FS= 65.526,  E.C.=   -1.27
ANALYSES ABOVE ARE STORED IN LOCAL FILE TAPE11


* * * ARC    6 * * *
ARC NO.=    6   CENTER(X,Y)=  40.00, 580.00   EXIT(X,Y)= 117.28, 480.48
RAD.= 126.00    LOWEST Y= 454.00      SLICE NO.= 16         WL= 461.00
 CASE I US

FS=  5.756,  E.C.=    -.01


* * * ARC    7 * * *
ARC NO.=    7   CENTER(X,Y)=  80.00, 580.00   EXIT(X,Y)= 143.91, 471.41
RAD.= 126.00    LOWEST Y= 454.00      SLICE NO.= 14         WL= 461.00
 CASE I US

FS=  2.650,  E.C.=    -.01
```

```
* * * ARC    2 * * *
ARC NO.=    2   CENTER(X,Y)=  80.00, 540.00   EXIT(X,Y)= 135.48, 474.28
RAD.=  86.00    LOWEST Y= 454.00     SLICE NO.= 13        WL= 461.00
 CASE I US

FS=   2.750,  E.C.=    -.00


* * * ARC    3 * * *
ARC NO.=    3   CENTER(X,Y)= 120.00, 540.00   EXIT(X,Y)= 168.53, 469.00
RAD.=  86.00    LOWEST Y= 454.00     SLICE NO.= 12        WL= 461.00
 CASE I US

FS=   2.584,  E.C.=    -.01


* * * ARC    4 * * *
ARC NO.=    4   CENTER(X,Y)= 160.00, 540.00   EXIT(X,Y)= 208.53, 469.00
RAD.=  86.00    LOWEST Y= 454.00     SLICE NO.=  7        WL= 461.00
 CASE I US

FS=   4.163,  E.C.=    -.04


* * * ARC    5 * * *
ARC NO.=    5   CENTER(X,Y)= 200.00, 540.00   EXIT(X,Y)= 248.53, 469.00
RAD.=  86.00    LOWEST Y= 454.00     SLICE NO.=  5        WL= 461.00
 CASE I US
THE RESULTS ARE NOT CORRECT--ERROR OF CLOSURE NOT CONVERGED DUE TO THE INTER SLICE TENSILE FORCE EXISTS.

FS=  65.526,  E.C.=   -1.27
ANALYSES ABOVE ARE STORED IN LOCAL FILE TAPE11


* * * ARC    6 * * *
ARC NO.=    6   CENTER(X,Y)=  40.00, 580.00   EXIT(X,Y)= 117.28, 480.48
RAD.= 126.00    LOWEST Y= 454.00     SLICE NO.= 16        WL= 461.00
 CASE I US

FS=   5.756,  E.C.=    -.01


* * * ARC    7 * * *
ARC NO.=    7   CENTER(X,Y)=  80.00, 580.00   EXIT(X,Y)= 143.91, 471.41
RAD.= 126.00    LOWEST Y= 454.00     SLICE NO.= 14        WL= 461.00
 CASE I US

FS=   2.650,  E.C.=    -.01
```

```
* * * ARC   8 * * *
ARC NO.=   8   CENTER(X,Y)= 120.00, 580.00   EXIT(X,Y)= 179.62, 469.00
RAD.= 126.00   LOWEST Y= 454.00    SLICE NO.= 15      WL= 461.00
 CASE I US

FS=  2.247,  E.C.=    .05


* * * ARC   9 * * *
ARC NO.=   9   CENTER(X,Y)= 160.00, 580.00   EXIT(X,Y)= 219.62, 469.00
RAD.= 126.00   LOWEST Y= 454.00    SLICE NO.= 10      WL= 461.00
 CASE I US

FS=  3.378,  E.C.=   -.05


* * * ARC  10 * * *
ARC NO.=  10   CENTER(X,Y)= 200.00, 580.00   EXIT(X,Y)= 259.62, 469.00
RAD.= 126.00   LOWEST Y= 454.00    SLICE NO.=  8      WL= 461.00
 CASE I US

FS= 32.609,  E.C.=   -.01


* * * ARC  11 * * *
ARC NO.=  11   CENTER(X,Y)=  40.00, 620.00   EXIT(X,Y)= 125.47, 477.69
RAD.= 166.00   LOWEST Y= 454.00    SLICE NO.= 17      WL= 461.00
 CASE I US

FS=  6.172,  E.C.=   -.06


* * * ARC  12 * * *
ARC NO.=  12   CENTER(X,Y)=  80.00, 620.00   EXIT(X,Y)= 149.83, 469.40
RAD.= 166.00   LOWEST Y= 454.00    SLICE NO.= 15      WL= 461.00
 CASE I US

FS=  2.930,  E.C.=    .06


* * * ARC  13 * * *
ARC NO.=  13   CENTER(X,Y)= 120.00, 620.00   EXIT(X,Y)= 188.96, 469.00
RAD.= 166.00   LOWEST Y= 454.00    SLICE NO.= 18      WL= 461.00
 CASE I US

FS=  2.242,  E.C.=    .08
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```
* * * ARC   14 * * *
ARC NO.=  14   CENTER(X,Y)= 160.00, 620.00   EXIT(X,Y)= 228.96, 469.00
RAD.= 166.00   LOWEST Y= 454.00    SLICE NO.= 13        WL= 461.00
 CASE I US

FS=  3.020,  E.C.=    .01


* * * ARC   15 * * *
ARC NO.=  15   CENTER(X,Y)= 200.00, 620.00   EXIT(X,Y)= 268.96, 469.00
RAD.= 166.00   LOWEST Y= 454.00    SLICE NO.= 10        WL= 461.00
 CASE I US

FS= 11.790,  E.C.=   -.04


* * * ARC   16 * * *
ARC NO.=  16   CENTER(X,Y)=  40.00, 660.00   EXIT(X,Y)= 131.74, 475.56
RAD.= 206.00   LOWEST Y= 454.00    SLICE NO.= 18        WL= 461.00
 CASE I US

FS=  6.722,  E.C.=   -.10


* * * ARC   17 * * *
ARC NO.=  17   CENTER(X,Y)=  80.00, 660.00   EXIT(X,Y)= 157.17, 469.00
RAD.= 206.00   LOWEST Y= 454.00    SLICE NO.= 19        WL= 461.00
 CASE I US

FS=  3.299,  E.C.=    .01


* * * ARC   18 * * *
ARC NO.=  18   CENTER(X,Y)= 120.00, 660.00   EXIT(X,Y)= 197.17, 469.00
RAD.= 206.00   LOWEST Y= 454.00    SLICE NO.= 18        WL= 461.00
 CASE I US

FS=  2.416,  E.C.=    .04


* * * ARC   19 * * *
ARC NO.=  19   CENTER(X,Y)= 160.00, 660.00   EXIT(X,Y)= 237.17, 469.00
RAD.= 206.00   LOWEST Y= 454.00    SLICE NO.= 16        WL= 461.00
 CASE I US

FS=  2.697,  E.C.=    .06
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```
* * * ARC   20 * * *
ARC NO.=   20   CENTER(X,Y)= 200.00, 660.00   EXIT(X,Y)= 277.17, 469.00
RAD.= 206.00    LOWEST Y= 454.00     SLICE NO.= 12        WL= 461.00
 CASE I US

FS=  6.856,  E.C.=    -.04


* * * ARC   21 * * *
ARC NO.=   21   CENTER(X,Y)=  40.00, 700.00   EXIT(X,Y)= 136.78, 473.84
RAD.= 246.00    LOWEST Y= 454.00     SLICE NO.= 17        WL= 461.00
 CASE I US

FS=  7.172,  E.C.=    -.04


* * * ARC   22 * * *
ARC NO.=   22   CENTER(X,Y)=  80.00, 700.00   EXIT(X,Y)= 164.59, 469.00
RAD.= 246.00    LOWEST Y= 454.00     SLICE NO.= 19        WL= 461.00
 CASE I US

FS=  3.657,  E.C.=     .06


* * * ARC   23 * * *
ARC NO.=   23   CENTER(X,Y)= 120.00, 700.00   EXIT(X,Y)= 204.59, 469.00
RAD.= 246.00    LOWEST Y= 454.00     SLICE NO.= 19        WL= 461.00
 CASE I US

FS=  2.655,  E.C.=     .00


* * * ARC   24 * * *
ARC NO.=   24   CENTER(X,Y)= 160.00, 700.00   EXIT(X,Y)= 244.59, 469.00
RAD.= 246.00    LOWEST Y= 454.00     SLICE NO.= 19        WL= 461.00
 CASE I US

FS=  2.600,  E.C.=    -.05


* * * ARC   25 * * *
ARC NO.=   25   CENTER(X,Y)= 200.00, 700.00   EXIT(X,Y)= 284.59, 469.00
RAD.= 246.00    LOWEST Y= 454.00     SLICE NO.= 14        WL= 461.00
 CASE I US

FS=  4.866,  E.C.=    -.01
ANALYSES ABOVE ARE STORED IN LOCAL FILE TAPE12


LIST OF ARC/FS FOR LOWEST Y=  454.00,  NO.OF ARC/FS
   1/ 5.817,   2/ 2.758,   3/ 2.584,   4/ 4.163,   5/65.526,   6/ 5.756,   7/ 2.650,   8/ 2.247,   9/ 3.378,  10/32
  11/ 6.172,  12/ 2.930,  13/ 2.242,  14/ 3.020,  15/11.790,  16/ 6.722,  17/ 3.299,  18/ 2.416,  19/ 2.697,  20/ (
  21/ 7.172,  22/ 3.657,  23/ 2.655,  24/ 2.600,  25/ 4.866,

THE MIN FS IS 2.242,  AT CENTER NO.  13
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ANALYSES ABOVE ARE STORED IN LOCAL FILE TAPE13
 CODE: 1:NEW ARC FILE.  2:RERUN AN ARC.  3:MODIFY GRID.  4:STOP
?3
READ NEW GRID, 8 VAR. :
DEL,XBC,YBC,XEND,YEND,YGLOWY,WL,KOUTER
? 40 40 580 200 740 464 461 0


* * * ARC    1 * * *
ARC NO.=    1   CENTER(X,Y)=  40.00, 580.00   EXIT(X,Y)= 105.72, 484.41
RAD.= 116.00    LOWEST Y= 464.00      SLICE NO.= 11        WL= 461.00
 CASE I US

FS=   5.383,  E.C.=    -.01


* * * ARC    2 * * *
ARC NO.=    2   CENTER(X,Y)=  80.00, 580.00   EXIT(X,Y)= 130.99, 475.81
RAD.= 116.00    LOWEST Y= 464.00      SLICE NO.= 12        WL= 461.00
 CASE I US

FS=   2.685,  E.C.=     .00


* * * ARC    3 * * *
ARC NO.=    3   CENTER(X,Y)= 120.00, 580.00   EXIT(X,Y)= 153.69, 469.00
RAD.= 116.00    LOWEST Y= 464.00      SLICE NO.= 11        WL= 461.00
 CASE I US

FS=   2.208,  E.C.=     .06


* * * ARC    4 * * *
ARC NO.=    4   CENTER(X,Y)= 160.00, 580.00   EXIT(X,Y)= 193.69, 469.00
RAD.= 116.00    LOWEST Y= 464.00      SLICE NO.=  8        WL= 461.00
 CASE I US

FS=   2.952,  E.C.=     .00


* * * ARC    5 * * *
ARC NO.=    5   CENTER(X,Y)= 200.00, 580.00   EXIT(X,Y)= 233.69, 469.00
RAD.= 116.00    LOWEST Y= 464.00      SLICE NO.=  4        WL= 461.00
 CASE I US
THE RESULTS ARE NOT CORRECT--ERROR OF CLOSURE NOT CONVERGED DUE TO THE INTER SLICE TENSILE FORCE EXISTS.

FS=  81.221,  E.C.=    -.25
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```
* * * ARC   6 * * *
ARC NO.=   6   CENTER(X,Y)=  40.00, 620.00   EXIT(X,Y)= 112.77, 482.01
RAD.= 156.00   LOWEST Y= 464.00     SLICE NO.= 13        WL= 461.00
 CASE I US

FS=  6.349,  E.C.=    -.02


* * * ARC   7 * * *
ARC NO.=   7   CENTER(X,Y)=  80.00, 620.00   EXIT(X,Y)= 135.60, 474.24
RAD.= 156.00   LOWEST Y= 464.00     SLICE NO.= 13        WL= 461.00
 CASE I US

FS=  2.982,  E.C.=     .03


* * * ARC   8 * * *
ARC NO.=   8   CENTER(X,Y)= 120.00, 620.00   EXIT(X,Y)= 159.18, 469.00
RAD.= 156.00   LOWEST Y= 464.00     SLICE NO.= 14        WL= 461.00
 CASE I US

FS=  2.127,  E.C.=    -.06


* * * ARC   9 * * *
ARC NO.=   9   CENTER(X,Y)= 160.00, 620.00   EXIT(X,Y)= 199.18, 469.00
RAD.= 156.00   LOWEST Y= 464.00     SLICE NO.=  9        WL= 461.00
 CASE I US

FS=  2.535,  E.C.=     .01


* * * ARC  10 * * *
ARC NO.=  10   CENTER(X,Y)= 200.00, 620.00   EXIT(X,Y)= 239.18, 469.00
RAD.= 156.00   LOWEST Y= 464.00     SLICE NO.=  4        WL= 461.00
 CASE I US

FS= 341.184,  E.C.=    -.07


* * * ARC  11 * * *
ARC NO.=  11   CENTER(X,Y)=  40.00, 660.00   EXIT(X,Y)= 118.06, 480.21
RAD.= 196.00   LOWEST Y= 464.00     SLICE NO.= 13        WL= 461.00
 CASE I US

FS=  7.130,  E.C.=    -.02
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```
* * * ARC  12 * * *
ARC NO.=  12  CENTER(X,Y)=  80.00, 660.00  EXIT(X,Y)= 138.99, 473.09
RAD.= 196.00   LOWEST Y= 464.00    SLICE NO.= 13      WL= 461.00
 CASE I US

FS=  3.359,  E.C.=     .00


* * * ARC  13 * * *
ARC NO.=  13  CENTER(X,Y)= 120.00, 660.00  EXIT(X,Y)= 163.99, 469.00
RAD.= 196.00   LOWEST Y= 464.00    SLICE NO.= 14      WL= 461.00
 CASE I US

FS=  2.254,  E.C.=     .05


* * * ARC  14 * * *
ARC NO.=  14  CENTER(X,Y)= 160.00, 660.00  EXIT(X,Y)= 203.99, 469.00
RAD.= 196.00   LOWEST Y= 464.00    SLICE NO.= 11      WL= 461.00
 CASE I US

FS=  2.244,  E.C.=     .02


* * * ARC  15 * * *
ARC NO.=  15  CENTER(X,Y)= 200.00, 660.00  EXIT(X,Y)= 243.99, 469.00
RAD.= 196.00   LOWEST Y= 464.00    SLICE NO.=  5      WL= 461.00
 CASE I US
THE RESULTS ARE NOT CORRECT--ERROR OF CLOSURE NOT CONVERGED DUE TO THE INTER SLICE TENSILE FORCE EXISTS.

FS=  31.607,  E.C.=    -.05


* * * ARC  16 * * *
ARC NO.=  16  CENTER(X,Y)=  40.00, 700.00  EXIT(X,Y)= 122.24, 478.79
RAD.= 236.00   LOWEST Y= 464.00    SLICE NO.= 14      WL= 461.00
 CASE I US

FS=  7.947,  E.C.=    -.01


* * * ARC  17 * * *
ARC NO.=  17  CENTER(X,Y)=  80.00, 700.00  EXIT(X,Y)= 141.63, 472.19
RAD.= 236.00   LOWEST Y= 464.00    SLICE NO.= 14      WL= 461.00
 CASE I US

FS=  3.766,  E.C.=     .02
```

```
* * * ARC  18 * * *
ARC NO.=  18  CENTER(X,Y)= 120.00, 700.00  EXIT(X,Y)= 168.32, 469.00
RAD.= 236.00  LOWEST Y= 464.00    SLICE NO.= 14      WL= 461.00
 CASE I US

FS=  2.472,  E.C.=    .03


* * * ARC  19 * * *
ARC NO.=  19  CENTER(X,Y)= 160.00, 700.00  EXIT(X,Y)= 208.32, 469.00
RAD.= 236.00  LOWEST Y= 464.00    SLICE NO.= 14      WL= 461.00
 CASE I US

FS=  2.136,  E.C.=    .00


* * * ARC  20 * * *
ARC NO.=  20  CENTER(X,Y)= 200.00, 700.00  EXIT(X,Y)= 248.32, 469.00
RAD.= 236.00  LOWEST Y= 464.00    SLICE NO.= 10      WL= 461.00
 CASE I US
AT X=   149.86THERE MAY EXIST A BAD BOUND., OR SLICE,CHECK GRAPHICALLY
AT X=   151.68THERE MAY EXIST A BAD BOUND., OR SLICE,CHECK GRAPHICALLY


* * * ARC  21 * * *
ARC NO.=  21  CENTER(X,Y)=  40.00, 740.00  EXIT(X,Y)= 125.66, 477.63
RAD.= 276.00  LOWEST Y= 464.00    SLICE NO.= 16      WL= 461.00
 CASE I US

FS=  8.720,  E.C.=   -.04
ANALYSES ABOVE ARE STORED IN LOCAL FILE TAPE11


* * * ARC  22 * * *
ARC NO.=  22  CENTER(X,Y)=  80.00, 740.00  EXIT(X,Y)= 143.76, 471.47
RAD.= 276.00  LOWEST Y= 464.00    SLICE NO.= 15      WL= 461.00
 CASE I US

FS=  4.204,  E.C.=    .03


* * * ARC  23 * * *
ARC NO.=  23  CENTER(X,Y)= 120.00, 740.00  EXIT(X,Y)= 172.30, 469.00
RAD.= 276.00  LOWEST Y= 464.00    SLICE NO.= 16      WL= 461.00
 CASE I US

FS=  2.727,  E.C.=    .05
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```
* * * ARC  24 * * *
ARC NO.=  24   CENTER(X,Y)= 160.00, 740.00   EXIT(X,Y)= 212.30, 469.00
RAD.= 276.00    LOWEST Y= 464.00     SLICE NO.= 17        WL= 461.00
 CASE I US

FS=  2.204,  E.C.=     .09


* * * ARC  25 * * *
ARC NO.=  25   CENTER(X,Y)= 200.00, 740.00   EXIT(X,Y)= 252.30, 469.00
RAD.= 276.00    LOWEST Y= 464.00     SLICE NO.= 12        WL= 461.00
 CASE I US

FS=  4.712,  E.C.=    -.02


LIST OF ARC/FS FOR LOWEST Y=  464.00,  NO.OF ARC/FS
   1/ 5.383,   2/ 2.685,   3/ 2.208,   4/ 2.952,   5/81.221,   6/ 6.349,   7/ 2.982,   8/ 2.127,   9/ 2.535,  10/******,
  11/ 7.130,  12/ 3.359,  13/ 2.254,  14/ 2.244,  15/31.607,  16/ 7.947,  17/ 3.766,  18/ 2.472,  19/ 2.136,  20/99.000,
  21/ 8.720,  22/ 4.204,  23/ 2.727,  24/ 2.204,  25/ 4.712,

THE MIN FS IS 2.127,  AT CENTER NO.   8


ANALYSES ABOVE ARE STORED IN LOCAL FILE TAPE12
 CODE: 1:NEW ARC FILE.  2:RERUN AN ARC.  3:MODIFY GRID.  4:STOP
? 3
 READ NEW GRID, 8 VAR. :
 DEL,XDC,YDC,XEND,YEND,TCLOWY,WL,KOUTER
? 40 80 660 240 820 474 461 0


* * * ARC   1 * * *
ARC NO.=   1   CENTER(X,Y)=  80.00, 660.00   EXIT(X,Y)= 122.12, 478.83
RAD.= 186.00    LOWEST Y= 474.00     SLICE NO.= 11        WL= 461.00
 CASE I US

FS=  2.940,  E.C.=     .04


* * * ARC   2 * * *
ARC NO.=   2   CENTER(X,Y)= 120.00, 660.00   EXIT(X,Y)= 134.62, 474.58
RAD.= 186.00    LOWEST Y= 474.00     SLICE NO.= 12        WL= 461.00
 CASE I US

FS=  1.972,  E.C.=     .05
```

* * * ARC 9 * * *
NO ANALYSIS,FAILURE ARC CANNOT BE FORMULATED
CENTER, (X,Y), AT 200.00 700.00

* * * ARC 10 * * *
NO ANALYSIS,FAILURE ARC CANNOT BE FORMULATED
CENTER, (X,Y), AT 240.00 700.00

* * * ARC 11 * * *
ARC NO.= 11 CENTER(X,Y)= 80.00, 740.00 EXIT(X,Y)= 125.03, 477.84
RAD.= 266.00 LOWEST Y= 474.00 SLICE NO.= 12 WL= 461.00
CASE I US

FS= 3.718, E.C.= .03

* * * ARC 12 * * *
ARC NO.= 12 CENTER(X,Y)= 120.00, 740.00 EXIT(X,Y)= 135.06, 474.43
RAD.= 266.00 LOWEST Y= 474.00 SLICE NO.= 12 WL= 461.00
CASE I US

FS= 2.387, E.C.= -.03

* * * ARC 13 * * *
ARC NO.= 13 CENTER(X,Y)= 160.00, 740.00 EXIT(X,Y)= 131.96, 475.48
RAD.= 266.00 LOWEST Y= 474.00 SLICE NO.= 9 WL= 461.00
CASE I US

FS= 1.693, E.C.= .00

* * * ARC 14 * * *
NO ANALYSIS,FAILURE ARC CANNOT BE FORMULATED
CENTER, (X,Y), AT 200.00 740.00

* * * ARC 15 * * *
NO ANALYSIS,FAILURE ARC CANNOT BE FORMULATED
CENTER, (X,Y), AT 240.00 740.00

```
* * * ARC    3 * * *
ARC NO.=    3   CENTER(X,Y)= 160.00, 660.00   EXIT(X,Y)= 128.34, 476.71
RAD.= 186.00    LOWEST Y= 474.00     SLICE NO.=  4        WL= 461.00
 CASE I US

FS=  1.820,  E.C.=    -.02



* * * ARC    4 * * *
NO ANALYSIS,FAILURE ARC CANNOT BE FORMULATED
CENTER, (X,Y), AT    200.00    660.00




* * * ARC    5 * * *
NO ANALYSIS,FAILURE ARC CANNOT BE FORMULATED
CENTER, (X,Y), AT    240.00    660.00




* * * ARC    6 * * *
ARC NO.=    6   CENTER(X,Y)=  80.00, 700.00   EXIT(X,Y)= 123.75, 478.28
RAD.= 226.00    LOWEST Y= 474.00     SLICE NO.= 11        WL= 461.00
 CASE I US

FS=  3.327,  E.C.=     .00



* * * ARC    7 * * *
ARC NO.=    7   CENTER(X,Y)= 120.00, 700.00   EXIT(X,Y)= 134.87, 474.49
RAD.= 226.00    LOWEST Y= 474.00     SLICE NO.= 12        WL= 461.00
 CASE I US

FS=  2.155,  E.C.=     .00



* * * ARC    8 * * *
ARC NO.=    8   CENTER(X,Y)= 160.00, 700.00   EXIT(X,Y)= 130.72, 475.91
RAD.= 226.00    LOWEST Y= 474.00     SLICE NO.=  7        WL= 461.00
 CASE I US

FS=  1.739,  E.C.=     .03
```

* * * ARC 16 * * *
ARC NO.= 16 CENTER(X,Y)= 80.00, 780.00 EXIT(X,Y)= 126.07, 477.49
RAD.= 306.00 LOWEST Y= 474.00 SLICE NO.= 14 WL= 461.00
CASE I US

FS= 4.145, E.C.= .04

* * * ARC 17 * * *
ARC NO.= 17 CENTER(X,Y)= 120.00, 780.00 EXIT(X,Y)= 135.20, 474.38
RAD.= 306.00 LOWEST Y= 474.00 SLICE NO.= 13 WL= 461.00
CASE I US

FS= 2.640, E.C.= .00

* * * ARC 18 * * *
ARC NO.= 18 CENTER(X,Y)= 160.00, 780.00 EXIT(X,Y)= 132.74, 475.22
RAD.= 306.00 LOWEST Y= 474.00 SLICE NO.= 11 WL= 461.00
CASE I US

FS= 1.863, E.C.= -.08

* * * ARC 19 * * *
NO ANALYSIS,FAILURE ARC CANNOT BE FORMULATED
CENTER, (X,Y), AT 200.00 780.00

* * * ARC 20 * * *
NO ANALYSIS,FAILURE ARC CANNOT BE FORMULATED
CENTER, (X,Y), AT 240.00 780.00

* * * ARC 21 * * *
ARC NO.= 21 CENTER(X,Y)= 80.00, 820.00 EXIT(X,Y)= 126.92, 477.20
RAD.= 346.00 LOWEST Y= 474.00 SLICE NO.= 14 WL= 461.00
CASE I US

FS= 4.540, E.C.= .01

* * * ARC 22 * * *
ARC NO.= 22 CENTER(X,Y)= 120.00, 820.00 EXIT(X,Y)= 135.32, 474.34
RAD.= 346.00 LOWEST Y= 474.00 SLICE NO.= 13 WL= 461.00
CASE I US

FS= 2.896, E.C.= -.01

```
* * * ARC   23 * * *
ARC NO.=   23   CENTER(X,Y)= 160.00, 820.00   EXIT(X,Y)= 133.28, 475.03
RAD.= 346.00   LOWEST Y= 474.00     SLICE NO.= 12       WL= 461.00
 CASE I US

FS=  2.042,  E.C.=     .03


 * * * ARC   24 * * *
NO ANALYSIS,FAILURE ARC CANNOT BE FORMULATED
CENTER, (X,Y), AT    200.00    820.00


* * * ARC   25 * * *
NO ANALYSIS,FAILURE ARC CANNOT BE FORMULATED
CENTER, (X,Y), AT    240.00    820.00


LIST OF ARC/FS FOR LOWEST Y=  474.00,  NO.OF ARC/FS
   1/ 2.940,   2/ 1.972,   3/ 1.820,   4/99.000,   5/99.000,   6/ 3.327,   7/ 2.155,   8/ 1.739,   9/99.000,  10/99.
  11/ 3.718,  12/ 2.387,  13/ 1.693,  14/99.000,  15/99.000,  16/ 4.145,  17/ 2.640,  18/ 1.863,  19/99.000,  20/99.
  21/ 4.540,  22/ 2.896,  23/ 2.042,  24/99.000,  25/99.000,

THE MIN FS IS 1.693,  AT CENTER NO.  13


ANALYSES ABOVE ARE STORED IN LOCAL FILE TAPE11
 CODE: 1:NEW ARC FILE.  2:RERUN AN ARC.  3:MODIFY GRID.  4:STOP
 ?
3
READ NEW GRID, 8 VAR. :
DEL,XDC,YDC,XEND,YEND,TGLOWY,WL,KOUTER
? 40 120 740 240 820 484 461 0


* * * ARC    1 * * *
ARC NO.=    1   CENTER(X,Y)= 120.00, 740.00   EXIT(X,Y)= 105.78, 484.40
RAD.= 256.00    LOWEST Y= 484.00     SLICE NO.= 10       WL= 461.00
 CASE I US

FS=  2.071,  E.C.=     .02
ANALYSES ABOVE ARE STORED IN LOCAL FILE TAPE11


* * * ARC    2 * * *
NO ANALYSIS,FAILURE ARC CANNOT BE FORMULATED
CENTER, (X,Y), AT    160.00    740.00
```

```
* * * ARC    3 * * *
NO ANALYSIS,FAILURE ARC CANNOT BE FORMULATED
CENTER, (X,Y), AT    200.00    740.00



* * * ARC    4 * * *
NO ANALYSIS,FAILURE ARC CANNOT BE FORMULATED
CENTER, (X,Y), AT    240.00    740.00



* * * ARC    5 * * *
ARC NO.=    5   CENTER(X,Y)= 120.00, 780.00   EXIT(X,Y)= 105.96, 484.33
RAD.= 296.00    LOWEST Y= 484.00     SLICE NO.= 11        WL= 461.00
 CASE I US

FS=  2.320,  E.C.=     .01


* * * ARC    6 * * *
ARC NO.=    6   CENTER(X,Y)= 160.00, 780.00   EXIT(X,Y)=  73.96, 496.78
RAD.= 296.00    LOWEST Y= 484.00     SLICE NO.=  6        WL= 461.00
 CASE I US

FS=  1.464,  E.C.=     .01


* * * ARC    7 * * *
NO ANALYSIS,FAILURE ARC CANNOT BE FORMULATED
CENTER, (X,Y), AT    200.00    780.00



* * * ARC    8 * * *
NO ANALYSIS,FAILURE ARC CANNOT BE FORMULATED
CENTER, (X,Y), AT    240.00    780.00



* * * ARC    9 * * *
ARC NO.=    9   CENTER(X,Y)= 120.00, 820.00   EXIT(X,Y)= 106.09, 484.29
RAD.= 336.00    LOWEST Y= 484.00     SLICE NO.= 11        WL= 461.00
 CASE I US

FS=  2.575,  E.C.=     .01
```

```
* * * ARC   10 * * *
ARC NO.=   10   CENTER(X,Y)= 160.00, 820.00   EXIT(X,Y)=  84.84, 492.51
RAD.= 336.00    LOWEST Y= 484.00     SLICE NO.=  6        WL= 461.00
 CASE I US

FS=  1.675,  E.C.=     .03


* * * ARC   11 * * *
NO ANALYSIS,FAILURE ARC CANNOT BE FORMULATED
CENTER, (X,Y), AT    200.00    820.00


* * * ARC   12 * * *
NO ANALYSIS,FAILURE ARC CANNOT BE FORMULATED
CENTER, (X,Y), AT    240.00    820.00


LIST OF ARC/FS FOR LOWEST Y=  484.00,  NO.OF ARC/FS
   1/ 2.071,   2/99.000,   3/99.000,   4/99.000,   5/ 2.320,   6/ 1.464,   7/99.000,   8/99.000,   9/ 2.575,  10/ 1.675,
  11/99.000,  12/99.000,

THE MIN FS IS 1.464,  AT CENTER NO.   6


ANALYSES ABOVE ARE STORED IN LOCAL FILE TAPE12
 CODE: 1:NEW ARC FILE.  2:RERUN AN ARC.  3:MODIFY GRID.  4:STOP
? 3
 READ NEW GRID, 8 VAR. :
 DEL,XBC,YBC,XEND,YEND,TCLOWY,WL,KOUTER
? 40 120 620 120 620 464 461 0


* * * ARC    1 * * *
ARC NO.=    1   CENTER(X,Y)= 120.00, 620.00   EXIT(X,Y)= 159.18, 469.00
RAD.= 156.00    LOWEST Y= 464.00     SLICE NO.= 14        WL= 461.00
 CASE I US

FS=  2.127,  E.C.=    -.06


LIST OF ARC/FS FOR LOWEST Y=  464.00,  NO.OF ARC/FS
   1/ 2.127,

THE MIN FS IS 2.127,  AT CENTER NO.   1


ANALYSES ABOVE ARE STORED IN LOCAL FILE TAPE11
 CODE: 1:NEW ARC FILE.  2:RERUN AN ARC.  3:MODIFY GRID.  4:STOP
? 2
PERM FILE GGXUS1  COPIED TO LOCAL FILE TAPE1
```

SOIL DATA

INDEX KS L	BRK.PT KSF	J=1 COHE KCF	J=1 T.PHI	J=2 COHE KSF	J=2 T.PHI	MOI DEN. KCF	SAT DEN. KCF
***							
1 1	100.00	0.0000	.6750	0.0000	.6750	.1390	.1450
1 2	100.00	0.0000	.6750	0.0000	.6750	.1390	.1450
1 3	100.00	0.0000	.6750	0.0000	.6750	.1390	.1450
***							
2 1	100.00	0.0000	.7270	0.0000	.7270	.1430	.1450
2 2	100.00	0.0000	.7270	0.0000	.7270	.1430	.1450
2 3	100.00	0.0000	.7270	0.0000	.7270	.1430	.1450
***							
3 1	100.00	0.0000	.4250	0.0000	.4250	.1050	.1050
3 2	100.00	0.0000	.4250	0.0000	.4250	.1050	.1050
3 3	100.00	0.0000	.4250	0.0000	.4250	.1050	.1050
***							
4 1	100.00	0.0000	.7000	0.0000	.7000	.1190	.1190
4 2	100.00	0.0000	.7000	0.0000	.7000	.1190	.1190
4 3	100.00	0.0000	.7000	0.0000	.7000	.1190	.1190
***							
5 1	100.00	0.0000	.5100	0.0000	.5100	.1240	.1240
5 2	100.00	0.0000	.5100	0.0000	.5100	.1240	.1240
5 3	100.00	0.0000	.5100	0.0000	.5100	.1240	.1240

"***PROFILE INPUT***"

```
      1        1        6
 -12.00   525.00    12.00   525.00    53.00   505.00
 104.00   485.00   151.00   469.00   500.00   469.00

      2        2        8
-168.00   464.00  -104.00   485.00   -53.00   505.00
 -12.00   525.00     0.00   522.00   110.00   460.00
 130.00   448.00   500.00   448.00

      3        3        7
-500.00   464.00  -168.00   464.00  -122.00   460.00
 110.00   460.00   118.00   455.00   130.00   448.00
 500.00   448.00

      4        4        6
-500.00   430.00  -140.00   430.00     0.00   455.00
 118.00   455.00   130.00   448.00   500.00   448.00

      5        5        6
-500.00   374.00  -260.00   373.00   -40.00   404.00
   0.00   435.00   165.00   445.00   500.00   445.00

      6        6        2
-500.00   345.00   500.00   345.00
```

CONTROL VAR. :

NSLOP	NCASE	NLEVEL	NPORE	NBETA	EQCOE	ULAFT	KAFT	NU	NUAFT
1	1	1	1	3	0.00	0.00	0	0	0

INPUT: ARC=, CENTER X,Y
7 ,120,620

```
* * * ARC   1 * * *
ARC NO.=    1   CENTER(X,Y)= 120.00, 620.00   EXIT(X,Y)= 159.18, 469.00
RAD.= 156.00    LOWEST Y= 464.00     SLICE NO.= 14        WL= 461.00
 CASE I US
X AND Y COORD. OF SLICE BOUND:
    -3.74  525.00,    -1.72  522.43,     0.00  520.32,
    12.00  507.43,    25.67  495.75,    39.33  486.48,
    53.00  479.12,    68.93  472.60,    84.87  468.01,
   100.80  465.19,   104.00  464.82,   119.67  464.00,
   135.33  464.76,   151.00  467.11,   159.18  469.00,
 PRINT HT. & PORE TABLES? Y OR N
? Y
 *** SEGMENT HT. OF VERTICAL SLICE BOUND. FT***
```

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SOIL 1	0.0	2.6	3.0	9.8	10.8	11.8	12.9	15.6	18.3	21.1	20.2	15.7	9.6	1.9	0.0
SOIL 2	0.0	0.0	1.7	7.8	11.8	13.4	13.0	10.6	6.2	0.0	0.0	0.0	0.0	0.0	0.0
SOIL 3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SOIL 4	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SOIL 5	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SOIL 6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
SOIL 7	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0

*** PORE WATER PRESSURE AND SLICE WT.***

SLIC	U BACK KIP	U FR'T KIP	U BASE KIP	PIZ B. ELE FT	PIZ F. ELE FT	WT. F. KIP	WT. B. KIP	WT.SLIC KIP	WATER KIP
1	0.0	0.0	0.0	461.0	461.0	0.0	.4	.4	0.0
2	0.0	0.0	0.0	461.0	461.0	.4	.7	.9	0.0
3	0.0	0.0	0.0	461.0	461.0	.7	2.5	18.8	0.0
4	0.0	0.0	0.0	461.0	461.0	2.5	3.2	38.7	0.0
5	0.0	0.0	0.0	461.0	461.0	3.2	3.6	46.1	0.0
6	0.0	0.0	0.0	461.0	461.0	3.6	3.6	49.2	0.0
7	0.0	0.0	0.0	461.0	461.0	3.6	3.7	58.4	0.0
8	0.0	0.0	0.0	461.0	461.0	3.7	3.4	56.6	0.0
9	0.0	0.0	0.0	461.0	461.0	3.4	2.9	50.7	0.0
10	0.0	0.0	0.0	461.0	461.0	2.9	2.8	9.2	0.0
11	0.0	0.0	0.0	461.0	461.0	2.8	2.2	39.0	0.0
12	0.0	0.0	0.0	461.0	461.0	2.2	1.3	27.5	0.0
13	0.0	0.0	0.0	461.0	461.0	1.3	.3	12.5	0.0
14	0.0	0.0	0.0	461.0	461.0	.3	0.0	1.1	0.0

SLIC	BASE COHE. KSF SEG.1	SEG.2	BASE TAN.PHI SEG.1	SEG.2	HORI.WDTH FT	BASE WDTH FT	INCL.BETA DEG
1	0.00	0.00	.68	.68	2.02	3.27	360.00
2	0.00	0.00	.73	.73	1.72	2.72	360.00
3	0.00	0.00	.73	.73	12.00	17.61	360.00
4	0.00	0.00	.73	.73	13.67	17.98	360.00
5	0.00	0.00	.73	.73	13.67	16.52	338.00
6	0.00	0.00	.73	.73	13.67	15.52	338.00
7	0.00	0.00	.73	.73	15.93	17.22	338.00
8	0.00	0.00	.73	.73	15.93	16.58	338.00
9	0.00	0.00	.73	.73	15.93	16.18	338.00
10	0.00	0.00	.68	.68	3.20	3.22	338.00
11	0.00	0.00	.68	.68	15.67	15.69	338.00
12	0.00	0.00	.68	.68	15.67	15.68	338.00
13	0.00	0.00	.68	.68	15.67	15.84	338.00
14	0.00	0.00	.68	.68	8.18	8.39	360.00

ERROR OF CLOSURE = 16.26 TRIAL FS = 2.5000

ERROR OF CLOSURE = 12.32 TRIAL FS = 2.4000

ERROR OF CLOSURE = -.06 TRIAL FS = 2.1265

*** RESULTS FROM COMPOSITE FORCE POLYGON ***

SLIC	SOIL INDEX KS L J	* DEVE'D STREN'H * COHE. KIP	TAN PHI	PHI DEG	*INT. SLI. F.* PUSH. KIP	RESI'T KIP	EFF. N. STRESS KIP	NORMAL FORCE KIP	WT+PORE RESUL'T KIP
1	1 1 1	0.00	.3	17.6	0.0	.2	.1	.42	.36
2	2 1 1	0.00	.3	18.9	.2	.8	.4	.97	.87
3	2 1 1	0.00	.3	18.9	.8	10.8	1.1	20.16	18.78
4	2 1 1	0.00	.3	18.9	10.8	24.3	1.7	30.08	38.67
5	2 1 1	0.00	.3	18.9	24.3	36.6	2.5	40.69	46.06
6	2 1 1	0.00	.3	18.9	36.6	44.8	2.9	44.25	49.23
7	2 1 1	0.00	.3	18.9	44.8	48.5	3.1	54.03	58.37
8	2 1 1	0.00	.3	18.9	48.5	45.4	3.3	54.73	56.62
9	2 1 1	0.00	.3	18.9	45.4	36.4	3.2	51.75	50.65
10	1 1 1	0.00	.3	17.6	36.4	34.2	3.0	9.68	9.18
11	1 1 1	0.00	.3	17.6	34.2	22.0	2.7	42.96	39.03
12	1 1 1	0.00	.3	17.6	22.0	9.0	2.1	32.08	27.49
13	1 1 1	0.00	.3	17.6	9.0	.6	1.1	16.85	12.49
14	1 1 1	0.00	.3	17.6	.6	-.1	.1	1.19	1.07

FS= 2.127, E.C.= -.06

BISHOP SIMPLIFIED METHOD: USING S STRENGTH FOR ALL CASE

CONVERGED FS=2.119433752235

ONONDAGA DAM, NY

WAVE ANALYSIS

APPENDIX E

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

APPENDIX E

WAVE ANALYSIS
FOR
ONONDAGA DAM*

E1. GENERAL

The wave analysis for Onondage Dam was accomplished using guidelines established in ETL 1110-2-221 - "Wave Runup and Wind Setup on Reservoir Embankments." A stage-frequency analysis using maximum peak and daily pool elevations for Onondage Dam was done to determine pool levels to be used in the design analysis.

E2. POOL STAGE FREQUENCY CURVES

Pool stage-frequency curves were developed using maximum peak (or instantaneous) pool elevations and maximum daily pool elevations for water years 1953 through 1983. Both the peak and daily pool elevations were ranked from highest to lowest and plotted on probability paper. The plotting positions of the data was determined using the Median Plotting Position Method. These curves can be found on Figure E1 and E2. The data used for the frequency curve can be found on Table E1. The instantaneous and daily pool stage-frequency curves were plotted together on Figure E3.

The stage-frequency curve used in this analysis was the curve developed using the daily data. Wave generation depends on wind speed and duration, thus using the daily stage-frequency curve would provide a stable pool level for wave generation. Using Figure E2, the 100-year daily pool elevation would be elevation 490.0 feet NGVD.

The Probable Maximum Flood (PMF) estimate was re-developed during the dam break analysis for Onondaga Dam. The instantaneous peak PMF pool elevation is elevation 519.0 feet NGVD. The pool behind the Onondaga Dam would be at or near elevation 519.0 feet NGVD for around 6 hours, so elevation 519.0 feet NGVD was used as the pool elevation in the wave analysis.

E3. MAXIMUM WINDS

The design wind and duration was developed using paragraph 3 of ETL 1110-2-221: Design Wind Velocity Curves. Using the regional winds statistics found on Figure 2 through 9 in ETL 1110-2-221, the following wind criteria for Onondaga Dam is applicable:

	Wind Speed			
Period	Winter	Spring	Summer	Fall
1 Minute	60 MPH	55 MPH	50 MPH	60 MPH
1 Hour	40 MPH	35 MPH	30 MPH	40 MPH

*Performed by a Hydrologic Investigations Sections, Buffalo District

Since most of the peak annual events occur in the late winter - early spring months (as seen in Table E1) it was decided to use the largest of the two wind statistics to develop the wind velocity duration curve.

Table E1 - Maximum Peak and Daily Ponding Elevation for Onondaga Dam Date (peak/daily)

WY	Peak	Daily	Date
1953	468.06	467.6	(12-12/12-11
1954	472.07	471.9	(5-4/5-4)
1955	473.15	472.4	(3-2/3-1)
1956	476.96	471.9	(3-9/3-8)
1957	473.18	472.8	(1-23/1-23)
1958	471.9	471.7	(4-8/4-7)
1959	477.5	477.4	(1-22/1-22)
1960	485.9	485.1	(4-1/4-1)
1961	477.3	472.2	(2-26/2-26)
1962	471.0	470.4	(3-13/3-12)
1963	471.0	471.0	(3-26/3-26)
1964	478.2	476.9	(3-6/3-5)
1965	466.8	466.0	(2-9/2-8)
1966	471.1	471.1	(2-14/2-14)
1967	464.4	464.3	(3-30/3-29)
1968	467.0	467.0	(6-29/6-28)
1969	467.10	467.02	(2-2/2-2)
1970	467.28	467.24	(4-5/4-5)
1971	468.34	468.32	(3-19/3-19)
1972	480.43	480.11	(6-24/6-24)
1973	469.06	469.00	(12-8/12-8)
1974	469.23	466.79	(4-4/4-5)
1975	477.73	477.12	(9-27/9-27)
1976	474.99	474.10	(4-16/4-17)
1977	472.89	472.58	(3-14/3-14)
1978	477.40	477.03	(10-18/10-18)
1979	483.80	482.96	(3-6/3-7)
1980	473.68	472.85	(3-22/3-22)
1981	469.16	468.43	(2-12/2-12)
1982	479.58	478.94	(10-29/10-29)
1983	475.04	474.81	(4-27/4-27)

The raw wind statistics so far developed must be expanded and modified to include larger durations and also to take into account the fact that wind travels faster over water then land. Using information provided in Paragraph 3 of ETL 1110-2-221, the raw data can be modified to produce the following statistics:

Wind Duration (Hours)	Percent of 1 Hour Velocity (mph)	1 Hour Velocity (mph)	Velocity (mph)
1	100	40	40
2	96	40	38
3	93	40	37
4	91	40	36
6	88	40	35

Before the wind velocity - duration curve can be adjusted to reflect the difference in wind speed over water to wind speed over land, the effective Fetch (Fe) must be calculated.

The effective Fetch (Fe) was calculated using the guidelines in paragraph 4 of ETL 1110-2-221, Effective Water Fetch (Fe) for Wave Generation. Wind generated waves are influenced by both the direction of the wind and the distance the wind blows over the surface of the reservoir or the fetch. Since inland reservoir's shorelines are generally narrower then open water, an effective Fetch (Fe) concept was use to compensate for the smaller waves found on reservoirs. The Fe adjustment is based on drawing radial lines from the dam embankment to various points on the reservoir shoreline. The radials are of equal adjustment and encompass an area of 45° on each side of the central radial. Five independent Fe calculations were done for the reservoir. The Fe resulting from these calculation ranged between 2,900 feet to 3,950 feet. Since maximum wave heights depend on the maximum effective fetch, a Fe of 3,950 feet was chosen for design purposes. The Fe calculations for the Fe of 3,950 feet can be found on Figure E4.

The Wind Velocity Ratio (velocity over water/velocity over land) for a fetch of 3,950 feet or a .75 miles is approximately 1.11. The wind velocity-duration curve was then adjusted for this ratio and is:

Wind Duration	Wind Velocity Over Land	Wind Velocity Over Water
1 Minute	60 MPH	67 MPH
1 Hour	40 MPH	44 MPH
2 Hours	38 MPH	42 MPH
3 Hours	37 MPH	41 MPH
4 Hours	36 MPH	40 MPH
6 Hours	35 MPH	39 MPH

This wind velocity-duration curve can be found on Figure E5.

The wind velocity and duration parameters that are needed to calculate wave height are found at the intersection of the regional wind velocity-curve developed above and the wind velocity duration curve for a .75 mile fetch of open water. The wind velocity duration curve for the .75 mile fetch is calculated using Figure 11 from ETL 1110-2-221. This curve is as follows:

Wind Duration	Wind Speed
25 Minutes	13.5 MPH
20 Minutes	22 MPH
15 Minutes	43 MPH

This curve is then plotted on Figure E5. The intersection of this curve and the regional wind velocity - duration curves gives you the wave design parameters of wind velocity and duration for Onondaga Reservoir. The intersection of the two lines is at a wind velocity of 52 MPH and a wind duration of 14 minutes.

E4. WAVE HEIGHT

Using the design wind of 52 mph and a wind duration of 14 minutes, the design "significant wave" height (H_s) would be approximately 2 feet (using Figure 11 of ETL 1110-2-221). This wave height is for the deep water condition. To see if deep water conditions are prevalent, the criteria that depth of water be greater then 1/2 the wave length must be met. The wave length can be calculated using the equation:

$$L = 5.12\ (T)^2$$

where: L = wave length
T = wave period.

The wave period can be calculated by using Figure 12 of ETL 1110-2-221. Using this figure, the wave period is approximately 2.6 seconds. The wave length would then be 35 feet. The average depth of the Onondaga Reservoir with a full pool is 20 feet. Thus 20 > 1/2 (35), deep water conditions are met. The average depth of the reservoir pool that is in the effective fetch range is probabley greater then 20 feet. This is because the reservoir is generally deeper in the area near the dam then the areas in the upper part of the pool area. The maximum fetch length is around the dam area, not the upper pools of the reservoir (See Figure E4).

This wave height of 2 feet would be applicable over a range of reservoir pool levels. The shoreline prevalent in the maximum fetch area has relatively steeps sides. Thus, an increase in pool elevation does not increase pool size in this area, thus the effective fetch would remain the same.

E5. WAVE RUNUP

The Shore Protection Manual defines wave runup as "The rush of water up a structure or beach on the breaking of a wave. Also, Uprush. The amount of runup is the vertical height above stillwater level that the rush of water reaches." The wave runup for Onondaga Dam was calculated by using the guidelines in Paragraph 5 - Wave Runup of ETL 1110-2-221.

The wave runup (vertical height) was calculated by using equation 2 of ETL 1110-2-221. This equation is:

$$R_s/H_s = (.4 + (H_s/L_o)^{1/2} \text{ COT } 0)^{-1}$$

Where: R_s = wave Runup
H_s = wave height = 2 feet
L_o = wave length = 35 feet
COT 0 = COT of angle of side slope of embankment = 1.5

$$R_s/2 = (.4 + (2/35)^{1/2} \; 1.5)^{-1} = 1.32$$

$$R_s = 1.32(2) = 2.64 \text{ feet}$$

Since equation 2 uses the significant wave height (H_s) in it's calculation, the amount of wave runup is understated. This is due to the fact that 13 percent of the waves in the wave train will be higher then the significant wave height. To compensate for this, it is assumed (ETL 1110-2-221) that the wave heights higher then the significant wave height would increase wave runup by 50 percent. Thus, the maximum runup (R_m) would be:

$$R_m = 1.5 \; R_s = 1.5 \; (2.64) = 3.96 \text{ feet} \quad 4 \text{ feet}$$

E6. WIND SETUP

The Shore Protection Manual defines wind setup as "The vertical rise in the still water level on the leeward side of a body of water caused by wind streses on the surface of the water." The wind setup for Onondage Dam was calculated using Equation 3 of ETL 1110-2-221. This equation is:

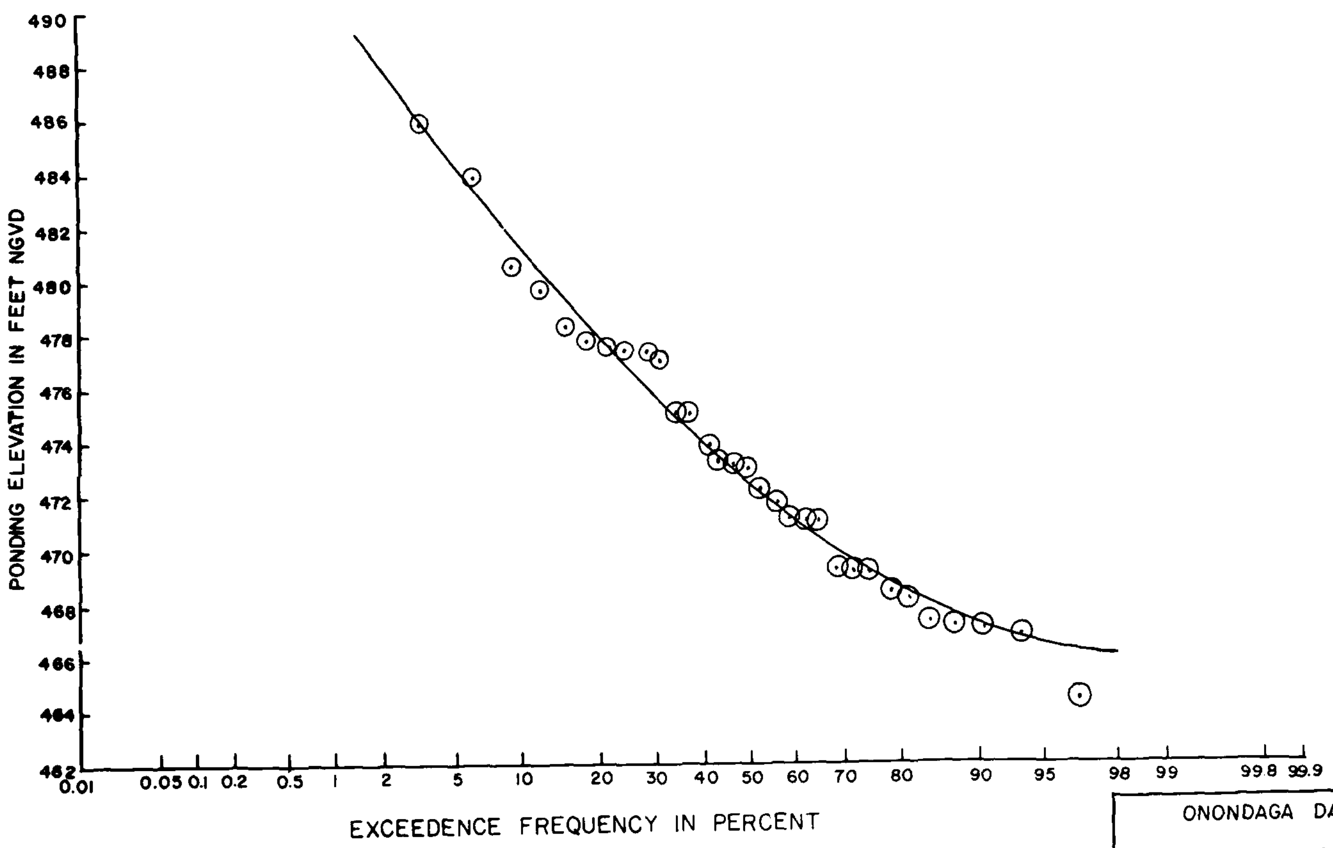
$$S = U^2F/1,400(D)$$

Where: S = Wind Setup
U = Design wind velocity = 52 MPH
F = Fetch = 2 X Fe = 1.50 miles
D = Average water depth; for 100-year pool elevation = 15.1 feet
for PMF pool elevation = 23 feet

Using the 100-year pool elevation, the wind setup would be .20 feet, using the PMF pool elevation, the wind setup would be .13 feet.

E7. DESIGN HEIGHTS

The maximum vertical distance embankment protection is required would be the sum of the stillwater pool elevation, the wind setup, and wave runup. For the 100-year pool event, this elevation would be elevation 494.2 feet NGVD. For the PMF event, the pool level would be elevation 523.13 feet NGVD.

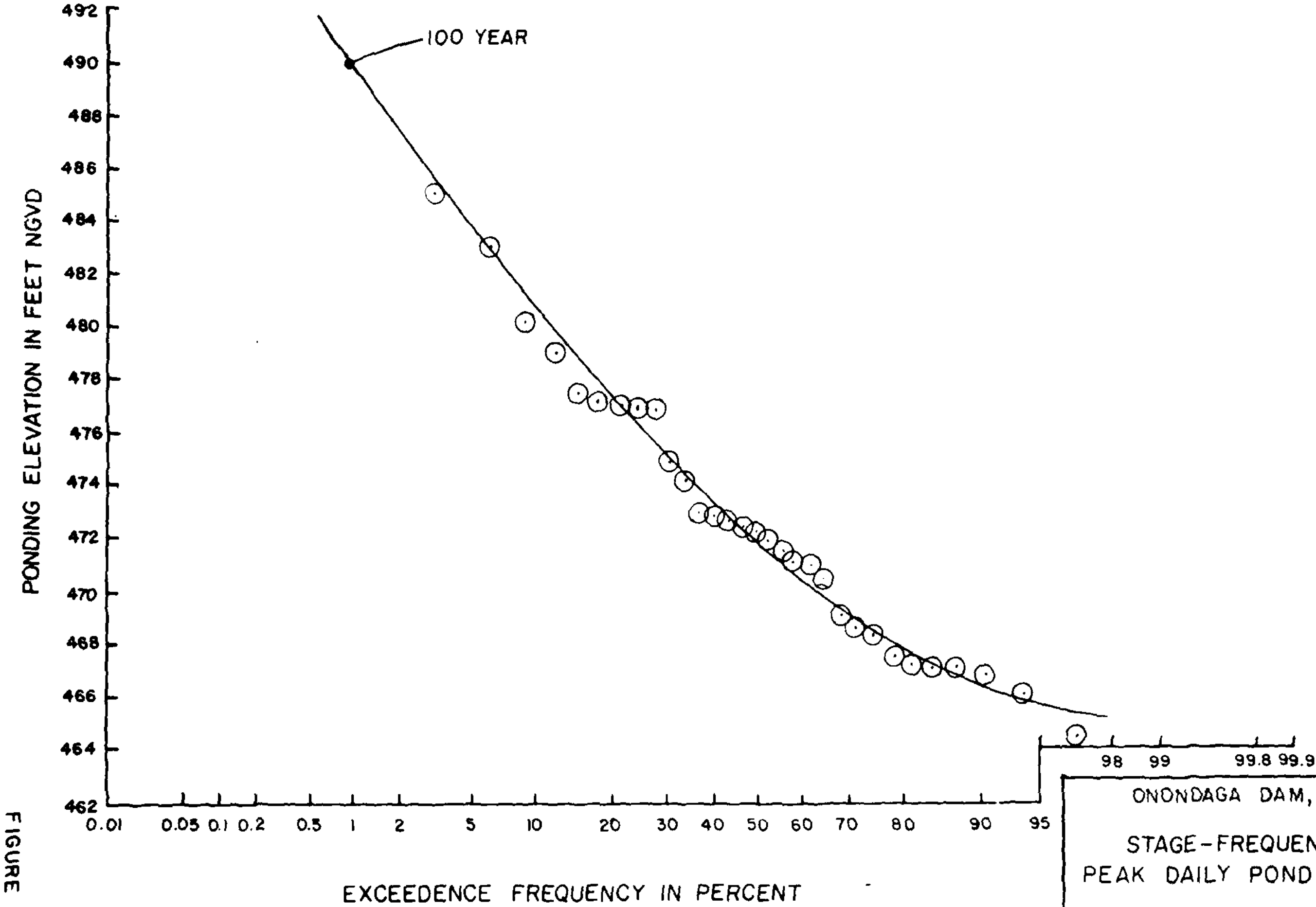


ONONDAGA DAM, NEW YORK

STAGE-FREQUENCY CURVE
INSTANTANEOUS PEAK
POND ELEVATIONS

U.S. ARMY ENGINEER DISTRICT BUFFALO
TO ACCOMPANY STABILITY ANALYSIS
DATED:

FIGURE E1

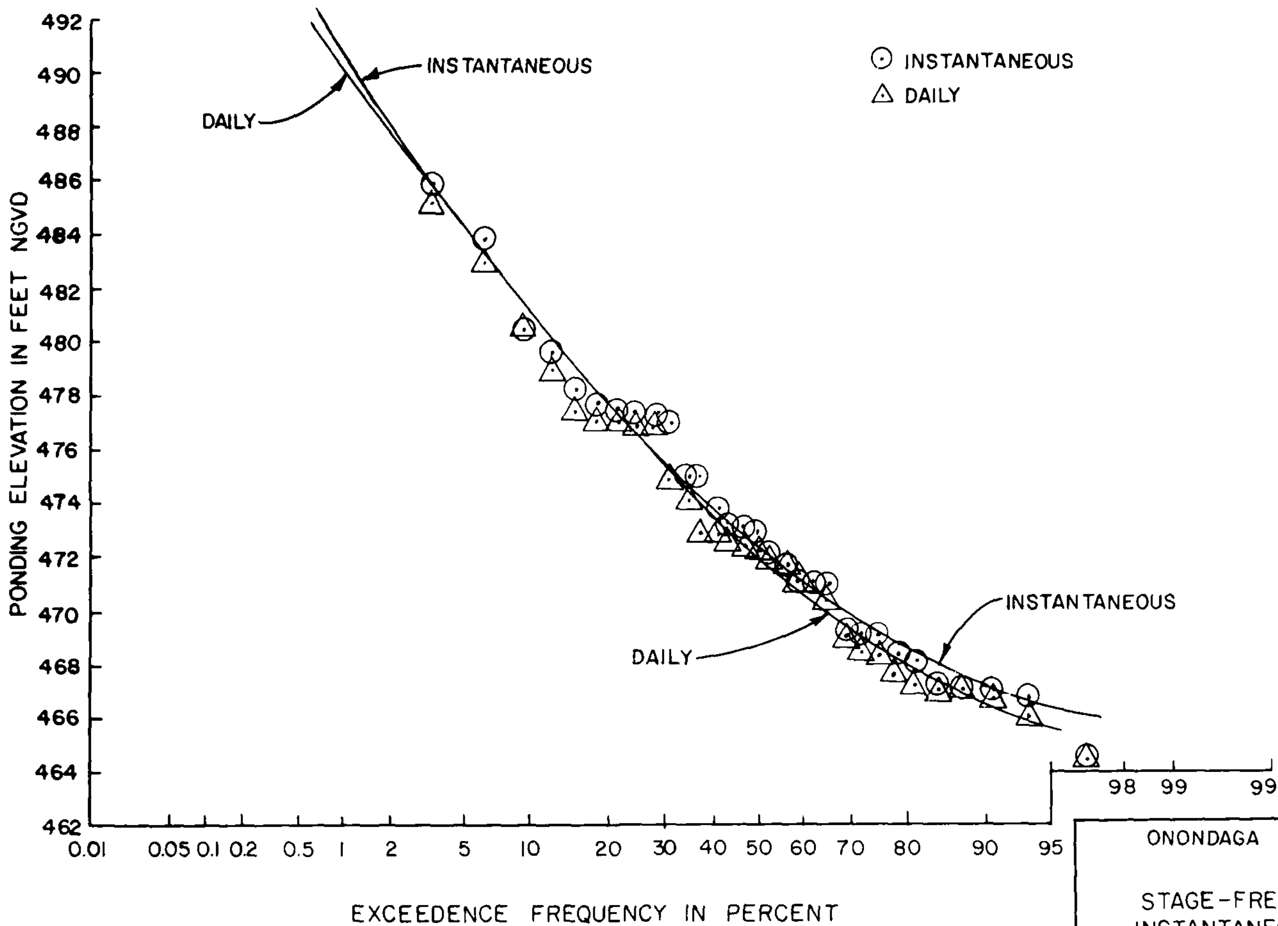


ONONDAGA DAM, NEW YORK

STAGE-FREQUENCY CURVE
PEAK DAILY POND ELEVATIONS

U.S. ARMY ENGINEER DISTRICT BUFFALO
TO ACCOMPANY STABILITY ANALYSIS
DATED:

FIGURE E2

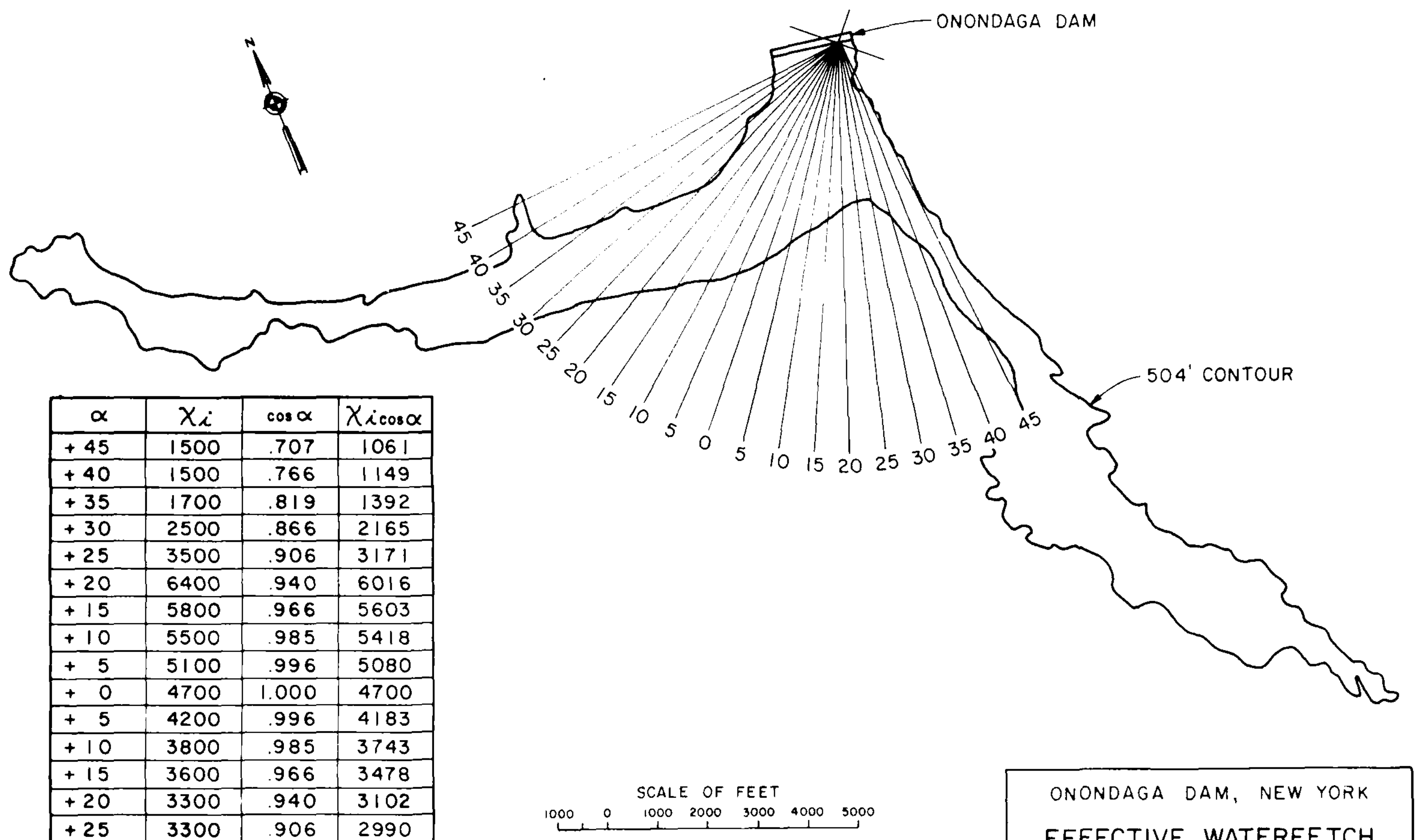


ONONDAGA DAM, NEW YORK

STAGE-FREQUENCY CURVE
INSTANTANEOUS AND DAILY

U.S. ARMY ENGINEER DISTRICT BUFFALO
TO ACCOMPANY STABILITY ANALYSIS
DATED:

FIGURE F3



α	X_i	cos α	$X_i \cos α$
+ 45	1500	.707	1061
+ 40	1500	.766	1149
+ 35	1700	.819	1392
+ 30	2500	.866	2165
+ 25	3500	.906	3171
+ 20	6400	.940	6016
+ 15	5800	.966	5603
+ 10	5500	.985	5418
+ 5	5100	.996	5080
+ 0	4700	1.000	4700
+ 5	4200	.996	4183
+ 10	3800	.985	3743
+ 15	3600	.966	3478
+ 20	3300	.940	3102
+ 25	3300	.906	2990
+ 30	3300	.866	2858
+ 35	3700	.819	3030
+ 40	4200	.766	3217
+ 45	6300	.707	4454

ONONDAGA DAM, NEW YORK

EFFECTIVE WATERFETCH CALCULATION

U S ARMY ENGINEER DISTRICT BUFFALO
TO ACCOMPANY STABILITY ANALYSIS
DATED

FIGURE E4

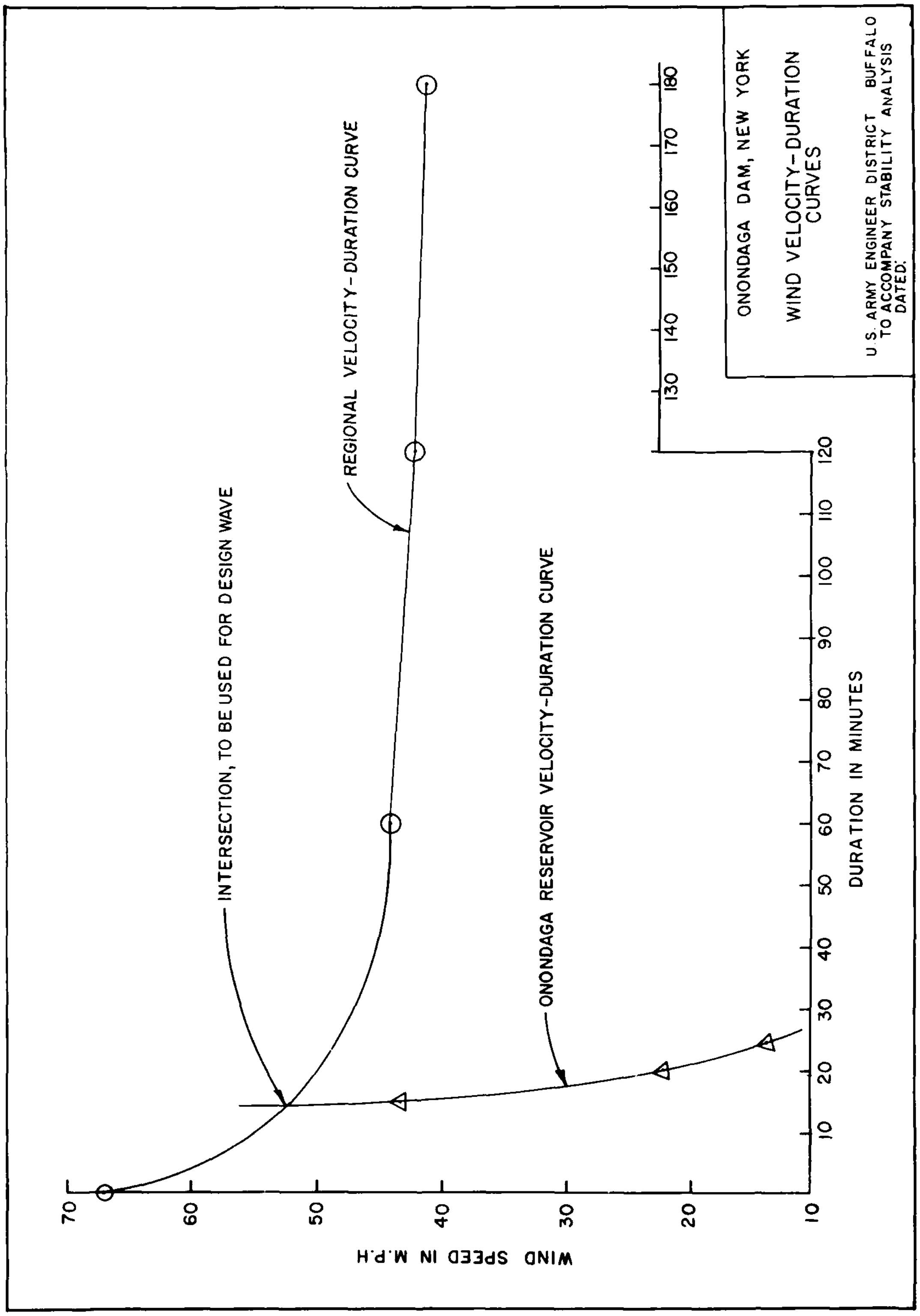

ONONDAGA DAM, NEW YORK
WIND VELOCITY-DURATION CURVES
U.S. ARMY ENGINEER DISTRICT BUFFALO
TO ACCOMPANY STABILITY ANALYSIS
DATED:
REGIONAL VELOCITY-DURATION CURVE
INTERSECTION, TO BE USED FOR DESIGN WAVE
ONONDAGA RESERVOIR VELOCITY-DURATION CURVE
WIND SPEED IN M.P.H
DURATION IN MINUTES
70
60
50
40
30
20
10
10
20
30
40
50
60
70
80
90
100
110
120
130
140
150
160
170
180

FIGURE E5

ONONDAGA DAM, NY

SLOPE PROTECTION CALCULATIONS
APPENDIX F

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

Page ___ of ___ pages.

Subject: ONONDAGA DAM STABILITY ANALYSIS

Computation of: RIPRAP DESIGN

Computed by: G.L. Checked by: ___ Date: 2/4/86

REF: EM1110-2-2300 "EARTH AND ROCKFILL DAMS GENERAL DESIGN AND CONSTRUCTION CONSIDERATIONS" DATED 10 MAY 82.

A.) LAYER THICKNESS:

$$\gamma_{STONE} = G_{STONE}\,\gamma_w = 2.65(62.4) = 165.4\ lb/ft^3$$

$$G_{STONE} = 2.65$$

$$H_s = 2\ ft.$$

$$\cot\alpha = 2.5$$

$$W_a = \frac{\gamma (H_s)^3}{4.37 \cot\alpha (G-1)^3} \quad \text{(MEDIAN SIZE STONE WEIGHT)}$$

$$W_a = \frac{165.4(2)^3}{4.37(2.5)(2.65-1)^3} = 27.5\ lbs$$

$$W_{MAX} = 4W_a = 4(27.5\ lbs) = 110\ lbs$$

$$W_{MIN} = \frac{W_a}{8} = \frac{27.5\ lbs}{8} = 3.4\ lbs$$

$$T = 20\left(\frac{W_a}{\gamma}\right)^{1/3} = 20\left(\frac{27.5\ lbs}{165.4\ lb/ft^3}\right)^{1/3} = 11\ in$$

SAY 12 in

Page ___ of ___ pages.

Subject ______
Computation of ______
Computed by ______ Checked by ______ Date ______

B.) GRADATION;

T=12in.

PERCENT LIGHTER BY WEIGHT	LIMITS OF STONE WEIGHT (lbs)
100	86 - 35
50	26 - 17
15	13 - 5
10	4 - 12

ONONDAGA DAM, NY

SPILLWAY STABILITY ANALYSIS

ATTACHMENT NO. 1

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

NCDED-T (5 Mar 79) 1st Ind
SUBJECT: Periodic Inspection Report No. 3, Onondaga Dam, Onondaga Creek, NY

DA, North Central Division, Corps of Engineers, 536 South Clark Street, Chicago, Illinois 60605 2 [illegible] MAR 1979

TO: District Engineer, Buffalo

1. The subject Periodic Inspection Report is approved.

2. Copies of the original 1945 stability analysis are not considered a satisfactory update of embankment stability in accordance with current standards. Recompute and resubmit this analysis prior to the next scheduled periodic inspection.

3. It will be important to monitor the observed seepage (page 4, paragraph 8b) during periods of high pool.

FOR THE DIVISION ENGINEER:

wd incl

DONALD J. LEONARD
Acting Chief, Engineering Division

Copy furnished:
DAEN-CWE-BB, w/cy of bsc and incl

NCBED-DM 5 March 1979

SUBJECT: Periodic Inspection Report No. 3,
Onondaga Dam, Onondaga Creek, NY

Division Engineer, North Central
ATTN: NCDED-T

1. Request approval of the attached document.

2. Enclosed are five copies of the "Periodic Inspection Report No. 3, Onondaga Dam Onondaga Creek, NY" dated 9 November 1978.

DONALD M. LIDDELL
Chief, Engineering Division

Incl.
as

NCBED-D
NCBED-DM

B. Spillway Analysis

The spillway is being analyzed under present day criteria; reference EM 1110-2-2200. The main change between the original design and the criteria outlined in this manual derives from uplift pressure requirements. The original design was based on uplift over 50% of the concrete - bedrock interface area. Presently the EM requires, "The uplift pressure at any point under the structure will be tailwater pressure plus the pressure measured as an ordinate from tailwater to the hydraulic gradient between upper and lower pool. Uplift pressure will be considered as acting over 100% of the area upon which it impinges.

Where no provision for uplift reduction has been made, the hydraulic gradient will be assumed to vary, as a straight line, from headwater to tailwater."

There are two section of the spillway being analyzed, at ELEV. 485.4' And 461.5'. The section at 485.4 is the concrete and bedrock interface, while at 461.5' is a

Subject ___
Computation of ___
Computed by ___ Checked by ___ Date ___

section sliced through the bedrock at the spillway channel bottom Elevation. The loading cases analyzed are as follows:

(A). Section at Elev. 485.4 ft

Case I @ El 485.4'

a). water surface at Elev. 520.3'
b). full hydrostatic pressure against upstream face.
c). Effective tailwater at Elev. 497.5'
d). uplift 100% headwater at the heel decreasing uniformly to 100% effective tailwater at the toe.

Case II @ El 485.4'

a). water surface at Elev. 520.3'
b). full hydrostatic pressure against upstream face.
c). Effective tailwater at zero
d). uplift 100% headwater at the heel decreasing uniformly to zero at the toe.

Case III @ El 485.4'

a) Same as Case I @ 485.4', except effective tailwater is at El 504.5'.

Subject ____
Computation of ____
Computed by ____ Checked by ____ Date ____

(B) Sections at Elev. 461.5'

Case I @ El 461.5'

a). Same as Case I at El 485.4'

Case II @ El 461.5'

– Original Case II is not considered applicable for an analysis at Elev. 461.5', because it was felt impossible for an condition of full headwater to exist with no effective tailwater. Case III below assumptions was considered a sufficiently severed condition to cover the original assumption of case II.

Case III @ El 461.5'

a). Same as case I @ El 461.5', except that effective tailwater Elev. at 504.5'.

Case IV @ El 461.5'

a) Same as Case I @ El 461.5', except that effective tailwater Elev. at 485.4'.

Case V @ El 461.5.

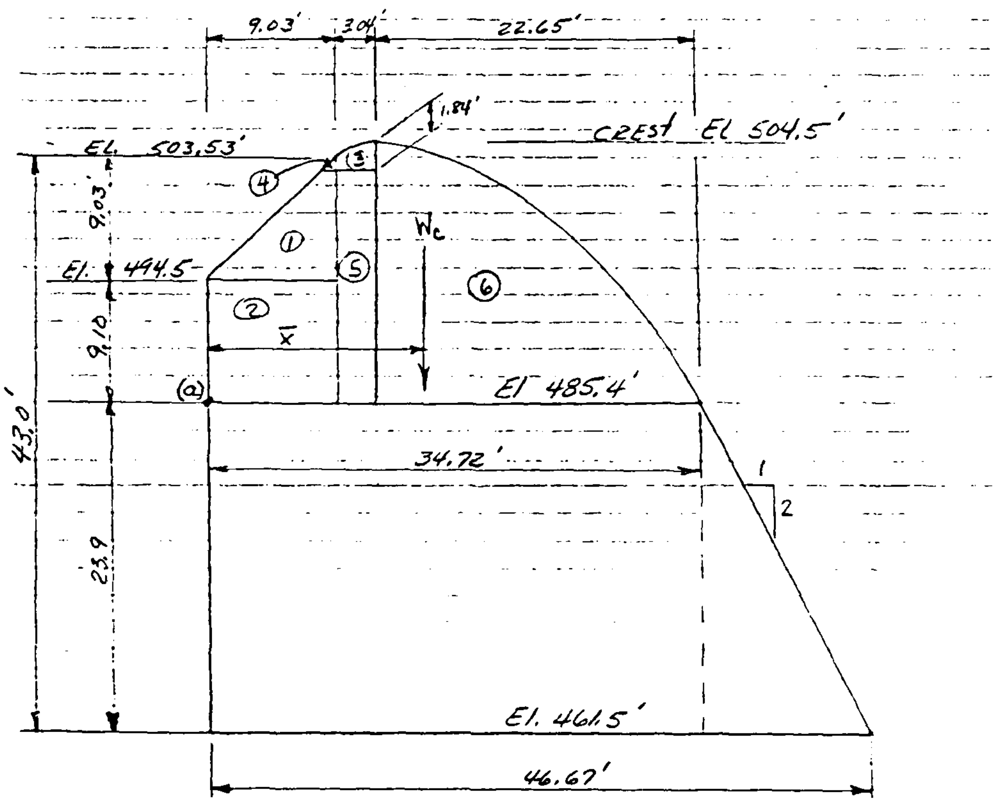
a). water surface at Elev. 504.5'
b). full hydrostatic pressure against upstream face.
c). No tailwater on spillway side.
d). Uplift 100% headwater at the heel decreasing to zero at the toe.

Sliding Coef
1) Concrete to Rock = 0.65
2) Rock to Rock = 0.30.

Subject ___

Computation of ___

Computed by ___ Checked by ___ Date ___



Properties of Concrete wier section above El 485.4

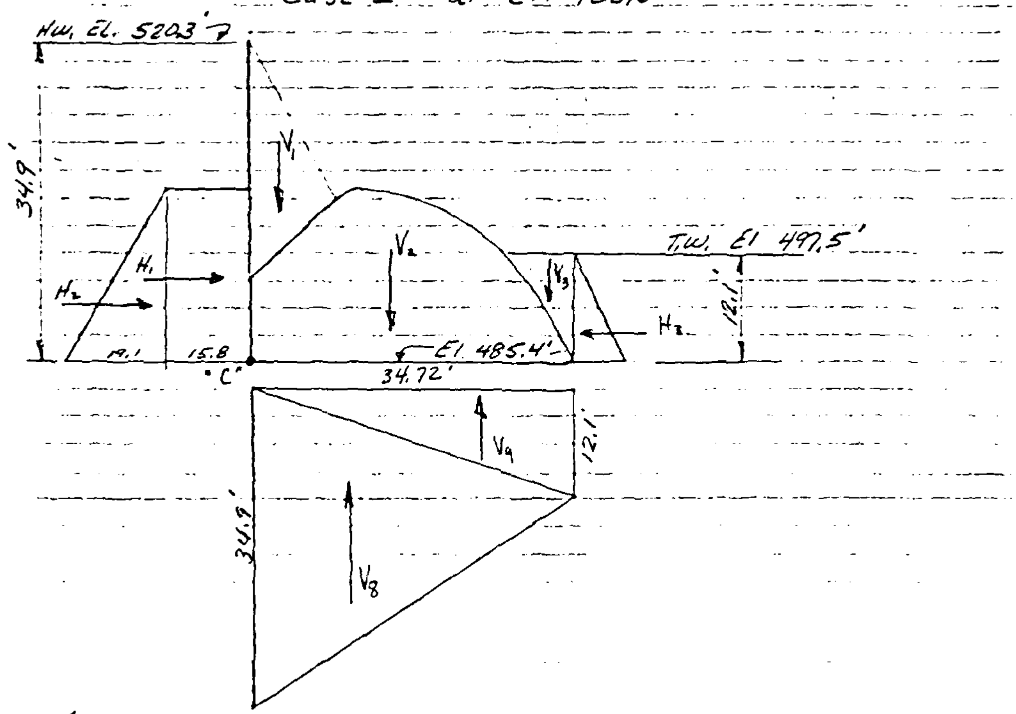
section	area	×	m.a.	=	ΣM(a)
① ½ · 9.03 · 9.03 =	40.77	×	6.02	=	245.44
② 9.03 · 9.10 =	82.17	×	4.52	=	371.42
③ (π · 1.84 · 3.45) ÷ 4 =	4.99	×	10.62	=	52.99
④ − ½ × 0.84 × 0.41 =	−0.18	×	8.89	=	−1.60
⑤ 3.04 × 17.26 =	52.47	×	10.55	=	553.56
⑥ ⅔ · 20 · 22.65 =	301.94	×	20.56	=	6209.11
Total	ΣA = 482.16 sq ft				ΣM(a) = 7430.82

$$\bar{x} = \frac{\Sigma M_a}{\Sigma A} = \frac{7430.8}{482.2} = \underline{15.41\ ft}$$

$$W_c = A \cdot 150^{\#}/_{CF} = 482.2^{ft^2} \times 0.15^{k}/_{F} = \underline{72.32\ kip/ft}$$

Subject ______
Computation of ______
Computed by ______ Checked by ______ Date ______

Case I at El. 485.6'



$\circlearrowleft + \Sigma M_{(c)}$ about Pt. C.

	ΣV (kip)	ΣH (kip)	m.a.	ΣMc (k-ft)
V1 = ½ · 25.8 · 9.03 · 0.0625 =	7.28	—	3.01	21.91
V2 = see pg #4	72.32	—	15.41	1114.45
V3 = ½ · 8.9 · 12.1 × 0.0625 =	3.37	—	31.75	107.0
V8 = −½ · 34.9 · 34.72 × 0.0625 =	−37.87	—	11.57	−438.16
V4 = −½ · 12.1 × 34.72 × 0.0625 =	−13.13	—	23.15	−303.96
H1 = 19.1 × 15.8 × 0.0625 =	—	18.86	9.55	180.11
H2 = ½ · 19.1 × 19.1 × 0.0625 =	—	11.40	6.37	72.62
H3 = −½ · 12.1 × 12.1 × 0.0625 =	—	−4.78	4.03	−19.26
Total	ΣV = 31.97	ΣH = 25.48		ΣM = 734.71

$$\bar{y} = \frac{\Sigma M}{\Sigma V} = \frac{734.71^{k\text{-}ft}}{31.97^{k}} = \underline{\underline{22.98\ ft}}$$

Subject ___
Computation of ___
Computed by ___ Checked by ___ Date ___

$\frac{b}{3} = \frac{34.72}{3} = 11.57$ ft

$e = 5.63$ ft $< e_{max} = 5.79$ ft okay

∴ Resultant is 0.17 ft within the middle third of base.

Sliding Coef (without Rails)

$\frac{\Sigma H}{\Sigma V} = \frac{25.48}{31.97} = 0.797 > 0.65$ N.G ✓

Sliding Coef (with Rail) using monolith #1 with 5 Rails (#70 ASCE).

$F_1 = \frac{5 \text{ rail} \times 6.81 \text{ in}^2/\text{rail}}{33.33 \text{ ft}} \times 12 \text{ K/in}^2 = 12.26$ kip/ft

$\text{Coef} = \frac{H_1 - F_1}{V_1} = \frac{25.48 - 12.26}{31.97}$

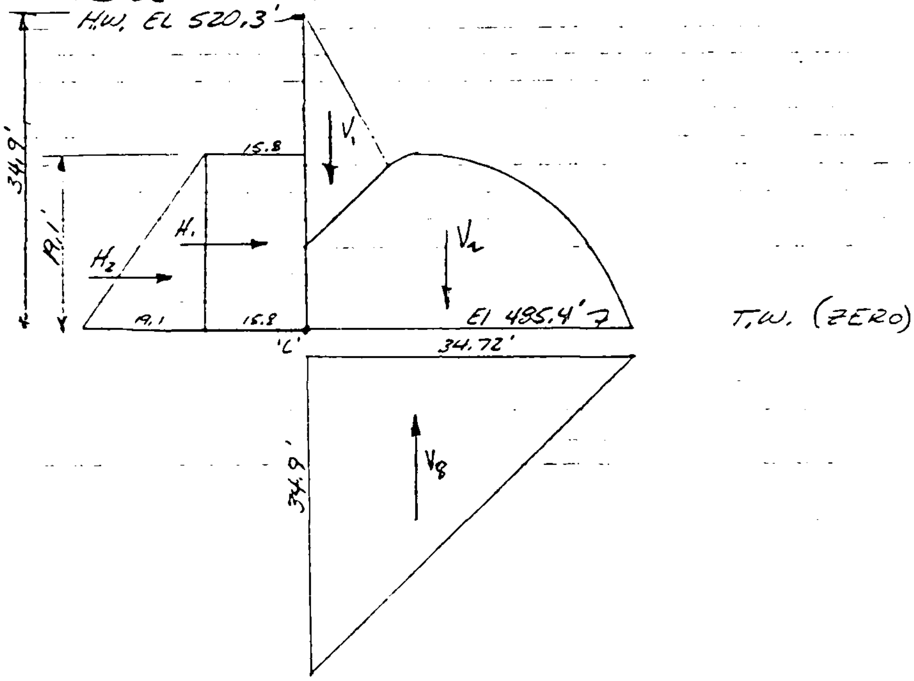
[Sliding Coef = 0.41] < 0.65 OKAY ✓

Max. Ftn. Pressure $= \frac{31.97^k}{34.72^{ft}}\left(1 + \frac{6(5.63)}{34.72}\right) = 1.82$ k/SF

Min Ftn. Pressure $= \frac{31.97^k}{34.72^{ft}}\left(1 - \frac{6(5.63)}{34.72}\right) = 0.025$ K/SF

Subject ___
Computation of ___
Computed by ___ Checked by ___ Date ___

Case II Elev. 485.4 ft.



(+ΣM(c)) about Pt C.

		ΣV	ΣH	ma	ΣMc (k.ft)
V1 =	See pg 5.	7.28	—	3.01	21.91
V2 =	"	72.32	—	15.41	1114.45
VB =	"	-37.87	—	11.57	-438.16
H1 =	"	—	18.86	9.55	180.11
H2 =	"	—	11.40	6.37	72.62

Totals ΣV = 41.73 ΣH = 30.26 ΣM = 950.93

$$\bar{y} = \frac{\Sigma M}{\Sigma V} = \frac{950.93}{41.73} = 22.79 \text{ ft.}$$

Subject ____
Computation of ____
Computed by ____ Checked by ____ Date ____

$\frac{b}{3} = 11.57$

$e = 5.43$ ft $< e_{max} = 5.79$ (okay)

Resultant is 0.36 ft within the middle third of base.

Sliding Coef (without Rails).

$\frac{\Sigma H}{\Sigma V} = \frac{30.26^k}{41.73} = 0.725 > 0.65$ N.G

Sliding Coef with Rails.

$F_1 =$ (see Pg 6) $= 12.26$ k/ft.

Sliding Coef $= \frac{H_{II} - F_1}{V_{II}} = \frac{30.26 - 12.26}{41.73}$

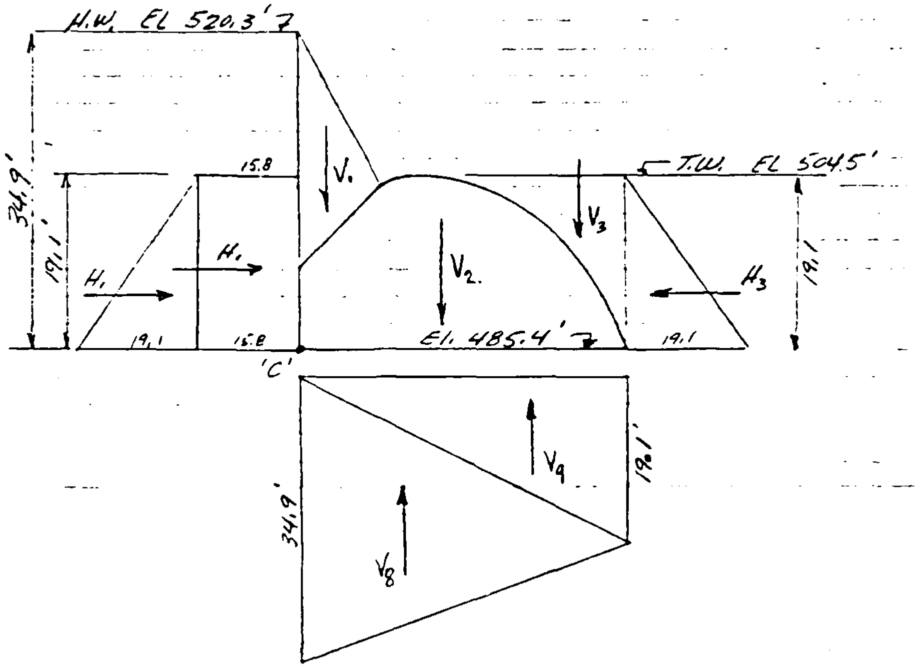
[Sliding Coef = 0.43] < 0.65 okay

Max Ftn. Pressure $= \frac{41.73^k}{34.72'}\left(1 + \frac{6(5.43)}{34.72}\right) = 2.33$ k/sf

Min Ftn. Pressure $= \frac{41.73^k}{34.72'}\left(1 - \frac{6(5.43)}{34.72}\right) = 0.075$ k/s

Subject ___
Computation of ___
Computed by ___ Checked by ___ Date ___

Case III Elev. 485.4 ft.



$\curvearrowright + \Sigma M_{(c)}$ at Point "C"

		ΣV	ΣH	ma	ΣMc
V_1 =	See pg #5 =	7.28	—	3.01	21.91
V_2 =	" =	72.32	—	15.41	1114.45
V_3 =	[(22.65 × 19.1) − 301.94] 0.0625 =	8.17	—	17.73	144.85
V_8 =	" =	−37.87	—	11.57	−438.16
V_9 =	− ½ × 19.1 × 34.72 × 0.0625 =	−20.72	—	23.15	−479.67
H_1 =	" =	—	18.86	9.55	180.11
H_2 =	" =	—	11.40	6.37	+72.62
H_3 =	− ½ × 19.1 × 19.1 × 0.0625 =	—	−11.40	6.37	−72.67
	Totals	ΣV = 29.18	ΣH = 18.86		ΣM = 543.49

$$\bar{y} = \frac{\Sigma M}{\Sigma V} = \frac{543.49}{29.18} = 18.63 \text{ ft}$$

Subject ___
Computation of ___
Computed by ___ Checked by ___ Date ___

$\frac{b}{3} = 11.57$ ft.

$e = 1.27$ ft $< e_{max} = 5.79$ ft ... OKAY

Resultant is 4.52 ft within the middle third of base.

Sliding Coef (without Rails)

$$\frac{\Sigma H}{\Sigma V} = \frac{18.86^k}{29.18} = 0.65 \approx 0.65$$ ✓

Sliding Coef (with Rails)

F_1 = see pg #6 = 12.26 k/ft.

$$Coef = \frac{H_{III} - F_1}{V_{III}} = \frac{18.86 - 12.26}{29.18}$$

Sliding Coef = 0.23 < 0.65 OKAY

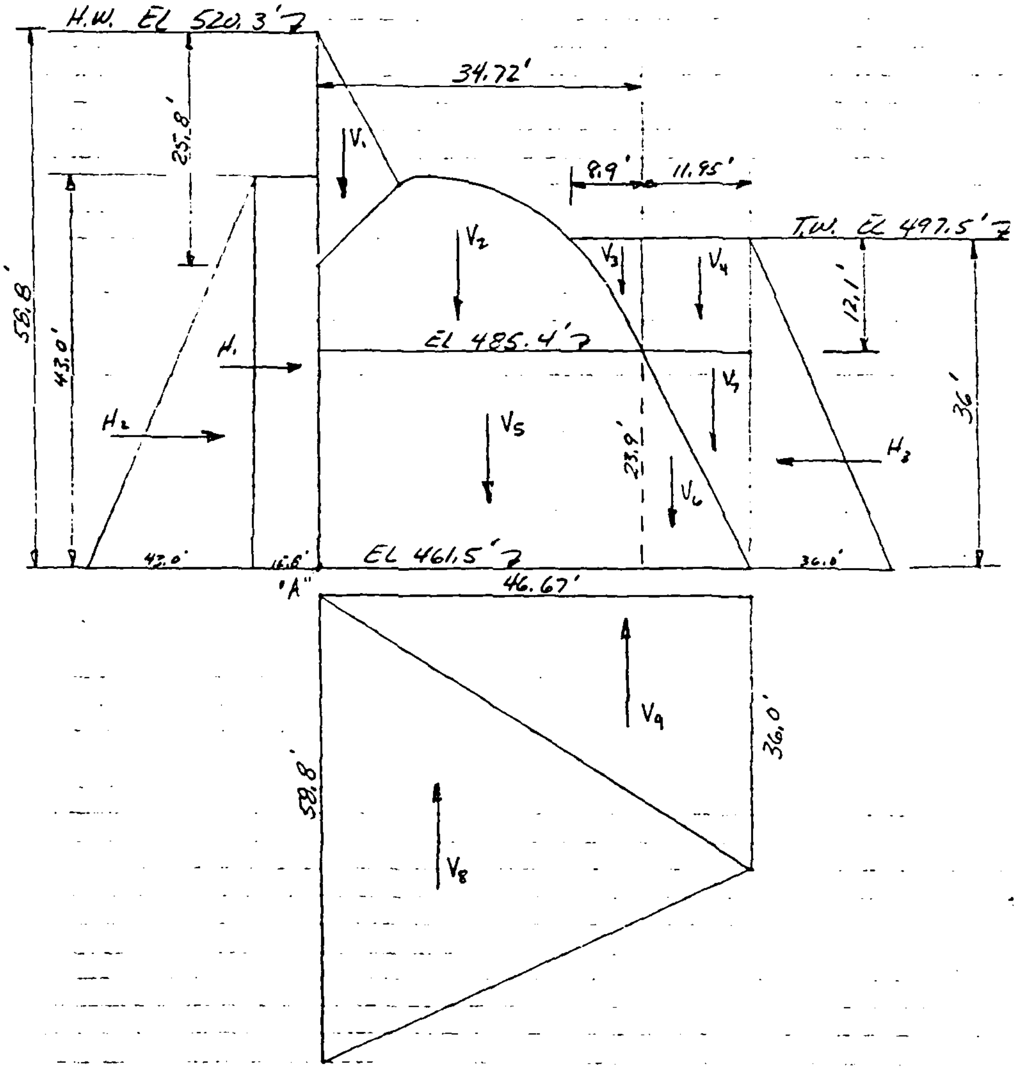
$$\text{Max Ftn Pressure} = \frac{29.18^k}{34.72^{ft}}\left(1 + \frac{6(1.27)}{34.72}\right) = 1.02 \text{ k/sf}$$

$$\text{Min Ftn. Pressure} = \frac{39.18^k}{34.72^{ft^2}}\left(1 - \frac{6(1.27)}{34.72}\right) = 0.656 \text{ K/sf}$$

Subject: Spillway Stability Analysis – Elev 461.5
Computation of: Onondaga Dam
Computed by: K. Owen Checked by: ______ Date: April 19__

Investigation of conditions at Elev. 461.5 ft.

Case I at Elev 461.5'



Subject ___
Computation of ___
Computed by ___ Checked by ___ Date ___

$\Sigma M_{(A)}$ about Pt. A

		ΣV	ΣH	ma	$\Sigma M_{(A)}$
V_1 =	½ × 25.8 × 9.03 × 0.0625 =	7.28	—	3.01	21.91
V_2 =	see pg # 4. =	72.32	—	15.41	1114.45
V_3 =	½ × 8.9 × 12.1 × 0.0625 =	3.37	—	31.75	107.00
V_4 =	11.95 × 12.1 × 0.0625 =	9.04	—	40.70	367.93
V_5 =	34.72 × 23.9 × 0.150 =	124.47	—	17.36	2160.82
V_6 =	½ × 11.95 × 23.9 × 0.150 =	21.42	—	38.70	828.95
V_7 =	½ × 11.95 × 23.9 × 0.0625 =	8.93	—	42.68	381.13
V_8 =	−½ × 46.67 × 58.8 × 0.0625 =	−85.76	—	15.56	−1334.42
V_9 =	−½ × 46.67 × 36.0 × 0.0625 =	−52.50	—	31.11	−1633.33
H_1 =	15.8 × 43.0 × 0.0625 =	—	42.46	21.50	912.89
H_2 =	½ × 43. × 43. × 0.0625	—	57.78	14.33	829.18
H_3 =	−½ × 36 × 36 × 0.0625	—	−40.50	12.00	−486.00
	Totals	ΣV = 108.57	ΣH = 59.74		ΣM_A = 3270.51

$$\bar{y} = \frac{\Sigma M}{\Sigma V} = \frac{3270.51}{108.57} = 30.12 \text{ ft.}$$

$$\frac{b}{3} = \frac{46.67}{3} = 15.56 \text{ ft.}$$

$$e = 6.80' < e_{max} = 7.78 \text{ ft}$$ OKAY

Resultant is 0.98' with in the middle third of base.

Sliding Coef (with out Rails).

$$\text{Coef} = \frac{\Sigma H}{\Sigma V} = \frac{59.74}{108.57} =$$

Coef = 0.55 ≮ 0.30 N.G

Sliding Coef (with Rails) (monolith # 6.)

$$F_6 = \frac{(13 \text{ rails}) \times 6.81 \text{ in}^2/\text{rail}}{33.33 \text{ ft}} \times (12 \text{ K/in}^2)$$

$$F_6 = 31.87 \text{ kip/ft.}$$

Subject ___
Computation of ___
Computed by ___ Checked by ___ Date ___

$$Coef = \frac{H_1 - F_c}{V_1} = \frac{59.74 - 31.87}{108.57}$$

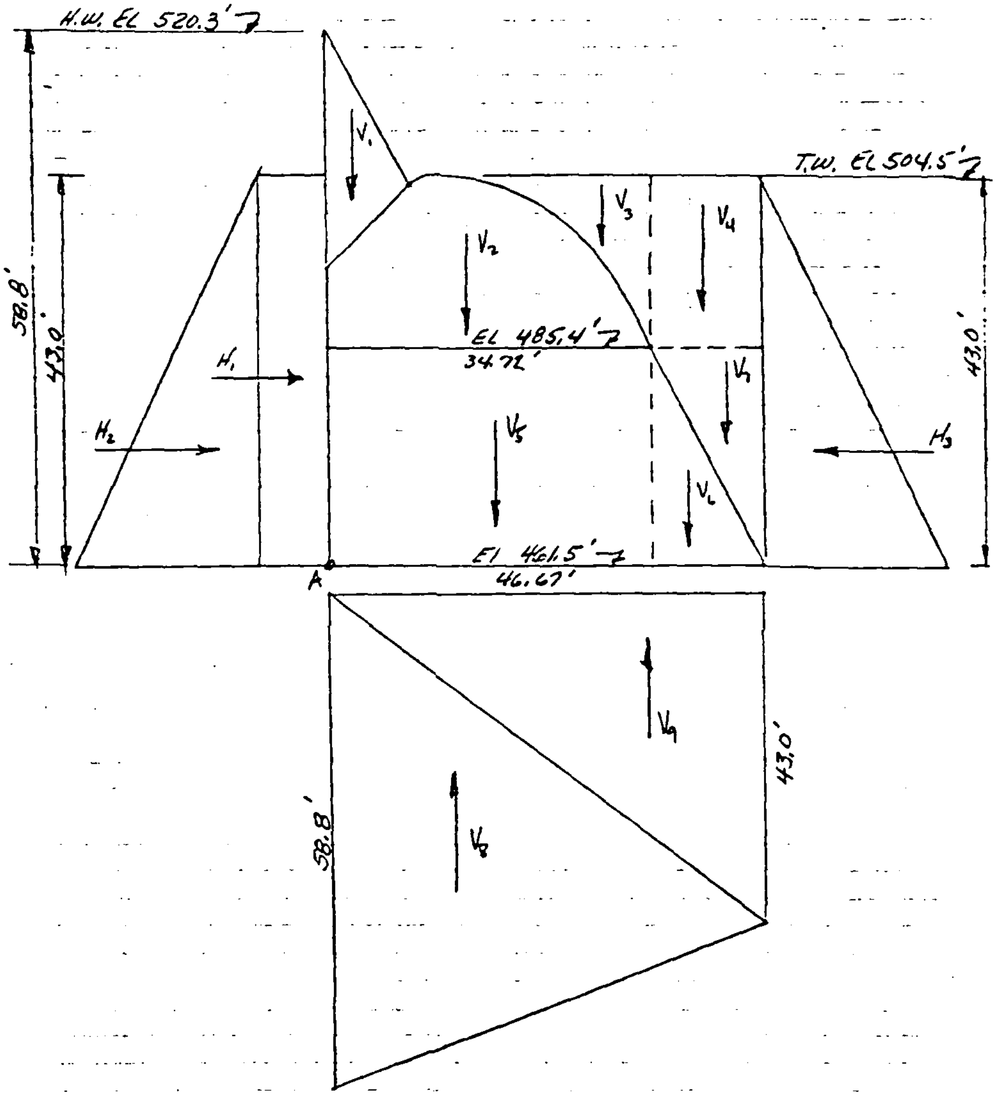
[Sliding Coef = 0.26] < 0.30 OKAY

$$\text{Max Ftn. Pressure} = \frac{108.59^k}{46.67 ft^2}\left(1 + \frac{6(6.8)}{46.67}\right) = 4.36\ K/SF$$

$$\text{Min Ftn. Pressure} = \frac{108.59^k}{46.67 ft^2}\left(1 - \frac{6(6.8)}{46.67}\right) = 0.293\ K/SF$$

Subject ___
Computation of ___
Computed by ___ Checked by ___ Date ___

Case III at Elev 461.5 ft.



Subject ____
Computation of ____
Computed by ____ Checked by ____ Date ____

ΣM(A) about Pt. A

		ΣV	ΣH	ma	ΣM(A)
V_1 =	see pg # 12	7.28	—	3.01	21.91
V_2 =	"	72.32	—	15.41	1114.45
V_3 =	[(19.1 × 22.65) − (2/3 × 19.1 × 22.65)] × 0.0625	9.01	—	27.17	244.80
V_4 =	19.1 × 11.95 × 0.0625	14.27	—	40.70	580.79
V_5 =	see pg # 12	124.47	—	17.36	2160.82
V_6 =	"	21.42	—	38.70	828.95
V_7 =	"	8.93	—	42.68	381.13
V_8 =	"	−85.76	—	15.56	−1334.42
V_9 =	−½ × 43 × 46.67 × 0.0625	−62.71	—	31.11	−1950.98
H_1 =	see pg # 12	—	42.46	21.50	912.89
H_2 =	"	—	57.78	14.33	829.18
H_3 =	−½ × 43 × 43. × 0.0625	—	−57.78	14.33	−829.18
	Totals	ΣV = 109.23	ΣH = 42.46		ΣM = 2960.34

$$\bar{y} = \frac{\Sigma M}{\Sigma V} = \frac{2960.34}{109.23} = 27.10 \text{ ft.}$$

$\frac{b}{3}$ = 15.56 ft. $e = 3.76$ ft < $e_{max} = 7.78$ ft OK!!

Resultant is 4.0 ft within the middle third of base. ✓

Sliding Coef (without Rails)

$$\text{Coef} = \frac{\Sigma H}{\Sigma V} = \frac{42.46^k}{109.23}$$

Coef = 0.389 ≮ 0.30 NG.

Subject ___
Computation of ___
Computed by ___ Checked by ___ Date ___

Sliding Coef (with Rails).

F_L = (see pg # 12) = 31.87 kip/ft.

$$Coef = \frac{H_{III} - F_L}{V_{III}} = \frac{42.46^k - 31.87^k}{109.23^k}$$

[Sliding Coef = 0.10] < 0.30 OK

$$\text{Max Ftn Pressure} = \frac{109.23^k}{46.67\,ft^2}\left(1 + \frac{6(3.76)}{46.67}\right) = 3.47\ k/SF$$

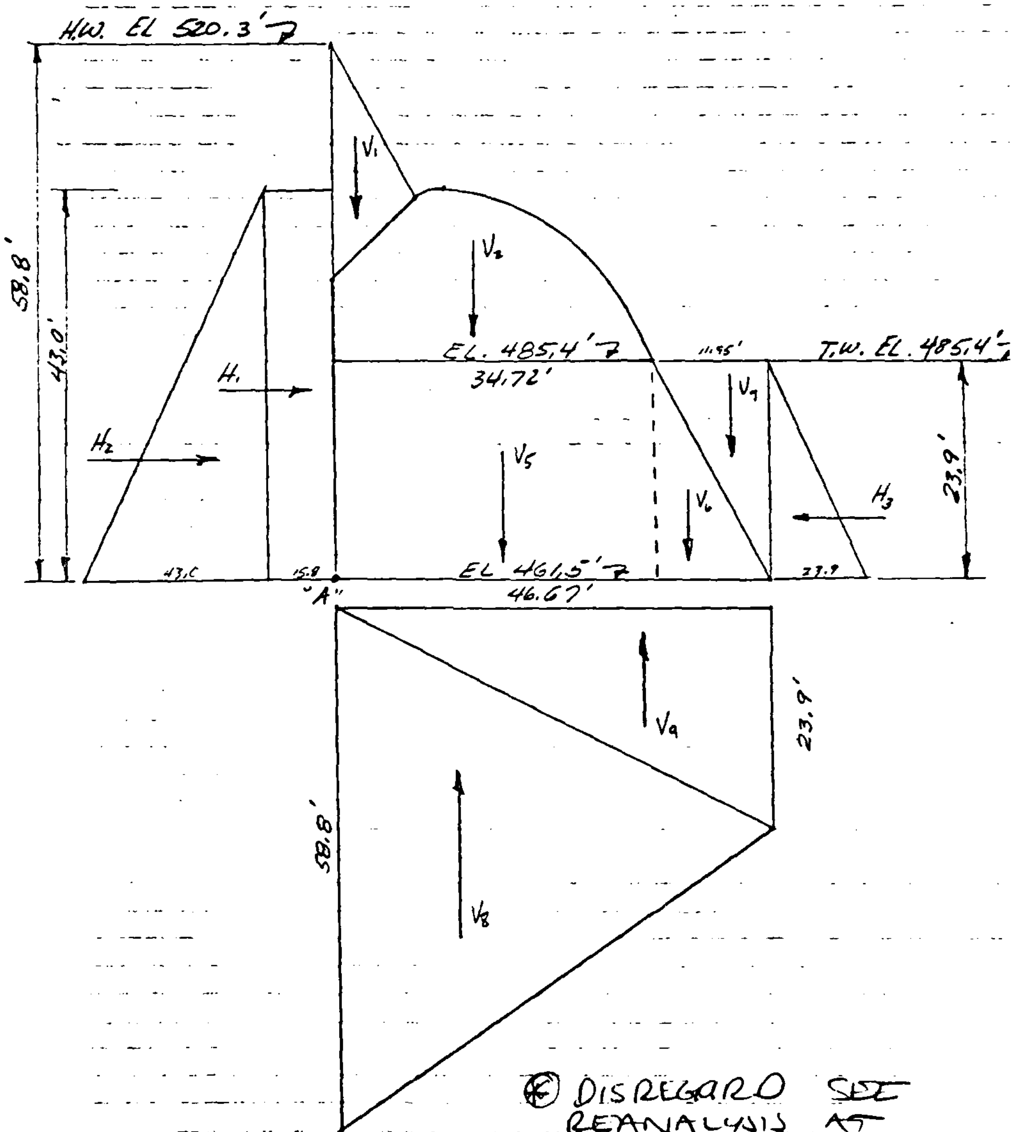
$$\text{Min Ftn Pressure} = \frac{109.23^k}{46.67\,ft^2}\left(1 - \frac{6(3.76)}{46.67}\right) = 1.21\ k/SF$$

Subject ______

Computation of ______

Computed by ______ Checked by ______ Date ______

Case IV at Elev 461.5 ft. (*)



(*) DISREGARD SEE REANALYSIS AT END OF THIS APP.

Subject ___
Computation of ___
Computed by ___ Checked by ___ Date ___

$\Sigma M_{(A)}$ about Pt. A.

		ΣV	ΣH	ma	$\Sigma M_{(A)}$
V_1 =	see pg #12	7.28	—	3.01	21.91
V_2 =	"	72.32	—	15.41	1114.45
V_5 =	"	124.47	—	17.36	2160.82
V_6 =	"	21.42	—	38.70	828.95
V_7 =	"	8.93	—	42.68	321.13
V_8 =	"	-85.76	—	15.56	-1334.42
V_9 =	$-\frac{1}{2} \times 23.9 \times 46.67 \times 0.0625$	-34.85	—	31.11	-1084.22
H_1 =	see pg #12	—	42.46	21.50	912.89
H_2 =	"	—	57.78	14.33	828.18
H_3 =	$-\frac{1}{2} \times 23.9 \times 23.9 \times 0.0625$	—	-17.85	7.97	-142.21
	Totals	ΣV = 113.81	ΣH = 82.39		ΣM_A = 3627.48

$$\bar{y} = \frac{\Sigma M_A}{\Sigma V} = \frac{3627.48}{113.81} = 31.87 \text{ ft}$$

$$\frac{b}{3} = 15.56' \qquad [e = 8.53 > e_{max} = 7.78] \quad \text{N.G.}$$

Resultant is 0.75 ft outside the middle third of base. N.G

Sliding Coef (with out Rails)

$$\text{Coef} = \frac{\Sigma H}{\Sigma V} = \frac{82.39^k}{113.81^k}$$

Sliding Coef = 0.724 $\nless$ 0.30 N.G.

Subject ___
Computation of ___
Computed by ___ Checked by ___ Date ___

Sliding Coef (with Rails)

$$Coef = \frac{H_{IV} - F_6}{V_{IV}} = \frac{82.39^K - 31.87^K}{113.81^K}$$

[Sliding Coef = 0.44] ≯ 0.30 N.G.

$$\text{Max Ftn. Pressure} = \frac{113.81}{46.67}\left(1 + \frac{6(8.53)}{46.67}\right) = 5.11 \text{ k/SF}$$

$$\text{Min Ftn. Pressure} = \frac{113.81}{46.67}\left(1 - \frac{6(8.53)}{46.67}\right) = -0.24 \text{ k/SF}$$

N.G.

Min Ftn. Pressure is -.24 k/SF which indicates a "tension zone"

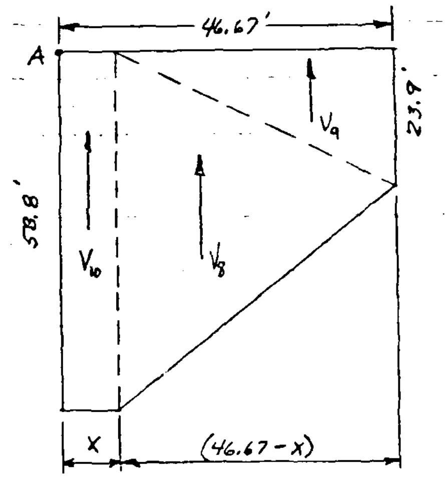
Case IV shows instability in all areas of analysis.

1) Resultant falls out of middle 1/3 of base.
2) Sliding Coef > 0.30.
3) tension zone in Ftn.

Case IV is re-analysed with a tension zone to see if this would result in the Resultant Force falling within the middle 1/3 of the compression zone. Analysis is as follows (Pg #20 thru Pg #2).

Subject ___
Computation of ___
Computed by ___ Checked by ___ Date ___

Case IV   Analysis w/ tension zone.



ΣM_A about Pt. A.

		ΣV	ma	ΣM
V_8 :	$\frac{1}{2} \cdot 58.8 \cdot (46.67 - X) \cdot 0.0625$ =	$(85.75 - 1.84X)$ ·	$[X + \frac{1}{3}(46.67 - X)]$	$= -1.23X^2 + 28.55X + 1333.$
V_9 :	$\frac{1}{2} \cdot 23.9\,(46.67 - X) \cdot 0.0625$ =	$(34.85 - 0.75X)$ ·	$[X + \frac{2}{3}(46.67 - X)]$	$= -0.25X^2 - 11.72X + 1084.$
V_{10} =	$58.8\,(X)\;\;0.0625$ =	$3.675(X)$ ·	$(X/2)$	$= 1.84X^2$

totals $\Sigma V = (120.6 + 1.09X)$ $\Sigma M = 0.36X^2 + 16.83X + 2418.$

From pg # 12 & 18.

		ΣV	ΣH	ma	$\Sigma M_{(A)}$
V_1 =	see pg # 12 =	7.28	—	3.01	21.91
V_2 =	" =	72.32	—	15.41	1114.45
V_5 =	" =	124.47	—	17.36	2160.62
V_6 =	" =	21.42	—	38.70	828.95
V_7 =	" =	8.93	—	42.68	381.13
H_1 =	" =	—	42.46	21.50	912.89
H_2 =	" =	—	57.78	14.33	828.18
H_3 =	" =	—	-17.85	7.97	-142.21

$\Sigma V = 234.42$ $\Sigma H = 82.39$ k. $\Sigma M = 6106.12$ k.ft

Subject ____
Computation of ____
Computed by ____ Checked by ____ Date ____

$\bar{y} = \frac{\Sigma M}{\Sigma V}$

Resultant location is given by "$\bar{y}$". The max. Range of "$\bar{y}$" would be the outside limit of the Kern point. Therefore $\left[\bar{y} = x + \frac{2}{3}(46.67 - x)\right]$.

$$\bar{y} = \frac{\Sigma M}{\Sigma V} = \left[x + \frac{2}{3}(46.67 - x)\right]$$

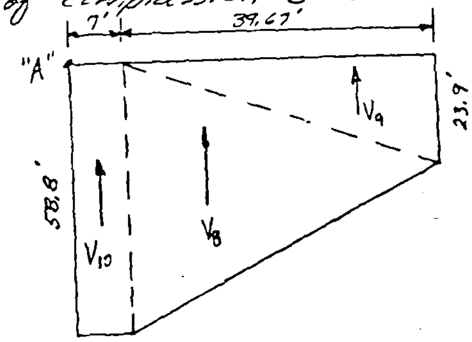
$$\Sigma M = 6106.12 - (0.36x^2 + 16.83x + 2418.11)$$

$$\Sigma V = 234.42 - (120.6 + 1.085x)$$

subsituting & solving for x

$\underline{x = 7.0 \text{ ft}}$ tension zone.

Checking analysis with a 7.0 ft tension zone, to see if Resultant will fall with in the middle 1/3 of compression zone.



AD-A169 722 REPORT ON SEISMIC STABILITY ONONDAGA DAM NEW YORK(U) CORPS OF ENGINEERS BUFFALO NY BUFFALO DISTRICT MAY 86 3/3

UNCLASSIFIED F/G 13/2 NL

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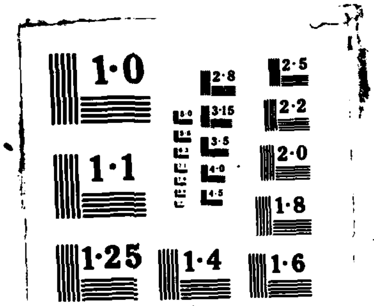

1·0
2·8
2·5
3·15
2·2
3·5
2·0
1·1
4·0
4·5
1·8
1·25
1·4
1·6

Subject ____
Computation of ____
Computed by ____ Checked by ____ Date ____

$\circlearrowleft + \Sigma M_{(A)}$ about Point A

		ΣV	ΣH	ma	$\Sigma M_{(A)}$
V_1 =	see pg #12	= 7.28	———	3.01	21.91
V_2 =	"	= 72.32	———	15.41	1114.45
V_5 =	"	= 124.47	———	17.36	2160.82
V_6 =	"	= 21.42	———	38.70	828.95
V_7 =	"	= 8.93	———	42.68	381.13
V_8 =	$-\frac{1}{2} \times 58.8 \times 39.67 \times 0.0625$	= −72.89	———	20.22	−1473.91
V_9 =	$-\frac{1}{2} \times 23.9 \times 39.67 \times 0.0625$	= −29.67	———	33.45	−991.12
V_{10} =	$58.8 \times 7.0 \times 0.0625$	= −25.76	———	3.50	−90.04
H_1 =	see pg #12	= ———	42.46	21.50	912.89
H_2 =	"	= ———	57.78	14.33	828.18
H_3 =	"	= ———	−17.85	7.97	−142.21
totals		$\Sigma V = 106.17^k$	$\Sigma H = 82.39$		$\Sigma M_A = 3551.05$ k.

$$\bar{y} = \frac{\Sigma M}{\Sigma V} = \frac{3551.05^{k.ft}}{106.17^{k}} = \underline{33.45 \text{ ft}}$$

$$\frac{b}{3} \left(\text{compression zone}\right) = \frac{39.67}{3} = 13.22 \;;\; e_{max} = 6.61 \text{ ft.}$$

$$e_{(actual)} = 6.61 \text{ ft} \leq e_{max} \quad \underline{\text{okay}}$$

∴ Resultant falls within the middle ⅓ of compression zone of base.

Sliding Coef. (with Rails); there are 13 Rails

$$\text{Coef} = \frac{H_{II} - F_6}{V_{II}} = \frac{82.39 - 31.87}{106.17}$$

{Sliding Coef = 0.48} > 0.30 for Rock to Rock

<u>No. good!!</u>

Subject ___
Computation of ___
Computed by ___ Checked by ___ Date ___

Calculate the Required amount of Steel So that Sliding coef = 0.30.

$$\frac{H - F}{V} = 0.30$$

$$F = H - 0.30V$$

$$F = 82.39^{k} - 0.3(106.17) = 50.54 \text{ kips}$$

knowing that:

$$F = \left[(\#\text{Rails} \times \text{Area/Rail}) \div \text{length of Monolith}\right] \times \text{shear strength of Rail.}$$

$$= \left[(N \times A) \div L\right] S$$

solving for $N = \frac{F \cdot L}{A S}$

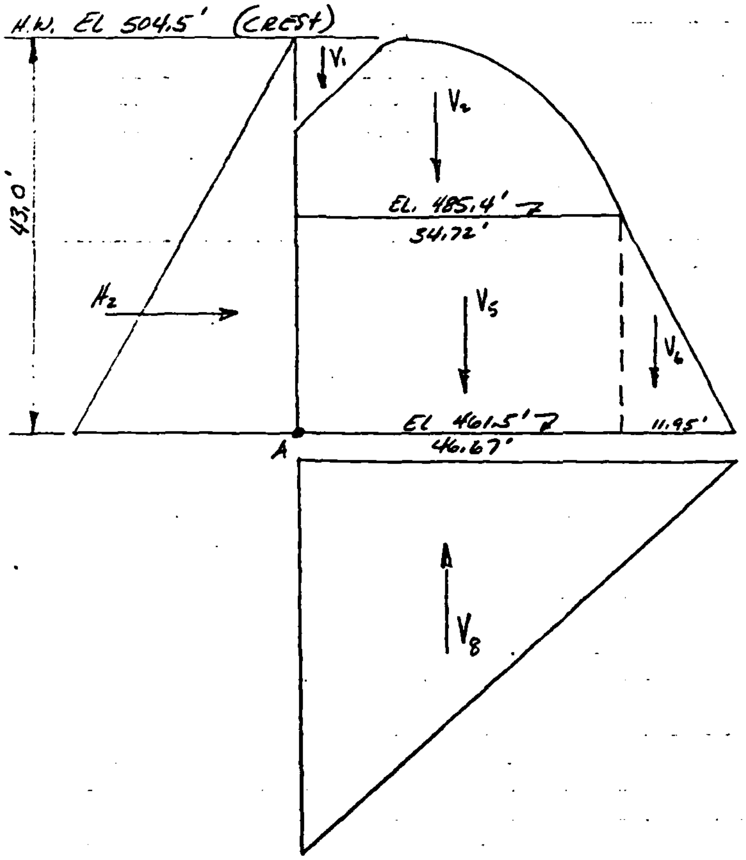
$$\text{Number of Rail} = N = \frac{(50.54^{k})(33.33^{ft})}{6.81\,in^2 \times 12^{k}/in^2} = 20.6$$

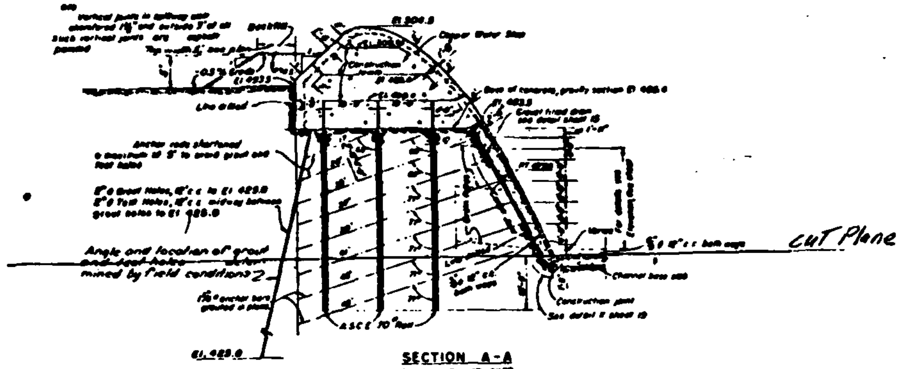
or USE 21 Rails - (HSCE #70)

{ there were 13 rails provided, therefore an additional 8 rails are needed, if there has to be a sliding coef = 0.30. }

Subject ___
Computation of ___
Computed by ___ Checked by ___ Date ___

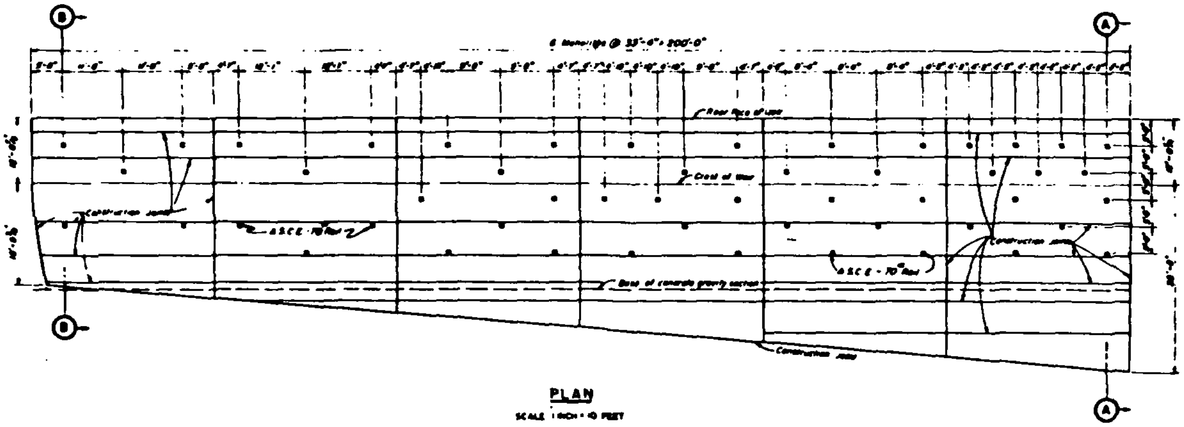
Case V at Elev. 461.5 ft.





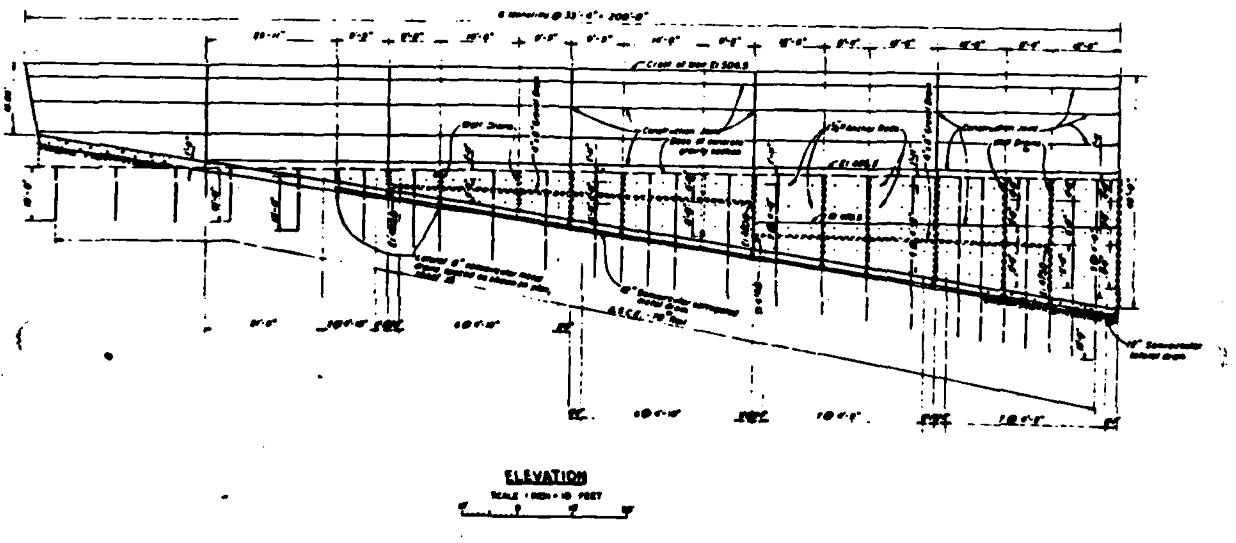
SECTION A-A

SCALE 1 INCH = 10 FEET



PLAN

SCALE 1 INCH = 10 FEET



ELEVATION

SCALE 1 INCH = 10 FEET

Subject ____

Computation of ____

Computed by ____ Checked by ____ Date ____

$\circlearrowright + \Sigma M_{(A)}$ about Pt. A.

		ΣV	ΣH	m.a.	$\Sigma M_{(A)}$
V_1	= ½ × 10 × 10 × 0.0625 =	3.13		3.33	10.43
V_2	= see pg #12 =	72.32		15.41	1114.45
V_5	= " =	124.47		17.36	2160.82
V_6	= " =	21.42		38.70	828.95
V_8	= ½ × 43 × 46.67 × 0.0625 =	−62.71		15.56	−975.77
H_2	= ½ × 43 × 43. × 0.0625 =		57.78	14.33	828.18
	totals	$\Sigma V = 158.63$	$\Sigma H = 57.78$		$\Sigma M_A = 3967.06$

$$\bar{y} = \frac{\Sigma M}{\Sigma V} = \frac{3967.06}{158.63} = 25.01 \text{ ft.}$$

$$\frac{b}{3} = 15.56'$$

$e = 1.68$ ft $< e_{max} = 7.78$ ft   Okay

Resultant is 6.11 ft. with in the middle third of base.

Sliding Coef (with out Rails)

$$\text{Coef} = \frac{\Sigma H}{\Sigma V} = \frac{57.78^k}{158.63^k}$$

sliding Coef = 0.364 $\not<$ 0.3 N.G.

Subject ___
Computation of ___
Computed by ___ Checked by ___ Date ___

Sliding Coef (with Rails)

$$Coef = \frac{H_v - F_L}{V_v} = \frac{57.78 - 31.87}{158.63}$$

[Sliding Coef = 0.16] < 0.30 OK

Max Ftn. PRESSURE $= \frac{158.63^k}{46.67^{ft}}\left(1 + \frac{6(1.68)}{46.67}\right) = 4.13$ k/SF

Min Ftn. Pressure $= \frac{158.63^k}{46.67^{ft}}\left(1 - \frac{6(1.68)}{46.67}\right) = 2.66$ k/SF.

Subject ___
Computation of ___
Computed by ___ Checked by ___ Date ___

C. Conclusion

The stability analysis of Onondaga Dams' spillway structure resulted in stability for all cases investigated except for the conditions under Case IV. Case IV investigation was for the following loading conditions:

a) analysis at Elev. 461.5 ft.

b) full design headwater at Elev. 520.3 ft.

c) tailwater elevation of 485.6 ft.

d) full uplift pressure over base area (100% headwater varying to 100% tailwater).

e) full hydrostatic pressure against upstream face.

The results of the analysis under Case IV shows that the resultant force falls within the middle one-third of the compression zone, with a seven foot tension zone at the heel of the cross-section. The analysis also reveiled a failure in sliding, with the actual sliding coefficient (0.48) to be in excess of the allowable design value (0.30).

Subject ___
Computation of ___
Computed by ___ Checked by ___ Date ___

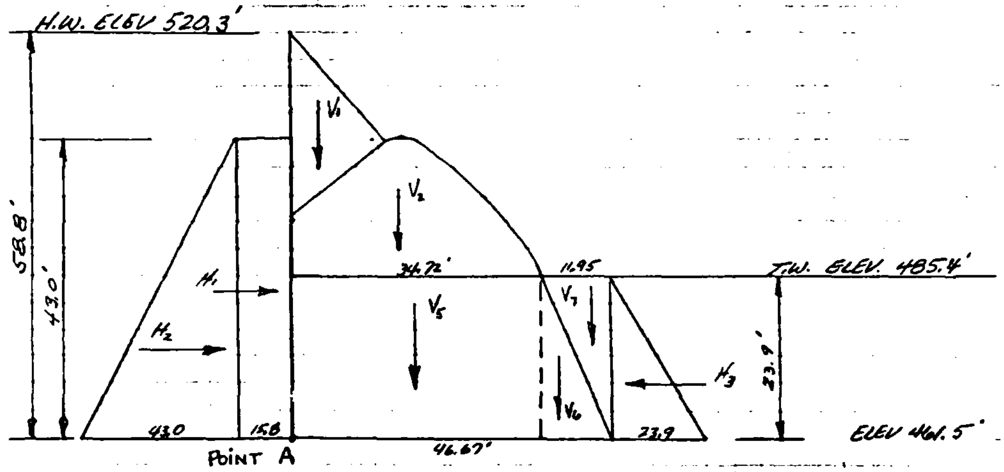
Based on the above analysis, Buffalo District proposes to provide additional anchorage to ensure stability in the monoliths that are affected by the loading and design criteria of Case IV.

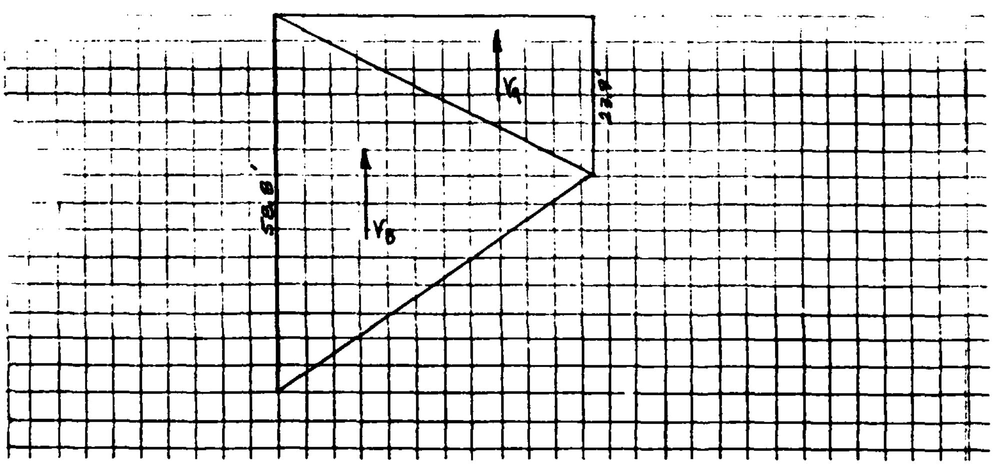
Request from NCDED-T, either concurrence on the above analysis and proposed action or guidance as to the relaxation of design criteria.

Subject: Onondaga Dam
Computation of: Re-Analysis of Case IV, Spillway Analysis
Computed by: KGO   Checked by: [signature] 7/28/79   Date: 2/26/79

I CASE IV EVALUATED AT ELEV. 461.5'

a. WATER SURFACE AT ELEV 520.3'
b. FULL HYDROSTATIC PRESSURE AGAINST UPSTREAM FACE.
c. EFFECTIVE TAILWATER AT ELEV. 485.4'
d. UPLIFT, 100% HEADWATER AT THE HEEL DECREASING UNIFORMLY TO 100% EFFECTIVE TAIL WATER AT THE TOE.





Subject: Onondaga Dam
Computation of
Computed by: KGO Checked by: 2/28/79 Date: 2/26/79.

$\Sigma M_{(A)}$

	ΣV	ΣH	mA	ΣM(A)
$V_1 = \frac{1}{2} \times 25.8 \times 9.03 \times 0.0625$	7.28		3.01	21.91
V_2 = Wt. of Concrete	72.32		15.41	1114.45
$V_5 = 34.72 \times 23.9 \times 0.150$	124.47		17.36	2160.82
$V_6 = \frac{1}{2} \times 11.95 \times 23.9 \times 0.150$	21.42		38.70	828.95
$V_7 = \frac{1}{2} \times 11.95 \times 23.9 \times 0.0625$	8.93		42.68	381.13
$V_8 = -\frac{1}{2} \times 46.67 \times 58.8 \times 0.0625$	−85.76		15.56	−1334.42
$V_9 = -\frac{1}{2} \times 46.67 \times 23.9 \times 0.0625$	−34.85		31.11	−1084.22
$H_1 = 15.8 \times 43.0 \times 0.0625$		42.46	21.50	912.89
$H_2 = \frac{1}{2} \times 43.0 \times 43.0 \times 0.0625$		57.78	14.33	829.18
$H_3 = -\frac{1}{2} \times 23.9 \times 23.9 \times 0.0625$		−17.85	7.97	−142.21
TOTALS:	113.81k	82.39k		3627.48k'

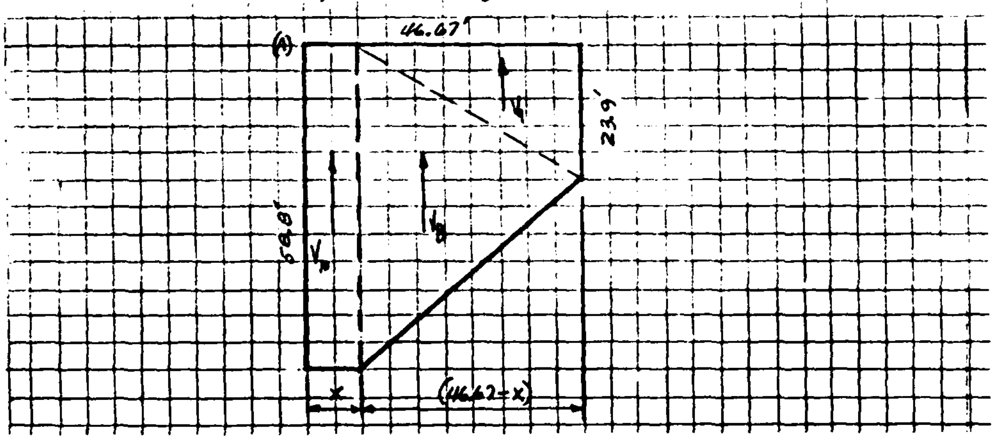
Location of Resultant:

$$\bar{y} = \frac{\Sigma M_{(A)}}{\Sigma V} = \frac{3627.48^{k'}}{113.81^{k}} = 31.87'$$

$$\frac{base}{3} = \frac{46.67}{3} = 15.56' \qquad e = 8.53' > e_{max} = \frac{15.56}{2} = 7.78'$$

∴ Resultant is outside of middle ⅓ of base

tension zone - uplift Diagram.



Subject: Onondasa Dam
Computation of
Computed by: KGO   Checked by: [illegible] 2/28/79   Date: 2/26/79.

$\Sigma M_{(A)}$ (uplift)   V   MA   =   MOMENT

$V_8 = \frac{1}{2} \cdot 58.8 \cdot (46.67 - x) \cdot 0.0625 = (85.75 - 1.84x) \cdot [x + \frac{1}{3}(46.67 - x)] = -1.23x^2 + 28.55x + 1333.89$

$V_9 = \frac{1}{2} \cdot 23.9 \cdot (46.67 - x) \cdot 0.0625 = (34.85 - 0.75x)[x + \frac{2}{3}(46.67 - x)] = -0.25x^2 - 11.72x + 1084.22$

$V_{10} = 58.8(x) \cdot 0.0625 = 3.68(x)[x/2] = 1.84x^2$

TOTALS: $[\Sigma V_{uplift} = 120.6 + 1.09x]$

$[\Sigma M_{uplift} = 0.36x^2 + 16.83x + 2418.11]$

FROM Pg #2.

$\Sigma V = V_1 + V_2 + V_5 + V_6 + V_7 = 234.42^k$

$\Sigma H = H_1 + H_2 + H_3 = 82.39^k$

ΣM_A = (without uplift forces) = 6106.12 k·ft

$\bar{y} = \frac{\Sigma M}{\Sigma V}$

THE LOCATION OF THE RESULTANT IS GIVEN BY:

$\bar{y} = x + \frac{2}{3}(46.67 - x)$

$\bar{y} = \frac{\Sigma M}{\Sigma V} = x + \frac{2}{3}(46.67 - x)$

$\Sigma M = 6106.12 - (0.36x^2 + 16.83x + 2418.11)$

$\Sigma V = 234.42 - (120.6 + 1.085x)$

Solving For (x)

$x = 7.0$ ft

Substituting $x = 7.0$ ft

$V_8 = -72.89^k$

$V_9 = -29.67^k$

$V_{10} = -25.76^k$

Subject Cronoaga Dam
Computation of
Computed by KGO Checked by JJK 2/29/79 Date 2/26/79

TOTALS: $\Sigma H = 82.39^k$
$\Sigma V = 106.17^k$ $\Sigma M_A = 3551.05$ k.ft

PERCENTAGE OF BASE IN COMPRESSION

$$= \left(\frac{46.67 - 7'}{46.67}\right)100 = 85\% > 75\% \text{ MIN (OK)}.$$

RESISTANCE FORCE FOR RAILS - ASCE. 70#

$$F_{RAIL} = \frac{13 \text{ RAIL} \times 6.81 \text{ in}^2/\text{rail}}{33.33 \text{ ft/monolith}} \times 12 \text{ k/in}^2 = \underline{\underline{31.87}} \text{ kips/ft of Monolith}$$

RESISTANT FORCE FOR Anchor BARS - 1¼" □.
(SEE ATTACHED DRAWING)

1. THERE ARE THREE ROWS of Anchor bars
2. THERE ARE EIGHT BARS/ROW.
3. BARS ARE INCLINED AT 71° to the VERTICAL.

$$F_{BAR} = \left[\frac{(3 \text{ rows} \times 8 \text{ bars/row}) \times (1\tfrac{1}{4}")^2}{33.33 \text{ ft monolith}} \times 20 \text{ k/in}^2\right] \cos 19°$$

$$F_{BAR} = \underline{\underline{21.28}} \text{ kips/ft. of Monolith}$$

SLIDING COEFFICIENT

1. DURING THE CONSTRUCTION OPERATIONS WEAKNESS ALONG A HORIZONTAL PLANE IN THE SUPPORTING ROCK WAS REVEALED. IN THE PROCESS OF BLASTING ROCK TO EXCAVATE FOR THE KEY AT THE HEEL OF THE GRAVITY SECTION, A LAYER OF ROCK APPROXIMATELY 120 FT. LONG, 20 FT. WIDE, AND 4 FT. THICK MOVED TOWARD THE SPILLWAY CHANNEL UP TO ABOUT ONE FOOT, SLIDING ON A PLANE AT APPROXIMATELY ELEV. 485.4'

IT WAS DECIDED TO CLEAN OFF THE ROCK

Subject Onondaga Dam
Computation of
Computed by KGD Checked by GQX 2/28/79 Date 2/26/79

TO ELEV. 485.4', CONSTRUCT THE GRAVITY CONCRETE SPILLWAY WEIR SECTION WITH BASE AT THIS ELEVATION AND ELIMINATE THE KEY. TO ELIMINATE THE POSSIBILITY OF SLIDING ON SIMILAR PLANES OF WEAKNESS BELOW ELEV. 485.4', IT WAS DECIDED TO STRENGTHEN THE ROCK SUPPORTING THE CONCRETE WEIR BY THE FOLLOWING MEASURES:

a) TO GROUT STEEL RODS EXTENDING FROM THE CONCRETE SLAB FACING INTO THE ROCK SUPPORTING THE WEIR A DISTANCE NECESSARY TO ENGAGE A MASS OF ROCK SUFFICIENT TO PROVIDE STABILITY AGAINST OVERTURNING.

b) TO GROUT VERTICALLY H-STEEL BEAMS IN HOLES DRILLED THROUGH THE ROCK BENEATH THE CONCRETE WEIR SECTION TO RESIST THAT PART OF THE HORIZONTAL FORCES TENDING TO CAUSE SLIDING NOT RESISTED BY THE SLIDING FRICTION OF THE ROCK.

c) THE COEFFICIENT OF SLIDING FRICTION OF 0.3 IS TO BE USED DUE TO THE HIGHLY FRACTURED ROCK, BOTH HORIZONTALLY AND VERTICALLY AND THE PRESENT OF SEAMS WITHIN THE ROCK MASS.

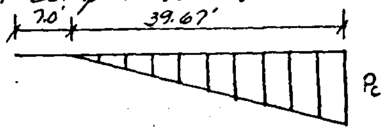
$$\text{SLIDING COEF.} = \frac{\Sigma H - F_{RAIL} - F_{BM}}{\Sigma V}$$

$$= \frac{82.39^k - 31.87^k - 21.28^k}{106.17^k} = \frac{29.24^k}{106.17^k}$$

[SLIDING COEF = 0.275 ≤ Allowable 0.3] (OK)

Subject: Onondaga Dam
Computation of
Computed by: KGO Checked by: [illegible] 7/19/79 Date: 2/26/79.

Maximum Compression Foundation pressure



$$\Sigma V = \tfrac{1}{2} \cdot P_c \cdot 39.67^{ft^2}$$

$$P_c = \frac{2 \cdot \Sigma V}{39.67^{ft^2}} = \frac{2(106.17^{kip})}{39.67\ ft^2}$$

$$\left[P_c = 5.35\ kip/ft^2 \right]$$

Summary and Conclusion:

THIS REVISED SPILLWAY ANALYSIS RE-EVALUATES CASE IV LOADING CONDITION AT SECTION ELEV. 461.5'. THE REVISED ANALYSIS MAINTAINS THE ORIGINAL ALLOWABLE COEFFICIENT OF SLIDING FRICTION OF 0.3 AND INCORPORATES THE SLIDING RESISTANT PROVIDED BY THE VERTICAL STEEL RAILS AND THE INCLINED 1¼ INCH SQUARE FACING ANCHOR BARS. THE ABOVE ANALYSIS SHOWS THE FOLLOWING RESULTS:

A) THE RESULTANT FALLS WITHIN A REASONABLE DISTANCE INSIDE OF BASE (85% OF BASE IN COMPRESSION).

B) THE RESULTING COEFFICIENT OF SLIDING FRICTION OF 0.275 IS LESS THEN THE ALLOWABLE OF 0.3.

C) THE MAXIMUM COMPRESSIVE FOUNDATION PRESSURE IS WITHIN ACCEPTABLE LIMITS.

THIS REVISION INDICATES THE SPILLWAY SECTION IS STABLE AT THE CRITICAL SECTION OF ELEV. 461.5' AND UNDER ALL LOADING CONDITIONS.

END

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