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EVALUATION OF POWERLINE, VINEYARD AND RITTENHOUSE FLOODWATER RETARDING STRUCTURES

Pinal County, Arizona

prepared for

Flood Control District of Maricopa County
3335 West Durango Street
Phoenix, Arizona 85009

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1 July 1977

Flood Control District
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3335 West Durango Street
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Attention: Mr. Jack Leavitt

Project: Evaluation of Powerline, Vineyard and Rittenhouse Floodwater Retarding Structures, Pinal County, Arizona

Job No. 712-280
Inv. No. 1120555

In accordance with our agreement, ETL No. 112-1785A and Amendment No. 1, this firm has performed soil engineering services relative to the subject project.

The accompanying report contains the results of the subsurface exploration, laboratory testing and the conclusions and recommendations derived from our engineering evaluation. This evaluation has been formulated in accordance with generally accepted professional engineering principles and practices.

Should any questions arise regarding the report, please do not hesitate to contact us.

Respectfully submitted,
ENGINEERS TESTING LABORATORIES, INC.
Geotechnical Services

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/jm

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Evaluation of Powerline, Vineyard
and Rittenhouse Floodwater Retarding
Structures, Pinal County, Arizona
Job No. 712-280

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PART I

REPORT

Evaluation of Powerline, Vineyard
and Rittenhouse Floodwater Retarding Structures
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INTRODUCTION

Powerline, Vineyard and Rittenhouse Floodwater Retarding Structures are located in Pinal County, Arizona and extend in a south-southeast direction from the intersection of Vineyard and Baseline Roads to near Queen Creek Road. The structures provide protection against floodwater originating in the Superstition Mountain Range for Williams Field Air Force Base, The GMC Proving Grounds, and the towns of Higley and Queen Creek, Arizona. A plan view of the structures is provided on Figure 1 in Part II.

The embankments are of homogeneous construction using on-site materials excavated from the retention basin, east of the structures. The approximate lengths of Powerline, Vineyard and Rittenhouse structures are 2.53 miles, 5.46 miles and 3.60 miles, respectively. Crest width for each structure is approximately 14.0 feet with downstream slopes of 2:1 (horizontal to vertical) and upstream slopes of 3:1 (horizontal to vertical). Crest elevations and embankment heights vary for each structure with Powerline at a maximum height of 24 feet and a crest elevation of 1589.1 feet; Rittenhouse at a maximum height of 20 feet and a crest elevation of 1602.3 feet; and Vineyard at a maximum crest height of 16.5 feet and a crest elevation of 1579.5 feet. The embankments were constructed during 1967 to 1969. Additional information for each structure may be found in Table 1 in Part II.

Numerous cracks, both longitudinal and transverse have developed within these structures. Embankment cracking was initially observed in 1970. At that time, an evaluation of the cracking was conducted by the Soil Conservation Service to determine the structural integrity of the embankments. It was concluded that the cracks posed no imminent danger to the structures; however, surveillance of the embankments was continued to note any progressive deterioration. Since the initial study, the amount and severity of cracking has increased to a degree warranting further investigation.

Subsequently, a phased program was developed to evaluate the present conditions of the structures and to present alternative remedial measures to upgrade the overall structural integrity of the embankments. The initial phase of the evaluation consisted of data collection and review, field reconnaissance and exploration, laboratory testing, engineering evaluation and recommendations for remedial measures if required.

DATA REVIEW

To aid in preparation of this report a review of previous data was undertaken. The review provided a basis for our exploration work, laboratory testing and engineering analysis.

The construction specifications and procedures were reviewed to determine if a particular event or practice prompted the formation of cracks. The construction embankment moisture contents were compared to the present values in order to evaluate the degree of desiccation. The cross-sections of the partially overexcavated foundation materials were examined and compared with the boring logs. This comparison indicated that portions of the native soil remain beneath the downstream section of the embankments. Upon review of the engineering properties of the foundation (compression index, grain size, etc.) soils, a settlement analysis was performed for areas of the embankments where cracking exists.

In addition, general information and background data was obtained from a review of all the data and discussion with Jack Leavitt of Flood Control District of Maricopa County; Ralph Arrington and Jack Stevenson of the Soil Conservation Service; Lowell H. Heaton of the Bureau of Reclamation and other personnel of all the cooperating agencies. The following is a list of the data which was reviewed in detail. In addition, all the data concerned with the design and construction of the embankments was made available by the Soil Conservation Service. This information was perused and certain items selected for a detailed review. In some cases

duplicate items were collected from more than one source.

Source	Item
Flood Control District of Maricopa County	1. "Plans for Construction of Rittenhouse Floodwater Retarding Structure" (pre-construction and as-built)
	2. "Plans for Construction of Vineyard Road Floodwater Retarding Structure" (as-built)
	3. "Plans for Construction of Powerline Retarding Dam" (pre-construction and as-built)
	4. "Rittenhouse Dam Geology Report" (duplicate 5/77)
	5. "Special Report Embankment Cracking Vineyard Road Dam Williams-Chandler Watershed" By SCS
	6. "Special Report - Embankment Cracking, Vineyard, Rittenhouse and Powerline Retarding Structures" by FCDMC
	7. Crack survey and photos along a portion of Rittenhouse Dam
	8. Maintenance reports of FCDMC 1974 to 1976
	9. Land ownership maps of portions of Pinal and Maricopa Counties.
Soil Conservation Service	1. "Rittenhouse Design Computations"
	2. "Powerline Dam & Hydrology & Hydraulics & Structures Design"
	3. "Williams-Chandler W.P.P. Arizona Design Computations Rittenhouse Dam"
	4. "Rittenhouse Dam Williams-Chandler W.P.P. Weekly Summary of Density Determinations"

Evaluation of Powerline, Vineyard
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Source	Item
Soil Conservation Service	5. "Vineyard-Road Dam Hydrology & Hydraulics"
	6. "Engineering Williams-Chandler (566) Vineyard Road Dam Design Data 13-5 Geologic Reports Soil Mechanics Reports"
	7. "Williams-Chandler Watershed Project Vineyard Road Dam Weekly Summary of Density Determinations"
	8. "Williams-Chandler W.P.P. Vineyard Road Dam Design Comp."
	9. "Cross-Sections of Dam Powerline Retarding Dam Apache Junction-Gilbert W.P.P. Pinal County, Arizona"
	10. "X-Sections and Plans for Geologic Investigation, Powerline Retarding Dam Apache Junction-Gilbert W.P.P. Maricopa & Pinal Counties, Arizona" (as-built)
	11. "Vineyard Road Dam Williams-Chandler W.P.P." (cross-sections as-built)
Arizona State Water Commission	1. "Weekly Summary of Density Determinations, Vineyard Road Dam"
	2. "Weekly Summary of Density Determination Powerline Dam"
	3. "Weekly Summary of Density Determination Rittenhouse Dam"
	4. "Geologic Report Vineyard Road Dam"
	5. "Geologic Report Powerline Dam"
Bureau of Reclamation	1. "Central Arizona Project Salt-Gila Aqueduct Subsidence Leveling" locations, descriptions and profile

Evaulation of Powerline, Vineyard
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Source	Item
Bureal of Reclamation	2. "Salt-Gila Aqueduct Typical Canal Section"
	3. "Salt-Gila Aqueduct Topography Reach 1, 2 & 3"
	4. "Preliminary Topography and Ground Profile"
	5. 10 - 18"x18" air photos CBR 344-314-1 4-5-72

SITE AND SOIL CONDITIONS

The three floodwater retarding structures are located in an alluvial basin near the foothills of the Superstition Mountains.

The topography of the area consists of sparsely vegetated, flat desert interrupted by narrow, shallow washes where vegetation is concentrated. The ground surface slopes downward to the west-southwest. In general, the upper ten feet of in-situ soils consist of silty sands (SM/SP) with the upper three feet highly desiccated. Lightly to heavily cemented sand and gravel (SP/GP) is generally located below a depth of 10 feet and extends to a depth of about 15 to 20 feet. Detailed boring logs may be found in the original geologic investigation report issued for each structure by the Soil Conservation Service.

Visual Inspection: The field exploration program consisted of a visual inspection of each structure, subsurface exploration by means of trenches and test pits and aerial inspection of the surrounding topography to determine the existence of atypical land features such as fissures or sink holes. Preliminary observations and detailed inspection logs for each embankment were presented in our preliminary report of June 22, 1977 and in Table 2 of Part II. These logs reflect embankment conditions as of June 1, 1977.

Reconnaissance of each embankment revealed varying concentrations of surface exposure of holes and/or animal furrows, transverse and longitudinal cracks, slope erosion, and water percolation marks on the slopes within localized areas along the majority of the length of the structure. Few cracks or holes were observed in those sections of the embankments comprised primarily of granular and gravelly soils. The heaviest concentration of water percolation marks and slope erosion coincided with the greatest concentration of surface exposure of cracks and holes along the crest. Locations of water percolation marks varied from the toe to the crest of the embankments along both the upstream and downstream slopes.

Surface expression of cracking within the embankments is characterized by cracks in the crest and series of elliptically-shaped holes forming a basic linear pattern. The observed cracking runs only in directions orthogonal to the axes of the embankments; no diagonal cracking was noted. Some transverse cracks appeared, from the surface, to fully penetrate the width of the embankments. Most longitudinal cracks were located about three feet upstream of and parallel to the centerline of the embankment. Exposure of longitudinal cracking in some instances continued up to 75 feet along the embankment. Typical surface crack features (transverse and longitudinal) on the embankments may be found in Photographs 1 through 10 of Part IV.

In relative terms, Powerline was found to have only limited visible deterioration, consisting of localized holes and animal furrows along the crest. Vineyard has a heavy concentration of holes and indications of longitudinal and transverse cracking, the majority of which are located in the southern half of the structure. The severest visible cracks and large diameter holes, heavy surface erosion and percolation marks near the toes of both the upstream and downstream slopes were found in the northern portion of the Rittenhouse structure. The approachways to all structures appeared to be in satisfactory condition.

Subsurface Exploration: Subsurface exploration to determine the depth and extent of cracking within the embankments was performed by excavation of six trenches and 12 test pits at the locations shown on Figures 2, 3 and 4, Part II. The trenches were utilized to determine the frequency of crack occurrence and to enable cracked areas of the dam to be checked as water-carrying openings. Test pits were used to determine the depth of individual cracks. The intersections of transverse and longitudinal cracks were also revealed by the test pits, indicating potential water conduits existing in multiple directions.

Excavation within the embankments revealed cracks extending both transverse and parallel to the longitudinal axis of the structures. Although surface exposure of these cracks indicated crevices in excess of three inches wide, the excavated cracks ranged in width from 1/8 inch to 3/4 inch. Typically, the cracks were found to be 1/4 inch to 1/2 inch wide. In general, the longitudinal cracks appeared slightly wider than the transverse cracks. Some cracks were partially filled with loose (wind-blown & water-carried) deposits of sandy silt. This material was easily removed by flushing with water to expose the crack.

In general, the longitudinal cracks extend to a greater depth than the transverse. The deepest longitudinal crack excavated during this program extended to a depth of eight feet below the crest of the dam at Station 183+82 of the Rittenhouse structure (Excavation R-2-D). Photographs 11 through 13 in Part IV illustrate this crack. The deepest transverse crack excavated during this exploratory program extended to a depth of ten feet below the embankment crest at Station 129+82 of the Rittenhouse structure (Excavation R-1-D). This crack is partially shown in Photographs 14 and 15 of Part IV. A typical interlacing system of cracks consisting of a six to eight foot deep longitudinal crack and three transverse cracks ranging in depth from 3½ to 5½ feet deep were also encountered at Station 183+82 of the Rittenhouse structure (Excavation R-2-D).

Photographs 16 through 18 illustrate the cracks comprising this network.

Most longitudinal cracks extended to an average depth of five to six feet and were approximately 1/2 inch to 3/4 inch wide. Transverse cracks were generally found to be between 1/4 and 1/2 inch wide and only extended to an average depth of three to four feet below the embankment crest. The depth of transverse cracking appeared to decrease from the centerlines of the embankments out to the slopes. The pattern of transverse cracking appeared to be essentially parabolic across the width of the dam. Water directed into transverse cracks at the crest of the dam was usually found following the slope of the embankment, near the surface, until it penetrated the embankment face. Photographs 19 through 28 illustrate water percolating through and following beneath the embankment slopes. In some cases water would percolate from upstream and downstream slopes. Percolation of water was found not only near the crest, but also near the toe of the slopes.

The frequency of transverse cracking appeared to be fairly regular within the localized, extensively cracked areas of the embankments. Distances between large trasnverse cracks were generally about six to ten feet. Rarely did more than one longitudinal crack occur in a given cross-section.

Material excavated in the upper five feet of each embankment was in a desiccated state. Typical existing water contents of compacted embankment soil excavated from depths of between one to ten feet below crest elevation are presented in Part III.

Upon completion of sampling and crack observation, all excavations were backfilled in a series of eight to twelve inch compacted lifts. The excavated soil was thoroughly mixed with water to bring its water content to near optimum. Compaction of each lift was performed

with a minimum of five passes of a Wacker gasoline hand tamper and/or a compressed air-operated hand tamper (pogo stick).

Table 3, Part II lists and describes the major excavations performed on the Vineyard and Rittenhouse structures. Photographs 29 through 35 illustrate other exposed cracks found during this investigation. No excavations were performed on the Powerline embankment as the visual inspection revealed that this structure appeared to be less damaged than the other two.

Land Features and Subsidence Crack Investigation: Examination of low altitude aerial photographs, flown in 1972 and provided by the Bureau of Reclamation, revealed several anomolous linears existed in close proximity to the existing flood retarding structures. Research for other photographic coverage of the subject area at the Arizona Department of Transportation and at private aerial photographers indicated a lack of readily available recent aerial photography. Consequently, several of these linears extending skew to the general drainage pattern of the basin were examined by aerial overflight, ground reconnaissance and field exploration. The linears were inspected to determine if these land features were indicators of large-scale soil mass movements. On the surface the linears were characterized by longitudinal depressions approximately three to four feet wide by one to two feet deep. Deposits of uniform sands and gravels indicate heavy water flow through these gullies during flood conditions. Although erosion was noted along sections of the linear, there was no indication of scarps or differential soil movement on the surface.

During this reconnaissance and exploration work, no evidence of active subsidence cracks was noted along the embankments. Three test pits were excavated across one such lineation approximately 1,500 feet northeast of the Rittenhouse structure near Station 149+92, but

no evidence of differential soil movement was discovered. Plan location of the test pits is shown on Figure 4 of Part II. Photographs 36 through 38, Part IV, illustrate portions of a lineation and location of the test pits.

Aerial observation was made at low altitude along the embankments and over an area extending upstream and downstream approximately two miles from the structures. Earth fissures were noted in a localized zone west and northwest of Hawk Rock approximately one mile west of the north end of the Powerline Floodwater Retarding Structure. These cracks are active, extending for hundreds of feet, and appear to be associated only with the isolated bedrock protrusion. The aerial view of the site and basin area provided no other evidence indicating the existence of atypical land features such as fissures, depressions or cracking. The subtle ground features which formed the air photo linears were apparently old and could no longer be positively identified; however, it appears that most of the ground lineations were formed as cultural features such as trails or shallow canals.

The only surface irregularities found in the proximity of the embankments were several shallow holes of diameters varying from one to three feet, found in the retention basin of Rittenhouse. The holes were located approximately 50 feet east of the upstream embankment toe and appear to have been produced by collapse of poorly compacted waste fill material. Photographs 39 through 41 illustrate these irregularities. Test pits were excavated at these locations, but only relatively shallow, two to three foot deep cracks were found and do not appear to be detrimental to the structual integrity of the embankment.

LABORATORY INVESTIGATION

In addition to field reconnaissance and exploration, laboratory analysis of representative samples was performed. Laboratory analysis of samples obtained during the excavation of test pits

included grain size analyses, determination of in-situ moisture contents, shrinkage tests, determination of index properties, specific gravity, and dispersion testing. The results of laboratory analysis are presented in Part III.

Grain Size Analyses: Sieve analyses were performed on six soil samples from excavations in the Vineyard and Rittenhouse embankments. Four of these tests included hydrometer analyses to determine the gradation of silts and clays in the samples. The samples were found to be primarily sandy silts and clays containing traces of gravel.

Moisture Contents: Moisture contents of samples obtained along the structures at various depths were taken to determine the variation of moisture within the upper lifts of the embankments. In general, the moisture increased with depth from about six percent at one foot below crest elevation to approximately 10 percent six feet below the crest. During construction the soil in these zones was typically installed at a moisture content ranging from 10 to 15 percent.

Shrinkage Tests: Because desiccation and subsequent shrinkage was suspect of causing much of the transverse cracking in the embankments, a series of shrinkage tests were conducted to determine sample volume change as a function of moisture loss. A total of 9 soil blocks were prepared using material obtained from excavations in heavily cracked sections of the embankments and 3 soil blocks prepared from a section where no cracking was found. The soil blocks measured 2½ inches high by 3 inches wide by 10 inches long ((2½" x 3" x 10"). The material was compacted to a density equivalent to about 96 to 103 percent of that determined in accordance with ASTM: D698. The maximum density used at each location was an average of values used in that area during construction. The moisture content was brought to near that at which the material was

initially compacted during construction. The blocks were then systematically weighed, measured and air/oven dried. The test results indicate that volumetric shrinkage of 1.6 to 5.8 percent in the cracked areas and 0.3 to 0.6 percent in the uncracked areas can occur within the general moisture loss range through which the embankment soil has already undergone.

Atterberg Limits and Specific Gravity: In order to define the relative plasticity and physical characteristics of the embankment soils, the liquid limit, plastic limit, plasticity index and specific gravity of samples were determined. The water content at which the soil changes from liquid state to plastic state is the liquid limit of the soil, that from plastic state to solid state is the plastic limit. The difference between the liquid limit and the plastic limit is called the plasticity index and represents the range of water content in which the soil remains plastic. The specific gravity provides an indication of the volumetric concentration of finer-gradation soil particles.

The plastic limits of the soils analyzed ranged from 16 to 18, the liquid limits from 19 to 34, and the plasticity index ranged from 1 to 18. The specific gravity of the soils ranged from 2.71 to 2.73. Values for each sample may be found in the lower right-hand corner of the particle size distribution charts.

Dispersion Testing: In order to determine the susceptibility of the embankment soils to erosion, dispersion tests were performed on four soil samples. Two testing procedures were used, a chemical test and the "pin hole" test. The chemical test was performed in accordance with the procedure outlined in the paper by T. Allan Haliburton, "Identification and Treatment of Dispersive Clay Soils".[1]

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[1] Haliburton, A., Petry T., Hayden M., "Identification and Treatment of Dispersive Clay Soils", Report to U.S. Dept. of the Interior, Bureau of Reclamation, School of Civil Engineering, Oklahoma State University, Stillwater, July, 1975.

The procedure for the pin hole test was presented by J. L. Sherard et al in the 1972 American Society of Civil Engineers Specialty Conference on the Performance on Earth and Earth Supported Structures.[2]

CONCLUSIONS AND RECOMMENDATIONS

General: Cracking of the type exhibited by the Powerline, Vineyard and Rittenhouse embankments are typical of low dams constructed with homogeneous sections of clayey type soil, especially in the arid southwestern part of the United States. Within the project area the greatest depth and frequency of cracking was found to occur on the Rittenhouse structure. Vineyard was found to be subject to moderate deterioration, while the least damaged structure appeared to be Powerline. The cracks appear to be the result of differential settlement and desiccation which normally result in longitudinal and transverse cracking, respectively, of the dam. The surface expression of the cracks found along the embankments has either been enlarged by erosion and/or animals or has been partly filled and obscured by infilling by wind deposition and/or maintenance. Most areas of cracking are apparent; however, there may be some areas where the cracks may not be obvious.

Based on the limited shrinkage test data and in-situ moisture contents of embankment materials, it appears that the major portion of the shrinkage and resulting cracking has occurred and that future crack development should attenuate. However, the existent cracks, both apparent and obscured, may exhibit growth from both continuing erosion and desiccation.

The cracks which cause the most concern are those which run transversely, creating a possible path for concentrated seepage. The concern associated with longitudinal cracks is that they may occur

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[2] Sherard, J.L., Decker, R.S., and Ryker, N.L., Proceedings, American Society of Civil Engineers Specialty Conference on the Performance of Earth and Earth-Supported Structures, Vol. 1, 1972, pp. 589-626.

in conjunction with visible and unexposed transverse cracks and are natural planes of weakness which could lead to slope instability.

Transverse cracking of the embankments appears to be primarily caused by shrinkage of the structures due to drying. The relatively high volumetric shrinkage observed in the test samples and physical characteristics (gradation, atterberg limits, etc.) of the soils are conducive to this effect. It is also possible that some transverse cracking may have been aided by differential settlement between adjacent lengths of the embankment.

Review of the construction procedure, the cross-sections illustrating the overexcavated foundation materials, and a settlement analysis indicate that longitudinal cracking may be primarily attributed to differential settlement on the order of 1.5 inches between the upstream and downstream sections of the embankments after construction. Tensile stresses causing longitudinal cracking were increased due to shrinkage during deisccation of the embankment soils.

Remedial Measures: Cracking of the Vineyard and Rittenhouse structures has occurred to an extent which, in our opinion, may impair the ability of the system as a whole to retard the design volume of floodwater. It is recommended that some form of remedial measures which will limit risk potential be initiated for these structures. It is recommended that all outlet gates be locked in a full open condition and periodic inspection and reports (including specific location of areas which have deteriorated) be performed. Immediate remedial measures are not deemed necessary on the Powerline embankment; however, continuous inspection and monitoring of the structure, especially during and after heavy rainfall, is necessary.

Most cracks exposed during the field exploration work extended to a maximum depth of six feet below the crest of the embankments.

Considering a possible potential crack propagation of approximately two feet, the average maximum depth of cracking may be assumed as eight feet below crest elevation. The corresponding elevations for average maximum crack depth for Vineyard and Rittenhouse structures are 1571.5 feet and 1594.3 feet, respectively.

Several alternative immediate remedial measures along the structures have been considered and are presented below. These alternate methods are not presented in any specific order of preference and apply to both Rittenhouse and Vineyard structures. In addition, it may be possible to combine some of these measures.

One method of short-term alleviation of risk is to lower the retention capacity of the basins to an elevation at or below that of the average maximum cracking. This may be most easily accomplished by lowering the elevations of the emergency spillways to the average elevation of crack penetration. Consequently, the emergency spillway at the southern end of Rittenhouse would be lowered, approximately three and one-half feet, to Elevation 1594. The emergency spillways at the northern and southern end of Vineyard would be lowered, approximately three and one-half feet, to Elevation 1571. Lowering the spillway at the southern end of Vineyard entails projecting and lowering the outlet channel of the principal spillway of Rittenhouse. The western end of this outlet channel should be constructed to an elevation which prevents the flow of water through the rebuilt emergency spillway of Vineyard. The outlet and principal spillway structures are shown on Sheet 7 of the Rittenhouse Floodwater Retarding Structure Plans, entitled "Details of Principal Spillway".

Full design flood retention capabilities of the structures could still be achieved by the addition of floodgate structures in the lowered spillways. The floodgates would remain closed as long as inspection of the structure during and after heavy rainfall and retention periods indicate no uncontrolled flows through the structures.

Should sign of possible flow or piping be noted, then the floodgates could be opened to reduce the impoundment level.

Another alternative for limiting the potential risk of failure utilizes a "cut-off" or interceptor trench constructed within the embankment along severely cracked sections. The purpose of such a trench would be to prevent heavy water flow in transverse cracks which extend through the structure. This would reduce the potential for failure due to erosion and/or piping. Location and extent of the trench would be dependent upon inspection of the embankment prior to and during excavation. Heavily eroded slopes, percolation marks and visible cracking would provide preliminary indication as to the extent of trenching. Inspection of the trench after excavation by a geotechnical engineer would ensure that the trench fully covered the range of heavy cracking. An eight foot deep trench excavated parallel to and upstream of the embankment's centerline would intersect a major percentage of the cracks. Those cracks extending below the depth of the trench could be filled and sealed with a sand or silt slurry. Several alternatives for backfilling of the trench can be utilized. The method used should be based on a detailed cost analysis and anticipated effectiveness of each method.

1. Backfilling the trench with a relatively clean, compacted material of a gradation which will limit the migration of the backfill into open downstream cracks.

2. Backfilling the lower 4 feet of trench with 2 to 4 inch diameter gravel entirely wrapped in a drainage fabric (such as Mirafi 140). The upper portion of trench should then be backfilled with excavated embankment material and compacted at a moisture content below optimum.

3. Backfilling the lower 4 feet of trench with compacted excavated material partially wrapped along the bottom and upstream side of trench in a drainage fabric. The upper portion of the trench should then be backfilled with compacted excavated material.

In the first and second method the backfilled trench will perform in the same manner as a lateral interceptor subdrain. In order to prevent the buildup of hydrostatic pressure within the trench, outlet relief drains should be installed from the trench through the downstream side of the embankment. Both of these methods could concentrate flow from the entire trench towards any deep transverse cracks which were not detected during trenching operation or which are poorly sealed. This concentrated flow could result in piping and a possible progressive failure.

In the second and third method the drainage fabric will interrupt the migration or erosion of the soil through the cracks. The drainage fabric is installed by laying the fabric in the trench bottom and along one or both sides depending on the method. The lower 4 feet of trench is then backfilled with compacted material. In method 2 the fabric should extend above the backfill level and be lapped closed. The remainder of the trench is backfilled with compacted excavated material. Compaction should be performed at a water content one to two percent below optimum in an effort to limit further surface cracking due to desiccation.

Backfill method 3 has several advantages over the subdrain type backfills (methods 1 and 2). The backfilled trench will serve as a cut-off trench which will limit the flow of water and the fabric will provide a permanent strong filter barrier which is not subject to erosion or cracking. In addition, the trench will not collect and concentrate large quantities of seepage flow which could be intercepted by undetected deep transverse cracks. Should cracks

develop in the trench backfill or existing cracks increase in size, the fabric should be of sufficient strength to remain intact and function as designed. The filter fabric will allow the transmission by wicking of small quantities of water to the downstream cracks so that hydrostatic pressure will be reduced at the upstream side of the trench.

The risk resulting from excavation of very large quantities of impounded water through a failure of an embankment may be reduced by dividing the retention basin behind the embankments into several smaller pools. The basin could be segmented by constructing embankments perpendicular to the existing structures in the upstream retention area. One newly constructed embankment placed along the centerline of the retention area could effectively cut the floodwater discharge in half in the case of sudden embankment failure. The smaller pool areas would be interconnected by the installation of outlet structures in the stilling basin through the divider embankments.

Several other measures, such as facing the embankments with a new fill section and/or liners or soil cement, grouting the existing cracks, and others have also been evaluated. These measures were considered to be either too costly, relatively ineffective and/or take too long to complete.

One or a combination of the recommended remedial measures may provide a long term solution. In our opinion the most viable long term solution short of complete reconstruction of the embankments would be to install floodgates in lowered spillways and to install the cut-off type trench (method 3) in areas where embankment deterioration has occurred. This combination of measures should limit the risk from an embankment failure by providing a method of lowering the pool level at a known location in a relatively short time while still having the capability of retaining design capacity. However, due to the limited time in which remedial

measures can be completed prior to the 1977 storm season and potential cost of the combined measures, the short term solution which appears to limit risk and cost would be to lower the spillways. The remaining measures could then be undertaken as time and funding becomes available. The remaining measures should be accomplished at the same time since one is dependent on the other. It is our opinion that the installation of either the cut-off trench or interceptor trench alone will still involve risk in that all areas of severe cracking may not be detected and repaired.

PART II

FIGURES & TABLES

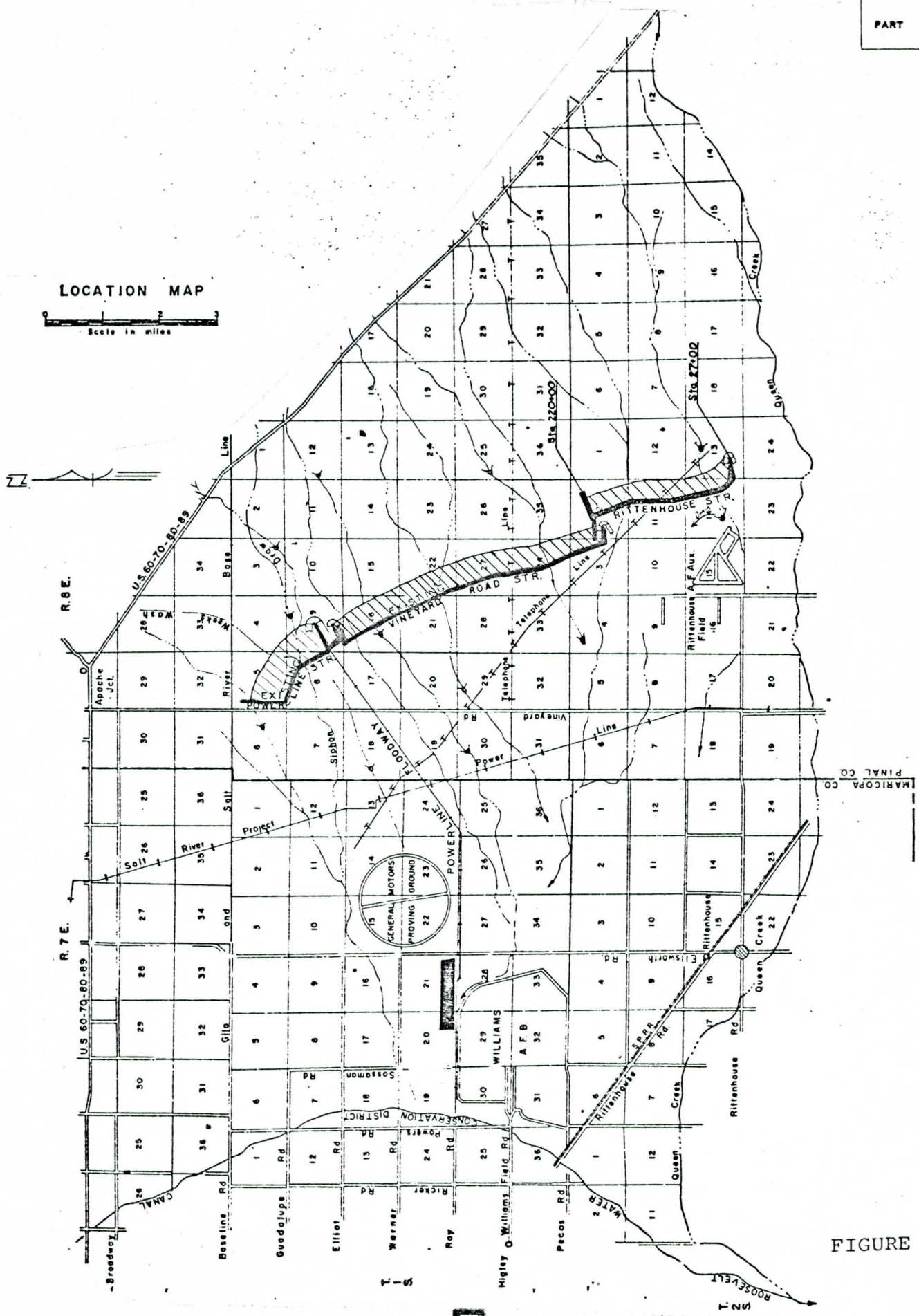

LOCATION MAP
Scale in miles
U.S. 60-70-80-89
R.8E.
R.7E.
Apache Jct.
Broadway
Baseline Rd
Guadalupe
Elliot
Warner
Ray
Higley
Williams Field Rd
Pecos Rd
Queen Creek
Rittenhouse Rd
Ellsworth Rd
Vineyard Rd
Power Rd
Sossaman Rd
Riggs Rd
Base Line
Gila and Salt River Project
Salt River
Sipoa
Telephone Line
Power Line
Canal
Water
Roosevelt
Dry Wash
Wash
EXISTING POWER LINE STR.
VINEYARD ROAD STR.
RITTENHOUSE STR.
Sta 220+00
Sta 27+00
FLOODWAY
POWER LINE
GENERAL MOTORS PROVING GROUND
WILLIAMS A.F.B.
Rittenhouse Field
A.F. Aux
S.P.R.R.
CONSERVATION DISTRICT
MARICOPA CO
PINAL CO

FIGURE 1

SITE PLAN

NOTE: No subsurface exploration performed on Powerline embankment

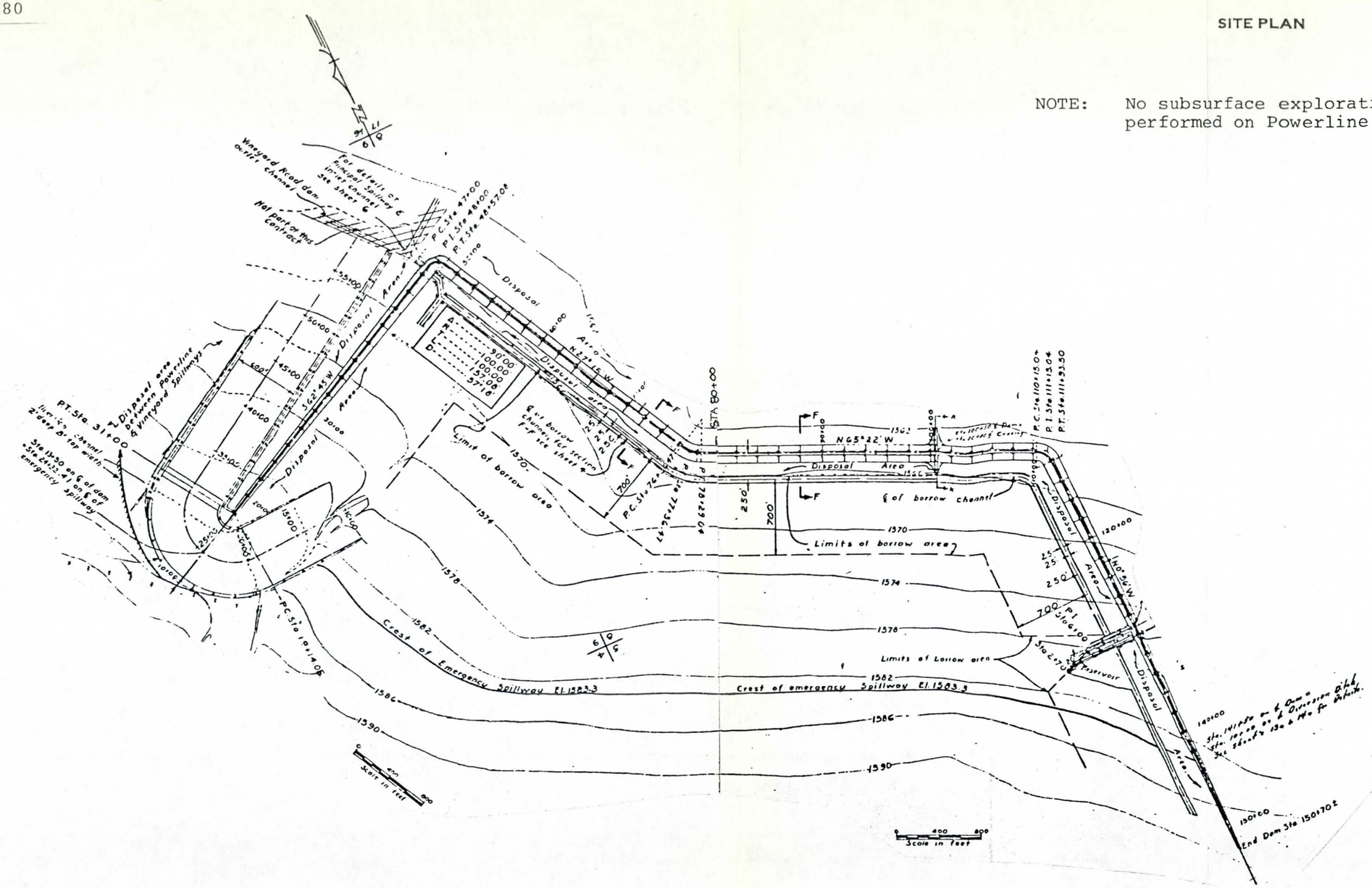
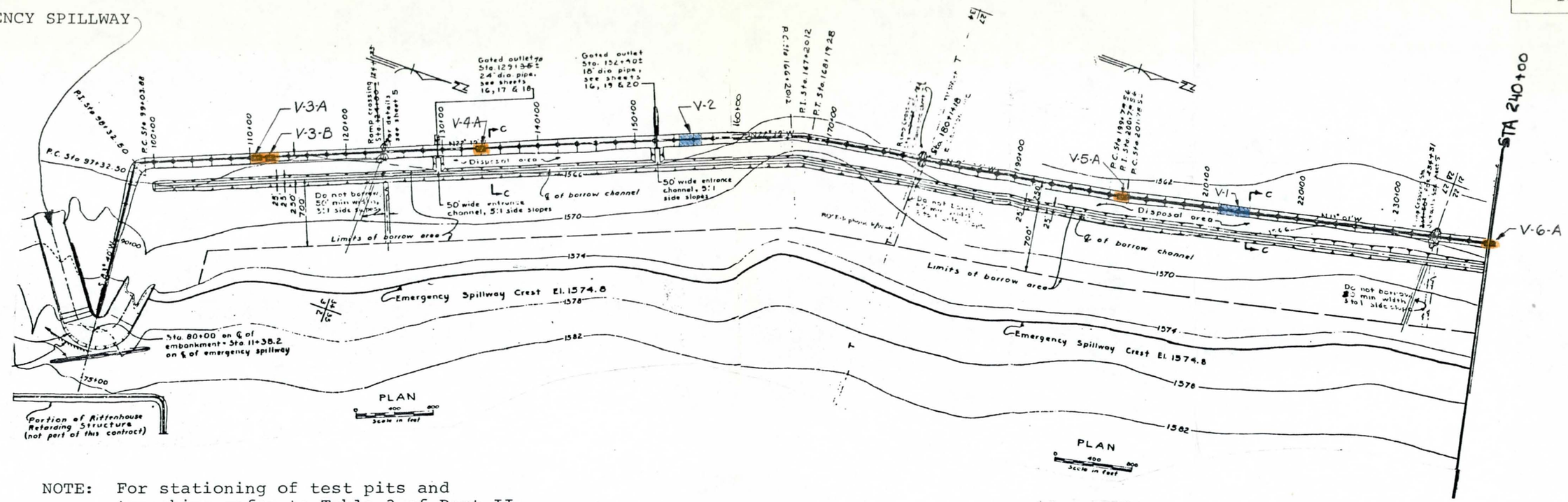


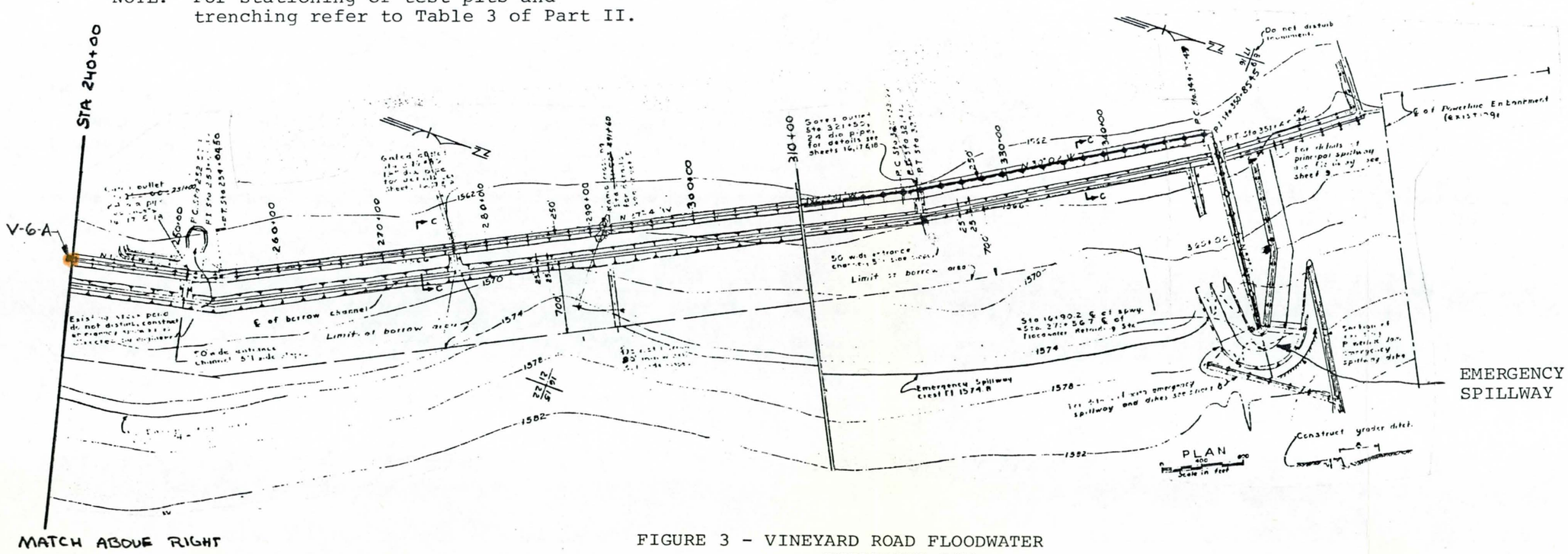
FIGURE 2 - POWERLINE RETARDING DAM

SITE PLAN

EMERGENCY SPILLWAY



NOTE: For stationing of test pits and trenching refer to Table 3 of Part II.



LEGEND

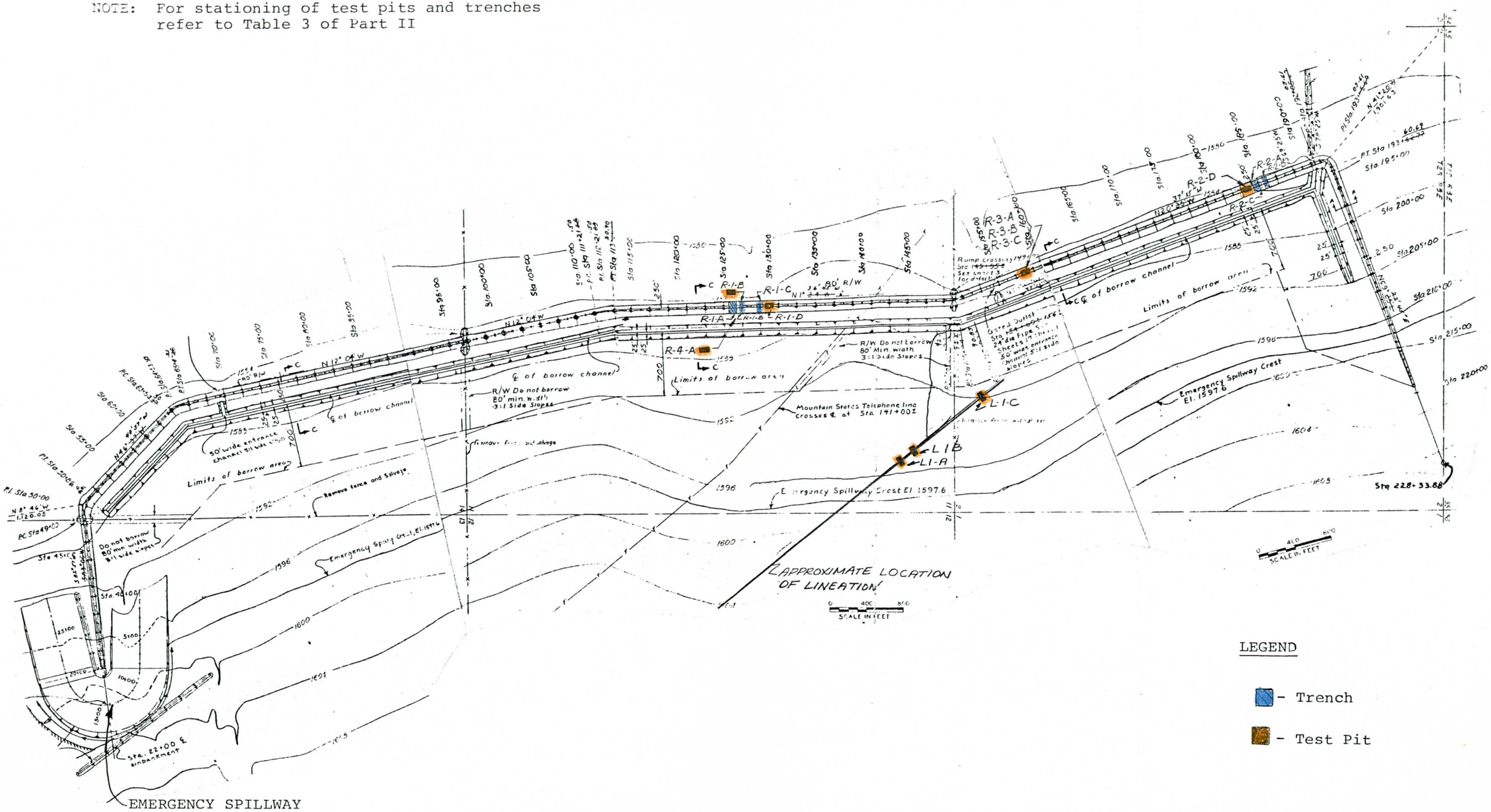
- Trench
- Test Pit

EMERGENCY SPILLWAY

FIGURE 3 - VINEYARD ROAD FLOODWATER RETARDING DAM

SITE PLAN

NOTE: For stationing of test pits and trenches refer to Table 3 of Part II



LEGEND

- Trench
- Test Pit

FIGURE 4 - RITTENHOUSE FLOODWATER RETARDING DAM

E

TABLE 1
SPECIFICATIONS - POWERLINE, VINEYARD & RITTENHOUSE STRUCTURES

	POWERLINE	VINEYARD	RITTENHOUSE
Length:	2.53 miles	5.46 miles	3.6 miles
Maximum height;	24'	16.5'	20'
Elevation at top of structure:	1589.1'	1579.5'	1602.3'
Width at top of structure	14'	14'	14'
Side slopes:	3:1 upslope side 2:1 downslope side	3:1 upslope side 2:1 downslope side	3:1 upstream 2:1 downstream
Earthwork quantity:	820,500 cubic yards	1,154,394 cubic yds.	829,400 cubic yds.
Drainage area:	49.9 square miles	57.8 sq. miles	51.3 sq. miles
Reservoir capacity:	4,194 acre feet	4,310 acre feet	4,060 acre feet
Freeboard:	4.8'	4.7'	4.7'
Principal spillway:	36" ungated concrete pipe	56" ungated conc. pipe	33" ungated
Elevation at crest of emergency spillway:	1583.3'	1574.8'	1597.6'
Width of emergency spillway:	600'	300'	600'
Capacity of emergency spillway:	17,500 cfs	8,000 cfs	17,000 cfs
Total cost of project:	$377,258	$512,154	$393,000
Project completed:	March 17, 1967	July 3, 1968	1969

Job No. 712-280

TABLE 2 - VISUAL INSPECTION REPORT

A) POWERLINE -

Station	Observed Condition
50+00	Centerline of outlet structure; no surface cracks or holes noted; slight surface erosion of downstream slope; material appears fairly coarse grained.
64+20	Small hole on downstream side of embankment crest.
70+00	No cracking or holes noted; some evidence of percolation on downstream slope.
74+22	Two small holes on downstream side of embankment crest; some evidence of slope erosion.
74+72	Some slope erosion; small hole on crest.
80+00	No evidence of cracks, holes or percolation.
83+88	3" diameter hole on downstream side of embankment crest.
84+14	6" x 3" hole in downstream side of embankment crest; material somewhat finer grained.
84+89	6" x 3" hole in downstream side of embankment crest.
90+00	Small hole and some slope erosion on downstream slope; no cracking.
94+00	No additional cracking or holes noted; vegetation slightly heavier; material coarser grained from Sta. 94+00 to 100+00.
100+00	Centerline of embankment crossing.
105+00	Relatively heavy surface erosion; occasional small holes; no cracking noted; coarse-grained material.
112+00	No cracking or holes.

B) VINEYARD -

99+00	Some surface cracking 1" to 12" long.
100+32	Transverse crack.

Job No. 712-280

TABLE 2 - VISUAL INSPECTION REPORT (continued)

B) VINEYARD -

Station	Observed Condition
100+72 to 101+00	Increasing frequency of transverse cracking.
101+00	Frequency of cracks decreasing.
102+30	Longitudinal cracking on downstream side of embankment crest.
103+90	Transverse and longitudinal cracking on upstream side of embankment crest.
105+28	No cracks or holes noted.
107+10 to 110+20	Heavy transverse and longitudinal cracking on both upstream and downstream sides of embankment.
110+70 to 111+34	Moderate transverse and longitudinal cracks on both upstream and downstream sides of embankment crest.
112+89 to 113+94	Predominantly upstream crest cracks and some small holes.
114+66 to 115+18	Occasional upstream transverse and longitudinal cracking.
116+68 to 118+68	Very occasional small cracks and holes in embankment crest.
118+68 to 119+45	Moderate occurrence of holes.
120+54 to 120+92	Moderate longitudinal cracking on downstream side of crest.
124+10	Longitudinal crack in crest; embankment crossing centerline.
133+56 to 135+07	Heavy longitudinal cracking on upstream side of embankment crest; heavy slope erosion; schrapnel and 5' diameter crater found in downstream slope.
137+50 to 144+00	Occasional holes (animal furrows) and cracking.
144+42	Occasional surface cracking and holes in dam crest; slight slope erosion.

Job No. 712-280

TABLE 2 - VISUAL INSPECTION REPORT (continued)

B) VINEYARD -

Station	Observed Condition
149+10 to 152+56	Occasional holes; moderate longitudinal cracking on upstream side of embankment crest.
154+62	Moderate to heavy longitudinal cracking and occasional transverse cracks.
160+16	Large longitudinal crack in embankment crest.
180+14	Centerline of embankment crossing.
192+90	Moderate longitudinal and transverse cracking; some evidence of slope erosion and percolation.
194+92 to 195+50	Occasional to moderate cracking and holes.
196+89 to 204+74	Moderate to heavy presence of holes indicating transverse and longitudinal cracking; percolation on slopes.
213+92	Large crack (hole).
217+92 to 234+31	Very light cracking and occasional holes in embankment surface.
291+60	Centerline of embankment crossing.
324+76	Two small holes on downstream side of crest (animal furrows).
339+40	Small hole located on embankment centerline.
350+00	No apparent cracks or holes.

C) RITTENHOUSE -

50+86 to 79+62	No holes or cracking; material is very coarse grained, consisting of gravels and some cobbles.
79+62	No apparent holes or cracking; material turns finer grained; previously excavated and backfilled trench starts.
82+00	End of old trench.

Job No. 712-280

TABLE 2 - VISUAL INSPECTION REPORT (continued)

C) RITTENHOUSE -

Station	Observed Condition
87+00	Previously excavated and backfilled trench starts; no apparent holes or surface cracking.
95+92	No evidence of severe cracks; fine grained material; trench only partially backfilled.
99+30	No cracks or holes; trench not backfilled.
100+00	Open trench.
102+64	No cracks or holes; end of open trench; continuation of backfilled trench.
103+92	Open trench.
104+46	6" diameter hole located one foot below crest on upstream slope.
105+00	Occasional small holes begin.
105+32	Moderate concentration of holes and animal furrows.
105+78	Large 2"-3" wide longitudinal crack 5' long located on upstream side of embankment crest.
106+48	End of open trench; three small animal furrows located 1' to 3' below upstream crest of embankment.
110+00	Occasional small diameter holes on embankment crest.
120+00	Drainage holes forming in poorly backfilled trench.
118+00 to 121+00	Moderate concentration of holes in embankment crest.
122+90	End of previous trenching; no apparent holes or cracking.
126+86	Large 2" wide crack approximately 2' long located on upstream side of embankment crest.
126+86 to 127+00	Occasional holes in embankment crest.

Job No. 712-280

TABLE 2 - VISUAL INSPECTION REPORT (continued)

C) RITTENHOUSE -

Station	Observed Condition
128+88	Large 2" wide x 2' long crack on upstream and downstream crest of dam.
129+82	Large 2" wide x 3' long crack on upstream side of crest; large 2" wide x 1' long crack on downstream side of embankment crest.
130+00 to 133+34	No apparent cracking or holes.
133+34	Occasional small holes on upstream side; percolation marks on downstream slope.
137+00 to 138+00	Heavy percolation marks on downstream slope.
140+00	No cracking or holes on embankment crest; percolation marks on downstream side of slope.
146+00 to 148+00	Occasional holes on crest of embankment (animal furrows).
149+92	Centerline of embankment crossing.
150+12	Small holes on each side of embankment crest.
150+90 to 158+00	Occasional to moderate concentration of large holes.
158+00	2" wide longitudinal and transverse cracks each 1½' long.
158+44	Moderate concentration of longitudinal crack holes on upstream side of crest.
160+00 to 170+00	Occasional to moderate concentration of holes in embankment crest; percolation marks in downstream slope.
180+00	No cracking or holes on surface.
183+78	Moderate holes and transverse cracks in crest; percolation marks in downstream slope.
184+16	1" wide x 2' long longitudinal crack along embankment centerline; moderate concentration of holes.

Job No. 712-280

TABLE 2 - VISUAL INSPECTION REPORT (continued)

C) RITTENHOUSE -

Station	Observed Condition
184+78	1" wide x 5' long longitudinal crack along embankment centerline.
185+00	Moderate to heavy concentration of longitudinal cracks and holes in embankment crest.
187+68	Moderate to heavy concentration of holes in crest on upstream side.
188+50	Heavy concentration of percolation marks on downstream slope.
193+03	Longitudinal cracking; 2" wide x 8' long crack; heavy slope erosion of downstream side.

TABLE 3 - EMBANKMENT EXCAVATIONS

Excavation	Embankment	Stationing	Type	Description
R-1-A	Rittenhouse	125+88 to 126+28	Trench	Surface holes and cracks; longitudinal trench; vertical cracks located at 6', 22' and 28' from Sta. 125+88; cracks 1/4" to 2" wide.
R-1-B	Rittenhouse	126+69 to 127+01	Trench	Surface holes and cracks; longitudinal trench; 1"-2" wide vertical crack located at Sta. 126+86; heavy water flow through crack; percolation through downstream midslope.
R-1-B	Rittenhouse	126+86	Test Pit	Large transverse surface crack and holes; large 1"-2" wide crack penetration only 2'-3' below crest of embankment; appears to carry surface runoff.
R-1-C	Rittenhouse	128+64 to 128+88	Trench	Large transverse surface crack; longitudinal trench; vertical cracks located at 3', 10', 13' and 24' from Sta. 128+64; at Sta. 128+67 crack is multi-directional; at Sta. 128+88 crack is 1"-3" wide with heavy water flow through toe of downslope; water percolation from downstream slope toe.
R-1-D	Rittenhouse	129+82	Test Pit	Large transverse surface crack 1/2"-3/4" wide; crack penetrates to depth of 10' below crest; 6" x 3' void located at base of crack; heavy water flow into crack.
R-2-A	Rittenhouse	184+84	Trench	Surface holes in longitudinal pattern; transverse trench; 3" diameter circular hole located 1' below surface; apparent animal furrow.

TABLE 3 - EMBANKMENT EXCAVATIONS (continued)

Excavation	Embankment	Stationing	Type	Description
R-2-B	Rittenhouse	185+82	Trench	Surface holes in longitudinal pattern for 15' on each side of trench; transverse trench; large 3/4"-1" wide crack penetrates about 3½' below ground surface; 3/4" wide longitudinal crack extending 7'-0" below crest; moist soil occurs 3'-6" below crest.
R-2-C	Rittenhouse	184+92 to 185+61	Trench	Surface holes and cracks in transverse pattern across dam; longitudinal trench; vertical cracks 1/4" to 1" wide located at 17', 30', 40', 44' and 56' from Sta. 184+92; 3" diameter hole 3' below surface running transverse to dam at Sta. 185+38.
R-2-D	Rittenhouse	183+82	Test Pit	Surface holes; 5 major cracks noted in rectangular pit; longitudinal cracks to depths of 6'-0" and 8'-0"; transverse cracks to depths of 5'-6", 5'-6" and 3'-6" (did not penetrate other side).
R-3-A	Rittenhouse	158+04	Test Pit	Surface holes and 4" wide x 1' long transverse crack on upstream crest; excavation located on upstream crest, adjacent to embankment centerline. Material extremely difficult to excavate; 1 transverse crack 3/4" wide x 5' deep and 1 longitudinal crack of same dimensions penetrate all sides of excavation.
R-3-B	Rittenhouse	158+04	Test Pit	Surface holes and cracking on upstream side of crest; excavation located near top of upstream slope; 1/2" wide transverse crack located to a depth of 3'-0" near crest and 2'-6" further downslope; crack was not visible on surface of slope.

TABLE 3 - EMBANKMENT EXCAVATIONS (continued)

Excavation	Embankment	Stationing	Type	Description
R-3-C	Rittenhouse	158+04	Test Pit	Excavation used to determine if transverse cracking found in R-3-A and R-3-B fully penetrated embankment; no evidence of cracks found in excavation.
R-4-A	Rittenhouse	126+82	Test Pit	Transverse pattern of surface holes; longitudinal crack 1/2" wide x 3' deep; crack angles downward; heavy water flow into crack; large percolation marks near toe of slope.
V-1	Vineyard	212+72 to 215+36	Trench	Surface cracking and transverse pattern of holes; 1/8" - 1" wide vertical cracks located at 4', 12', 20', 34', 36', 48', 51', 54', 64', 69', 72', 75', 81', 89', 97', 110', 114', 126', 142' and 145' from Sta. 212+72; cracks generally penetrate a minimum of 1'-0" below surface.
V-2	Vineyard	154+67 to 156+75	Trench	Transverse surface holes and cracking; vertical cracks 1/8"-3/4" wide generally penetrating a minimum of 2' located 46', 102', 105', 116', 126', 136', 154', 163', 177', 189' and 199' from Sta. 154+67; many cracks not visible on embankment surface.
V-3-A	Vineyard	111+08	Test Pit	Many surface cracks and holes 2"-8" in diameter; transverse crack 2'-6" deep and 1/4" to 1/2" wide.
V-3-B	Vineyard	111+45	Test Pit	Short, but wide surface holes in longitudinal and transverse directions; shallow 1'-6" cracks extending below crest.

TABLE 3 - EMBANKMENT EXCAVATIONS (continued)

Excavation	Embankment	Stationing	Type	Description
V-4-A	Vineyard	133+81	Test Pit	Surface holes in transverse and longitudinal pattern; 1/2" wide longitudinal crack penetrates 6' below surface; transverse crack 1/2" wide intersects longitudinal crack to a depth of 5'; longitudinal surface holes appear for 50' along crest.
V-5-A	Vineyard	200+00	Test Pit	Three 6" diameter holes on upstream side of crest; 1/2" - 3/4" wide transverse crack extends to a depth of 3' below crest; moist soil excavated at a depth of 3'-6".
V-6-A	Vineyard	240+00	Test Pit	No evidence of surface cracks or holes; no evidence of cracks in excavation; excavation used as a control and to obtain laboratory samples.

PART III

LABORATORY ANALYSES

Job No. 712-280

Lab No.

LABORATORY REPORT

Type of Material/Specimens EMBANKMENT FILL

Source of Material/Specimens AS NOTED

Test Procedure IN-SITU MOISTURE CONTENT

RESULTS

EXCAVATION	STATION	DEPTH BELOW EMBANKMENT CREST (ft.)	ELEVATION (ft.)	MOISTURE CONTENT (%)
R-1-B	126+86	1	1601.3	4.2
		3	1599.3	5.9
		5	1597.3	7.4
R-1-D	129+82	1	1601.3	5.8
		3	1599.3	6.3
		4	1598.3	5.7
		6	1596.3	7.3
		8	1594.3	10.9
		10	1592.3	9.5
R-2-B	185+82	2	1600.3	12.3
		4	1598.3	14.3
		6	1596.3	14.3
		8	1594.3	16.8
R-2-D	183+82	2	1600.3	8.5
		4	1598.3	10.8
		6	1596.3	11.2
		8	1594.3	12.6
		10	1592.3	9.7
R-3-A	158+04	1	1601.3	7.2
		2	1600.3	5.9
		3	1599.3	8.7
		4	1598.3	8.3
		5	1597.3	7.1
V-4-A	133+81	2	1577.5	8.7
		4	1575.5	9.4
		6	1573.5	9.5
V-5-A	200+00	1	1578.5	7.2
		2	1577.5	7.5
		3	1576.5	8.3
		4	1575.5	9.2
		5	1574.5	8.6
V-6-A	240+00	1	1578.5	5.9
		2	1577.5	10.9
		3	1576.5	9.8
		4	1575.5	8.5
		5	1574.5	8.7
		6	1573.5	10.6

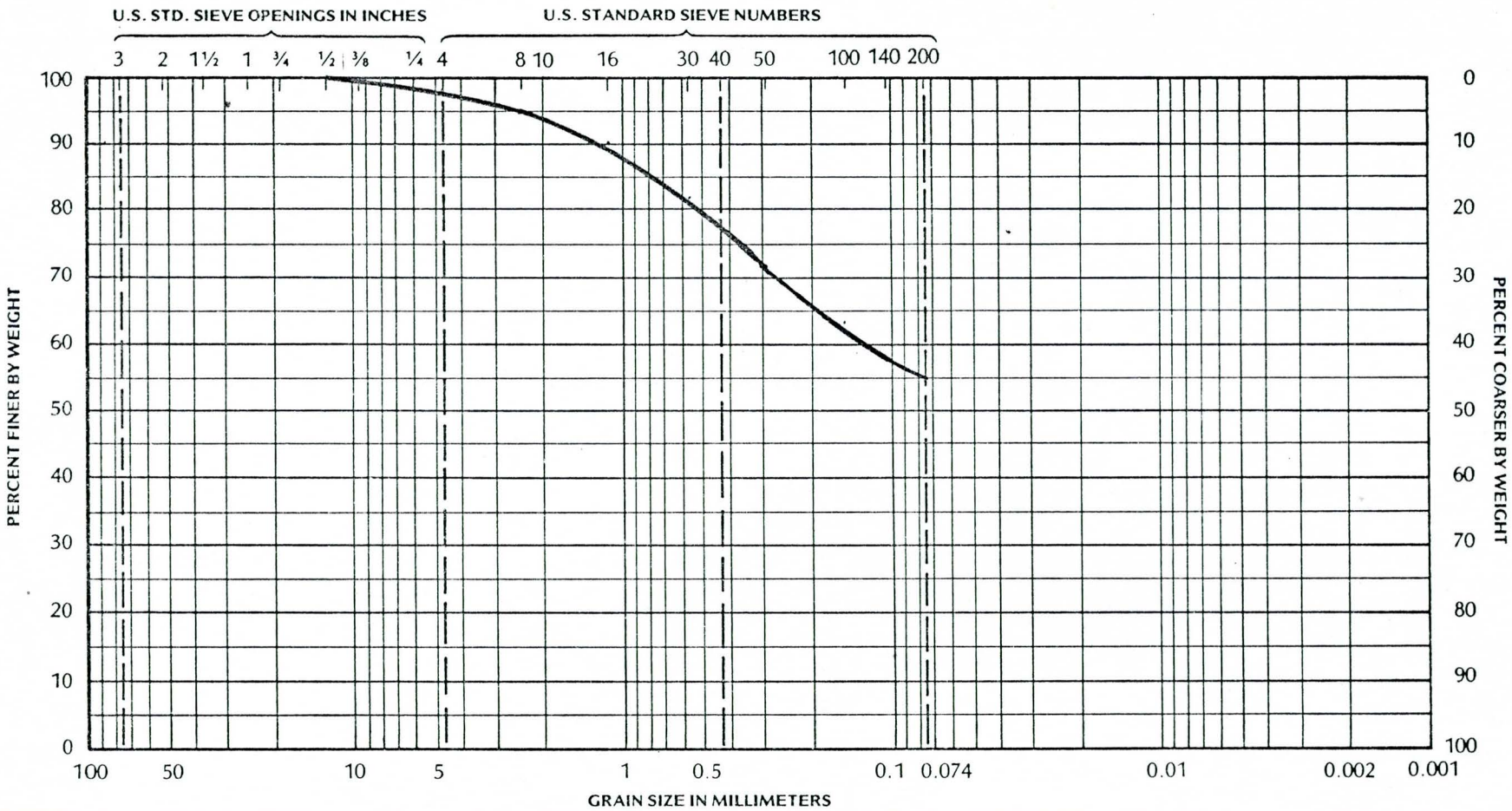
*R - Rittenhouse
V - Vineyard

Type of Material SILT AND SAND TRACE GRAVEL (ML-SM) Job No. 712- 280

Source of Material RITTENHOUSE EXCAVATION R-1-D STATION 129+82 2' DEPTH Lab/Inv. No.

Test Procedure Tested/Calc. By Date

Reviewed By Date



Unified	Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt or Clay	
AASHTO	Gravel		Coarse Sand	Fine Sand	Silt	Clay

Particle Size, Percent Passing																Atterberg Limits			
2''		1''		½''	100	#10	94	#30	82	#100	63	0.05 mm		Liquid Limit	19	P.I.	1
1½''		¾''		#4	98	#16	90	#50	72	#200	54.8	0.002 mm		Plastic Limit	18	Sp. Gr.	–

PARTICLE SIZE DISTRIBUTION CHART

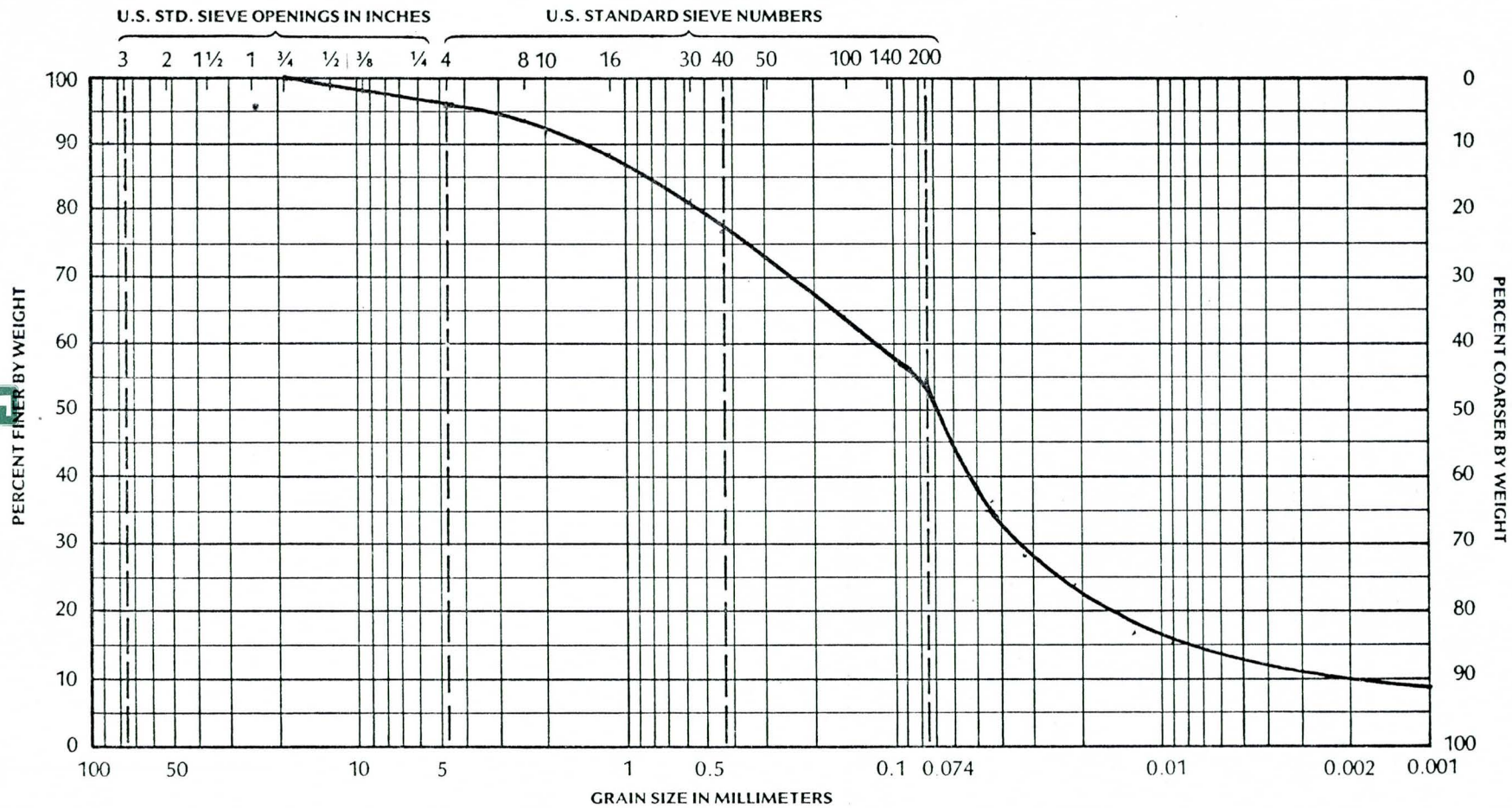
10-21

Type of Material CLAYEY SILT AND SAND TRACE GRAVEL (CL-ML) Job No. 712-280

Source of Material RITTENHOUSE EXCAVATION R-1-D STATION 129+82 10' DEPTH Lab/Inv. No.

Test Procedure Tested/Calc. By Date

Reviewed By Date



Unified	Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt or Clay	
AASHTO	Gravel		Coarse Sand	Fine Sand	Silt	Clay

Particle Size, Percent Passing																		Atterberg Limits			
2''		1''		½''	99	#10	92	#30	81	#100	64	0.05 mm	38	Liquid Limit	24	P.I.	7
1½''		¾''	100	#4	96	#16	88	#50	73	#200	54.8	0.002 mm	10	Plastic Limit	17	Sp. Gr.	2.71

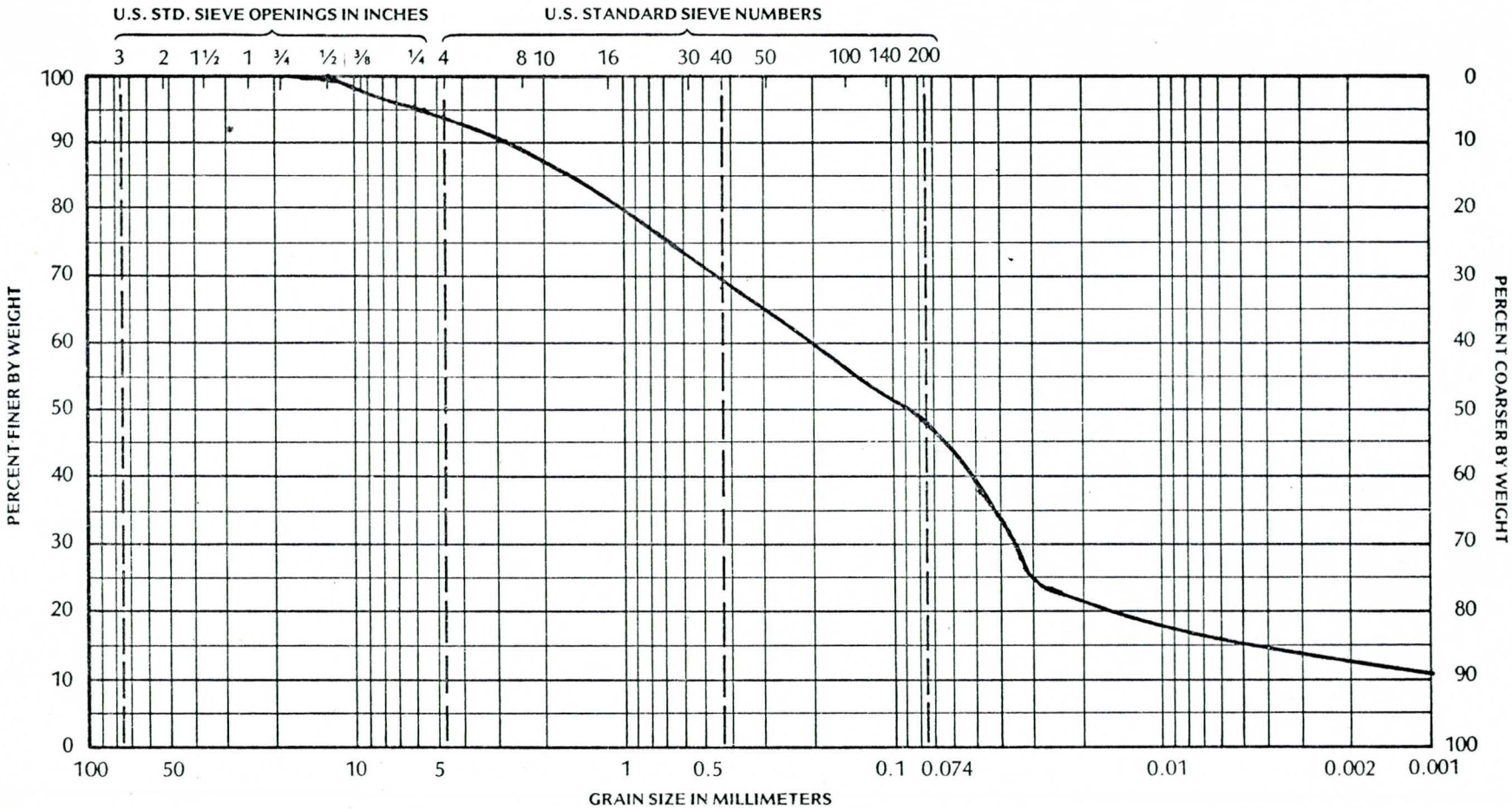
PARTICLE SIZE DISTRIBUTION CHART

Type of Material CLAYEY SAND, SOME SILT, TRACE GRAVEL (SC-CL) Job No. 712-280

Source of Material RITTENHOUSE EXCAVATION R-2-D STATION 183+82 5' DEPTH Lab/Inv. No.

Test Procedure Tested/Calc. By Date

Reviewed By Date



Unified	Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt or Clay	
AASHTO	Gravel		Coarse Sand	Fine Sand	Silt	Clay

Particle Size, Percent Passing																		Atterberg Limits			
2″		1″		½″	97	#10	87	#30	72	#100	56	0.05 mm	39	Liquid Limit	34	P.I.	18
1½″		¾″	100	#4	94	#16	81	#50	64	#200	48	0.002 mm	13	Plastic Limit	16	Sp. Gr.	2.72

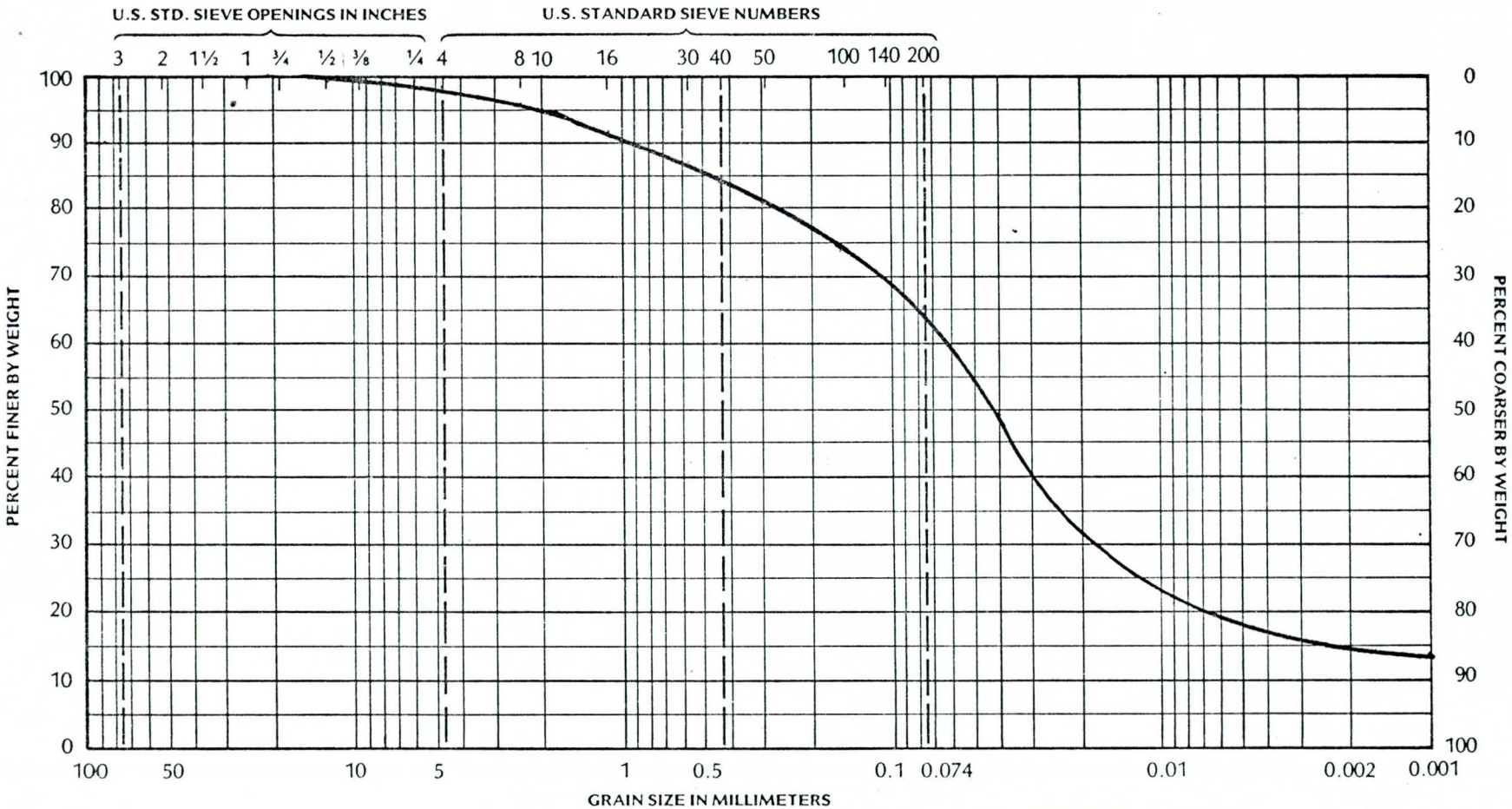
PARTICLE SIZE DISTRIBUTION CHART

Type of Material SANDY SILT AND CLAY, TRACE GRAVEL (CL) Job No. 712-280

Source of Material VINEYARD EXCAVATION V-4-A STATION 133+81 5' DEPTH Lab/Inv. No.

Test Procedure Tested/Calc. By Date

Reviewed By Date



Unified	Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt or Clay	
AASHTO	Gravel		Coarse Sand	Fine Sand	Silt	Clay

Particle Size, Percent Passing																		Atterberg Limits			
2''		1''		½''	99	#10	95	#30	87	#100	74	0.05 mm	48	Liquid Limit	25	P.I.	9
1½''		¾''	100	#4	98	#16	92	#50	81	#200	65.1	0.002 mm	14	Plastic Limit	16	Sp. Gr.	2.73

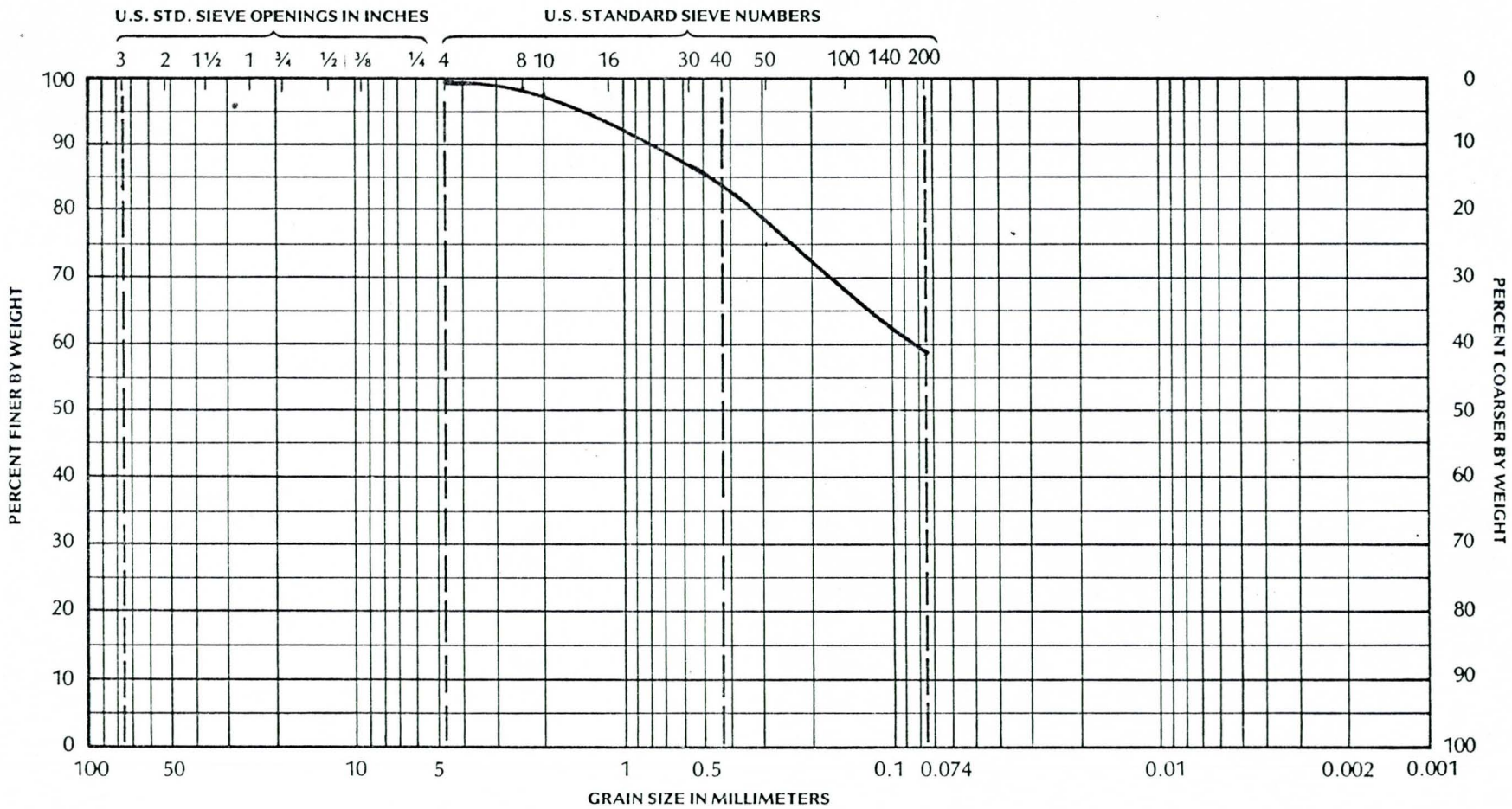
PARTICLE SIZE DISTRIBUTION CHART

Type of Material SANDY CLAY (CL) Job No. 712-280

Source of Material VINEYARD EXCAVATION V-5-A, STATION 200+00, 2' DEPTH Lab/Inv. No.

Test Procedure Tested/Calc. By Date

Reviewed By Date



Unified	Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt or Clay	
AASHTO	Gravel		Coarse Sand	Fine Sand	Silt	Clay

Particle Size, Percent Passing																Atterberg Limits		
2''		1''		½''		#10	97	#30	87	#100	68	0.05 mm		Liquid Limit	25	P.I.	9
1½''		¾''		#4	100	#16	93	#50	75	#200	58.2	0.002 mm		Plastic Limit	16	Sp. Gr.	

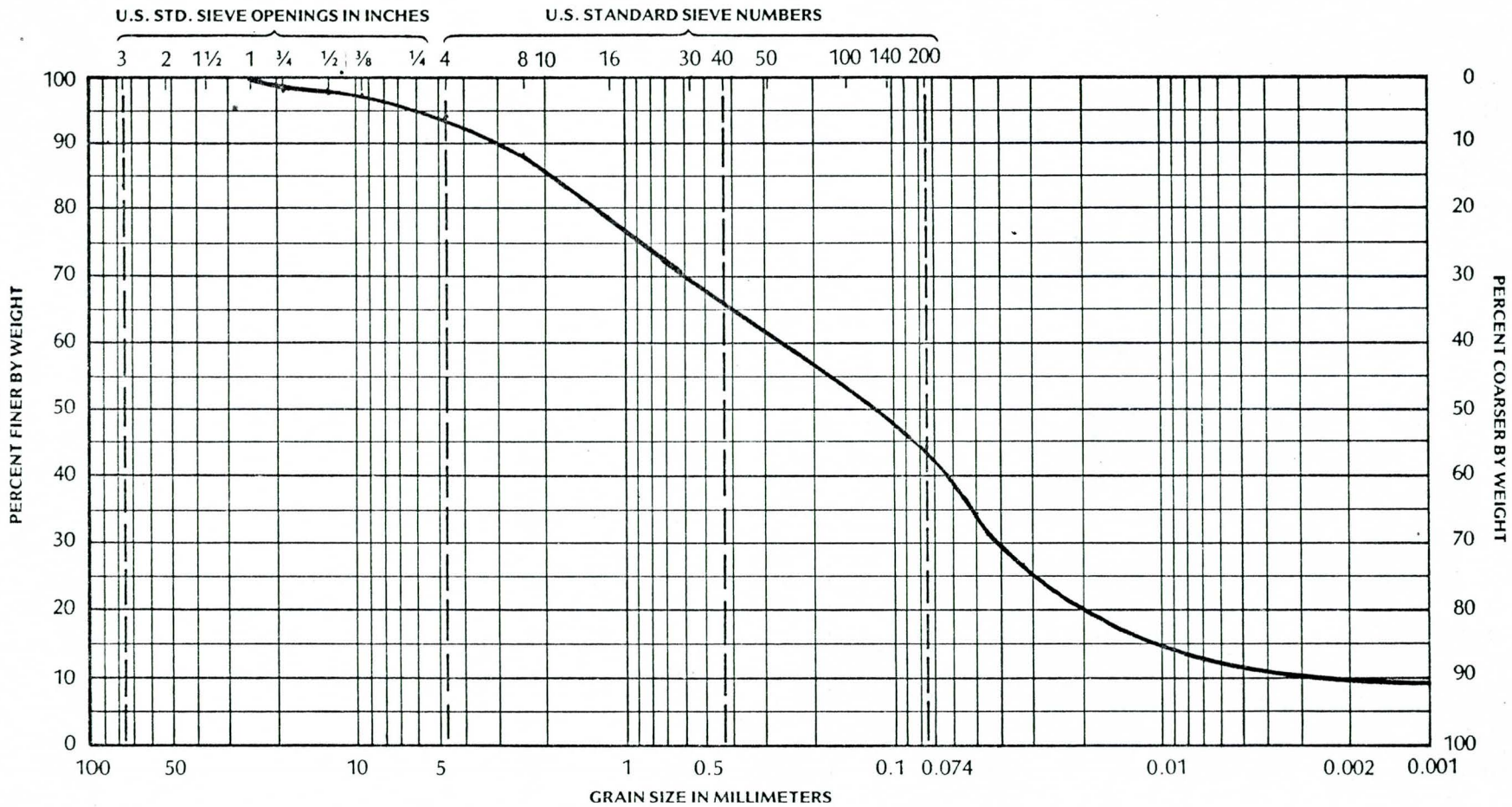
PARTICLE SIZE DISTRIBUTION CHART

Type of Material SAND AND CLAY, TRACE GRAVEL (SC-CL) Job No. 712-280

Source of Material VINEYARD EXCAVATION V-6-A, STATION 240+00, 4' DEPTH Lab/Inv. No.

Test Procedure Tested/Calc. By Date

Reviewed By Date



Unified	Gravel	Coarse Sand	Medium Sand	Fine Sand	Silt or Clay	
AASHTO	Gravel		Coarse Sand	Fine Sand	Silt	Clay

Particle Size, Percent Passing																		Atterberg Limits			
2''		1''	100	½''	95	#10	86	#30	69	#100	53	0.05 mm	34	Liquid Limit	30	P.I.	13
1½''		¾''	98	#4	94	#16	79	#50	61	#200	44.8	0.002 mm	10	Plastic Limit	17	Sp. Gr.	2.71

PARTICLE SIZE DISTRIBUTION CHART

Job No. 712-280

LABORATORY REPORT

Type of Material/Specimens CLAYEY SILT AND SAND, TRACE GRAVEL (CL-ML)

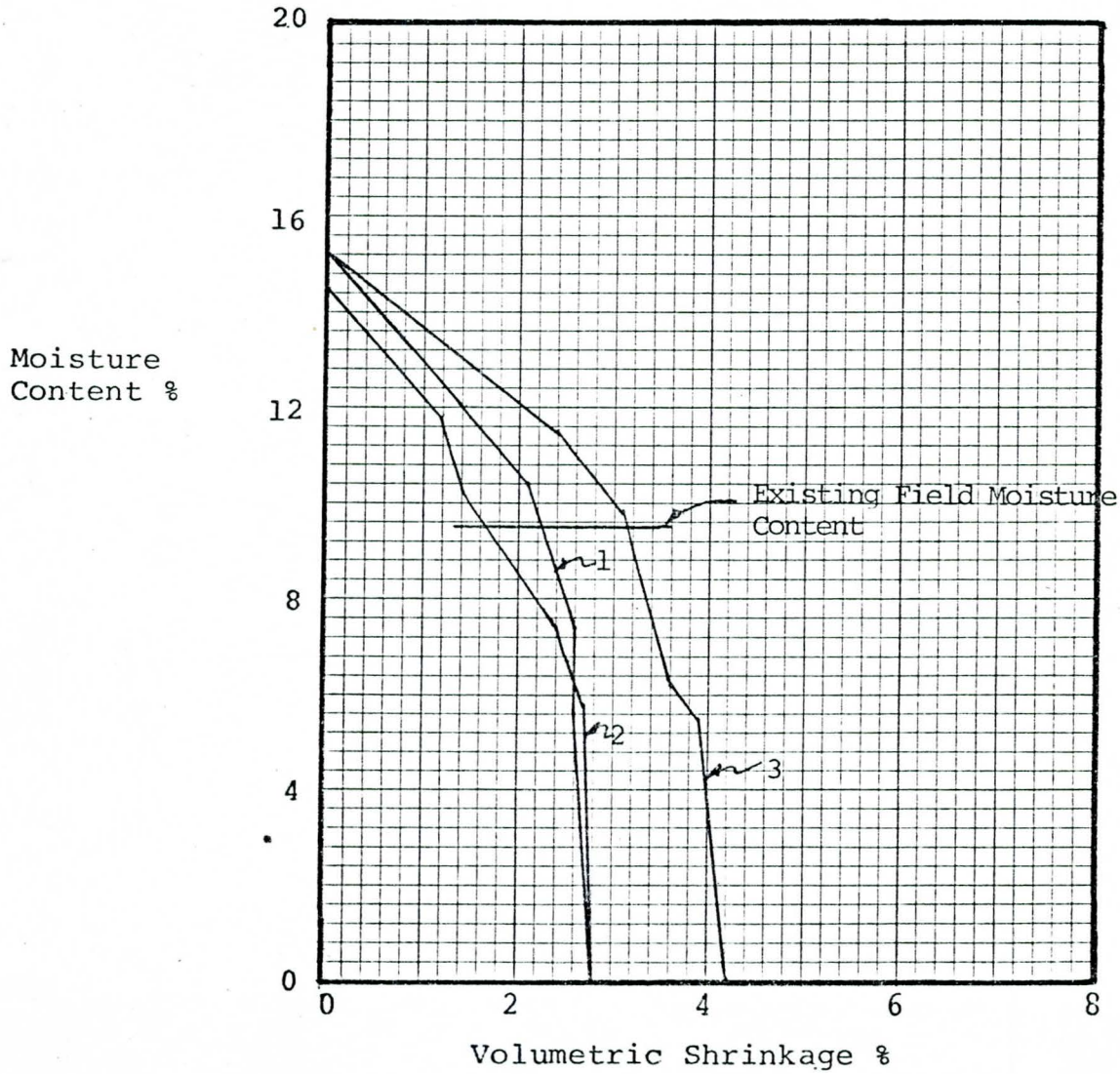
Source of Material/Specimens RITTENHOUSE EXCAVATION R-1-D, STATION 129+82 10' DEPTH

Test Procedure Volumetric Shrinkage Test (Test Specimen approx. 3"x2½"x10")

RESULTS

Average construction field moisture content = 15.0 %
Average construction maximum dry density (ASTM: D698) = 116.8 PCF

Curve Number	Dry Density (pcf)	Moisture Content %
1	116.8	15.2
2	119.6	14.5
3	116.5	15.2



Job No. 712-280

LABORATORY REPORT

Type of Material/Specimens CLAYEY SAND, SOME SILT, TRACE GRAVEL (SC-CL)

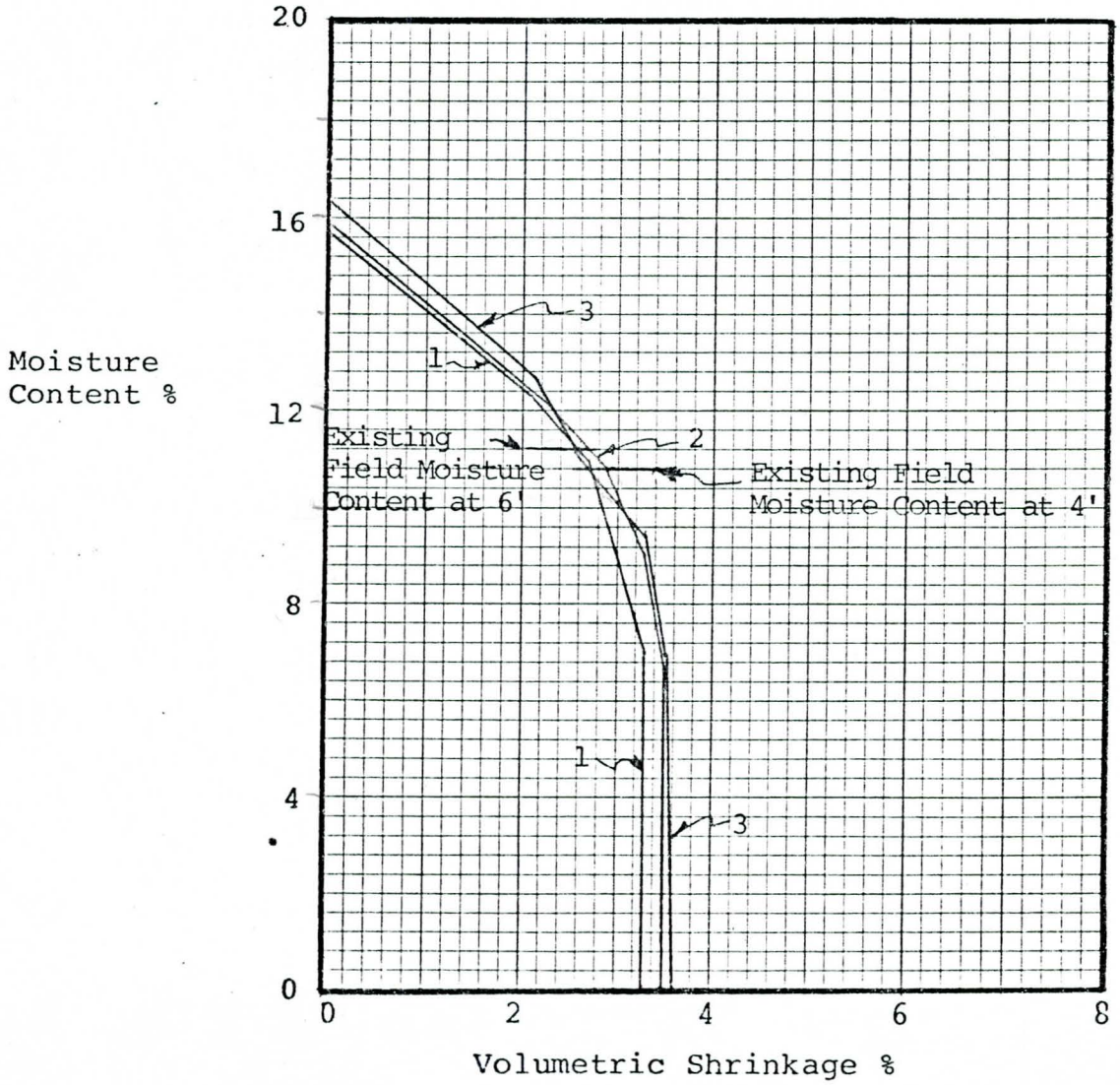
Source of Material/Specimens RITTENHOUSE EXCAVATION R-2-D, STATION 183+82, 5' DEPTH

Test Procedure Volumetric Shrinkage Test (Test Specimen approx. 3"x2½"x10")

RESULTS

Average construction field moisture content = 15.0%
Average construction maximum dry density (ASTM: D698) = 113.7 PCF

Curve Number	Dry Density (pcf)	Moisture Content %
1	110.3	15.7
2	112.5	15.9
3	109.2	16.3



Type of Material/Specimens SANDY SILT AND CLAY, TRACE GRAVEL (CL)

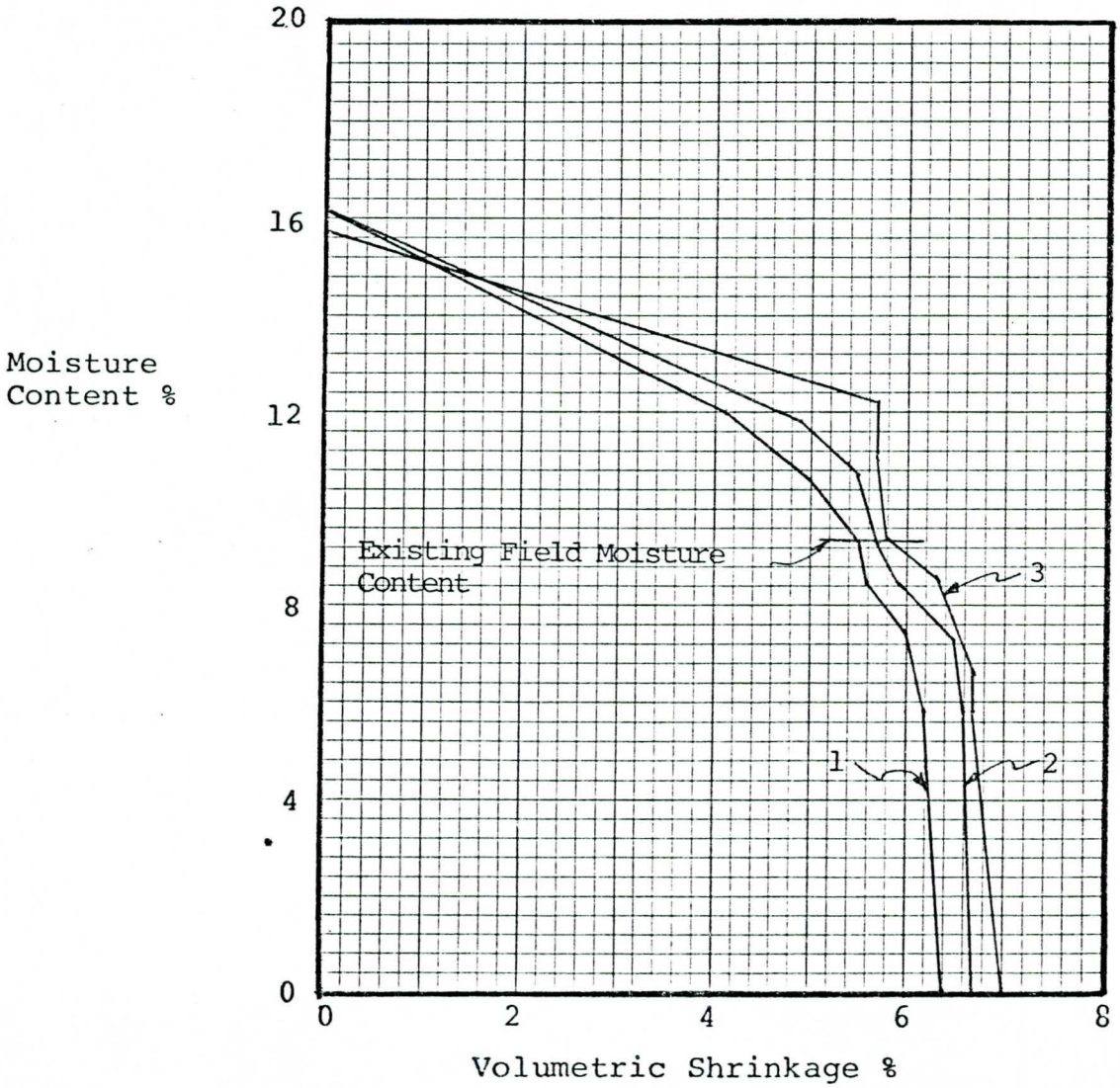
Source of Material/Specimens VINEYARD EXCAVATION V-4-A, STATION 133+81, 5' DEPTH

Test Procedure Volumetric Shrinkage Test (Test Specimen approx. 3"x2½"x10")

RESULTS

Average construction field moisture content = 14.5%
Average construction maximum dry density (ASTM: D698) = 113.7 PCF

Curve Number	Dry Density (pcf)	Moisture Content %
1	115.7	16.1
2	116.4	15.7
3	117.0	16.2



Job No. 712-280

LABORATORY REPORT

Type of Material/Specimens SAND AND CLAY, TRACE GRAVEL (SC-CL)

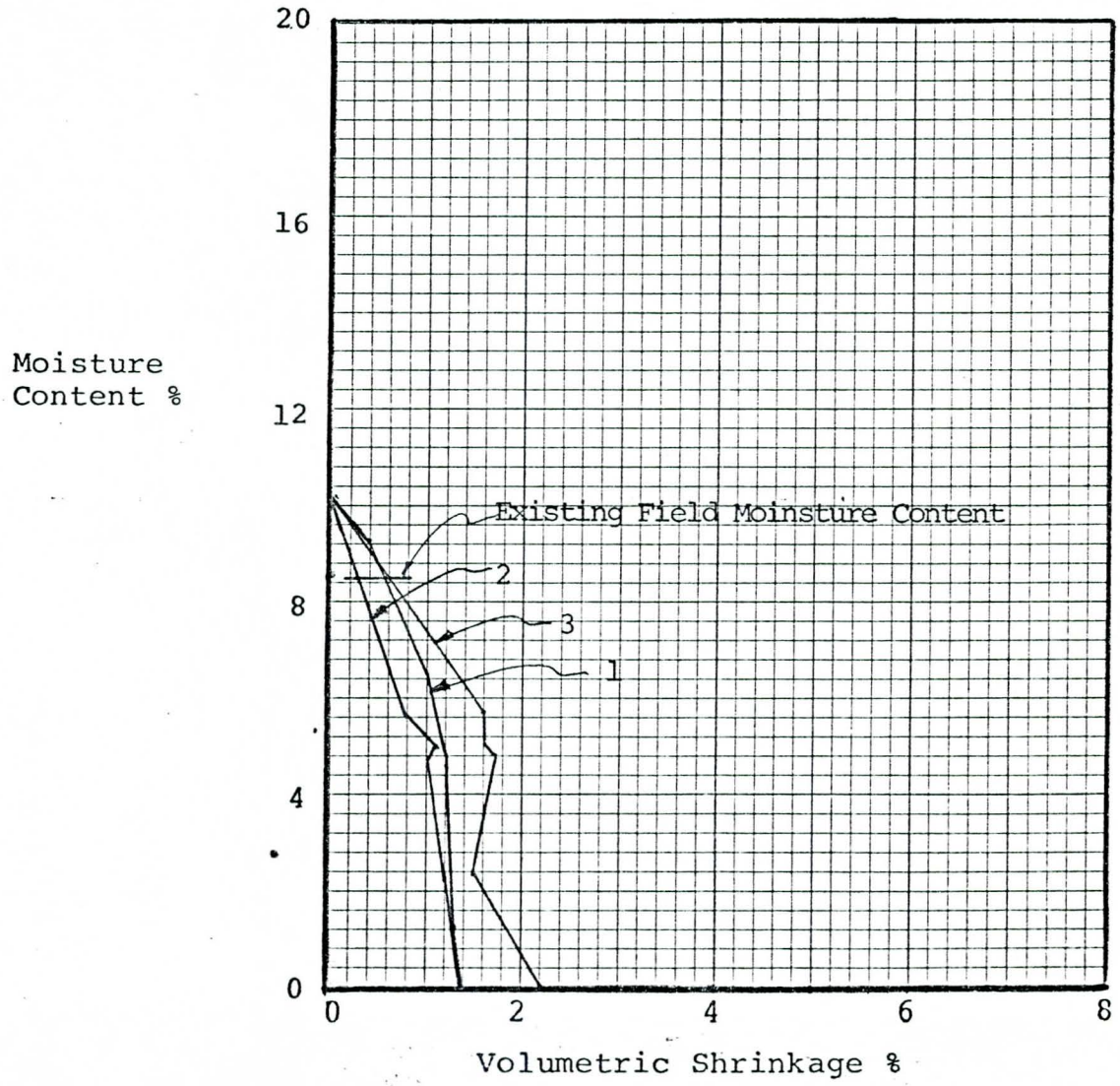
Source of Material/Specimens VINEYARD EXCAVATION V-6-A, STATION 240+00, 4' DEPTH

Test Procedure Volumetric Shrinkage Test (Test Specimen approx. 3"x2½"x10")

RESULTS

Average construction field moisture content = 12.0%
Average construction maximum dry density (ASTM: D698) = 118.9 PCF

Curve Number	Dry Density (pcf)	Moisture Content %
1	122.0	10.2
2	123.5	10.1
3	123.3	10.2



Job No. 712-280

Lab No.

LABORATORY REPORT

Type of Material/Specimens EMBANKMENT FILL

Source of Material/Specimens AS NOTED

Test Procedure DISPERSITIVITY TESTS - PIN HOLE TEST AND CHEMICAL TEST

RESULTS

EXCAVATION*	STATION	DEPTH (ft.)	PIN HOLE TEST RESULTS	CHEMICAL TEST SAR+	CHEMICAL TEST RESULTS
R-1-D	129+82	10	Non-Dispersive (ND1)	4.5	Non-Dispersive
R-2-D	183+82	5	Non-Dispersive (ND1)	3.2	Non-Dispersive
V-4-A	133+81	5	Non-Dispersive (ND1)	5.0	Non-Dispersive
V-6-A	240+00	4	Non-Dispersive (ND1)	3.7	Non-Dispersive

* R - Rittenhouse, V - Vineyard

\+ SAR - Sodium Absorption Rate

PART IV

PHOTOGRAPHS

Photograph 1 Transverse Crack-
Rittenhouse Station
128+88 (R-1-C)

Photograph 2 Transverse Crack-
Rittenhouse Station
129+82 (R-1-D)

Photograph 3 Transverse Crack-
Rittenhouse Station
126+86 (R-1-B)

Photograph 4 Transverse Crack-
Rittenhouse Station
128+88 (R-1-C)

Photograph 5 Transverse Crack-
Rittenhouse Station
126+20 (R-1-A)

Photograph 6 Longitudinal Crack-
Vineyard Station
133+81 (V-4-A)

Photograph 7 Longitudinal Crack-
Vineyard Station
133+81 (V-4-A)

Photograph 8 Longitudinal Crack-
Vineyard Station
133+81 (V-4-A)

Photograph 9 Longitudinal Crack-
Vineyard Station
111+45 (V-3-B)

Photograph 10 Longitudinal Crack-
Rittenhouse Station
185+82 (R-2-B)

Photograph 11 Longitudinal Exposed Crack-Rittenhouse Station 183+82, N. side of Excavation (R-2-D)

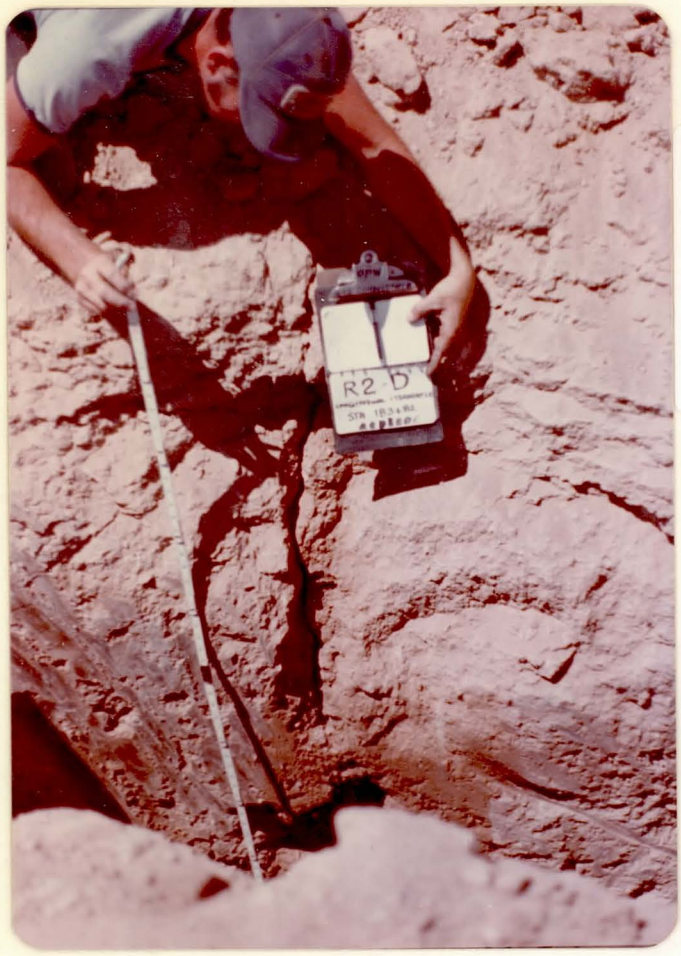
Photograph 12 Longitudinal Exposed Crack-Rittenhouse Station 183+82, N. side of Excavation (R-2-D)

Photograph 13 Longitudinal Exposed Crack-Rittenhouse Station 183+82, S. side of Excavation (R-2-D)

Photograph 14 Transverse Exposed Crack Extending to Depth of Ten Feet Below Crest-Rittenhouse Station 129+82, W. side of Excavation (R-1-D)

Photograph 15 Transverse Exposed Crack Extending to Depth of Eight Feet Below Crest- Rittenhouse Station 129+82, E. side of Excavation (R-1-D)

Photograph 16 Transverse Crack Extending to 5'-6" Below Crest- Rittenhouse Station 183+82, W. side of Excavation (R-2-D)



Photograph 17 Transverse Crack Extending to 3'-6" Below Crest- Rittenhouse Station 183+82, E. side of Excavation (R-2-D)

Photograph 18 Transverse Crack Extending to 5'-6" Below Crest- Rittenhouse Station 183+82, W. side of Excavation (R-2-D)

Photograph 19 Water Percolating From Downstream Side of Rittenhouse; Water Originating in 3-ft. Deep Trench Along Centerline.

Photograph 20 Water Flow Through Downstream Side of Rittenhouse near Station 185+82; Water Originating in 3-ft. Deep Trench Along Centerline.

Photograph 21 Breakout of Water on Downstream Midslope of Rittenhouse at Station 126+10.

Photograph 22 Water Flowing near Surface of Slope.

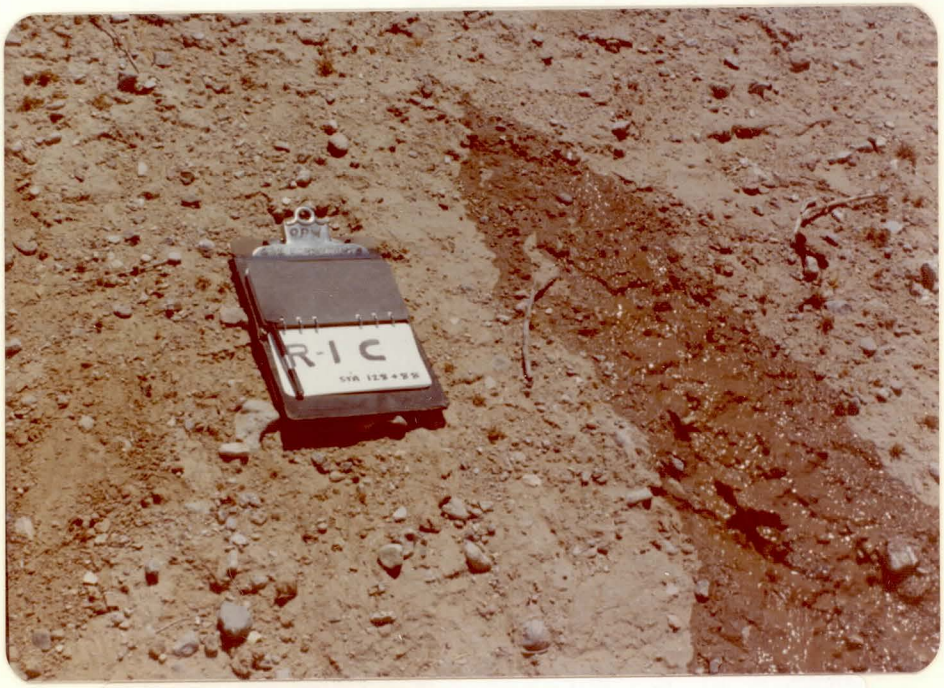
Photograph 23 Percolation of Water Through Upper Slope, Rittenhouse Station 126+86.

Photograph 24 Beginning of Seepage Through Slope; Rittenhouse near Station 126+10.

Photograph 25 Heavy Flow Starting Through Slope as Seepage Continues; Rittenhouse near Station 126+10.

Photograph 26 Transverse Crack Directing Heavy Water Flow Through Slope; Rittenhouse Station 126+10 (R-1-A).

Photograph 27 Flow of Water Eroding Slope of Embankment. Note Evidence of Prior Erosion.



Photograph 28 Seepage Near Toe of Downstream Slope; Rittenhouse Station 128+88 (R-1-C).

Photograph 29 Exposed Transverse Crack, Vineyard Station 200+00 (V-5-A)

Photograph 30 Exposed Transverse Crack, Vineyard Station 111+08 (V-3-A)

Photograph 31 Exposed Transverse Crack, Vineyard Station 111+08 (V-3-A)

Photograph 32 Exposed Shallow Transverse Crack, Vineyard Station 111+08 (V-3-A)

Photograph 33 Wide Surface Crack Extending to Shallow Depth, Vineyard Station 111+45 (V-3-B)

Photograph 34 Wide Longitudinal Crack Penetrating 7'-0" Below Crest, Rittenhouse Station 185+82 (R-2-B)

Photograph 35 Very Wide Transverse Crack Extending 3'-0" Below Crest, Rittenhouse Station 126+86

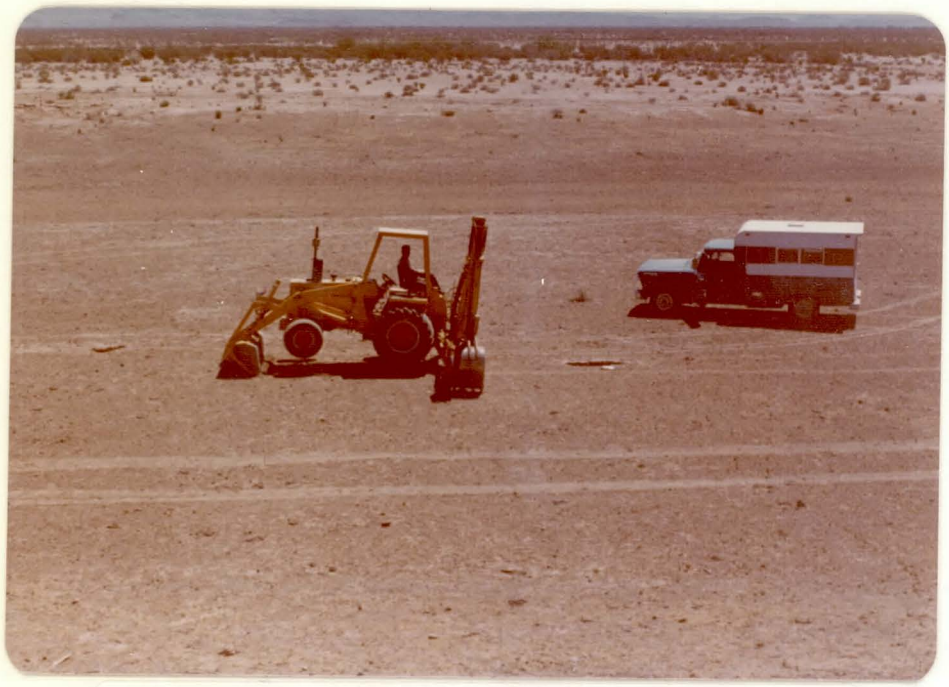
Photograph 36 Lineation Located Skew to General Drainage Pattern of Basin.

Photograph 37 Vegetation Along Lineation.

Photograph 38 Vegetation Along Lineation.

Photograph 39 Surface Hole in Retention Basin Behind Rittenhouse (Sta. 159+75).

Photograph 40 Surface Hole in Retention Basin Behind Rittenhouse (Sta. 159+75).



Photograph 41 Surface Hole in Retention Basin Behind Rittenhouse (Sta. 159+75).