



VIRGINIA GEOTECHNICAL SERVICES, P.C.

8211 Hermitage Road ■ Richmond, Virginia 23228-3031 ■ (804) 266-2199

DRAFT

**Report of Subsurface Exploration
and Preliminary Geotechnical Evaluation
for the Proposed Fort
Darling Slope Stabilization Project
Chesterfield, Virginia
VGS Project No. GT-625**

**Prepared for:
National Park Service
Richmond, Virginia**

**Prepared by:
Virginia Geotechnical Services, P.C.
Richmond, Virginia**

March 1992



VIRGINIA GEOTECHNICAL SERVICES, P.C.

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March 24, 1992

DRAFT

Richmond National Battlefield Parks
National Park Service
Department of the Interior
3215 East Broad Street
Richmond, Virginia 23223

Attention: Mr. Erv Gasser

Reference: Report of Subsurface Exploration
and Preliminary Geotechnical Evaluation
for the Proposed Fort Darling
Slope Stabilization Project
Chesterfield, Virginia
VGS Project No. GT-625

Dear Mr. Gasser:

Virginia Geotechnical Services, P.C., (VGS) is pleased to submit this report of our subsurface exploration, geologic site reconnaissance and geotechnical evaluation relating to the proposed slope stabilization project at the above referenced site. Our services were performed in general accordance with VGS Proposal No. 128-91 as authorized by you. This report presents a review of our scope of services, site and project description, discussion of the subsurface exploration, discussion of the geologic site reconnaissance, results of our laboratory testing services, and our conclusions and preliminary recommendations for slope stabilization based on the geotechnical and geologic aspects of the proposed construction.

1.0 SITE AND PROJECT DESCRIPTION

Fort Darling/Drewrys Bluff is located about 1.3 miles south of the Chippenham Parkway, Interstate 95 interchange, on the south bank of the James River in Chesterfield County, Virginia (Approximate Site Location Map, Drawing No. 1, Appendix 1). The site is a part of the Richmond National Battlefields Park system. The site of the fort is located at the top of a near-vertical outcrop rising approximately 80 to 90 feet above the James River.

The slope of the outcrop at Drewry's Bluff is actively being eroded by the James River, and historically significant Ft. Darling will be destroyed by continued erosion of the bluff. We understand that the National Park Service is interested in evaluating alternative methods available to improve slope stability and prevent further erosion of the bluff. This report includes a preliminary geotechnical evaluation of the slope and preliminary recommendations for slope remediation and stabilization.

2.0 SCOPE OF SERVICES

Our scope of services for the referenced project included the supervision of drilling services, a geologic site reconnaissance, laboratory testing services, and professional geotechnical analysis to develop:

1. A description of subsurface soil conditions and groundwater levels within the area studied at the time of drilling.
2. A description of the outcrop based on geologic, visual, and stratigraphic studies.
3. Preliminary recommendations for slope remediation and stabilization.
4. Conclusions and recommendations pertaining to the geotechnical aspects of the project and a description of unusual soil conditions, if encountered.

Our scope of services did not include site surveying, long term groundwater level monitoring, or the performance of an environmental site assessment for the presence of hazardous materials.

3.0 SUBSURFACE EXPLORATION PROGRAM

The subsurface exploration program for this project consisted of three (3) Standard Penetration Test (SPT) borings to depths of approximately 100 feet. The borings were completed between December 3 and December 6, 1991 by Dvorak Geotechnical Services of Chesterfield, Virginia using a truck-mounted drill rig with a hollow-stem auger. The boring depths and locations were selected during a site visit with representatives from the National Park Service, VGS, and Dewberry & Davis. The boring locations and elevations were surveyed by Dewberry & Davis prior to the start of drilling. The boring locations are shown on the Approximate Boring Location Plan (Drawing No. 2, Appendix 1).

Soil samples were collected using a split-spoon sampler in conjunction with the Standard Penetration Test (ASTM D1586). Drill monitoring and visual soil classifications were conducted by a VGS Engineer. Representative portions of each split-spoon sample were placed in clean jars, sealed, and transported to our laboratory for testing. The boring logs are included in Appendix 2.

4.0 SITE GEOLOGY AND SUBSURFACE CONDITIONS

4.1 REGIONAL SETTING

The Drewry's Bluff site is located in the Coastal Plain physiographic province of Virginia. Published geological literature is available only at regional scale. The area is underlain by relatively thin deposits of fluvial, and possibly estuarine and marine sediments. These sediments form a wedge which thins to zero thickness at the fall line and increases in thickness to the east (Drawing No 3, Appendix 1). Sediment was eroded from the highlands west of the fall line and transported eastward to the ancestral Atlantic Ocean.

A copy of a subsurface map of the basement surface prepared by Meng and Harsh (1988, Hydrogeologic Framework of the Virginia Coastal Plain, U.S.G.S. Professional Paper 1404-C) is presented as Drawing No 4 in Appendix 1. Drawing No. 4 indicates that the altitude of the top of the basement surface is about elevation -56 feet (MSL) based on a nearby control well. Based on the ground surface elevation of about 80 to 90 feet (MSL), Drawing No. 4 indicates sediment thickness in the Drewry's Bluff area is approximately 140 feet. Mapping by Mixon et al (1989, Geologic Map and Generalized Cross Sections of the Coastal Plain and Adjacent Parts of the Piedmont, Virginia, U.S.G.S. Miscellaneous Investigations Series, Map I-2033) indicates that surficial deposits at the site are assignable to the Potomac Formation of Cretaceous age. This interpretation is supported by paleontological evidence at a nearby site described by Crane and Upchurch (1987, *Drewria Potomacensis* Gen. Et Sp. Nov., an Early Cretaceous Member of the Gnetales From the Potomac Group of Virginia, American Journal of Botany).

Published descriptions describe updip (deposits close to the fall line such as at the site) deposits of Potomac Formation sediments as fluvial deltaic in origin. Fluvial deltaic sediments are characterized by fining upwards sequences of sediments. Coarse deposits consisting of gravel and sand are deposited by river channels. Finer silts and clays are deposited usually during floods in lower energy swamps and interfluv. Fluvial deltaic deposits are also characterized by rapid lateral variation.

4.2 GEOLOGIC SITE RECONNAISSANCE

A geologic reconnaissance was made at the Drewry's Bluff site on January 29, 1992. The purpose of the reconnaissance was to observe sedimentary strata exposed along Drewry's Bluff on National Park Service (NPS) property and to observe slope conditions with respect to erosion and slumping. An initial transect was made along the crest of the bluff to familiarize field team members with site conditions. Subsequently, the bluff was observed along transects near the base of the bluff near the down stream NPS property corner and from the upstream NPS property corner to approximately the upstream corner of Fort Darling. The area from the vicinity of the fort to the vicinity of the downstream NPS property corner was inaccessible due to steep slopes at the crest of the bluff and the base of the bluff.

A composite stratigraphic column was prepared based on observations made at the locations which were accessible (Drawing No 5, Appendix 1). Rapid lateral variation of strata was observed. Apparent dip was observed to be northward. Three dimensional observations of dipping strata were not possible due to outcrop geometry, so true dip could not be observed.

The composite stratigraphic column was divided into six strata. Photographs of the strata observed are presented in Appendix 4, and these photographs are referred to in the following descriptions of the strata observed. Stratigraphic descriptions follow below in descending order.

CLM
STRATUM 1: STRATUM 1 sediments are typically reddish-brown clayey fine sand to sandy clay. Bedding is massive. Some portions of STRATUM 1 are fill from fort structures. Several gravity failure (slump) zones were observed at the top of Drewry's Bluff in STRATUM 1 sediments. STRATUM 1 sediment and slump features are shown in Photographs No 1 and 2. STRATUM 1 was approximately 18 ft thick. In the borings, the soils interpreted to be STRATUM 1 sediments were classified as SM, SC and CL soils according to the ASTM Soil Classification System. Standard Penetration Test blow counts (N-values) ranged from 8 to 83 blows per foot (bpf), indicating loose to very dense relative densities in these sediments.

STRATUM 2: Stratum 2 sediments consist of an upper sequence of red-brown and yellow-brown fining upwards packages of cobbles, gravel, sand, and clayey fine sand. Beds are commonly 2 to 3 ft thick. Trough cross stratification is common in this unit. The upper portion of STRATUM 2 is shown in Photograph No 3. The lower portion of

STRATUM 2 is a greenish gray sand with silt fining upwards to fine sandy silt. Some small rounded quartz pebbles were observed at the base of the unit. This portion of the section is visible near the top of Photograph 4. Many of the upper slope slump features affected STRATUM 2 as well as STRATUM 1. STRATUM 2 is approximately 20 ft thick. In the borings, soils interpreted to be STRATUM 2 sediments were classified as SM soils, and N-values ranged from 31 to 87 bpf, indicating dense to very dense relative densities.

STRATUM 3: STRATUM 3 sediments consist of a massive cobble layer. The sediments are clast supported with abundant rock fragment and some mud clast and rounded quartz cobbles. The matrix consists of rounded quartz sand. STRATUM 3 is shown in Photographs 4, 5, and 6. The base of STRATUM 3 is sharp and truncates cross bedding and laminations in STRATUM 4 (Photograph 6). STRATUM 3 generally appears to be more resistant to slumping than STRATA 1 and 2 as shown by its vertical profile. STRATUM 3 is approximately 10 feet thick. In the borings, soils interpreted to be STRATUM 3 sediments were classified as SM and GM soils, and N-values ranged from 31 to over 100 bpf, indicating dense to very dense relative densities.

STRATUM 4: STRATUM 4 consists of a distinct white and yellow brown laminated and trough cross stratified fine to medium clayey sand (Photographs 4, 5, 6). Accumulations of black organic material formed planar laminations within this unit (Photograph 7). A layer of small (6 in) to large (>3 ft) clay boulders form a horizon near the base of this unit. The base of STRATUM 4 is covered by sediments which have eroded or slumped from above. The maximum observed thickness of STRATUM 4 was approximately 20 feet. In the borings, soils interpreted to be STRATUM 4 sediments were classified as SC and SM soils, and N-values ranged from 31 to over 100 bpf, indicating dense to very dense relative densities.

STRATUM 5: STRATUM 5 consists of a cobble layer similar to STRATUM 3. The contact Between Stratum 4 and 5 was not observed. STRATUM 5 was observed near the downstream corner of the NPS property. The overlying

strata were observed near the middle of the riverfront of the NPS property. The rapid lateral variations observed at the site suggest that STRATUM 5 may pinch out in the upstream direction. In the borings, soils interpreted to be STRATUM 5 sediments were classified as SM and SC soils, and N-values ranged from 52 to over 100 bpf, indicating a very dense relative density.

STRATUM 6: STRATUM 6 is a blue-gray to maroon clay with blocky weathering and sandy in part. The clay cobbles and boulders observed near the base of STRATUM 4 appear to be fragments of STRATUM 6. STRATUM 6 was observed underlying STRATUM 5 near the downstream NPS property corner. STRATUM 6 is believed to underlie STRATUM 4 in other parts of the site based on boring logs. Steep erroded slopes of STRATUM 6 sediment were observed at two locations on the site at river level. In the borings, soils interpreted to be STRATUM 6 sediments were classified as CL, CH, SC and SM soils, and N-values ranged from 65 to over 100 bpf, indicating a very dense relative density.

5.0 LABORATORY TESTING SERVICES

Selected soil samples obtained during our field activities were subjected to laboratory testing including classification tests and natural moisture content tests. The classification tests for this project included grain-size analysis and Atterberg Limits. The data developed from our laboratory testing program are presented in Appendix 3.

The natural moisture content test results indicated test values ranging from 12.8 to 27.7 percent. In general, the grain-size analyses indicated that the samples tested were predominantly fine-to medium-grained sands with between 12 and 37 percent by weight passing the No. 200 sieve. Atterberg limits tests yielded Liquid Limit values of 42 to 66, and Plasticity Index values of 16 to 39. These test values are indicative of silty SANDS and clayey SANDS (SM and SC type soils) according to the ASTM Soil Classification System. One sample tested was classified as a lean CLAY (CL). The laboratory test results were generally consistent with our visual-manual classifications.

6.0 CONCLUSIONS AND PRELIMINARY RECOMMENDATIONS

The bluff which rises approximately 80 to 90 feet from the James River to the location of Ft. Darling is unstable and will continue to fail if measures are not taken to protect the toe of the slope from erosion and to regrade the steep slopes above the riverbank. Based on the condition of the bluff at the time of our field reconnaissance, we believe that the slope failures below Ft. Darling are the result of the erosive effects of the James River and not a general instability of the hillside. This general conclusion is based on the slump-type failures observed on the slope as opposed to rotational-type, deep-seated slope failures which often occur as the result of weak strata either within a slope or within the underlying foundation soils.

We base our general conclusion that the slope failures observed are shallow, slump-type failures on the relatively straight trunks of the trees which are growing on the slope, and on the history of the slope which has stood for over 100 years below the fort. We understand that the slope has experienced continuing slumping-type failures which have progressively taken more and more of the slope over the years.

Based on the available data, we believe that remediation of the slope should address two major concerns:

- Reducing future erosion at the toe of the slope.
- (●) Regrading the existing slope to prevent future slump-type failures due to erosion which has already taken place.

In general, erosion at the toe of the slope can be reduced by protecting the riverbank with either materials which are more resistant to erosion, such as rip-rap or concrete revetments, or with structures such as retaining walls, H-piles with lagging or precast concrete panels, sheet-piling or bin walls. Regrading of the existing slope is necessary to eliminate nearly vertical sections of the bluff which have developed as a result of the slump-type failures and to account for loose, gravity-deposited soils near the base of the bluff. The regrading can consist of either cutting back the top of the bluff to reduce the steepness of the exposed soils to a flatter, more stable slope angle or building up the toe of the slope by placing backfill behind a new structure to reduce the steepness of the angle for the new, reconstructed slope.

Based on the data developed from this exploration and the initial site survey information provided by Dewberry and Davis, we considered three different general remediation methods that could be applicable to this site. The three alternative remediation methods considered were as follows:

- Protect the riverbank with riprap and flatten the existing slope.
- Construct a relatively tall reinforced concrete retaining wall and backfill.
- Construct an inexpensive structure at the toe of the slope and a steepened, reinforced soil slope above.

The first two alternative remediation methods are expected to be unacceptable to the National Parks Service and possibly the U.S. Army Corps of Engineers for different reasons which are discussed in the following paragraphs. The third alternative method has several variations which are likely to be more acceptable solutions for this site.

6.1 Riprap and Flattened Slope

One option for increasing the resistance to erosion and improving the stability of the slope is to protect the riverbank with riprap and flatten the existing slope. For this alternative, the slope would have to be flattened by cutting back the top of the slope to an angle which provides a suitable factor of safety with respect to stability. While this would be the least expensive alternative, it would also have the most impact on Ft. Darling at the top of the slope.

For example, we anticipate that a slope of about 1-1/2 horizontal to 1 vertical (1-1/2 on 1) is likely to be the steepest allowable slope for this site. If the slope were cut back to 1-1/2 on 1, we estimate that the top of the regraded slope would be approximately 60 feet west of the current top of the slope (Figure 6, Appendix 1). A cut of this magnitude would take out the west wall of the fort, the gun emplacements and the overlook viewing stand. Furthermore, the Corps of Engineers might be interested in the effects of regrading the slope on the hydrology of the river channel in this area.

6.2 Reinforced Concrete Wall and Backfill

Another remediation option for this site consists of constructing a reinforced concrete retaining wall near the toe of the slope and placing a sloped backfill behind the wall. With this option, the location of the top of the regraded slope could be left unchanged from the existing location of the top of the slope. However, in order for a 1-1/2 on 1 backfill slope to intersect the existing top of slope position, we estimate that the retaining wall would have to be on the order of 40 to 50 feet tall (Figure 7, Appendix 1).

While this alternative could have little to no effect on the fort at the top of the slope, a retaining wall 40 to 50 feet high and designed to support a sloped backfill would be a very massive and expensive structure. Furthermore, a large

volume of select backfill material would have to be imported to the site, and the effects of restricting the river channel may have to be evaluated.

6.3 Economical Structure(s) and Reinforced Backfill

A third alternative remediation option for this site consists of constructing an earth retention structure at the toe of the slope, with possibly one or more additional structures at higher elevations on the slope, and backfilling behind the structure(s) with either select backfill materials or steepened, reinforced soil backfill. We believe that a single structure at the toe of the slope will provide a feasible solution, but a second structure may be required depending on a more detailed profile of the existing slope and the actual length of soil reinforcement required. The second structure might be required at about the mid-height of the slope to provide an adequate horizontal width of backfill for embedding the required lengths of reinforcement in new fill.

This alternative would have little to no effect on the fort at the top of the slope, and the effects on the river channel would be the least of the three alternatives considered. The need for one or more structures at different elevations on the slope will depend on the results of detailed stability analyses that would have to be accomplished as a part of the evaluations for design. Possible alternative structures considered for use at this site include:

- Crib walls
- Tied-back sheetpiling.
- Tied-back soldier piles with wood or precast concrete lagging.

Crib walls would provide a relatively economical alternative for a structure near the toe of the slope; however, the riverbank would require additional slope protection to prevent the undermining of the toe of the bin wall which would result in failure of the wall. This type of structure is planned for regrading efforts proposed on the adjoining upstream property.

Although use of a similar type wall on both the National Park Service and adjoining properties would provide for a consistent appearance from the river, there are several potential concerns about the use of a crib bin wall for the National Park Service site. First, the resistance to overturning caused by lateral earth pressure acting against the back of this type wall is provided solely by the mass of the wall components and the material contained within the wall. Behind the wall, a relatively steep regraded slope will be required to minimize the effects on the fort. As a result, the lateral earth pressure against the back of the wall will be much higher than normal, and it may be difficult to

incorporate sufficient mass into the wall to provide an adequate factor of safety against overturning. Second, the resistance to sliding of the wall is provided by friction acting on the bottom of the wall and by the passive earth resistance against the front of the wall. Because these types of walls are founded at relatively shallow depths, the foundation soils on which the wall is constructed must be protected against undermining from erosive forces such as the adjacent river.

A tied-back sheetpiling structure would provide a relatively economical alternative which would reduce or eliminate some of the concerns of the crib wall alternative. This alternative consists of driving sheetpiling along the base of the slope, and using permanent earth tiebacks anchored in the soils behind the wall to resist the lateral earth pressure from the sloped backfill behind the wall (Figure 8, Appendix 1). In order to minimize or eliminate the effects on the fort at the top of the existing slope, a steep reinforced soil slope would be constructed behind the wall. Depending on the length of reinforcing members required in the backfill and the amount of disturbance desired at the top of the existing slope, a second tied-back wall may be required approximately half way up the slope.

The tied-back sheetpiling alternative would provide a barrier to prevent future erosion at the toe of the slope, and the resistance to lateral earth pressure would be provided by the permanent earth tiebacks. A potential concern for this alternative is whether or not the sheetpiling can successfully be driven in the soils which are present at the toe of the slope. Additional soil test borings will be required along the toe of the slope for actual design evaluations.

Tied-back soldier piles and lagging provide another alternative which reduces or eliminates the concerns of the crib wall. This alternative consists of driving soldier piles at regular spacings along the base of the slope. A wall would be formed by placing lagging between the soldier piles. This lagging could consist of either treated wood or precast concrete panels. Permanent earth tiebacks anchored in the soils behind the wall would be installed to resist the lateral earth pressure from the sloped backfill behind the wall as proposed for the sheetpiling alternative. In order to minimize or eliminate the effects on the fort at the top of the existing slope, a steep reinforced soil slope such as that discussed for the sheetpiling alternative would be constructed behind the wall. Depending on the length of reinforcing members required in the backfill and the amount of disturbance desired at the top of the existing slope, a second tied-back wall may be required approximately half way up the slope.

Along the riverbank, additional erosion protection would be required to prevent the undermining of soils below the lagging. This erosion protection could consist of either riprap or gabion baskets. A potential concern for this

alternative is whether or not the soldier piles could be driven or would have to be predrilled in the soils which are present at the toe of the slope. Additional soil test borings will be required along the toe of the slope for actual design evaluations.

6.4 Conclusions

Based on the available data, we believe that the most desirable solution for the erosion and slope failure problems at the Ft. Darling site is likely to consist of either a tied-back sheetpiling wall with a reinforced soil slope behind the wall or a tied-back soldier pile and lagging wall with a reinforced soil slope above the wall. Both of these alternatives would produce typical reconstructed slope profiles similar to the approximate profile presented in Figure 8 in Appendix 1, and the two wall systems could be bid as alternatives.

In order to complete detailed design evaluations, additional subsurface information will be required along the toe of the slope. This information will be necessary to determine the nature of the soils which will be penetrated by the proposed structures and will affect the overall stability of the reconstructed slope.

7.0 LIMITATIONS

This report has been prepared for the exclusive use of the National Park Service for specific application to the proposed slope stabilization and remediation at the Fort Darling/Drewrys Bluff National Battlefield Park. No other warranty, expressed or implied is made.

Our conclusions and preliminary recommendations are based on limited data obtained from the previously described subsurface exploration program, the geologic site reconnaissance, our preliminary geotechnical analysis and our previous experience. These conclusions and preliminary recommendations do not reflect variations in subsurface conditions which could exist between the boring locations or in unexplored areas of the site.

This report has been prepared for pre-design planning purposes related to the proposed slope stabilization project and is not intended to be used for final geotechnical design of structures or regraded slopes at this site. The preliminary recommendations presented in this report shall not be considered valid unless a final report is prepared by our firm and our conclusions and recommendations are verified in writing.

8.0 ACKNOWLEDGEMENTS

DRAFT

Virginia Geotechnical Service, P.C., appreciates the opportunity to be of service to you on this project. If there are any questions, or if we may be of further service, please feel free to contact our office at (804) 266-2199.

Sincerely,
VIRGINIA GEOTECHNICAL SERVICES, P.C.

Douglas D. R. Palmore, EIT
Engineer

Kenneth L. McCurdy, P.E.
Senior Project Manager

Ann M. Samford, P.E., P.G.
Principal

Attachment: Appendices

LIST OF APPENDICES

APPENDIX 1: ILLUSTRATIONS

Site Location Plan (Drawing No. 1)
Approximate Boring Location Plan (Drawing No. 2)
Regional Geologic Setting (Drawing No. 3)
Altitude of Top of Basement Surface (Drawing No. 4)
General Stratigraphic Column (Drawing No. 5)
Riprap and Flattened Slope Alternative (Drawing No. 6)
Reinforced Concrete Retaining Wall (Drawing No. 7)
Tied-back Structure with Reinforced Slope (Drawing No. 8)

APPENDIX 2: FIELD EXPLORATION PROGRAM

Boring Logs for Borings A, B-1 and C-2
Hollow-stem Auger Drilling and Sampling Method
Key to Boring Log Terminology
Key to ASTM Soil Classification Terminology

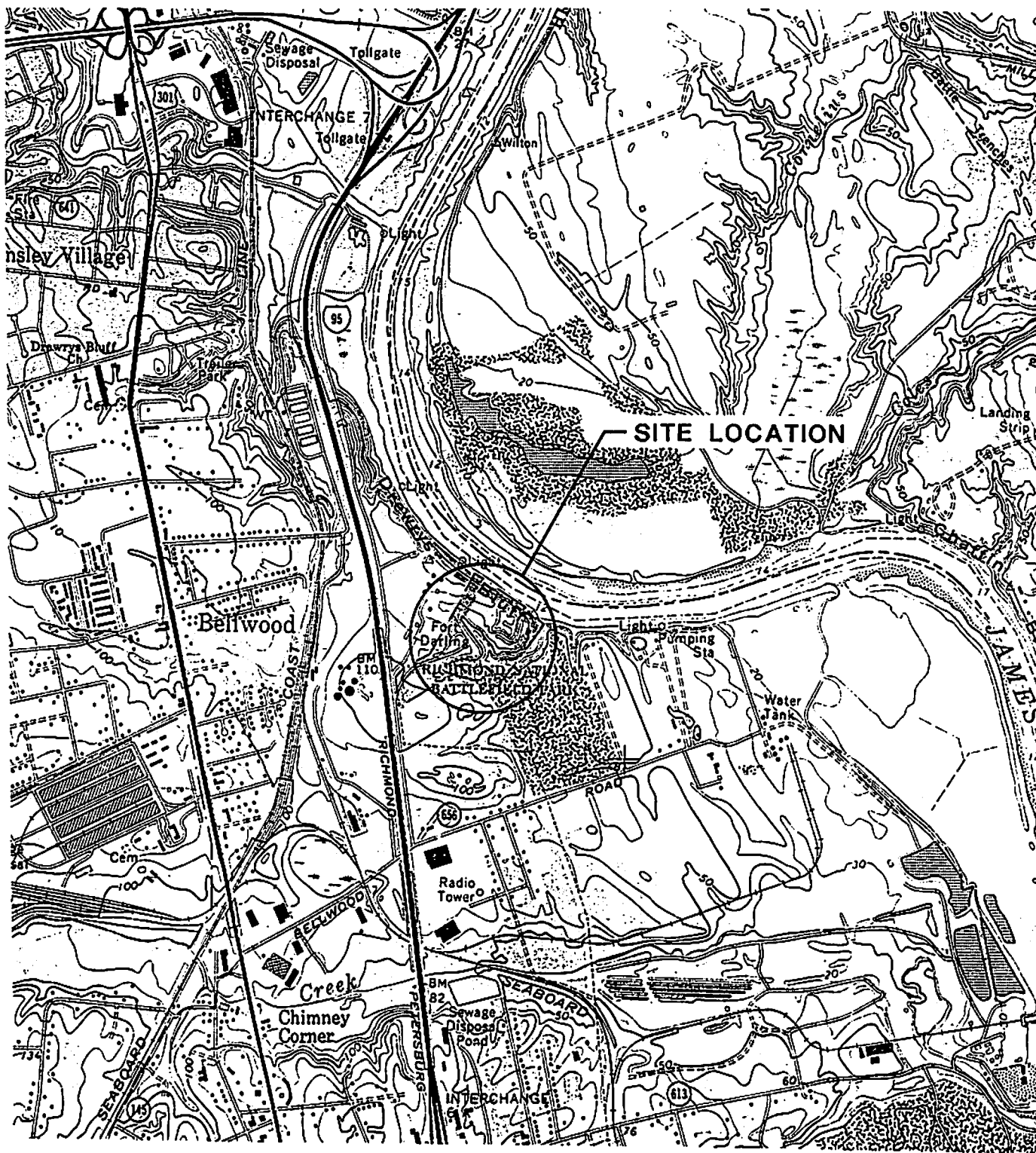
APPENDIX 3: LABORATORY TESTING PROGRAM

Summary of Laboratory Test Results

APPENDIX 4: PHOTOGRAPHS

Log of Photographs
Photographs (No. 1 through 7)

Appendix 1
ILLUSTRATIONS



GRAPHIC SCALE (FEET)

2000 0 2000

FROM:
U.S.G.S. 7.5 MIN. MAP OF THE
DREWRY'S BLUFF (1980) TOPOGRAPHIC
QUADRANGLES.



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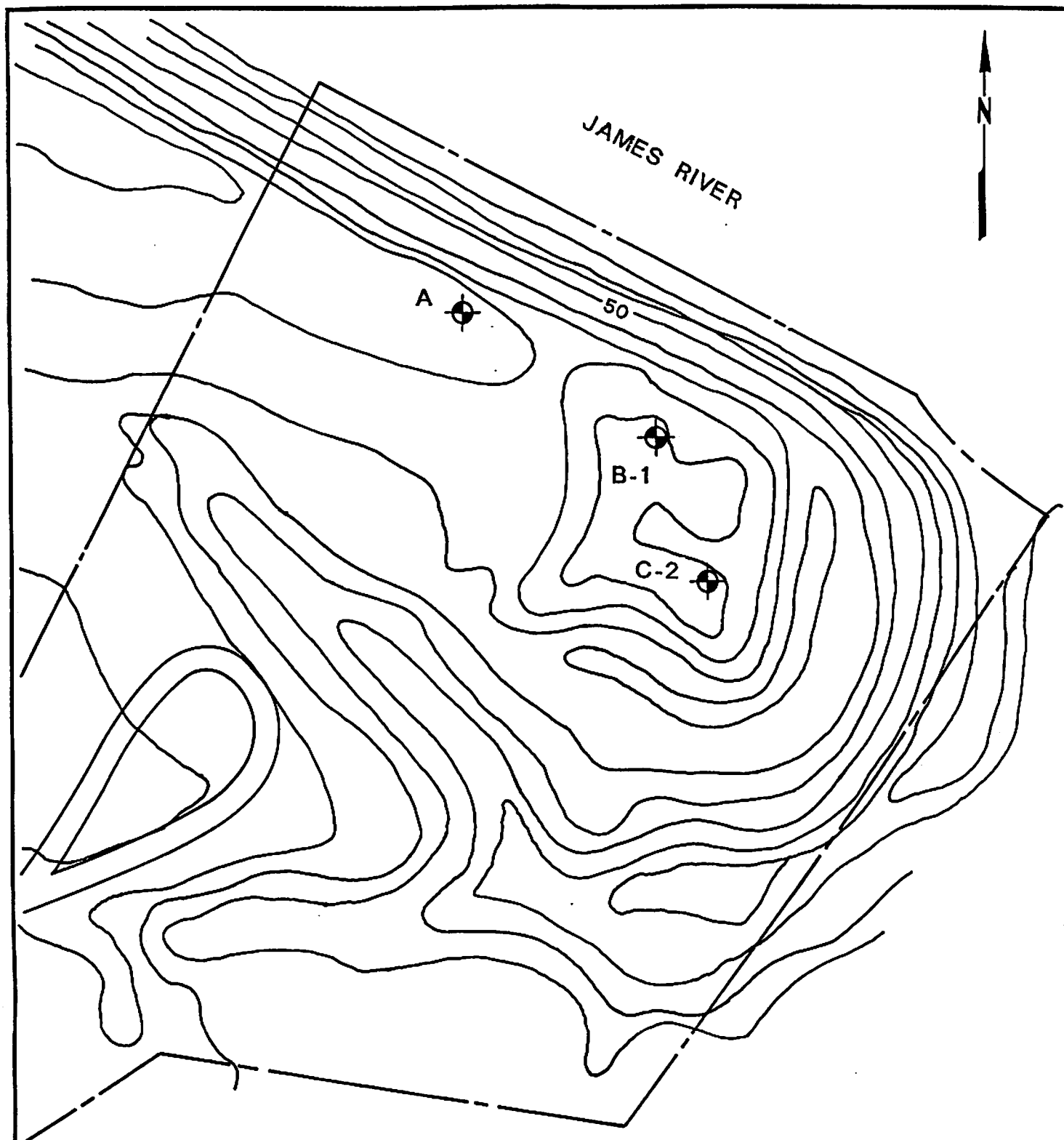
GT-625
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CHESTERFIELD COUNTY, VIRGINIA

SITE LOCATION PLAN

DRW. NO.

DRAFTER: NS SCALE: 1"=2000' DATE: MARCH 1992

1



LEGEND



SOIL TEST BORING LOCATIONS



VIRGINIA GEOTECHNICAL SERVICES, P.C.

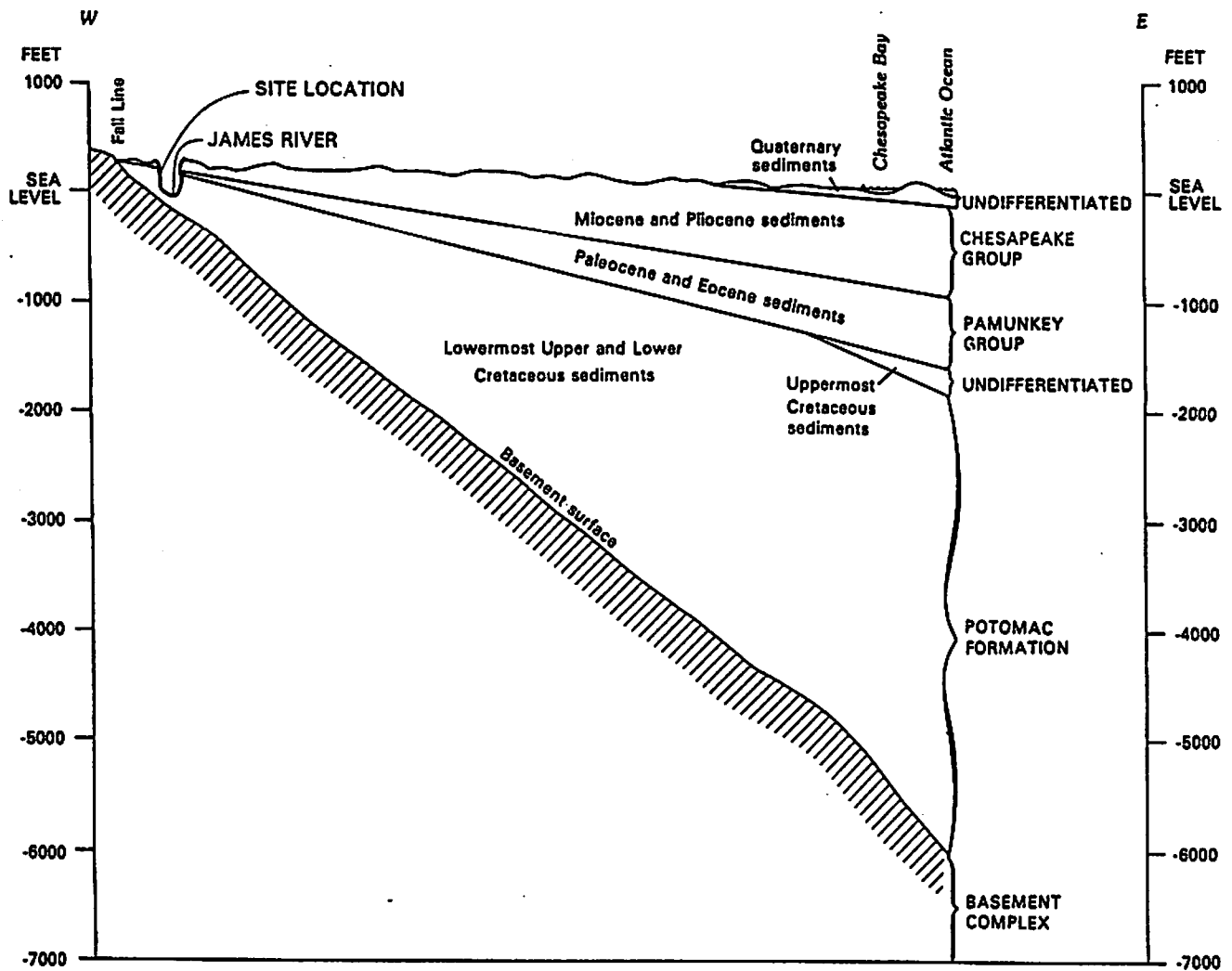
**GT-625
NATIONAL PARK SERVICE
CHESTERFIELD COUNTY, VIRGINIA**

APPROXIMATE BORING LOCATION PLAN

DRW. NO.

DRAFTER: NS SCALE: 1"=200' DATE: MARCH 1992

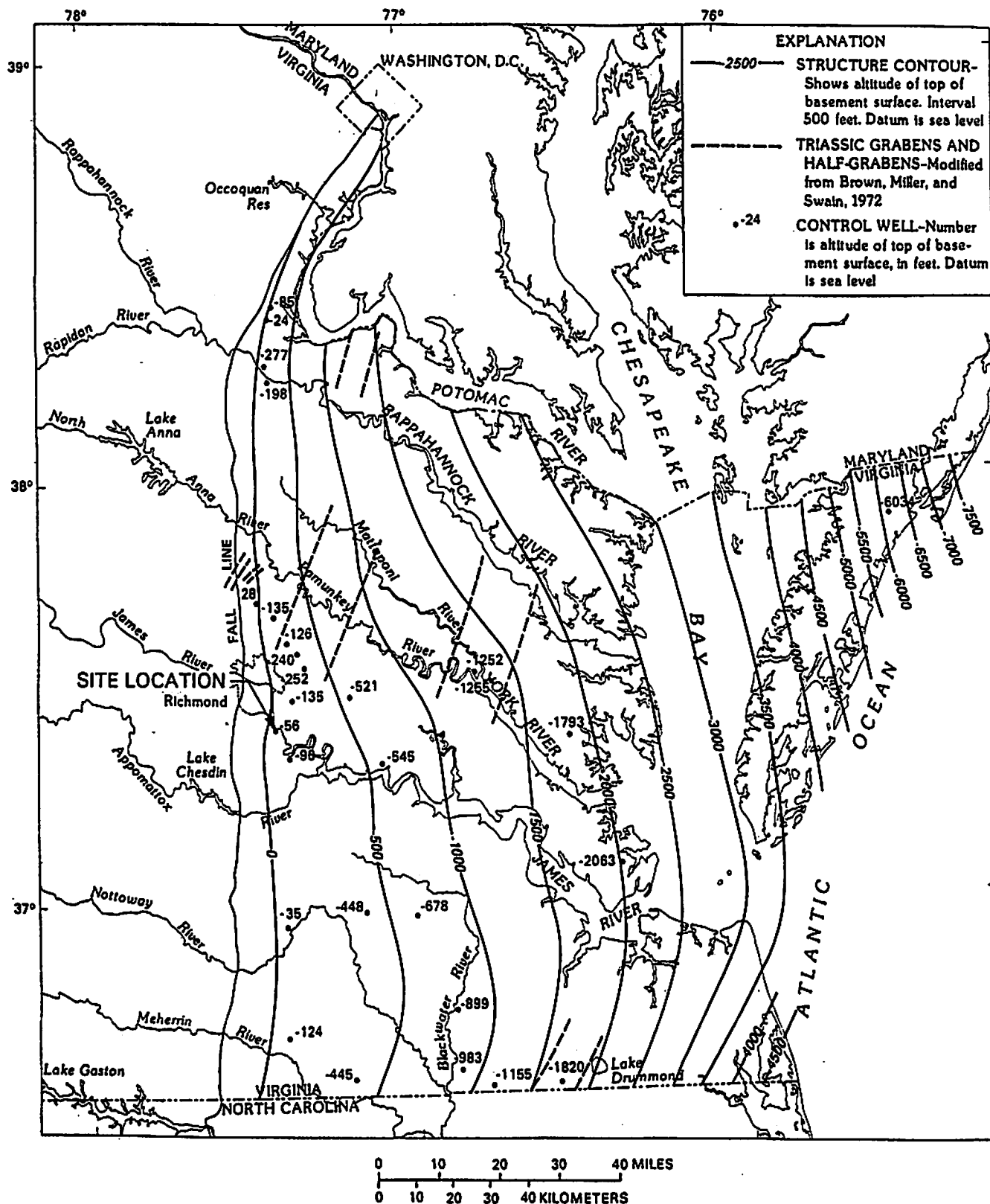
2



AFTER: MENG & HARCH, 1988

SCALE:
VERT: AS SHOWN
HORIZ: NONE

	VIRGINIA GEOTECHNICAL SERVICES, P.C.	
	GT-625 NATIONAL PARK SERVICE CHESTERFIELD COUNTY, VIRGINIA	
REGIONAL GEOLOGIC SETTING		DRW. NO.
DRAFTER: NS SCALE: AS NOTED DATE: MARCH 1992		3



AFTER: MENG & HARCH, 1988



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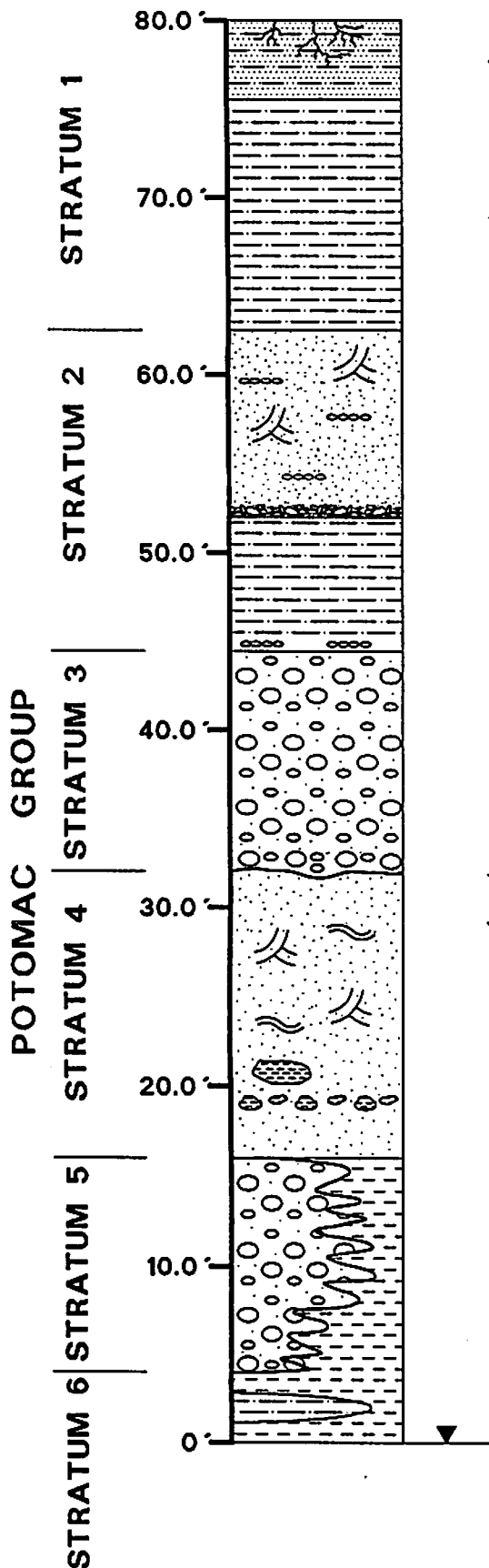
GT-625
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CHESTERFIELD COUNTY, VIRGINIA

ALTITUDE OF TOP OF BASEMENT SURFACE

DRW. NO.

DRAFTER: NS SCALE: AS NOTED DATE: MARCH 1992

4



- FILL FROM FORT STRUCTURES.
- REDDISH-BROWN CLAYEY FINE SAND.
- RED-BROWN AND YELLOW-BROWN FINING-UPWARDS LAYERS OF COBBLES, GRAVEL AND CLAYEY FINE SAND. GRAVEL MOSTLY ROUNDED, SAND MOSTLY QUARTZOSE. SOME BLACK HEAVY MINERALS ARE PRESENT. ABUNDANT TROUGH CROSS STRATA. THIN IRON OXIDE CEMENT LAYER AT BASE OF UNIT.
- GREENISH-GRAY FINE SAND WITH SILT, FINING UPWARDS TO FINE SANDY SILT. SOME SMALL, ROUNDED QUARTZ PEBBLES AT BASE. ABUNDANT ROCK FRAGMENTS AND FELDSPARS INCLUDED IN SAND.
- MASSIVE COBBLE LAYER, CLAST SUPPORTED, ABUNDANT ROCK FRAGMENT COBBLES, SOME QUARTZ ROUNDED CLASTS, SOME CLAY CLASTS. SANDY WELL-ROUNDED MATRIX. LAYER PINCHES OUT TOWARDS THE EAST.
- DISCONFORMITY
- WHITE AND YELLOW-BROWN LAMINATED AND TROUGH CROSS-STRATIFIED FINE-TO-MEDIUM CLAYEY SAND. PLANAR-LAMINATED WITH BLACK ORGANIC MATERIAL. SOME IRON OXIDE CEMENT PRESENT. DARK GRAY CLAY BOULDER AND COBBLE CLASTS.
- STRATA SHOWN BELOW 18' WERE OBSERVED AT DOWN STREAM PROPERTY CORNER AND MAY NOT BE LATERALLY CONTINUOUS.
- COBBLE LAYER SIMILAR TO THAT DESCRIBED ABOVE. OBSERVED AT EAST END OF SITE, MAY BE DISCONTINUOUS TO THE WEST.
- BLUE-GRAY TO MAROON FAT CLAY, BLOCKY WEATHERING, SANDY IN PART.



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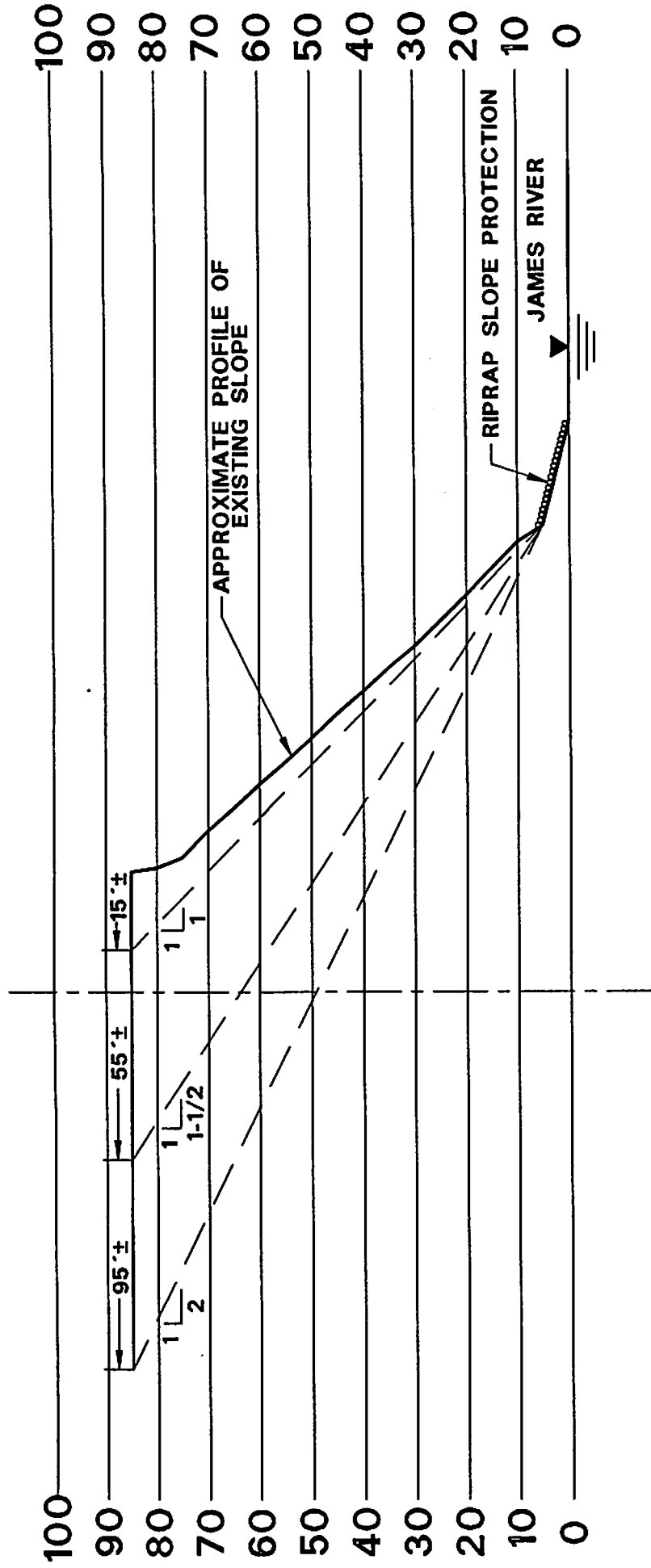
NATIONAL PARK SERVICE
CHESTERFIELD COUNTY, VIRGINIA

GENERAL STRATIGRAPHIC COLUMN

DRW. NO.

DRAFTER: NS SCALE: 1"=10' DATE: MARCH 1992

5



GRAPHIC SCALE (FEET)



LEGEND

— — — POTENTIAL PROFILES OF REGRADED SLOPES



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GT-625

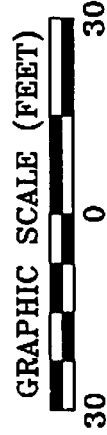
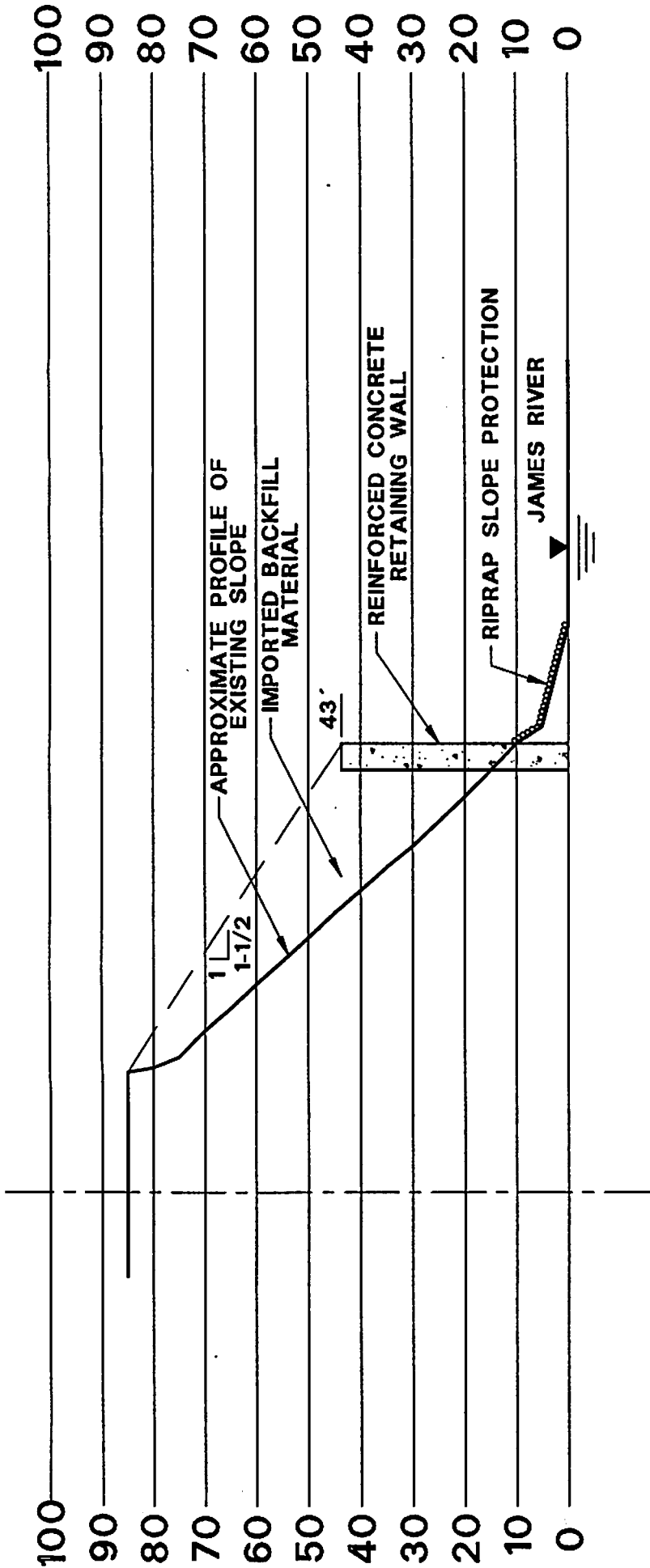
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CHESTERFIELD COUNTY, VIRGINIA

RIPRAP AND FLATTENED SLOPE
ALTERNATIVE

DRW. NO.

6

DRAFTER: NS SCALE: 1"=30' DATE: MARCH 1992



LEGEND

— — — POTENTIAL PROFILES OF REGRADED SLOPES



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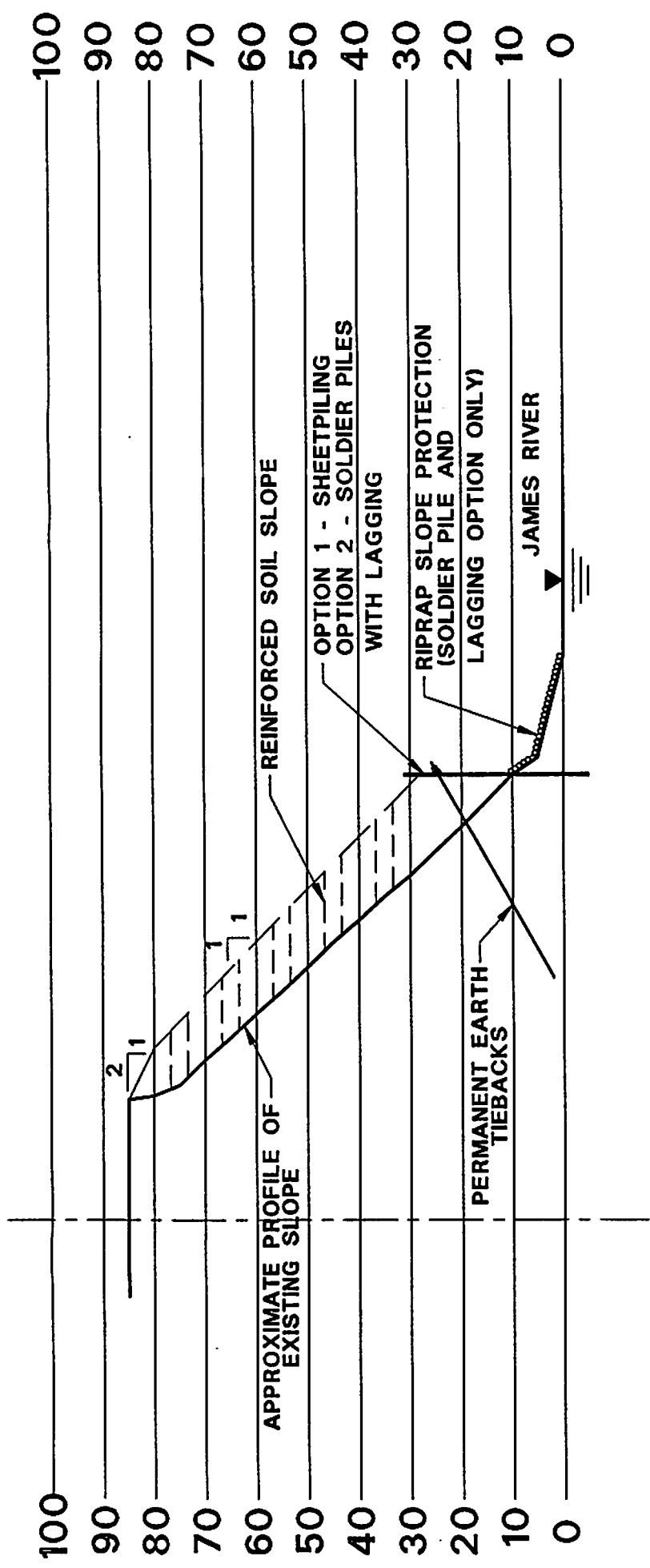
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CHESTERFIELD COUNTY, VIRGINIA

REINFORCED CONCRETE RETAINING WALL

DRW. NO.

7

DRAFTER: NS SCALE: 1"=30' DATE: MARCH 1992



LEGEND

— — — POTENTIAL PROFILES OF REGRADED SLOPES

		VIRGINIA GEOTECHNICAL SERVICES, P.C. GT-625 NATIONAL PARK SERVICE CHESTERFIELD COUNTY, VIRGINIA	
TIED-BACK STRUCTURE WITH REINFORCED SLOPE		DRW. NO. 8	
DRAFTER: NS		SCALE: 1"=30' DATE: MARCH 1992	

Appendix 2
FIELD EXPLORATION PROGRAM



VIRGINIA GEOTECHNICAL SERVICES, P.C.

8211 Hermitage Road ■ Richmond, Virginia 23228-3031 ■ (804) 266-2199

BORING LOG

BORING NO. A Page 1 of 4

PROJECT: Drewry's Bluff		INSPECTOR: Doug Palmore	
CLIENT: National Park Service		DRILLER: Dvorak Geotechnical Services	
LOCATION: See Attached Boring Location Plan		DRILLING METHOD: 2 1/4" ID Hollow Stem Auger	
JOB NO: GT-625		SURFACE ELEVATION: 84.43 ±	
DATE STARTED: 12-05-91		TOTAL DEPTH: 99.9 ft	
DATE COMPLETED: 12-06-91		DEPTH TO WATER: 57.5 ft	

ELEV	DEPTH	DESCRIPTION	BLOW COUNT	N VALUE	REMARKS
84.43	0.0				0.3' Organic matter.
83.93	0.5		3		
		Medium dense, grey-brown, fine clayey SAND, dry (SC).	7	14	STRATUM 1
			7		
					PP = 1.5 TSF
					PP = 4.5+ TSF
79.43	5.0	Hard, yellow-brown sandy lean CLAY, dry (CL).	21	83	
			40		
			43		
					PP = 4.5+ TSF
74.43	10.0		17	62	
			25		
			37		
72.43	12.0				
		Very dense, yellow-brown.			STRATUM 2
69.43	15.0	Silty SAND with gravel, dry (SM).	51	87	
			37		
			50		
64.43	20.0	More gravel.	19	73	
			40		
			33		
					Rough drilling from 21.0 to 23.0 ft.
59.43	25.0	Dense, yellow-brown, gray mottled silty SAND (SM).	14	34	
			17		
			17		

GT625-B-AP1

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BORING LOG

BORING NO. A Page 2 of 4

PROJECT: Drewry's Bluff
CLIENT: National Park Service
LOCATION: See Attached Boring Location Plan
JOB NO: GT-625
DATE STARTED: 12-05-91
DATE COMPLETED: 12-06-91

INSPECTOR: Doug Palmore
DRILLER: Dvorak Geotechnical Services
DRILLING METHOD: 2 1/4" ID Hollow Stem Auger
SURFACE ELEVATION: 84.43 ±
TOTAL DEPTH: 99.9 ft
DEPTH TO WATER: 57.5 ft

ELEV	DEPTH	DESCRIPTION	BLOW COUNT	N VALUE	REMARKS
59.43	25.0	Dense, yellow-brown, gray, mottled silty SAND (SM).			
			10		PP = 1.5 TSF
54.43	30.0	Becoming very fine graded.	14	31	
			17		STRATUM 3
					Rough drilling from 30.5 to 33.0 ft.
49.43	35.0	Becoming very gravelly.	9	35	White quartz gravel.
			17		Rough drilling from 36 to 38 ft.
			18		
44.43	40.0		14	91	
			29		Rough drilling from 40.5 to 43 ft.
			62		
39.43	45.0	Very dense gray, poorly graded SAND with clay, trace gravel, dry (SP-SC).	43	57/0.2"	*57/0.2'
			*		
34.43	50.0		35	85	
			35		
			50		

GT625-B-AP2

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BORING LOG

BORING NO. A Page 3 of 4

PROJECT: Drewry's Bluff CLIENT: National Park Service LOCATION: See Attached Boring Location Plan JOB NO: GT-625			INSPECTOR: Doug Palmore DRILLER: Dvorak Geotechnical Services DRILLING METHOD: 2 1/4" ID Hollow Stem Auger		
DATE STARTED: 12-05-91 DATE COMPLETED: 12-06-91			SURFACE ELEVATION: 84.43 ± TOTAL DEPTH: 99.9 ft DEPTH TO WATER: 57.5 ft		
ELEV	DEPTH	DESCRIPTION	BLOW COUNT	N VALUE	REMARKS
34.43	50.0				
29.43	55.0	Very dense, light gray, fine graded clayey SAND, dry (SC).	52 43 65	108	PP = 1.75 TSF
24.43	60.0	Becoming wet.	20 33 46	79	Water encountered at 57.5 ft during drilling. PP = 1.75 TSF
22.43	62.0				STRATUM 6
19.43	65.0	Very dense, blue-gray clayey SAND with gravel, damp (SC).	33 44 45	89	
14.43	70.0		49 *	100/0.5'	*51/0.0'
9.43	75.0	Very dense, yellow-brown, gray, mottled clayey SAND, damp (SC).	37 54 *	100/0.9'	Rock in nose of spoon. *46/0.4'

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BORING LOG

BORING NO. A Page 4 of 4

PROJECT: Drewry's Bluff
CLIENT: National Park Service
LOCATION: See Attached Boring Location Plan
JOB NO: GT-625

INSPECTOR: Doug Palmore
DRILLER: Dvorak Geotechnical Services
DRILLING METHOD: 2 1/4" ID Hollow Stem Auger

DATE STARTED: 12-05-91
DATE COMPLETED: 12-06-91

SURFACE ELEVATION: 84.43 ±
TOTAL DEPTH: 99.9 ft
DEPTH TO WATER: 57.5 ft

ELEV	DEPTH	DESCRIPTION	BLOW COUNT	N VALUE	REMARKS
9.43	75.0	Very dense, yellow-brown, gray, mottled clayey SAND, damp (SC).			
4.43	80.0	Becoming blue-gray with gravel.	46	54/0.2'	STRATUM 5
-0.57	85.0	More gravel, wet.	35	65/0.4'	*54/0.2'
-5.57	90.0		64	36/0.2'	*65/0.4'
-10.57	95.0		38	100/0.8'	*36/0.2'
-15.47	99.9	Boring terminated upon completion. Boring backfilled upon completion.	38	62/0.4'	*47/0.3'
					*62/0.4'
					Water level upon completion 85.0'. Cave depth 86.4'.

GT625-8-AP4

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BORING LOG

BORING NO. B-1 Page 1 of 4

PROJECT: Drewry's Bluff CLIENT: National Park Service LOCATION: See Attached Boring Location Plan JOB NO: GT-625			INSPECTOR: Doug Palmore DRILLER: Dvorak Geotechnical Services DRILLING METHOD: 2 1/4" ID Hollow Stem Auger		
DATE STARTED: 12-04-91 DATE COMPLETED: 12-05-91			SURFACE ELEVATION: 78.40 ± TOTAL DEPTH: 99.3 ft DEPTH TO WATER: 61.0 ft		
ELEV	DEPTH	DESCRIPTION	BLOW COUNT	N VALUE	REMARKS
78.40	0.0				Top 0.3' - organic.
77.90	0.5	Loose, brown, silty SAND (SM), dry.	3 4 4	8	STRATUM 1 PP = 1.60 TSF
73.40	5.0	Dense, yellow-brown, silty SAND with gravel (SM), dry.	15 24 24	48	STRATUM 2 PP = 3.25 TSF
68.40	10.0	More gravel.	20 23 18	41	
66.90	11.5				STRATUM 3 Rough drilling.
63.40	15.0		* 100/0.1'		*100/0.1' Sample refusal. (Bouncing spoon) Gravel in spoon. SEE NOTE
58.40	20.0	Very dense, yellow-brown, gray, mottled silty GRAVEL with sand (GM).	* 100/0.4'		Extremely rough drilling. *100/0.4'
53.40	25.0	Dense, yellow-brown, white stratified silty SAND (SM).	13 17 24	41	STRATUM 4 Stratified with trace iron oxide cement.

Note: Initial boring was terminated at 14.5' due to auger refusal. A second boring offset 4' was advanced to 14.0' where the sampling routine was continued.



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BORING LOG

BORING NO. B-1 Page 2 of 4

ELEV	DEPTH	DESCRIPTION	BLOW COUNT	N VALUE	REMARKS
53.40	25.0				
48.40	30.0	Dense, gray, yellow-brown, mottled silty SAND with gravel (SM).	12 15 17	32	
43.40	35.0	More stratified.	12 15 25	40	Stratified sand-silt-clay-sand...
38.40	40.0	Dense, light gray, silty SAND (SM).	11 13 18	31	PP = 1.25 TSF
33.40	45.0		13 18 20	38	
28.40	50.0	Color changing to yellow-brown, more gravel (coarse).	18 24 28	52	STRATUM 5 Rough drill (brief).

GT625-B1P2

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BORING LOG

BORING NO. B-1 Page 3 of 4

PROJECT: Drewry's Bluff CLIENT: National Park Service LOCATION: See Attached Boring Location Plan JOB NO: GT-625			INSPECTOR: Doug Palmore DRILLER: Dvorak Geotechnical Services DRILLING METHOD: 2 1/4" ID Hollow Stem Auger		
DATE STARTED: 12-04-91 DATE COMPLETED: 12-05-91			SURFACE ELEVATION: 78.40 ± TOTAL DEPTH: 99.3 ft DEPTH TO WATER: 61.0 ft		
ELEV	DEPTH	DESCRIPTION	BLOW COUNT	N VALUE	REMARKS
28.40	50.0				
					Rough drill (brief).
					White quartz gravel.
		Becoming very dense.	40	60/0.5'	*60/0.5'
23.40	55.0				
18.40	60.0		42 31	64	Spoon wet. Water level 61.0 ft.
			33		
16.40	62.0				
		Very dense, blue-gray clayey SAND with gravel (SC).			A very hard, dry, cement- like material was in nose of spoon.
13.40	65.0		31 27	61	
			34		
8.40	70.0	Sand becoming very coarse (fewer fines).	59	41/0.3'	*41/0.3'
3.40	75.0	Clay content increasing, sand well- graded.	36 51	400/0.7'	*49/0.2'

GT625-B1P3

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BORING LOG

BORING NO. B-1 Page 4 of 4

PROJECT: Drewry's Bluff CLIENT: National Park Service LOCATION: See Attached Boring Location Plan JOB NO: GT-625			INSPECTOR: Doug Palmore DRILLER: Dvorak Geotechnical Services DRILLING METHOD: 2 1/4" ID Hollow Stem Auger		
DATE STARTED: 12-04-91 DATE COMPLETED: 12-05-91			SURFACE ELEVATION: 78.40 ± TOTAL DEPTH: 99.3 ft DEPTH TO WATER: 61.0 ft		
ELEV	DEPTH	DESCRIPTION	BLOW COUNT	N VALUE	REMARKS
3.40	75.0	Very dense, blue-gray, clayey SAND with gravel (SC).			
					STRATUM 6
-1.60	80.0		33 42 64	106	
-6.60	85.0	Hard, blue-gray, sandy lean CLAY (CL), dry.	32 *	68/0.5'	*68/0.5' PP = 4.5 + TSF
					Soil very stratified and varied throughout; sand-silt-clay etc.
-11.60	90.0	Very dense, blue-gray, silty SAND (SM), dry.	21 28 37	65	Extremely dense, hard to remove from spoon.
-16.60	95.0	Increasing amount of sand.	* *	100/0.3'	*100/0.3'
-20.9	99.3	Boring terminated at 99.3 ft. Backfilled with cuttings upon completion.	* *	100/0.3'	*100/0.3' Water level immediately after boring - 64.7'. 45 min. later 61.0'. Cave depth 65.3'.



VIRGINIA GEOTECHNICAL SERVICES, P.C.

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BORING LOG

BORING NO. C-2 Page 1 of 4

PROJECT: Drewry's Bluff
CLIENT: National Park Service
LOCATION: See Attached Boring Location Plan
JOB NO: GT-625

INSPECTOR: Doug Palmore
DRILLER: Dvorak Geotechnical Services
DRILLING METHOD: 2 1/4" ID Hollow Stem Auger

DATE STARTED: 12-03-91
DATE COMPLETED: 12-04-91

SURFACE ELEVATION: 76.77 ±
TOTAL DEPTH: 100.3 ft
DEPTH TO WATER: 61.5 ft

ELEV	DEPTH	DESCRIPTION	BLOW COUNT	N VALUE	REMARKS
76.77	0.0				Top 0.3' organic matter.
76.27	0.5		2		
		Stiff yellow-brown fat CLAY, damp (CH).	4	9	STRATUM 1
			5		PP = 2.50 TSF.
					PP = 1.25 TSF.
71.77	5.0		8	27	
			11		
			16		
69.71	7.0				
					PP = 0.0 TSF.
66.77	10.0	Medium dense, yellow-brown silty SAND, damp (SH).	3	14	
			5		
			9		
					STRATUM 4
					Rough drilling from 11.0 ft to 12.5 ft (gravel).
					PP = 0 TSF.
					White quartz gravel.
61.77	15.0	Very dense, yellow-brown, gray mottled silty SAND with gravel (SH).	17	53	
			25		
			28		
					PP = 1.75 TSF.
					6.0" recovery.
56.77	20.0	Very dense, yellow-brown, gray mottled silty SAND with gravel (SH).	23	43	
			20		
			23		
51.77	25.0	More gravel.	12	33	
			15		
			18		

GT625-B-C2P1

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BORING LOG

BORING NO. C-2 Page 2 of 4

PROJECT: Drewry's Bluff
CLIENT: National Park Service
LOCATION: See Attached Boring Location Plan
JOB NO: GT-625

INSPECTOR: Doug Palmore
DRILLER: Dvorak Geotechnical Services
DRILLING METHOD: 2 1/4" ID Hollow Stem Auger

DATE STARTED: 12-03-91
DATE COMPLETED: 12-04-91

SURFACE ELEVATION: 76.77 ±
TOTAL DEPTH: 100.3 ft
DEPTH TO WATER: 61.5 ft

ELEV	DEPTH	DESCRIPTION	BLOW COUNT	N VALUE	REMARKS
51.77	25.0				
46.77	30.0	Dense, yellow-brown, white, mottled clayey SAND with gravel (SC).	13 19 20	39	PP = 0.0 TSF
41.77	35.0	More white, gray than yellow-brown.	11 16 18	34	Sample very difficult to remove from spoon.
36.77	40.0		14 17 21	38	
31.77	45.0	Dense, gray, yellow-brown, mottled SAND with silty gravel (SM).	15 18 22	40	Trace iron oxide cement. White quartz gravel. Rough drill (gravel).
26.77	50.0		40 33 33	66	Stratified Sample



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BORING LOG

BORING NO. C-2 Page 3 of 4

PROJECT: Drewry's Bluff
 CLIENT: National Park Service
 LOCATION: See Attached Boring Location Plan
 JOB NO: GT-625
 DATE STARTED: 12-03-91
 DATE COMPLETED: 12-04-91

INSPECTOR: Doug Palmore
 DRILLER: Dvorak Geotechnical Services
 DRILLING METHOD: 2 1/4" ID Hollow Stem Auger
 SURFACE ELEVATION: 76.77 ±
 TOTAL DEPTH: 100.3 ft
 DEPTH TO WATER: 61.5 ft

ELEV	DEPTH	DESCRIPTION	BLOW COUNT	N VALUE	REMARKS
26.77	50.0	Dense, gray, yellow-brown mottled SAND with gravel (SM).	40 33 33	66	Trace iron oxide cement. Stratified.
21.77	55.0	Very dense, yellow-brown, gray mottled silty SAND with gravel (SM).	14 24 28	52	No iron oxide cement.
16.77	60.0		8 18	39	Spoon wet.
16.27	60.5	Very dense, gray-blue silty SAND with gravel, damp (SM).	21		STRATUM 5
11.77	65.0	Same with more gravel.	23 44 60	104	Water in spoon. White quartz gravel.
6.77	70.0		46 *	54/0.5'	*54/0.5'
1.77	75.0	Less gravel.	35 *	65/0.4'	*65/0.4' PP = 3.5 TSF

GT625-B-C2P3

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BORING LOG

BORING NO. C-2 Page 4 of 4

PROJECT: Drewry's Bluff CLIENT: National Park Service LOCATION: See Attached Boring Location Plan JOB NO: GT-625			INSPECTOR: Doug Palmore DRILLER: Dvorak Geotechnical Services DRILLING METHOD: 2 1/4" ID Hollow Stem Auger		
DATE STARTED: 12-03-91 DATE COMPLETED: 12-04-91			SURFACE ELEVATION: 76.77 ± TOTAL DEPTH: 100.3 ft DEPTH TO WATER: 61.5 ft		
ELEV	DEPTH	DESCRIPTION	BLOW COUNT	N VALUE	REMARKS
1.77	75.0				
					STRATUM 6
-3.23	80.0	Hard, blue-gray, lean CLAY with sand (CL).	12 19 60	79	PP = 4.5 + TSF Sample refusal in last 0.05'-bouncing spoon.
-8.23	85.0		27 32 44	76	PP = 4.5 + TSF Material very difficult to remove from spoon.
-13.23	90.0	Hard, blue, gray, fat CLAY with sand (CH), dry.	33 57	100+	Thin iron stained layers.
-18.23	95.0	Very dense, blue-gray, clayey SAND with gravel (SC).	34 *	100+	*66/0.3'
-23.23 -23.26	100 100.3	Hard, blue-gray, fat CLAY with sand (CH). Boring terminated at 100.3 ft. Backfilled with cuttings upon completion.	30 38 *	138/0/8'	*100/0.3' Sample refusal. Water level upon completion 93.5'. Cave depth 58.0'. Dry.



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HOLLOW STEM AUGER DRILLING AND SAMPLING METHOD

Hollow stem augers with a solid center plug are rotated into the soil. At a specified interval the center plug is removed and a standard split barrel sampling spoon is attached to the drill rods and lowered through the hollow stem augers to bear on the soil below. A 140 pound weight is repetitively allowed to free fall 30 inches to drive the sampling spoon. The number of blows (blow count) required to drive the sampling spoon is recorded for three successive 6-inch increments. This is the Standard Penetration Test. The Standard Penetration Test N-value is the sum of the blow counts for the last two 6-inch increments. If the blow count for any 6-inch increment exceeds 50 blows, the test may be terminated as "sampler refusal." The N-value is used as an indication of the consistency of fine grained soils (eg. soft, stiff, hard) or as an indication of relative density of coarse grained soils (eg. loose, dense, very dense).

SOIL CONTACTS

Contacts between soil types are shown on the boring logs. Sometimes these contacts are observed in soil samples and therefore their location is reasonably well known. At other times the contacts may be gradational or may occur between soil samples. The location of these soil contacts is then approximated or inferred. Therefore, it is appropriate to assume that the contacts shown on the boring logs are approximate. Contacts shown with solid lines on the boring logs are major contacts between soil strata while the contacts shown with dashed lines indicate variations within a single stratum.

SAMPLE DISPOSITION

All soil samples collected during the field exploration program and not used in laboratory testing will be stored for sixty (60) days after report date and then discarded unless other arrangements are completed.



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KEY TO BORING LOG TERMINOLOGY

Boring Log Soil Description Format:

Consistency (Density), Color, Major Modifier PRIMARY CONSTITUENT, minor modifiers or further descriptors, moisture content. (GROUP SYMBOL)

RELATIVE DENSITY - Used for <50% finer than #200 sieve.

Relative Density	N-Value
Very Loose	0 - 4
Loose	5 - 10
Medium Dense	11 - 30
Dense	31 - 50
Very Dense	50+

CONSISTENCY - Used for >50% finer than a #200 sieve

Consistency	N-Value
Very Soft	0 - 1
Soft	2 - 4
Medium Stiff	5 - 8
Stiff	9 - 15
Very Stiff	16 - 30
Hard	30+

GRAIN SIZE TERMINOLOGY - U.S. Standard Sieves

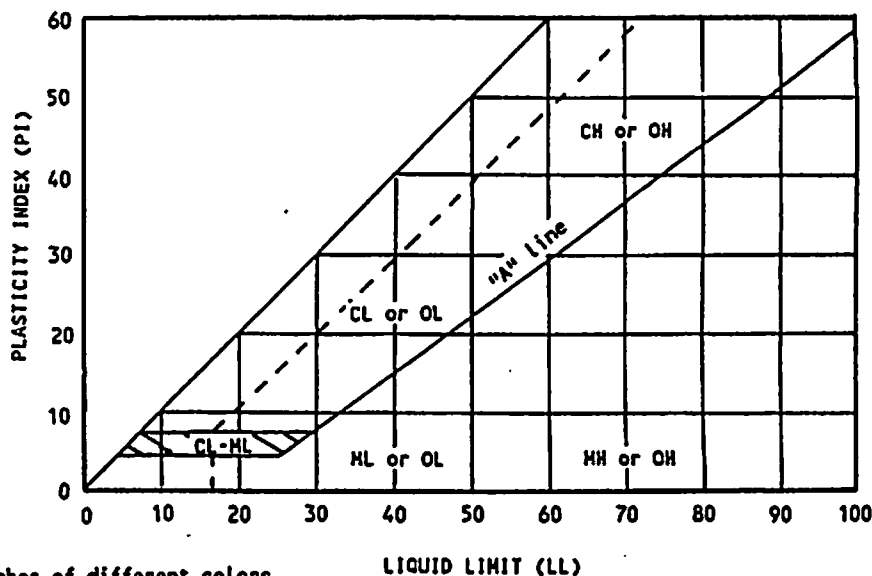
Term	Particle Size
Boulder	>12 inches
Cobble	3 - 12 inches
Coarse Gravel	3/4 - 3 inches
Fine Gravel	#4 - 3/4 inches
Coarse Sand	#10 - #4
Medium Sand	#40 - #10
Fine Sand	#200 - #40
Silt and Clay	<#200

COLOR - May use light and dark as modifiers.

White	Yellow-Brown
Gray	Red-Brown
Black	Gray-Brown
Brown	Green-Gray
Blue	Blue-Gray

mottled - irregularly marked with spots or patches of different colors.

PLASTICITY CHART - Used for material <#40 sieve.



NATURAL MOISTURE CONTENT

Dry	No apparent moisture
Damp	Contains apparent moisture
Moist	Contains significant apparent moisture
Wet	Appears saturated; contains free water

DESCRIPTIVE TERMS

trace	0 - 10%
little	11 - 25%
some	26 - 45%
mostly	46 - 100%

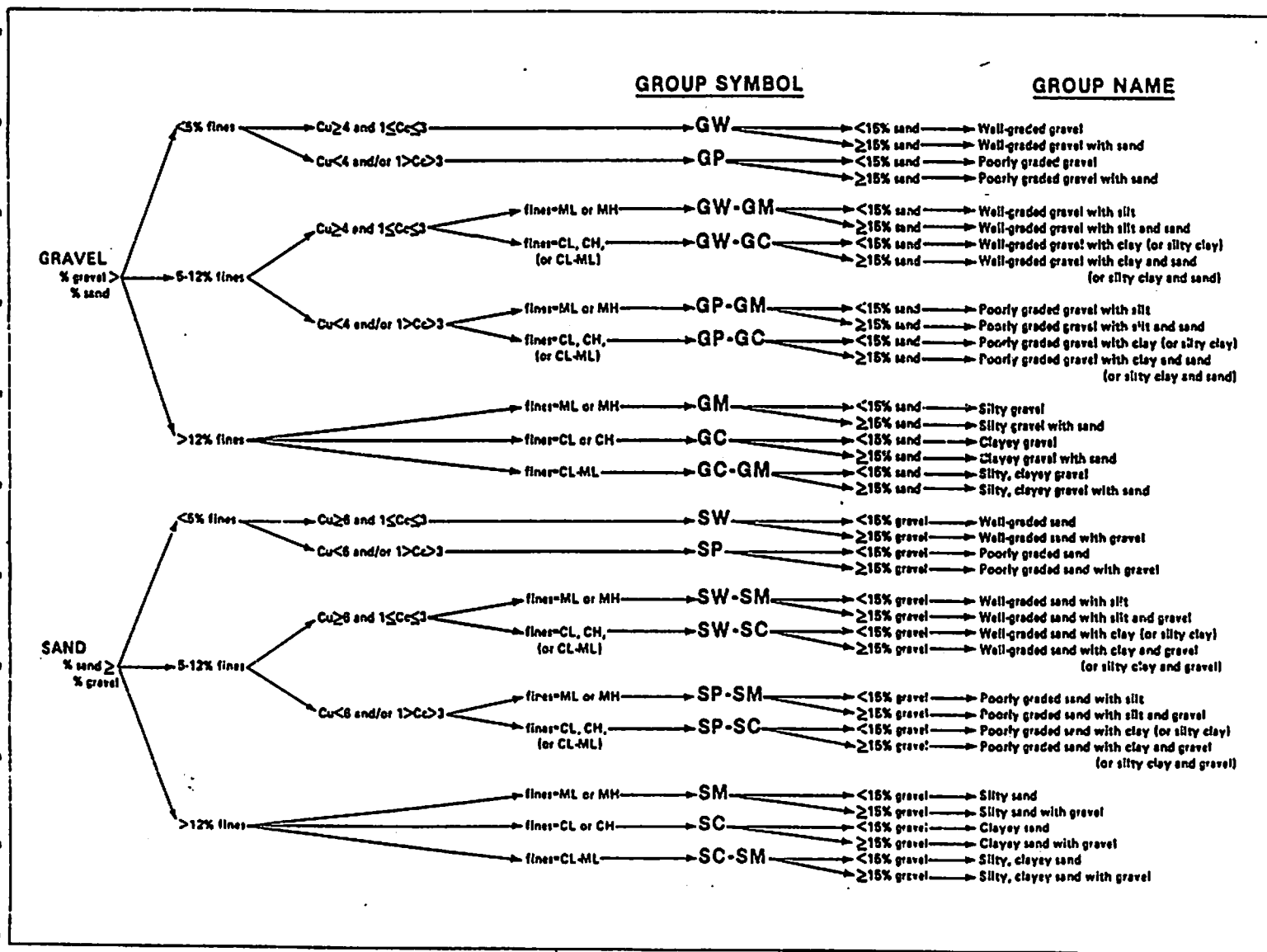


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Key to ASTM Soil Classification System*

FIG. 1 Flow Chart for Classifying Coarse-Grained Soils (More Than 50 % Retained on No. 200 Sieve)



* (ASTM D2487)

FIG. 2a Flow Chart for Classifying Fine-Grained Soil (50 % or More Passes No. 200 Sieve)

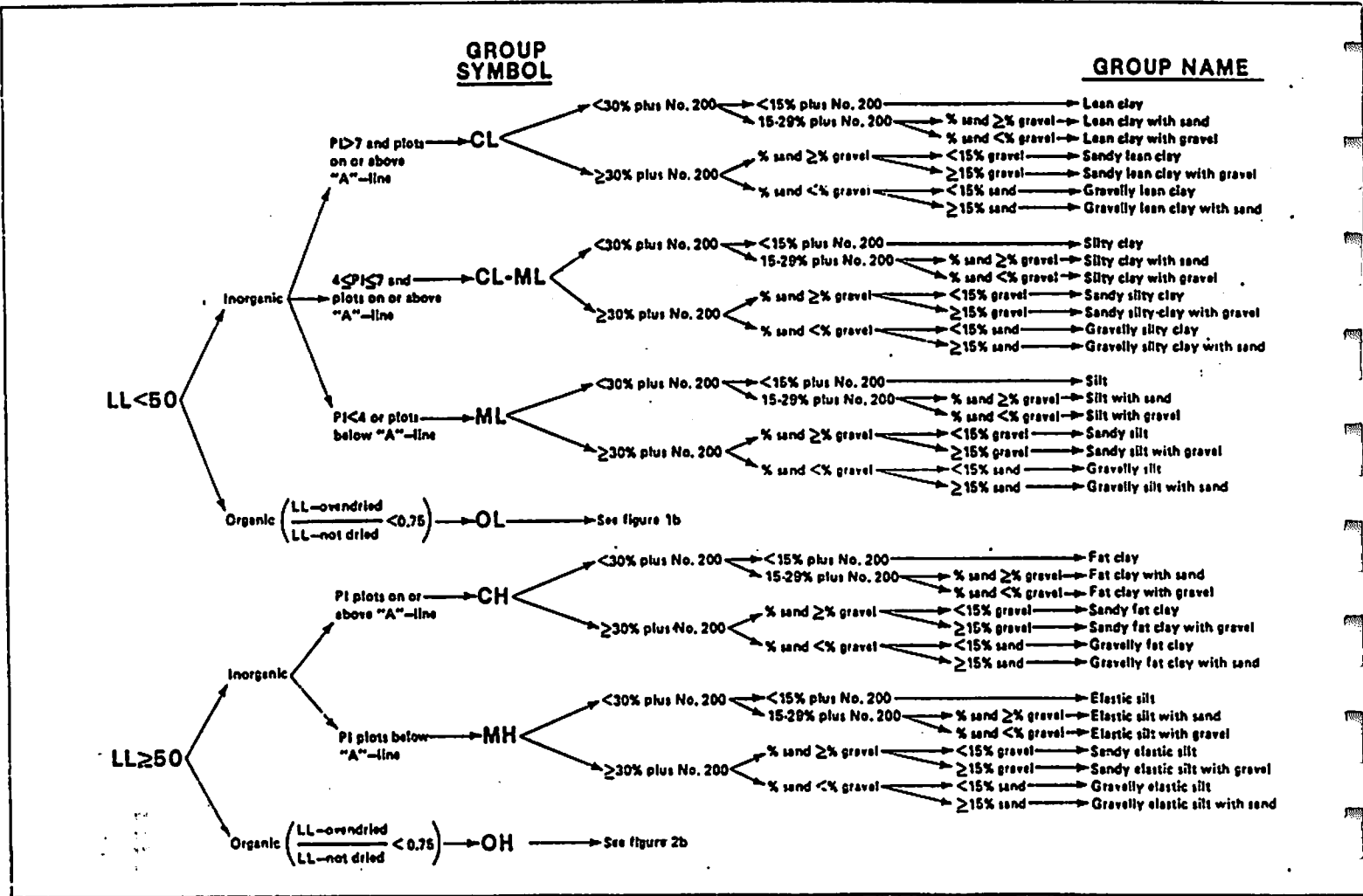
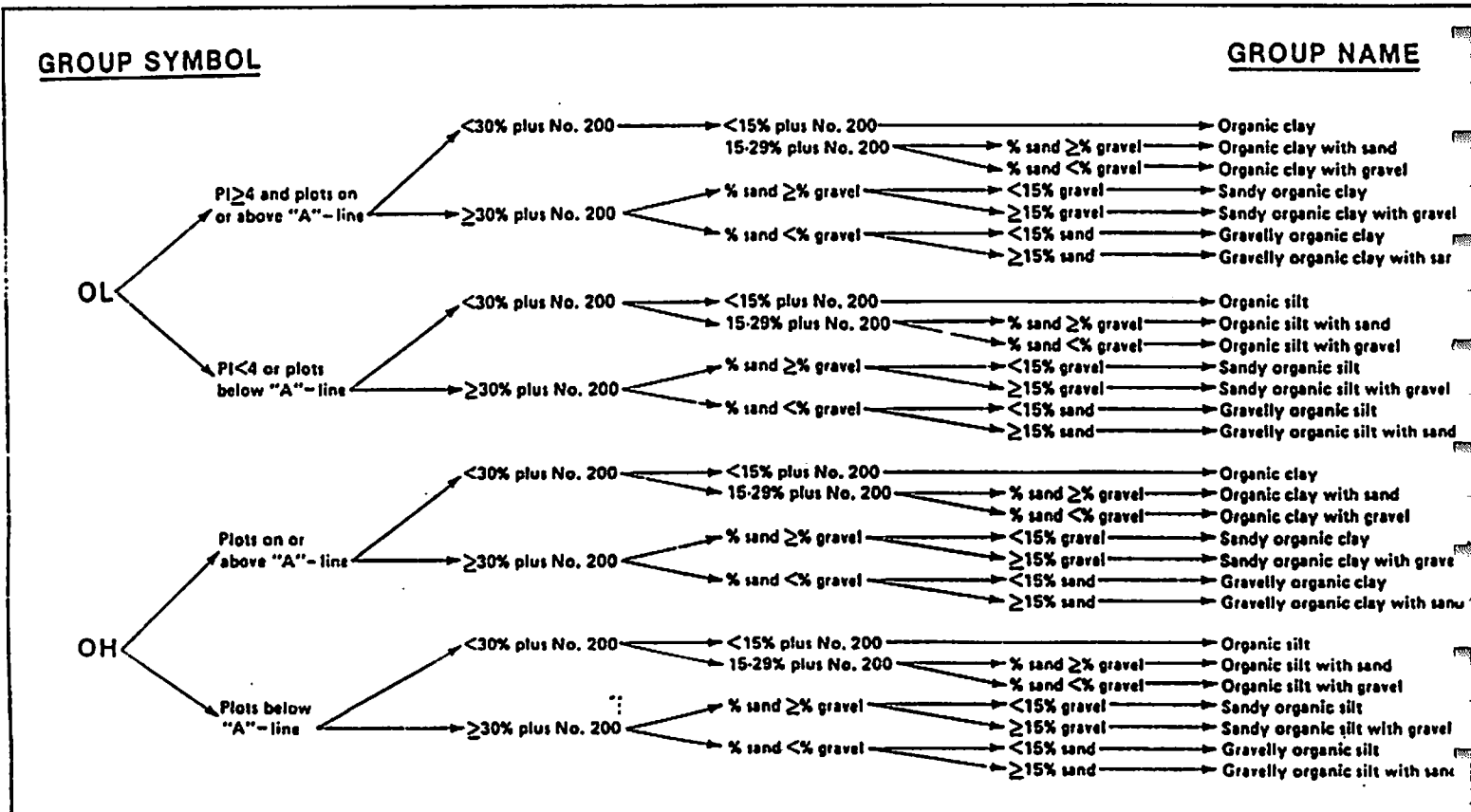


FIG. 2b Flow Chart for Classifying Organic Fine-Grained Soil (50 % or More Passes No. 200 Sieve)



Appendix 3
LABORATORY TESTING PROGRAM



VIRGINIA GEOTECHNICAL SERVICES, P.C.

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SUMMARY OF LABORATORY TEST RESULTS

FORT DARLING NATIONAL BATTLEFIELD PARK GT-625

Location:	A	A	A
Depth:	9.0-10.5	69.0-69.5	94.0-95.5
Lab Sample No:	1985	1987	1986
STRATUM:	1	6	5
<u>Natural Moisture (%)</u> :	14.6	16.8	14.7
<u>Atterberg Limits</u>			
Liquid Limit:	42	66	45
Plastic Limit:	25	27	19
Plasticity Index:	17	39	26
<u>Gradation Analysis</u>			
% Finer than 3/8 in	100	89.8	100
No. 4	100	85.6	99.2
No. 10	99.9	79.1	88.2
No. 40	96.1	50.0	33.9
No. 100	73.8	40.5	17.1
No. 200	62.8	34.2	12.1
<u>ASTM Soil Classification</u>			
Group Symbol:	CL	SC	SC



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SUMMARY OF LABORATORY TEST RESULTS

FORT DARLING NATIONAL BATTLEFIELD PARK GT-625

Location:	B1	B1	C2	C2
Depth (ft):	39.0-40.5	89.0-90.5	19.0-20.5	54.0-55.5
Lab Sample No:	1982	1981	1983	1984
STRATUM:	4	6	4	4
<u>Natural Moisture (%)</u> :	17.3	27.7	15.1	12.8
<u>Atterberg Limits</u>				
Liquid Limit:	45	61	54	65
Plastic Limit:	29	40	34	37
Plasticity Index:	16	21	20	28
<u>Gradation Analysis</u>				
% Finer than 3/8 in	100	100	100	88.6
No. 4	100	99.6	99.5	83.8
No. 10	99.9	98.4	98.9	73.1
No. 40	82.5	80.3	60.1	35.0
No. 100	34.1	50.9	31.5	23.6
No. 200	26.5	37.1	24.3	20.4
<u>ASTM Soil Classification</u>				
Group Symbol:	SM	SM	SM	SM

Appendix 4
PHOTOGRAPHS

LOG OF PHOTOGRAPHS

PHOTOGRAPH NO 1

Large coalescing slump feature at the top of Drewry's Bluff near the upstream corner of Fort Darling. Sediments shown are STRATUM 1.

PHOTOGRAPH NO 2

Composite photograph showing active slump at the top of Drewry's Bluff. STRATA 1, 2, and 3 are visible in the right photograph. Talus slope of eroded and slumped material is visible below STRATUM 3.

PHOTOGRAPH NO 3

Detail of the upper portion of STRATUM 2.

PHOTOGRAPH NO 4

The lower portion of STRATUM 2 is visible at the upper left. The fining upwards cobble/gravel layer is STRATUM 3. The laminated organic layers and an underlying massive portion of STRATUM 4 is shown beneath the cobbles. Note the talus slope covering a portion of STRATUM 4.

PHOTOGRAPH NO 5

Photograph 5 shows an overhanging root mat at the top of Drewry's Bluff. The lower portion of STRATUM 2, STRATUM 3, and STRATUM 4 are shown. Well developed cross stratification is visible in STRATUM 4. Note Steep vertical profile of STRATA 3 and 4. Talus slope morphology is shown well in this picture.

PHOTOGRAPH NO 6

Detail of the Stratum 3/STRATUM 4 contact. Note truncation of cross stratification in STRATUM 4.

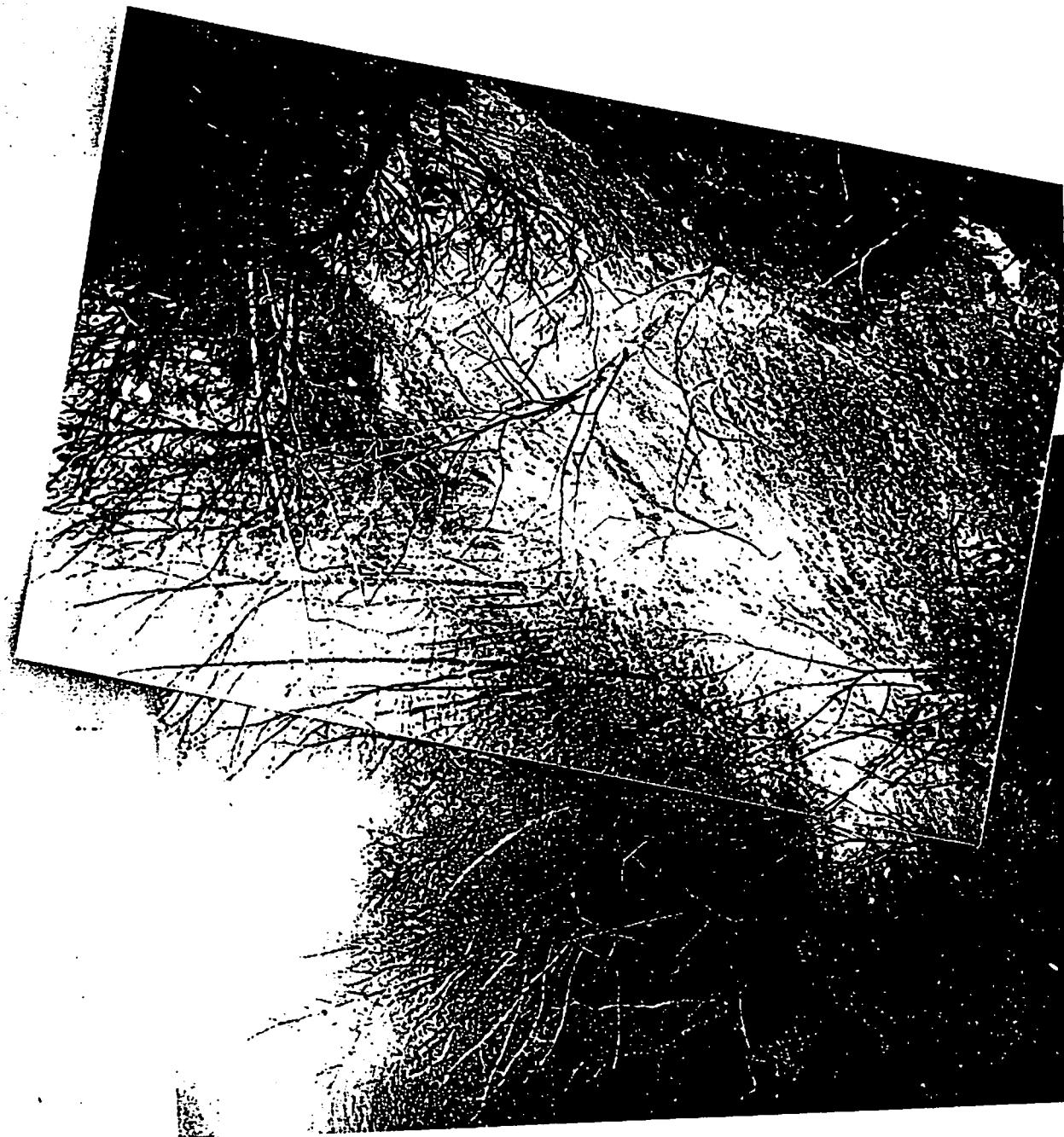
PHOTOGRAPH NO 7

Trowel is located in large "clay boulder" within STRATUM 4. Laminated organic horizons of STRATUM 4 are also shown.



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PHOTOGRAPH NO 2

Composite photograph showing active slump at the top of Drewry's Bluff. STRATA 1, 2, and 3 are visible in the right photograph. Talus slope of eroded and slumped material is visible below STRATUM 3.



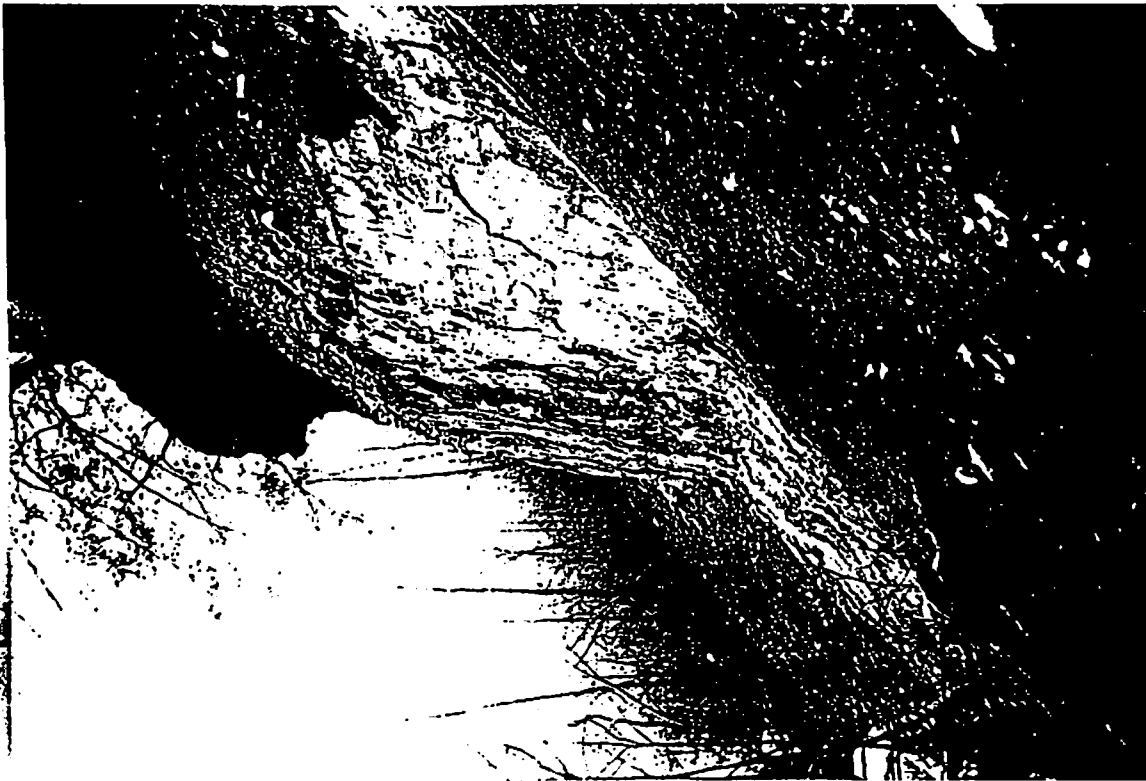
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Detail of the upper portion of STRATUM 2.



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Trowel is located in large "clay boulder" within STRATUM 4. Laminated organic horizons of STRATUM 4 are also shown.