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COASTAL ZONE
INFORMATION CENTER
JUN 14 1977

SHORE EROSION STUDY

TECHNICAL REPORT

APPENDIX 3

SHORELINE EROSION AND BLUFF STABILITY ALONG LAKE MICHIGAN
AND LAKE SUPERIOR SHORELINES OF WISCONSIN

MILWAUKEE COUNTY

D. M. Mickelson

R. Klauk

L. Acomb

T. Edil

B. Haas

FEBRUARY 1977

GB
459.5
.M5
S5
appendix 3

WISCONSIN

COASTAL MANAGEMENT

Wisconsin Coastal Zone Management Program.

This report has been prepared through the cooperative efforts of the Wisconsin Geological and Natural History Survey, the University of Wisconsin (Madison, Milwaukee, Parkside and Extension), the Wisconsin Department of Natural Resources and the Office of State Planning and Energy. Assistance was further provided by Owen-Ayres and Associates.

This report is being reproduced quickly and in a limited quantity for dissemination to local governments and interested parties. The report will be broadly available when reproduced in the fall of 1977 as an information circular from the Wisconsin Geological and Natural History Survey.

Financial assistance for this study has been provided by the Coastal Zone Management Act of 1972 administered by the federal Office of Coastal Zone Management, National Oceanic and Atmospheric Administration.

10673

COASTAL ZONE INFORMATION CENTER

SHORE EROSION STUDY
TECHNICAL REPORT

Appendix 3

Milwaukee County
Wisconsin

D. M. Mickelson, R. Klauk, L. Acomb
(Geology)

T. Edil, B. Haas
(Geotechnical Study)

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INTRODUCTION

This Appendix provides detailed information on shoreline conditions within much of the county. The order of materials in the Appendix is from south to north. Parts of the shoreline are broken down by reach (see County Map) and geographic section within each reach. There is a text which describes the characteristics of shoreline conditions at the beginning of each reach section. This is accompanied by a map of the whole reach which shows the sections, public perception of erosion hazards, shore damage in 1952, short- and long-term recession rates, bluff height, shore protection structures, houses per mile, and boat ramps.

Location of geotechnical borings is indicated on the county map at the beginning of the Appendix. Logs for geotechnical holes and detailed location maps are given at the end of all of the maps in the reach containing that geotechnical site. For each geographic section (one mile long) a map showing the location of shore protection structures which are numbered and described in reports on file with the Department of Natural Resources. Also on the map, locations of measured profiles are shown along the shoreline. A running description of bluff characteristics, materials making up the toe of the slope, and beach characteristics is also given. Engineering data such as safety factor, the confidence level on this safety factor, and the distance the slope must retreat to attain a stable slope angle is also given. It should be noted that this distance assumes no wave cutting at the base of the bluff. This distance is referred to in the text as a stable slope distance. Also included with each section is a set of profiles from the water's edge to the bluff top. These profiles show stratigraphy, slope angles, circles of failure, and calculated safety factors along the shoreline. The dis-

tance to a 5 foot depth of water is also given. The date when the profile was measured is also given. Remember that the bluff profile could have changed since the profiles were measured.

The meaning of abbreviations used in the Appendix is given on this page. For more detailed description of the methods used in compiling the data, regional interpretations, and conclusions about the engineering characteristics and types of slope failure taking place refer to the main report (Shoreline Erosion and Bluff Stability Along Lake Michigan and Lake Superior Shorelines of Wisconsin) available from the State Planning Office and the Wisconsin Geological Natural History Survey.

Symbols Used

(used as nouns and adjectives)

b	boulders
c	clay or clayey
co	coarse
f	fine
g	gravel
m	medium
p	pebbles
s	sand
si	silt
t	till
y	cobbles
t(1A)	till name
SF	Factor of Safety
	A - unsatisfactory (1.00)
	B - questionable (1.00-1.25)
	C - satisfactory (1.25)
CL	Confidence Level
	A - high confidence - at borehole
	B - medium confidence - near borehole, stratigraphy visible
	C - low confidence - away from borehole, stratigraphy questionable
SL	Stability line - the distance slope must retreat to attain a stable slope angle. This assumes no erosion at toe and unchanged conditions of nature of material and water table.

DEPARTMENT OF TRANSPORTATION

DIVISION OF INVESTIGATION

STATE OFFICE BUILDING

Address, Residence

SCALE MILES

Reach 7

Location

Reach 7 is located in southern Milwaukee County. It consists of approximately 4 miles of shoreline in sections 25, 24, 13, and 12, T5N., R.22E. and section 31, T.5N., R.23E. The southern boundary of the reach is at the Oak Creek Power Plant and the northern boundary is at the large groin in Grant Park. Land use in the southern $\frac{1}{2}$ of the reach consists of farming and parkland, whereas in the northern $\frac{1}{2}$ the land is used for residential and industrial purposes.

Reason for Criticality

This reach ranks 3rd on the Erosion Problem Area priority list with a value per mile of 26. This high ranking is based on 1) the Army Corps of Engineers 1952 Shore Damage Surveying, 2) the very high short term recession rate of 6 ft. per year, and 3) the Army Corps of Engineers critical area list.

Reach 7A

Reach 7 is divided into two parts based on the type and severity of bluff erosion. Reach 7A is an area of relatively stable bluff directly north of the Oak Creek Power Plant. It is $\frac{1}{2}$ mile long and located entirely in section 36, T5N.

Section 31, T.5N.

The part of section 31 that is included in reach 7 is directly north of the Oak Creek Power Plant. In this area the groin like action of the power plants protective structures have built a very wide sand beach. The sand beach dissipates the wave energy and protects the toe of the bluff so that stable slopes are maintained.

The bluff height in this stretch is about 80 ft. and the topographic profile of the bluff shows one long straight slope inclined at approximately 20° to 25° . The bluff is entirely vegetated with large trees.

The stratigraphy of the section consists of a gray clayey till near the foot of bluff overlain by a series of lacustrine silts and sands.

Reach 7B

The northern division of reach 7 is an area of highly unstable bluffs with rapid recession rates. The failure type is rotational slumping in most places with little or no vegetation on the bluff and narrow beaches not protecting the toe.

Section 25, T.5N.

Beginning at Oakwood Road and moving northward (Bluff Cond. map, sec. 25) about 1/3 of a mile consists of a scalloped bluff top with fairly large slump blocks and steep scars. These are discrete slumps, concave in plain view. The failures are seated in or at the base of the silt and interbedded fine sand just above the lower till unit. Profile 1 (sec. 25) shows a typical bluff profile across one of the slumps and profile 2 (sec. 25) shows a profile typical of areas between the slumps. Profile 3 is across an older slump block adjacent to a stream gully. The toe material is primarily slumped clayey, silty till. Exposures are reasonably good in areas between slumps although there is a skin layer of debris on the slope. Major seeps occur at the top of the lower till.

The middle 1/3 of section 25 (Bluff condition map) has few large discrete slumps but shows nearly continuous rotational failure in small blocks (oblique R22-9). This may be because more stratified material, including the silt-clay units are acting as individual failure surfaces. Exposures in this section are poor. Major seeps in this section occur at the top of the upper till and minor seeps are present at several levels within the clay and interbedded sand units above. Water can be seen in most of the depressions between slump blocks.

The beach in this area is less than 5 feet wide causing the slumped material at the toe to be eroded. No structures are present in section 25.

In the northern part of section 25 and southern part of section 24 the bluff has mainly straight slopes and failure is by slide and fall.

The stratigraphy of section 25 consists of a lower gray clayey till (with a few shale pebbles) which ranges in thickness from 6 ft. to 18 ft. A few inclusions of lacustrine material are present in the till. This till is overlain by a sequence of lacustrine deposits consisting primarily of silt interbedded with fine sand. The silts are overlain by till in all locations except profile 3 in section 25. Here a wedge of medium sand and silt interbedded with fine sand and is 60' thick. This wedge is local and was probably deposited in front of the advancing ice front which deposited the upper till.

The upper till, identical (in the field) to the lower till in the sequence ranges from 10 feet thick in the northern part of section 25 to 68 feet thick at the southern edge of section 25. The thick till is located in the intersection of the bluff with a moraine and coincides with the highest part of the bluff in this section.

Section 24, T.5N.

Section 24 is in the center of reach 7. Land use of the bluff top is primarily for industrial purposes. The conditions present in the section are as follows.

In the southern part of section 24 the bluff has straight slopes and failure is by sliding and falls. The beach is narrow or absent and exposure is reasonably good. There are relatively few seeps in this section, possibly because of lower infiltration because of fine-grained soils at top. Some minor seeps occur on top of the clay and interbedded sand unit (Sec. 24, profile 1. Some small slumps are also seated on this clay unit.

Approximately .25 miles north into section 24 the slope is covered with concrete debris and there is no exposure. This is a straight slope and is relatively stable except for the concrete blocks that are sliding downhill in

places. Manufacturing plants are present on the bluff top.

North of this (.4 miles N. of section line, the bluff has been graded and grassed. A road comes nearly to the water. What is assumed to be a pumping station (oblique R21-33) is protected by sheet pilings. Just north of the sheet piling, a small exposure exists on a straight slope (Oblique R-21-32). Material exposed in the vegetation-bare area is primarily debris from grading although about 8 feet of till occurs at the toe and is probably in place. Erosion is taking place here because it is just south of a breakwater.

At mile 24.5 (oblique R-21, 31) a breakwater protects the shoreline and a beach 720' wide exists. Most of the bluff is covered with industrial waste (ashes, unidentifiable material). The Slope is relatively stable and is represented by profile 2. A small pumping station is located at the north end of the breakwater.

North to the section line the slope is vegetated with grass and brush. Rubble has been dumped on the slope in many areas. Beach width is 5-20' wide except where the profile was done and here it is poor. At this location a possible light reddish-brown till is present at the top of the bluff. No obvious seeps are present in this area.

Section 24 ends at the water treatment plant which is protected by sheet piling. The bluff above this is graded and grassed and appears to be stable.

The stratigraphy of section 24 is similar to that in section 25. At the base of the bluff is a gray clayey pebbly till which is overlain by lacustrine sequence. In the southern 3/4 of the section the upper lacustrines are exposed at the bluff top but in the northern 1/4 a red brown till caps the bluff.

The texture of the lacustrine sediments varies throughout the section. In profile 1 the lower lacustrine deposits are coarse grained sands and gravels with frequent boulders. To the north the lower lacustrines are massive silts. The upper lacustrine units grade from clay at the southern section line to silt at the northern section line.

T.5N., Section 13

The section begins at the waste water treatment plant which occupies the southern .25 miles of section 13. The plant is surrounded by sheet piling and the slope above is graded and grassed. It appears stable. North of the treatment plant the beach is wide ($>20'$) and the upper part of the slope is graded. The slope is straight, partly covered with vegetation and appears stable to 13.5. Just north of this the beach becomes narrower and there is less vegetation on the bluff. At the bluff top, land use is residential. Bluff height is about 100 feet.

Profile 1 is typical of this zone. No large slumps occur and most failure is by flow or sliding. The lower part of the slope is made up of two tills similar in composition (clayey, sandy or silty) with sandy silt between. The upper till (about 40' thick) is overlain by lacustrine silts and clays with sand at the top. North to 13.8 the stratigraphy and bluff conditions remain the same although the top of the lower till decreases in elevation.

Throughout this area (to 13.9) seeps occur at the top of the lower and upper tills and more seeps occur in the clays about 25 feet below the bluff top. A major aspect of slope retreat here is spring sapping which takes place on top of this clay layer and on top of the upper till. Several ravines (13.7) have grown due to this process and also to some extent, surface run-off concentrated at the bluff top.

At 13.8 a fill and small docking facility is present. Just north of this the beach is wide ($>20'$) and the bluff is vegetated (70%) and reasonably stable. No large slumps or failures are present. North to the section line the bluff height drops to 80 feet and the beach narrows to >5 feet at the section line.

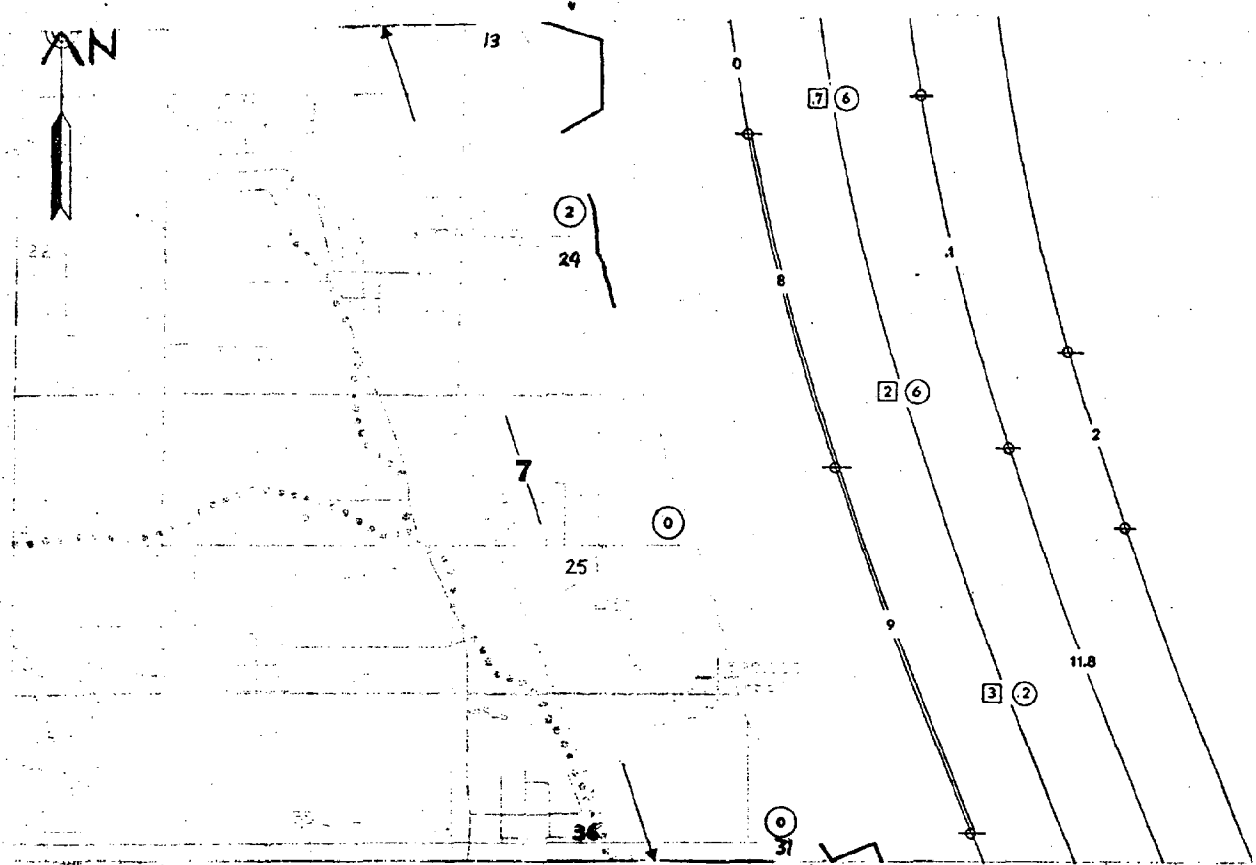
Profile 2 is a slope typical of the unvegetated, narrow beach zone in 13.9 - 12.0. The same stratigraphy is present as at profile 1 except the silt and fine sand unit between the tills thickens to 38 feet.

T.5N., Section 12

Much of this section has fairly low bluff. Bluff height is about 60 feet at the south end and it is fairly flat to about 12.4. This surface is a terrace of Oak Creek and is graded to 640'. Oak Creek enters the lake at 12.5 and more terrace occurs north of this point in southern Grant Park. The bluff then rises to about 90 feet at the north end of the section.

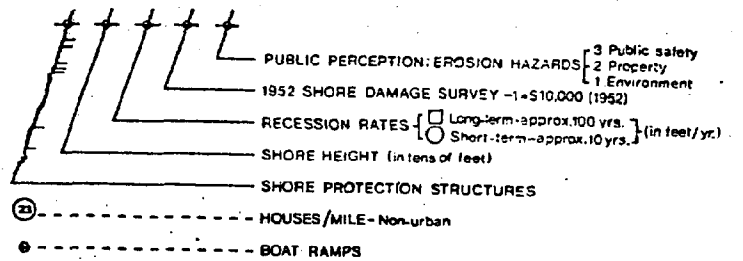
The bluff north to 12.25 is covered with flow and slide debris and has a beach 5 to 20 feet wide north to a 900 foot long revetment at 12.1. Above the revetment the slope is partially vegetation covered and is straight. Sliding is taking place with no large slumps. Minor seeps are present on top of the upper till at the south end.

North of the revetment some slump blocks (partially vegetated) are present and seated on top of the lower till. Seeps occur on top of this till in local areas. Much of the toe is covered by slump and flow debris and looks like Profile 1. The beach is wide (20 ft.) and little toe erosion is taking place north to 12.4.



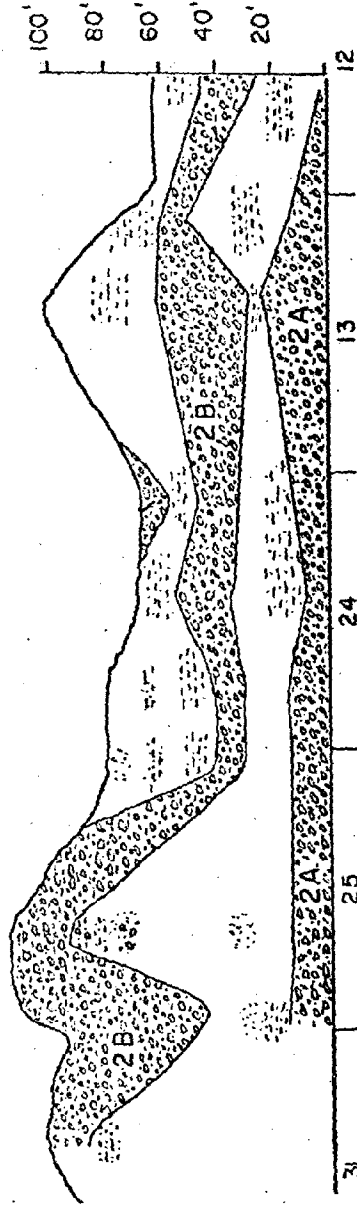
Reach 7

1 mile



Racine Co., Milwaukee Co.

T5N.

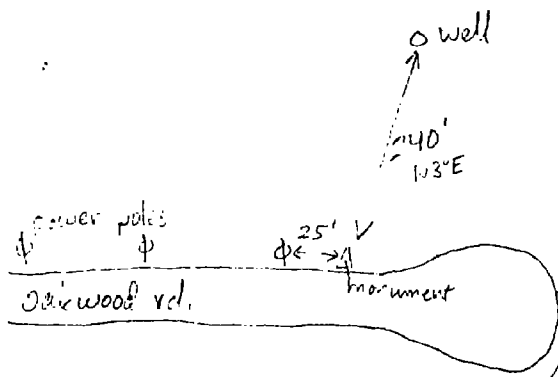
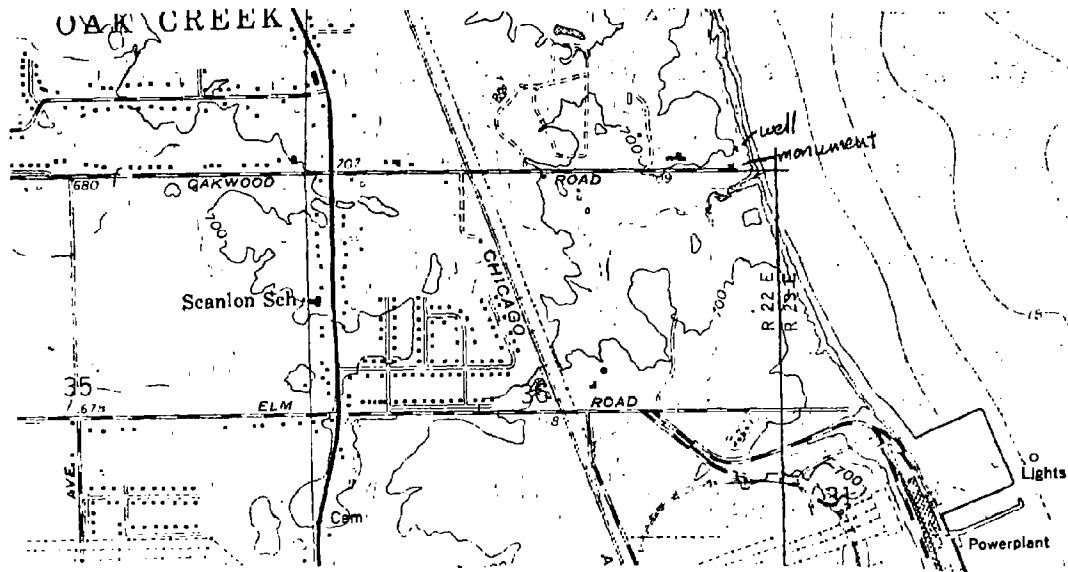


LEGEND

	SAND AND GRAVEL		CLAY		COVERED OR INACCESSIBLE
	SAND		SILT		TILL
	GRAVEL		CLAYEY SILT, SILTY CLAY		MIXED SEDIMENTS

Generalized longitudinal section showing bluff stratigraphy in Reach 7. Numbers along base of diagram are geographic (1 mile) sections.

GT-1, Racine North Quad, Milw. Co.
 SE 1/4 / SE 1/4 / sec. 25 / T. 5N. / R. 22 E



The monument is 25' east of the last power pole, on the north side of the road.

The well is 240 ft. from the monument on a bearing of N 3° E.

Borehole: GT-1 Location: Bender Park, Milwaukee County, sec. 25, T5N

Depth (feet)	Blow Counts (Split spoon) Standard Penetration	Pocket Penetrometer	w _n %	γ _d (psf)	w _L %	I _p %	% Clay & Silt	φ°	c (psf)	c _{vane} (psf)	USCS class.
5											
10											
15			14.4	119	23.2	8.6					
20											
25			14.9	119	23.4	8.1	29.6	31.4	0.0		CL
30											
35			14.1	121	21.8	7.2	27.6	85.2			CL-ML
40											
45											
50											
55			17.2	112	29.0	12.8					
60											
65											
70			29.0	112	24.6	10.6	31.2	91.1			
75											
80			20.1	111.5	29.4	10.0	45.8	25.6	1187		CL
85											
90			18.8	111.5	26.6	10.9	99.9				
95											
100			19.8	107	30.6	15.1					
105											
110			16.4	114	23.8	9.4	< 20.	31.0	0.0		CL
115											
120			18.0	113	27.7	12.4	93.3				CL-ML

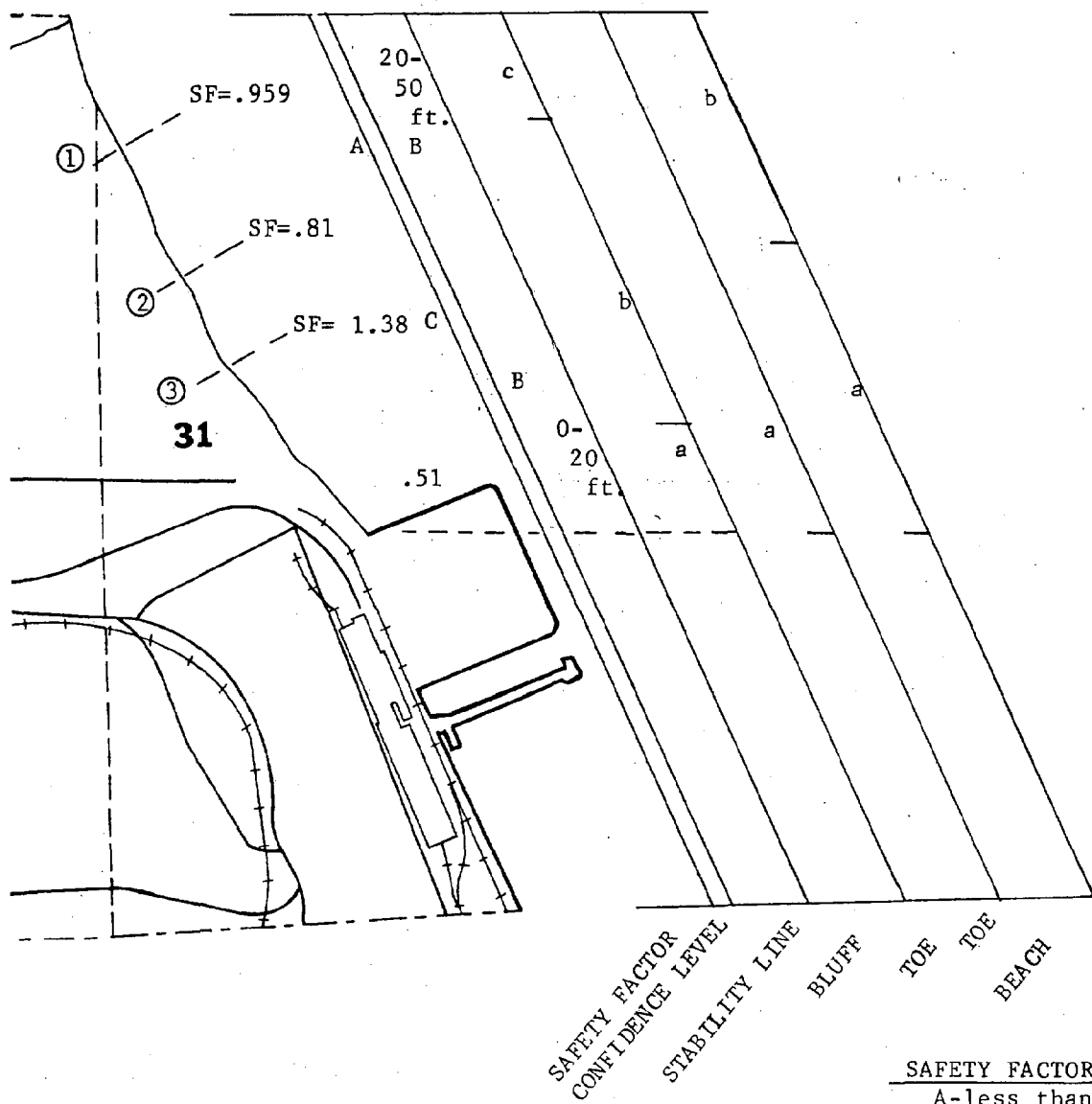
106'

71'

grey
silty
clay
fill

grey
lean
clay

grey
silty
clay
fill

SAFETY FACTOR

A-less than 1.00

B-1.00 to 1.25

C-greater than 1.25

CONFIDENCE LEVEL

A-boreholes

(high confidence)

B-near boreholes

stratigraphy visible

C-no stratigraphy

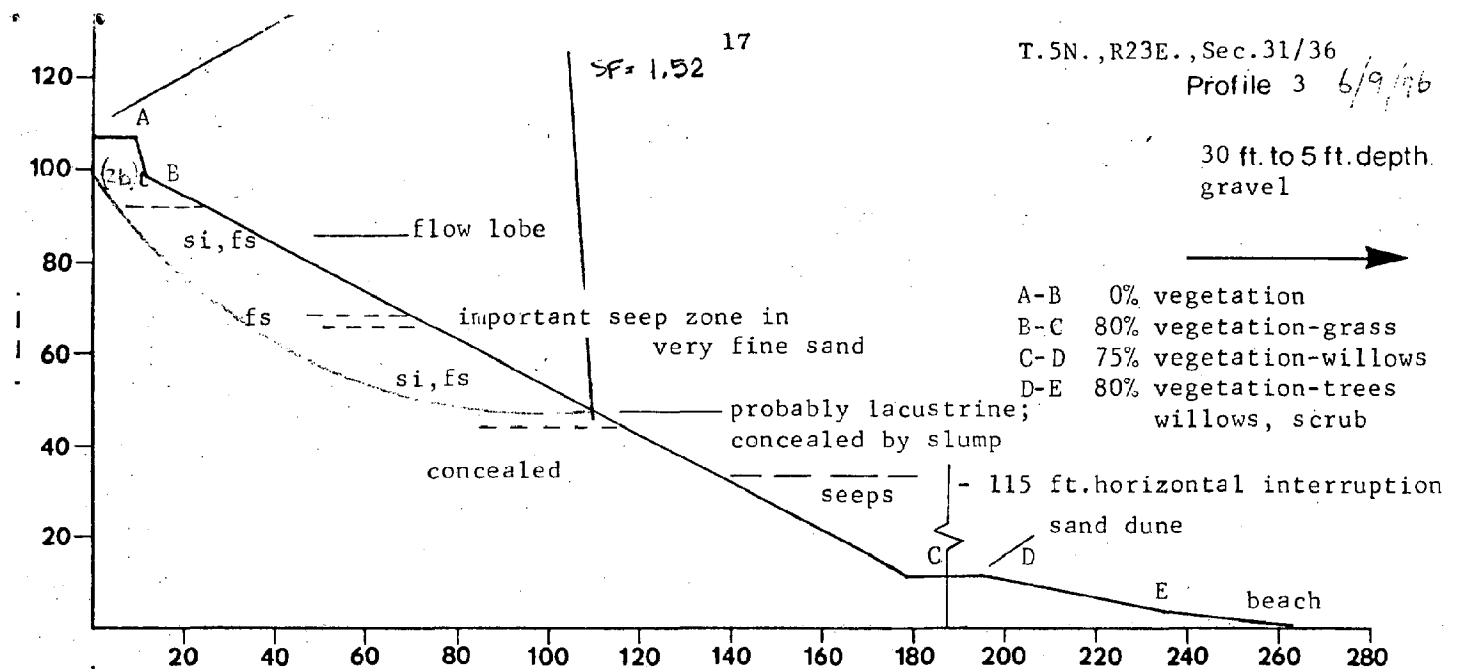
visible (low

confidence)

1. BLUFF	a-steeper slopes; middle portion of bluff less modified by flow units, smaller flow units	b-primarily earth flowage in two major recognizable episodes; tops of older flows form more or less continuous terrace, younger units cover lower 2/3 of bluff face	c-compound slope failure, slump debris fully modified by flowage
2. TOE	a-mostly consisting of slumped lacustrine sediments		
3. BEACH	a-less than 20 ft. sand and gravel	b-10 to 20 ft. sand and gravel, widens southward	

30 ft. to 5 ft. depth
gravel

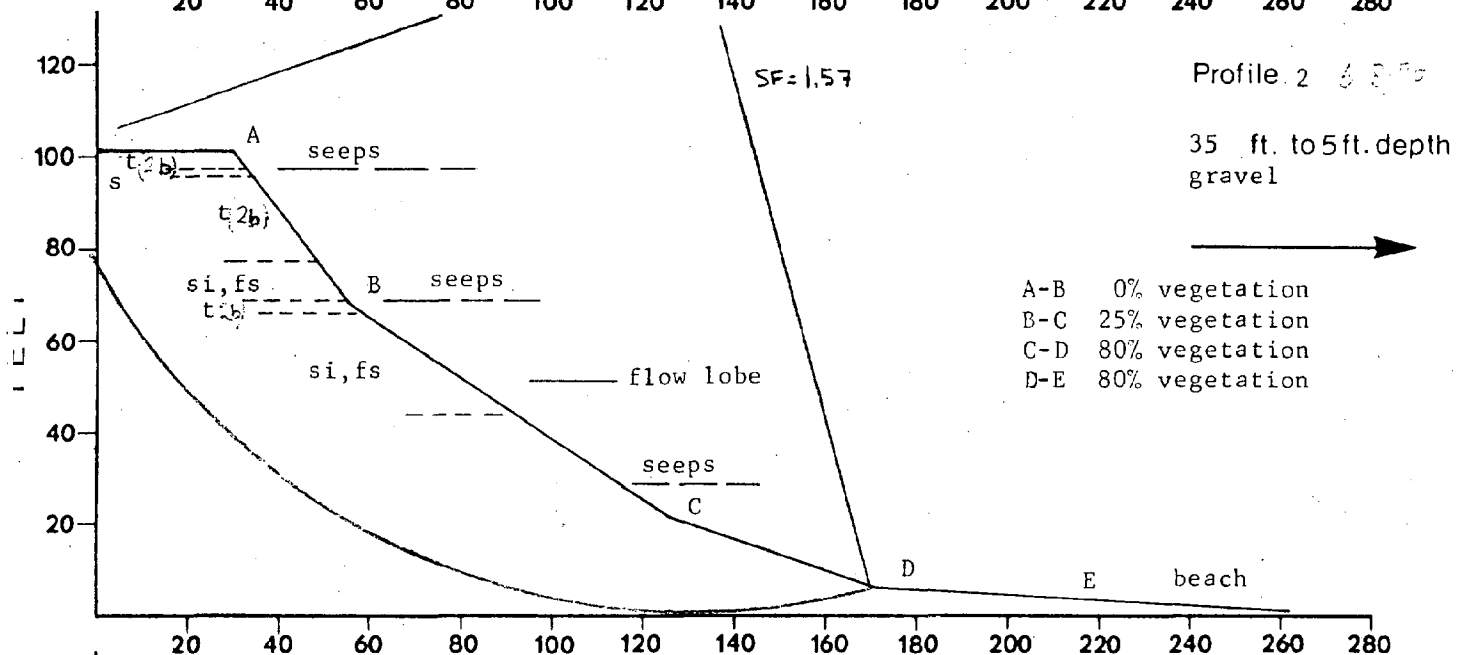
A-B 0% vegetation
 B-C 80% vegetation-grass
 C-D 75% vegetation-willows
 D-E 80% vegetation-trees
 willows, scrub



Profile 2 6/8/76

35 ft. to 5 ft. depth
gravel

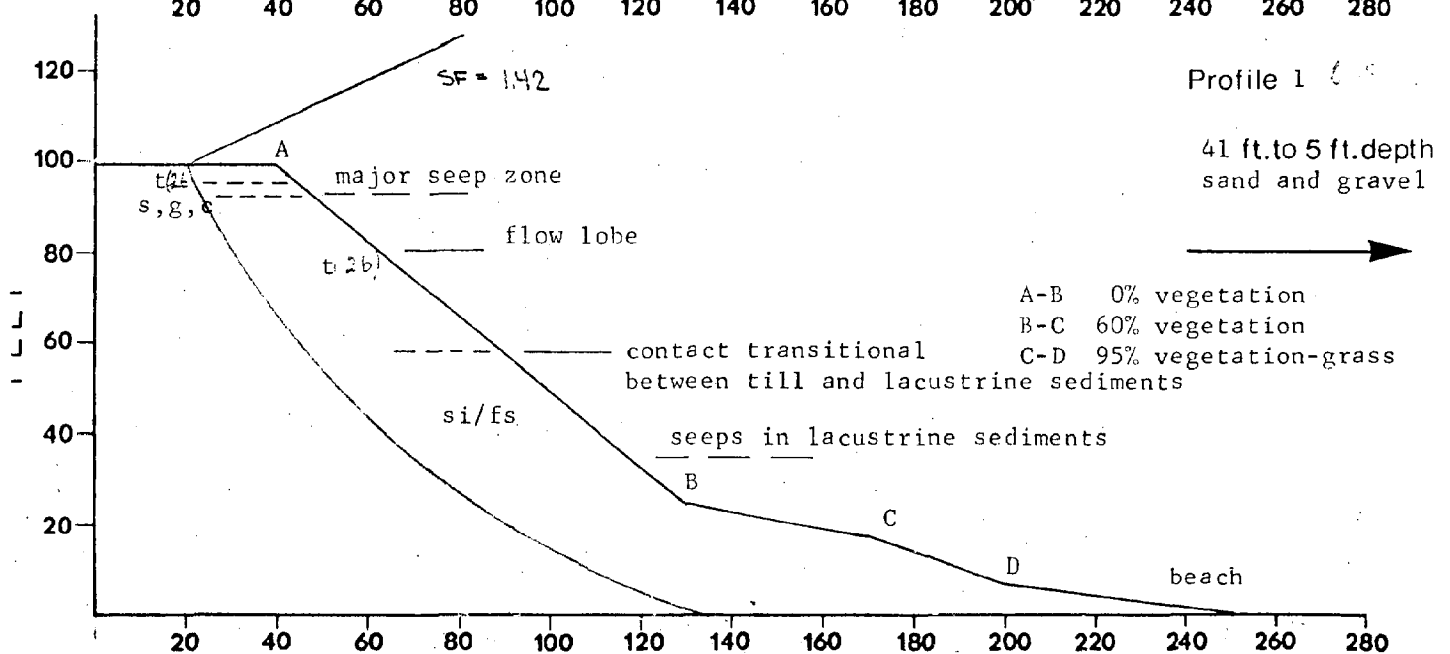
A-B 0% vegetation
 B-C 25% vegetation
 C-D 80% vegetation
 D-E 80% vegetation



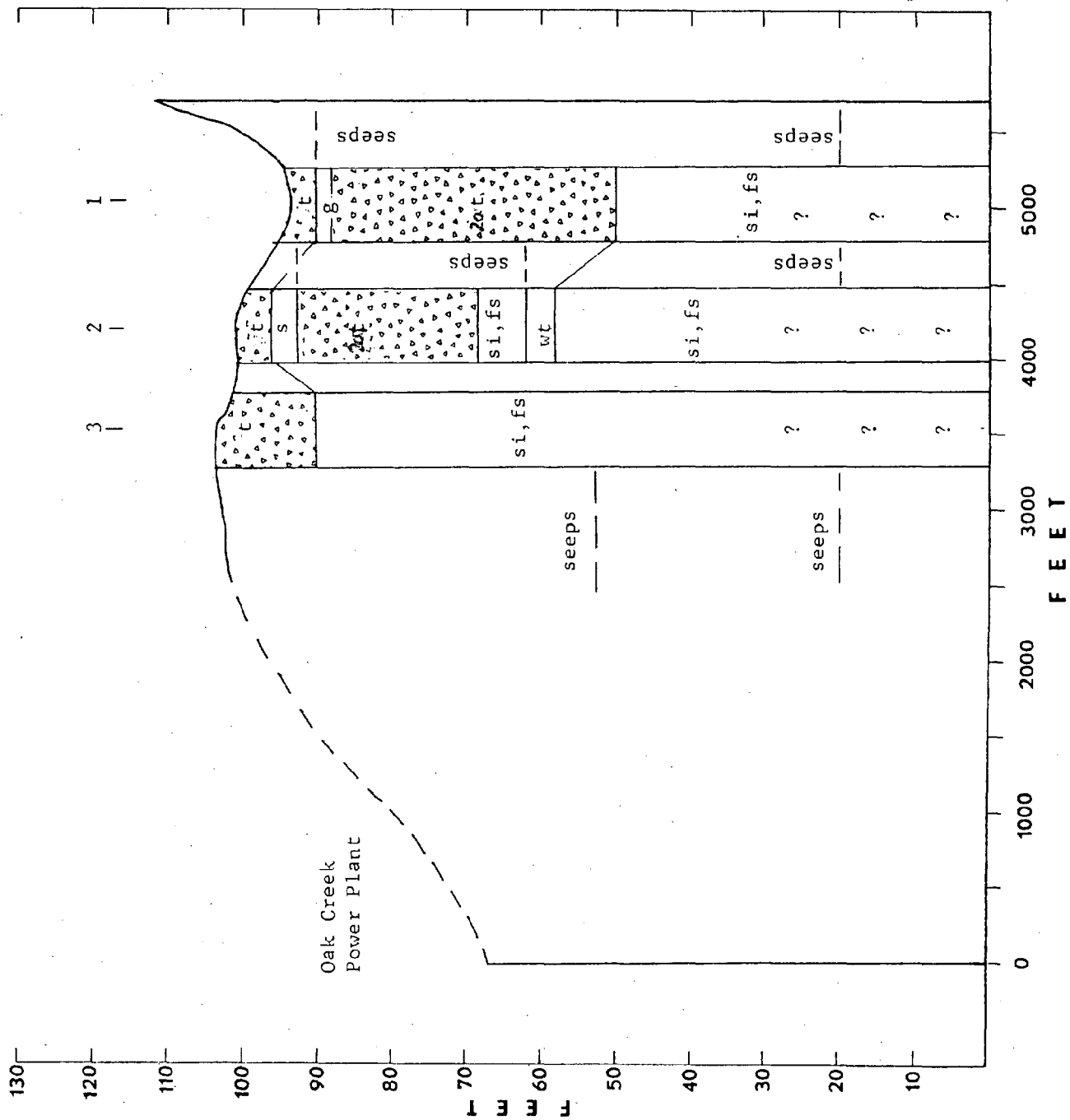
Profile 1 6/8/76

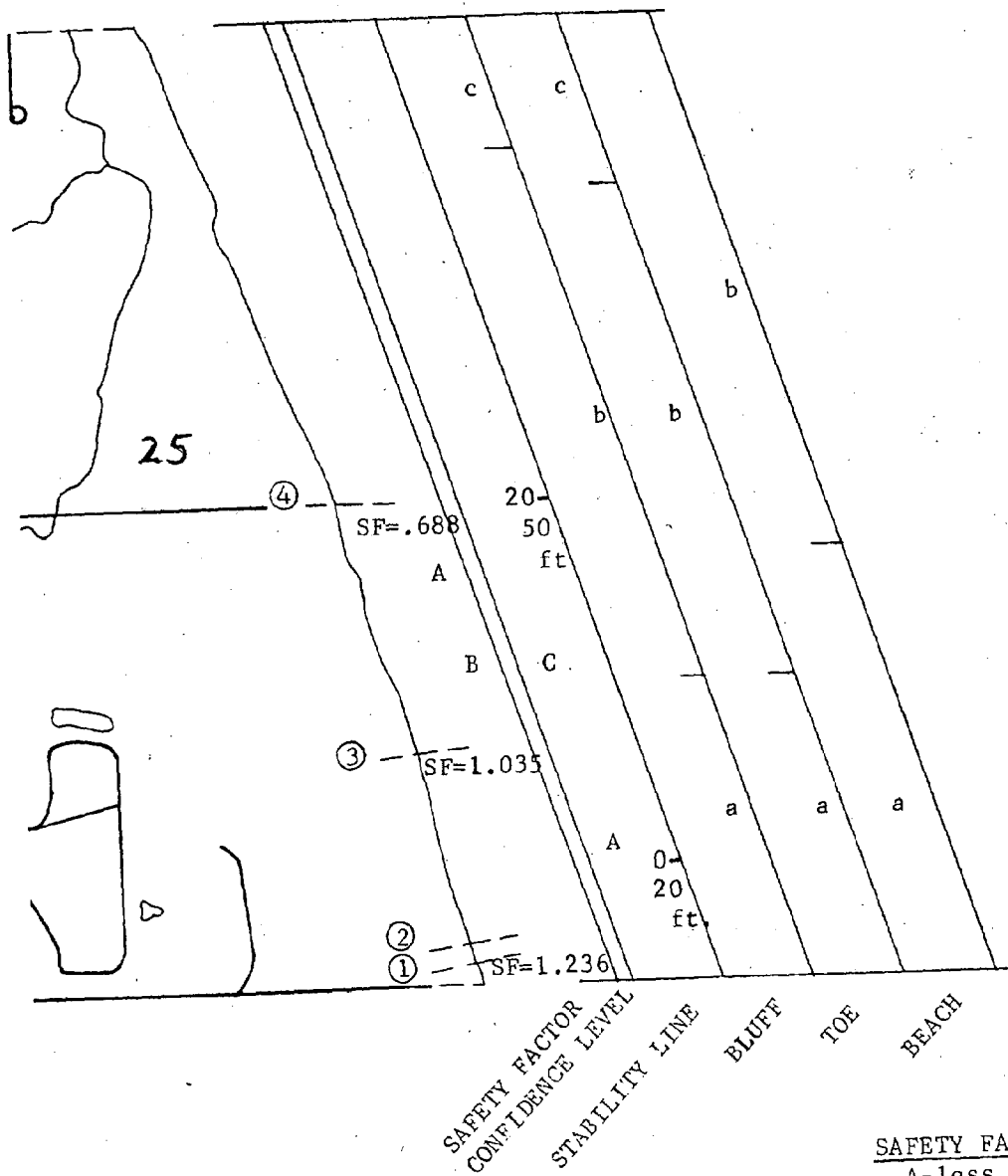
41 ft. to 5 ft. depth
sand and gravel

A-B 0% vegetation
 B-C 60% vegetation
 C-D 95% vegetation-grass



T.5 N., R.23 E., Sec. 31/36



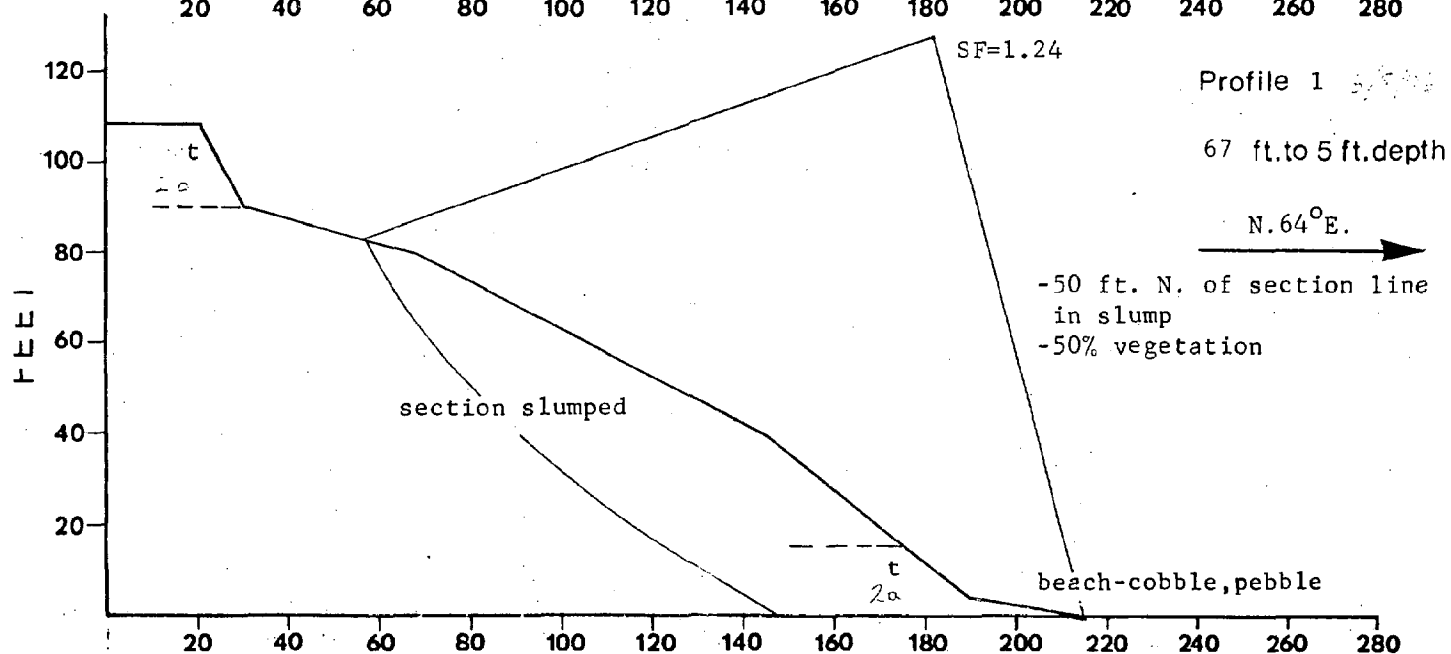
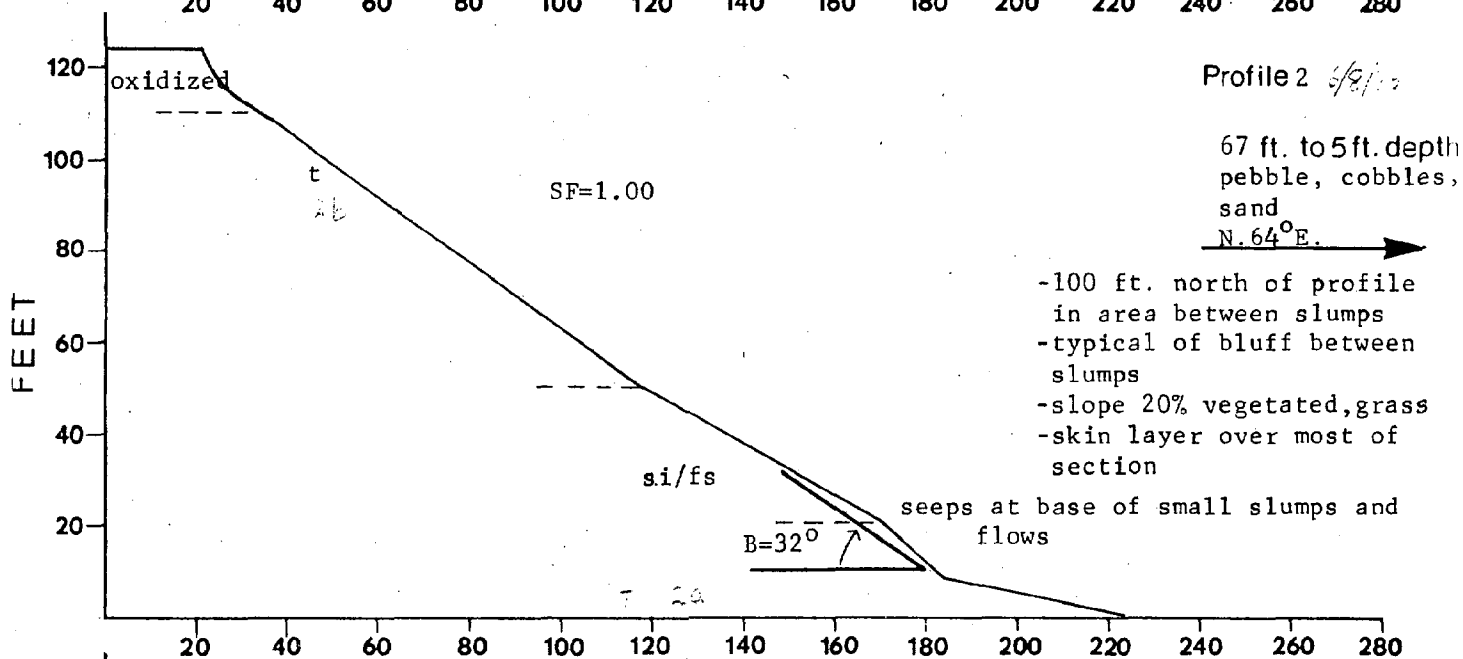
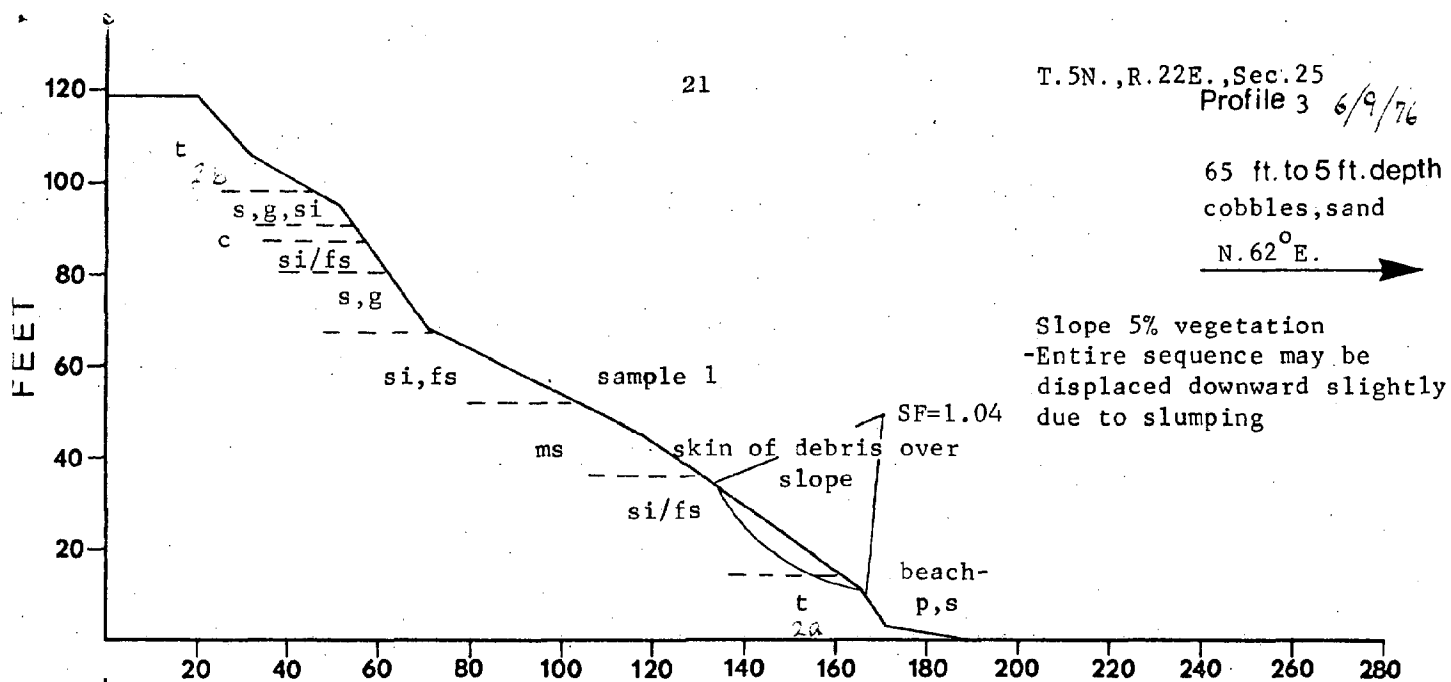
SAFETY FACTOR

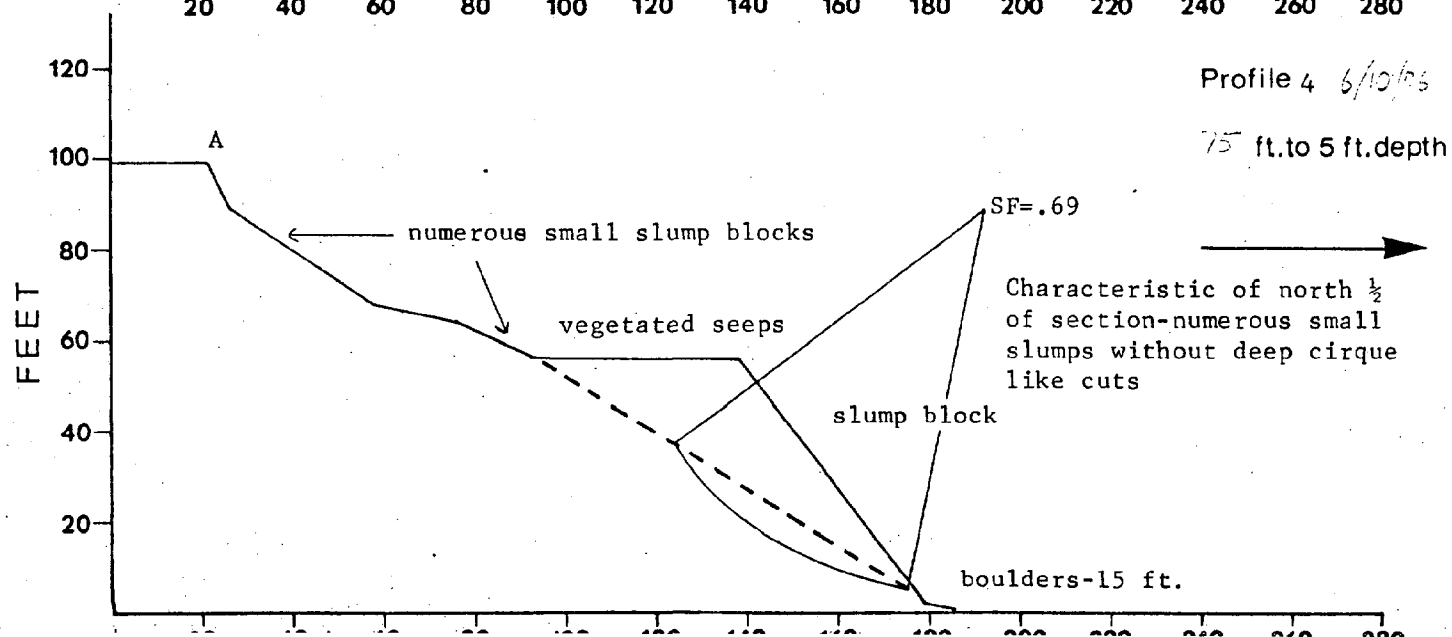
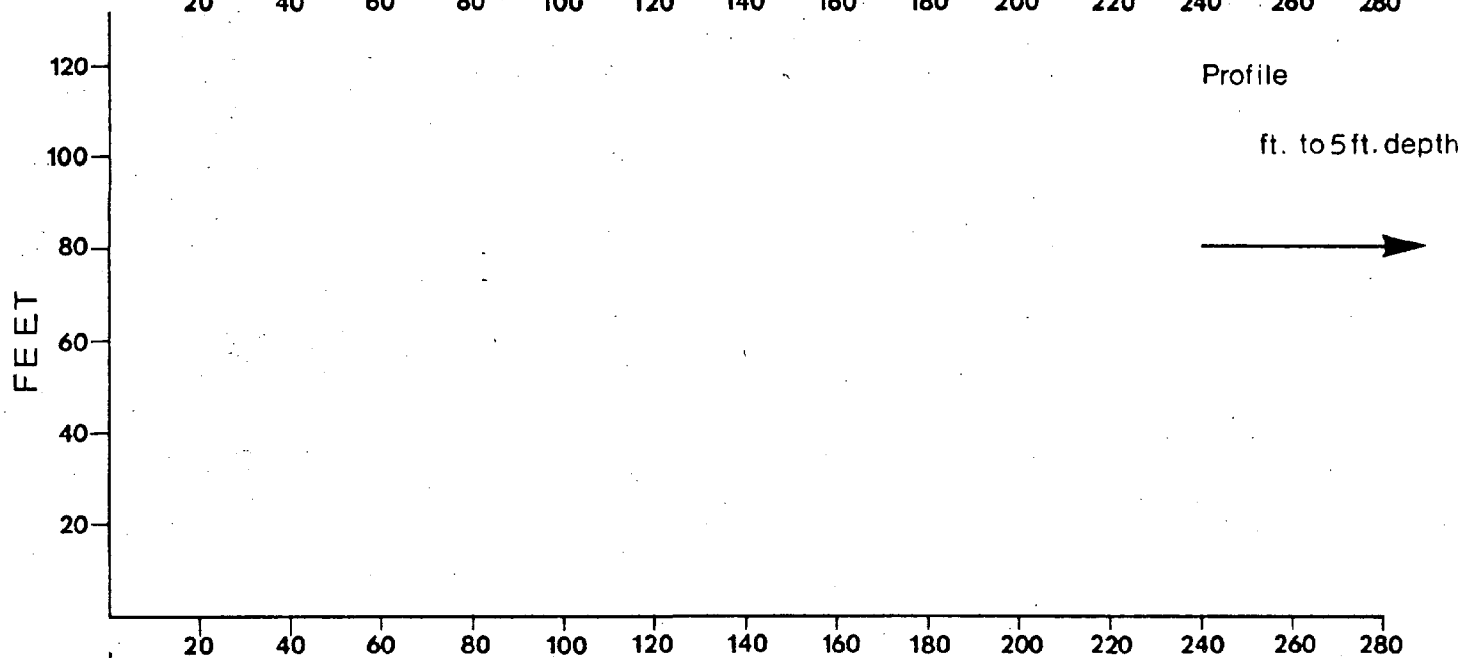
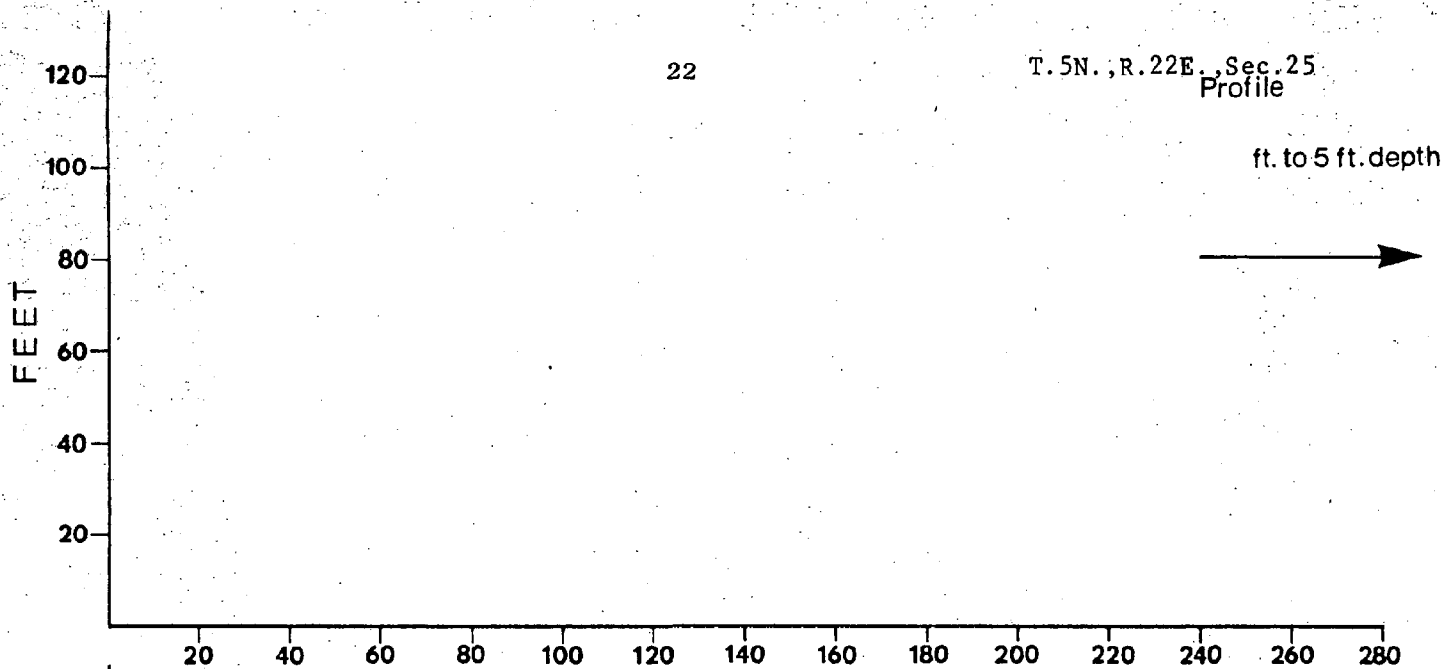
- A-less than 1.00
- B-1.00 to 1.25
- C-greater than 1.25

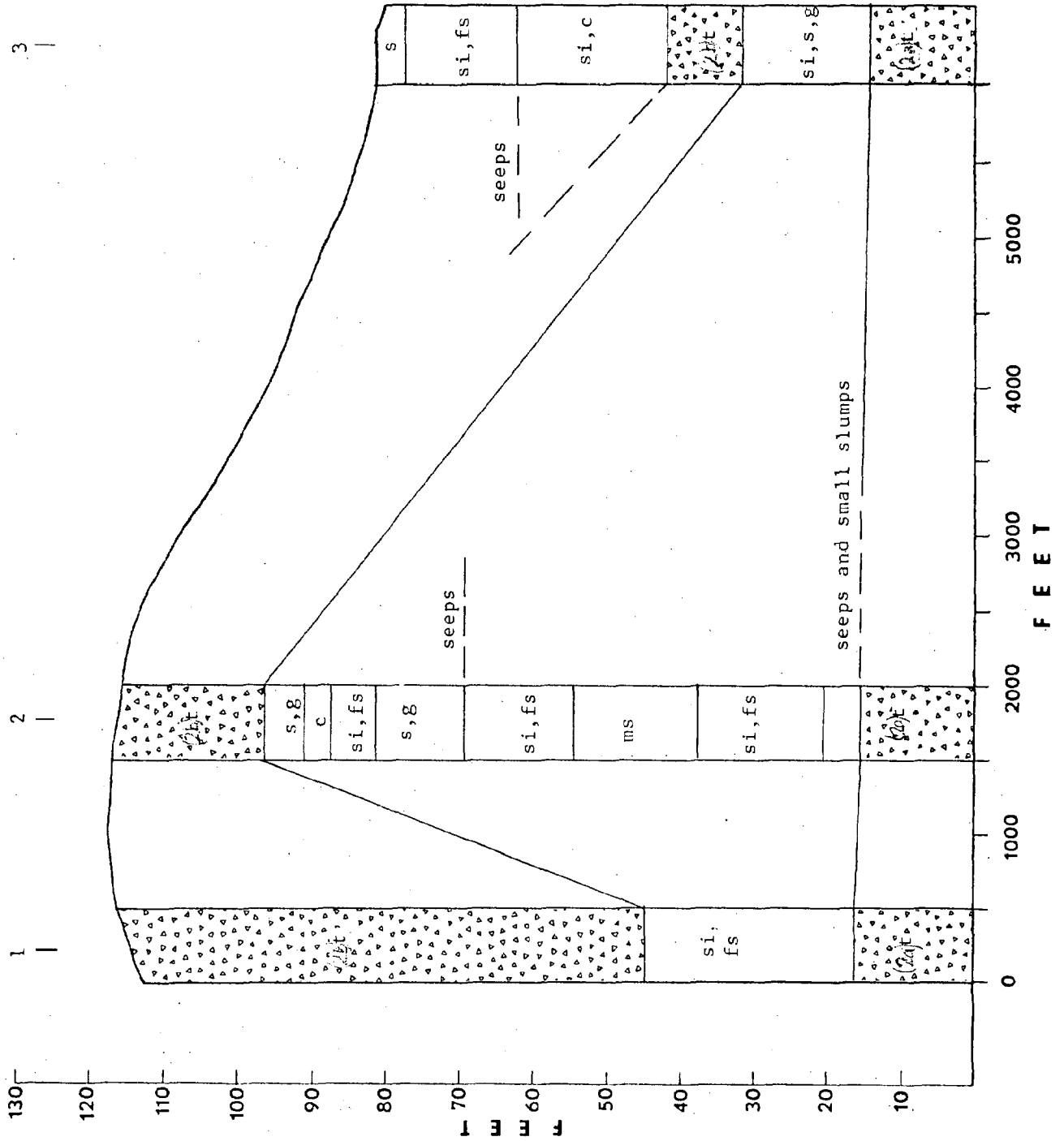
CONFIDENCE LEVEL

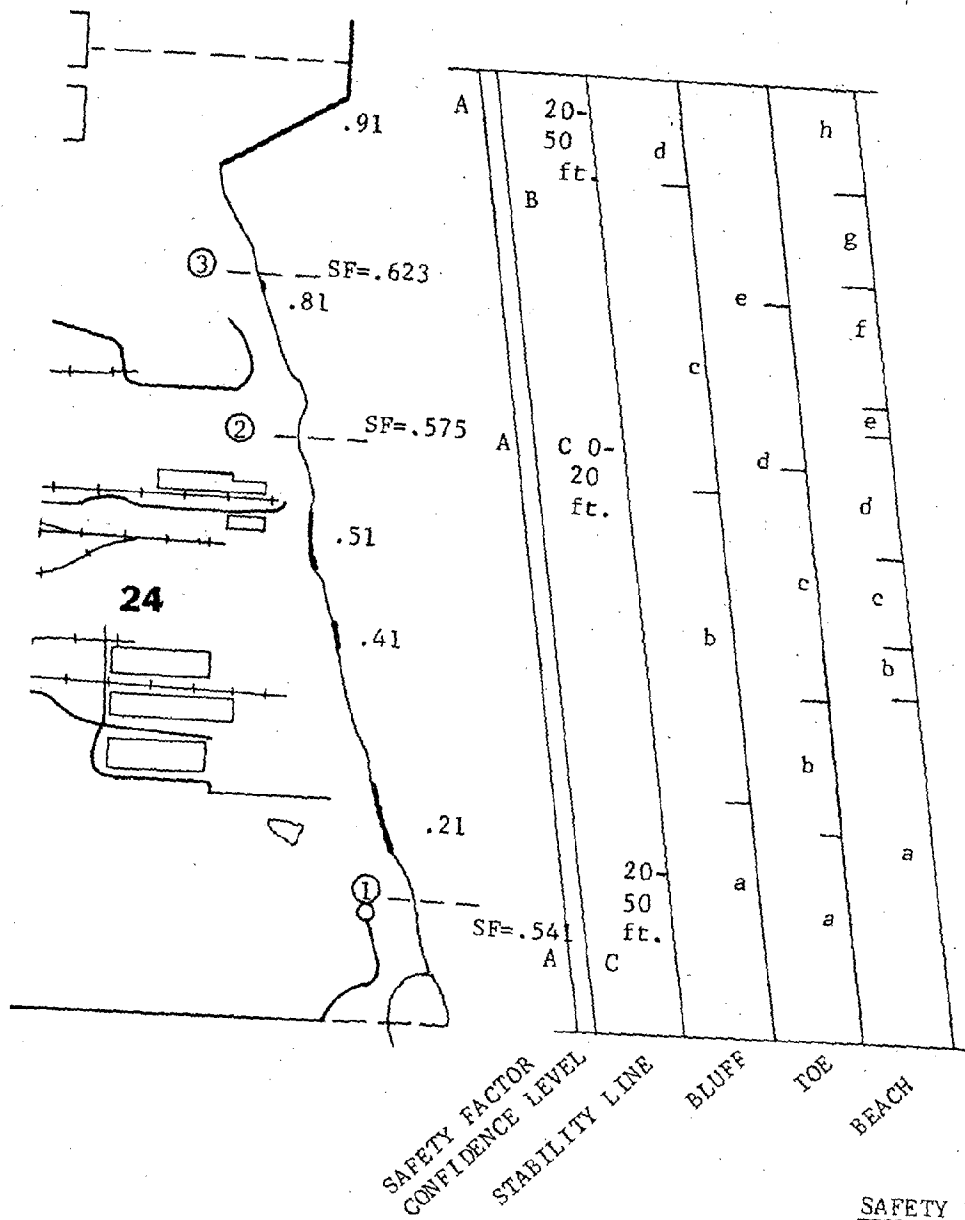
- A-boreholes
(high confidence)
- B-near boreholes
stratigraphy visible
- C-no stratigraphy
visible (low confidence)

1. BLUFF	a-discrete slumps leaving concave cuts and scalloped bluff top	b-small slumps, lateral spreading without discrete large slump blocks	c-eroding bluff, no large recent slump blocks although older blocks probably being truncated, shallow slides
2. TOE	a-50% till in place 50% lacustrine silt and till slumped	b-slumped mixed lacustrine silts and till	c-till, most in place
3. BEACH	a-5 to 20 ft. beach pebbles with cobbles	b-less than 5 ft. beach, cobbles, otherwise no beach	
4. STRUCTURES-none in this section			







SAFETY FACTOR

A-less than 1.00

B-1.00 to 1.25

C-greater than 1.25

CONFIDENCE LEVELA-boreholes
(high confidence)B-near boreholes
stratigraphy visibleC-no stratigraphy
visible (low
confidence)

1. BLUFF	a-			
2. TOE	a-till in place e-slump debris	b-broken concrete	c-sheet piling fill behind	d-till in place
3. BEACH	a-no beach	b-less than 5 ft., boulders	c-no beach	d-greater than 20 ft., sand
	e-no beach	f-5 to 20 ft. wide, pebble and sand	g-no beach	h-5 to 20 ft. wide, pebbles and sand

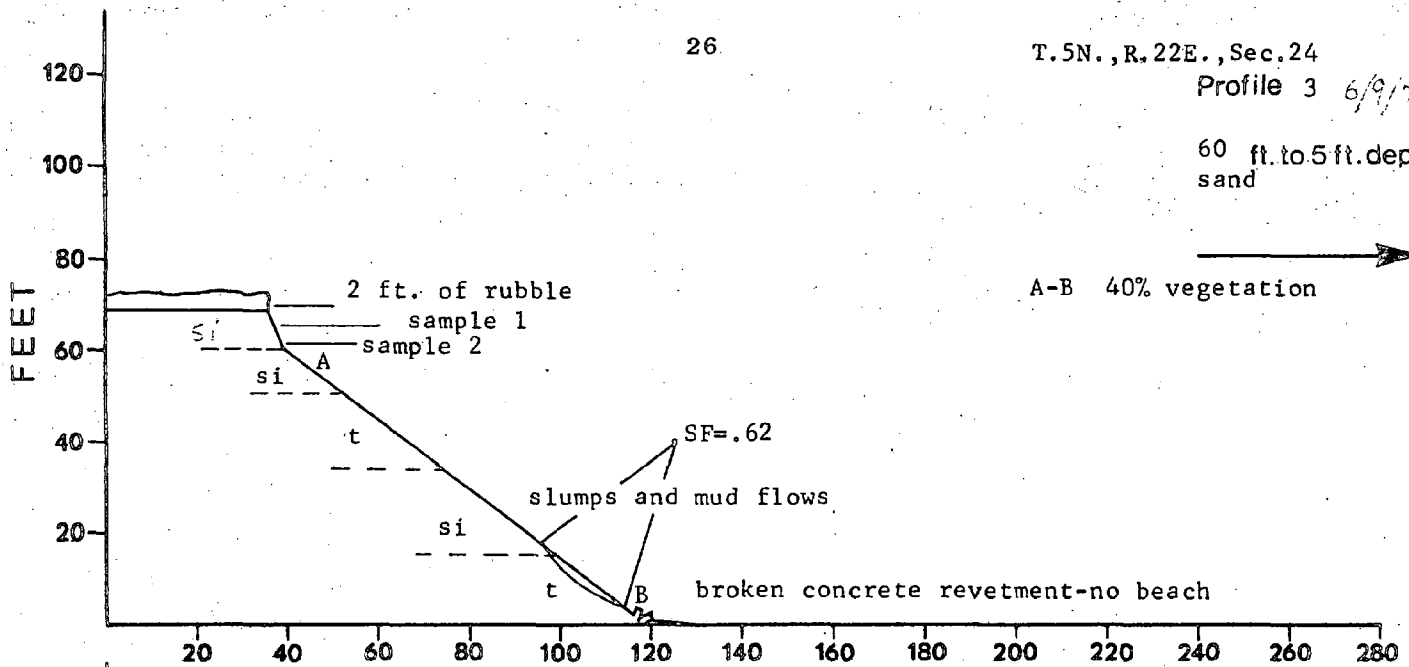
26.

T.5N., R.22E., Sec.24

Profile 3 6/9/76

60 ft. to 5 ft. depth
sand

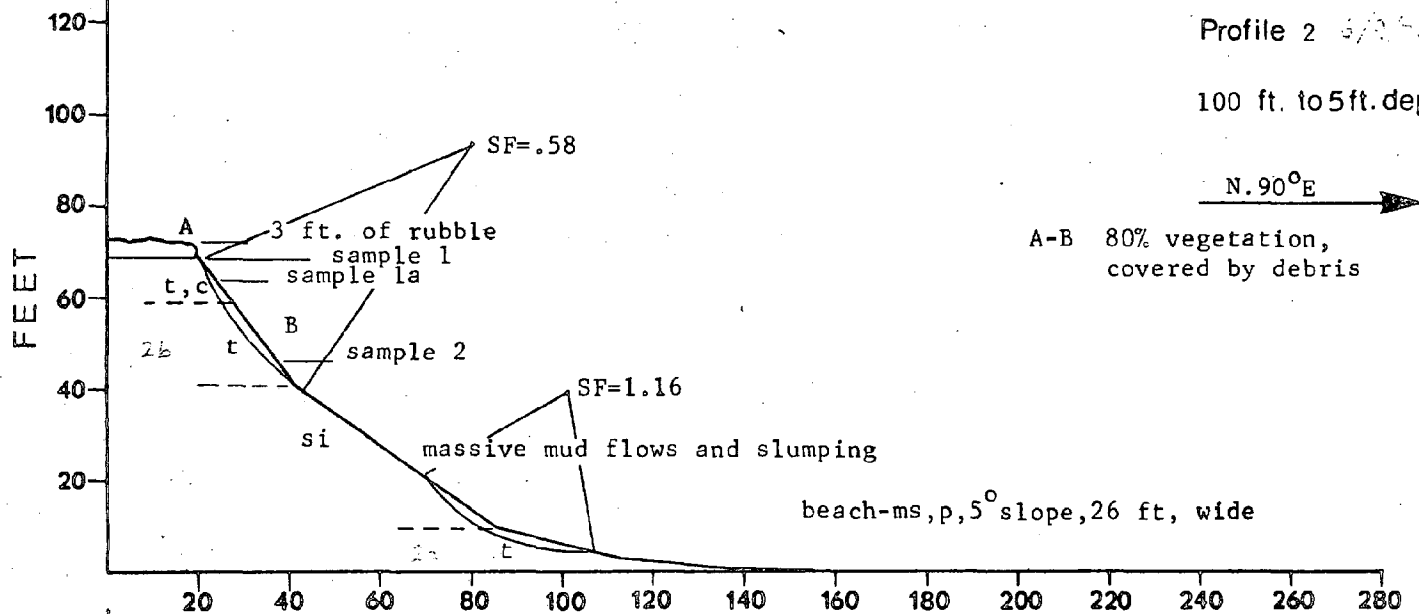
A-B 40% vegetation



Profile 2 6/9/76

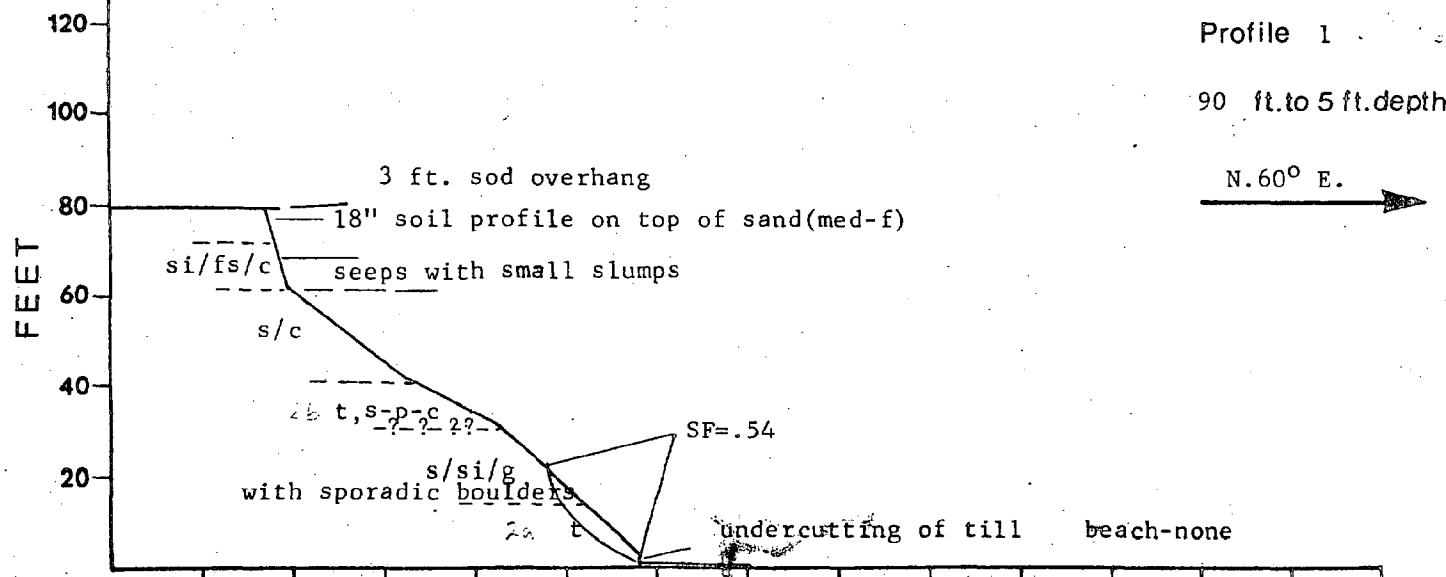
100 ft. to 5 ft. depth

N. 90° E
A-B 80% vegetation,
covered by debris

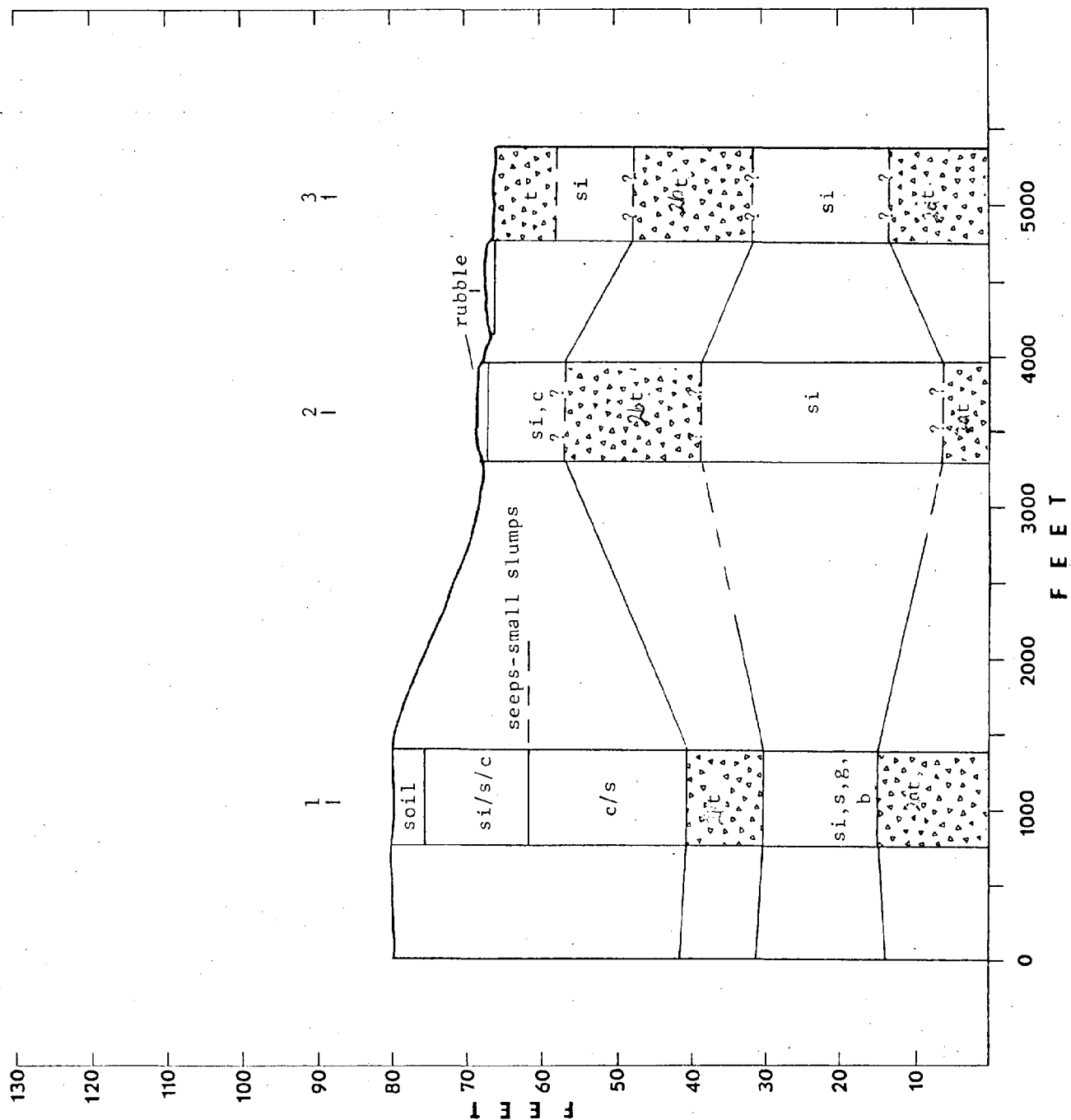


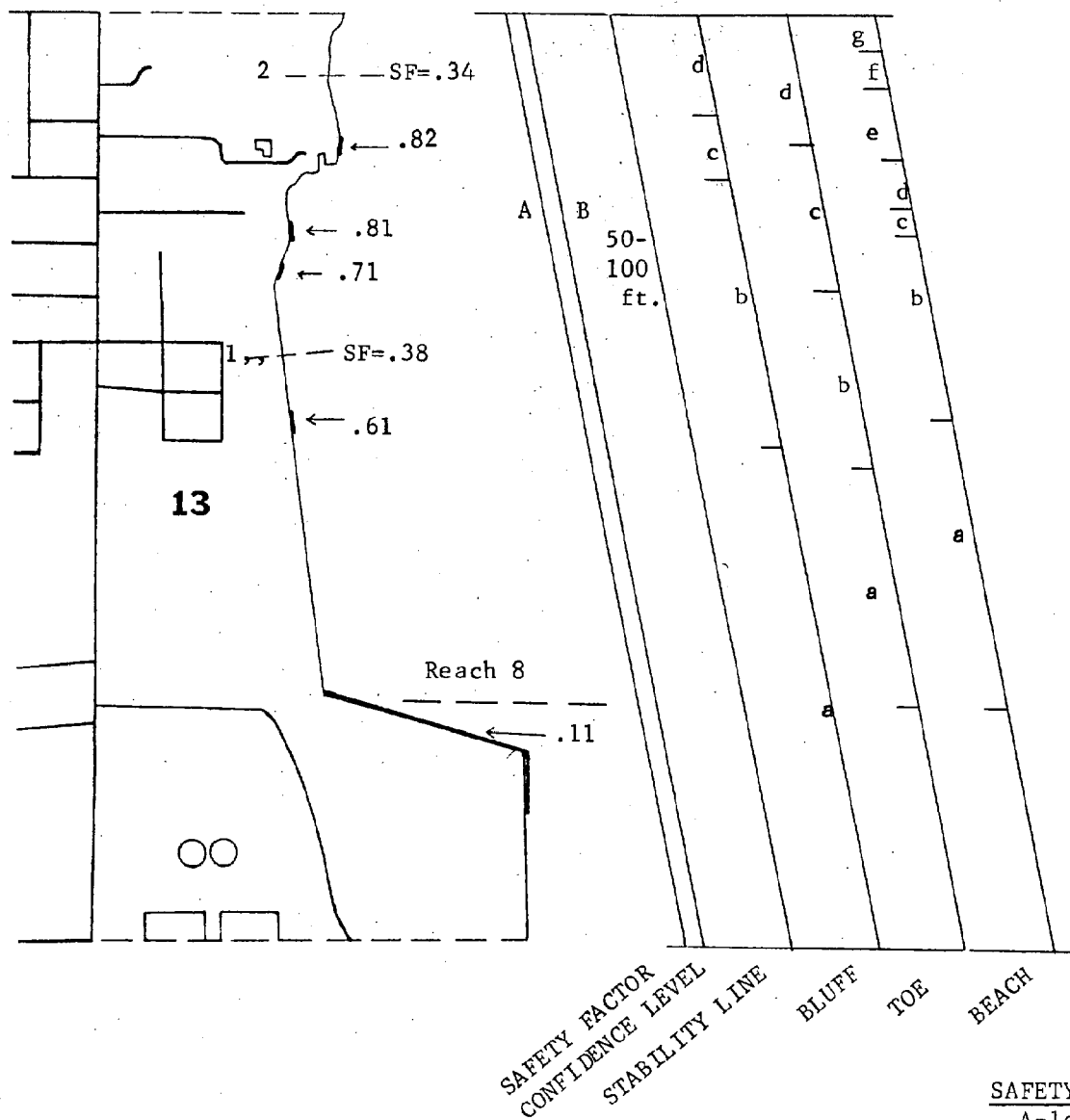
Profile 1

90 ft. to 5 ft. depth



I. D. N. N. 22 E., Dec. 24



SAFETY FACTOR

A-less than 1.00

B-1.00 to 1.25

C-greater than 1.25

CONFIDENCE LEVEL

A-boreholes (high confidence)

B-near boreholes stratigraphy visible

C-no stratigraphy visible (low confidence)

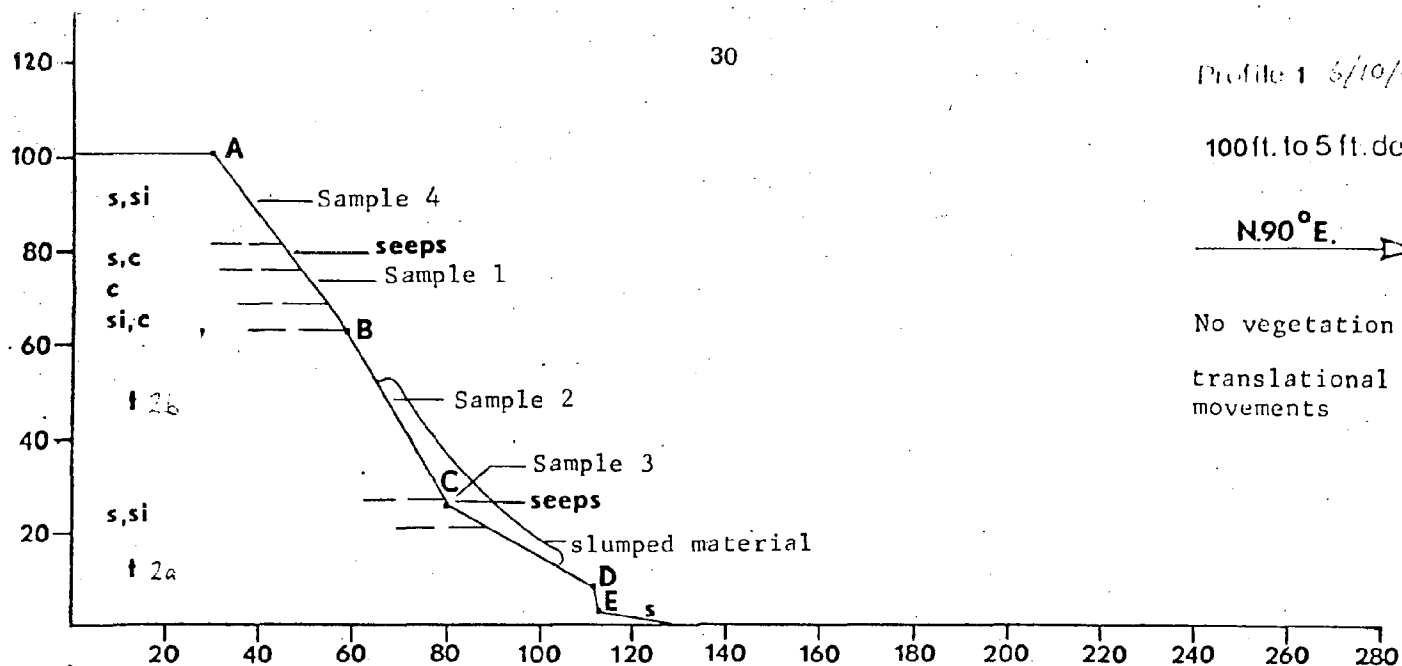
1. BLUFF	a-relatively stable, no recent failures, graded	b-shallow slides	c-protected, graded, relatively stable	d-shallow slides
2. TOE	a-slumped, vegetated, now graded	b-slumped, lacustrine silts	c-in place, till	d-flow, lacustrine silts
3. BEACH	a-sand, pebbles at water line, +20 ft. e-greater than 20 ft.	b-sand, pebbles at water line 5 to 20 ft. f-5 to 20 ft.,	c-boulders, broken concrete, no beach g-less than 5 ft.	d-sand, pebbles greater than 20 ft.

Profile 1 6/10/76

100 ft. to 5 ft. depth

N.90°E. →

No vegetation

translational
movements

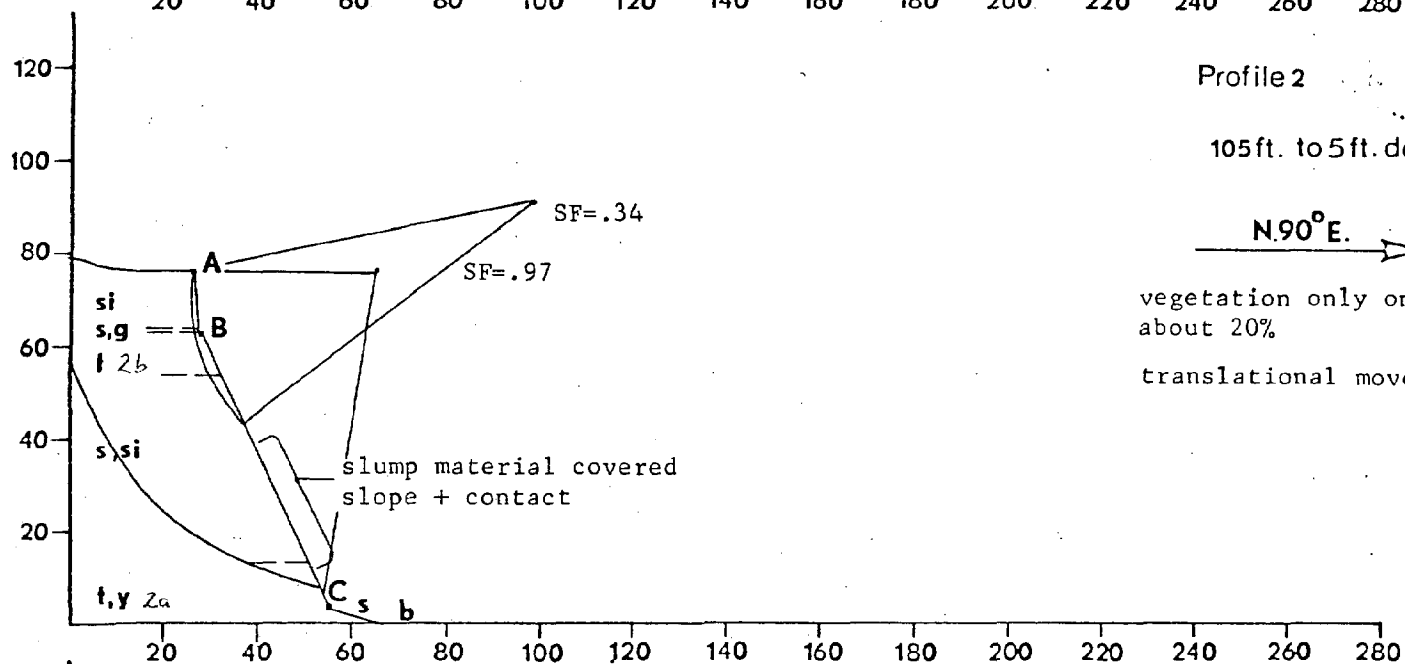
Profile 2

105 ft. to 5 ft. depth

N.90°E. →

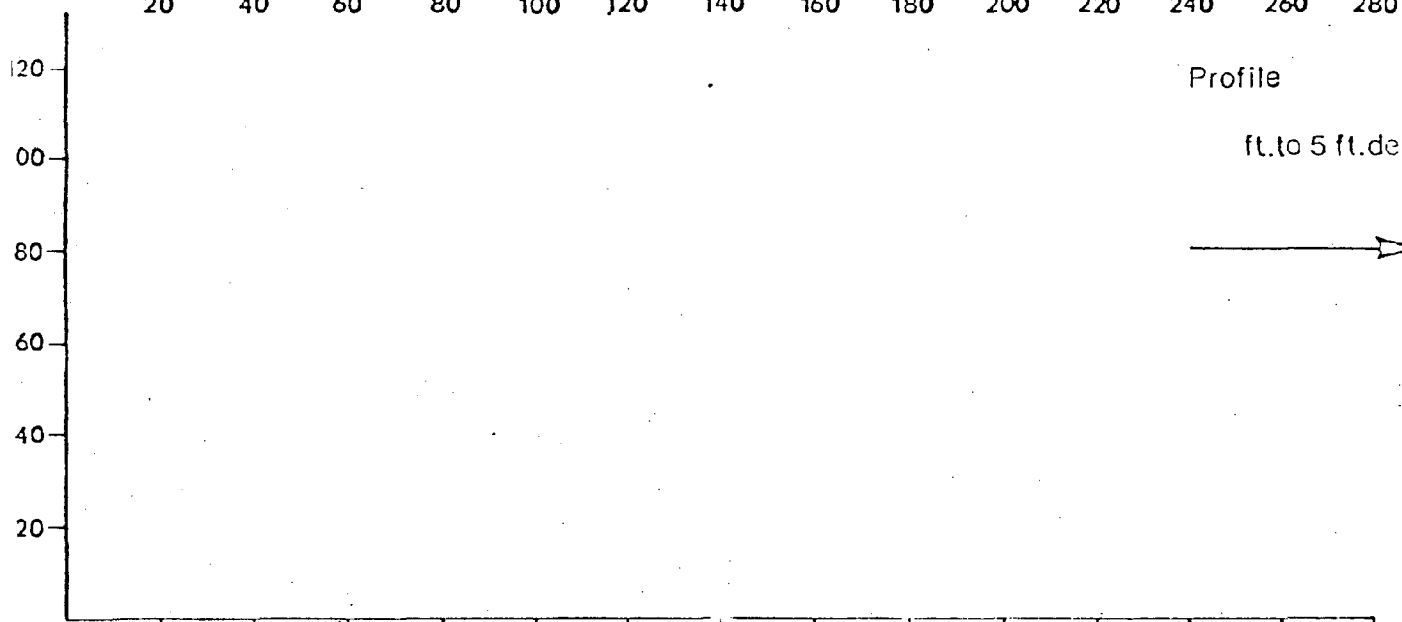
vegetation only on B-C
about 20%

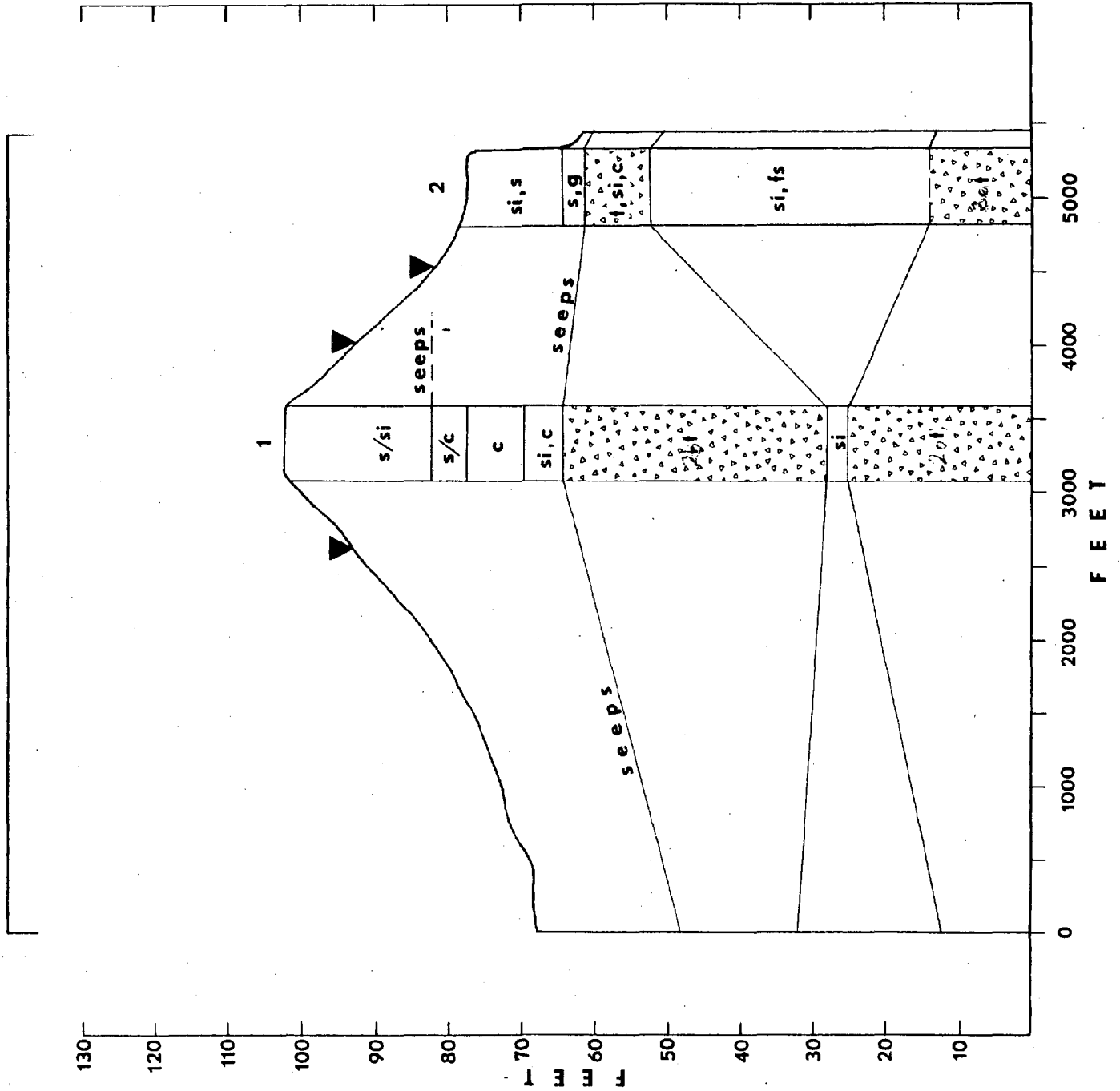
translational movement



Profile

ft. to 5 ft. depth





Field Report - Reach 8

Location

This reach is located in Townships 5 and 6 N., Range 22 E., in southern Milwaukee County. It is approximately 6.5 miles long and extends from the beach at Grant Part north to the part of Milwaukee County protected by a breakwater. Land use along the reach varies from industrial in the south to park land and some residential to the north.

Reason for Criticality

The reach ranks #8 in priority in the Erosion Problem Areas list with a value per mile of 12. This value is based on (1) the long term recession rate of 1 foot per year and the short term recession rate of 2 feet per year, (2) the Corp of Engineers 1952 Shore Damage Survey value of 2 to 3.2, and (3) the bluff height.

Reach 8A

Reach 8 is divided into 4 parts using the type of slope failure present. The southern most part, 8A, is an area of stable bluff with wide beaches formed by several groins. It extends from the central part of section 12 north to the southern part of section 1, T.5N. (Grant Park).

Section 12, T.5N

The northern half of section 12 is included in reach 12 and in particular in reach 12A. The area discussed here is in Grant Park and begins at the outlet of Oak Creek (no real bluff is present at the mouth of the creek. North of the creek a groin (structure 12.5) marks the southern edge of Grant Park. North of the groin a large beach and parking lot exists in front of the heavily vegetated bluff which rises to 640'. The beach and heavily vegetated bluff continues north to 12.8 (oblique R-21, 11).

Here the beach narrows to about 20 feet and small exposures are present at the base of the slope. It seems likely that this is due to the presence of sand approximately 10 feet thick at the foot of the slope (profile 2). In places it is covered with a veneer of slide and flow debris but in outliers it is exposed in nearly vertical cuts. Undercutting is probably responsible for failure at the slope bottom. The upper slope is vegetated with fairly large trees. The sand is dry where exposed. At the north end of the section the slope is reasonably well protected by groins. Stratigraphy is very poorly exposed on the wooded slopes.

Section 1, T5N

From the south section line north to 1.4 the slopes are tree covered and stable except for minor undercutting in basal sand unit. In most places this is not exposed. The height of the bluff decreases from about 90 feet at the section line to about 80 feet at 1.4. All of section 1 is within Grant Park. The shore north to 1.4 has a beach 20' wide probably due to the groin at the south end of the section.

Reach 8B

The second division of reach 8 extends from the southern part of section 1, T5N north to the northern part of section 25, T.6N. In this area the major portion of slope failure is by translational slides and groundwater sapping.

Throughout this stretch the stratigraphy consists of a lower gray clayey till separated from a yellow buff to pink silty till by a very thick sand sequence. The bluff height is near 100 feet in this area.

Section 1, T5N

The conditions present in the area of reach 8B are as follows.

North of 1.4, slope failure is taking place primarily by sliding. Several small slumps are seated on silty clay and clay at 60 feet above water level (oblique R 21-2). Seeps are excessive along the top of this unit, probably because of permeable materials along the bluff top. Less well-developed seeps

occur at the top of the till. Some spring sapping is associated with the slump blocks in the upper sand.

At the north end of section 1 (profile 3) a thin till is present at the top of the section. This till is clayey, sandy and gray when unoxidized. It is buff to pink when oxidized. This till continues to be present toward the north.

Section 36, T6N

This section has a uniform stratigraphy of till, (gray clayey, sandy) at base between 20 and 40 feet thick. The upper part of this till is less sandy than below. Some pink to red inclusions are present near the base.

Above the till lies a persistent unit of silt and interbedded fine sand. It is wet throughout and holds a steep face in some places (profile 2). Above the silt is primarily sand with minor interbedded silt. This unit is about 30 feet thick and is overlain by varying thickness of clayey gray till which weathers to buff-pink (0.12 feet thick).

Failure in this section is primarily by spring sapping and flow of sand above the unit of silt. Excellent examples can be seen on oblique photos (eg. R-20, 34). Below the silt slope wash, slides and flows are taking place. No large slumps are present. Throughout much of the section the upper slopes are wooded where sapping has not caused gully formation. Some old gullies have also become wooded. Lower parts of the slope are generally bare because of active sliding due to excessive water from top and within silt. Much of the toe is flow debris.

The beach throughout the section is >20' except at 36.7, just south of two storm sewer drains which act as groins. In the northern part of the section the bluff has numerous wooded ravines or sapping scars.

Section 25, T6N

The stratigraphy exposed in section 36 continues into this section, except that a sand unit is present at the toe. The occurrence of this unit is evidently coincident with the steepening of the bluff and the excellent exposure. Almost no vegetation is present between the south section line and 25.3 where structures cause an increase in beach width and undercutting of the toe is absent (profile 2). Throughout the section seeps occur above both silt layers although they are not as excessive as they are where only sand overlies the silts (to the south). Sapping does occur in the sand and gravel on top of the lower silt unit.

At 25.4 a pumping station has been built just above lake level and the slope is graded along a road down to it. North of the station to 25.6 the beach is 20 feet wide and the slope is about 50% vegetated (primarily the upper part of the slope). Sand still underlies the toe and when the beach narrows undercutting takes place producing falls of the till above (oblique R-20, 24, Profile 3). Except for ravines, the bluff remains 80-85 feet high with fairly straight slopes and little vegetation.

Reach 8C

Reach 8C is an area of stable bluff and wide beaches located behind the groin field in Sheridan Park. It includes the northern $\frac{1}{4}$ of section 25 and the southern $\frac{1}{3}$ of section 24, T6N.

Section 25, T6N

At 25.75 a groin field is present and slopes are wooded at the base. Some minor slides are present on the upper part of the slopes. The beach is well over 20 feet wide and thus there is no undercutting taking place. Sheridan Park extends north into section 24.

Section 24, T.6N.

Section 24 begins in the northern part of Sheridan Park and continues north for 0.5 miles. North of Sheridan Park crops occupy the field above the bluff. In the southern 1/3 of the section is protected by groins and beach width exceeds 20 feet and the bluff is wooded at the top and base. The central part of the slope is 50% vegetated with shrubs, grass, and occasional trees. No stratigraphy is exposed. Profile 1 shows a typical relatively stable slope. Some flow and slide occurs in the central part of the slope.

Reach 8D

The northernmost part of reach 8 is an area of steep unvegetated bluffs. The slopes are failing by translational sliding and bluff retreat is relatively rapid. The severity of the erosion could, in part, be attributed to the protective structures surrounding Milwaukee Harbor.

The area extends from the southern part of section 24 north to the electric power plant in section 14.

Section 24, T.6N.

The conditions present in section 24 north of the stable slope area are as follows.

North of 24.3 the beach narrows to less than 20 feet and vegetation becomes sparse. The slope steepens and drops from about 100 feet at profile 1 to about 70 feet at profile 2.

At the base of the section several feet of sand is exposed, overlain by 10 feet of reddish brown sandy till which is very compact and bouldery. This till has not been seen south of here in Milwaukee Co. Large boulders derived from the till are present along the beach and can be seen on the oblique (R-20, 13) and vertical photos. This till is probably equivalent to the Haeger till. Organics were collected from this unit just above water level. An excellent boulder pavement is present to the north where the unit is overlain by another till.

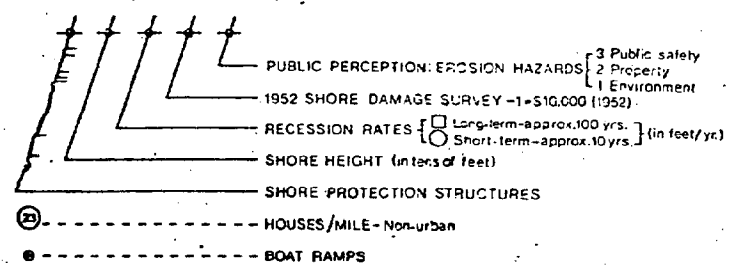
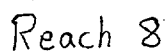
This pavement merges southward with a line of beach gravel which terminates this till and the overlying till.

The overlying till is gray, clayey, sandy or silty and is typical of Wadsworth till to the south. Organics are present dispersed in the till. Above the till is of fairly continuous thin layer of sand and sand and gravel. This unit is water bearing and a large number of seeps occur at the base. Undercutting in the gravels occurs especially where the unit is thicker between between profiles 2 and 3 (see longitudinal profile).

North of the profiles to the section line, the bluff decreases in elevation to 601 feet. At the section line the bluff top has been graded.

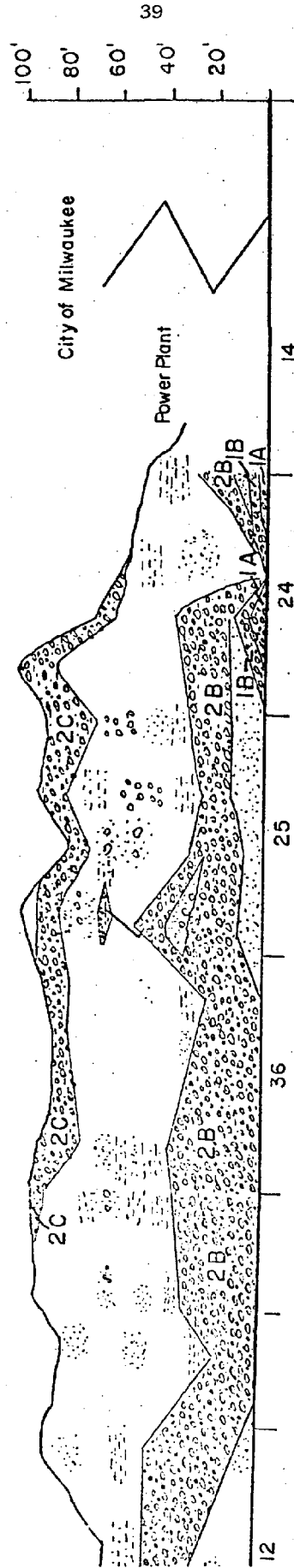
Section 14, T6N

At the south end of the section and north to the end of the reach (southern extent of Milwaukee Harbor breakwater) the bluff is protected by a revetment and north of that a breakwater around a power plant. Slopes are graded and there are no exposures. North of the power plant there are exposures but these were not examined because they are in reach 12 and this was not designated as critical.



T.5N.

T.6N.

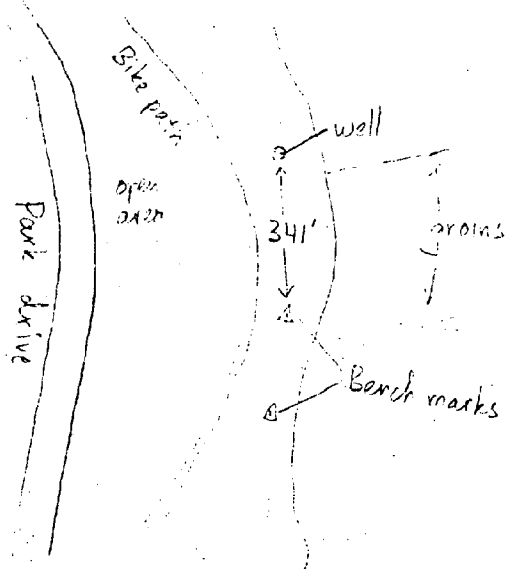
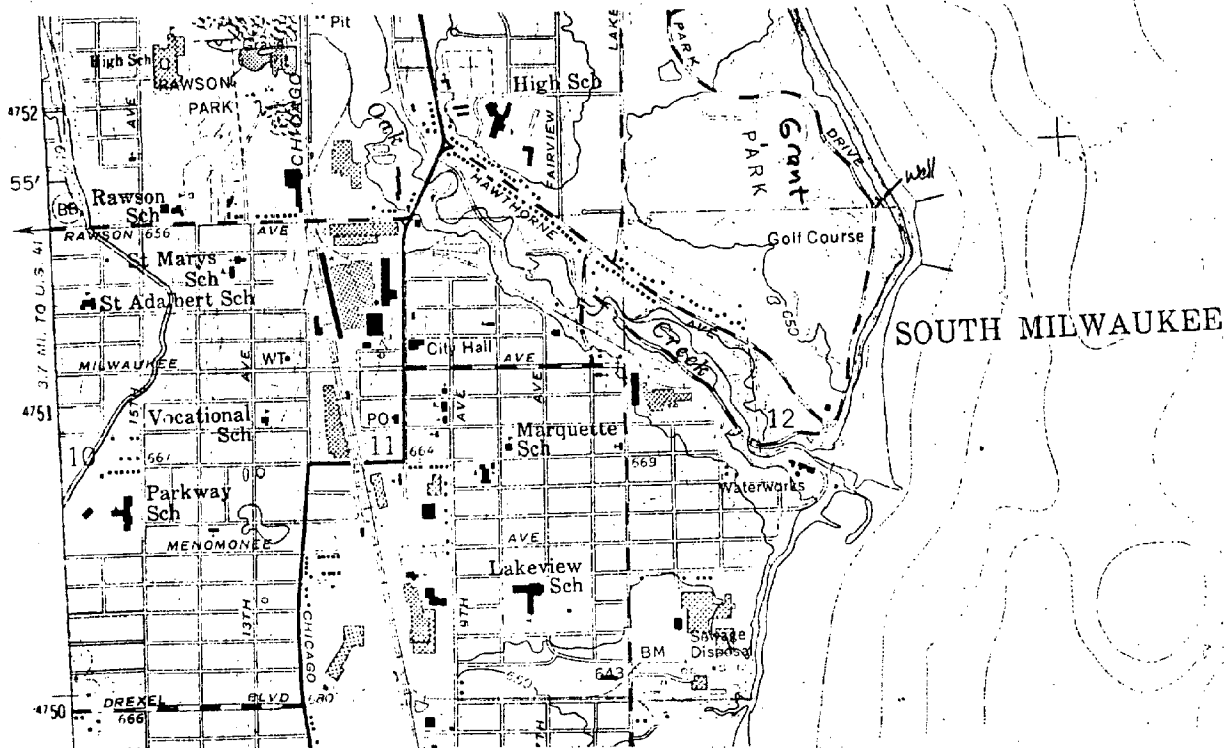


LEGEND

	SAND		SILT		COVERED OR INACCESSIBLE
	GRAVEL		CLAY		TILL
	SAND AND GRAVEL		CLAYEY SILT, SILTY CLAY		MIXED SEDIMENTS

Generalized longitudinal section showing bluff stratigraphy in Reach 8. Numbers along base of diagram are geographic (1 mile) sections.

GT-2, South Milw. Quad, Milw. Co.; Grant Park
 SW 1/4 / SE 1/4 / Sec. 1 / T. 5 N. / R. 22 E.



The well is 341 ft. from the
 northern bench mark on a bearing of
 N 24° E

Borehole: GT-2 Location: Grant Park, Milwaukee County, Sec. 12, T5N

Depth (feet)	Blow Counts (split spoon) Standard Penetration	Pocket Penetrometer	w_n %	γ_d (psf)	w_L %	I_p %	% Clay & Silt	% Clay & Silt	ϕ°	c (psf)	c (psf)	USCS class.
5												
10												
15												
20												
25												
30												
35												
40												
45												
50												
55												
60												

light
brown
sand

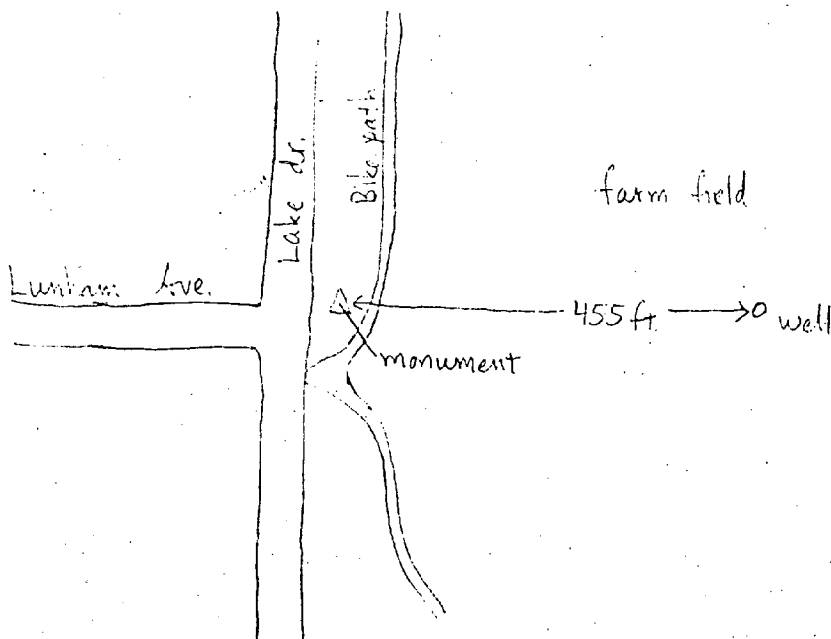
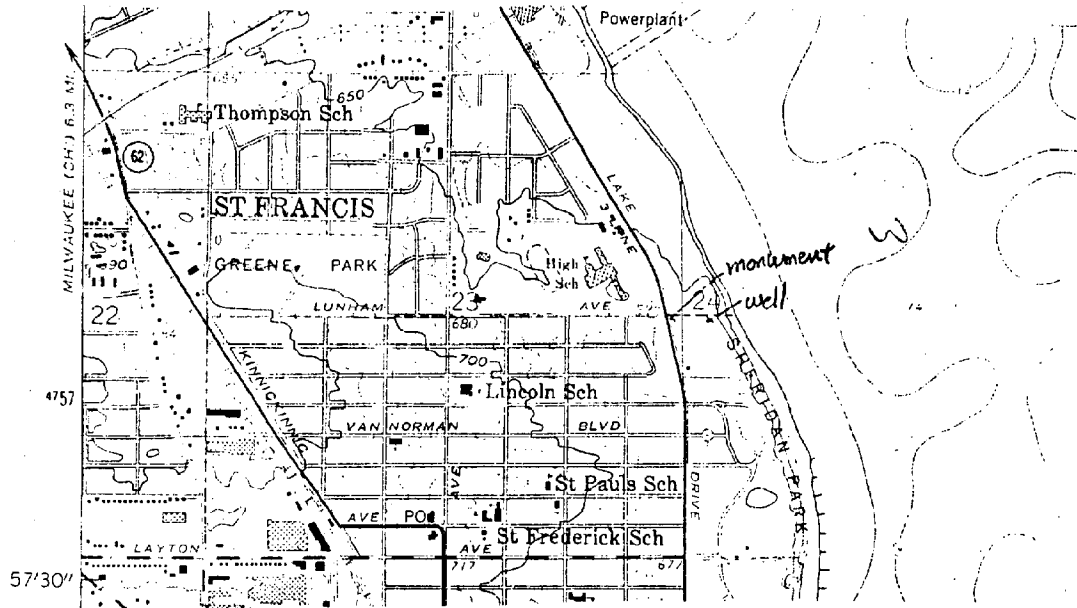
grey
silt

SP

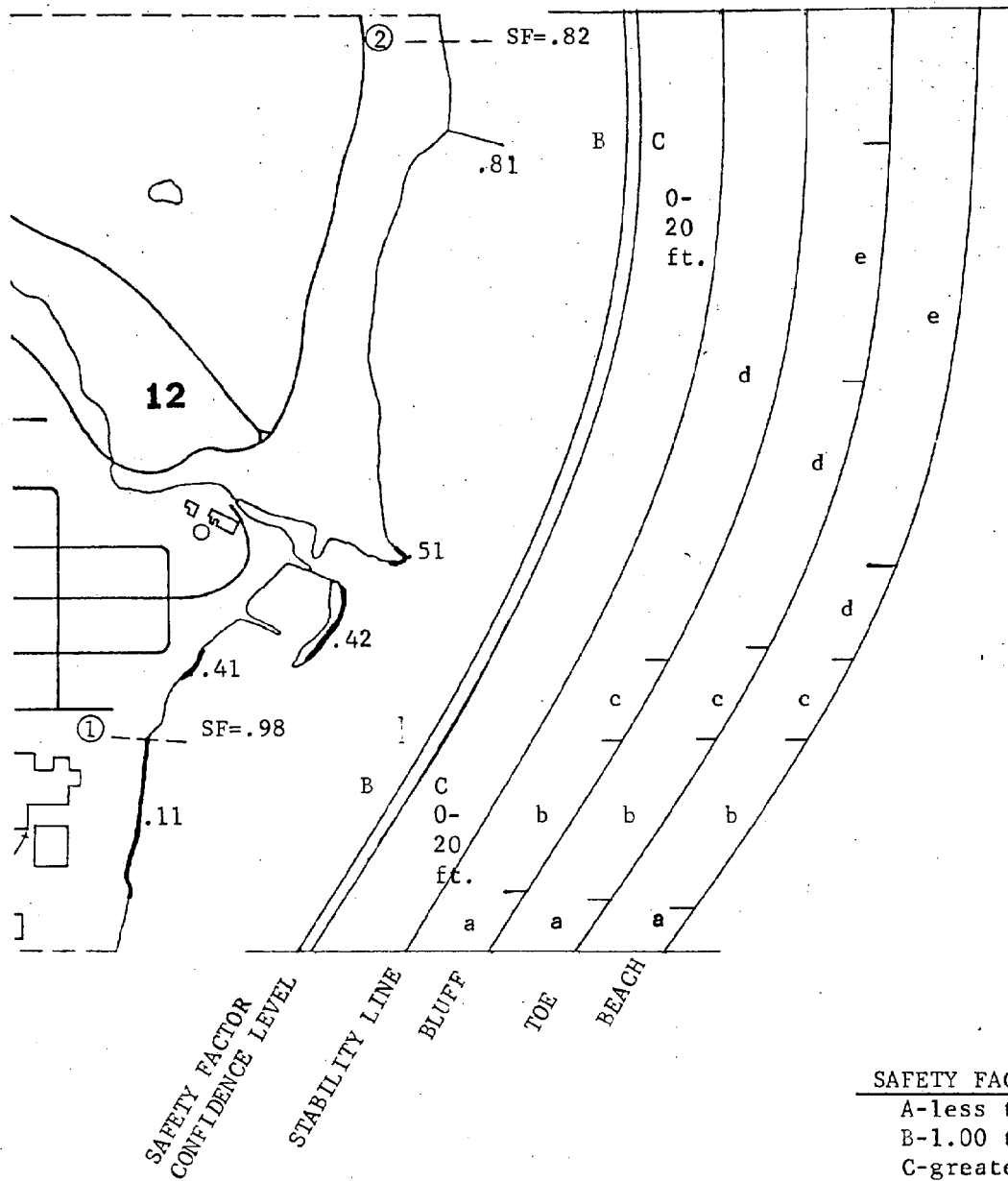
ML
CL-ML

GT-3, South Milw. Quad, Milw. Co., Sheridan Pk.

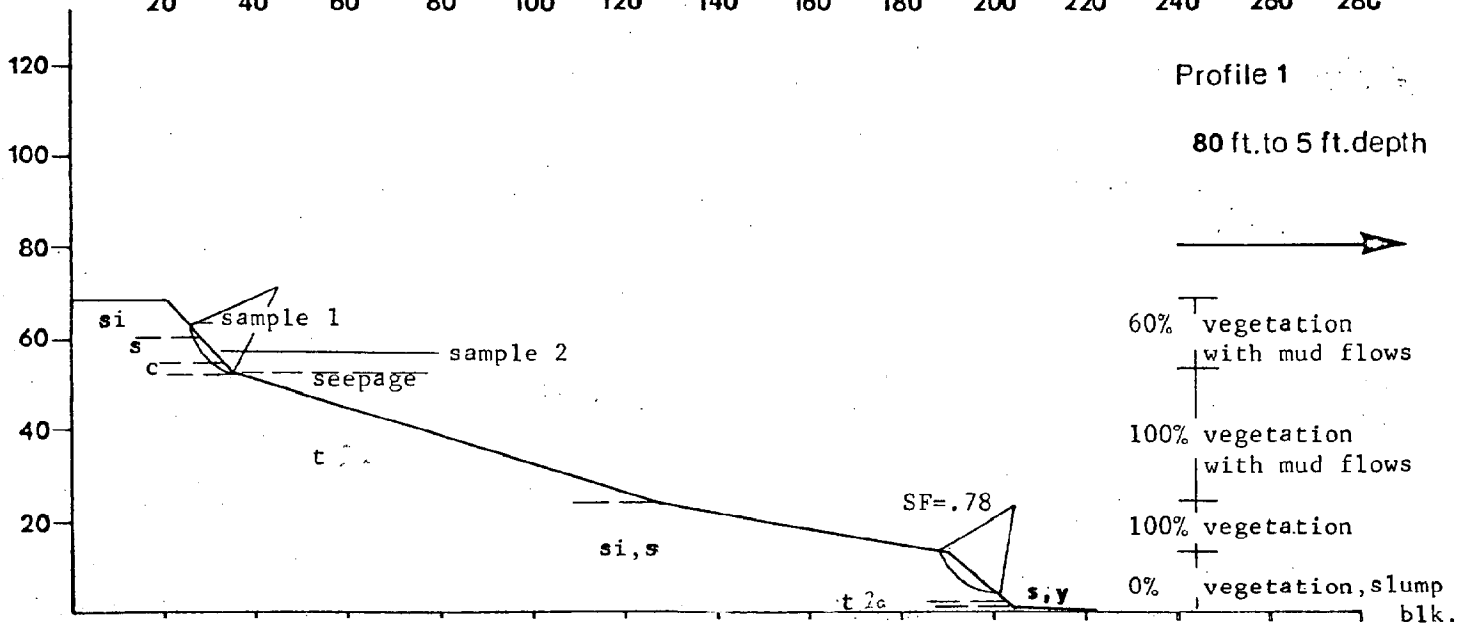
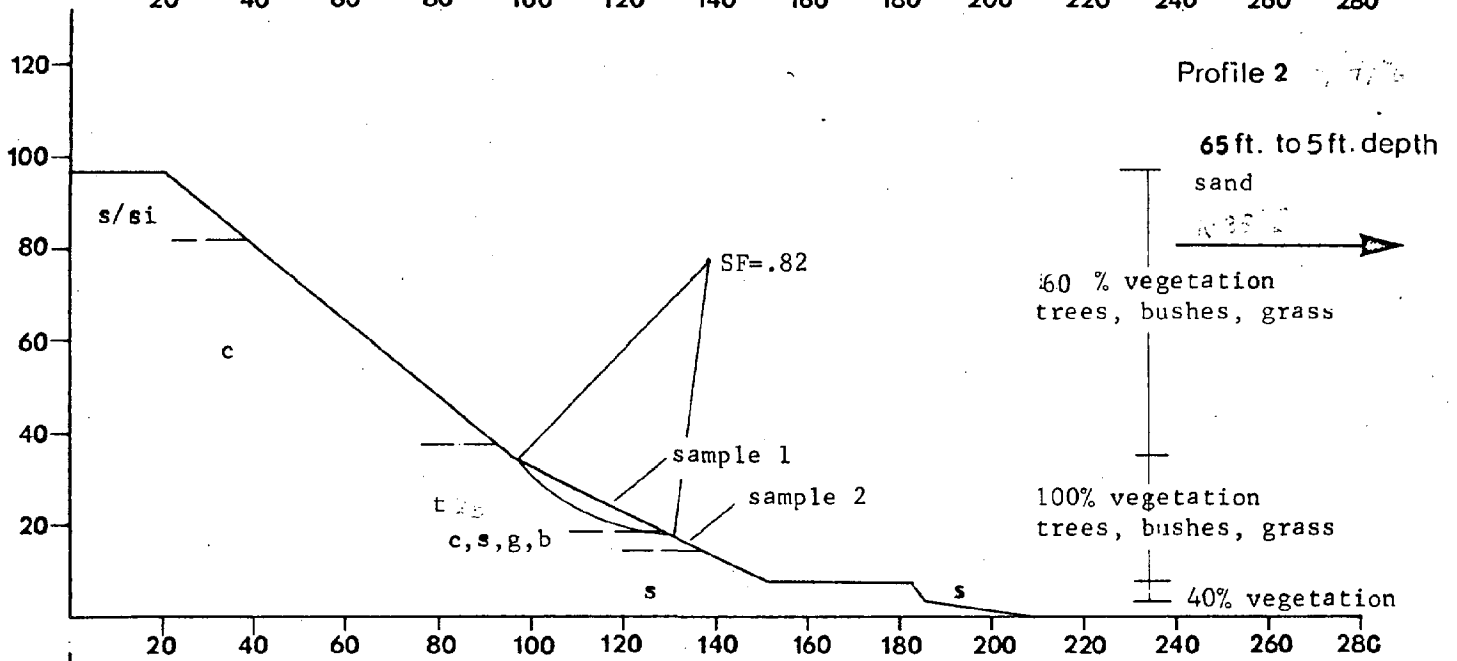
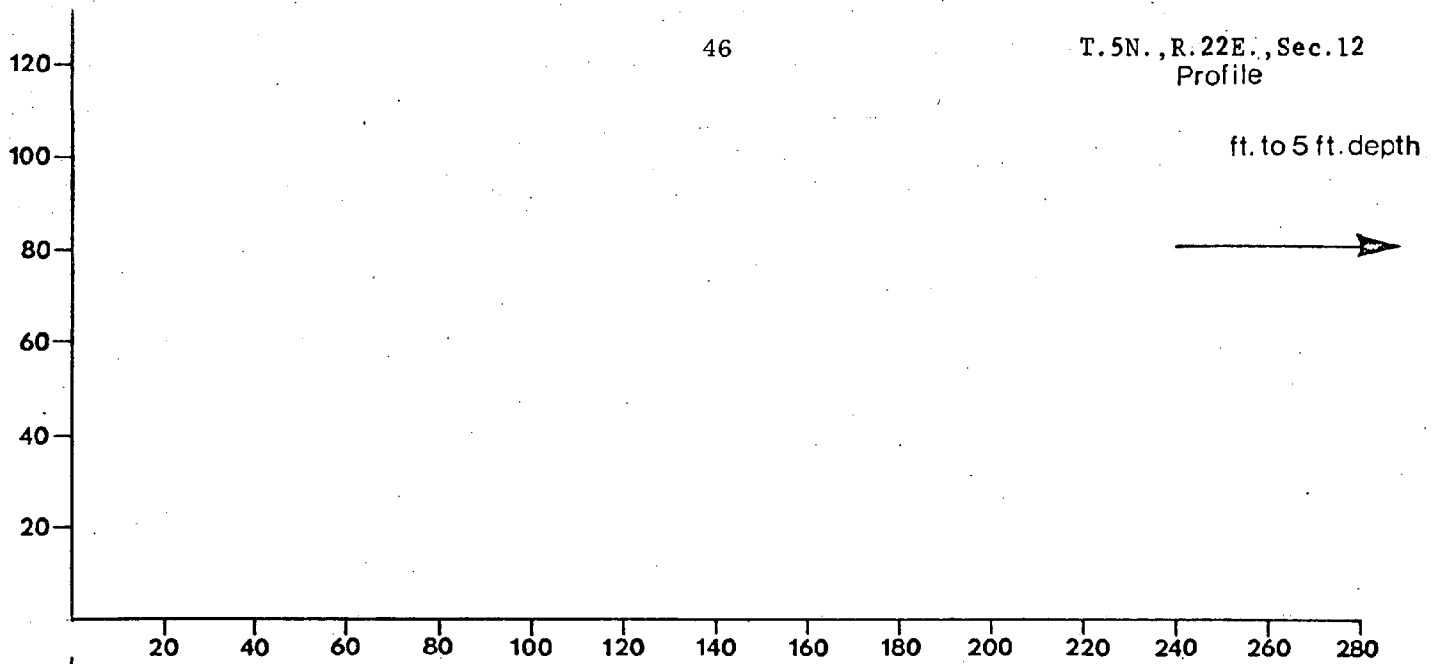
NE 1/4 / SE 1/4 / sec. 23 and NW 1/4 / SW 1/4 / sec. 24 / T. 6 N. / R. 22 E.

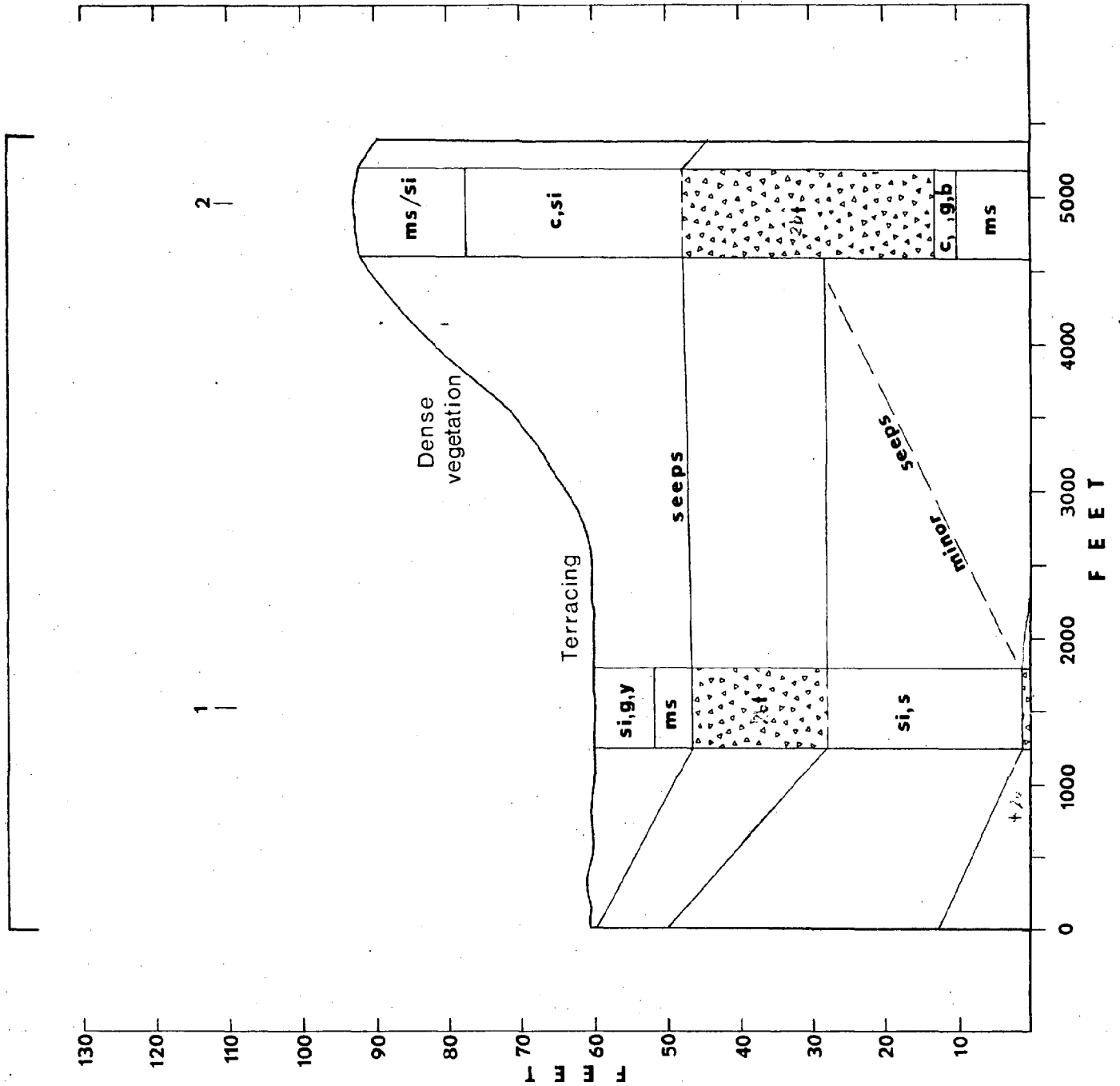


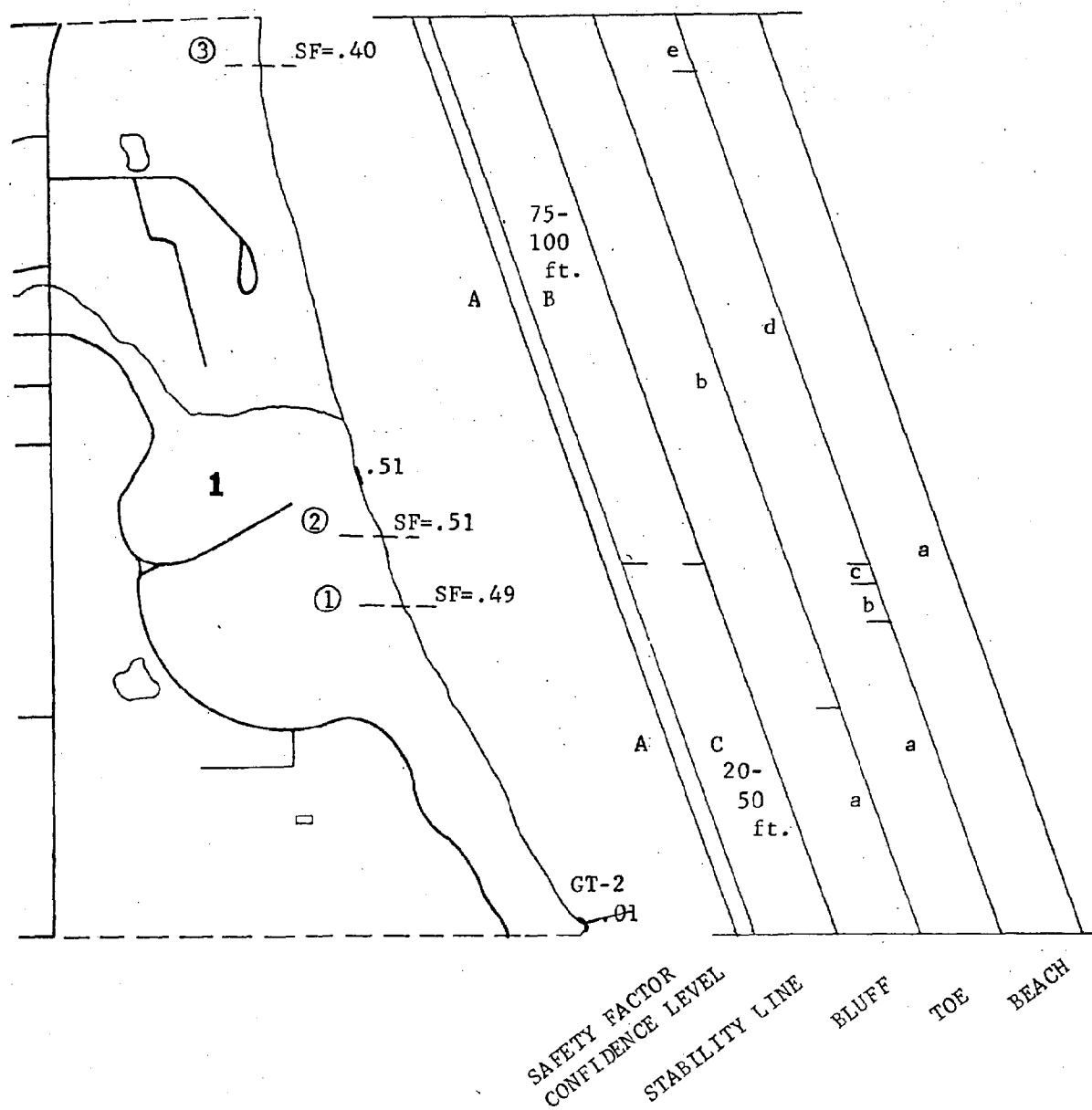
The well is 455' from
the monument on a bearing of
N 86° E



1. BLUFF	a-shallow slides	b-relatively stable - protected by revetment	c-shallow slides	d-relatively stable protective struc- ture and wide beach graded and wooded slopes responsible
2. TOE	a-in place	b-broken concrete nothing natural visible	c-toe material not visible slope graded	d-toe material not visible
	e-in place sand and boulder layer			
3. BEACH	a-5-20 ft. sand	b-concrete revetment no beach	c-+20 ft.	d-concrete revetment no beach
	e-+20 ft. sand			





SAFETY FACTOR

A-less than 1.00

B-1.00 to 1.25

C-greater than 1.25

CONFIDENCE LEVEL

A-boreholes

(high confidence)

B-near boreholes

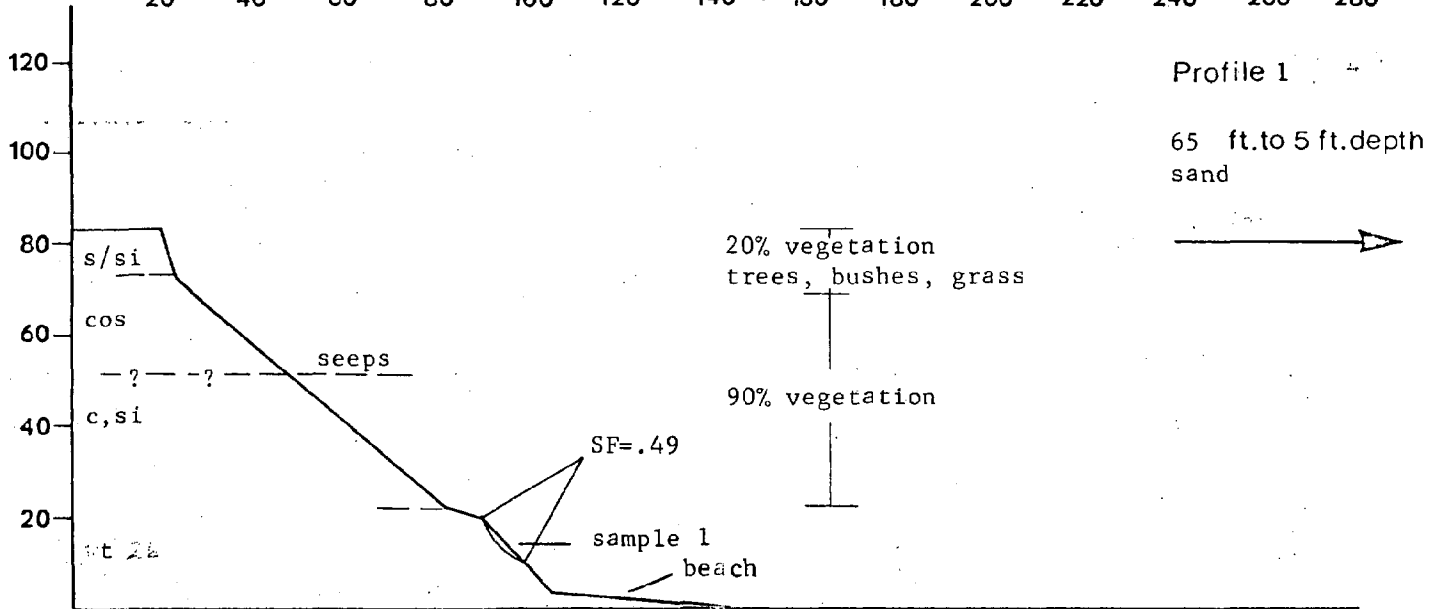
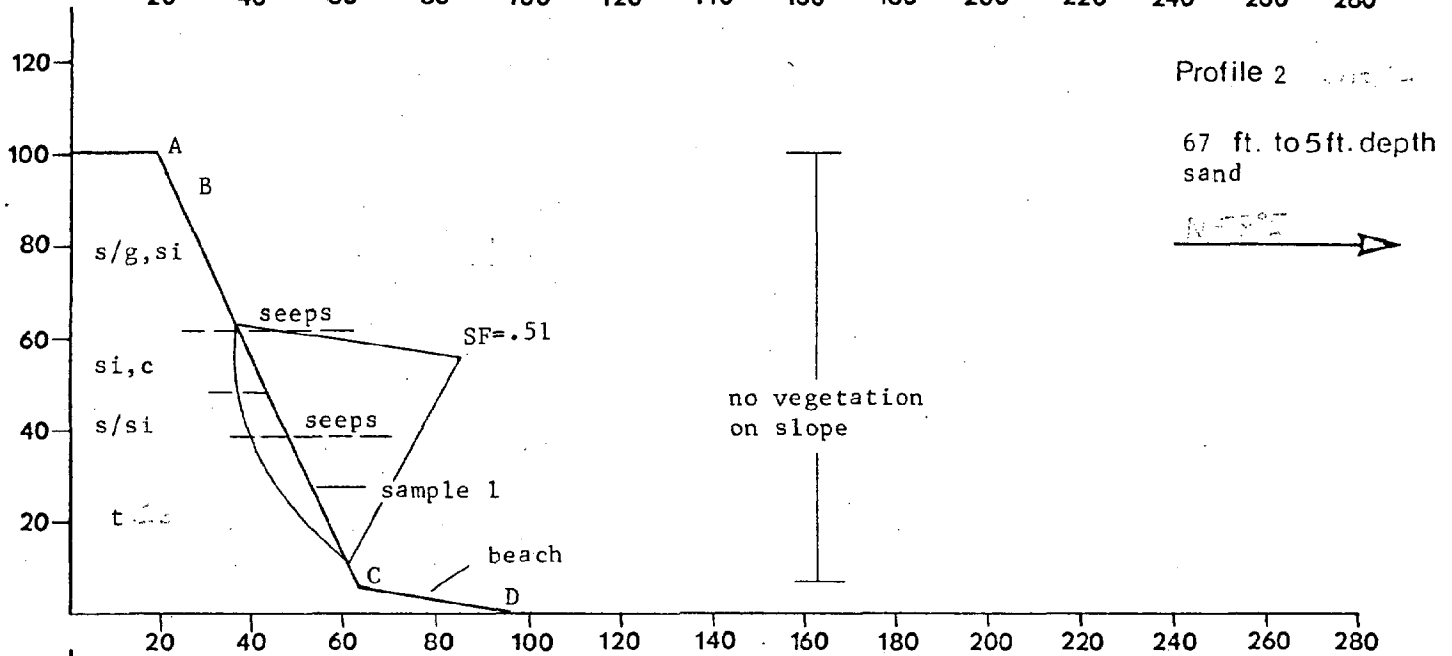
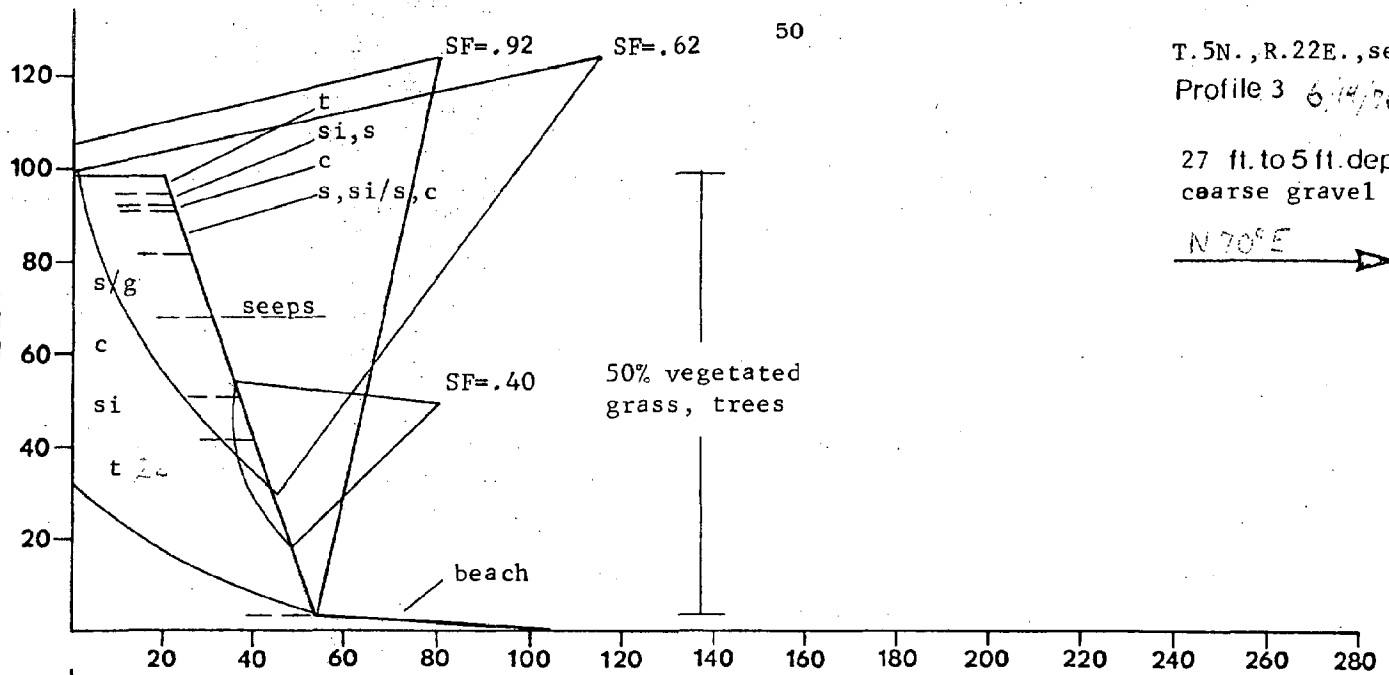
stratigraphy visible

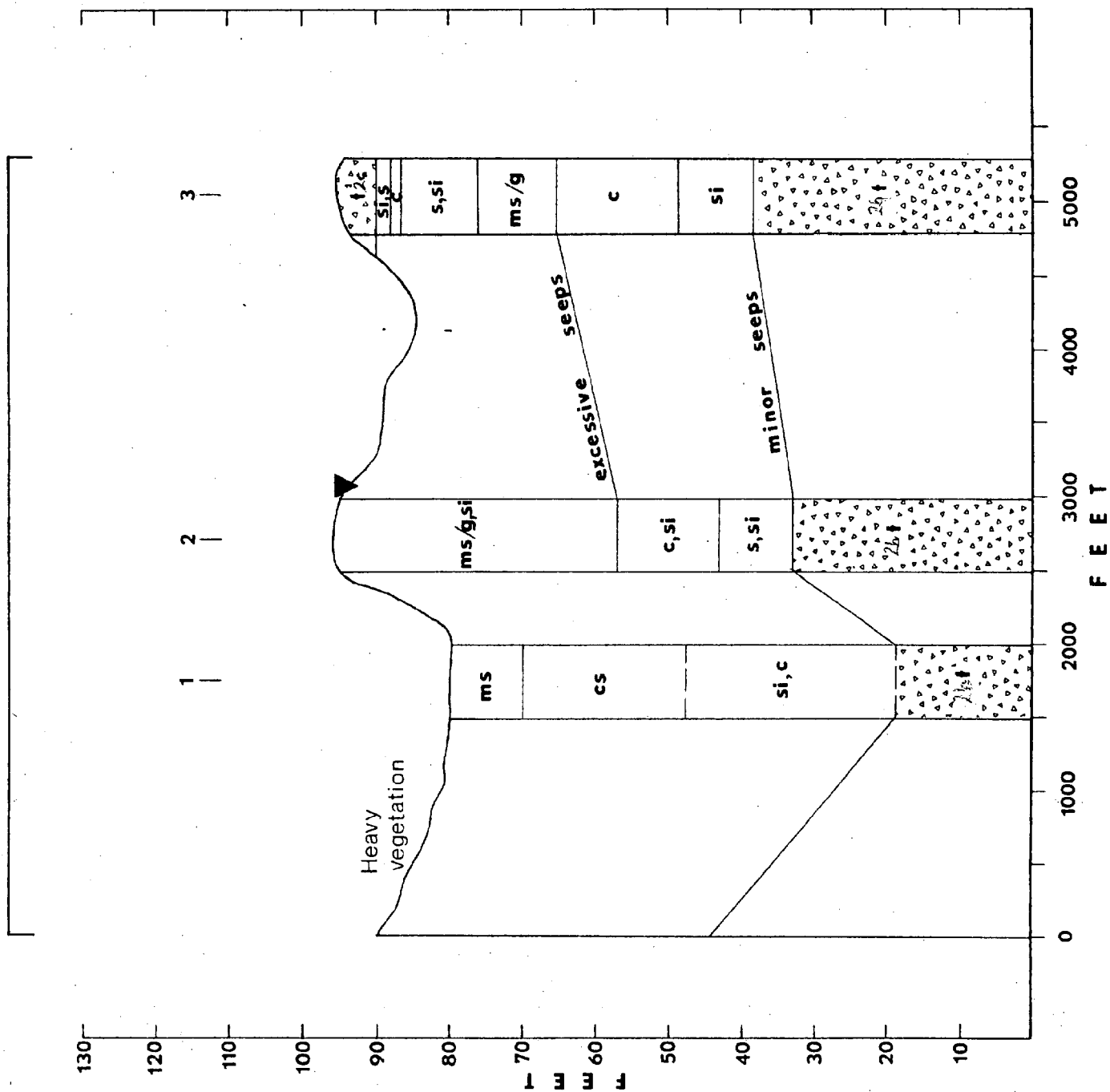
C-no stratigraphy

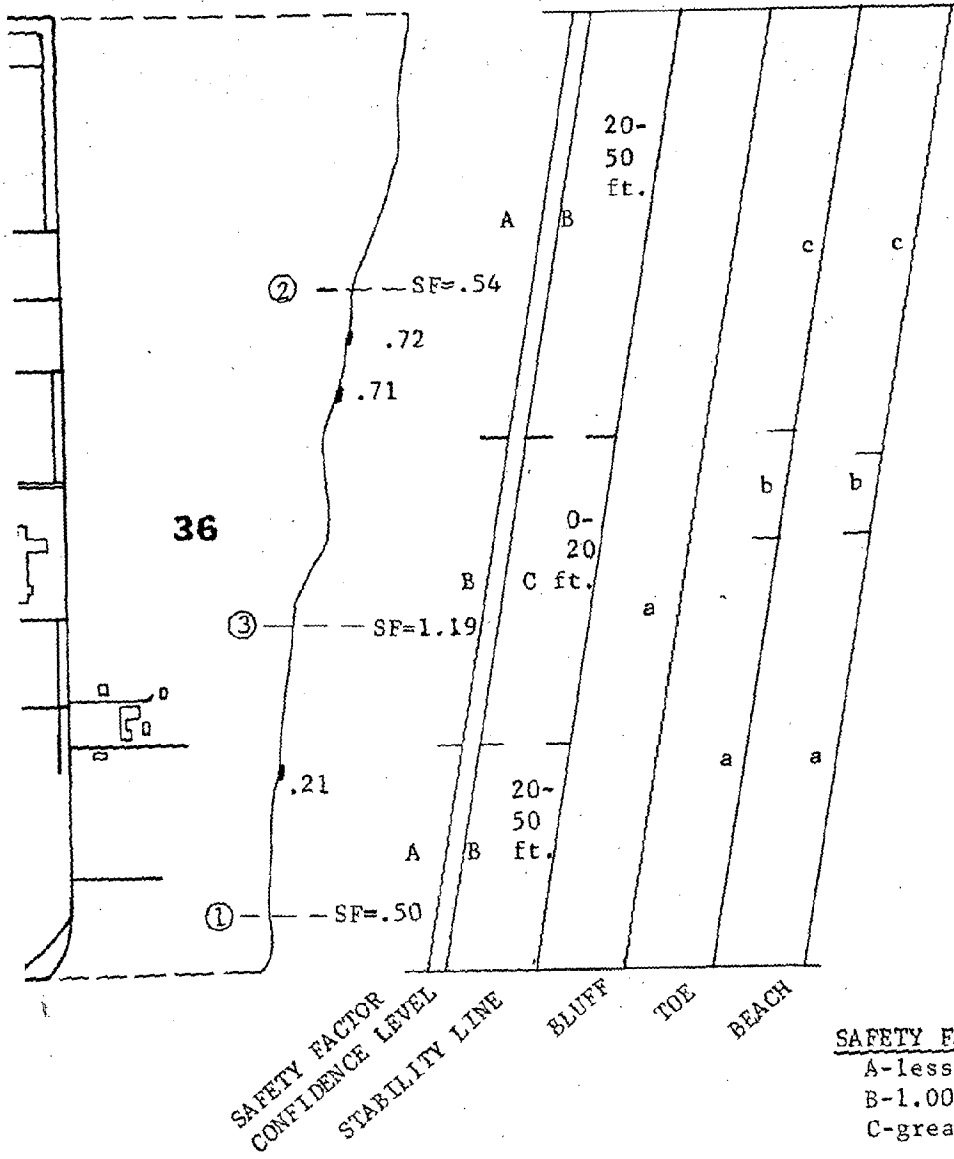
visible (low

Confidence)

1. ELUFF	a-stable vegetated, no recent failures	b-primarily slides, several shallow slumps		
2. TOE	a-sand with a tree, bush and grass -cover in place	b-slumped silt, sand with pebbles, cobbles and boulders -mudflows throughout	c-sand, in place	d-slumped material
3. BEACH	a- +20 ft. cobbles and pebbles grading into sand			





SAFETY FACTOR

- A-less than 1.00
- B-1.00 to 1.25
- C-greater than 1.25

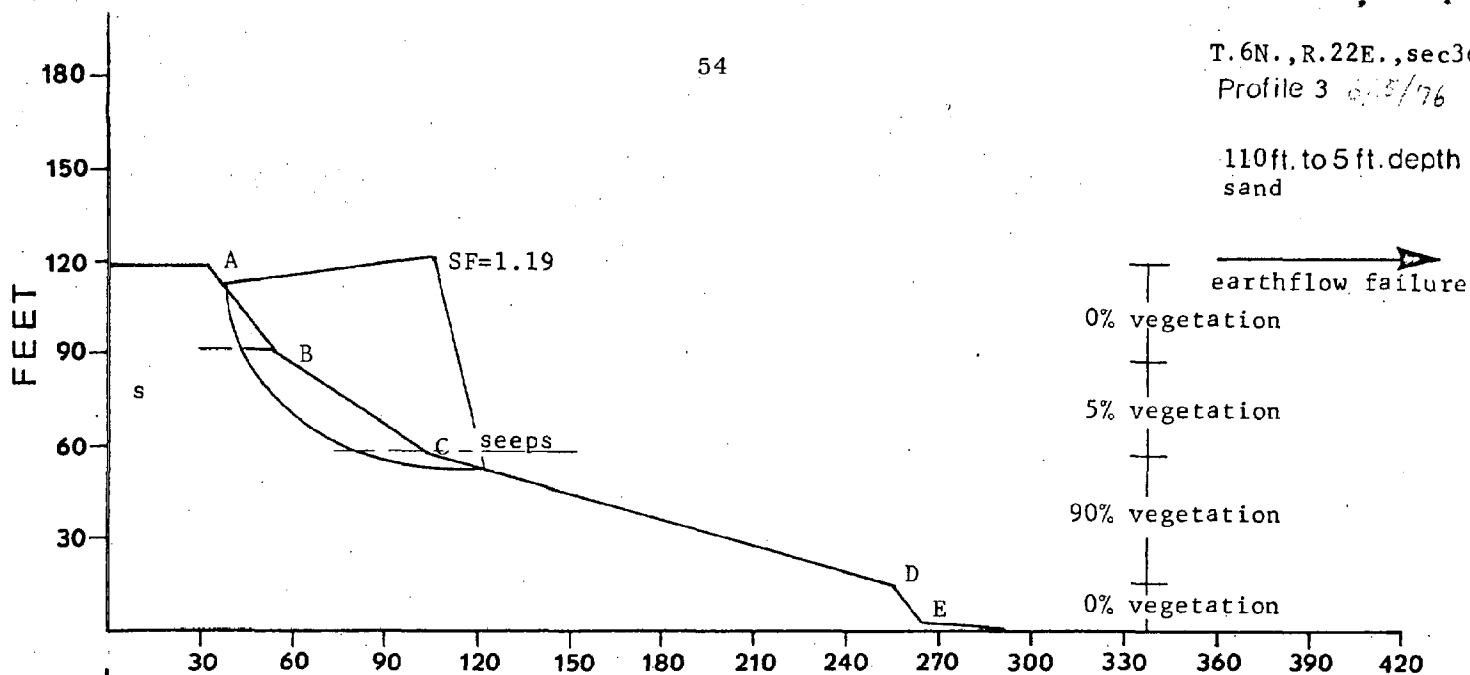
CONFIDENCE LEVEL

- A-boreholes (high confidence)
- B-near boreholes stratigraphy visible
- C-no stratigraphy visible (low confidence)

1. BLUFF	a-the entire section has shallow slides with the exception of several major slump blocks, flows and ravines due to spring.		
2. TOE	a-slumped silt, soil and till	b-in place till	c-slumped silt, sand
3. BEACH	a-greater than 20 ft., sand with pebbles and cobbles at high wave line.	b-5 to 20 ft., sand and pebbles, cobbles at high wave line	c-greater than 20 ft., sand with pebbles and cobbles at high wave line

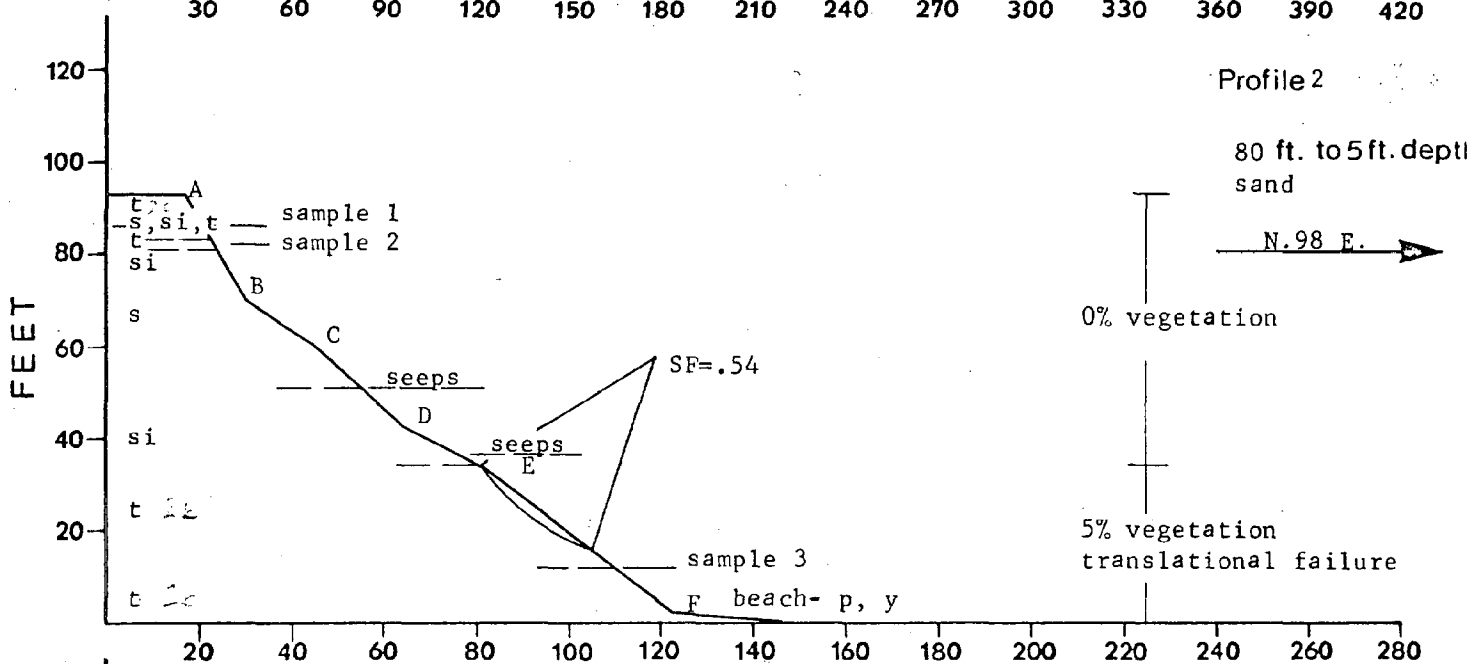
T. 6N., R. 22E., sec 30
Profile 3 6/5/76

110 ft. to 5 ft. depth
sand



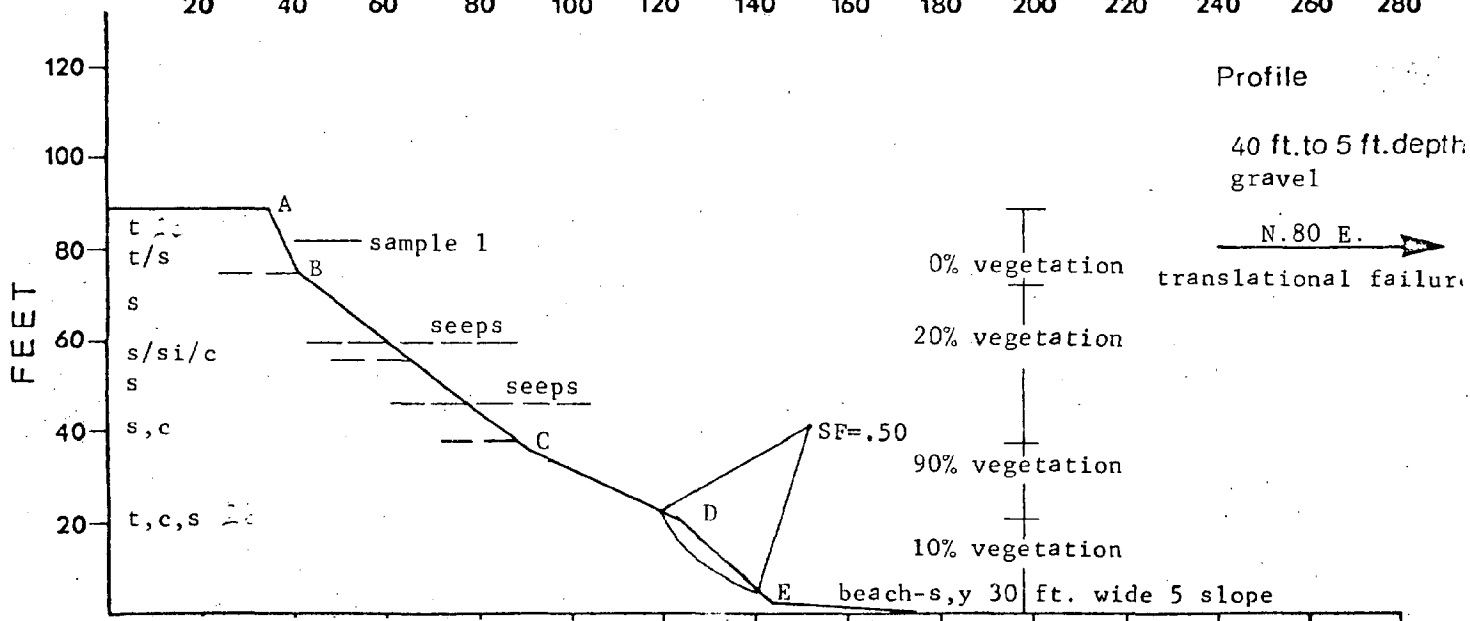
Profile 2

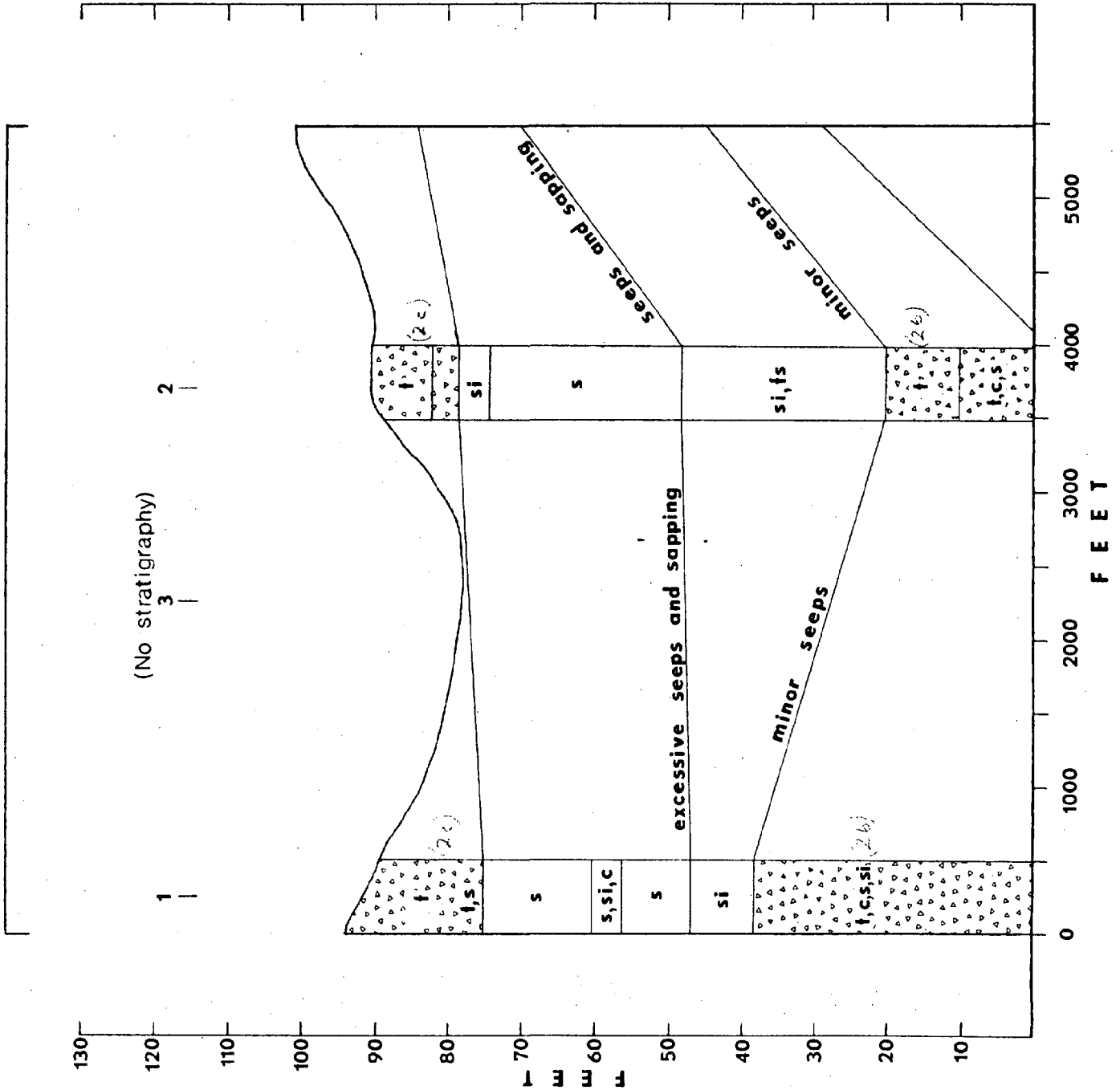
80 ft. to 5 ft. depth
sand

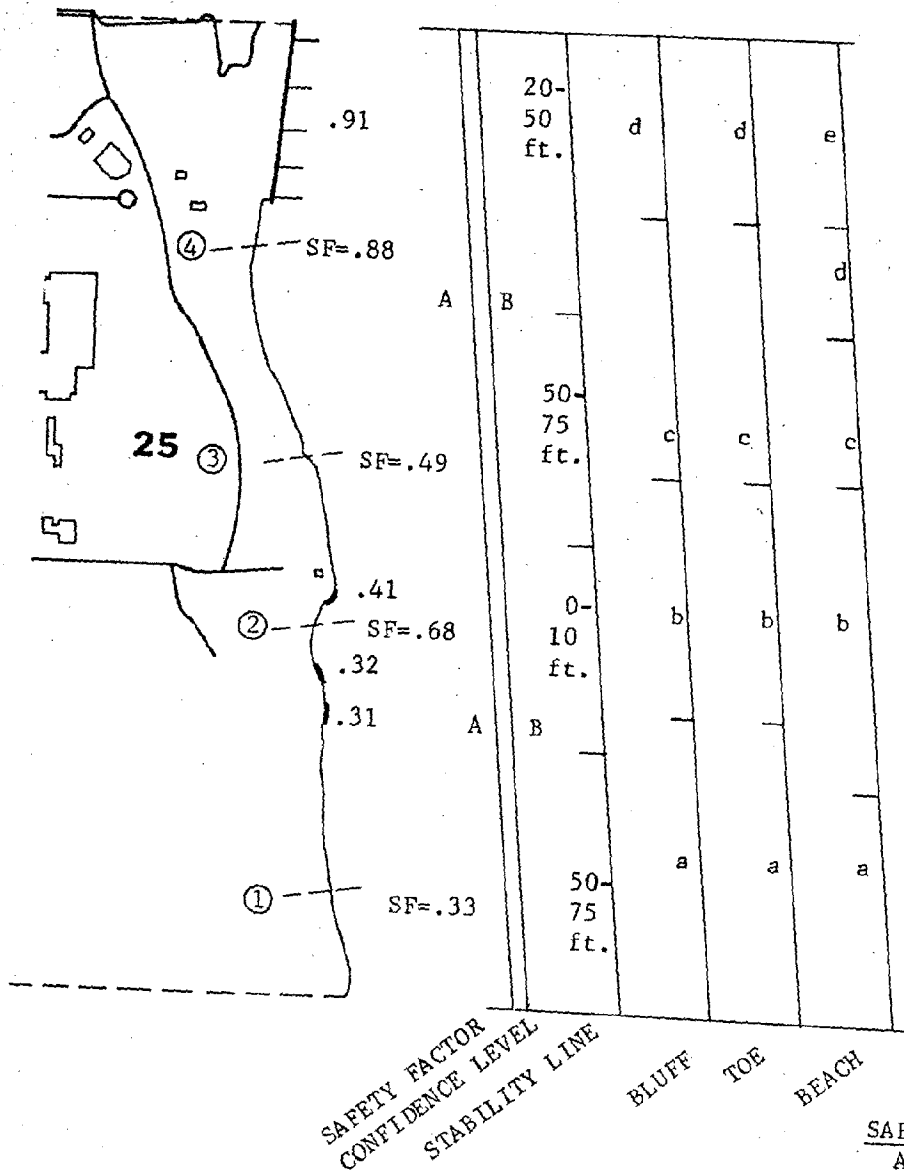


Profile

40 ft. to 5 ft. depth
gravel





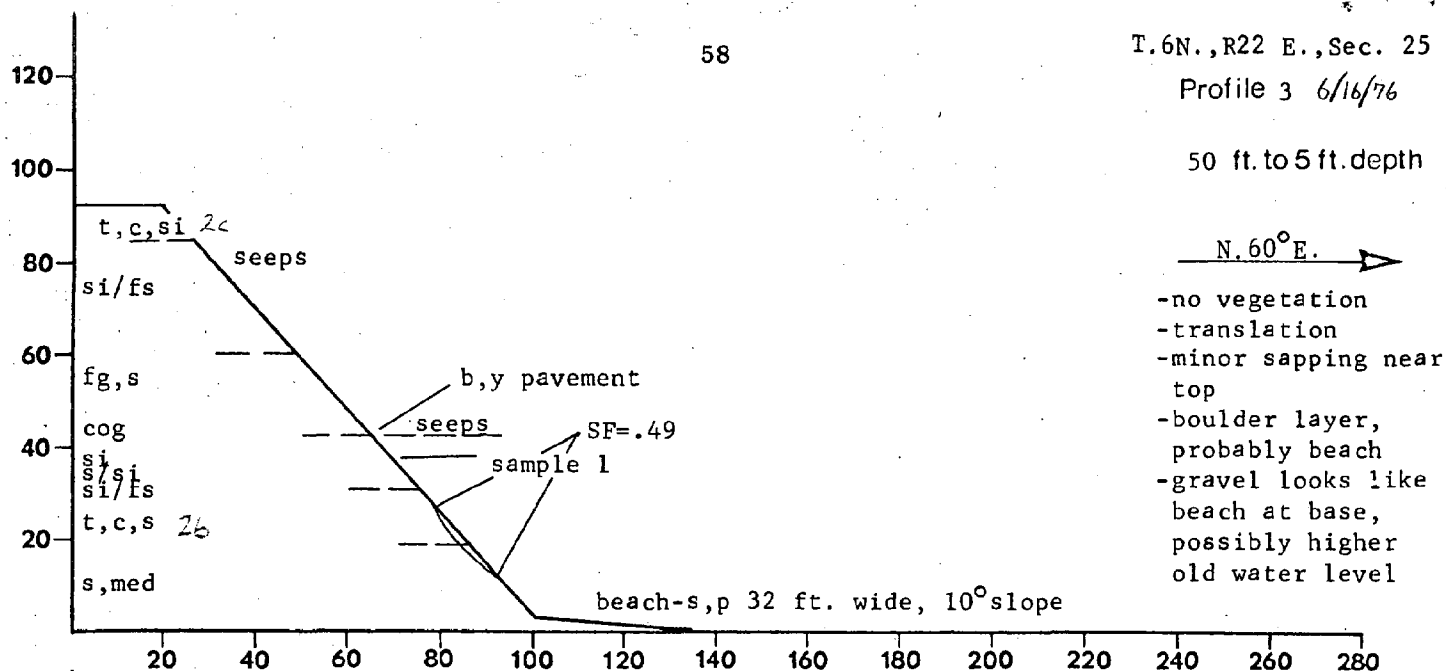


SAFETY FACTOR
 A-less than 1.00
 B-1.00 to 1.25
 C-greater than 1.25

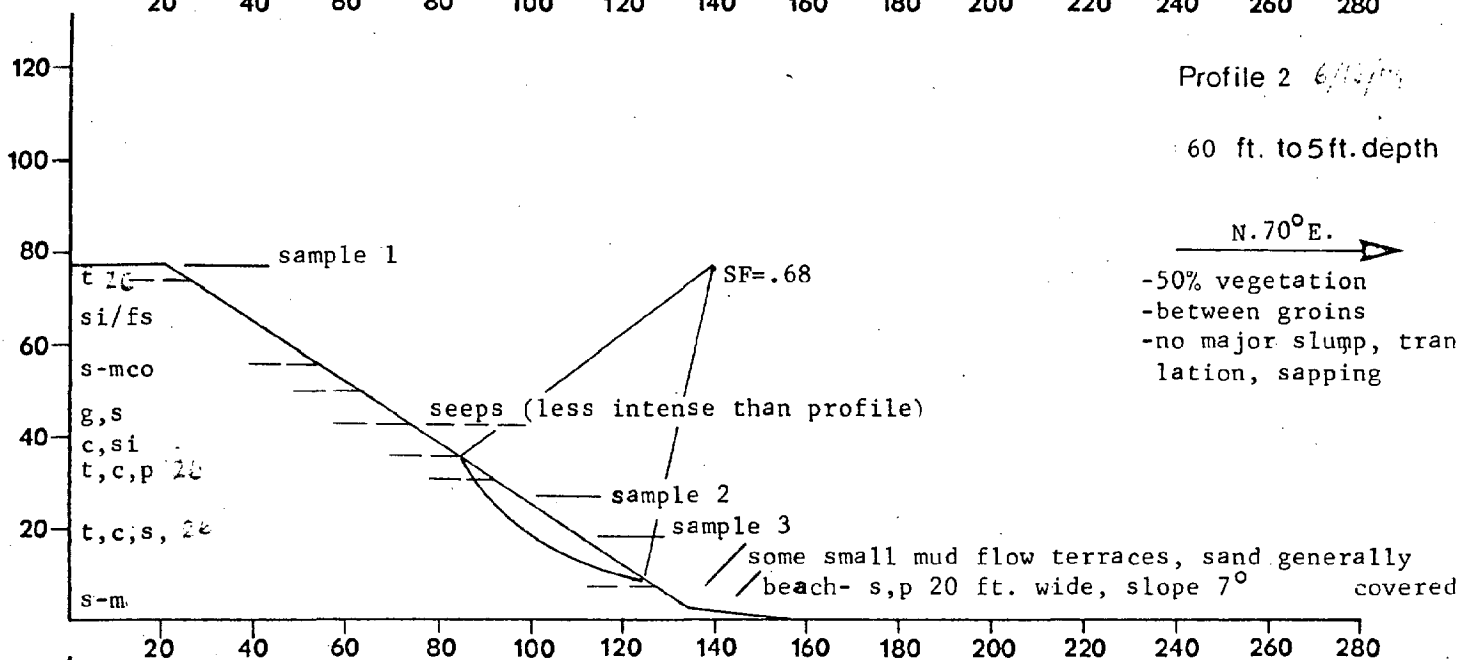
CONFIDENCE LEVEL
 A-boreholes (high confidence)
 B-near boreholes stratigraphy visible
 C-no stratigraphy visible (low confidence)

1. BLUFF	a-few large slumps, major seeps cause deep ravines due to sapping, excellent exposure	b-affected by structures, slopes more vegetated (50% grass), less sapping more flow (some flow terraces at base), a few slumps	c-few slumps, clean slope, no vegetation less sapping than southern part probably due to till cap, many cuts due to surface runoff	d-thick vegetation, more gentle slope, trees cover nearly 100 %
2. TOE	a-25% undercutting in sand, remainder thin flow, no vegetation, slide debris, mainly till, 6 to 15 ft., medium sand at base	b-sand not exposed, flow terraces of till and lacustrine silt, vegetated 6 to 15 ft., medium sand at base	c-25% sand exposed, remainder is unvegetated, fresh flow debris, till, silt, 6 to 15 ft., medium sand at base	d-all flow debris, 100% vegetated, 6 to 15 ft., medium sand at base
3. BEACH	a-greater than 5 ft., pebbles at water's edge, sand to base of bluff	b-5 to 20 ft., pebbles at water's edge sand to base of bluff	c-greater than 20 ft., pebbles at water's edge, sand to bluff	d-5 to 20 ft., pebbles at water's edge sand to base of bluff
	e-20 ft., pebbles at water's edge, sand to base of bluff			

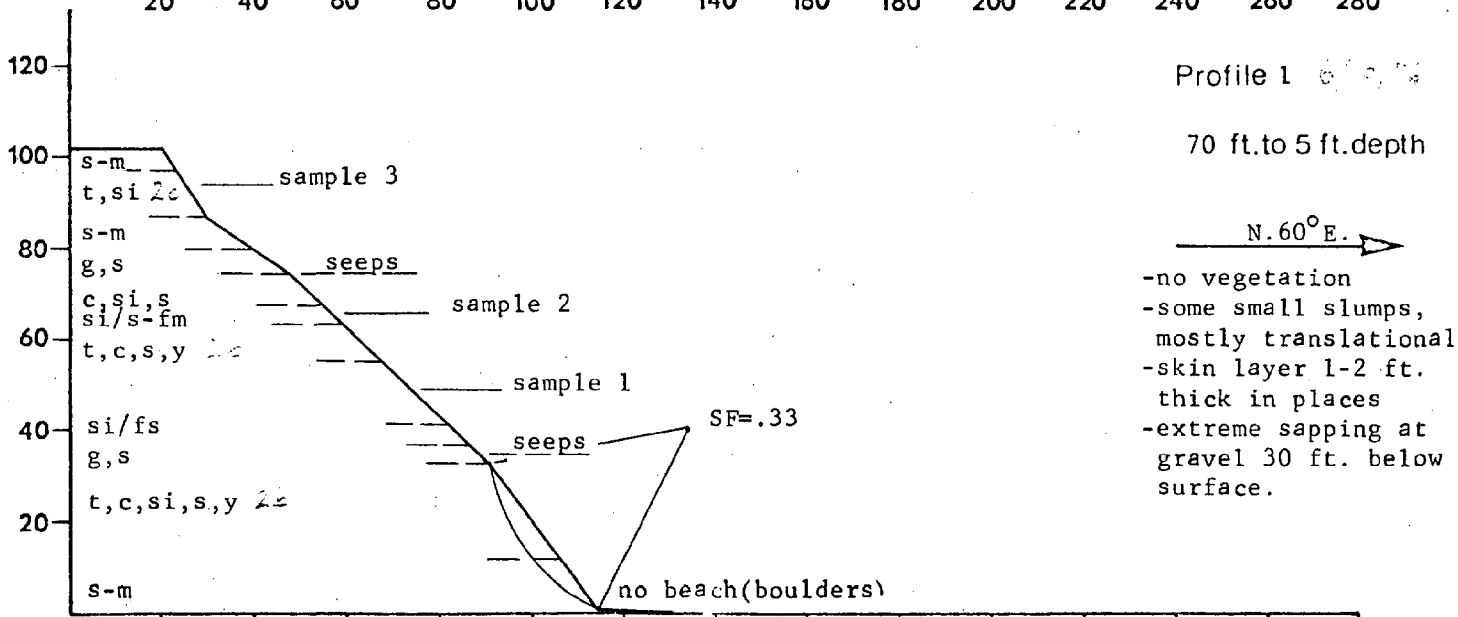
50 ft. to 5 ft. depth

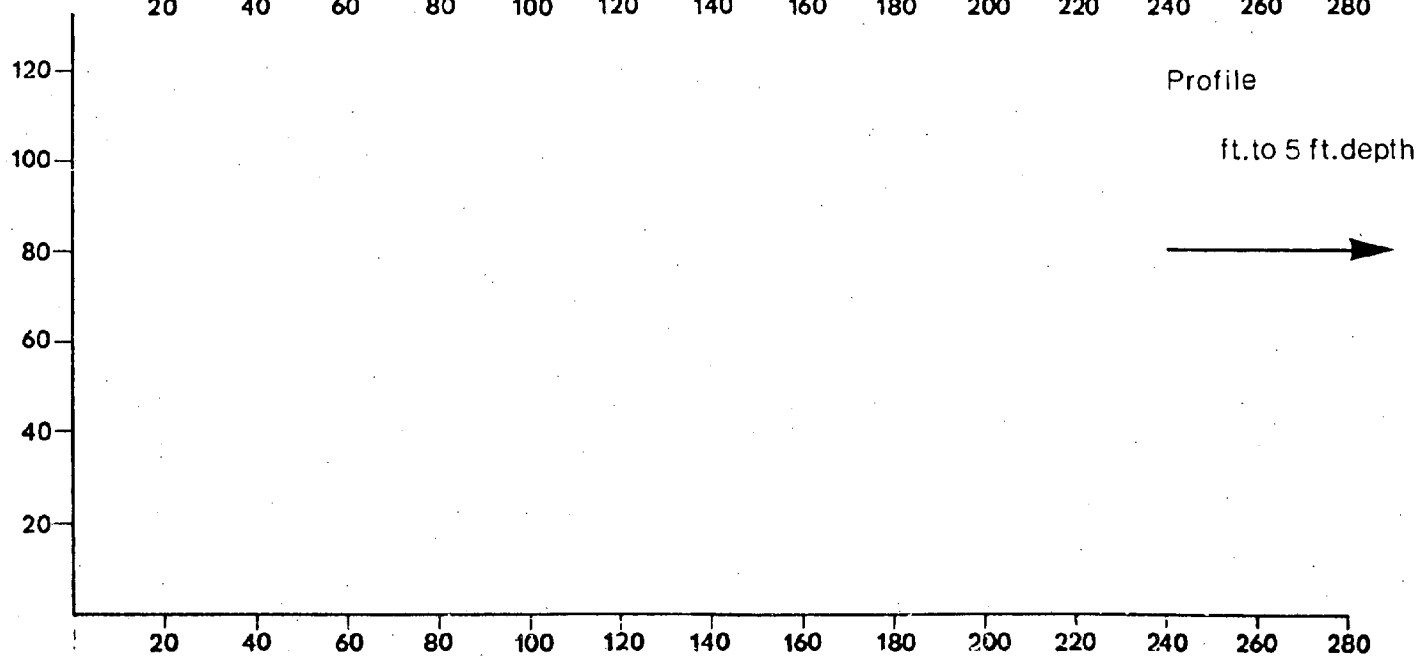
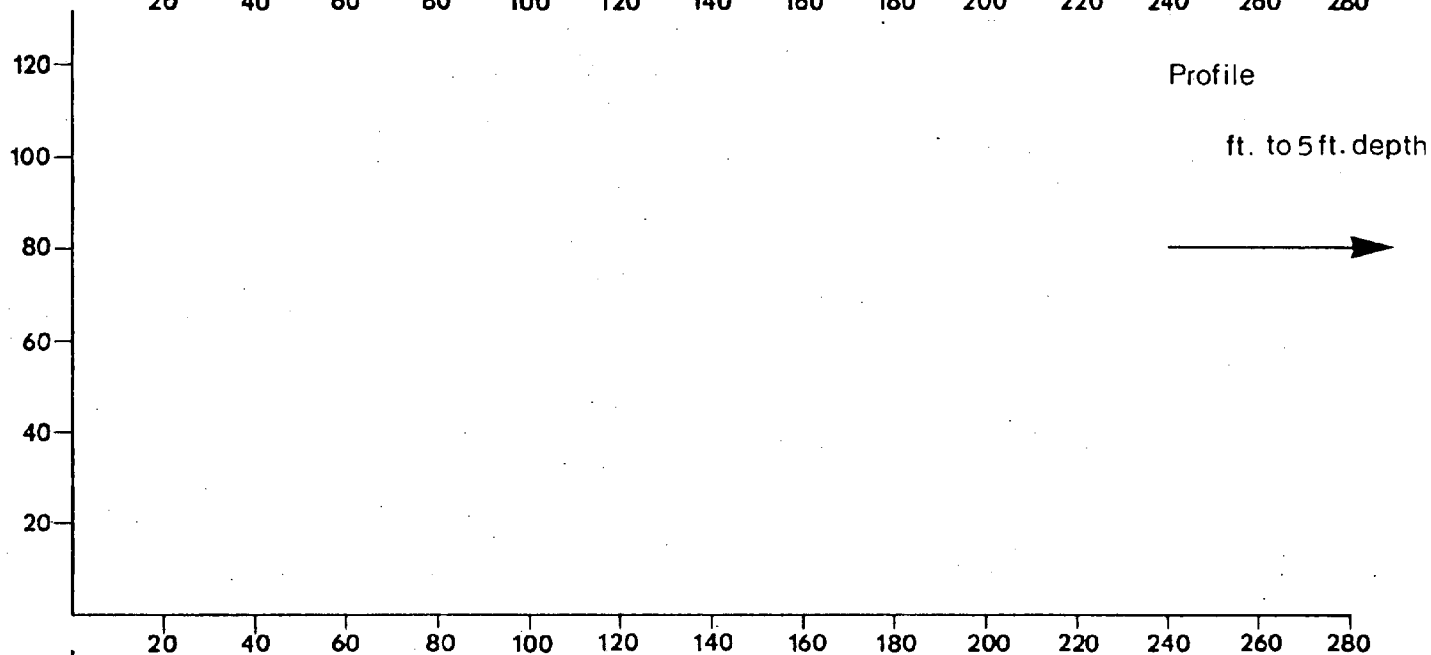
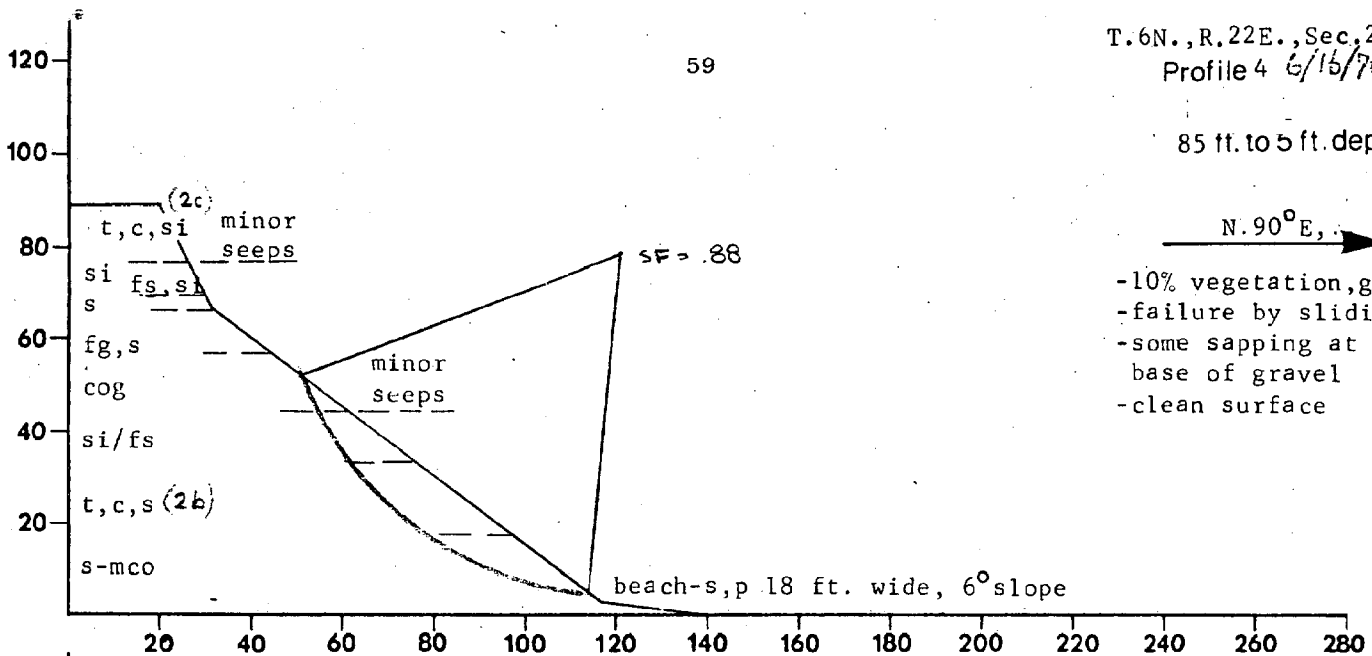


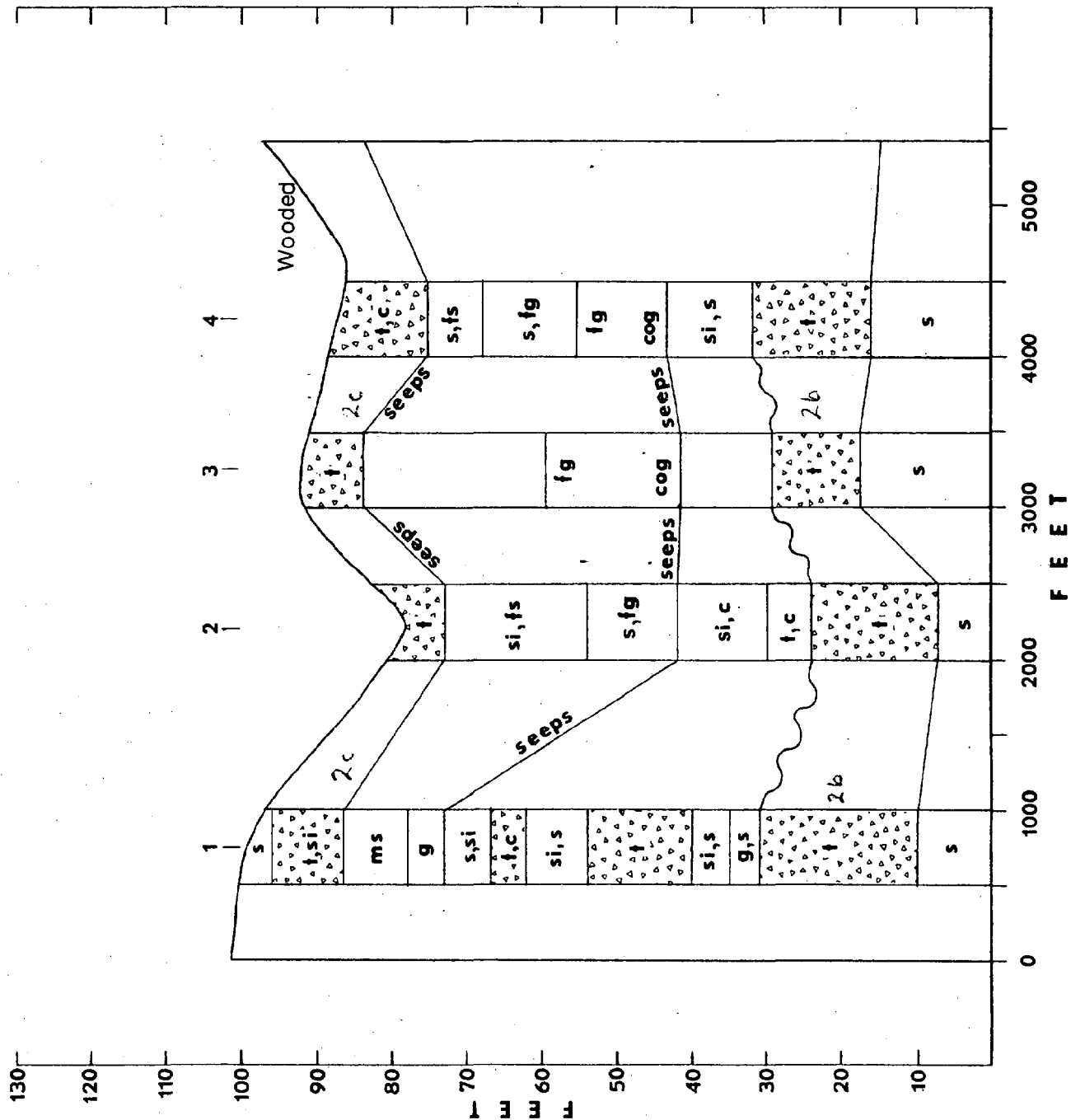
60 ft. to 5 ft. depth

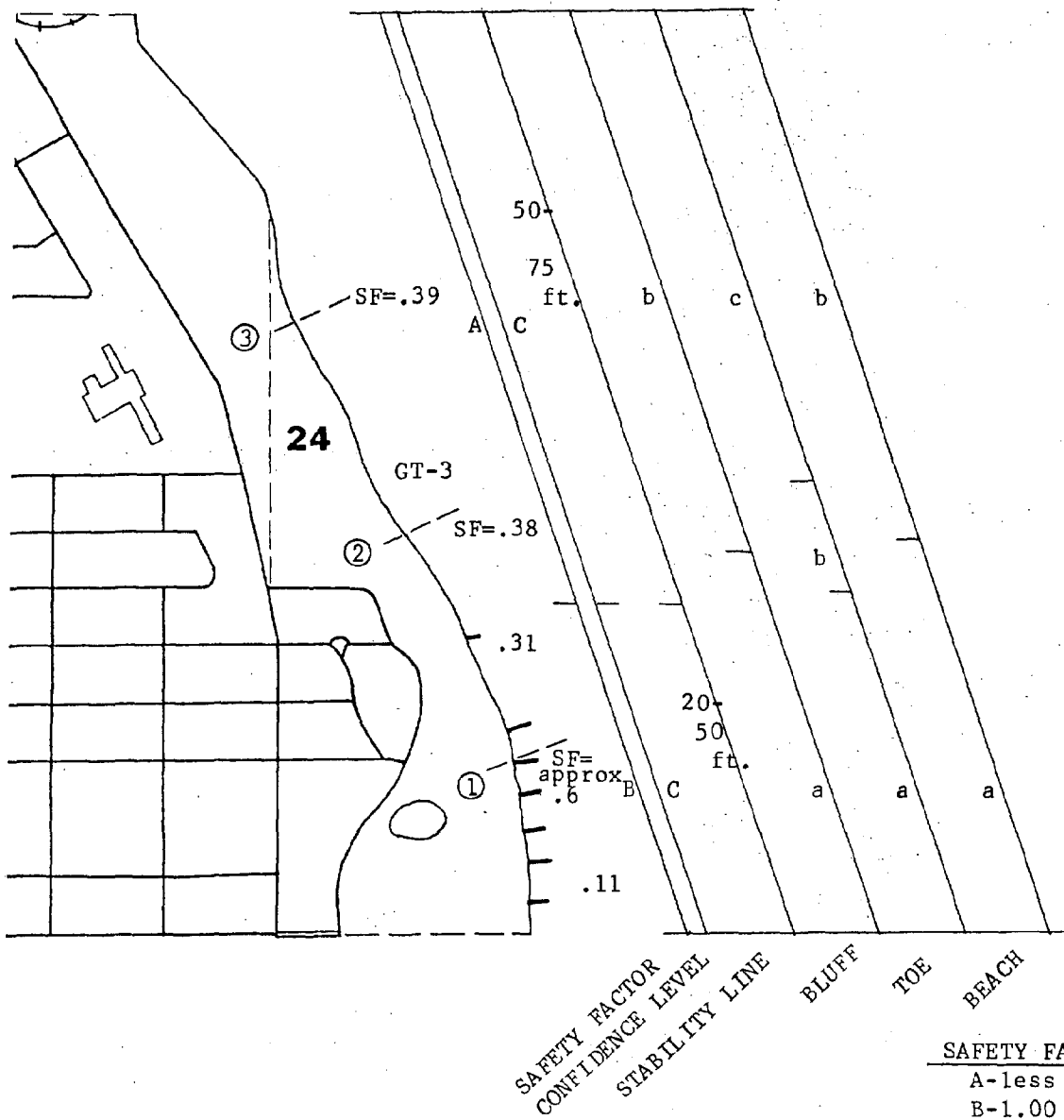


70 ft. to 5 ft. depth







SAFETY FACTOR

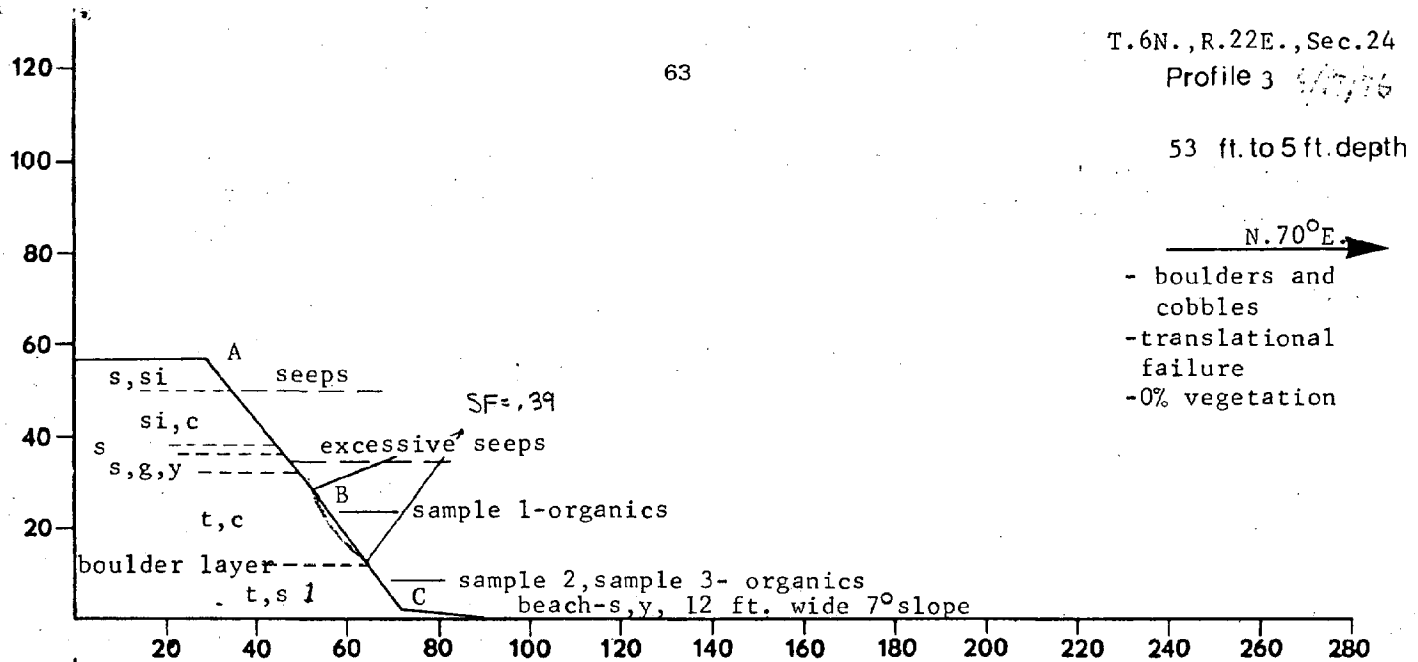
- A-less than 1.00
- B-1.00 to 1.25
- C-greater than 1.25

CONFIDENCE LEVEL

- A-boreholes (high confidence)
- B-near boreholes stratigraphy visible
- C-no stratigraphy visible (low confidence)

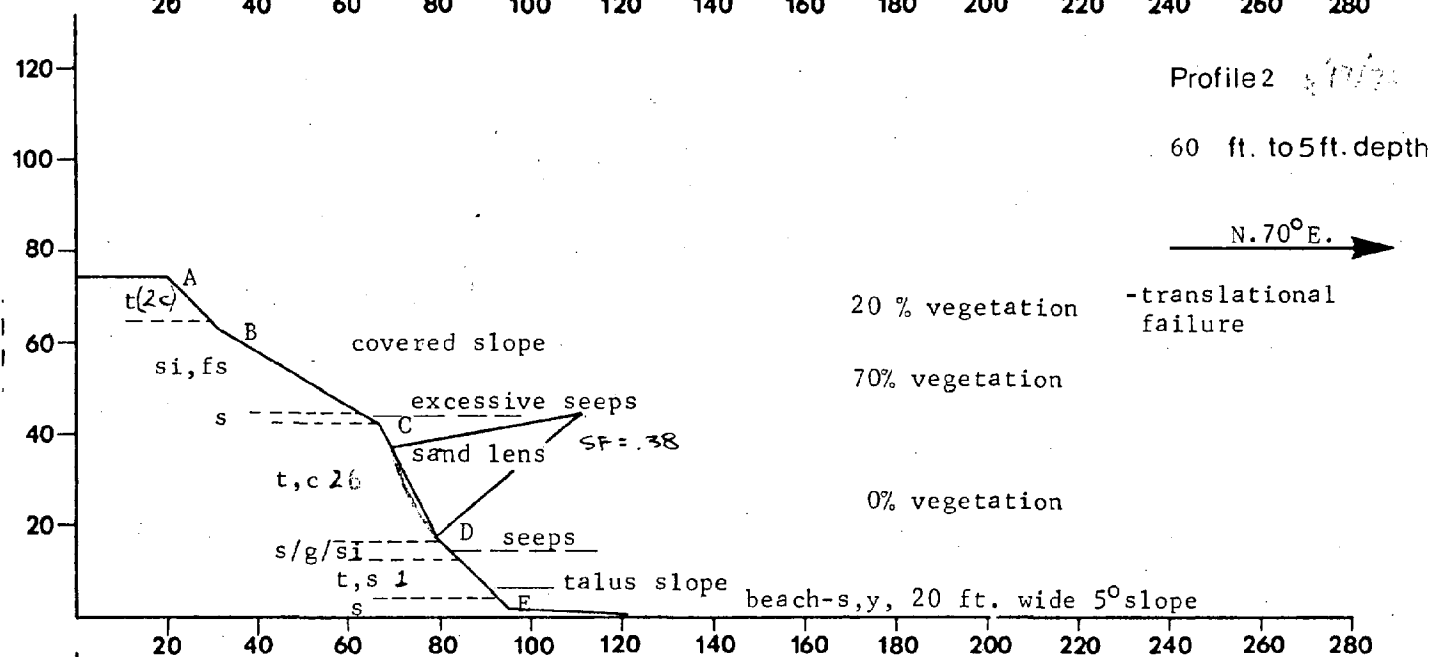
1. BLUFF	a-relatively stable no recent failures, well protected by groins	b-shallow slides translational movement only, very steep slope		
2. TOE	a-slumped till	b-in place sand	c-in place till	
3. BEACH	a-greater than 20 ft., sand	b-5 to 20 ft., sand and gravel with cobbles and boulders.		

53 ft. to 5 ft. depth



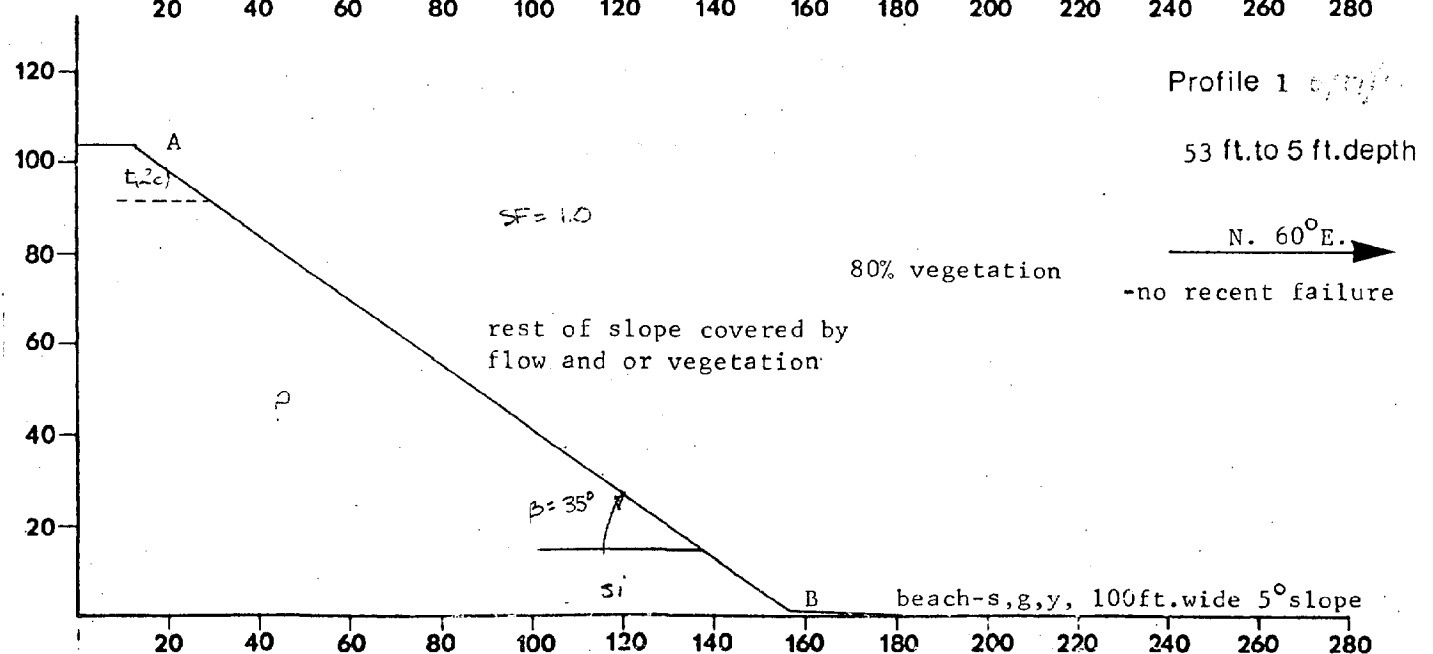
Profile 2 4/7/76

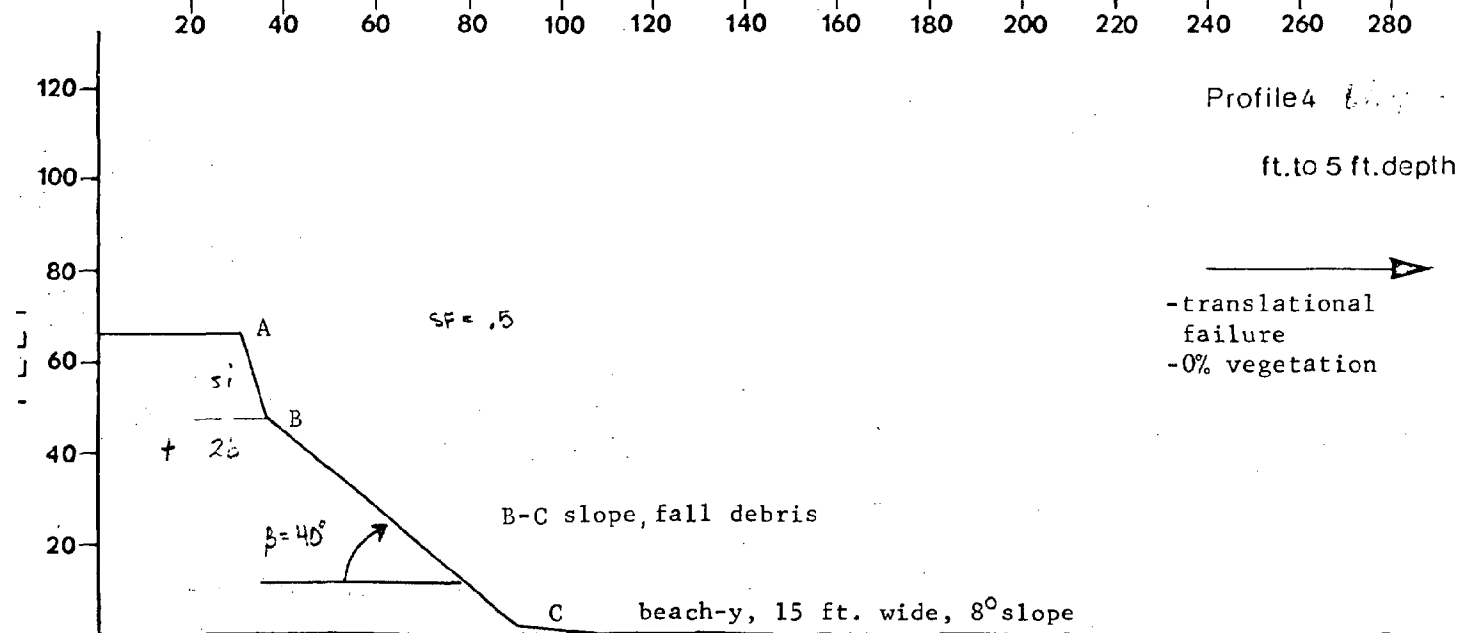
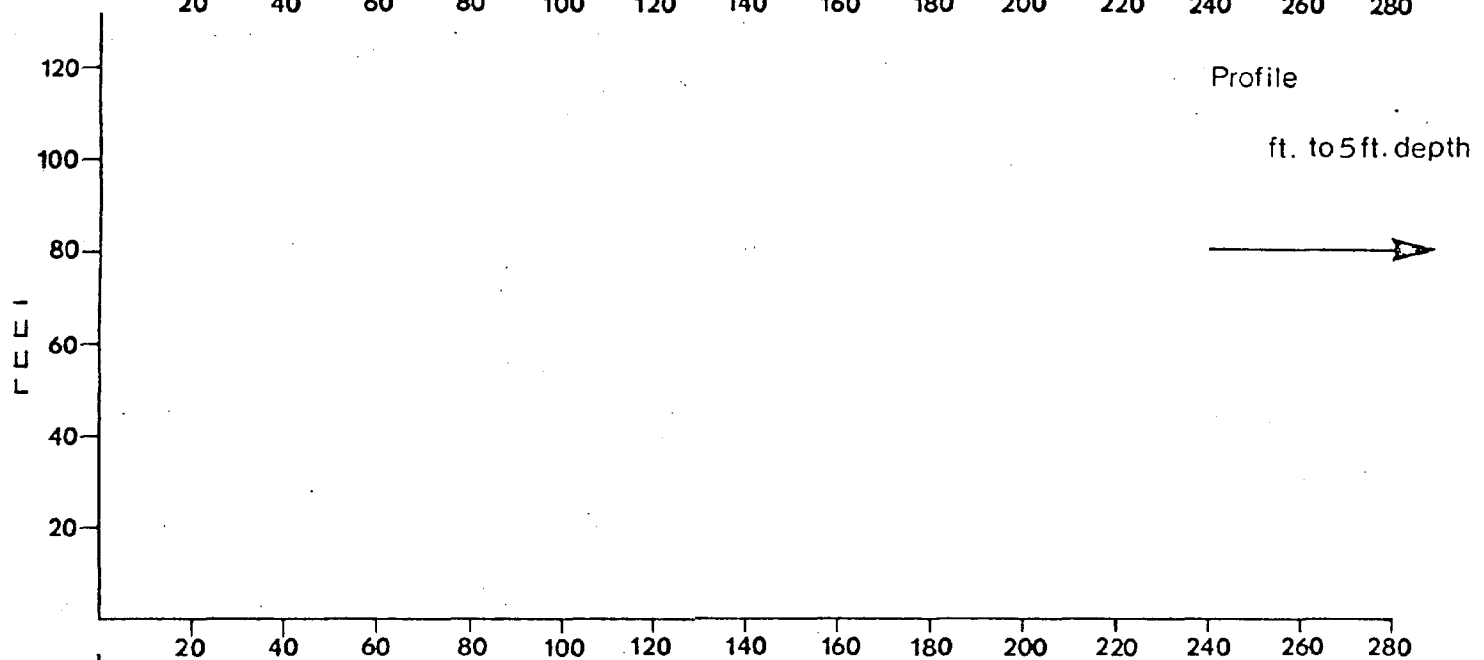
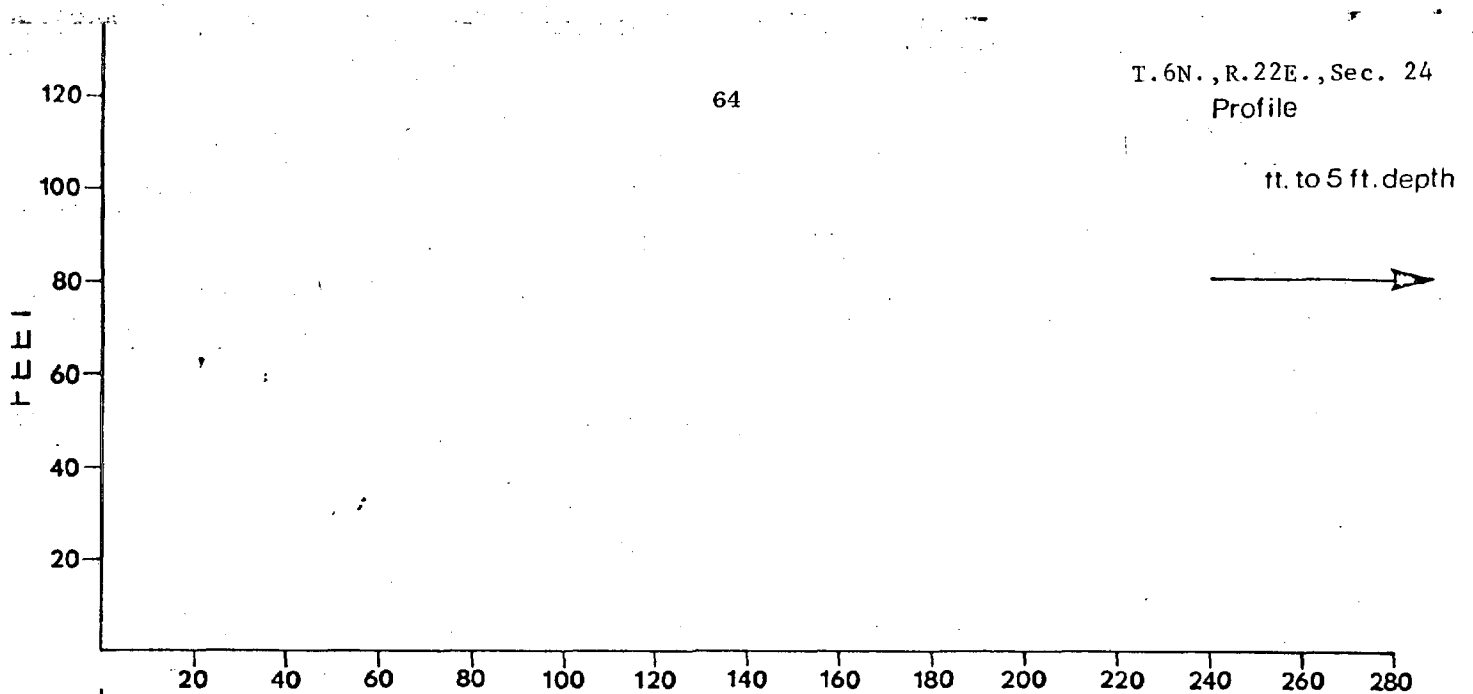
60 ft. to 5 ft. depth

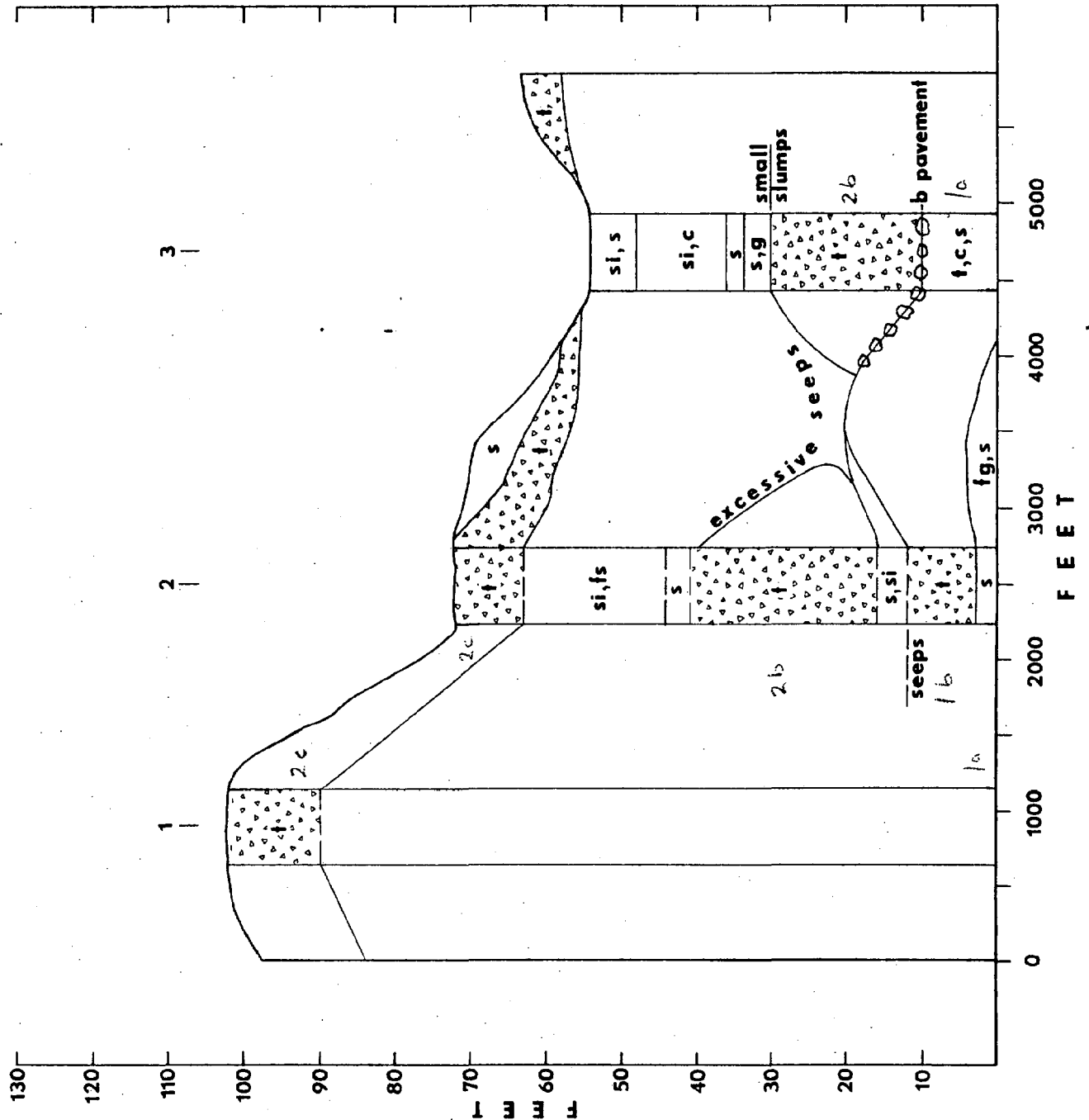


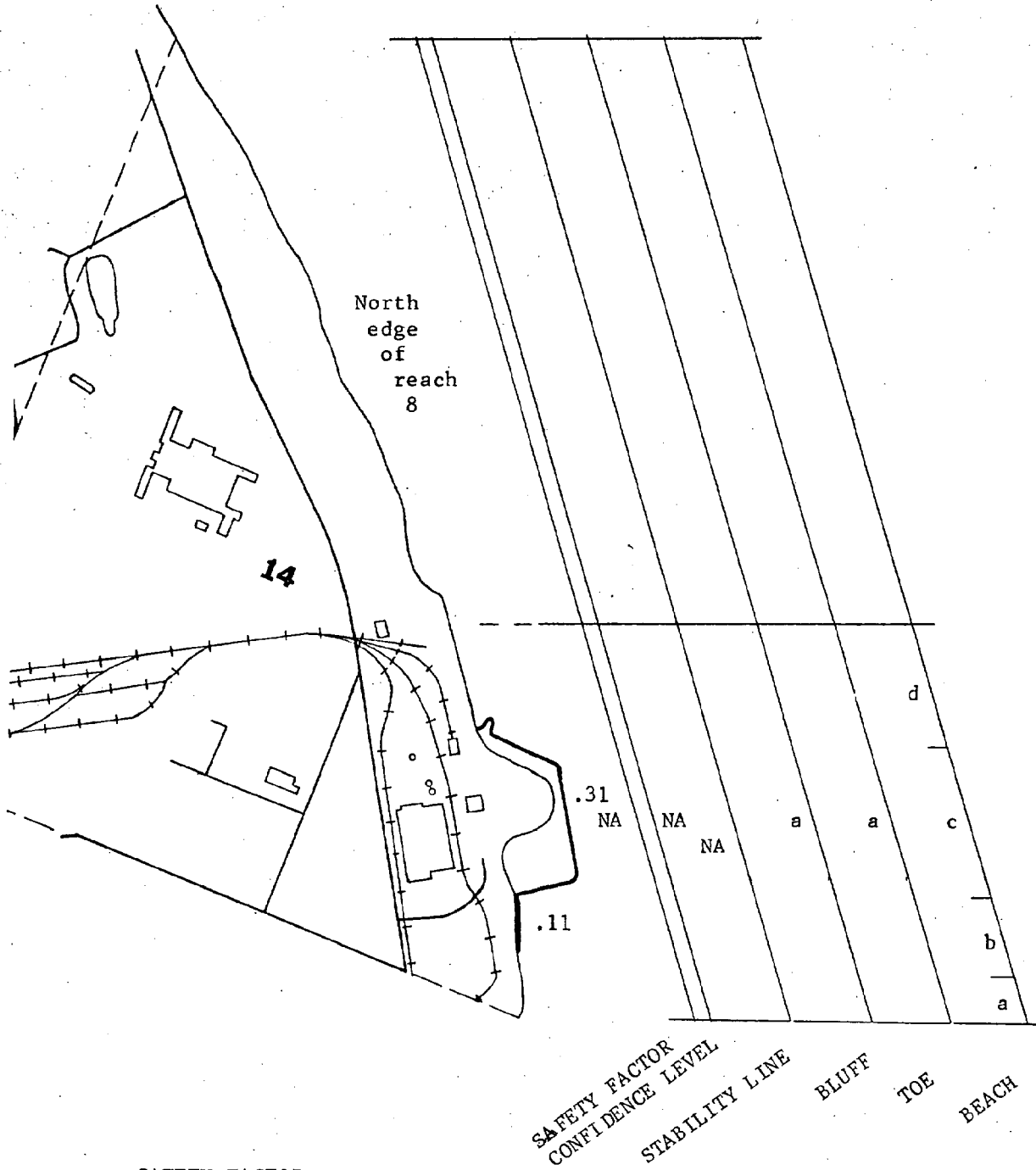
Profile 1 4/7/76

53 ft. to 5 ft. depth









1. BLUFF	a-all graded, grassed and stable			
2. TOE	a-all protected			
3. BEACH	a- -5 ft.	b-against revetment	c-protected- no beach	d- -5 ft. to revetment

Field Report on Reach 10

Location

Reach 10 is located in Townships 7 and 8 North, Range 22 East, in northern Milwaukee County. The reach is about 6.5 miles long and extends northward from the Waterworks at Lake Park to Fox Point. Land use in the reach is limited to residential areas (Shorewood, Whitefish Bay, Fox Point) and Parklands (Shorewood, Buckley, Big Bay, Silver Spring, Klode, and Doctors Parks).

Reason for Criticality

Reach 10 is ranked #6 on the Erosion Problem Area priority list having a value per mile of 20. This value is based on (1) the long term recession rate that varies from 20 to 30 ft. per 100 years; (2) the Corps of Engineers 1952 Shore Damage Survey value of 1.2 to 16.2; and on (3) the Corps of Engineers list of critical erosion areas.

Reach 10A

Reach 10 is divided into 5 parts based on the slope conditions of the bluff. Part 10A at the southern end of the reach (includes section 10 and $\frac{1}{2}$ of section 3) is a stretch of very stable bluff, heavily wooded bluff. T.7N., Section 10

Section 10, the southernmost section in reach 11 begins at the Waterworks in Lake Park. The plant is built entirely on land fill and is protected by a seawall constructed of sheet piling. The slope above the land fill is graded and grassed. Immediately north of the Waterworks, the bluff is very low, 40 to 60 feet and is well protected by a very wide beach (50 ft.) formed by the groin like action of the landfill seawall. The slope is gentle and tree covered. Northward the bluff height quickly increases to 100 feet (10.15) and then to almost 120 feet (10.2). At the same time the beach width decreases from 50 feet to only about 20 feet. At 10.2 a seawall and groin combination protect the toe. These protective structures

function well to 10.4. At this point an older seawall which has been overtopped, collapsed, and undermined fails to protect the toe, causing an 8' scarp to be formed. The material visible at the scarp is slumped soil. The upper slope is wooded and appears stable. The old seawall continues with several interruptions to the end of the section.

The first profile at 10.65 shows what appears to be a stable slope with its toe protected by a seawall (R-18-9). The bluff height is 116 feet and the angle of slope is 17° . There is no beach, instead a few cobbles and boulders protect the seawalling from being undermined. The vegetative cover was 100% before the property owner clearcut the bluff slope; at present the cover is 50% (low grasses and weeds). Although there is no noticeable erosion in this profile on the adjacent property owners land there is a large deep seated slump block. The slump block is marked by a six to eight foot scarp. Boring logs from Soil Testing Services, Inc. indicate that the upper red till extends to a minimum depth of 60 feet.

At 10.7 a small terrace begins, and extends north to 10.9. It reaches a maximum width of over 200 feet at 10.8.

The seawall is absent at 10.8 and the resulting eroded toe exposes 6 feet of sandy, clayey blue-gray till. At 10.85 another small exposure shows 4 feet of sandy, clayey, blue-gray till over which lies 3 feet of gravel and 4 ft. of medium yellow buff sand. At both of these exposures a small (5 ft.) beach of cobbles is formed.

A collapsed seawall at 10.9 is the site of the worst erosion in section 10. A 50 foot section of the seawall is collapsed and another 100 feet is seriously overtopped (R-18/6). The property owner, in an effort to protect his house, has dumped a large quantity of fill over and on the bluff. This is the first part of the section that is devoid of vegetation. There are several small scarps (2 feet) marking the location of several slump

blocks within the fill material. The bluff height at this point has decreased to about 80 feet.

From this location to the end of section 10 a functioning seawall protects the toe of the steepest slope in the section (27°). The vegetation on the slope is 80% to 100% and contains several large trees. The last 50 feet of the section has a sand beach that widens to about 25 feet.

The presence of seepage was not noticed, although the groundwater may be responsible for movement along the failure planes of the slump blocks.

The use of the bluff top is entirely residential in this section.

T.7N., Section 3

Section 3 starts at the southernmost groin in Shorewood Park. The bluff height at this point is 76 feet high as indicated in profile 1. The slope is relatively stable (27°) and completely grassed. Three groins at the park have built a wide (80 ft.) beach which protects the toe of the bluff.

North of the park the slopes are covered with trees (maple, basswood, ash, cherry, willow, poplar, oak and locust) with diameters up to 15 inches. The slope is stable and the beach wide (40 ft.) north to 3.35.

Profile 2 at 3.35 shows a stable 24° slope protected by a wide beach (20 ft.) and a small seawall. The bluff height is 80 feet and the vegetative covering is 100%. There is no evidence of seepage.

Reach 10B

Reach 10B is an area of unstable bluff which is characterized by both translational sliding and by rotational slumping. The area extends from the middle of section 3, T.7N., north to 21.8 T.8N.

The bluff height in 10B varies from 70' to 80' in sections 3, 33, and 28 (T.8N.) and rises to about 120' in section 21, T.8N.

The general stratigraphy of reach 10B has an upper red brown silty till separated from a trio of lower tills by a sequence of silt and interbedded

silt and sand. The thicknesses and the position in the bluff of the till and lacustrine sediments is variable and is best viewed on the longitudinal profile.

Throughout the reach two types of slope failure were evident. In one type rapid toe erosion of the bluff causes steep lower slopes and shallow translational slides on the more gentle upper slopes. In this case the toe material was usually in place (lower blue-gray sandy till or silt) or less often there was a small quantity of upper red till or silt debris covering the toe. (The slide material was carried away as rapidly as it fell). This type of failure is limited to the very active slopes.

Slumping, the other type of failure, is caused by toe erosion coupled with the presence of seeps and lubricated rotational failure planes. Slopes exhibiting this type of failure usually have large blocks of slumped debris (out of place) covering the toe. This characteristic is due to the fact that the slump blocks pile up at the base of the bluff faster than they are removed by wave action. The topographic profile shows a gentle lower slope and a steep upper slope. Rotational slump scarps were observed on even the most stable appearing slopes such as those protected by seawalls, groins, and terraces.

Throughout the reach several minor seeps occur in the lower part of the bluff either on top of the lower blue-gray clayey-sandy till or over a less permeable silt or clay layer. The presence of the seeps with their sapping action does not add greatly to the erosion problem. Their major contribution is in reducing strength along failure planes.

The beach conditions in the reach vary greatly depending on the protective structures. Where groins exist wide (60 ft.) sand beaches protected the slope. Where seawalls exist there is a small sand and cobble beach or none at all. Revetments usually have no beach.

Section 3, T.7N.

The northern $\frac{1}{2}$ of section 3 is markedly different from the southern $\frac{1}{2}$. The bluff height increases, the beach width decreases and the slope becomes very unstable.

North of profile 2 the beach narrows and the bluff height increases. At 3.5 the beach is 5 feet wide and the toe of the slope is being rapidly eroded. The vegetation is limited to the upper $\frac{1}{2}$ of bluff and the lower $\frac{1}{2}$ is marked by continuous shallow slides. The first in-place stratigraphy of section 3 was located at 3.55. Here a blue-gray sandy till with many cobbles and pebbles is exposed just above the lake level. Above this till is an intermediate till which is blue-gray, silty and not as pebbly as the lower till. On top of this intermediate till is a brown-gray, clayey till with a high shale pebble content. The thicknesses of the tills is as follows: lower blue-gray, sandy till - 12 feet thick; intermediate blue-gray silty till - 8 feet thick; brown-gray clayey till - 5 feet thick. Above the 3 till units is a thin 4 ft. thick layer of silt and sandy silt. The silt layer marks the top of this exposure.

The cobble beach widens slightly (5 to 20') and the bluff height increases to 108 feet at 3.67 (profile 3). Only the upper $\frac{1}{3}$ of the bluff is vegetated (90%) giving a good exposure in the lower $\frac{2}{3}$.

At the base of the exposure and extending 28 feet above the water level is a sequence of highly oxidized interbedded sands and fine gravels (2' dia.). Above this layer is a 10 foot thick layer of blue-gray, silty till with frequent boulders and a high gravel content. Above this unit is a brown-gray clayey, shaley till about 4 feet thick and a silt layer about 4 feet thick. These lower units form the steeper (40°) lower slope which is being rapidly eroded by wave action. It is thought that the lower sandy till is below the water level and that it is the intermediate silty till which is exposed over the sand and gravel layers.

The more gentle upper slope (29°) is composed of a red brown silty till which extends up to the bluff top making the layer 70 feet thick. The till in this layer is subject to shallow translational slides, with the base of the slides being at the red till - silt contact or at the brown gray till - silt contact. The upper limit of the slide scars is about 80 feet above lake level or about 52 feet above the base of the slide zone. No springs were observed at the profile 3 location.

From profile 3 at 3.67 northward to profile 4 at 3.87 the beach retains its 5' to 20' width while its texture changes from cobbles to sand and pebbles. The bluff height decreases to 72 feet and all of the stratigraphic layers dip to the north making them appear lower in the bluff.

Profile 4 located at 3.87 has bluff height of 72 feet and is vegetated only on the upper 1/3 (80%). The sequence exposed has the intermediate blue-gray silty and gravelly till at the base and extending 10 feet above the water level. (The thick sand and gravel unit exposed at the base of profile 3 is not visible at this location). On top of this till is 6 feet of brown-gray clayey till with a high shale pebble content. Over these lower tills and separating them from the upper red brown till is a lacustrine sequence including 4 feet of silty clay and 12 feet of pinkish brown silt. Above the pinkish brown silt is the red till, which extends 40 feet to the bluff top.

The shape of profile 4 is similar to profile 3. Wave action eroding the toe of the bluff has caused a steep lower slope (51°) triggering shallow translational slides which are responsible for the upper more gentle slope (30.5°). The break in slope occurs in the silty clay and is coincident with the occurrence of several minor seeps. The fact that the break in slope occurs much lower on the bluff in profile 4 than in profile 3 can be attributed to the impermeable silty clay and blue-gray till appearing lower in the bluff.

Northward to the end of section 3 similar conditions exist, the only changes are that the stratigraphic layers rise causing the break in slope to rise also. Most of the bluff top is used as a residential zone.

T.8N., Sections 33 & 34

Sections 33 and 34 are considered together because their combined length is only that of a normal section (the shore line just cuts a corner of section 34). The section line marking the southern extent of sections 33 and 34 runs along Hampton Avenue. Best access to the bluff and beach is through Big Bay Park.

From 34.0 to 34.2 the bluff height is about 70 feet to 75 feet. There is a 5 to 20 foot beach of sand and cobbles and almost no vegetation. Toe erosion is rapid causing steep lower slopes and shallow translational slides on the upper more gentle slopes. At the base of the bluff is the blue-gray sandy and gravelly till which is separated from an intermediate blue gray silty till by a boulder pavement. Over the silty till is a layer of brown gray shaley clayey till. The lower three tills are separated from the upper red brown till by a lacustrine sequence of silty clay, sandy silt and a widening wedge of sand. The thicknesses of all of these lacustrine layers increases toward the north, to profile 1 at 34.2.

A stone filled steel crib at 34.1 is intended to protect the bluff toe from wave action but has failed completely due to flanking and overtopping.

Minor seeps occur at the base of the medium sand at the base of the sandy silt. These springs reduce friction along failure surfaces but are not responsible for sapping on any large degree.

A seawall partially protects the toe of the bluff at about 34.18 causing the slope to be more highly vegetated. The upper 2/3 is 100% covered while the lower 1/3 is bare of vegetation. The failing seawall extends in part to 34.2. It is here that profile 1 was drawn.

The bluff height at profile 1 is 76 feet and the vegetative cover is 80% on the slope with the slide scars constituting the 20% that is unvegetated.

The stratigraphy of the profile includes a blue gray sandy gravelly till extending from the water level to a height of almost 20 ft., followed by an 8

foot thick layer of blue gray silty till and a 6 foot thick layer of brown gray clayey shaley till. These layers form the steeper (44°) lower slope where the more rapid toe erosion is occurring. Above the tills and their corresponding break in slope is a massive gray silt about 16 feet thick, a gray sandy silt 10 feet thick, a medium sand 8 feet thick, and the red till 8 feet thick extending to the bluff top. This sequence of lacustrine deposits and till form the more gentle (27°) upper slope. The slope failure scars are present all of the way to the bluff top in this profile.

Several springs occur above the lower clayey till in the massive gray silts. These contribute to the translational slides present on the upper slope. Within the upper slope more seeps occur at the base of the medium sand, but are not responsible for any increased rate of slope failure.

The beach at profile 1 is of sand 15 feet wide. This continues to 34.22 where a revetment protects the slope. Behind the revetment the slope is covered with fill debris which is subject to slides and slump in the near future due to its very steep slope.

Starting at 33.25 and continuing north to 33.45 a seawall protects the bluff below Big Bay Park. In this stretch the slope is 31° , relatively stable and completely vegetated (100% weeds and trees up to 15" in diameter). The bluff height is 69 feet and the beach is nonexistent except where a groin has been added to the seawall (33.3). This area of the bluff and shore is depicted in profile 2.

North of 33.45 the seawall is collapsed and the stratigraphy is exposed. Profile 3 (33.55) is typical of the bluff to about 33.63. The bluff height has increased to 86 feet and the beach width is 15 feet (pebbles). The vegetative cover is 100% on the upper 1/3 and 0% on the lower 2/3 of the bluff. The same stratigraphy is found in profile 3 as was described in profile 1, with the exception that the lowest blue gray sandy gravelly till is not present due to an overall lowering of the beds. At the base of the bluff is a 4 foot thick

layer of silty blue gray till and a 2 foot thick layer of brown gray clayey till. The tills are overlain by 25 feet of pink silts and 13 feet of interbedded gray clay, gray silt, and fine sand. Above these layers is 19 feet of cross bedded fine and medium sand and 23 feet of red brown till. The lower tills are covered in most places by slide debris which forms the low angle (25°) lower slope. The pink silt, gray clays, silts, and fine sand and the crossbedded fine and medium sand hold a second and steeper slope (47°). It is this slope that represents the cutting action of the waves.

The upper red brown till forms a third break in slope with an angle of 22° . This layer is being undermined by the rapidly eroding lacustrine deposits and is subject to translational slides.

Seeps are located in this profile above the lower gray till and above the gray clay, silts in the medium and fine sand. Both of the seeps are minor.

At 33.6 the slope configuration changes in that the shallow slides are no longer the major slope failure form. Here large deep seated slump blocks are present. The rotational failure planes extend from the top of the bluff to the lake level. The photos 17 and 18 (roll 17) show the large slump blocks resting at the bottom of the bluff (note the jumbled lean of the trees) and the rotational failure plane extending from the bluff top to the lake level. This stretch of shoreline should be very active in the near future because of the concentrated erosion focused on the area by the protruding Monestary structure.

At the monestary (33.7) an extravagant protection device was constructed by Foundation Engineering, Inc. It consists of a poured concrete seawall supported by wooden pilings with fill material placed behind it to stabilize the slope, (photo 18, roll 17). At this time protection against flanking seems inadequate.

North to the end of the section the bluff height decreases to 70 feet while the beach varies from 5 feet to a maximum of about 25 feet. This entire stretch of shoreline is affected by large rotational slumps with rapid toe erosion and shallow translation slides being added to those areas with narrow beaches.

Other than Big Bay, and Buckley Parks, the section is residential.

Section 28, T8N

Section 28 begins at Silver Spring park. Best access is through either Silver Spring Park or Klode Park. The bluff top use is both residential and parkland.

The conditions present at the beginning of the section continue north to profile 1 (28.24). The bluff height is about 70 feet (73 feet at profile 1) and the beach is 25 feet wide. In the zone of breakers the beach is of cobbles and beyond the line of waves the beach is sandy. The vegetative cover is about 90%. At 28.14 there is a very large stretch of bluff marked by a succession of slump blocks. Silt is exposed at the toe but this is slumped material. Numerous springs were observed on either side of slump blocks and standing water was observed on the rotated back edge of the lower slump blocks.

Profile 1 located at 28.24 shows a close look at the stratigraphy which has varied considerably from that in section 33. At the base 13 feet of silty clay is overlain by 7 feet of silt and 33 feet of interbedded sand and silt. Over the sand and silt is the familiar red brown till (19 feet thick). The blue gray, and brown gray tills, having dipped to the north, are not exposed. Also the crossbedded medium and fine sands below the red till in section 33 have pinched out and are replaced by the thicker sequence of interbedded sands and silt. Several flowing seeps are located at the contact between the interbedded sands and silt and the less permeable silt.

The topography of profile 1 was interesting in that a large mound of slumped till, silt, and sand had rotated to a point 45 feet in front of the toe of the bluff. The slumped material had a steep toe and a gentle back slope which descended to the true bluff toe. The lower slope of the bluff is in place silt and silty clay covered by a veneer of slumped till. This part of the slope is inclined at 23° . The single break on the bluff slope occurs at the top of the silt layer about 19 feet above lake level. Above this point the interbedded silt and sand and the red till have a bluff face angle of 40° . At the top of the bluff is a small overhanging escarpment. Failure was due to toe erosion and slumping along ground water lubricated planes.

From profile 1 (28.24) north to profile 2 (28.25) the beach remains constant (25 feet wide) and the bluff height increases from 73 feet to 82 feet. With the increase in bluff height the stratigraphic layers are exposed higher in the bluff.

At profile 2 (28.25) 21 feet of silty clay is exposed at the base of the bluff with 8 feet of silt over it and 32 feet of interbedded silt and sand on top of the silt. At the top of the bluff is 20 feet of red till. The topographic profile here is similar to the first in this section. The lower part of the slope is a gently sloping (20°) debris pile. The upper part of the slope is a more steeply sloping (40°) and marked by several (4) small escarpments. The slope is 40% vegetated. Slope failure is due to rapid toe erosion and slumping along the silt and interbedded sand and silt contact where flowing springs were numerous.

These conditions prevailed north to Klode Park (28.4, photo 27, roll 17) where the beach widens and the slope is graded and grassed. The bluff at the park is stable. However north of the park the slope steepens and becomes unstable again. The beach narrows to about 25 feet and the bluff height remains slightly over 80 feet. At profiles 3 and 4 the stratigraphy and slope was measured in an effort to compare a slumping unvegetated slope with a highly vegetated more stable looking slope.

Profile 3 the slumping area is about 50% vegetated. Its stratigraphy is the same as the other profiles in section 28 where there is silty clay (16 feet thick) at the base followed by silt (12 feet thick) and a sand lens (6 feet thick) which did not appear elsewhere in the section. Above the sand lens is 34 feet of interbedded silt and sand and 16 feet of red brown till which formed the bluff top. The slope was again in two sections, the lower part being slump debris at a low angle (20°), where as the upper slope holds a steeper slope (40°). A flowing spring was located in the medium sand above the more impermeable silt.

The more stable looking slope at profile 4 was 100% vegetated and had a more even slope with no breaks and an inclination angle of 33° . Despite the stable appearance of the profile a large opening scarp was forming at the bluff top.

The beach at both of these profiles and to the end of the section is about 25 feet wide and consists of sand and pebbles.

From profile 4 to profiles 5 and 6 the bluff height increases to 94 feet and the units within the bluff rise in relation to the lake level. The slopes of the bluff are completely vegetated (100%), with grass, bushes, and trees up to 15" in diameter. Between 28.52 and 28.9 a terrace formed by an old beach protects the toe of the bluff, making this stretch stable.

At 28.9 the terrace is gone and the toe of the bluff is subject to erosion. Profiles 5 (28.94) and 6 (28.96) show a rapidly eroding area and a more stable wooded slope. The stratigraphy at profile 5 is the same as that which has been described throughout the section, with the exception that the rise in units has exposed more the lower silty clay (28 feet). Above this is the sequence of silt (14 feet), interbedded silt and sand (41 feet) and red brown till (12 feet) at the top. Seeps occur at the bottom of the sand and silt layer and are in part responsible for the slumping which occurs in the silt layer. The toe material of the bluff is slumped till and silts.

The adjacent more stable slope depicted in profile 6 shows only one constant slope angle (28°), and is heavily wooded. The rapid toe erosion has triggered several small failures at periodic intervals on the bluff face (the largest of these is at the bluff top).

The conditions described here, alternating slumped and wooded slopes, continue to the end of the section.

Section 21, T8N

Section 21 begins with the conditions described at the end of section 28. The first stretch of the shore from 21.0 to 21.23 has a 25 foot beach of sand and pebbles and a bluff height that increases from 98 feet to about 112 feet. The slope along the stretch has a rapidly eroding toe with a steep lower slope and more gentle upper slope. The failure is mostly of a translational slide type but a scarp due to rotational slumping was visible along most of the bluff top. The lower $\frac{1}{2}$ of the slope is unvegetated while the upper $\frac{1}{2}$ is completely covered.

At 21.23 a small groin is responsible for a wide beach (50 feet) which protects the toe of the bluff north to 21.4. Along this region of beach the slope does not have a steep lower half and the trees extend down to the beach.

Profiles 1 (21.31) and 2 (21.33) are located at the northern end of the wider beach area. At this point the slope is less stable as shown in profile 1. Here the bluff height is 118 feet and the stratigraphy has graded to a slightly different composition or texture, than that which was reported in section 28. At the base of the bluff is a massive silty clay (17 feet thick) followed by a 21 foot layer of silt, silty clay, and clayey silt. Over these two units is a 50 foot thick layer of interbedded sand and silt and a 30 foot thick deposit of red brown till extending to the bluff top. The topography of the profile shows a steep toe of slumped material, above which is an almost even slope of 30° . At the top of the bluff in the red till is a small scarp. There is a flowing seep at the base of the interbedded sand and silt which forms a small bog on

the slumped toe material. This saturated zone supports numerous horsetails. The rest of the slope is 70% vegetated with trees, grasses and shrubs.

Profile 2 shows a stable slope that is 100% vegetated. This is a very interesting topographic profile in that it is the only convex slope found. The three breaks in slope form a bulging profile.

North of these profiles to the point located at 21.43 the slope is intermittently stable and failing. The beach becomes very narrow and the bluff remains almost 120 feet high throughout this stretch. At the point (21.44) just above the water level there is a small exposure that was interpreted as bedrock. The resistant nature of the bedrock is responsible for the point.

North of the point to about 21.52 a structure protects the toe and allows a stable slope to be maintained. The vegetation extends to the 5 foot to 20 foot wide beach. Beyond the structure the scars of several slumps and slides are evident on the generally wooded slopes. When present the failures are usually due to rapid toe erosion and then the sliding of the undercut upper units. Other than a slightly widening beach these conditions prevail to the beginning of the terrace at 21.8. Profile 3 at 21.76 is typical of the stretch.

At profile 3 the bluff is 118 feet high and the beach is 10 feet wide. The stratigraphy from the base up is as follows: 5 feet of blue-gray, sandy, gravelly till; 9 feet of intermediate blue-gray silty till; 2 feet of brown-gray, clayey, till; 10 feet of clayey silt and silty clay interbedded; 34 feet of silt and sand interbedding; 19 feet of silt; and finally 39 feet of red brown till at the top. This stratigraphy varies from the more southern exposures in that the thick lacustrine clays found at the base of the last 5 exposures are here pinched to only 10 feet while the interbedded silts and sands have attained a thickness greater than that which is exposed to the south. The slope has a short steep toe (45°) above which is a large even slope (35°). A small scarp marks the top of the bluff. Seeps occur at the base of the upper silt layer

and at the base of the interbedded silt and sand. The lower seep is very active and forms a small scarp from its sapping action. The entire slope is vegetated with shrubs and trees (locust and elm) up to 8" in diameter. Many broken concrete slabs add a minimal amount of toe protection. Profile 3 is at the end of the B part of reach 10.

Reach 10C

The third part of reach 10 is an area of Nipissing age terrace protecting a very stable wooded bluff.

Section 21, T8N

In section 21 from 21.8 to the northern end of the section an increasing wide terrace develops. (The maximum width of 320 feet is at the northern section line). The terrace is composed of the blue-gray sandy till just above or just below the water level and about 10 feet of sand, gravel and cobbles overlying the till. This combination provides excellent erosion protection for the bluff and the terrace itself, for as erosion takes place, a wider beach is built. In addition to this natural protection most of the property owners have installed a variety of seawalls, groins, revetments, and piers along the entire terrace. (Land use in this area is entirely residential.)

The bluff above the terrace is considered very stable being removed from the eroding areas and completely vegetated. The slope angle in profile 4 was 26° and there was no evidence of scarps.

Section 16, T8N

Profile 4 of section 21 can be considered profile 1 of section 16 as it was recorded along the dividing section line. The conditions described in this profile continue through the entire section with little variations. The land use is residential (Fox Point) so each property owner has constructed some type of protective structure on his own land. This leads to a continuously protected shoreline consisting of revetments, seawalls, and groins. The beach width varies with the type of structure used. It reaches a maximum of

40 feet at 16.51 where a large groin is used, and is almost nonexistent where revetments and seawalls are present.

The terrace width increases from 320 feet at 16.0 to almost 800 feet at 16.5 and then decreases to 480 at the end of the section. The stratigraphy is the same as that described earlier; blue-gray sandy till either just above or just below the water level with 8 or 10 feet of sand, gravel, and cobbles overlying the till.

The bluff behind the terrace decreases in height from 111 feet at the southern section line to 90 feet at the northern section line. The slope for the whole section is completely vegetated and can be considered very stable.

Section $10\frac{1}{2}$, T.8N.

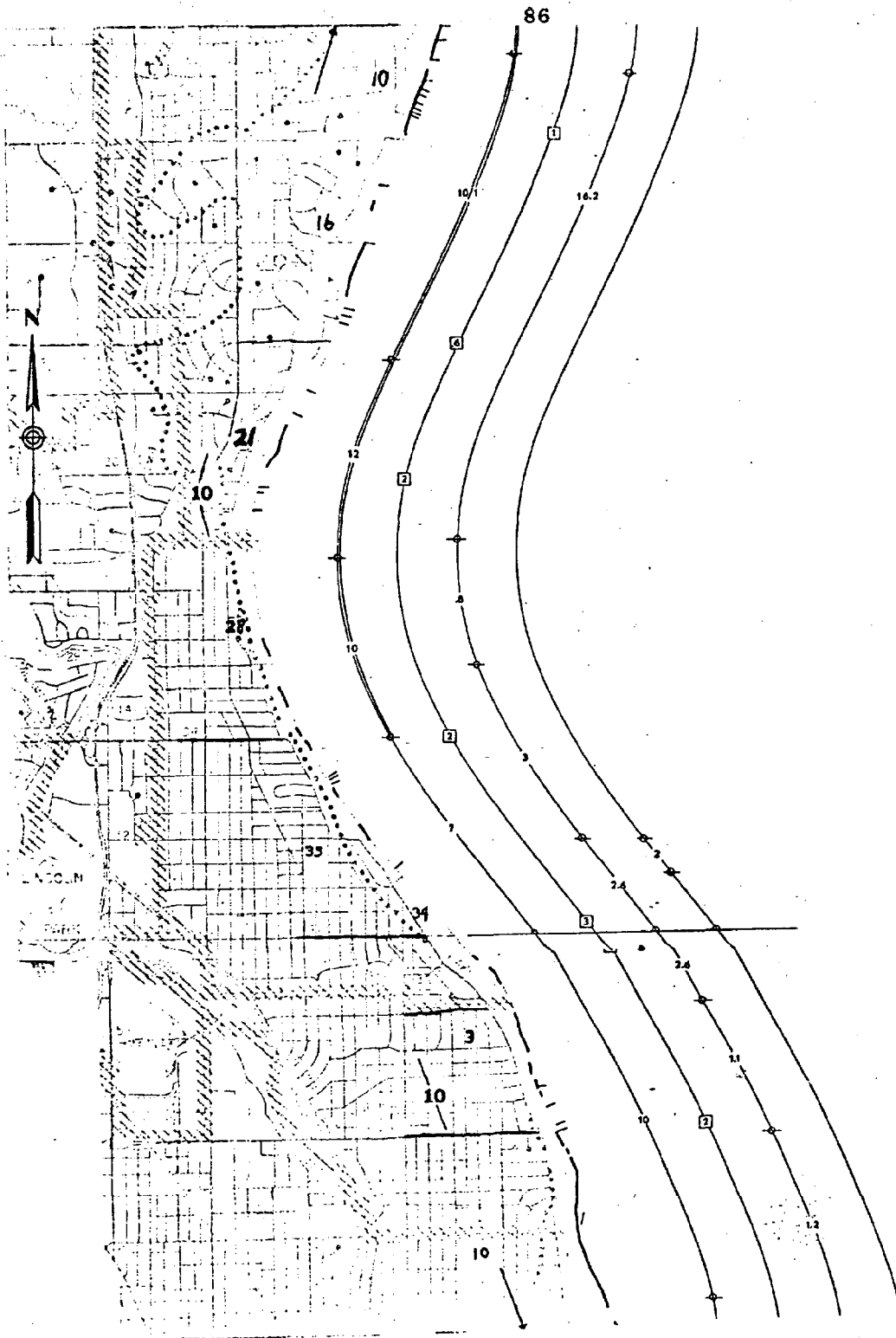
The lake terrace described previously continues along first .35 miles of the section 10 shoreline. This first stretch of shore is completely residential and is well protected by many privately owned groins, revetments, and seawalls.

Profile 1 along the 16/10 section line is characteristic of the first part of section 10. The terrace is 480 feet wide and, as expected, composed of sand, gravel, and cobbles with a blue-gray sandy till foundation. The bluff behind the terrace is 90 feet high and has a 25° slope for most of its length. (There is a short foot with an 18° slope.) Although this slope is completely vegetated, far removed from wave action, and without recorded seeps there were several minor slump scarps noted.

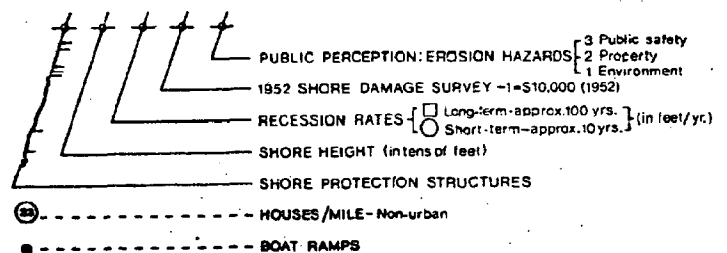
Reach 10D

At 10.35 the terrace disappears and the bluff is again subjected to the effects of wave action. The slope steepens slightly and the vegetative covering drops from 100% to about 70%. There are no major failures in this stretch due to adequate toe protection in the form of a seawall. These conditions extend to 10.5 where a series of 5 groins build a wide beach. The wide sand beach area ends at 10.75 which is beyond the end of reach 11. The slope in the groin

area is 100% vegetated and at a lower angle than the area behind the seawall. This slope is considered stable. The land use from 10.35 to the end of reach 11 at 10.62 is parkland (Doctors' Park).



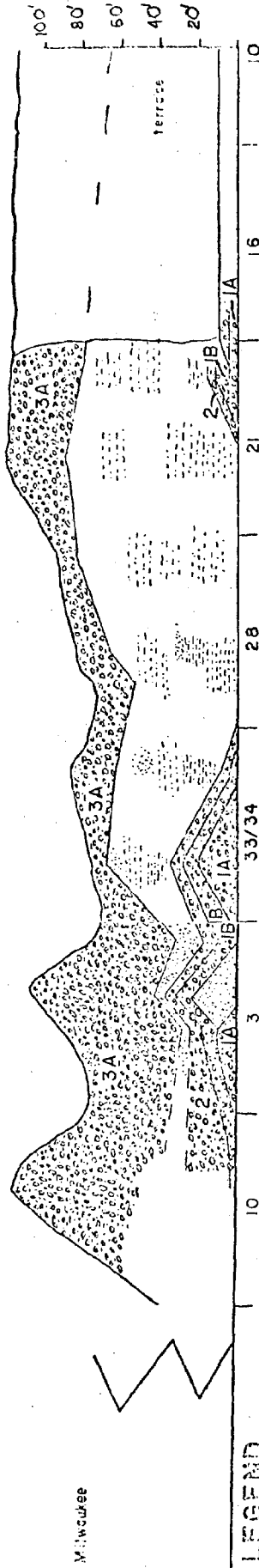
Reach 10



T7N.

T8N.

City of Milwaukee



Generalized longitudinal section showing bluff stratigraphy in Reach 10. Numbers along base of diagram are geographic (1 mile) sections.

LEGEND

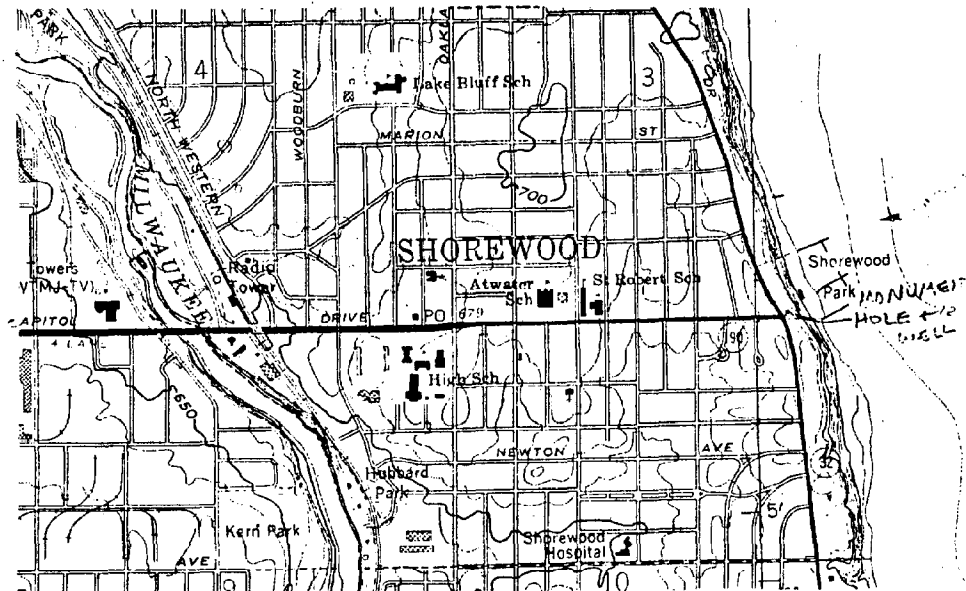
- SAND
- GRAVEL
- SAND AND GRAVEL
- SILT
- CLAY
- CLAYEY SILT, SILTY CLAY
- COVERED OR INACCESSIBLE
- TILL
- MIXED SEDIMENTS

LOCATION AND MONUMENTATION SKETCHES

Boring No. 8

Date

Drawn by

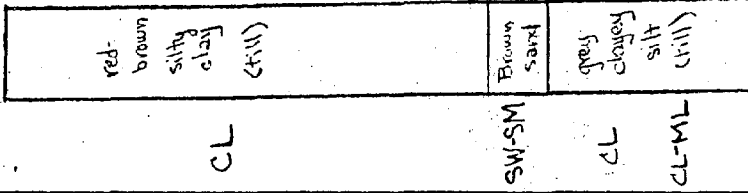


Capital Dec. (190)

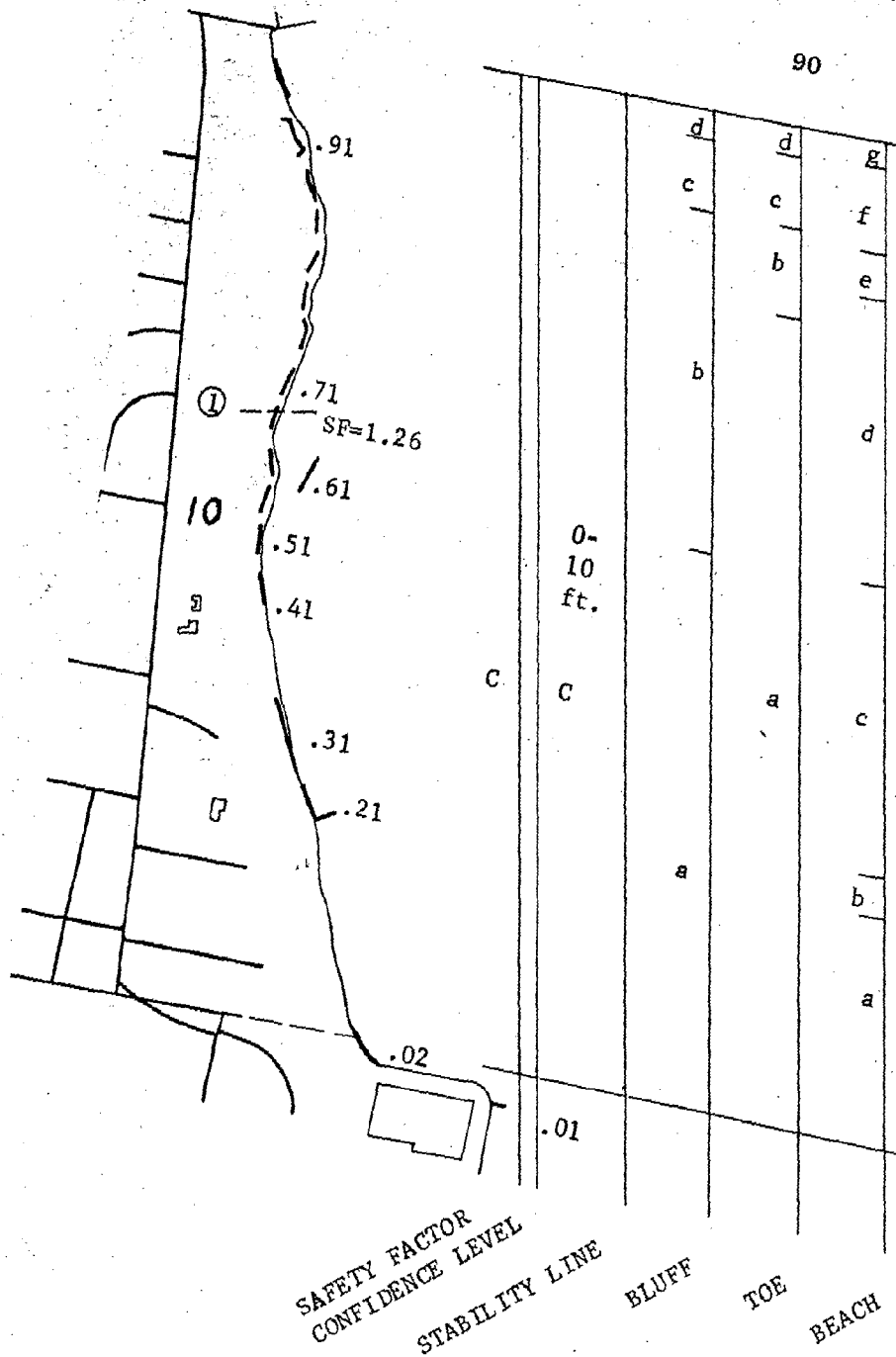
75 ft. hole
 1175' H



Depth (feet)	Blow Counts (split spoon)										Pocket Penetrometer	w_n %	γ_d (psf)	w_L %	I_p %	% Clay & Silt	ϕ°	c (psf)	c_v (psf)	USCS class.
	10	20	30	40	50	60	70	80	90	100										
5												17.7	113	31.0	14.9	92.3				
10												18.2	112	30.8	15.2	88.5				
15												18.1	112	29.0	10.4	92.0				
20																				
25																				
30																				
35																				
40												16.6	115	28.3	9.8	92.4				
45																				
50												17.9	113	sand		11.3 14.9	41.0	0		
55																				
60																				
65												25.0		23.0	10.5	46.6				
70														25.0	11.8	68.6				
75																				
80																				
85												14.6		20.5	7.7					
90																				



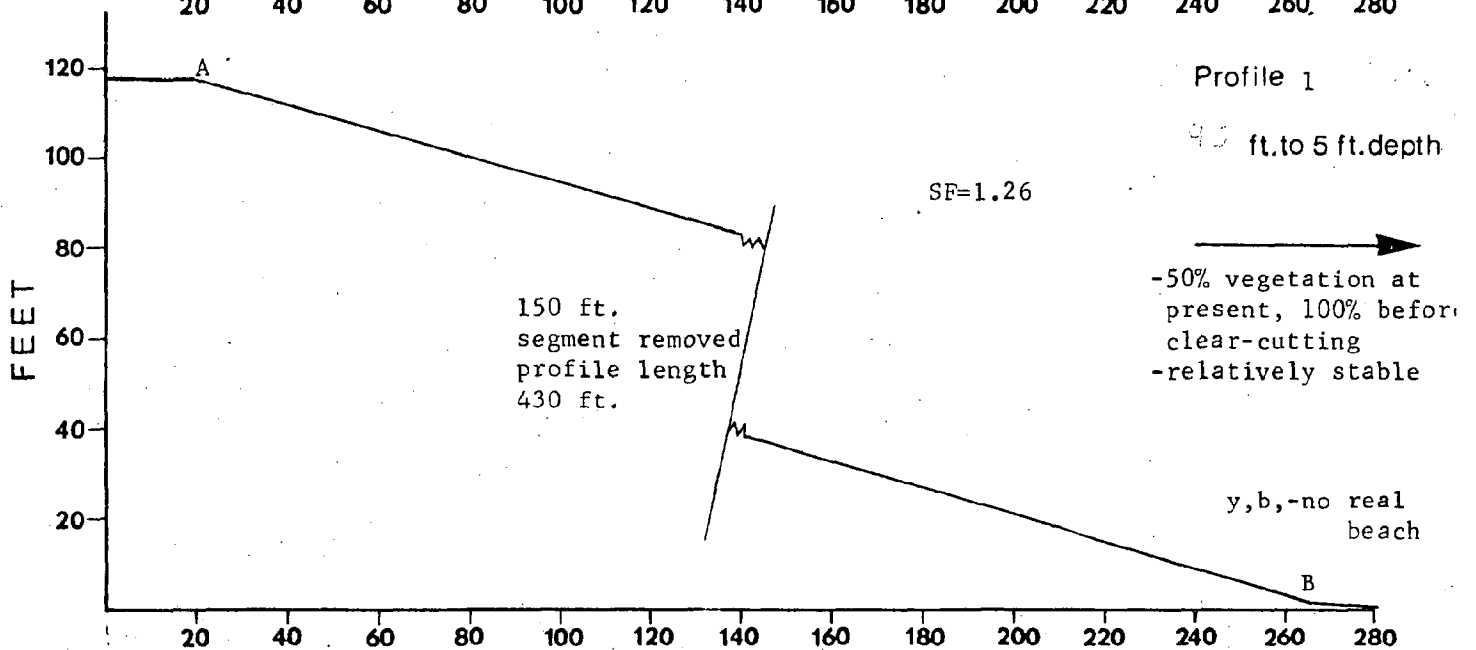
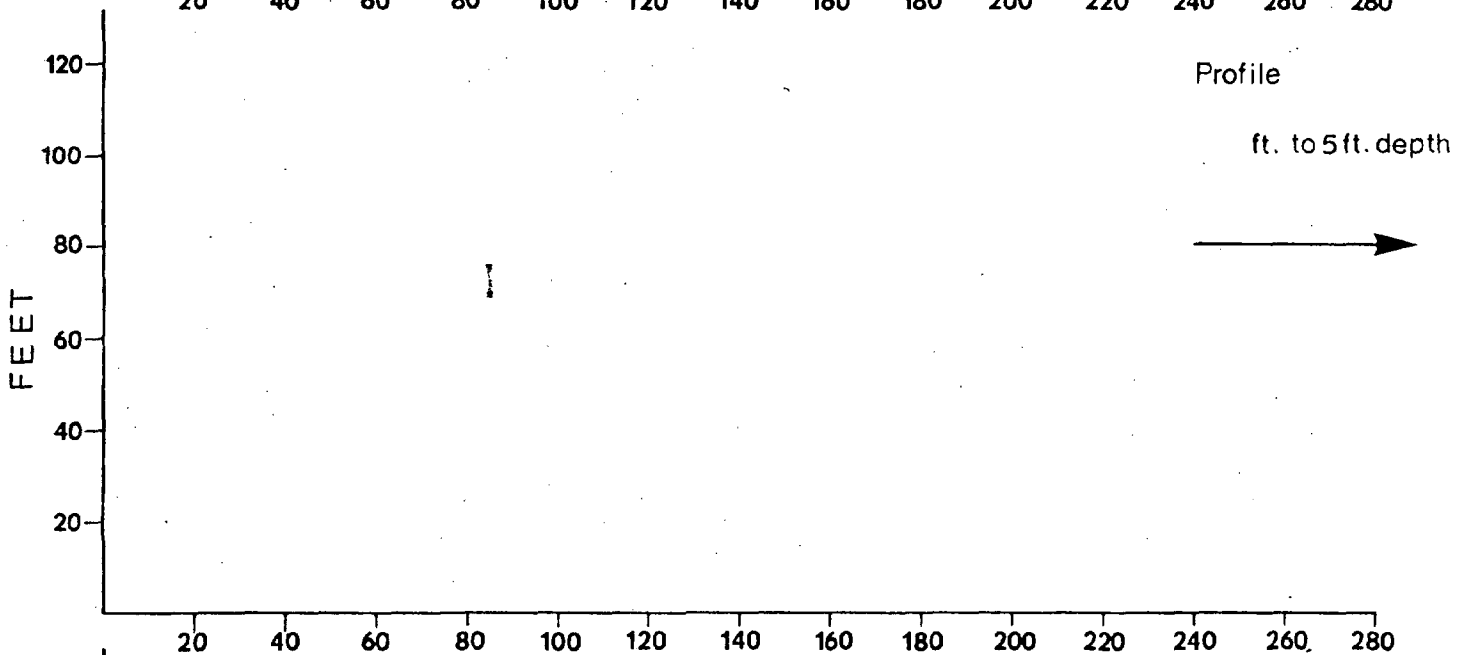
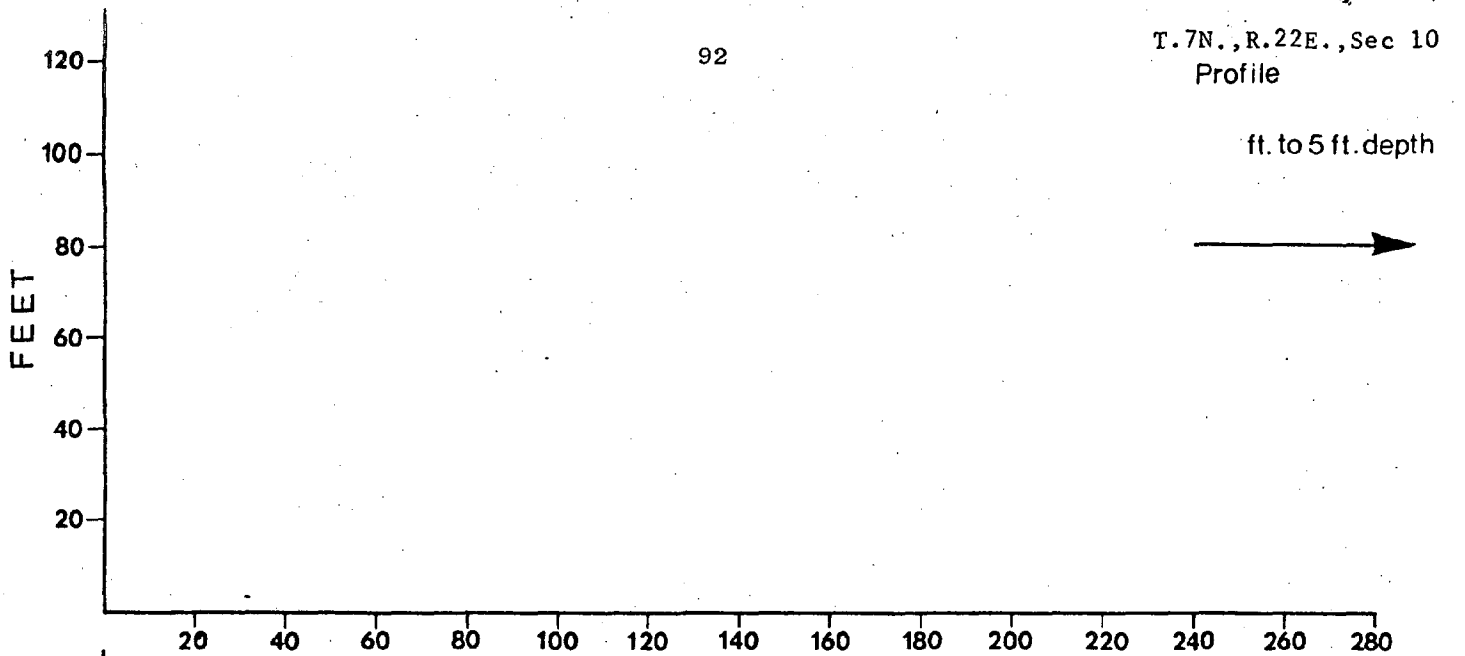
T.7N., R.22E., Sec. 10



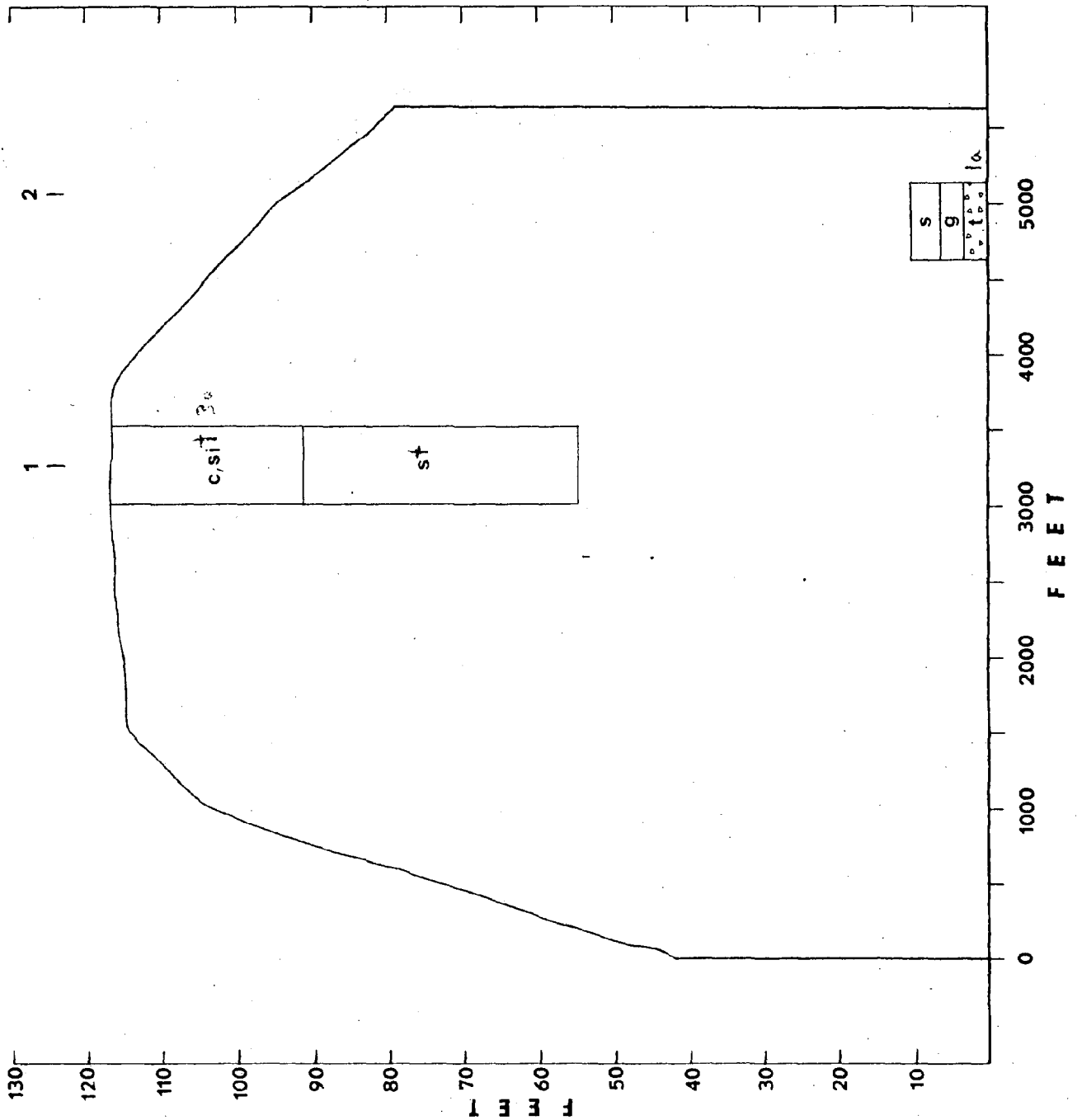
SAFETY FACTOR
 A-less than 1.00
 B-1.00 to 1.25
 C-greater than 1.25

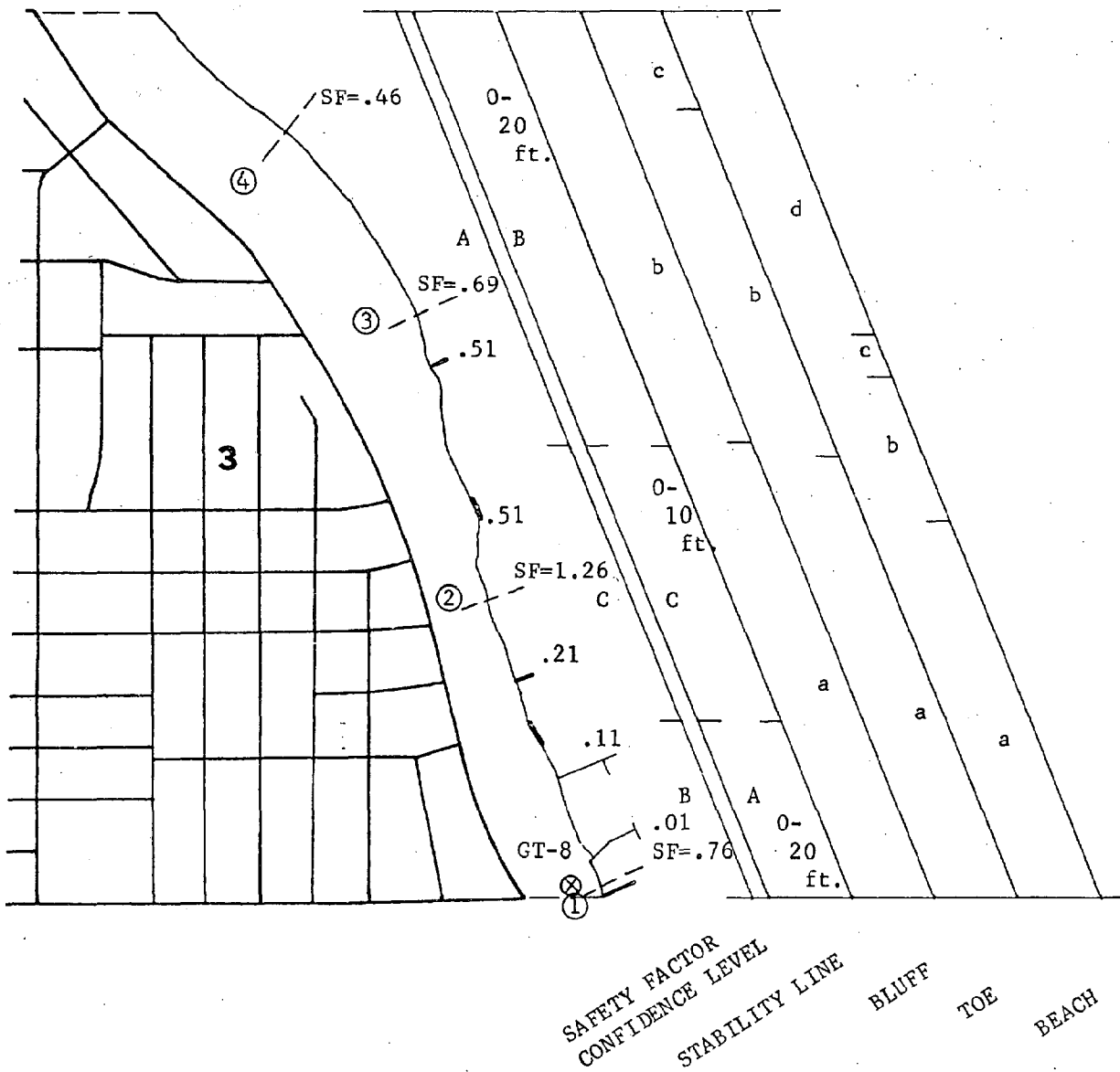
CONFIDENCE LEVEL
 A-boreholes
 (high confidence)
 B-near boreholes
 stratigraphy visible
 C-no stratigraphy
 visible (low
 confidence)

1. BLUFF	a-relatively stable no recent failures	b-toe erosion where seawall failing, several deep seated slow moving slump blocks on upper slope	c-severe toe erosion with translational and slumping above	d-relatively stable, no recent failures
2. TOE	a-not observed because of dense vegetation and thick soil, probably till in place	b-till overlain by sand and gravel in place	c-fill of till	d-not observed
3. BEACH	a- +20 ft. sand	b- -5 ft. seawall	c- +20 ft. sand	d- -5 ft. seawall and fallen trees
	e-5-20 ft. sand and cobbles	f- -5 ft. seawall	g- +20 ft. sand	



T. 7 N., R. 22E., Sec. 10



SAFETY FACTOR

A-less than 1.00

B-1.00 to 1.25

C-greater than 1.25

CONFIDENCE LEVEL

A-boreholes

(high confidence)

B-near boreholes

stratigraphy visible

C-no stratigraphy

visible (low

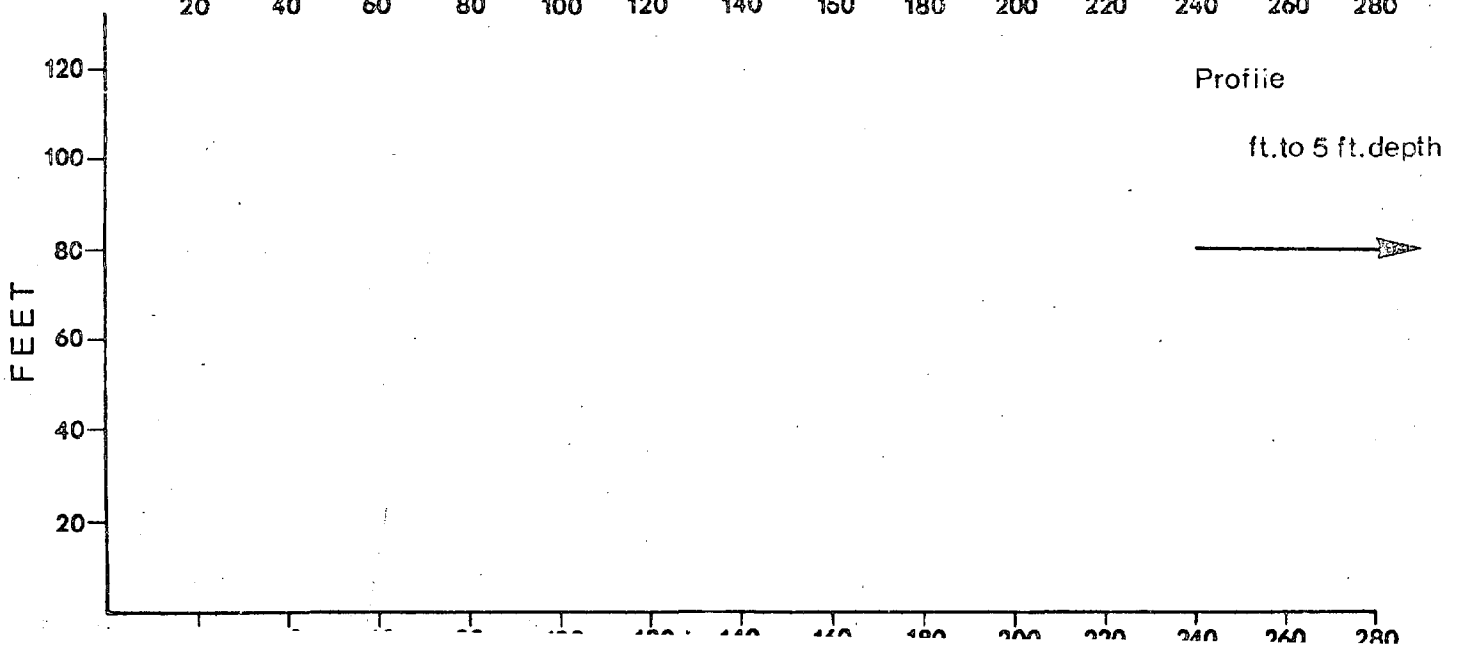
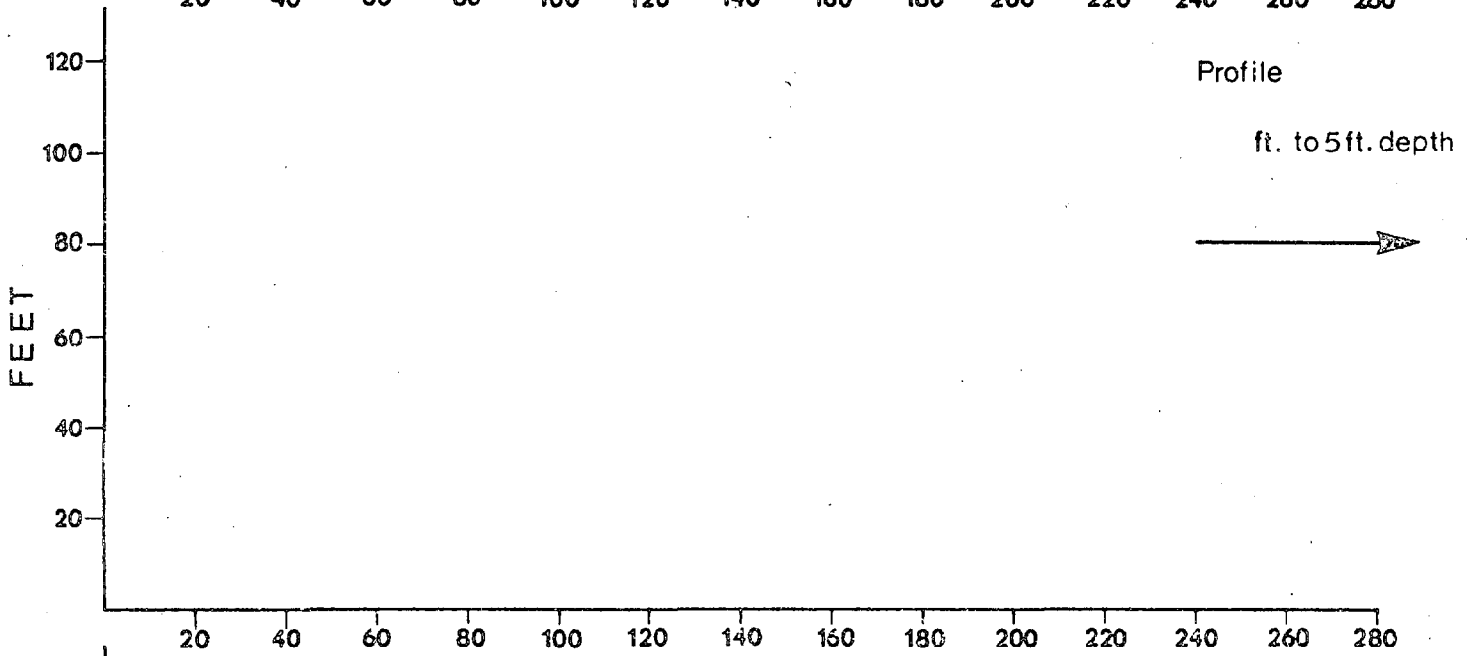
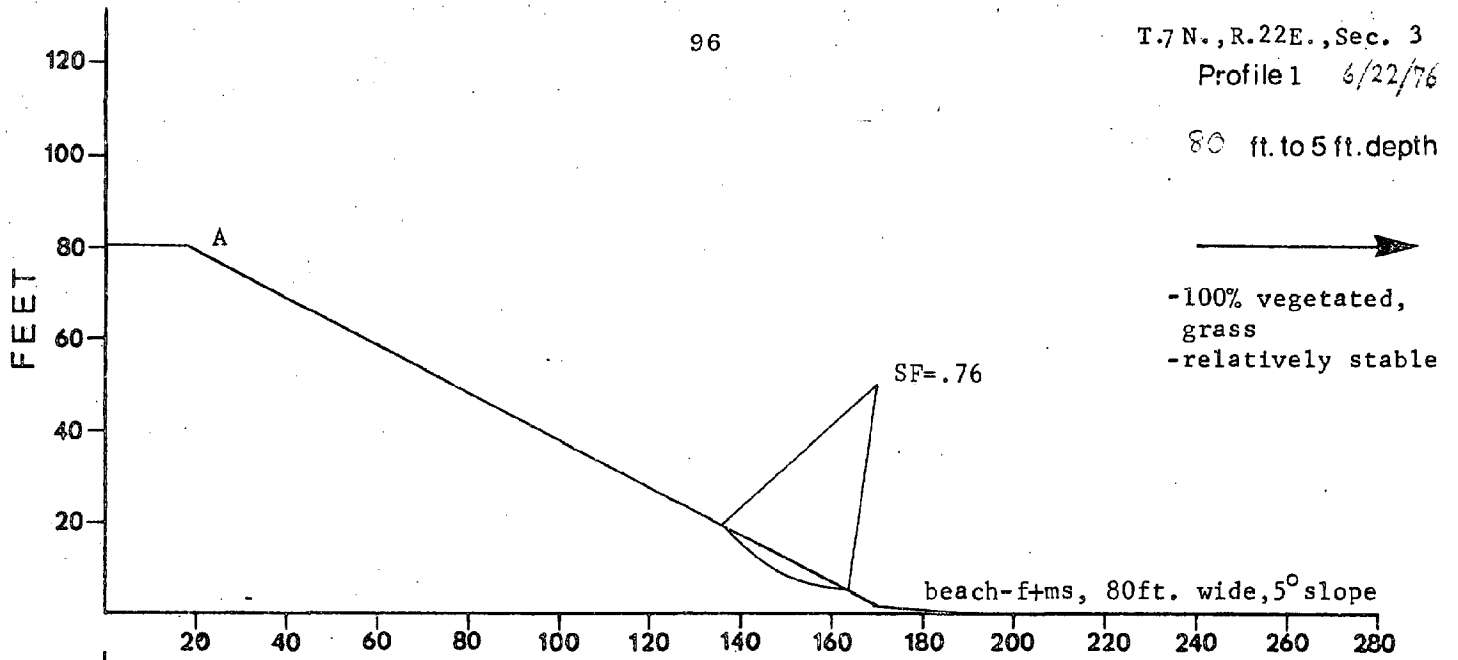
confidence)

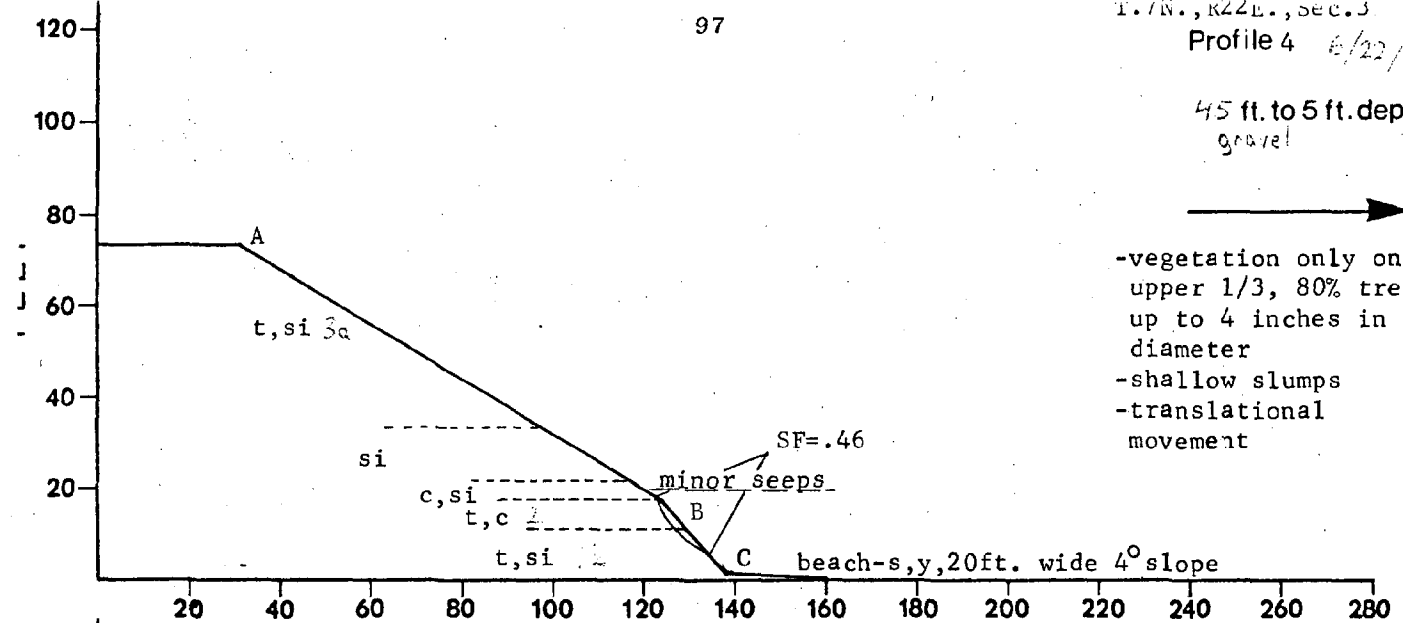
1. BLUFF	a-relatively stable, well protected	b-shallow translational slides, rapid toe erosion		
2. TOE	a-toe material not visible due to vegetation cover	b-slumped sandy till, in isolated places sand and gravel in place is visible	c-till in place	
3. BEACH	a- +20 ft. sand beach	b-5-20 ft. sand	c- -5 ft. sand and gravel	d-5-20 ft. sand and gravel

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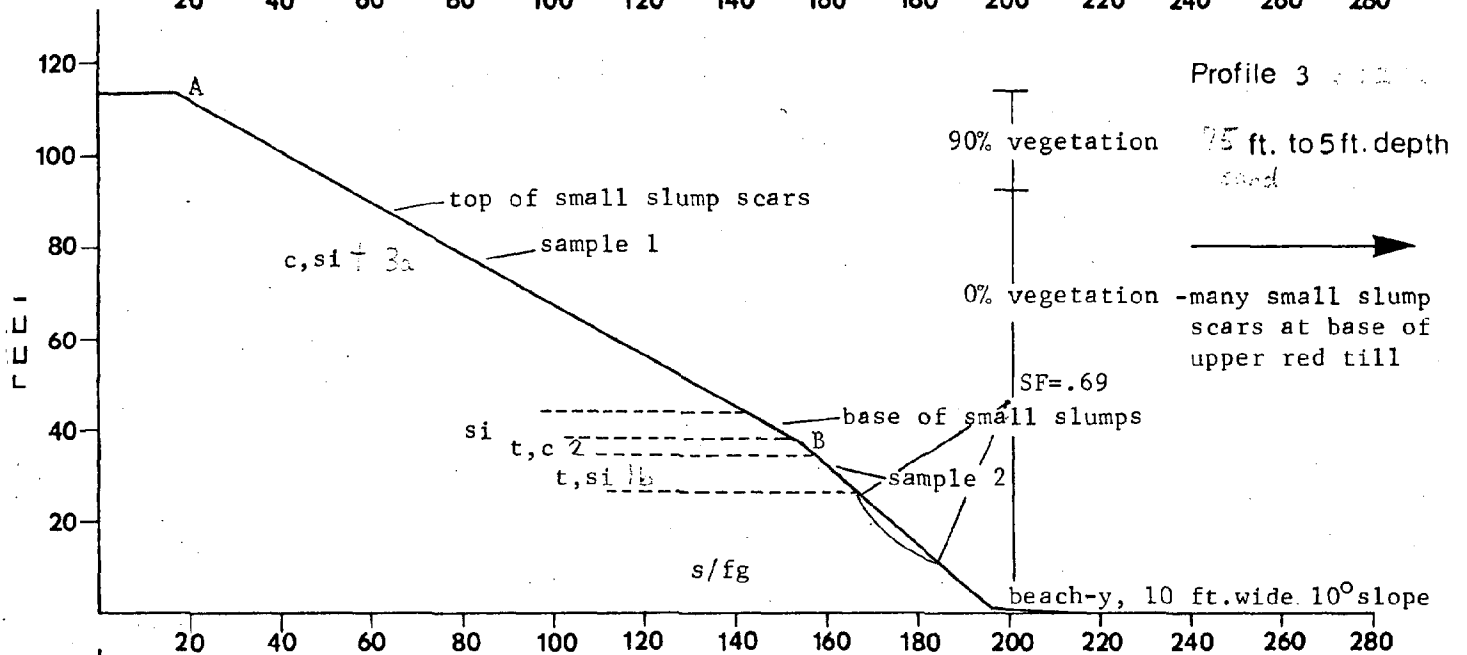
T.7 N., R.22 E., Sec. 3
Profile 1 6/22/76

80 ft. to 5 ft. depth

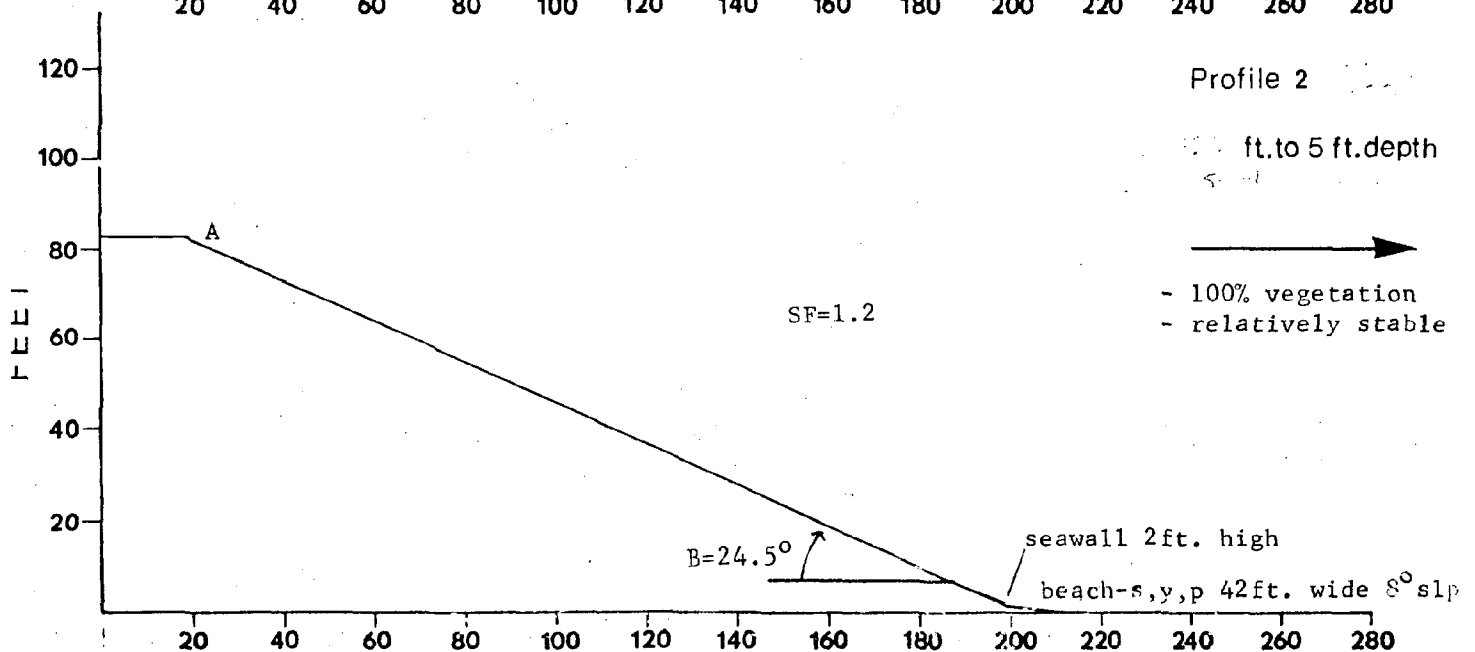


45 ft. to 5 ft. depth
gravel

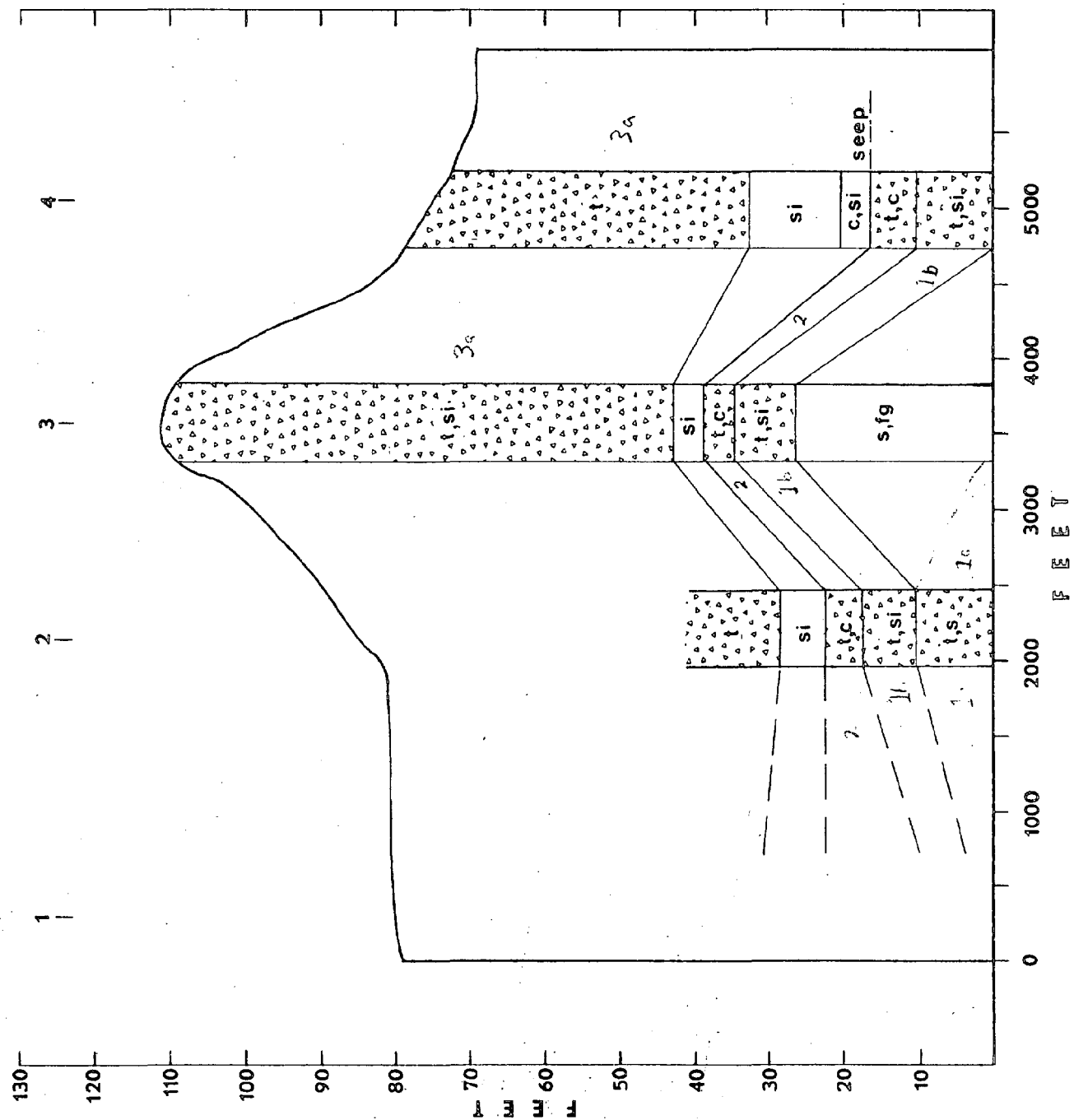
- vegetation only on upper 1/3, 80% trees up to 4 inches in diameter
- shallow slumps
- translational movement

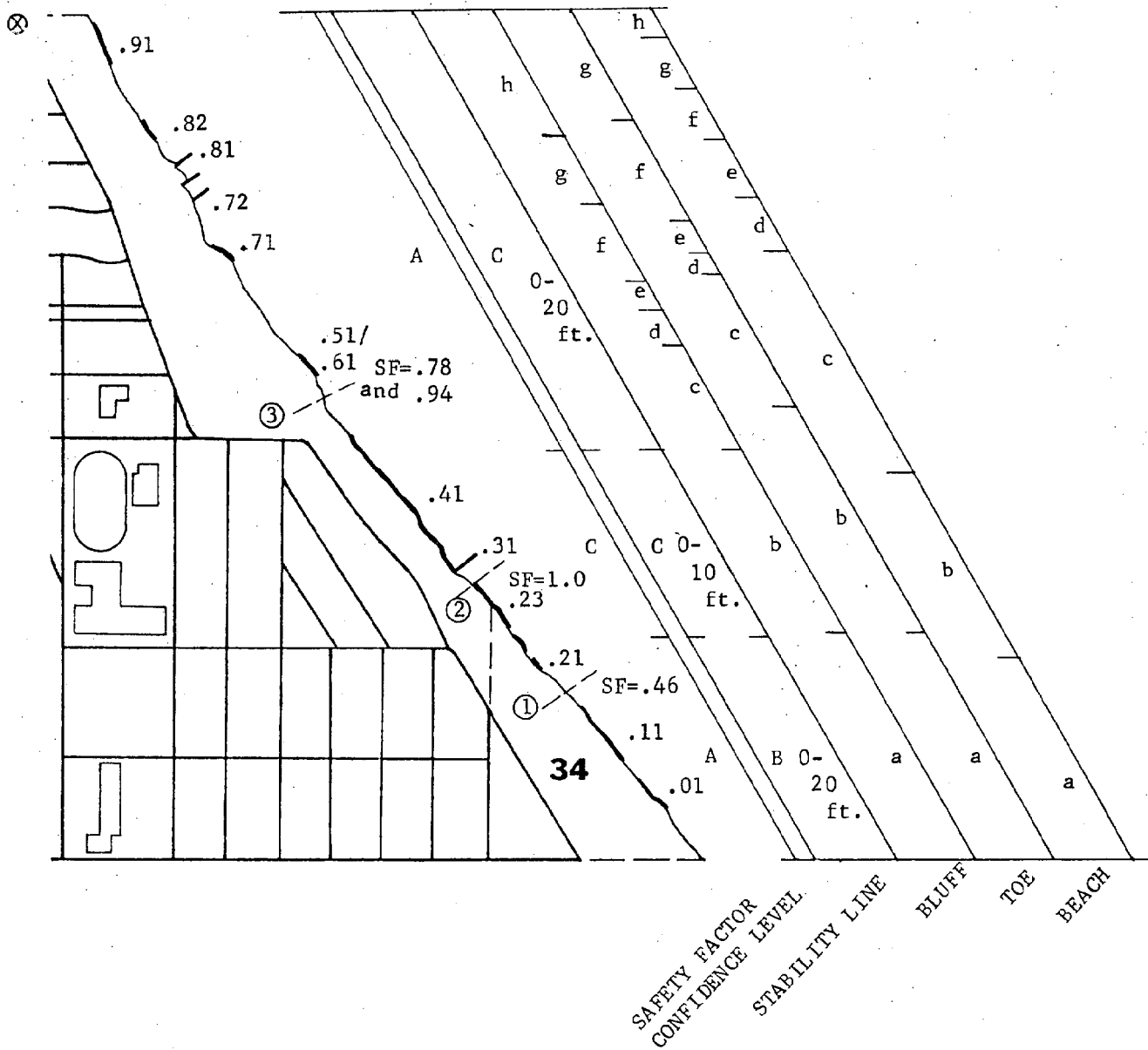
90% vegetation 75 ft. to 5 ft. depth
sand

0% vegetation -many small slump scars at base of upper red till

45 ft. to 5 ft. depth
sand

- 100% vegetation
- relatively stable



SAFETY FACTOR

A-less than 1.00

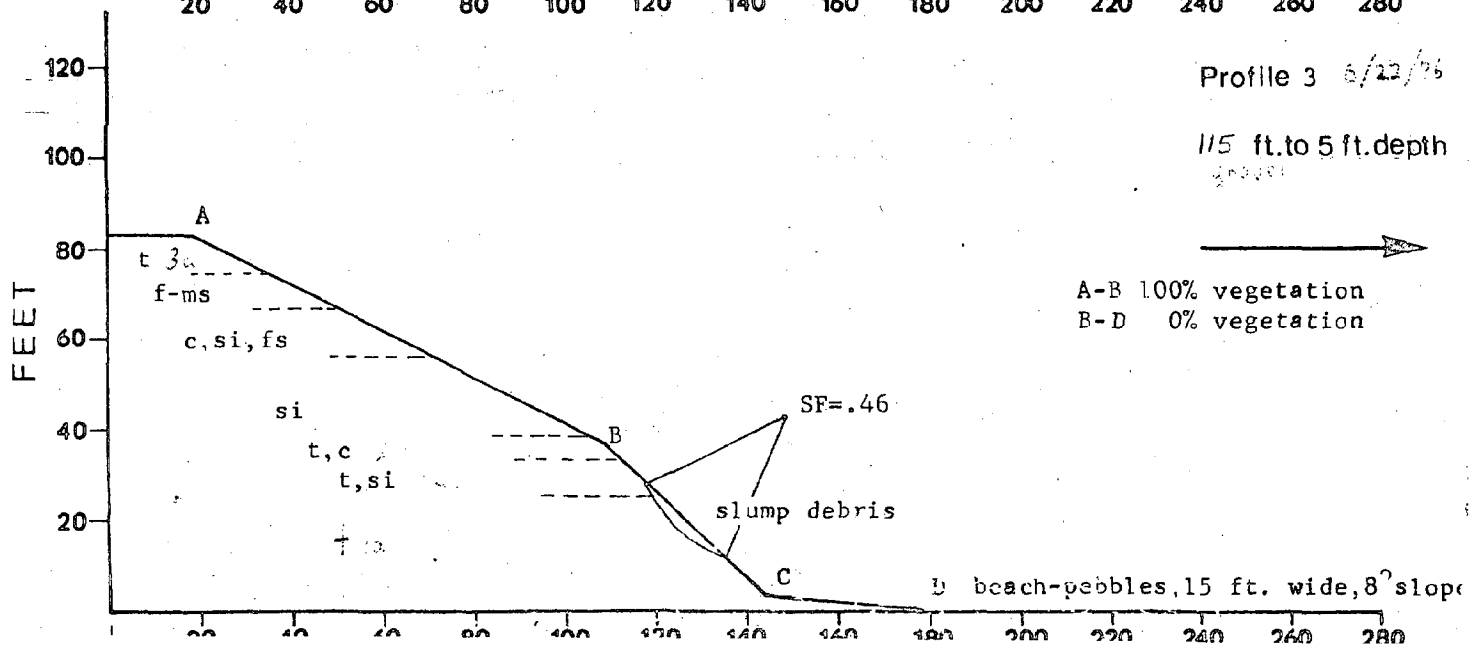
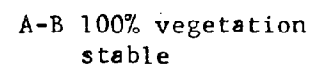
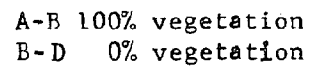
B-1.00 to 1.25

C-greater than 1.25

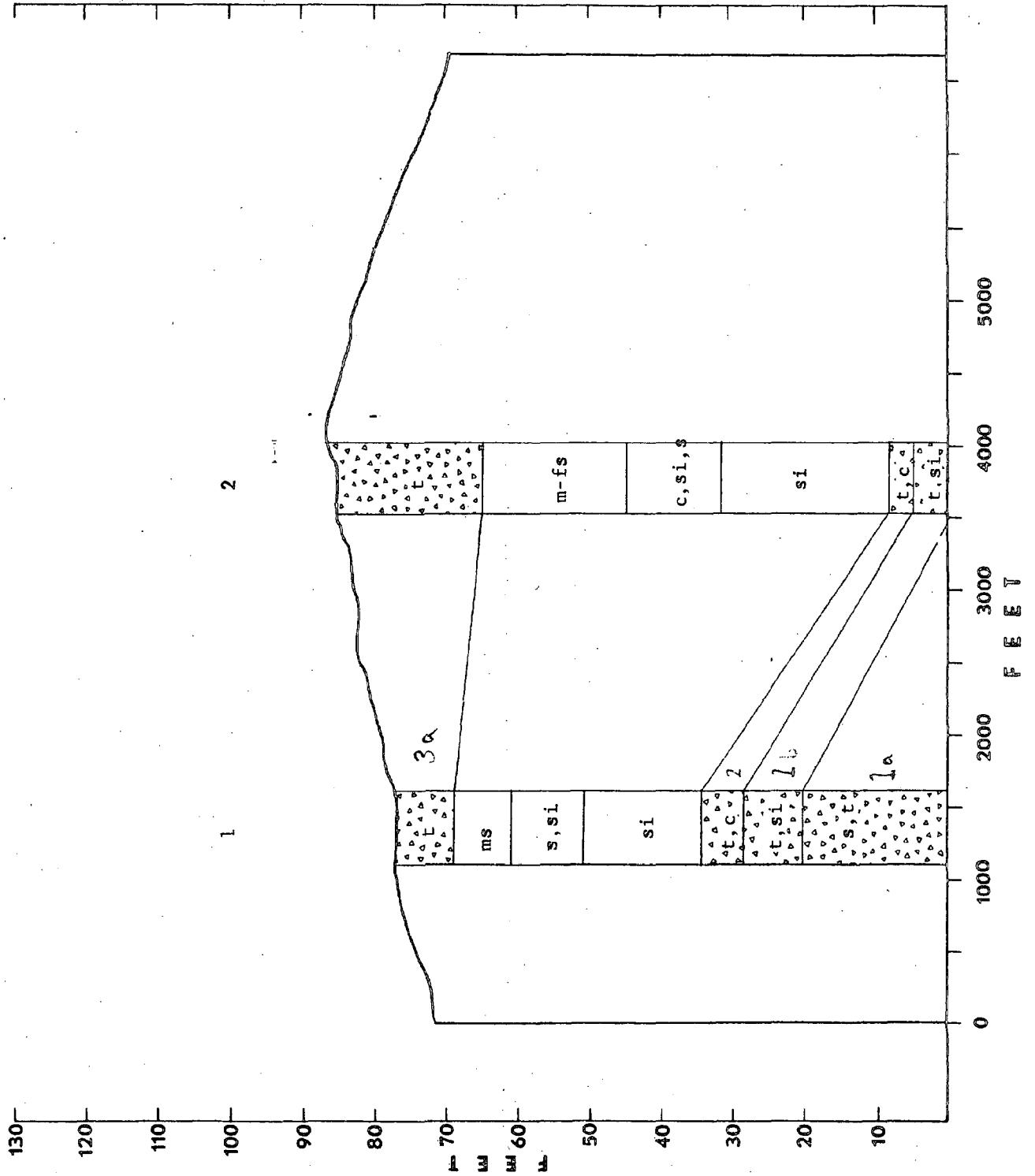
CONFIDENCE LEVELA-boreholes
(high confidence)B-near boreholes
stratigraphy visibleC-no stratigraphy
visible (low
confidence)

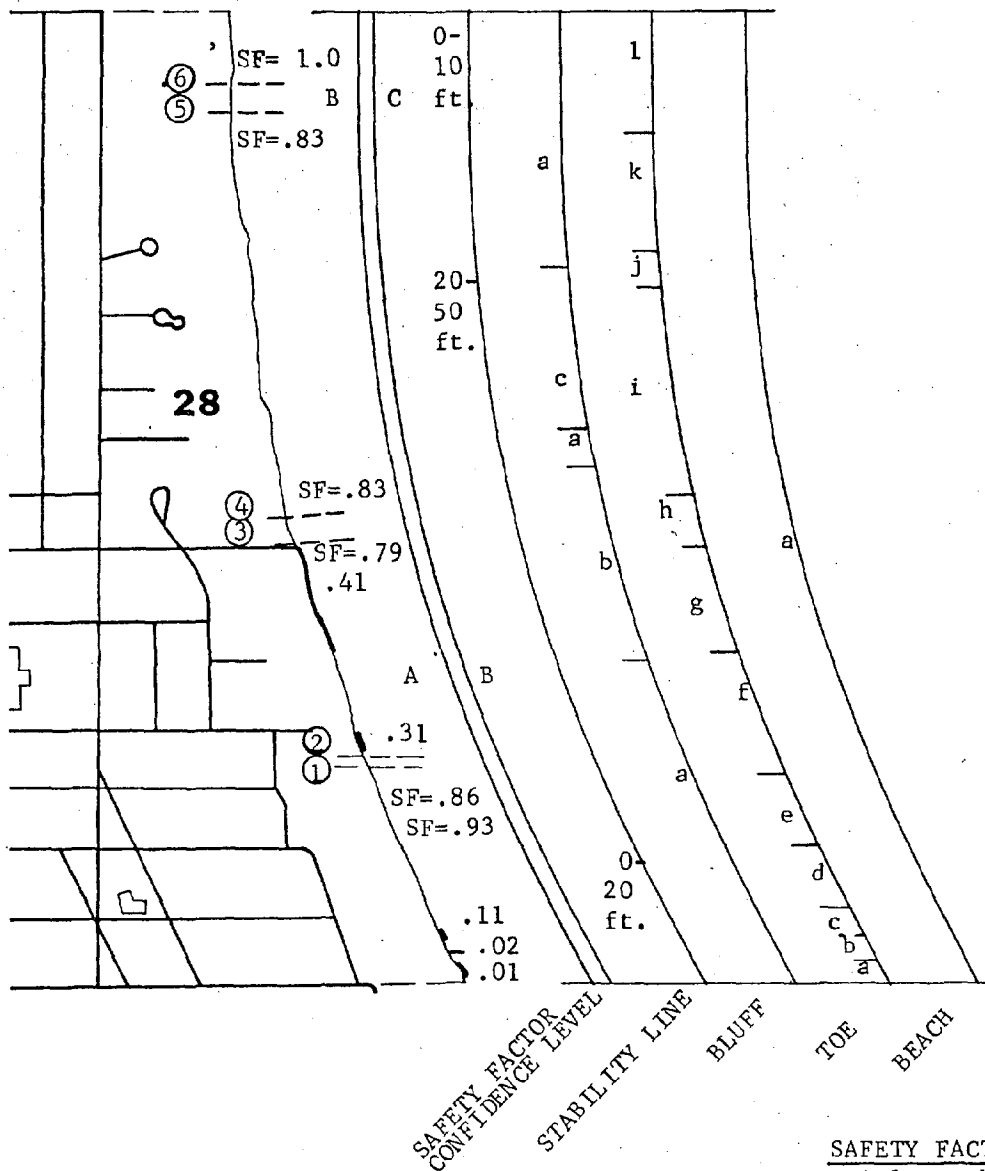
1. BLUFF	a-rapid toe erosion, slides (shallow) on upper slope	b-relatively stable protected by seawall	c-rapid toe erosion, slides on upper slope	d-large rotational slumping
	e-stable due to grading and seawall	f-slow erosion, translational slides and several slump blocks	g-rapid toe erosion	h-slow erosion translational slides
2. TOE	a-till in place	b-not visible due to vegetation covering	c-in place silt	d-slumped silt and till
	e-not visible	f-in place silt and lacustrine clays	g-slumped silt and till	
3. BEACH	a-5-20 ft. sand and cobbles	b- -5 ft. seawall	c-5-20 ft. sand	d- +20 ft. sand
	e- -5 ft. sand	f- +20 ft. sand	g- -5 ft. revetment	h-5-20 ft. cobble

120 ft. to 5 ft. depth

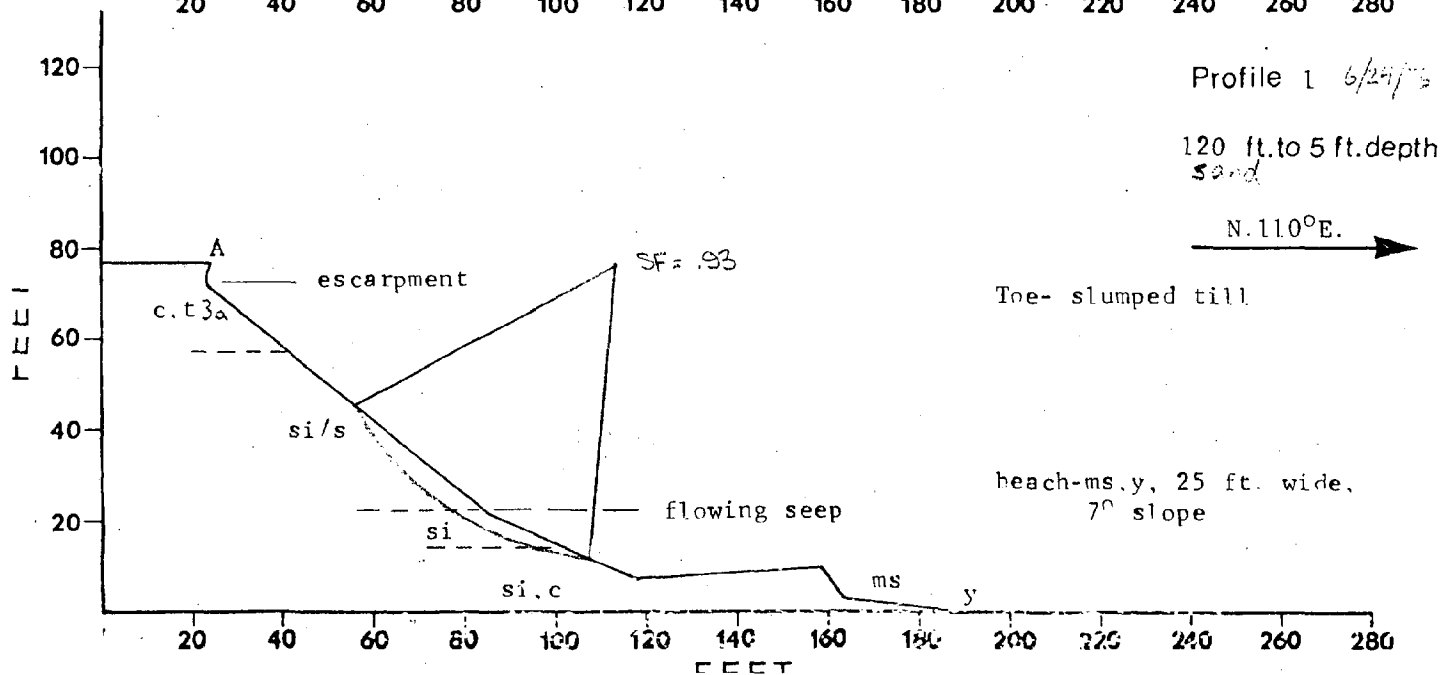
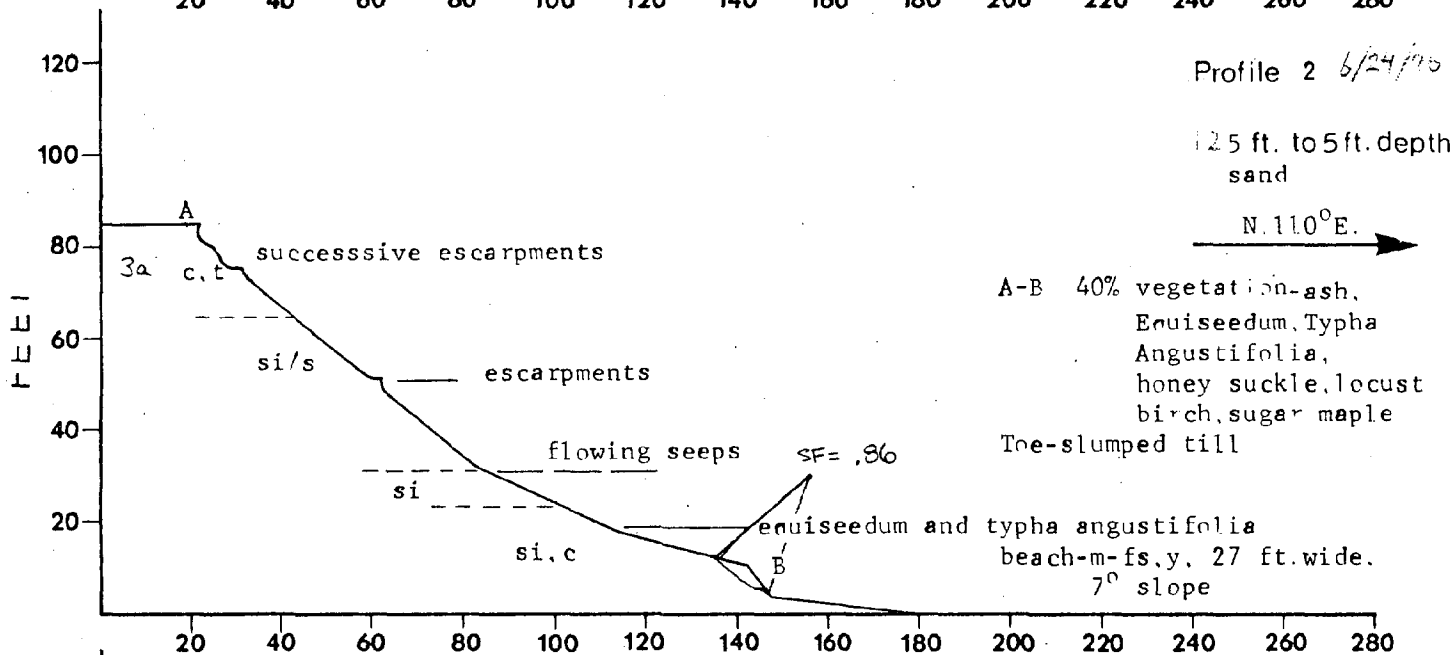
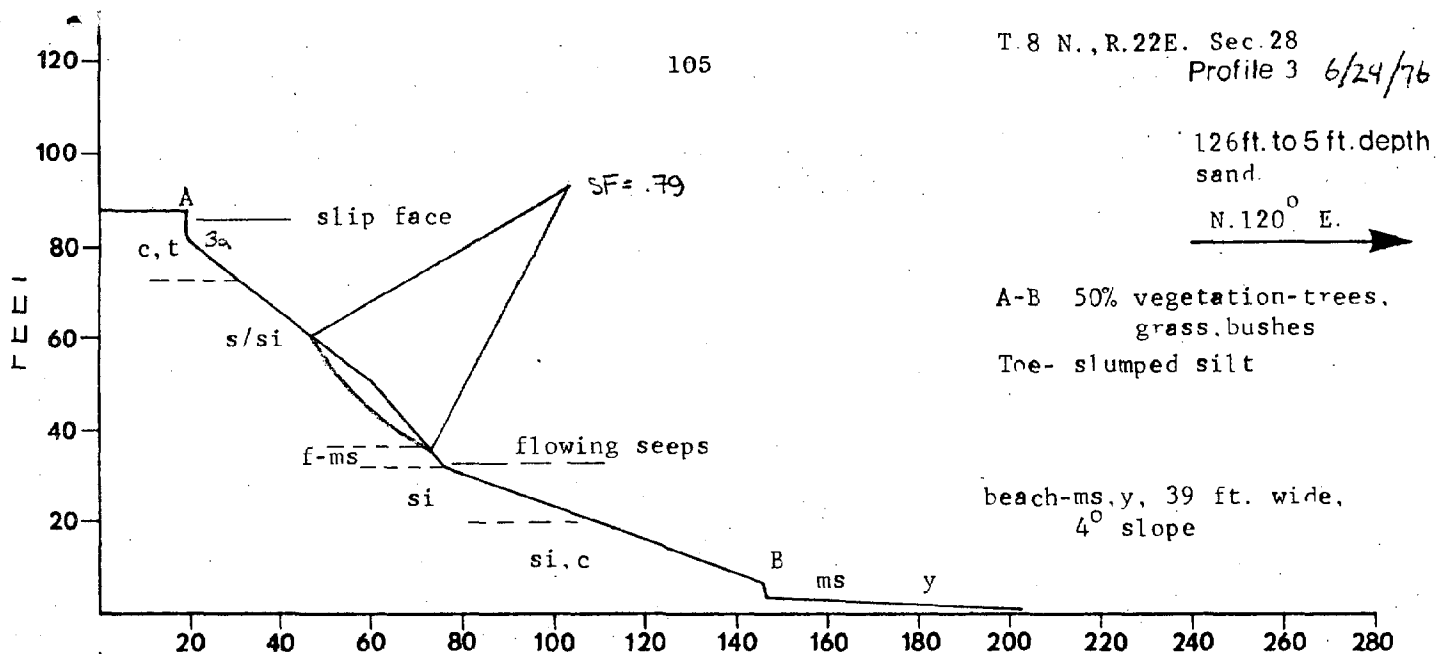


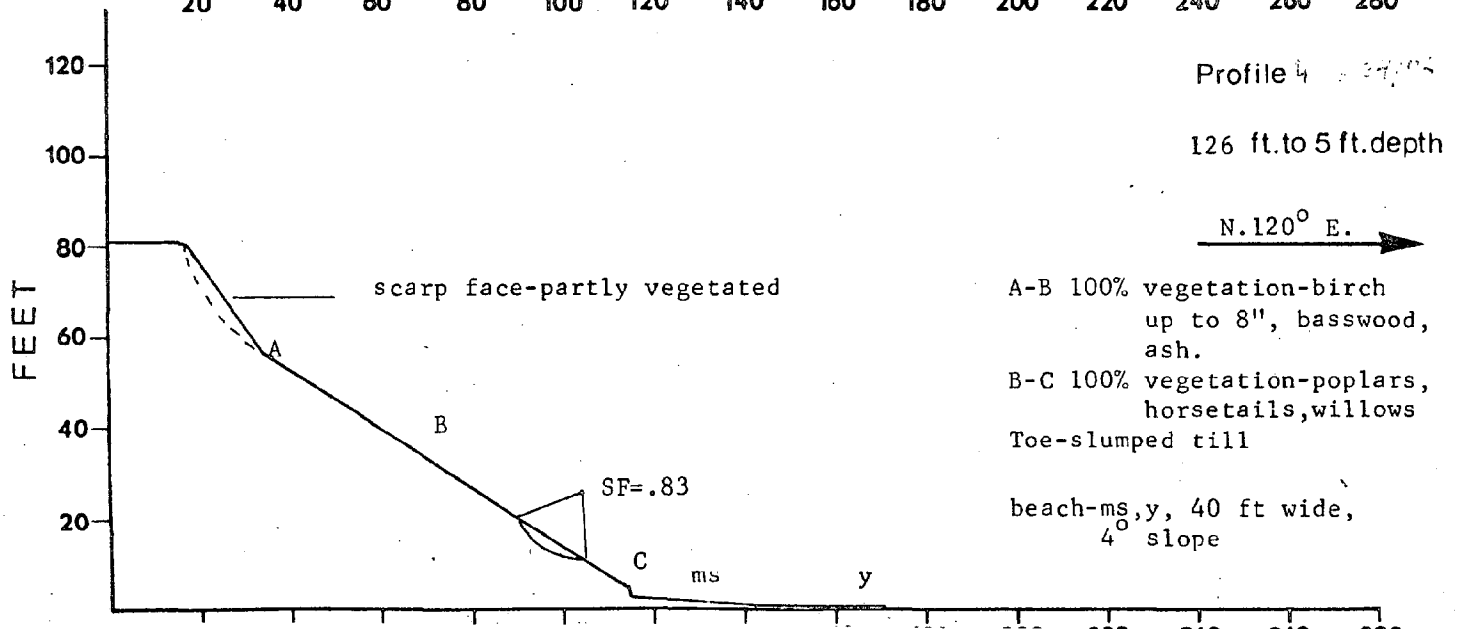
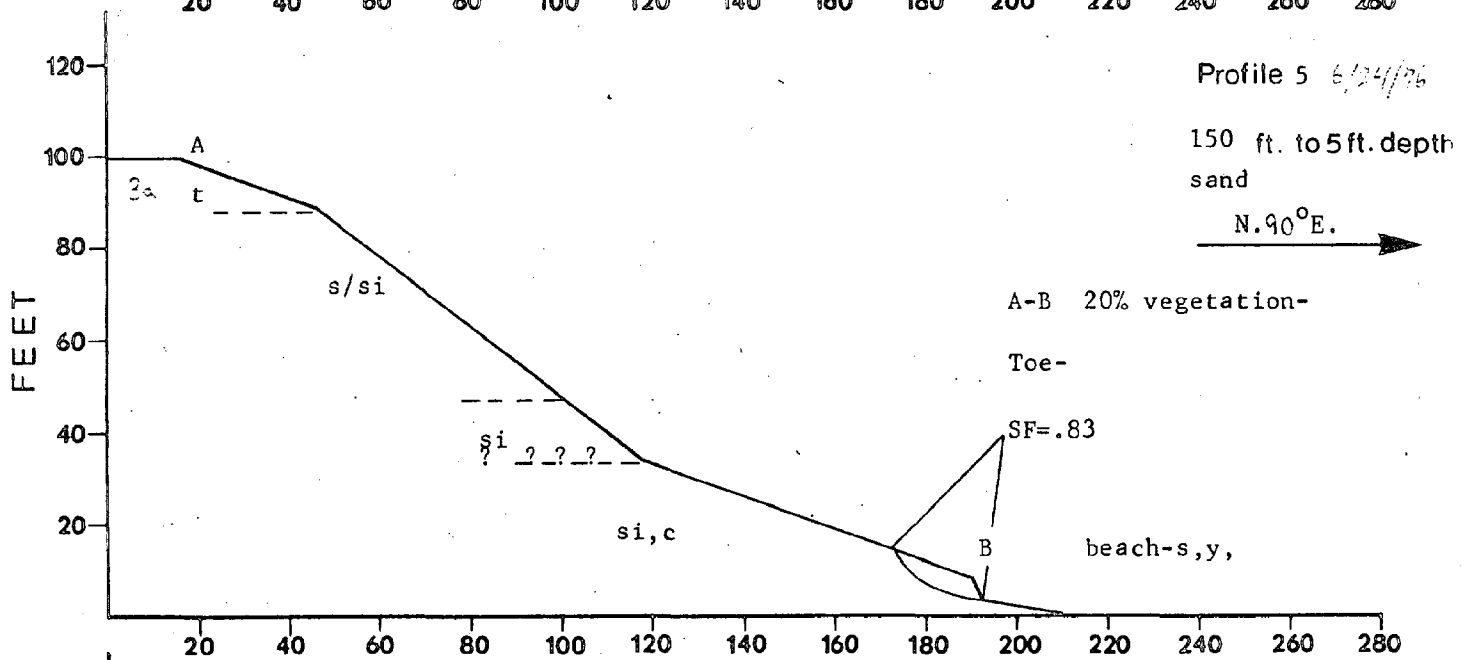
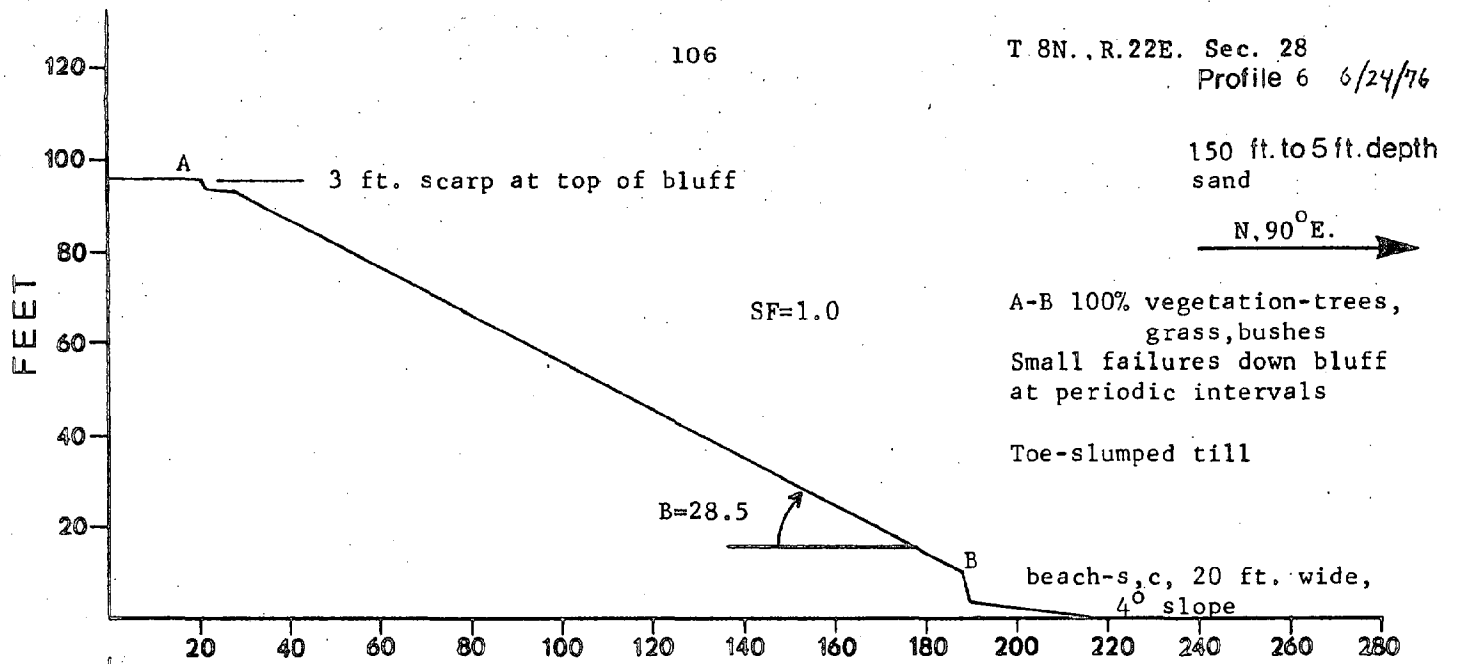
T. 8 N., R. 22 E., Sec. 33/34



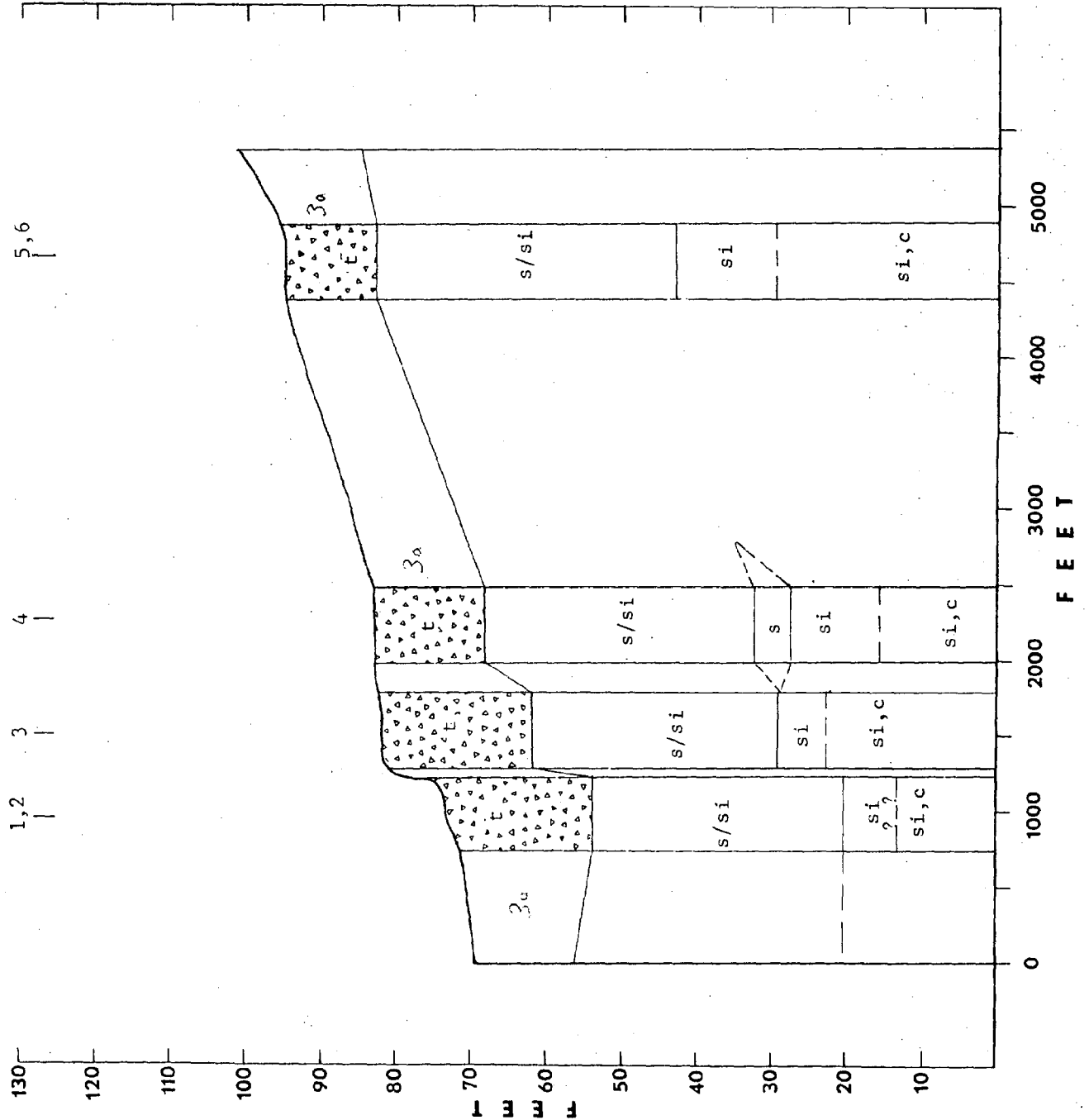


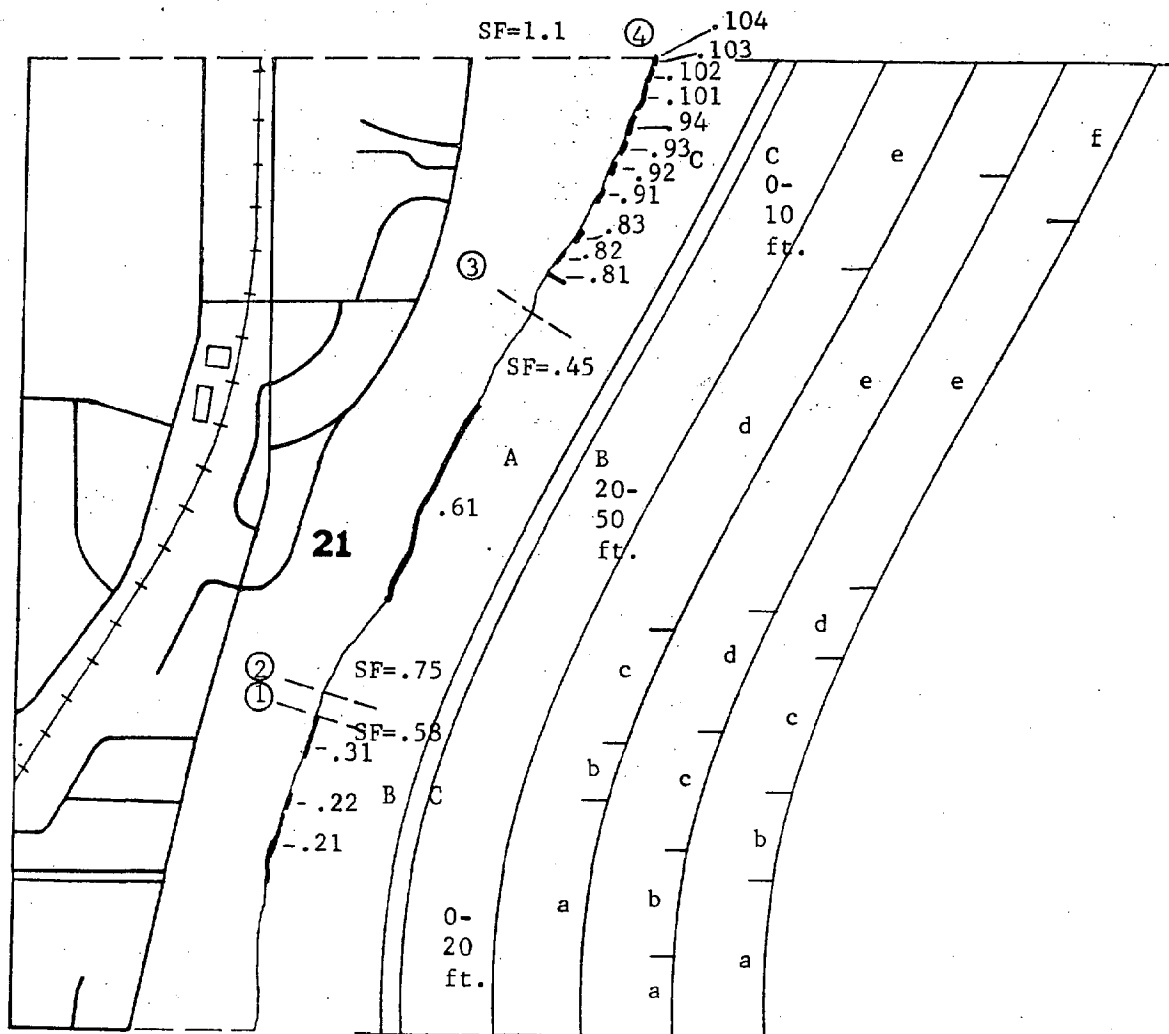
1. BLUFF	a-A series of rotational slumps, as waves erode toe, bluff becomes unstable. Springs prevalent in the silt layer, standing water on the bottom most slump -possible impermeable layer below which a lubricated plane is produced for the faults to slump down. Vegetation is prevalent throughout most of slope. Slope angle seems to be approximately 40°. Scarp face evident at the top of the bluff.		b-fairly stable condition due to the seawall and sand build-up behind it which protects the toe of the bluff. Scarp face evident at the top of the bluff	c-in stable condition although the presence of slumps, possibly due to the sand build-up at the toe from an old beach deposit which protects the toe. Heavily vegetated. Scarp face evident at the top of the bluff.
	d-same as a- above.			
2. TOE	a-slumped till	b-debris	c-slumped sand and silt	d-slumped till
	e-slumped silt	f-slumped till	g-sand resulting from waves overtopping seawall	h-slumped silt
	i-sand, possibly an old beach deposit	j-part of soil profile	k-slumped silt	l-slumped till
3. BEACH	a-greater than 25 ft.; approximately 10 ft. from the water's edge-pebbles and cobbles; to toe of bluff-medium sand.			





T.8 N., R.2E., Sec 28





T.8N., R.22E.

SAFETY FACTOR
CONFIDENCE LEVEL
STABILITY LINE
BLUFF
TOE
BEACH

SAFETY FACTOR

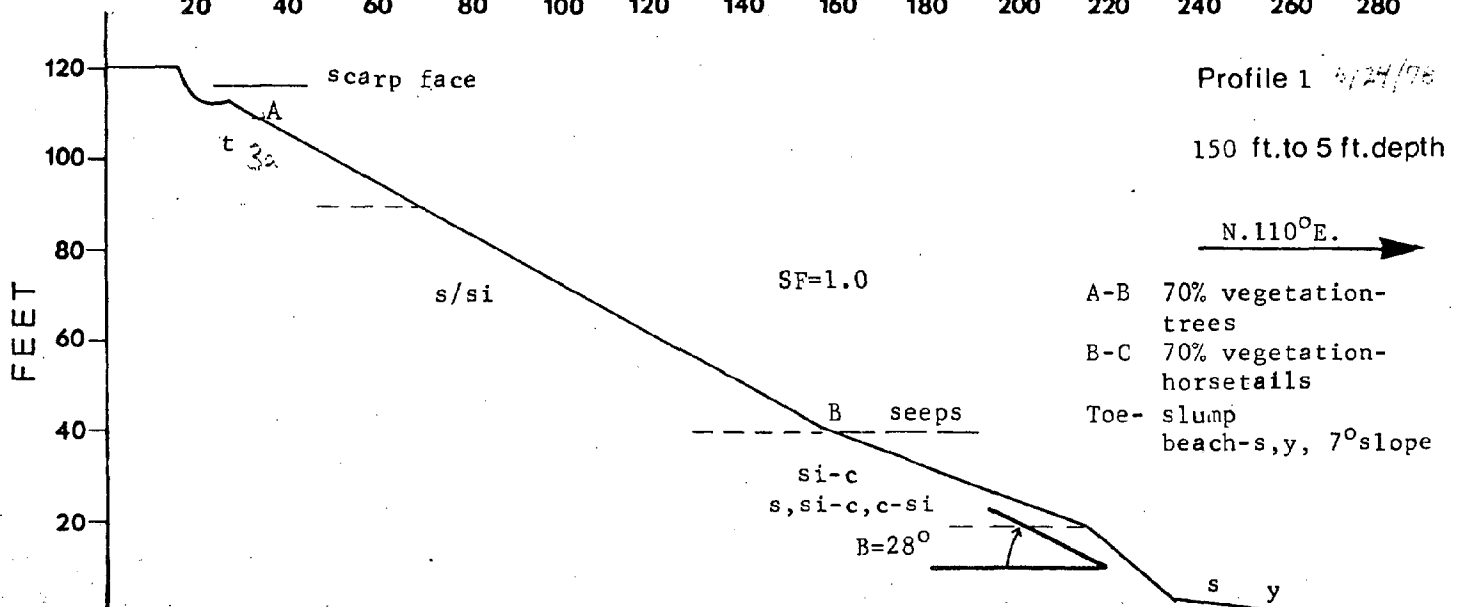
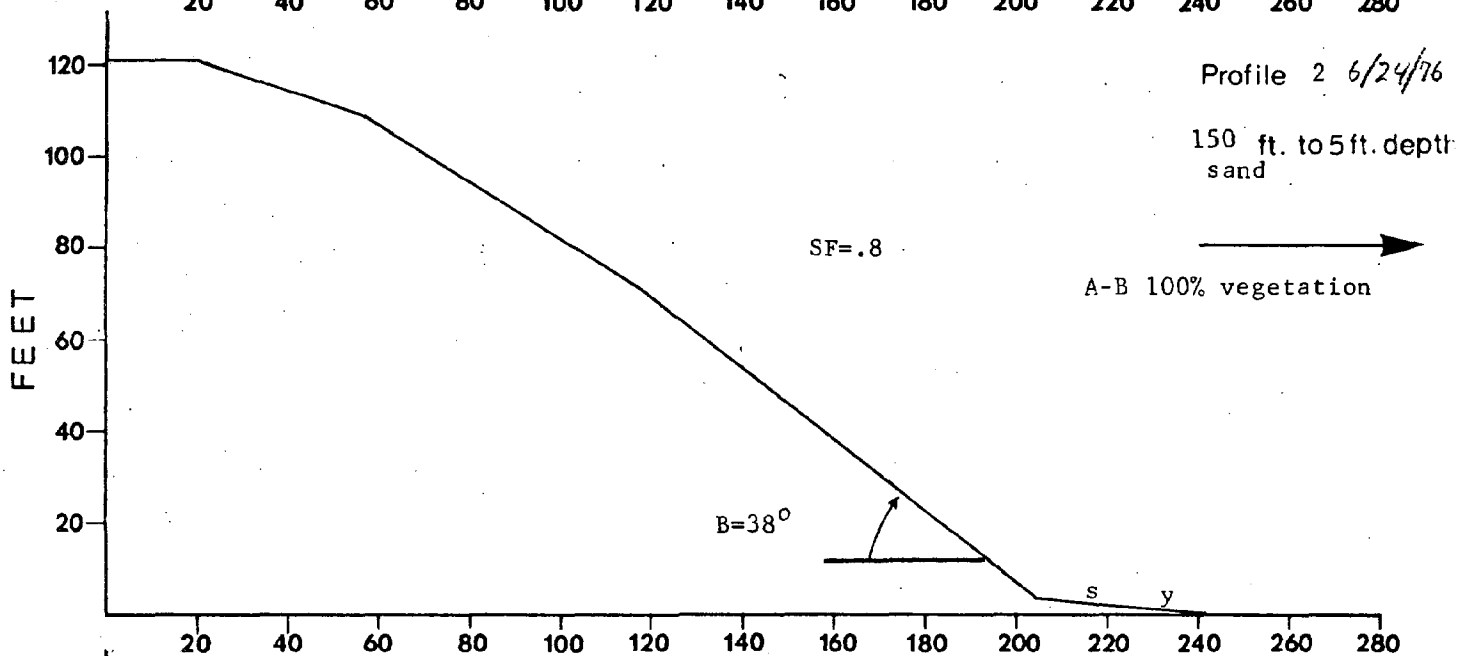
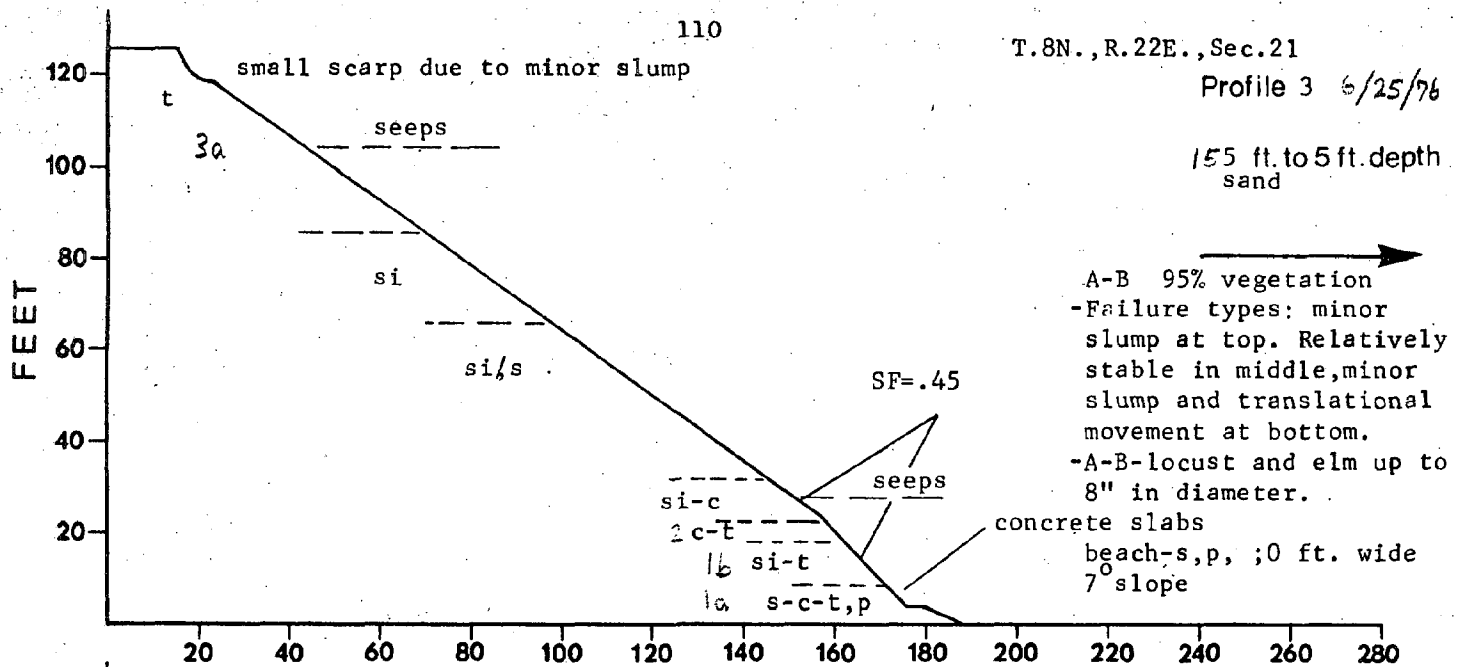
A-less than 1.00

B-1.00 to 1.25

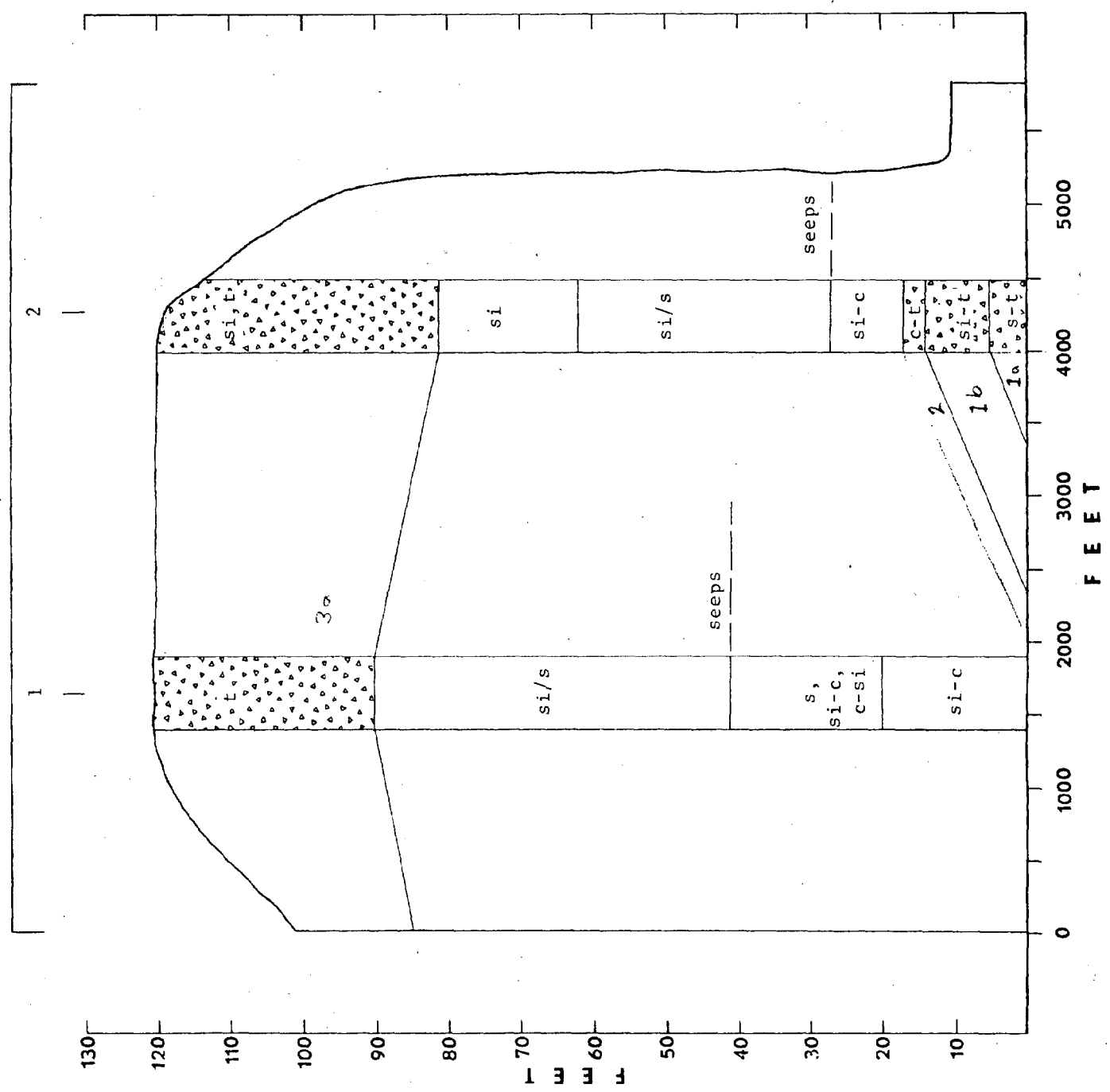
C-greater than 1.25

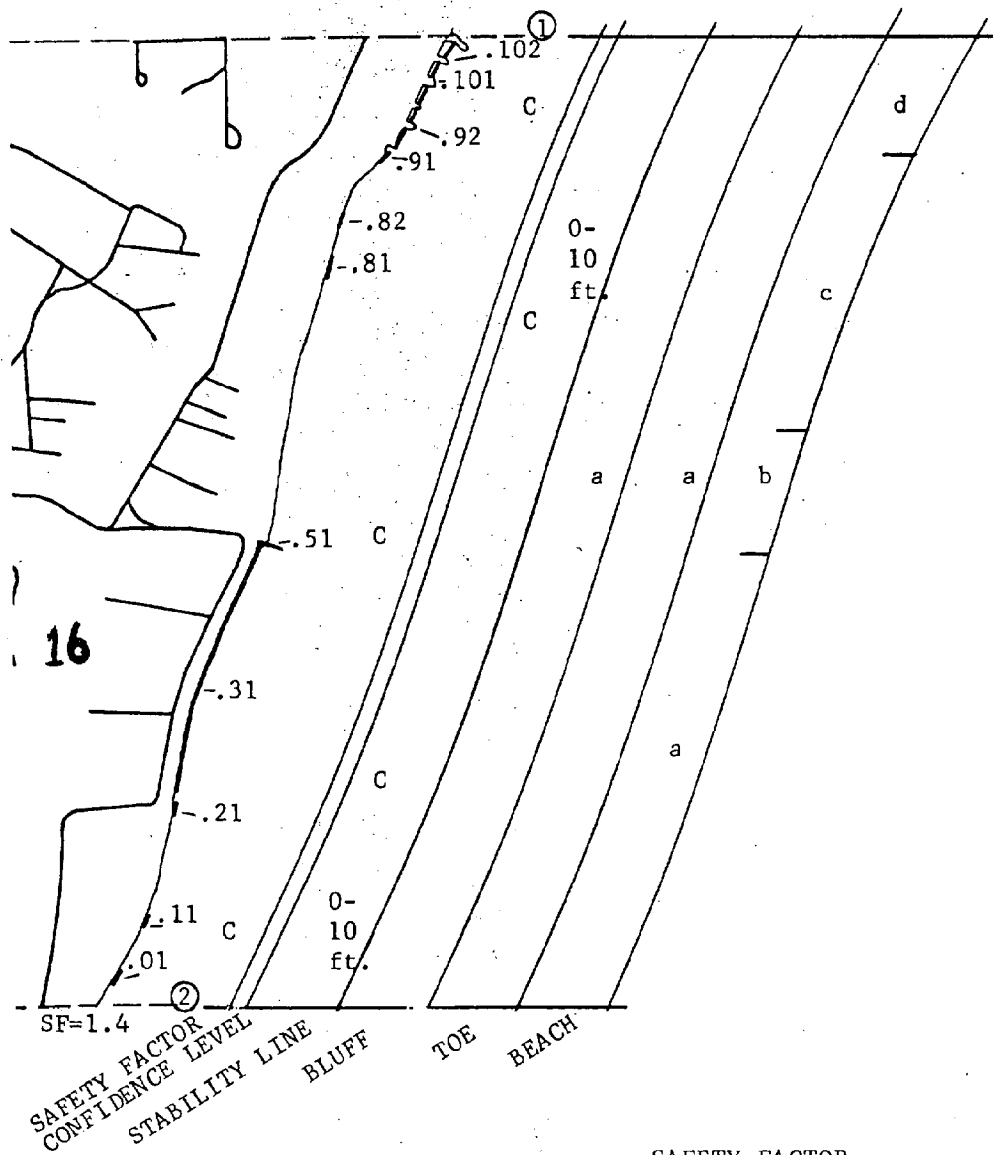
CONFIDENCE LEVELA-boreholes
(high confidence)B-near boreholes
stratigraphy visibleC-no stratigraphy
visible (low
confidence)

1.BLUFF	a-rapid toe erosion with translational slides above	b-relatively stable, no recent failures	c-slumping and toe erosion, many seeps, unstable	d-rapid toe erosion with translational slides above
	e-relatively stable, no recent failures			
2.TOE	a-in place silty clay	b-slide debris, red till, silt and sand	c-in place silty clay, not exposed	d-slide debris, red till, silt and sand
	e-intermittantly in place and covered by a thin veneer of slide and flow debris		f-in place paleo beach terrace	
3.BEACH	a-5 to 20 ft. sand	b-less than 5 ft., sand and cobbles	c-less than 20 ft., sand	d-less than 5 ft., cobbles and sand
	e-5 to 20 ft. sand	f-less than 5 ft., sand and cobbles, revetment		



T. 8 N., R. 22 E., Sec. 21



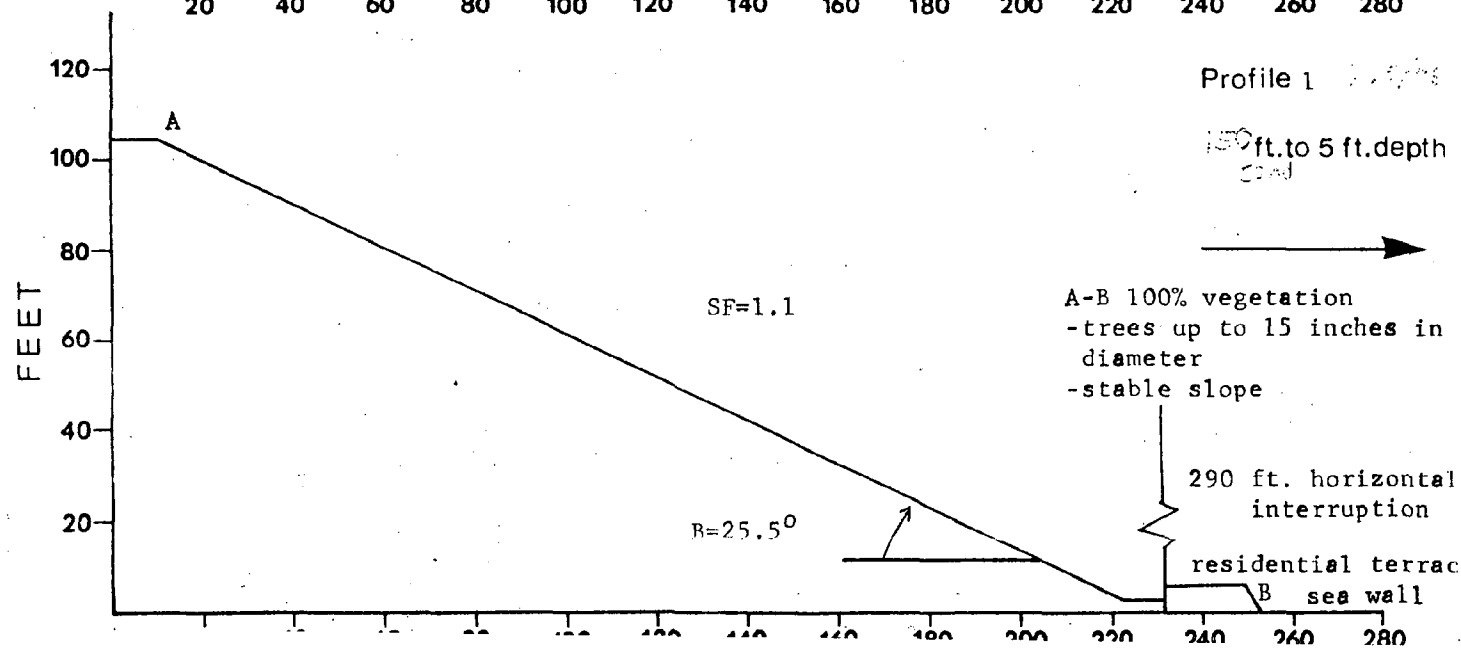
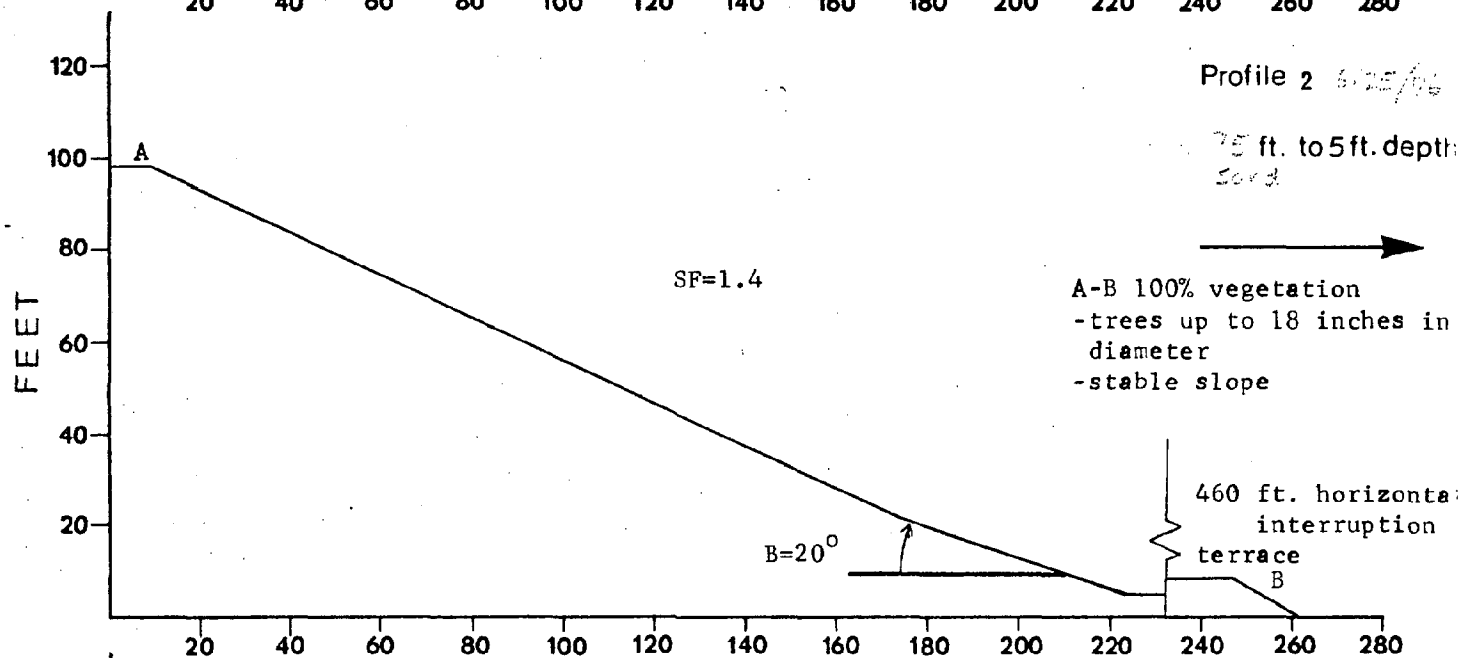
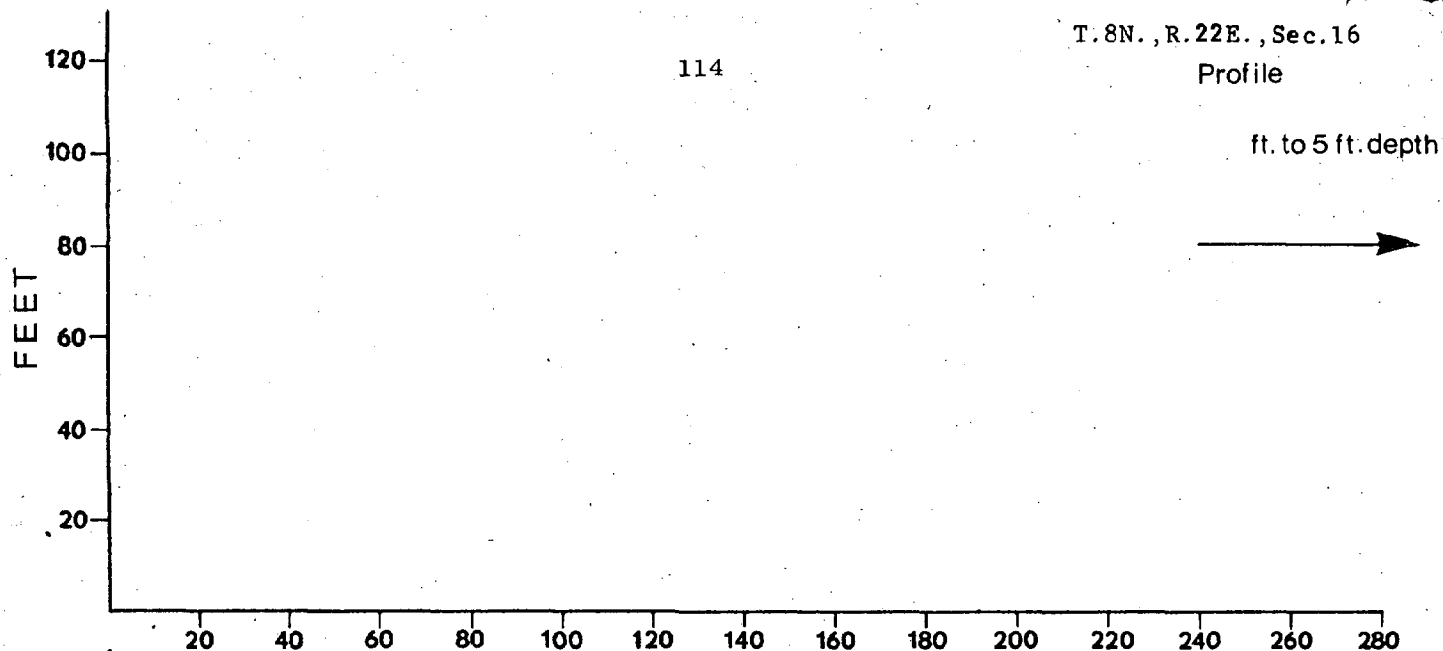
SAFETY FACTOR

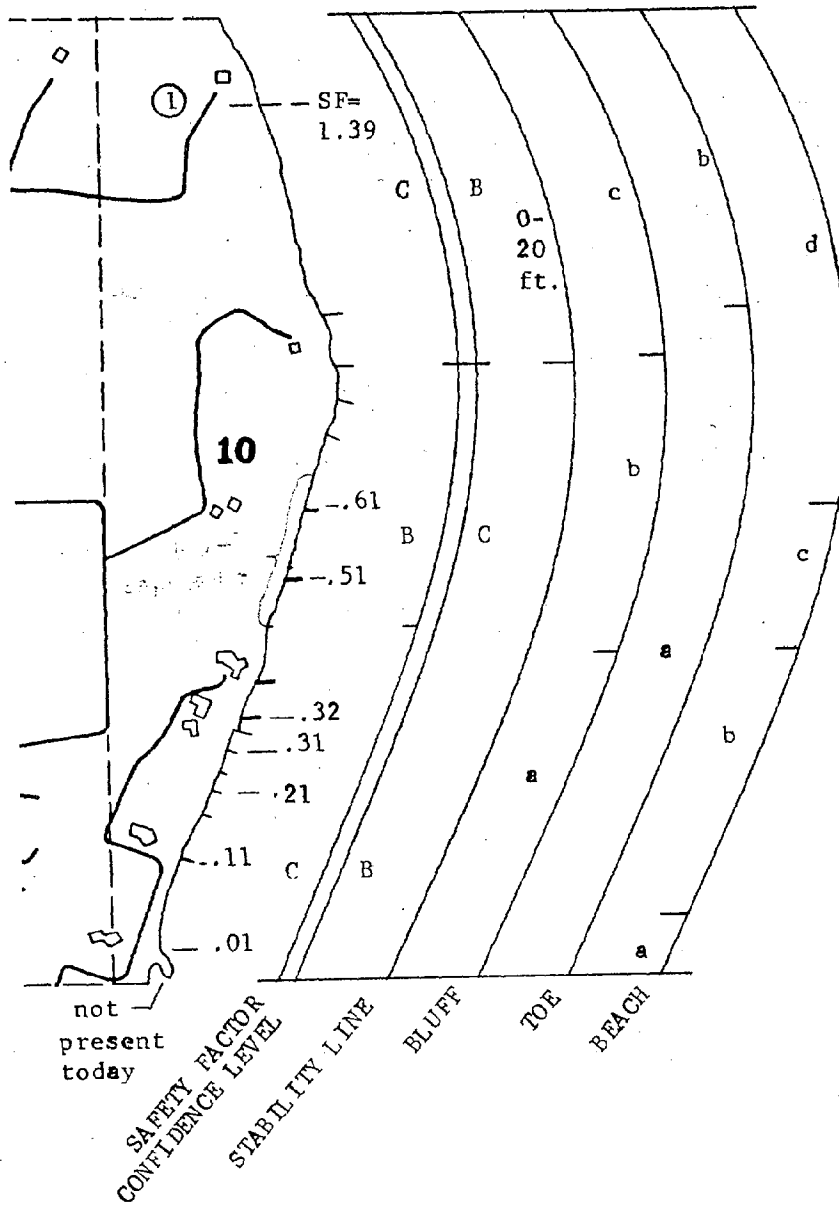
- A-less than 1.00
- B-1.00 to 1.25
- C-greater than 1.25

CONFIDENCE LEVEL

- A-boreholes
(high confidence)
- B-near boreholes
stratigraphy visible
- C-no stratigraphy
visible (low
confidence)

1. BLUFF	a-relatively stable, several slump scarps noted.			
2. TOE	a-in place paleo lake terrace, till and beach sand, gravel, cobbles			
3. BEACH	a-less than 5 ft. sand, revetment, seawall	b-less than 20 ft., sand	c-less than 5 ft., sand,revet- ment,seawall	d-less than 20 ft., sand



SAFETY FACTOR

A- less than 1.00

B- 1.00 to 1.25

C- greater than 1.25

CONFIDENCE LEVELA- boreholes
(high confidence)B- near boreholes
stratigraphy visibleC- no stratigraphy
visible (low
confidence)

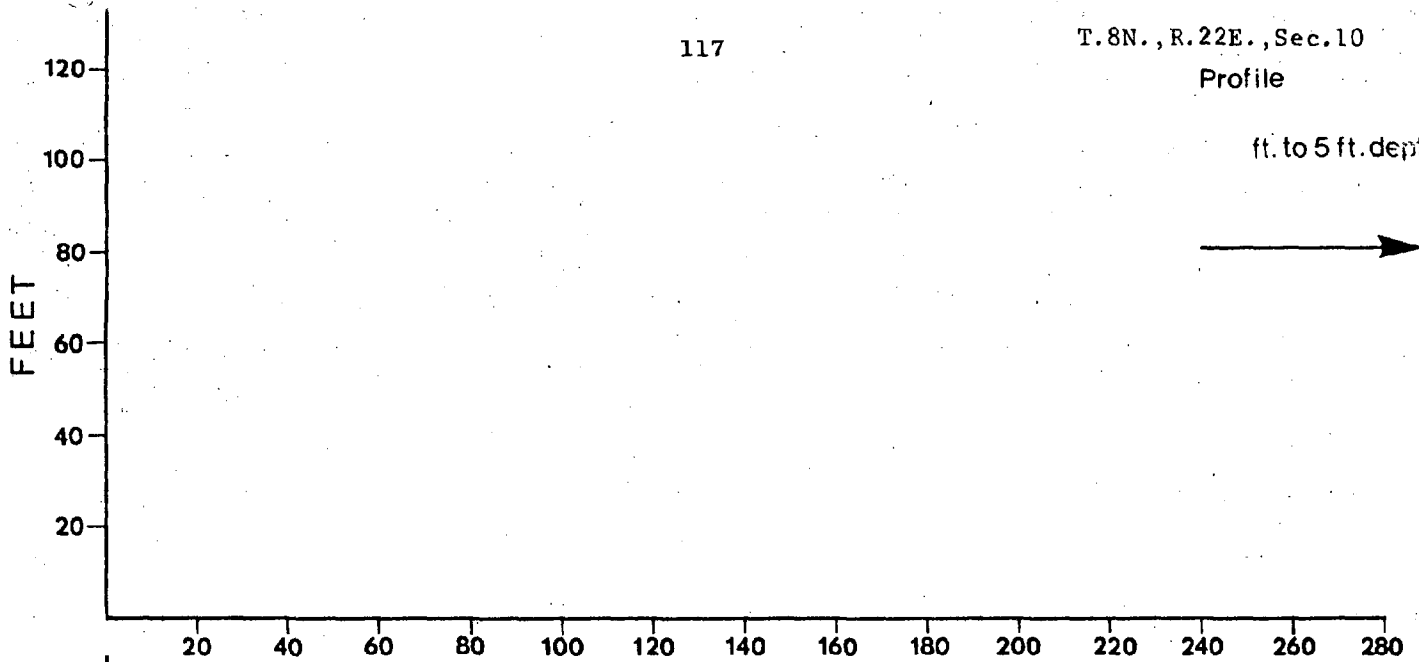
1. BLUFF	a-former lake terrace protects a bluff with approximately a 25° slope with 100% vegetation. No evidence of failure on the bluff.	b-No lake terrace, 100% vegetation on a stable bluff, 30° slope. Seawall to protect toe. no evidence of bluff failure.	c-Former lake terrace protects a bluff with approximately a 25° slope with 100% vegetation. No evidence of failure on the bluff.
2. TOE	a-toe material not visible due to shore structures and vegetation	b-sand	
3. BEACH	a- -30 ft. in the south grading to no beach in the north, composed of medium grained sand	b-no beach	c- -15 ft. medium grained sand
	d- +25 ft. medium grained sand		

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T.8N., R.22E., Sec.10

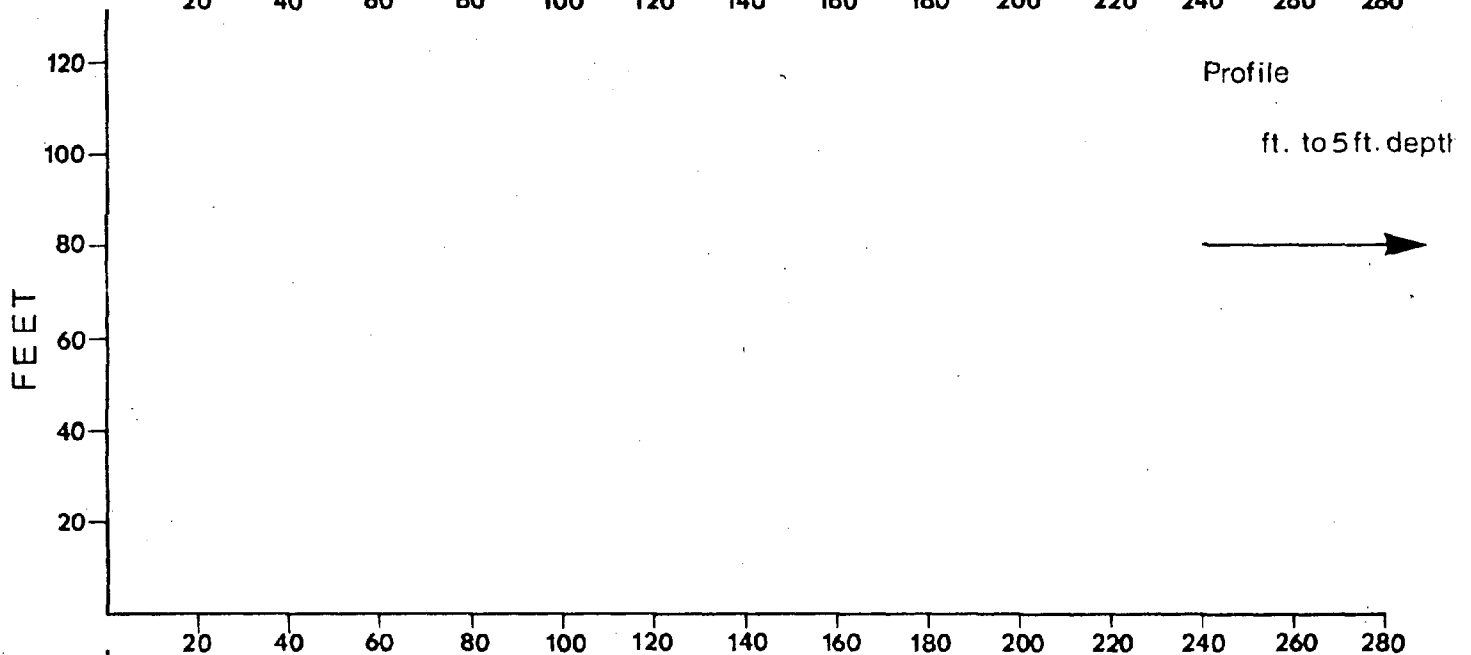
Profile

ft. to 5 ft. depth



Profile

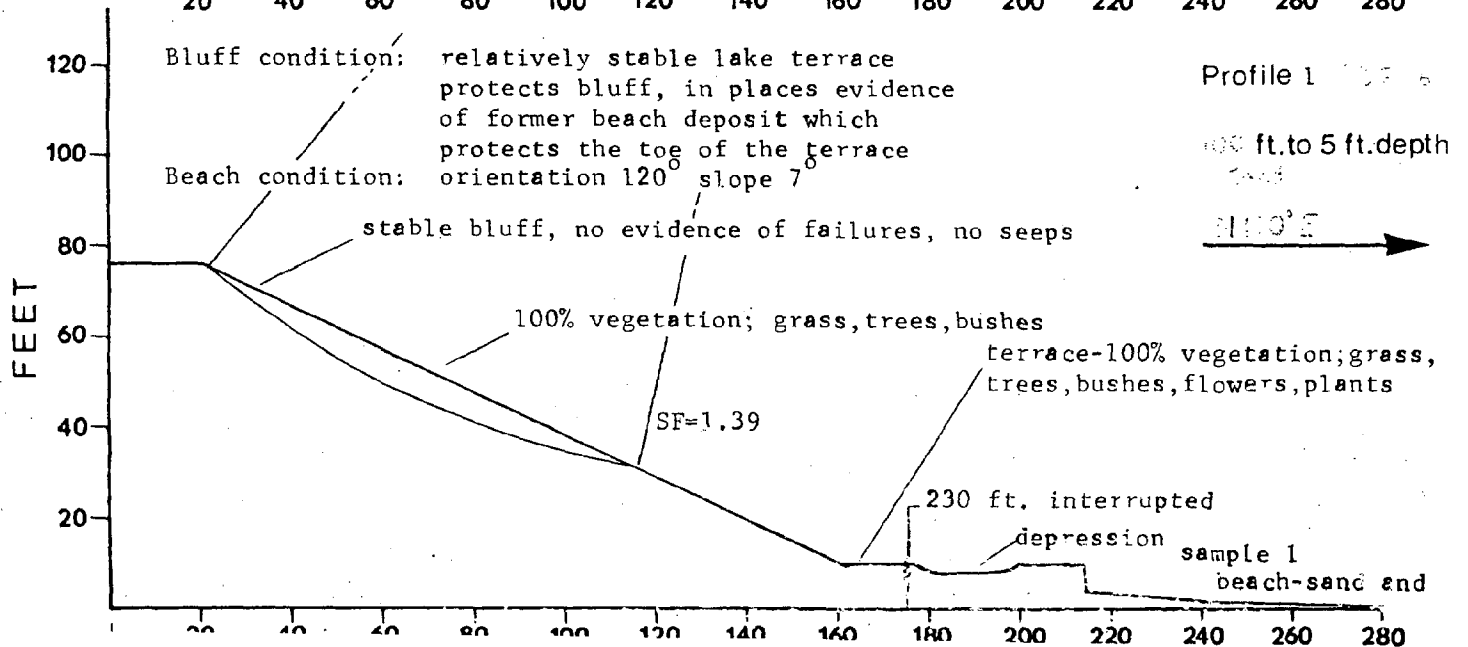
ft. to 5 ft. depth



Profile 1

ft. to 5 ft. depth

3110'E



**COASTAL ZONE
INFORMATION CENTER**

