STATE OF CALIFORNIA—THE RESOURCES AGENCY

GEORGE DEUKMEJIAN, *Governor*

DEPARTMENT OF WATER RESOURCES
1416 NINTH STREET, P.O. BOX 942836
SACRAMENTO, CA 94236-0001
(916) 445-9248

May 9, 1989

Ken Rodda
Wahler Associates
P. O. Box 10023
Palo Alto, CA 94303

Dear Mr. Rodda:

Levee Design Criteria

In our telephone conversation of May 1, 1989, you requested technical information concerning our study of landside geometry for Delta levees. Attached is a draft executive summary of a report which features our proposed geometry criteria for landside slopes for existing levees in the Sacramento-San Joaquin Delta. The criteria is expressed in four figures depicting minimum landside slope as a function of levee height, thickness of soft foundation soil, and land use. The entire report is being finalized and should be available sometime in June.

Also attached are computer input and output for two stability analyses. These analyses were performed on a 20-foot-high embankment with 1.5 feet of freeboard. One case assumes a foundation with 10 feet of peat and the other case assumes a foundation with 40 feet of peat. The sections are based on a generalized model which is also attached.

If you have any questions, please call me at (916) 445-3128.

Sincerely,

Leslie F. Harder, Jr., Chief
Canals and Levees Section
Civil Design Branch
Division of Design and Construction

Attachments

State of California
The Resources Agency
DEPARTMENT OF WATER RESOURCES
Division of Design and Construction

MINIMUM GEOMETRY CRITERIA FOR REHABILITATING EXISTING LEVEES IN SACRAMENTO-SAN JOAQUIN DELTA

DRAFT

Memorandum Report

March 1989

DRAFT

1. EXECUTIVE SUMMARY

<u>Recommendations</u>

The levee geometries suggested in this report represent minimum slopes needed to assure adequate slope stability for different foundation conditions and levee heights found in the Sacramento-San Joaquin Delta. They are intended for use as general guides for situations where detailed foundation conditions and strengths are not available. The level of safety is intended to be comparable with criteria which would satisfy the long-term requirements of the Federal Emergency Management Agency (FEMA).

The recommended geometries were developed to satisfy a slope stability factor of safety of 1.3. In light of the high hazard involving potential property damage, this factor of safety is relatively low. However, it is believed to be appropriate due to the fact that conservative parameters were adopted for foundation properties. In many locations, it may be possible to show with detailed soil explorations and tests that the foundation strengths are higher than those assumed in this study and that steeper slopes would be adequate. However, in such cases it is also necessary to go beyond simply laboratory test results and to adequately account for the potential destabilizing effects of high water levels and/or piping in the foundation.

It is also true that a wide variety of different levee berms could be used to achieve the same degree of stability. If other combinations of levee slopes and berms are used, the soil parameters determined in this study are recommended for use in the absence of detailed foundation information.

Background

The Island tracts within the Sacramento-San Joaquin Delta are protected against inundation by extensive systems of earthen levees. These levees have had a long history of levee instability and failure resulting primarily from unstable foundation conditions, poor construction and maintenance practices, and overtopping during the flood season.

Most of the tracts in the Delta contain layers of weak foundation soils at or near ground surface. These weak soils are generally composed of organic clays, organic silts, peat, or a combination thereof. Levees constructed over these soils are prone to subsidence and stability problems. The thickness of these weak soils ranges between zero and 60 feet with thicknesses between 10 and 30 feet commonly found at most tracts.

Most of the levees in the Delta were constructed by local farmers using available non-select material. Levees were generally placed uncompacted without engineering design and without good construction methods. Further, many levee reaches have crown elevations which are below the 100 year flood elevation. In the past, large storms have caused overtopping and failure of several levees which lacked sufficient freeboard.

Scope of Work

This report describes geometry criteria for rehabilitating existing levees in the Sacramento-San Joaquin Delta to help prevent levee failures and consequent flooding. This should be accomplished by raising, widening and strengthening the embankments as needed. The investigation consisted of the following steps:

1. Review of existing literature on soil strengths, levee design, and levee failures in the delta.
2. Determination of strength of weak organic soil underlying delta levees.
3. Development of a general model for stability analyses.
4. Determination of required levee geometry for different foundation conditions.
5. Recommendation of Construction Methods.

Authorization

In a June 1988 meeting, staff from the Division of Local Assistance requested staff of the Design Office to develop generic levee design parameters as functions of physical dimensions, foundation material, construction material, and land use. This request was formalized in a

1988-89 Work Order Assignment (form DWR 1498) with work to be charged equally to Work Order numbers 0070-0002 and 0070-0010.

<u>Summary of Findings</u>

A review of previous studies conducted by both the United States Army Corps of Engineers ~~(USACE)~~ and the California Department of Water Resources ~~(CDWR)~~ indicates a general consensus concerning minimum geometric criteria for Delta levees (e.g. References __,__, and __). For areas without significant amounts of soft foundation soils, this criteria is as follows:

Levee Crown Width = 16 feet

Freeboard above flood = 3 feet (Urban)

Freeboard above flood = 1.5 (Agricultural)

Upstream or waterside slope = 2:1

Downstream or landside slope = 3:1

In areas with significant amounts of weak foundation soils, previous studies have indicated the need for either flatter landside slopes, or the placement of berms buttressing the landside slope. This investigation was principally oriented towards determining the minimum landside geometry required for longterm levee stability for a wide range of possible levee heights and weak foundation conditions.

The results of studies performed in this investigation are as follows:

1. Presented in Figures 1 and 2 are the minimum landside levee slopes that would achieve a slope stability factor of safety of 1.3. The recommended slopes presented in Figure 1 are intended for levees protecting urban tracts (i.e. freeboard equal to 3 feet). The recommended slopes presented in Figure 2 are intended for levees protecting agricultural tracts (i.e. freeboard equal to 1.5 feet). As may be observed from the figures, in areas with very small levee heights and/or small amounts of weak foundation soils, the minimum slope becomes the 3:1 specified above. However, for large levee heights and foundation areas with extensive thicknesses of weak soil, the required landside slope becomes as flat as 7:1. The difference between the recommended slopes shown in Figure 1, using a freeboard of 3 feet, and Figure 2, using a freeboard of 1.5 feet, is only significant for levee heights less than about 15 feet where the largest difference in slope is about 0.5:1. For levee heights greater than 15 feet the difference in slope is not significant.
2. Presented in Figures 3 and 4 are alternative landside geometries that would achieve a slope stability factor of safety of 1.3. In both figures, a landside slope of 3:1 has been buttressed with a sloping berm originating at half the slope height. Figure 3 represents the case using a freeboard of 3

feet (urban tracts), and Figure 4 represents the case using a freeboard of 1.5 feet (agricultural tracts). As in Figures 1 and 2, there is no need for a slope flatter than 3:1 for small levee heights and/or small amounts of weak foundation soils. However, for large levee heights and foundation areas with extensive thicknesses of weak soil, the required landside slope of the berm becomes as flat as 13:1. As in Figures 1 and 2, the difference between using a freeboard of 3 feet and using a freeboard of 1.5 feet has a much larger effect on the acceptable slope for levees less than 15 feet high. This difference is about 1:1 for levee heights less than 15 feet and about 0.5:1 for levee heights greater than 15 feet.

In addition, the following findings should be noted:

A. The geometries reported in Figures 1 through 4 represent stable longterm conditions. Care needs to be taken that locations requiring additional fill are rebuilt using staged construction techniques in order to avoid short term loading failures.

B. The recommended geometries address principally landside slope stability. In areas where the existing levee embankment can erode or pipe during periods of high water levels, additional stabilization involving filters, drains, and other treatments are necessary.

C. In some cases, the geometries in Figures 3 and 4 are preferable to those shown in Figures 1 and 2 as the stresses in the foundation are usually less, the induced amount of settlement is usually less, and the volume of fill required to construct the berm may be less.

D. As mentioned previously, an infinite number of berm geometries with different berm widths, heights, and slopes can be shown to achieve the same factor of safety. The optimal geometry for any particular levee reach is likely to depend on the thickness of weak foundation material and the availability of land to be occupied by the stabilizing berm.

E. The geometries recommended are based on the assumption that mineral soils are to be used to buttress the landside slopes. This assumption was based on the previous practice of using dredged material obtained from adjacent sloughs and on the proposals to use imported dredged material from San Francisco Bay. If peat or other materials having low unit weights are to be used to buttress the existing levees, then slopes flatter than those recommended in this report will be necessary to achieve the same level of stability.

F. The geometries recommended principally address slope stability under static loading and do not necessarily represent stable conditions during and/or following significant earthquake loading. However, in general, post-seismic stability would also be improved following a flattening of a slope.

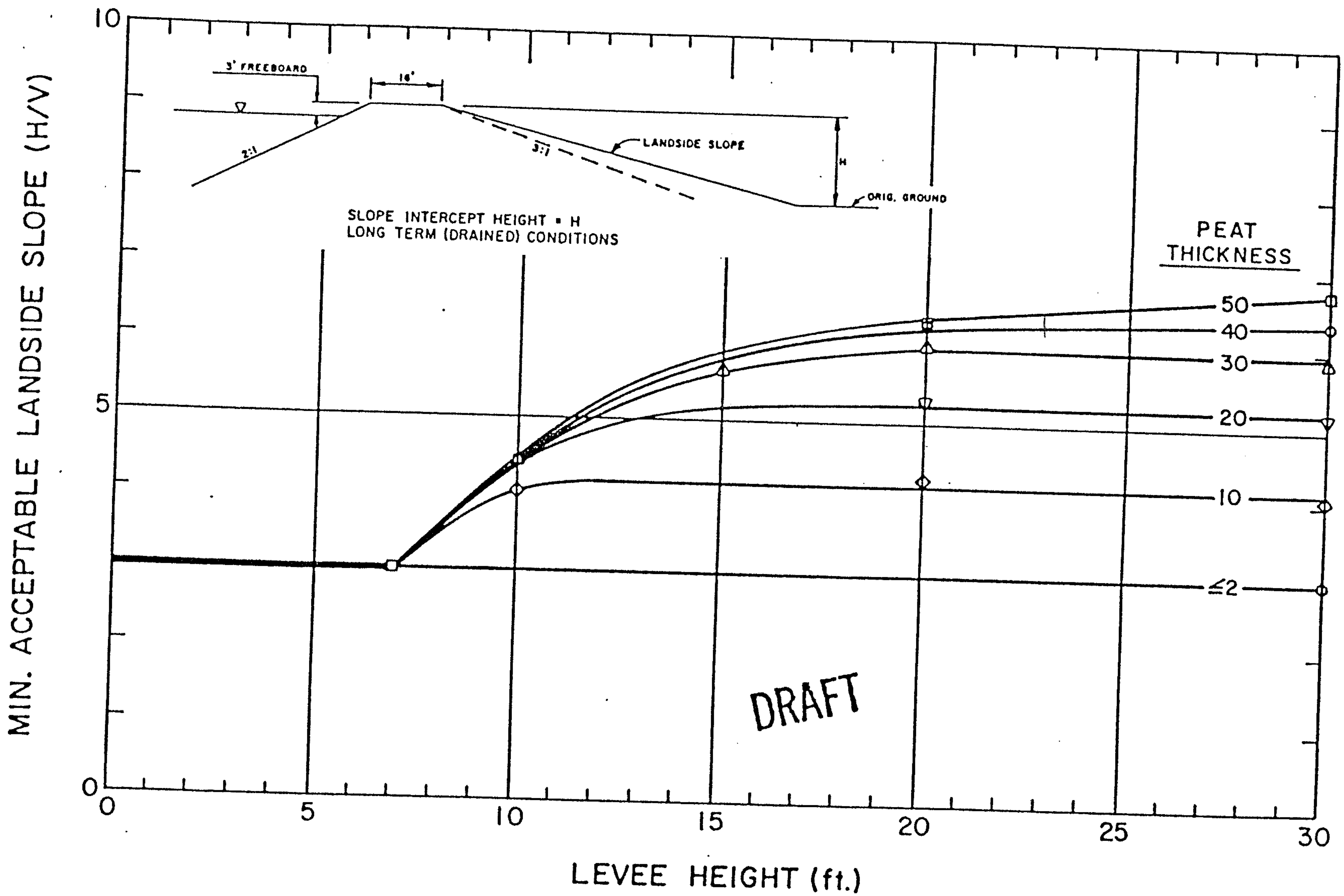

FIGURE 1: MINIMUM ACCEPTABLE LANDSIDE SLOPES FOR LEVEES PROTECTING URBAN TRACTS

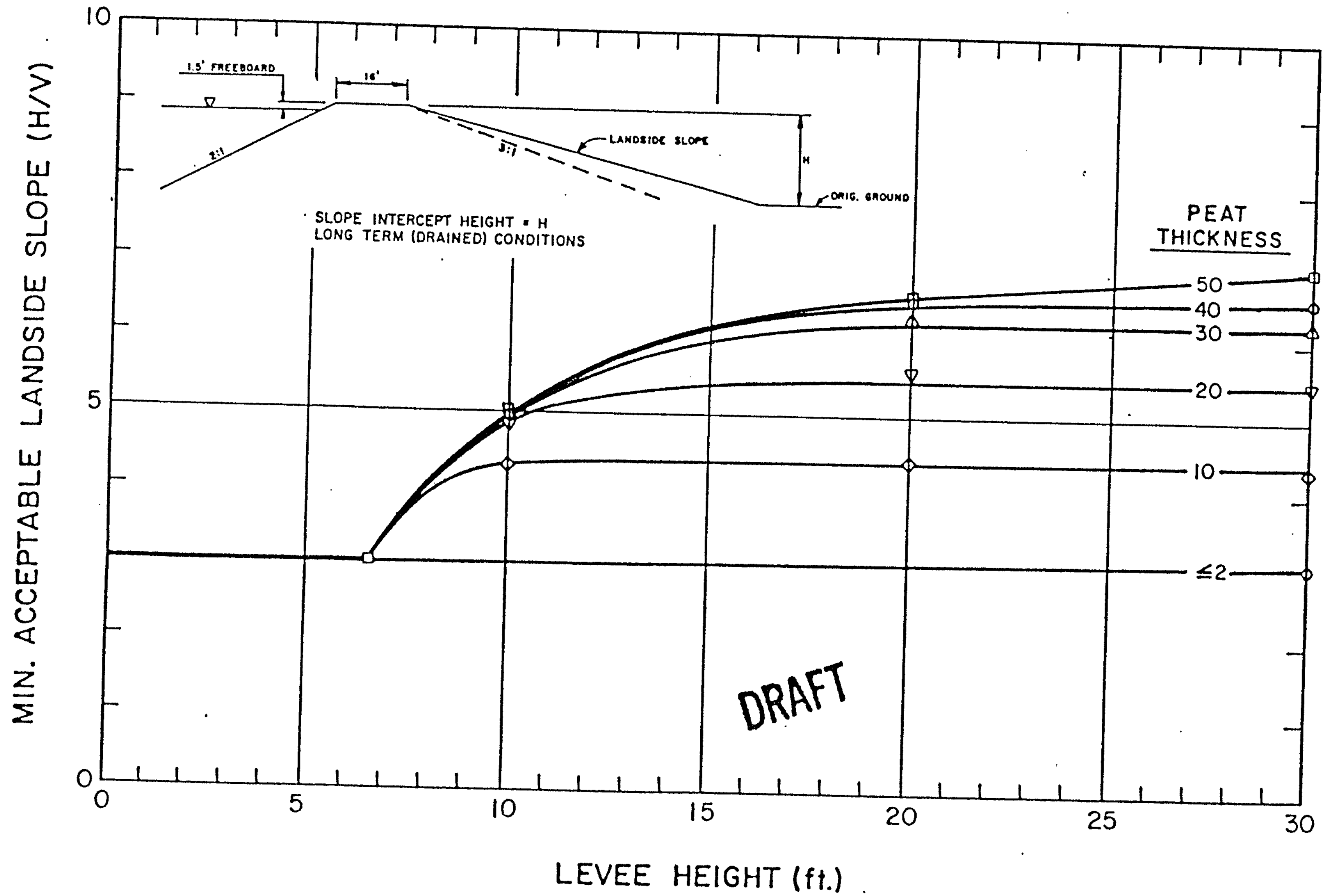

FIGURE 2: MINIMUM ACCEPTABLE LANDSIDE SLOPES FOR LEVEES PROTECTING AGRICULTURAL TRACTS

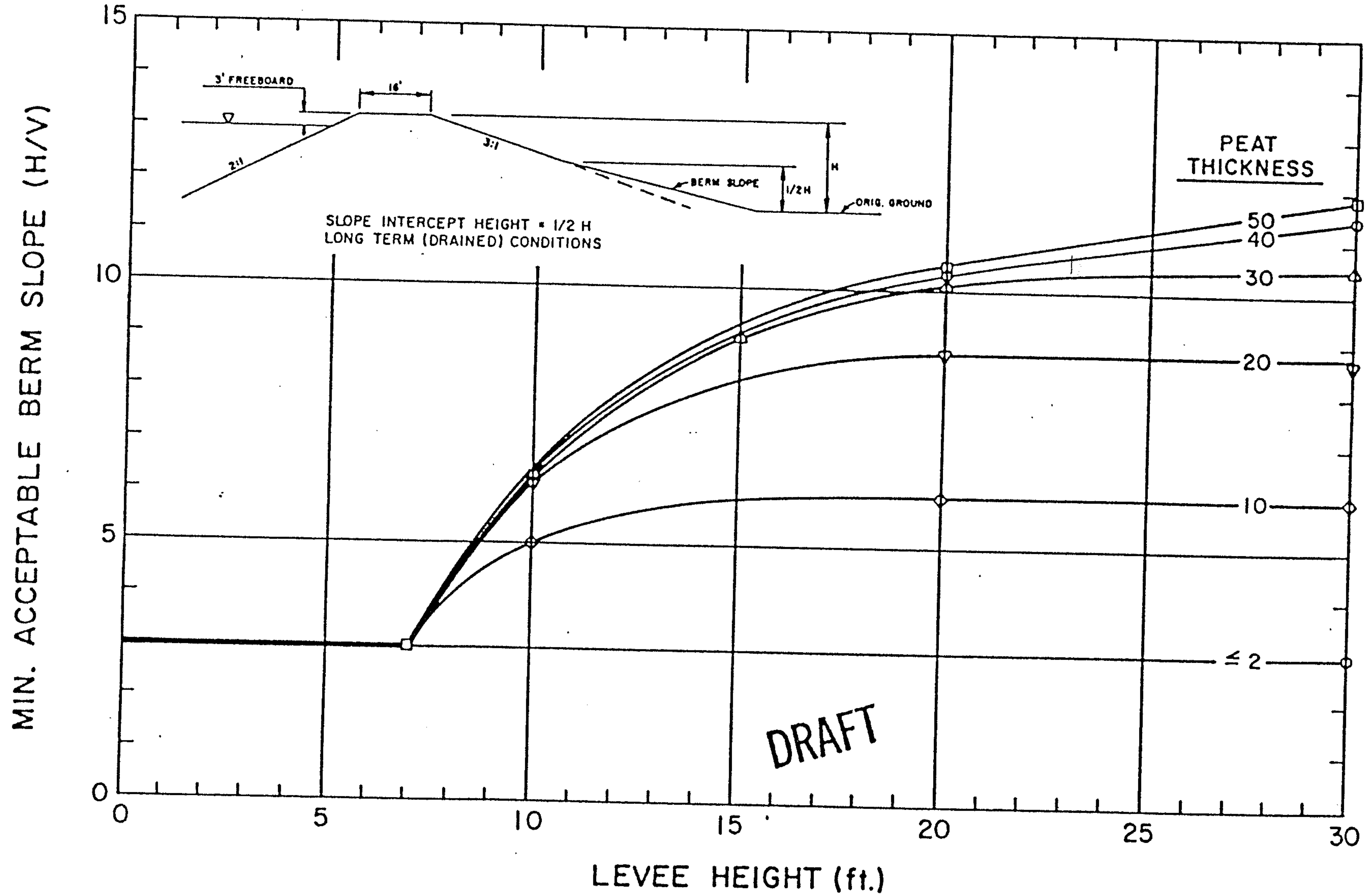

FIGURE 3: MINIMUM ACCEPTABLE BERM SLOPES FOR LEVEES PROTECTING URBAN TRACTS

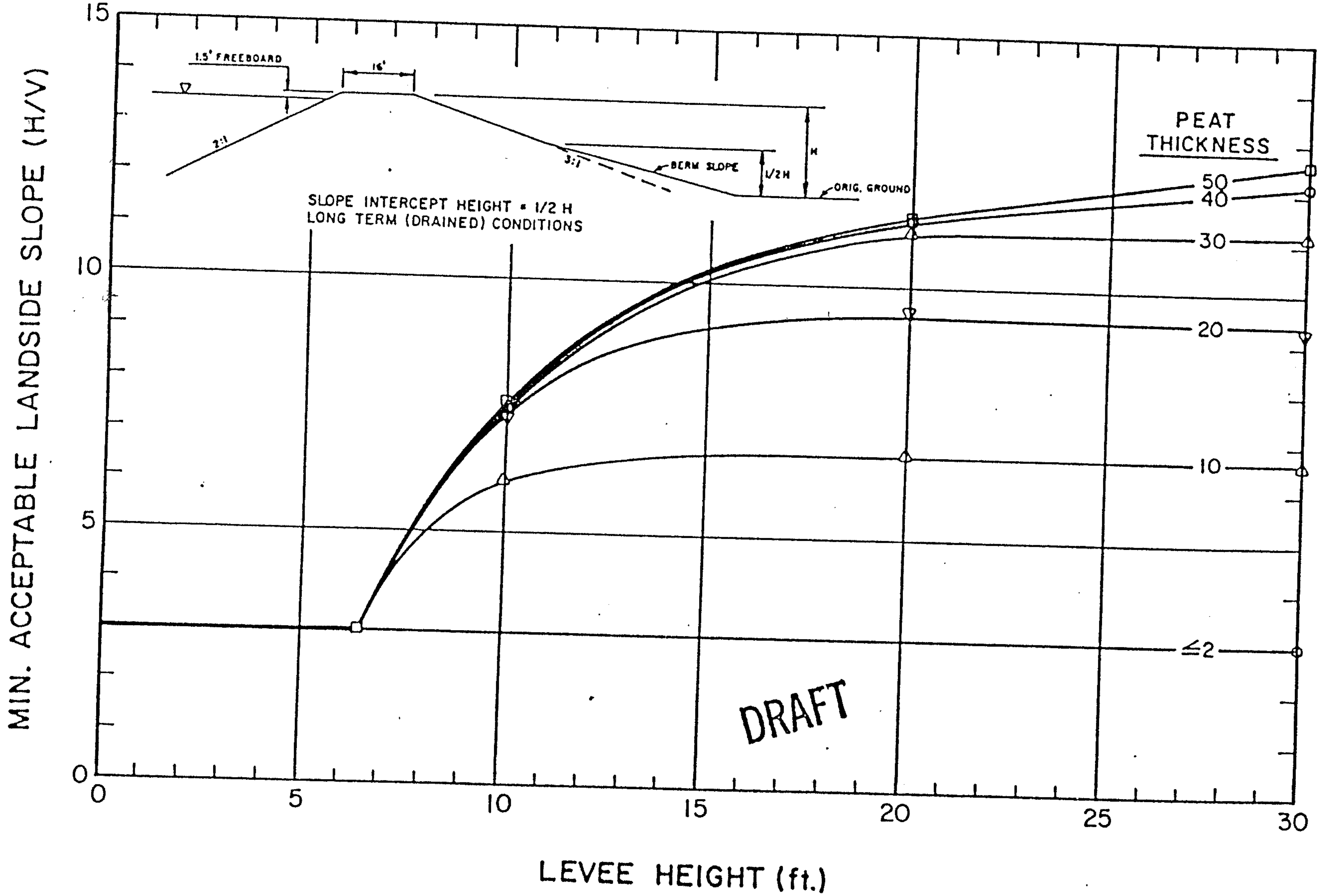

FIGURE 4: MINIMUM ACCEPTABLE BERM SLOPES FOR LEVEES PROTECTING AGRICULTURAL TRACTS

CROSS-SECTION OF GEOMETRY

DELTA STABILITY ANALYSES

1 FEB 16, 1989

HT - 20 FEET/PEAT - 40 FEET/6.6:1 SLOPE/1.5' FREEBOARD

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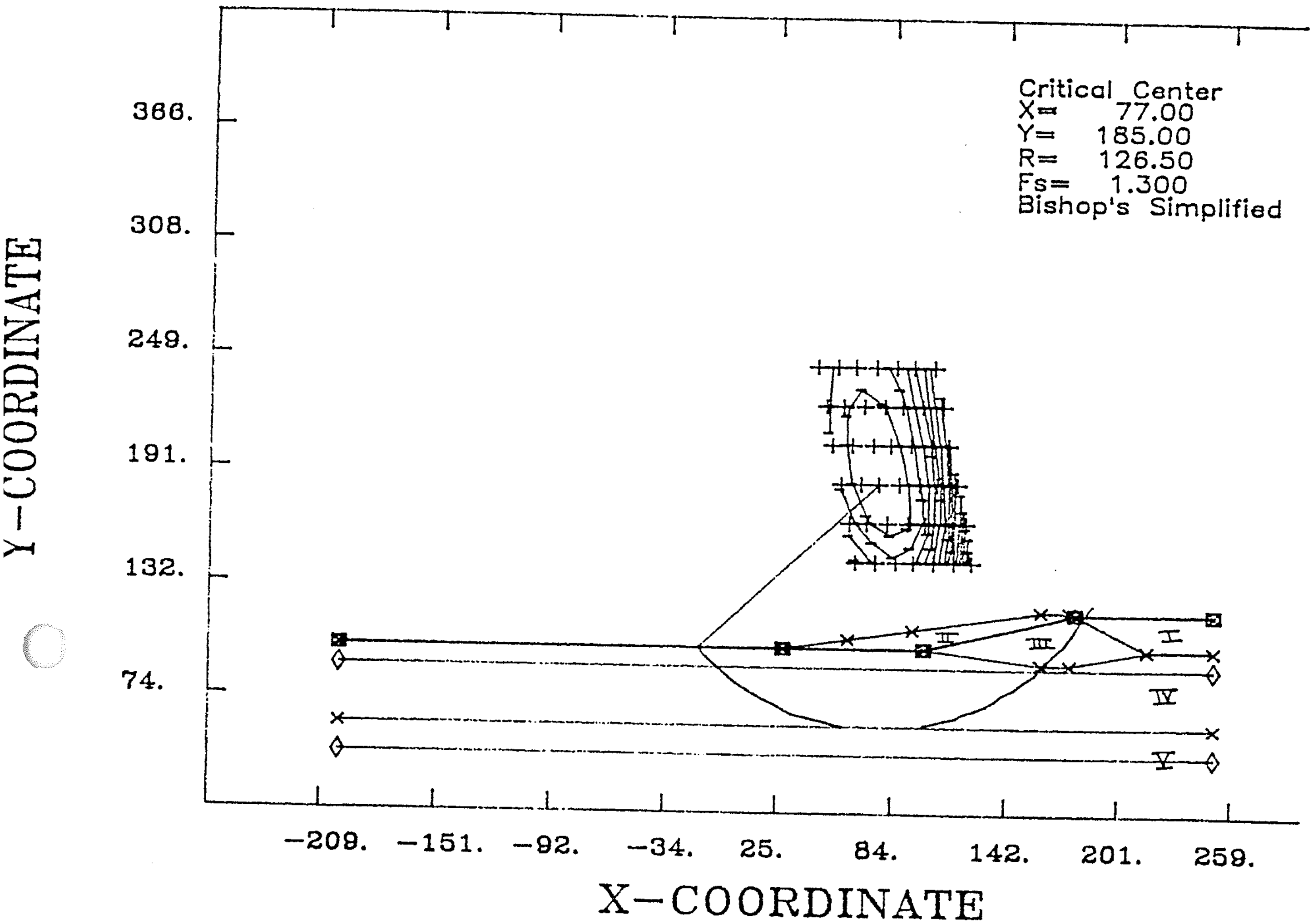

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IV	83.00	50.00	19.00	SATURATED PEAT - DRAINED STREN
V	-1.00	.00	.00	SATURATED DENSE SAND

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CROSS-SECTION OF GEOMETRY

DELTA STABILITY ANALYSES

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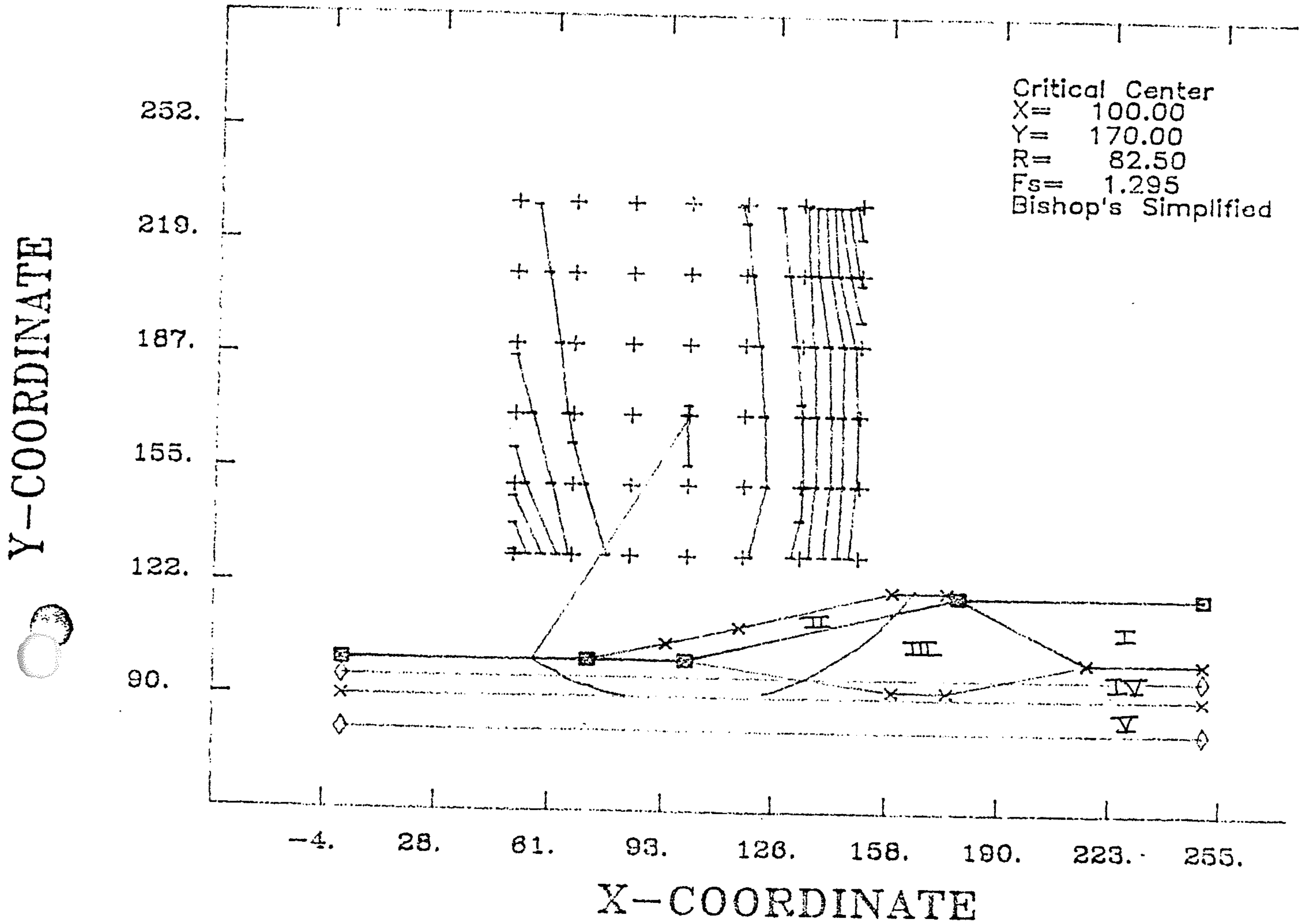

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SOIL PROPERTIES

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			C' (psf)	Ø' (degrees)	C (psf)	Ø (degrees)
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DENSE SAND	–	125	0	40	0	40

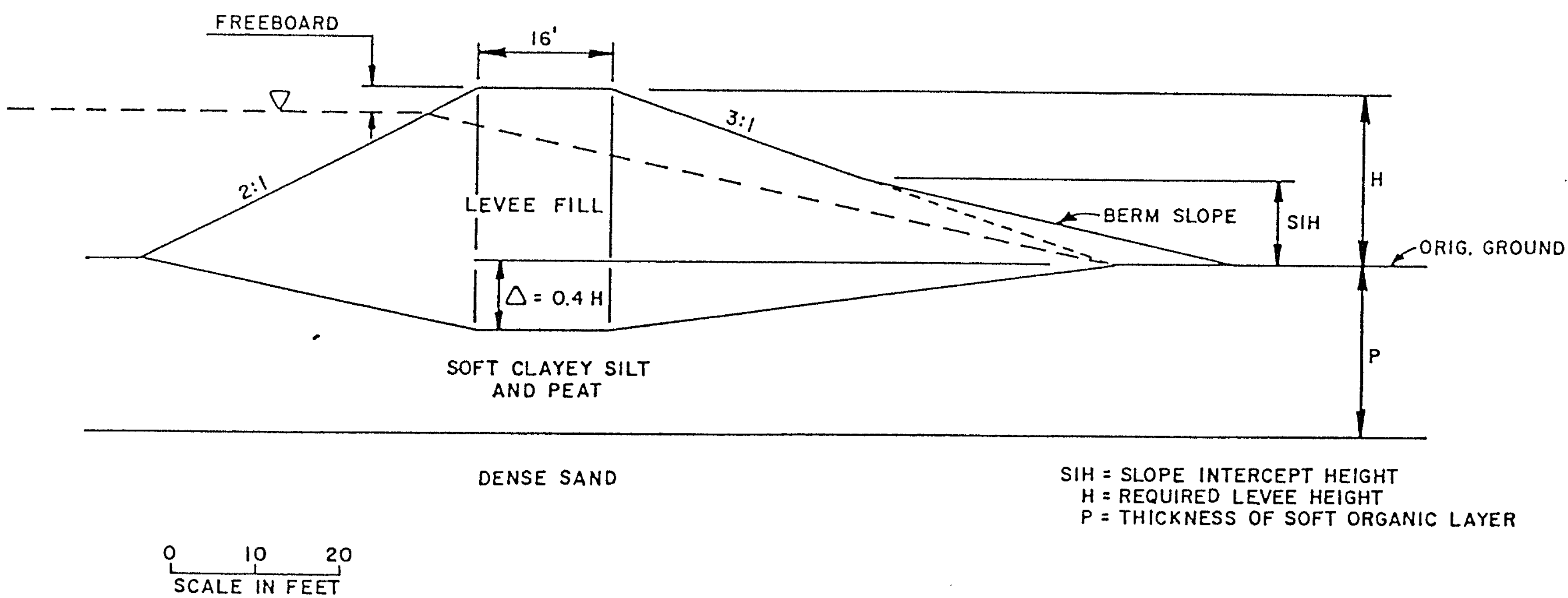

FIGURE STABILITY MODEL CROSS-SECTION FOR 100 YEAR PROTECTION