JUNE, 1963 to Panama Canal Company

DESIGN STUDIES

Fill Structure Across Trinidad Arm Of Gatun Lake

FOR

PANAMA CANAL

COMPANY

BALBOA HEIGHTS, CANAL ZONE

TUDOR ENGINEERING COMPANY • San Francisco

I AUTHORITY

This report and design study is submitted in accordance with the terms of Contract No. PC-2-851 (Negotiated) for Engineering Services dated August 21, 1962 between the Panama Canal Company and Tudor Engineering Company.

II PURPOSE AND SCOPE

1. Purpose. A previous report by Tudor Engineering Company titled, "Increasing the Water Supply of the Panama Canal" recommended a fill structure across Trinidad Arm of Gatun Lake as the most economical plan for solving the water supply problem. The details of this project are shown on Figure 1a.

The purpose of the study for this report was to develop a cross section for the fill structure only, which would utilize the material to be removed from Zone II of the Canal Widening through Bas Obispo-Las Cascadas Reaches of Gaillard Cut. Because it is assumed that bottom dump barges would be used to transport the material from the excavation to the dam site, elevation +75 is the limit the fill can be raised by this method. Also, according to estimates of the material that w be available from the canal widening, construction to elevation +75 is all that can be accomplished. Accordingly the study developed a cross section for the fill only, with construction to elevation +75 coordinated with the

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June 1, 1963

Panama Canal Company
Balboa Heights, Canal Zone

ATTN: Colonel M. C. Harrison, C.E., U.S.A.
Engineering and Construction Director

Gentlemen:

We are pleased to submit herewith our report on our design studies for a "Fill Structure Across Trinidad Arm of Gatun Lake." The studies are the result of a previous report by Tudor Engineering Company titled "Increasing the Water Supply of the Panama Canal," in which it was recommended that a fill structure across Trinidad Arm of Gatun Lake would be the most economical way to solve the water supply problem. This report is submitted in accordance with the provisions of a contract for Engineering Services, No. PC-2-851 dated 21 August 1962.

The study and report covers foundation investigations, the design for the embankment, placement of material in the embankment, construction schedule and estimated quantities and cost estimates. The study included a detailed foundation exploration program by the firm of Shannon & Wilson, Inc., soil mechanics and foundation engineers, Seattle, Washington, to determine the characteristics of the foundation material. The foundation material is commonly known as Atlantic Muck covering the area of the main section of the structure from the mainland or west shore to Guacha Island and

has a maximum depth of approximately 160 feet. The Atlantic Muck also appears over most of the area between Guacha and Tern Islands. The investigations found this material very low in strength, with the result that it became the controlling element in the stability analysis for the embankment section.

During the course of the design studies, a test fill at the embankment site was constructed by the Panama Canal Company, utilizing material then being removed from the Empire Reach section of the Canal Widening Project. The deposition of the material was uncontrolled and the material consisted principally of large boulders. Inspection of this test fill by divers showed that indiscriminate depositing of random size material ruptured the foundation material and caused displacement which destroyed what little strength existed in its undisturbed condition. The test fill corroborated results of laboratory studies, both of which showed that in order to construct an embankment on the foundation material at the embankment site without resorting to total displacement it would be necessary to protect the foundation from rupture as the fill material was placed and preserve the small strength therein.

The design studies were conducted utilizing a select material "mat" over the foundation and the final embankment section with this provision is the result. This mat serves the twofold purpose of (1) protecting the foundation material against rupture when material with large boulders is deposited as a part of the fill, and (2) as a drainage media as the foundation material consolidates under load. This consolidation produces a gain in foundation strength which is significant during the construction period, and the continued gain in strength after construction will make the embankment more stable as time progresses.

Permeability of the embankment constructed from the material excavated from canal widening will be minimum which with the low head differential and the long gradient through the embankment section will make water loss negligible.

TUDOR ENGINEERING COMPANY

Panama Canal Company June 1, 1963

The daily leakage through the dam is estimated to be only slightly more than the amount of water used in one through lockage and it is believed this will decrease with the age of the fill.

Our studies show that it is engineeringly possible to construct an embankment across the Trinidad Arm of Gatun Lake for the purpose required and that such a structure will be economically feasible if constructed in conjunction with the Canal Widening Project. We recommend that the construction be initiated with the next contract for the canal widening.

We wish to express our sincere appreciation for the cooperation and assistance rendered by all departments and personnel of the Canal Company in the conduct of this study.

Very truly yours,

Ralph A. Tudor

Design Studies for

Fill Structure Across Trinidad Arm of Gatun Lake

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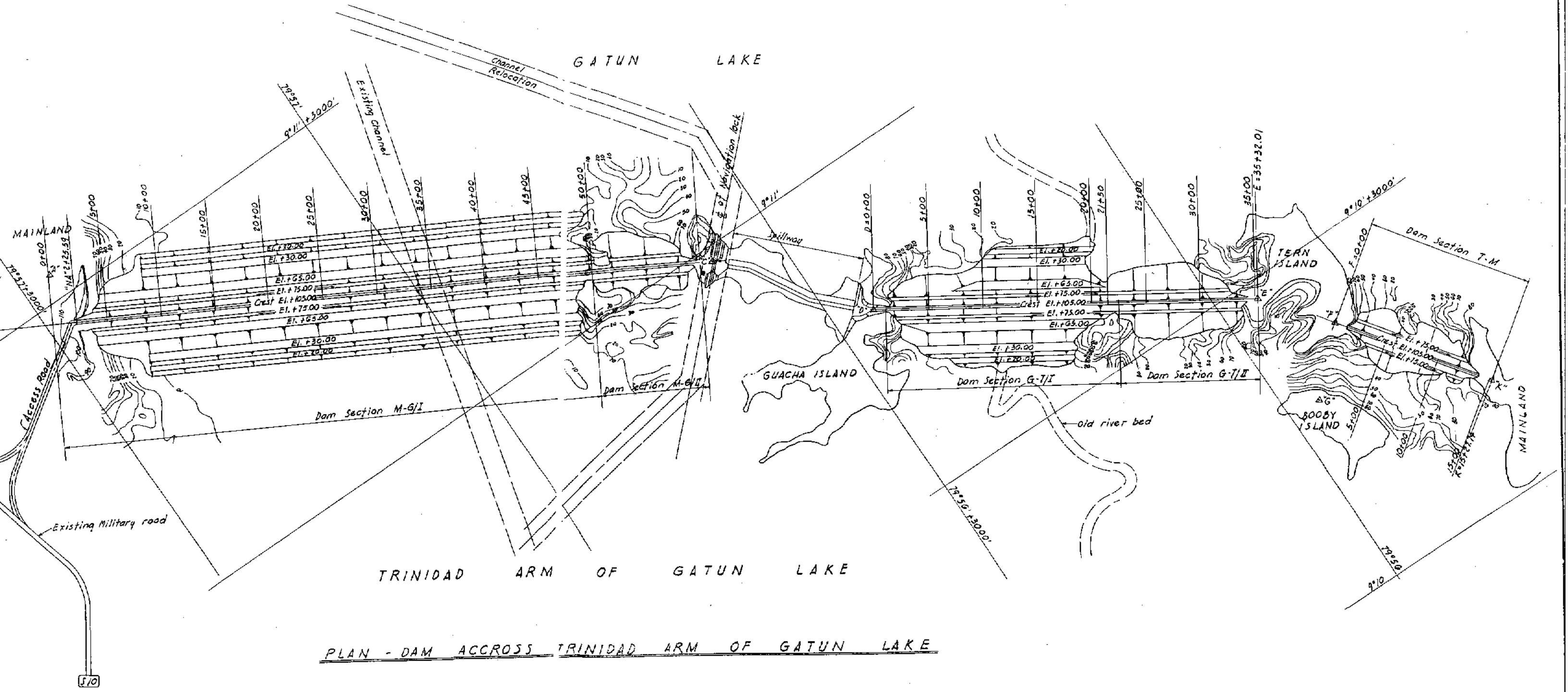


PLAN - DAM ACCROSS TRINIDAD ARM OF GATUN LAKE

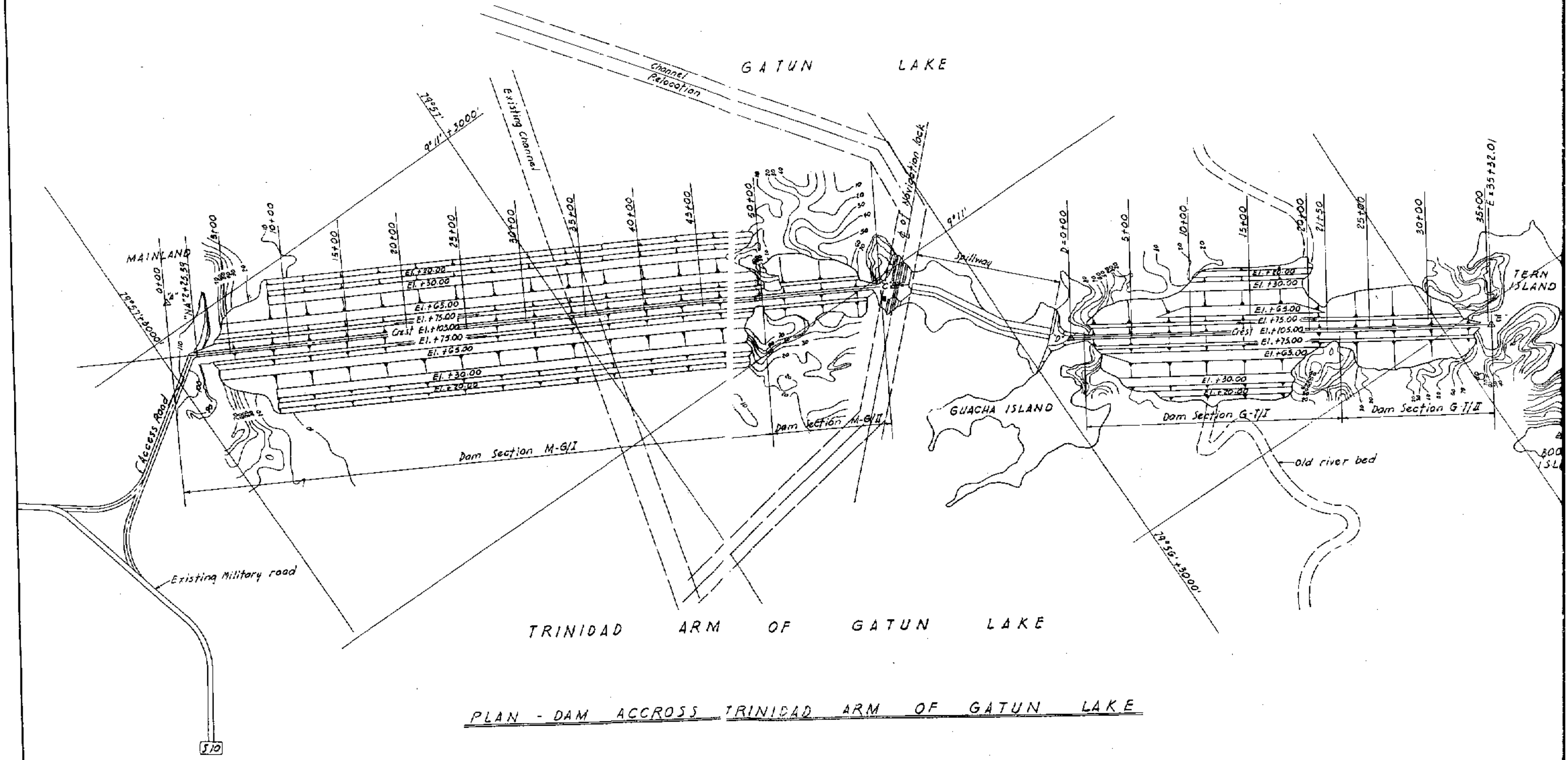
THE PANAMA CANAL COMPANY
BALBOA HEIGHTS, CANAL ZONE

DAM ACROSS TRINIDAD ARM OF GATUN LAKE

GENERAL PLAN

DESIGNED	TUDOR ENGINEERING COMPANY SAN FRANCISCO, CALIF.	DRAWING NUMBER
DATE		OF

FIGURE NO



PLAN - DAM ACCROSS TRINIDAD ARM OF GATUN LAKE

DAM

DESIGNED

DATE

canal widening. The top 35 feet of the dam is to be constructed later from material excavated from borrow areas on the mainland and suitable material excavated for the lock and spillway structures.

2. Scope. The scope of the work performed under this study includes the following:

a. Detailed investigation of foundation conditions at the site of the proposed structure in accordance with the program outlined by Shannon & Wilson, Inc., in their letter to Tudor Engineering Company dated July 23, 1962, subject, "Trinidad Dam, Panama Canal."

b. Preparation of a comprehensive report summarizing the field exploration, laboratory tests and engineering analyses.

c. Preparation of details of the fill section of the dam along its full length, based upon the results of the foundation investigation. and design analyses using cut widening material from the canal for the fill below elevation +75.

d. Preparation of placing schedule of the fill materials reflecting zone separations and lift separations that studies showed to be advisable.

e. Preparation of quantity estimates of all material to be placed in the fill sections from both the cut widening program and other sources.

f. Preparation of plans and technical specifications adequate to obtain contract bids for the construction of that part of the fill to be built from cut widening materials.

g. Preparation of cost estimates which included the additional cost to the cut widening program that will result from using the material in the fill section of the dam.

III FOUNDATION INVESTIGATIONS

1. Description of Site. The site of the proposed dam is in the Trinidad Arm of Gatun Lake extending from Punta Mala, near Escobal, on the west shore of Gatun Lake to Guacha Island, thence to Tern Island, and thence to the east shore. See Figure No. 1b. The length of the proposed dam will be approximately 9,700 feet when constructed to elevation +75. All elevations refer to Precise Level Datum.

Gatun Lake in this area occupies a broad flat valley having sides which slope upward from the valley at grades up to 40 percent. Water depths are 70 to 80 feet over approximately 80 percent of the site. The valley floor is at approximate elevation +10.

Approximately 6,000 feet of the foundation is underlain by the Atlantic Muck Formation varying in depth from 25 to 160 feet. The Atlantic Muck Formation consists of soft clays, silts, and peats in varying amounts. In the old river channel, the Atlantic Muck is underlain by a silt, sand and clay strata. Weathered rock in the remainder of the area is overlain by recent lake deposits to a depth of approximately 3 feet.

2. Field Exploration. A geophysical survey of the site was conducted in January, 1962 by Geo-Recon, Inc., a subsidiary of Shannon & Wilson, Inc., of Seattle, Washington using seismic and

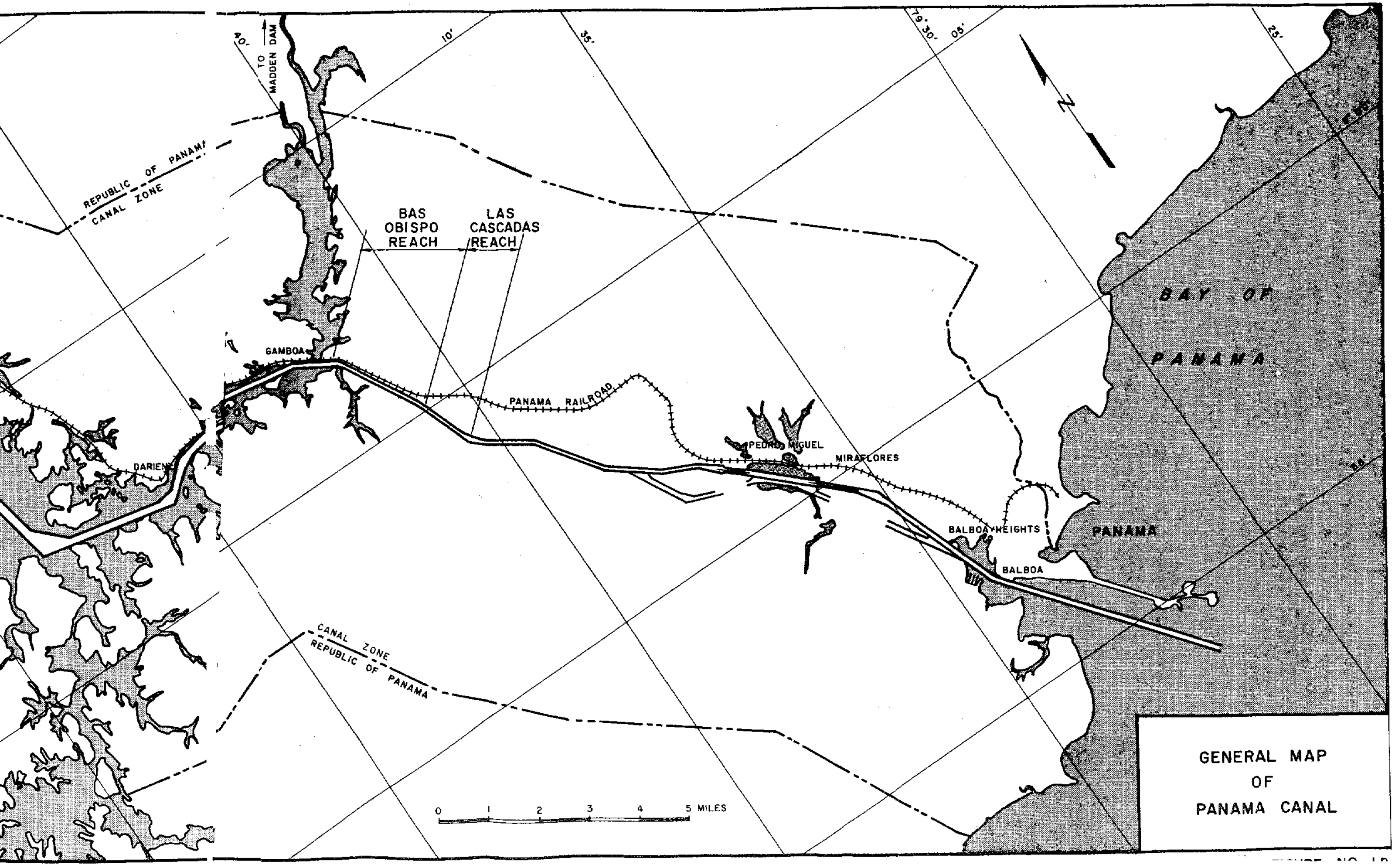
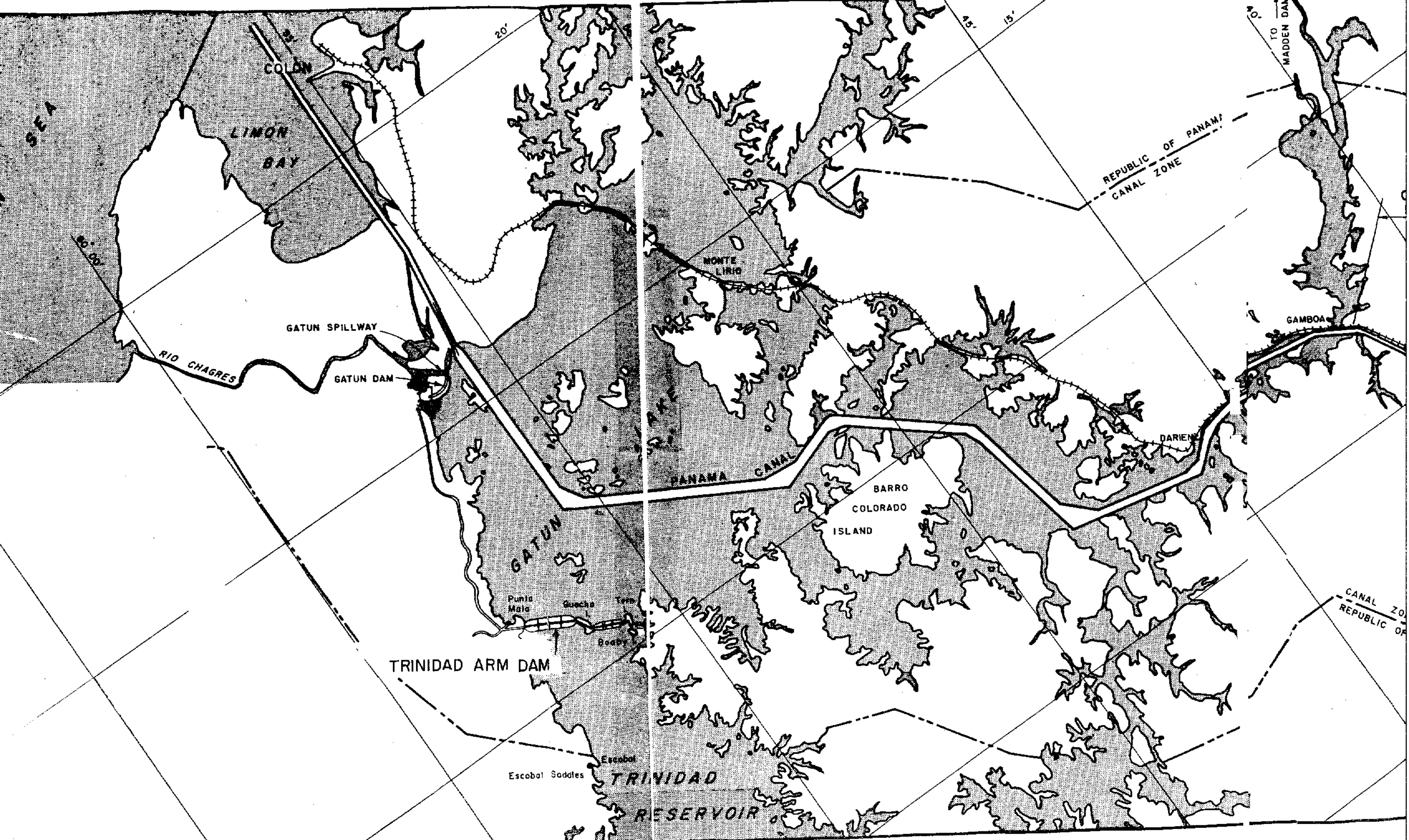

REPUBLIC OF PANAMA
CANAL ZONE
TO MADDEN DAM
BAS OBISPO REACH
LAS CASCADAS REACH
GAMBOA
PANAMA RAILROAD
PEDRO MIGUEL
MIRAFLORES
BALBOA HEIGHTS
BALBOA
DARIEN
BAY OF PANAMA
PANAMA
CANAL ZONE
REPUBLIC OF PANAMA
0 1 2 3 4 5 MILES
79°30'
05'
10'
35'
25'
N
GENERAL MAP
OF
PANAMA CANAL

FIGURE NO. 1 P


SEA
COLON
LIMON BAY
80° 00'
20'
GATUN SPILLWAY
RIO CHAGRES
GATUN DAM
GATUN
Punta Mala
Gueche
Toro
Boaby
TRINIDAD ARM DAM
Escobal
Escobal Saddles
TRINIDAD RESERVOIR
PANAMA CANAL
MONTE LIRIO
45'
15'
REPUBLIC OF PANAMA
CANAL ZONE
BARRO COLORADO ISLAND
DARIEN
TO MADDEN DAM
GAMBOA
CANAL ZONE
REPUBLIC OF

CARIBBEAN SEA

LIMON BAY

COLON

20'

15'

45'

REPUBLIC OF PANAMA

CANAL ZONE

MONTE LIRIO

GATUN SPILLWAY

RIO CHAGRES

GATUN DAM

PANAMA CANAL

DARIEN

BARRO COLORADO ISLAND

GATUN

Punta Mala

Guacho L.

Tem

Boella I.

TRINIDAD ARM DAM

Escobal

Escobal Saddles

TRINIDAD RESERVOIR

electrical resistivity methods. This survey served to delineate the approximate depth to bedrock. No indication of the properties of material was possible from this method of exploration.

Shannon & Wilson, Inc. of Seattle, Washington began a detailed field exploration of the site in September, 1962. Canal Company barge mounted drill rigs were employed to conduct the drilling program which was concentrated between the Mainland and Guacha Island. The program included a series of 77 cone penetrometer borings, 24 classification borings, 11 undisturbed sample borings, and 6 field vane shear borings.

In addition to the explorations by Shannon & Wilson, Inc. and Geo-Recon, Inc., the Panama Canal Company made a number of classification borings in the area of the embankment. Additional classification borings are to be made by the Company in the area between Guacha and Tern Islands. Samples from these borings will be tested in the field laboratory of the Canal Company at Gatun and the test data reviewed by Shannon & Wilson, Inc.

The cone penetrometer borings were performed by attaching a three inch diameter, 65 degree steel cone to a section of drill rod and driving the penetrometer by a 140 pound hammer dropping 30 inches on to the drill rod. A record of the number of blows per foot of penetration was made. This record was

correlated with penetration records of known materials in the area to determine the extent of the various materials.

The classification borings were performed at intervals along the axis of the proposed dam and at selected cross sections. The samples were classified and waxed immediately on removal from the sampler. These samples were taken to the field laboratory for study.

The undisturbed borings were made to obtain undisturbed samples for detailed laboratory analyses in the laboratory of Shannon & Wilson, Inc. at Seattle, Washington.

Field vane shear borings were made to determine the in-place shear strength of the soft overburden materials. Vanes were attached to drill rods at a 90 degree spacing and lowered through a casing to test depth. The weight of the drill rods was usually sufficient to penetrate the undisturbed soil. A torque wrench was used to measure the torque required to rotate the vane in the soil. The force required to overcome friction in the bearings in the casing was measured by lowering the drill rods to test depth without the vane and rotating the rod.

3. Laboratory Investigations. Laboratory investigations were carried on in the Panama Canal Zone and in Seattle, Washington.

a. A field laboratory was established in Gatun, Panama Canal Zone, for the performance of routine tests. The

following tests were performed in this laboratory:

(1) Visual Classification

(2) Water Content

(3) Atterberg Limits

(4) Unit Weight

(5) Unconfined Compression Tests.

b. The Seattle laboratory of Shannon & Wilson, Inc. was used for the major portion of the analysis of the samples and included the following:

(1) Visual Classification of all samples tested

(2) Water Content

(3) Atterberg Limits

(4) Unit Weight

(5) Specific Gravity and hydrometer analyses

(6) Triaxial tests

(7) Unconfined compression tests

(8) Vane shear tests

(9) Consolidation test

(10) Triaxial dissipation tests.

All tests, both in Panama and Seattle, were performed in accordance with accepted practices.

Results of Laboratory Investigations. Laboratory analyses

were carried on for a period of approximately six months.

A description of the tests, method of performance and results obtained are given in the report prepared for Tudor Engineering Company by Shannon & Wilson, Inc. entitled "Foundation Investigation, Proposed Rock and Earth Fill Embankment Across Trinidad Arm of Gatun Lake, Panama Canal Zone." A summary of this report is included as Appendix A of this Design Study.

Information obtained from the laboratory investigations was instrumental in establishing criteria used in the design of the embankment sections. These criteria are discussed in Section IV of this report.

5. Field Tests. A test fill was made by the forces of the Panama Canal Company as part of the investigations leading to the design of the dam. The material used was taken from the canal widening in the Empire Reach of Gaillard Cut. The material was from the Las Cascadas Formation and is indicative of material that will be removed from the Bas Obispo-Las Cascadas Reaches of the next canal widening contract and used as fill material in the dam across Trinidad Arm of Gatun Lake.

The material was loaded in barges as it was removed from the cut and transported to the test site. No attempt was made to segregate, select or otherwise process the material used in this

fill. An attempt was made to spread the material in layers of five feet maximum thickness but it was found necessary to completely open the gates of the bottom dump barges so that the large boulders could be discharged. As a result, no control of the dumping was possible.

6. Results of Field Tests. Much information was gained from review of data obtained in connection with the test fill.

The fill was constructed to a height of approximately 30 feet. Inspection and pictures by divers as well as topography made from soundings show that the fill, using random material, will stand on slopes as steep as 2.5 horizontal to 1 vertical. This is compatible with the slopes of 4 horizontal to 1 vertical used in the design of the embankment section.

Examination of the underwater embankment showed evidence of major disturbance to the foundation from the impact of the large material. The larger boulders penetrated the foundation to depths of 10 feet or more. Where an entire barge load of material was dumped en masse the foundation material at the side of the dumped material rose to heights of 10 feet or more with vertical faces showing as a result of shear failure in the foundation. Several mud waves, rising approximately 5 feet above the lake bottom, were observed beyond the toes of the fill indicating circular type failures such as have been studied in the slip circle analysis. This verified

earlier predictions that it will be necessary to initially place a mat of finer material over the Atlantic Muck in order to protect the integrity of the foundation. It was also found that the material must be spread in thin layers and to do this will require precise controls on the opening of the bottom gates in the barges. This is not presently possible with the Panama Canal Company barges.

IV DESIGN CRITERIA

Criteria used for design of the embankment section was logically divided into two categories. The foundation material is unique and special attention was directed to its properties in the design. The embankment fill material obtained from the canal widening is entirely different than the foundation and accordingly will have different properties and must be treated differently in the design studies. In addition, the method of treatment of the foundation and the method of placement of the fill is entirely different than the usual procedure in dam construction as all of this must be done under water. The criteria were established with these points in mind.

1. Foundation. The laboratory tests and analyses show that the Atlantic Muck foundation material has a very low shear strength in the upper 10 to 15 feet. This is the controlling factor in the design of the dam section. Below this upper layer the total shear strength increases with depth. During and after the construction of the embankment the foundation material will gain strength due to consolidation of the material from the imposed load. However, the gain is extremely slow and the material must be practically free draining in order to obtain the consolidation necessary to produce a gain in foundation strength. The mat material over the muck

must provide the filter zone as well as give protection against rupture as heavier fill material is placed.

Figures 7-1, 7-2, and 7-3 in Appendix A show the shear strengths of the foundation material at various times during the construction period.

Table IV-1 is a tabulation of data for the foundation material at different depths, used in the design analyses for the embankment section.

TABLE IV-1
FOUNDATION SOILS DATA

Soil Designation	Saturated Weight lbs / cf.	Strength Data
Atlantic Muck		
Elev. +10 to -14	85	Refer to Figures 7-1, 7-2, 7-3, App. A
Elev. -14 to -34	75	Refer to Figures 7-1, 7-2, 7-3, App. A
Elev. -34 to -54	90	Refer to Figures 7-1, 7-2, 7-3, App. A
Elev. -54 and below	93	Refer to Figures 7-1, 7-2, 7-3, App. A

2. Embankment. The material to be used in the embankment will come from the Canal Widening Project. This material is mostly rock and accordingly has entirely different characteristics than the foundation material.

Table IV-2 is a tabulation of fill material data used in the design studies. Refer to Figure 6 for the typical embankment section.

TABLE IV-2

EMBANKMENT SOILS DATA

Material Designation	Saturated Weight lbs/cf.	Internal Friction Angle	Cohesion lbs/sf.
Zone 4 Material	120	25°	500
Zones 2 & 3 Material	115	25°	0
Zone 1 Material	125	35°	0

3. Safety Factor. A minimum safety factor of 1.1 was used in the design. The safety factor will increase in the order of 5 percent per year due to consolidation of the foundation and the resulting gain in foundation strength. This gain in strength together with the conservative strength values used in the design makes it unnecessary to require a higher safety factor at the beginning. A delay in completion of the embankment from elevation +75 to +105 will also increase the safety factor at completion.

V DESIGN STUDIES

1. General. The total development will include a spillway and navigation lock and the dam fill to elevation +105. This design study is concerned only with the final sections for the dam and its construction to elevation +75 as the first stage. Early in the study it was recognized that the foundation would be the weakest part of the section. Major emphasis in the study was placed on the treatment of this material. Consideration was given to whether the muck should be placed laterally by the fill material or the embankment section so designed that it would be supported by the muck as a foundation without lateral displacement.

It was determined from field and laboratory tests that the minor strength of the foundation material could be maintained and that it would increase with time due to the effect of consolidation. Due to the thickness of the muck and the amount of fill material available from the cut widening, it was found necessary to maintain the strength of the foundation material and float the fill thereon so that the fill material required could be kept within the quantity available. It was determined that a 15-foot thick mat of 8" minus, clean

material would give adequate protection and provide the necessary drainage as the muck consolidates under the fill load as it is placed.

The mat serves a twofold purpose in that (1) it allows drainage as the foundation is loaded and (2) it will prevent the rupture of the foundation caused by the dumping of large boulders in the Zone 2 & 3 fill. The test fill constructed earlier demonstrated that large boulders would penetrate the foundation and cause loss of foundation strength.

2. Penetration. Studies and computations made during the course of investigations indicate that a rock 8 inches in diameter dropped through 70 feet of water will penetrate the foundation material to a depth of approximately 6 inches. A rock 4 inches in diameter will penetrate the foundation material approximately 2 inches. Larger rocks in the order of 4 feet in diameter would penetrate the foundation to a depth of 9 to 10 feet. This depth of penetration is borne out by inspection of the test fill constructed by the Panama Canal Company. The underwater inspection was made by a soils engineer and geologist of the Panama Canal Company.

Figure No. 2 shows curves prepared by plotting penetration and velocity versus size of material for a fall through 70 feet of water. The penetration was determined by computing the kinetic energy of a mass with submerged unit weight of 90 pcf falling through the water, and determining the displacement of the foundation material required to dissipate the energy, using a shear

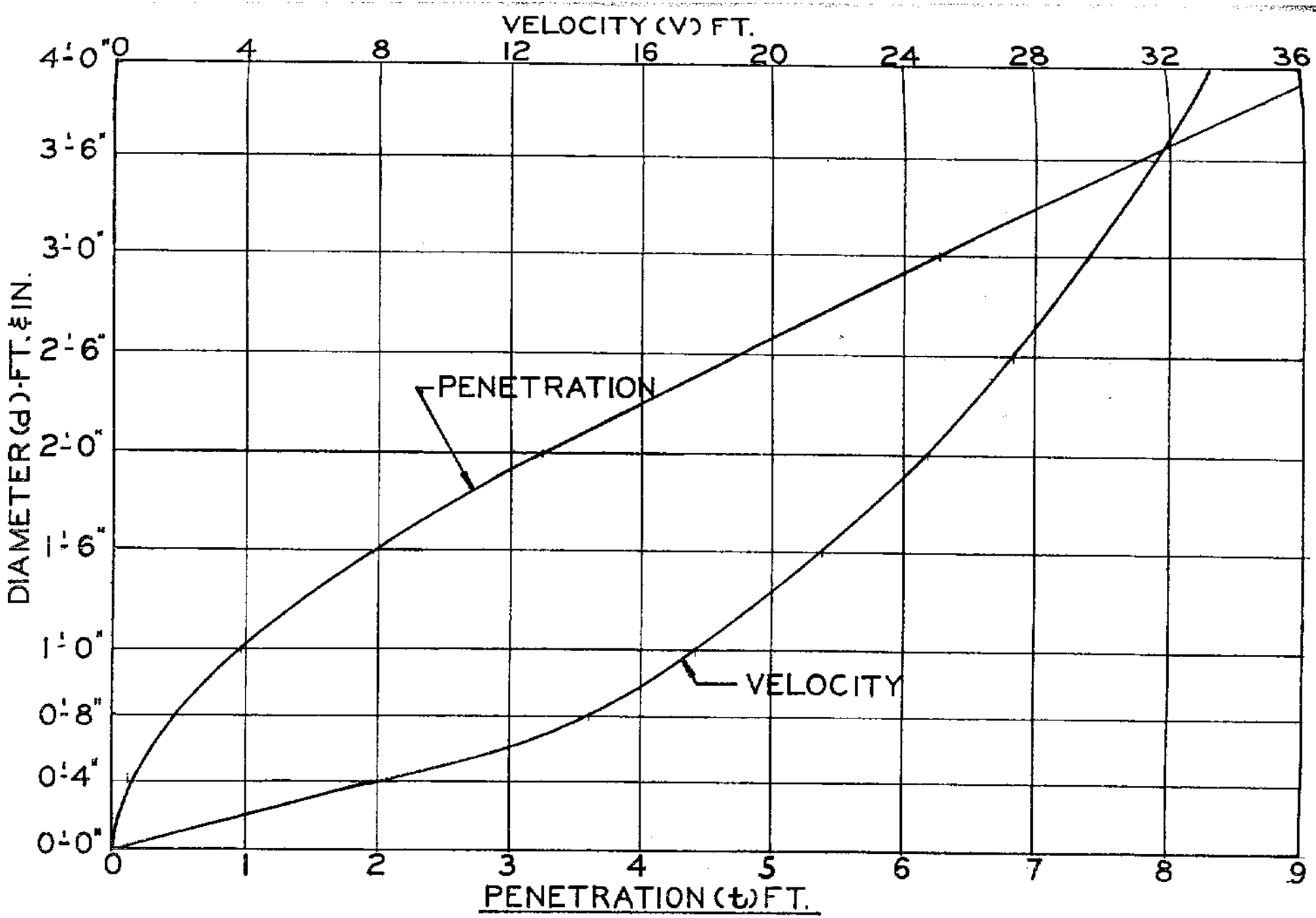

VELOCITY (V) FT.
0
4
8
12
16
20
24
28
32
36
4'-0"
3'-6"
3'-0"
2'-6"
2'-0"
1'-6"
1'-0"
0'-8"
0'-4"
0'-0"
DIAMETER (d)-FT. & IN.
PENETRATION
VELOCITY
0
1
2
3
4
5
6
7
8
9
PENETRATION (t) FT.

FIGURE NO. 2

strength of 80 psf and submerged weight of 35 pcf for the foundation material.

The underwater investigation of the test fill showed that little segregation of the material takes place during the dumping operation. Therefore a maximum penetration to be expected from an 8-inch minus material is in the order of 6 inches with a lesser average depth of penetration due to the gradation of the material.

The mat is to be placed over the area of the main embankment section between the Mainland and Guacha Island below elevation +20 and a portion of the area of the embankment section between Guacha and Tern Islands. Above this mat the fill will be random size material from the canal widening, controlled by the capacities of the equipment employed in the excavation procedure.

3. Permeability of Fill Material. Permeability tests were made in the Shannon & Wilson laboratory, Seattle, Washington on samples of material for the embankment above the mat. This material from the Empire Reach is approximately the same as much of the material to be removed from the Las Cascadas-Bas Obispo Reaches. The material has a permeability coefficient, k, ranging from 0.1 to 10^{-2} cm/sec. with an average of k of 10^{-1} cm/sec. The leakage through the dam with a k value of 10^{-1} cm/sec will be in the order of 100 cfs or 200 acre feet per day. This leakage was computed for a head differential of 14 feet. This quantity of water would

be slightly more than that required for one through lockage. It is not lost water and is simply an amount that would otherwise be moved through the control works.

4. Stability Studies. The stability of the embankment was studied employing both the slip-circle analysis and the sliding wedge analysis. Approximately 2,000 circles and wedges were analyzed in the studies. The computations were made on an electronic computer. Studies were made for various stages of construction with embankment elevations of +20, +45, +75 and +105.

As the major portion of the embankment will be submerged at all times, no computations were made for sudden drawdown conditions. Earthquake conditions were not considered to be applicable.

a. Slip Circle. In the slip circle analysis the sliding surface is represented by a circular arc. The section above the arc is divided into equal vertical slices and the following forces act on each slice (see Figure No. 3):

W_i - weight of slice, including buoyant force

T_i - tangential component of weight $W_i = \frac{(X_o - X_i)\, W_i}{R}$

N_i - normal component of weight $W_i = \frac{(Y_o - Y_i)\, W_i}{R}$

L_i - Arc length A-B

C_i and ϕ_i are the cohesion and the angle of internal friction respectively of the material cut by the arc. The safety factor for a

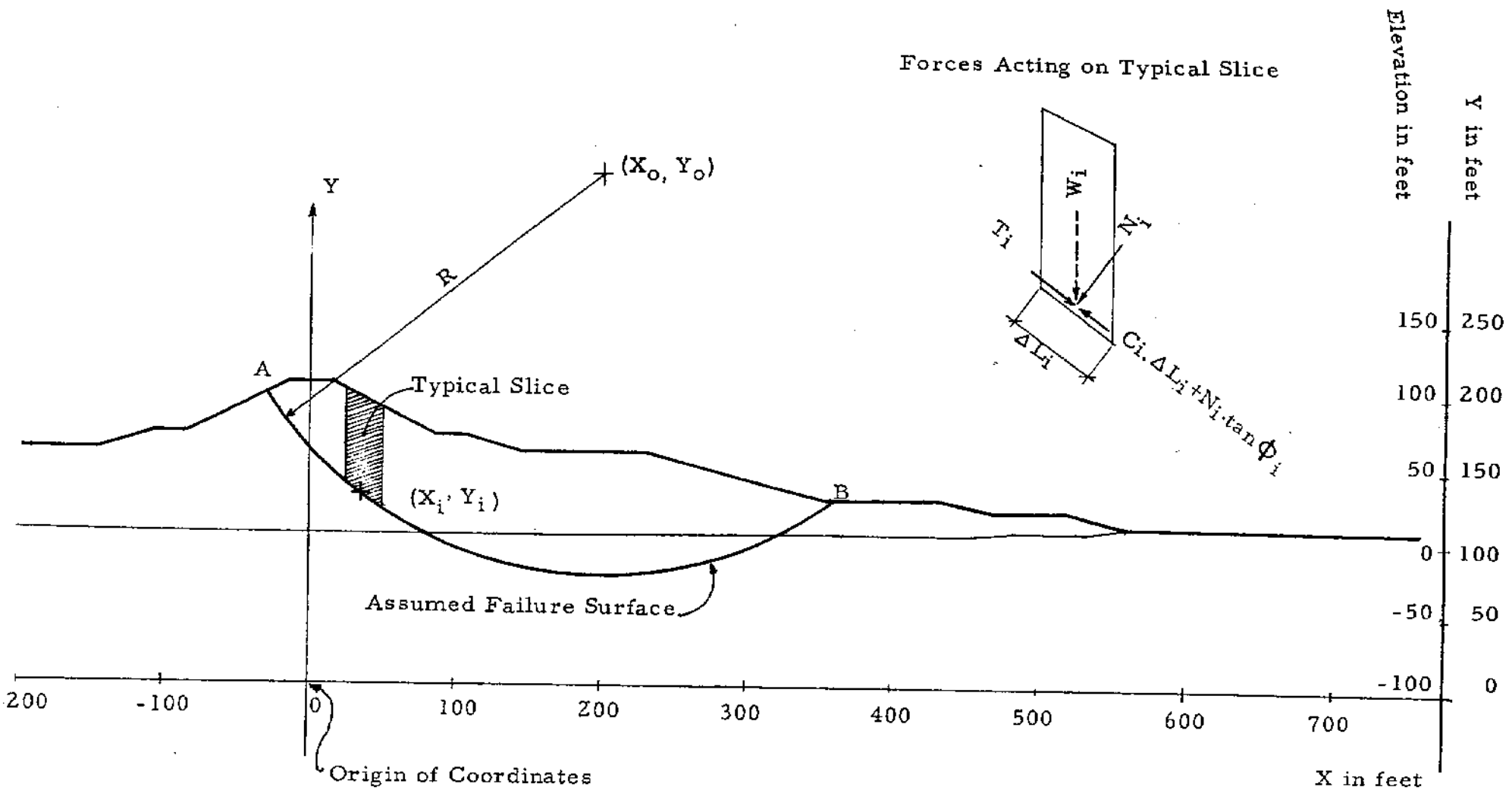


FIGURE NO. 3

TYPICAL SLIP CIRCLE

given circle is expressed by the formula:

$$SF = \sum_{A}^{B} \frac{(C_i \Delta L_i + N_i \cdot \tan \phi_i)}{\sum_{A}^{B} T_i}$$

Tables V-1 and V-2 show the resulting forces by slip circle analyses. These results are for the circle with the minimum factor of safety for each radius. A minimum of five locations was analyzed for each radius of the circle.

b. Sliding Wedge. The sliding wedge analysis was also used as part of the overall design procedure due to the possibility that a failure in the weaker layers of the foundation could result and allow a portion of the fill to slide out along this plane. The wedge method of analysis is illustrated on Figure 4.

The portion of the embankment under consideration is divided into three blocks; active wedge A; passive block B; and passive wedge C. Θ and Ω are the angles of the inclined surfaces of the active and passive wedges with respect to the horizontal.

W_i, T_i, N_i, C_i and ϕ_i have the same meaning as used for the slip circle analysis. The active pressure is computed as follows:

$$P_a = \cos \Theta \sum_{a}^{b} T_i - \cos \Theta \sum_{a}^{b} (N_i \tan \phi_i + C_i \Delta L_i)$$

The resisting forces are computed as follows:

$$R_b = \sum_{b}^{c} S_i \Delta L_i$$ where S_i is the total shear strength of the foundation element

$$R_c = \sum_{c}^{d} (N_i \tan \phi_i + C_i \Delta L_i + T_i)$$

TABLE V-1

SLIP CIRCLE ANALYSIS, EMBANKMENT ELEVATION +75

Circle with Least Factor of Safety
for Each Series of Circles Studied

R (ft.)	X_0 (ft.)	Y_0 (ft.)	Driving Force (lbs.)	Resisting Force (lbs.)	Safety Factor	
330.00	300.00	420.00	95306	208384	2.18	
310.00	300.00	400.00	91378	195371	2.13	
290.00	280.00	380.00	93574	183646	1.96	
270.00	280.00	360.00	90630	193236	2.13	
250.00	260.00	340.00	89007	197606	2.22	
230.00	260.00	320.00	87405	181020	2.07	
210.00	260.00	300.00	80929	165178	2.04	
190.00	260.00	280.00	77614	150670	1.94	
170.00	300.00	260.00	72670	128255	1.76	
150.00	300.00	240.00	65368	139702	2.13	
130.00	320.00	220.00	60468	108764	1.79	
110.00	320.00	200.00	53514	89818	1.67	All circles tangent to Elevation -10
335.00	320.00	420.00	100699	173963	1.72	
315.00	320.00	400.00	97916	165423	1.68	
295.00	300.00	380.00	98211	192414	1.95	
275.00	280.00	360.00	99511	188286	1.89	
255.00	280.00	340.00	95875	162989	1.70	
235.00	280.00	320.00	91675	147971	1.61	
215.00	280.00	300.00	87732	142071	1.61	
195.00	260.00	280.00	85528	157293	1.83	
175.00	300.00	260.00	75936	126424	1.66	
155.00	300.00	240.00	75629	113462	1.50	
135.00	300.00	220.00	70009	99360	1.41	
115.00	300.00	200.00	66205	102624	1.55	All circles tangent to Elevation -15
340.00	320.00	420.00	112322	195521	1.74	
320.00	320.00	400.00	107761	187360	1.73	
300.00	320.00	380.00	104905	167460	1.59	
280.00	300.00	360.00	103112	160876	1.56	
260.00	280.00	340.00	104990	160144	1.52	
240.00	280.00	320.00	99418	173933	1.74	
220.00	280.00	300.00	96046	146297	1.52	
200.00	280.00	280.00	88765	134639	1.51	
180.00	280.00	260.00	85477	120964	1.41	
160.00	300.00	240.00	80076	122015	1.52	
140.00	300.00	220.00	73701	101097	1.37	
120.00	300.00	200.00	69901	82015	1.17	All circles tangent to Elevation -20

Refer to Figure 3 for coordinates of centers of circles.

TABLE V-2

SLIP CIRCLE ANALYSIS, EMBANKMENT ELEVATION +105

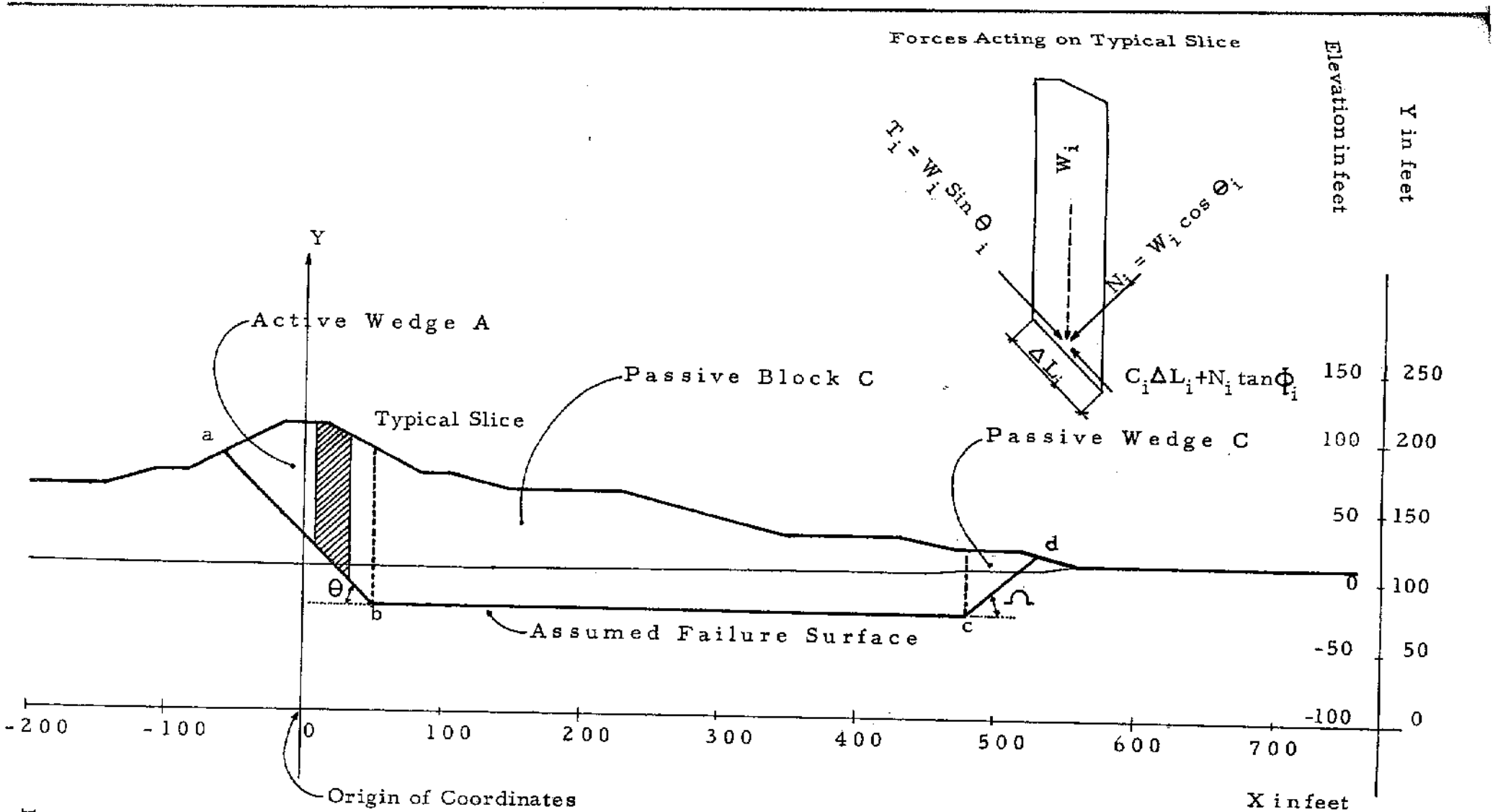
Circle with Least Factor of Safety
for Each Series of Circles Studied

R (ft.)	X_0 (ft.)	Y_0 (ft.)	Driving Force (lbs.)	Resisting Force (lbs.)	Safety Factor	
375.00	240.00	460.00	228616	372234	1.62	
355.00	220.00	440.00	243154	382032	1.57	
315.00	220.00	400.00	225897	357874	1.58	
295.00	200.00	380.00	227137	381124	1.67	
275.00	200.00	360.00	222560	349679	1.57	
255.00	200.00	340.00	202865	307102	1.51	
235.00	180.00	320.00	212919	317498	1.49	
215.00	160.00	300.00	202785	337965	1.66	
195.00	160.00	280.00	199555	309120	1.54	
175.00	120.00	260.00	203182	305753	1.50	
155.00	100.00	240.00	189823	278853	1.46	All circles tangent to Elevation -15
400.00	240.00	480.00	259551	390246	1.50	
360.00	240.00	440.00	240901	358131	1.48	
340.00	240.00	420.00	232323	351009	1.51	
320.00	220.00	400.00	240536	352223	1.46	
300.00	200.00	380.00	251674	352483	1.40	
280.00	200.00	360.00	234613	325471	1.38	
260.00	200.00	340.00	228150	329034	1.44	
240.00	180.00	320.00	223944	320704	1.43	
220.00	160.00	300.00	226710	312884	1.38	
200.00	160.00	280.00	211001	302244	1.43	
160.00	140.00	240.00	195262	281281	1.44	All circles tangent to Elevation -20
405.00	240.00	480.00	273556	395742	1.44	
385.00	240.00	460.00	271115	382061	1.40	
365.00	240.00	440.00	259045	370422	1.42	
345.00	240.00	420.00	252922	336193	1.32	
305.00	200.00	380.00	268332	360045	1.34	
285.00	220.00	360.00	238023	315828	1.32	
265.00	200.00	340.00	244471	305030	1.24	
245.00	200.00	320.00	225516	299565	1.32	
205.00	160.00	280.00	219983	263001	1.19	
185.00	160.00	260.00	208141	272477	1.30	
165.00	120.00	240.00	214211	276564	1.29	All circles tangent to Elevation -25

TABLE V-2 (Continued)

R (ft.)	X_0 (ft.)	Y_0 (ft.)	Driving Force (lbs.)	Resisting Force (lbs.)	Safety Factor	
390.00	240.00	460.00	286712	384284	1.34	All circles tangent to Elevation -30
370.00	240.00	440.00	282033	362927	1.28	
350.00	240.00	420.00	265577	363113	1.36	
330.00	240.00	400.00	262933	341382	1.29	
290.00	200.00	360.00	278696	337969	1.21	
270.00	200.00	340.00	257034	333542	1.29	
250.00	200.00	320.00	251202	287977	1.14	
230.00	160.00	300.00	252051	318218	1.26	
210.00	140.00	280.00	230593	286043	1.24	
190.00	160.00	260.00	225181	279601	1.24	
170.00	120.00	240.00	218464	245753	1.12	

Refer to Figure 3 for coordinates of centers of circles.



TYPICAL WEDGE

FIGURE NO. 4

The safety factor for a given wedge is expressed as a ratio of the total forces contributing to stability, to the total forces which contribute to sliding, as follows:

$$SF = \frac{\cos\theta \sum_{a}^{b} (N_i \tan\phi_i + C_i \Delta L_i) + \sum_{b}^{c} S_i \Delta L_i + \frac{1}{\cos\Omega} \sum_{c}^{d} (N_i \tan\phi_i + C_i \Delta L_i + T_i)}{\cos\theta \sum_{a}^{b} T_i}$$

Tables V-3 and V-4 show the resulting forces by the sliding wedge analyses. The results are for the wedge with the minimum factor of safety for each assumed failure surface. For each assumed failure surface the length of line b-c was varied and each length b-c was studied for varying angles of Θ and Ω.

c. Embankment Cross Sections. The cross section for the dam has 5 zones of material. These are shown in the typical cross sections of Figures No. 6, 8, 9 and 10. Zone 1 is the foundation mat as described before. This mat serves as a protection to the foundation, preventing rupture from dumping of large boulders and also serves as a drainage media for the water from the foundation material as the material consolidates under the progressive loading. Zone 2 material is the impervious section of the embankment. This will consist of random excavation with 30 to 50 percent of the material smaller than 4 to 6 inch size. Zone 3 material will be random excavation with no size limit or required gradation. The Zone 2 material will be placed in the upstream portion of the embankment.

TABLE V-3

SLIDING WEDGE ANALYSIS
EMBANKMENT ELEVATION +75
(Minimum Safety Factor for Each Failure Surface Studied)

Coordinates of Assumed Failure Surface *								Driving Force, lbs.	Resisting Force, lbs.	Safety Factor
X_a	Y_a	X_b	Y_b	X_c	Y_c	X_d	Y_d			
60	175	210	89	520	89	560	110	116643	171133	1.46
70	175	220	89	520	89	560	110	114656	167626	1.46
80	175	230	89	520	89	560	110	112481	163410	1.45
90	175	240	89	520	89	560	110	110493	159963	1.44
100	175	250	89	520	89	560	110	107231	155732	1.45
110	175	260	89	520	89	560	110	103987	152263	1.46
120	175	270	89	520	89	560	110	100481	148731	1.48
90	175	240	89	470	89	500	121	110493	167341	1.51
90	175	240	89	520	89	580	110	110493	157483	1.42
90	175	240	89	540	89	580	110	110493	153543	1.38
90	175	240	89	550	89	575	110	110493	149464	1.35
90	175	240	89	560	89	585	110	110493	151543	1.37
90	175	240	89	570	89	595	110	110493	152119	1.37

* Refer to Figure 4 for Location of Surfaces

TABLE V-4

SLIDING WEDGE ANALYSIS
EMBANKMENT ELEVATION +105
(Minimum Safety Factor for Each Failure Surface Studied)

Coordinates of Assumed Failure Surface *								Driving Force lbs.	Resisting Force, lbs.	Safety Factor
X_a	Y_a	X_b	Y_b	X_c	Y_c	X_d	Y_d			
-100	205	30	85	520	85	560	110	219738	264593	1.20
-100	205	40	85	520	85	560	110	234140	280260	1.19
-70	205	50	85	520	85	560	110	222140	267097	1.20
-70	205	60	85	520	85	560	110	232904	278159	1.19
-70	205	70	85	520	85	560	110	238920	289978	1.21
-50	205	80	85	520	85	560	110	220165	267133	1.21
-50	205	90	85	520	85	560	110	222340	275649	1.23
-70	205	60	85	470	85	510	120	232904	283702	1.21
-70	205	60	85	480	85	520	120	232904	286179	1.22
-70	205	60	85	490	85	530	120	232904	288495	1.23
-70	205	60	85	500	85	550	120	232904	280679	1.20
-70	205	60	85	520	85	570	110	232904	273151	1.17
-70	205	60	85	540	85	590	110	232904	268954	1.15

* Refer to Figure 4 for Location of Surfaces

Figure No. 11 is a mass distribution diagram. It shows the location of Zones 1, 2 and 3 material within the Bas Obispo-Las Cascadas Reaches of the Canal Widening Project and the manner of distribution to the various sections of the embankment across Trinidad Arm of Gatun Lake.

Zone 4 is that material above elevation +75. Elevation +75 is the practical limit for dumping material from bottom dump barges. Suitable material in excess of that required to construct the embankment to elevation +75 may be used in Zone 4 by depositing at elevation +75 and reworking with dipper dredges or barge mounted draglines to place it above elevation +75. It is expected that much of Zone 4 material will come from necessary excavation for the spillway and navigation lock on Gaucha Island, with the remainder to come from borrow areas on the Mainland at each end of the dam.

Zone 5 is the rip-rap faces of Zone 4 above elevation +75.

d. Embankment Height Limitation. Consideration was given to constructing the embankment across Trinidad Arm of Gatun Lake higher than elevation +105. This would make possible the conservation of more water and the generation of more power at the Gatun power plant. The final determination of the design elevation of +105 was dictated by the following conditions:

(1) The strength of the foundation material is so limited that a base width greatly in excess of that shown for the fill to elevation +105 would be required to support additional height. Material available from the Cut Widening Project is not sufficient in quantity to construct the larger section required for the higher dam.

(2) The ridge between Trinidad Arm Lake and the Atlantic Ocean is low and very thin. Additional height of water in Trinidad Arm Lake would necessitate construction of substantial saddle dams on this ridge in order to insure stability and imperviousness, thus very appreciably increasing the cost.

(3) The additional water storage behind a dam to elevation +105 will provide adequate water to operate the locks to their full capacity. Therefore, any additional height would be unnecessary for this purpose.

(4) The treaty with the Republic of Panama permits the storage of water to the 100-foot contour and to go any higher would require new treaty arrangements.

It is recognized that negotiations with the Republic of Panama could overcome the present boundary problems but the restrictions recited by conditions 1, 2 and 3 heretofore enumerated are sufficient to impose the height limitation of +105 on a Dam across the Trinidad Arm of Gatun Lake.

VI ADDITIONAL STUDIES AND TESTS

Sampling and testing of the material should continue during construction for the purpose of more accurately determining the physical characteristics of embankment material as it is excavated from the canal widening. Undisturbed samples taken from the foundation material at periodic intervals during placement of the fill should be tested to determine the degree of consolidation. Data thus obtained will confirm values used in the design and make possible refinements in the embankment section for the purpose of taking advantage of any economies possible or if necessary, change the design to insure stability.

Design reviews should be conducted throughout the construction period to accomplish the purposes set forth above.

Means to detect any failures that may occur, both in the fill and the foundation should be provided. Piles in clusters of three each, could be driven through the mat over the foundation at intervals of 500 feet along the upstream and downstream toes of the embankment. Periodic checks on these pile clusters to determine movement both laterally and vertically will serve to warn of incipient failure and provide information on settlement and movement.

Installation of piezometers at the pile locations will also give a record of foundation pore pressures during and after construction as the foundation consolidates.

Sieve analyses of the material as it is removed from the canal widening will determine the percentage of material that is less than 4 to 6 inches in size. This will determine material for Zone 2 in the embankment section. After several tests with known rock types and powder factors, the routing of the material to the Zone within the embankment may be done by visual inspection as the barges are loaded.

VII CONSTRUCTION SCHEDULE

A construction schedule showing materials for the embankment across Trinidad Arm of Gatun Lake is shown on Figure 12.

The purpose of this construction schedule is to maintain control over the construction of the embankment and assure the proper sequence of loading the foundation. It is imperative that the deposition of the fill material follow closely the sequence as shown in the schedule so that the foundation will not be ruptured and the maximum benefit of consolidation may be obtained.

It will be necessary to have qualified supervision of the job at all times to assure the delineation of the destination of each barge load of material removed from the Canal Widening. This must include a man at the dam site to see that the construction schedule is adhered to and the material dumped in layers as thin and uniform as possible.

After placing the mat over the foundation, the sequence of dumping is planned so that the succeeding fill is placed in a manner that will load the foundation uniformly.

The construction schedule provides for the embankment fill to elevation +75 in coordination with the Canal Widening Project. This limiting height is based on the estimated quantity of suitable material that will be available from the remaining canal widening, and clearance requirements assuming bottom dump barges will be used for transportation to

and deposition of the material at the embankment site. If fill material in excess of the quantity estimated is available and it is found advantageous to place it in the fill section above elevation +75, this may be so scheduled. Deposition in the embankment section above elevation +75 can be accomplished either by dozing from surface loaded barges or by recasting with a barge mounted drag line or a dipper dredge.

VIII COST ESTIMATE

The estimated quantities and cost estimate are for construction of the embankment to elevation +75. The estimate is based on current prices of similar operations where applicable. Where these are not available, sound engineering and construction methods were applied to arrive at the unit prices.

The cost estimate reflects only the additional costs over those that will apply to the Canal Widening Project with material wasted. These additional costs, which are logically chargeable to the embankment across Trinidad Arm of Gatun Lake, include additional blasting and handling or crushing required for Zone 1 material placed as a mat over the foundation, as well as charges for the length of haul beyond the designated spoil area for the canal widening. The additional cost of the material in Zone 2 and 3 of the embankment section reflects the charge for overhaul only, as no special blasting or handling is required.

The computed quantities reflect the estimated settlement in the foundation and embankment during construction shown in the embankment sections on Figures 6, 8, 9, and 10.

TABLE VIII - 1

Detailed Cost Estimate
Trinidad Arm Dam to Elevation +75

No.	Item	Quantity	Unit	Unit Price	Amount
1.	Zone 1 Material	3,067,000	c.y.	$0.40	$1,227,000
2.	Zones 2 & 3 Material	8,094,000	c,y.	0.18	1,457,000
			Subtotal		$2,684,000
	Contingencies @ 20% of Estimated Cost				$ 530,000
	*Administration and Engineering, including foundation exploration, surveys, design and supervision of construction				$ 519,000
			Total Estimated Cost		$3,740,000

* 7% of Estimated Cost computed with material from borrow areas other than Cut Widening.

IX CONTRACT SPECIFICATIONS

1. FOUNDATION MAT (Embankment Zone 1)

a. Scope. This section covers excavating, screening and/or crushing and placing of the material for the foundation mat, complete.

b. Excavation. The excavation of the material for the mat will be from above elevation +90 in the Las Cascadas-Bas Obispo Reaches of the Canal Widening Project. The material excavated shall be screened and/or crushed to assure that the maximum size will be 8 inch. The excavation shall be carried out in the location and manner prescribed by the Contracting Officer.

c. Placement. Screened and/or crushed material shall be loaded in barges for transportation to the embankment site in Trinidad Arm of Gatun Lake. Deposition from the barges shall be in such a manner that the thickness of each barge deposit shall be 5 feet or less. The total thickness of the mat (Zone 1) shall be a minimum of 15 feet. The routing of the barges shall be in accordance with the placing schedule shown on Figure 12, or as directed by the Engineer.

d. Measurement. The unit of measurement shall be the cubic yard, the quantity computed by the average end-area method from cross sections taken before and after the excavation operations. The quantity of material that is removed, screened and/or crushed, and deposited in the embankment site in Trinidad Arm of Gatun Lake shall

be paid for on the basis of measurement in place before it is excavated for the Canal Widening. Measurements of material in the embankment will not be made for purposes of payment, but will be made to determine conformance with the embankment section shown on the plans.

e. Payment. The embankment material, measured as described in subsection IX-1-d, shall be paid for at the contract unit price per cubic yard for "Embankment, Zone 1," which payment shall constitute full compensation for all labor, plant, equipment, tools, supplies and incidentals necessary to complete all items of work under this section, including all processing, hauling and placement of the materials as shown on the drawings and herein.

If it should be determined that transportation and placement of the excavated material in the embankment is to be done by the Panama Canal Company, the contract unit price per cubic yard for "Embankment Zone 1 material" shall constitute full payment for all labor, plant, equipment, tools, supplies and incidentals necessary to complete all items of work under this section, excepting the hauling and placement of the materials but including the processing, delivery and loading in the Panama Canal Company barges ready for transportation to the embankment site on Trinidad Arm of Gatun Lake.

2. RANDOM FILL (Embankment Zones 2 & 3)

a. Scope. This section of the specifications covers excavation

and placement of the material in Zones 2 & 3 of the embankment section, complete.

b. Excavation. The excavation of the material for Zones 2 & 3 shall be in accordance with the specifications for the canal widening.

c. Loading. The excavated material will be disposed of by depositing under water in the embankment across Trinidad Arm of Gatun Lake or, if to be wasted, in areas designated by the Contracting Officer. The material shall be loaded in barges and transported to the areas so designated. Care shall be taken during loading operations to prevent materials from entering the Canal prism. All such material entering the prism shall be removed by the Contractor as directed by the Contracting Officer.

d. Disposal of Material in Trinidad Arm of Gatun Lake.

Material shall be deposited in the embankment in the Trinidad Arm of Gatun Lake in accordance with the placing schedule shown on Figure 12. This material shall be random sized with no effort made to control the sizes. The size will be restricted to the safe handling capacity of the excavating machinery employed on the contract. The area of deposition in the embankment shall be as directed by the Contracting Officer or his engineer.

Use of bottom dump barges will permit deposition of material to approximately elevation +75 when Gatun Lake is at water surface +87.

Depositing of material above elevation +75 may be accomplished by the use of deck loading barges or by rehandling with barge drag line or dipper dredge. If it is determined by the Contracting Officer to be economically feasible such operations may be ordered if requested or agreed to by the Contractor.

e. Disposal of Material in other Spoil Areas. Materials not placed in the embankment across Trinidad Arm of Gatun Lake shall be deposited in spoil areas designated by the Contracting Officer.

f. Maintenance of Slopes. Slopes of material deposited in the embankment across Trinidad Arm of Gatun Lake shall be maintained to the lines shown on Figures No. 6, 8, 9 and 10. If at any time it is determined by the Contracting Officer that the slopes are not substantially as specified for the embankment sections material shall be deposited at the place and in the manner specified by the Contracting Officer to make the corrections necessary. Soundings to determine the configuration of the underwater fill will be made by the Contracting Officer as soon as possible after each barge load of material has been deposited. The sequence of disposal operations may be changed to maintain the integrity of the foundation material and conform to requirements of the design.

g. Measurement. The unit of measurement shall be the cubic yard, which will be computed by the average end-area method from

cross sections taken before and after the excavation operations. Prior to starting excavation a reference base line will be established by the Panama Canal Company. It shall be the responsibility of the Contractor to preserve this base line. The yardage to be paid for will be the number of cubic yards of material, measured in its original position, which is removed from within the excavation area and disposed of as specified herein. The measure will not include any yardage excavated below the overdepth tolerance limit specified unless such additional excavation is directed by the Contracting Officer. The measurement will not include the yardage of any excavation which may be performed prior to the taking of the original elevations and measurements of the undisturbed grade. Material placed in the embankment across Trinidad Arm of Gatun Lake will be measured by the average end-area method from cross sections taken before and after deposition. Volumes computed for excavation will be compared with volumes computed in place in the embankment to determine the percentage of bulking which takes place.

h. Payment. The yardage of excavation and disposal, measured as hereinbefore described, shall be paid for at the Contract Unit Price per cubic yard for: (1) Material removed and deposited in Zones 2 and 3 of the embankment in Trinidad Arm of Gatun Lake below elevation +75; and (2) Material removed and deposited in Zones 2 and 3 of the embankment in Trinidad Arm of Gatun Lake above

elevation +75 if so directed by the Contracting Officer; and (3) Material removed and deposited in areas other than Trinidad Arm of Gatun Lake.

X CONCLUSIONS AND RECOMMENDATIONS

1. CONCLUSIONS: The following conclusions have been reached as a result of the design studies:

a. An embankment can be constructed across Trinidad Arm of Gatun Lake as shown on the drawings.

b. A mat, constructed of 8 inch minus material, of at least 15 feet thickness is required to protect the foundation from the larger material sizes deposited for Zones 2 and 3 of the embankment and to allow drainage during consolidation of the foundation material under the embankment load.

c. With proper placing of materials in a specific zone of the embankment section, the permeability of the embankment within allowable limits will be assured.

d. There is sufficient suitable material available in the remaining Canal Widening Project to construct an embankment across Trinidad Arm of Gatun Lake to elevation +75.

2. RECOMMENDATIONS:

It is recommended that:

a. The embankment across Trinidad Arm of Gatun Lake be constructed to elevation +75 with material obtained from the Canal Widening Project. If material excess to this requirement is available from the Canal Widening, it be placed in Zone 4 if determined

to be economically feasible and agreeable to both parties to the construction contract.

b. The foundation mat be constructed as the first phase of the Trinidad Dam Project. The mat material to be processed by blasting, screening and/or crushing to obtain a maximum size of 8".

c. Sieve analyses be made of the various materials as they are removed from the Canal Widening, to determine the suitability of it and similar materials for Zone 2 of the embankment.

d. Pile clusters be installed in the mat at 500-foot intervals along the upstream and downstream toes of the embankment. Precise location of these piles be made followed by periodic checks to determine settlement and horizontal movement. Peizometers be installed at the pile clusters to check pore pressures in the foundation material.

e. Periodic design reviews during construction be made to confirm values used in the original design and to revise the designs if the values are found to be significantly changed.

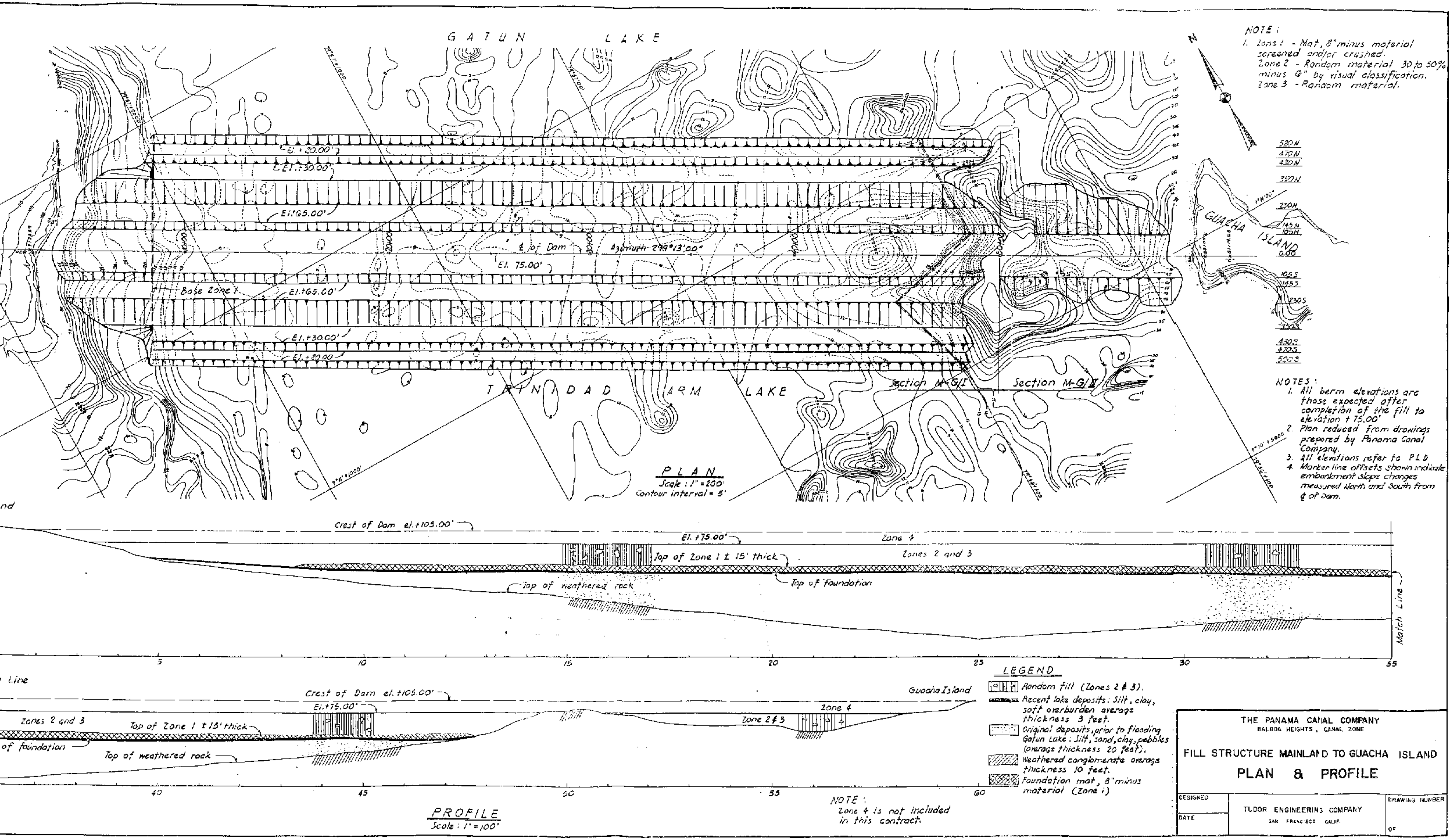

GATUN LAKE
TRINIDAD ARM LAKE
GUACHA ISLAND
NOTE:
1. Zone 1 - Mat, 8" minus material screened and/or crushed.
Zone 2 - Random material 30 to 50% minus 6" by visual classification.
Zone 3 - Random material.
NOTES:
1. All berm elevations are those expected after completion of the fill to elevation + 75.00'
2. Plan reduced from drawings prepared by Panama Canal Company.
3. All elevations refer to PLD
4. Marker line offsets shown indicate embankment slope changes measured North and South from ℄ of Dam.
El. + 20.00'
El. + 30.00'
El. + 65.00'
℄ of Dam
Azimuth 279°13'00"
El. 75.00'
Base Zone 1
Section M-G/I
Section M-G/II
PLAN
Scale: 1" = 200'
Contour interval = 5'
Crest of Dam el. + 105.00'
El. + 75.00'
Zone 4
Top of Zone 1 ± 15' thick
Zones 2 and 3
Top of weathered rock
Top of foundation
Match Line
Guacha Island
Zone 2 & 3
LEGEND
Random fill (Zones 2 & 3).
Recent lake deposits: Silt, clay, soft overburden average thickness 3 feet.
Original deposits, prior to flooding Gatun Lake: Silt, sand, clay, pebbles (average thickness 20 feet).
Weathered conglomerate average thickness 10 feet.
Foundation mat, 8" minus material (Zone 1)
NOTE:
Zone 4 is not included in this contract.
PROFILE
Scale: 1" = 100'
THE PANAMA CANAL COMPANY
BALBOA HEIGHTS, CANAL ZONE
FILL STRUCTURE MAINLAND TO GUACHA ISLAND
PLAN & PROFILE
DESIGNED
DATE
TUDOR ENGINEERING COMPANY
SAN FRANCISCO CALIF.
DRAWING NUMBER
OF

FIGURE NO. 5

GATUN LAKE

MAINLAND

TRINIDAD ARM LAKE

520 N
470 N
430 N
350 N
230 N
145 N
105 N
000
105 S
145 S
230 S
350 S
430 S
470 S
520 S

El. +20.00'
El. +30.00'
El. +65.00'
El. +75.00'
Base Zone 4
℄ of Dam
Azimuth 298°13'00"
Section M-G/I
Section M-G/II

PLAN
Scale : 1" = 200'
Contour interval = 5'

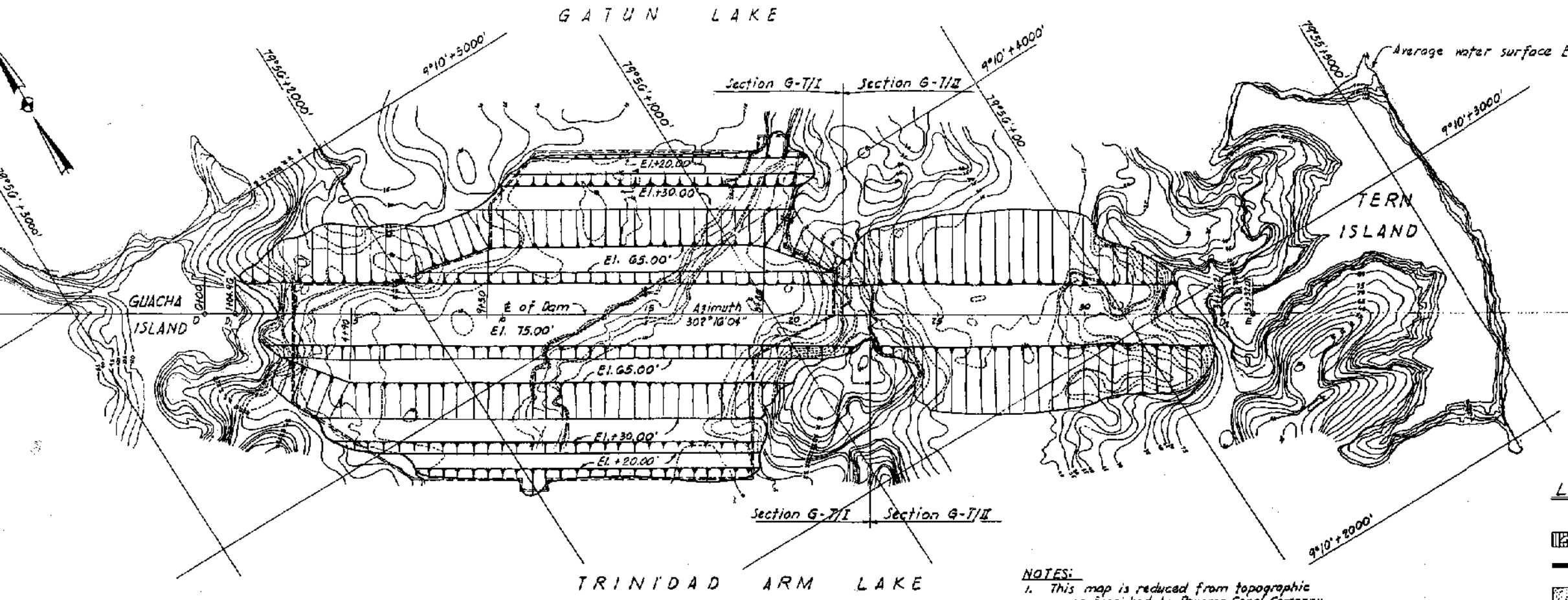
Mainland
Crest of Dam el. +105.00'
El. +75.00'
Zone 4
Zones 2 and 3
Top of Zone 1 x 15' thick
Top of foundation
Top of weathered rock
100
0
-100
-200
0
5
10
15
20
25

Match Line
Crest of Dam el +105.00'
El. +75.00'
Zones 2 and 3
Top of Zone 1 x 15' thick
Top of foundation
Top of weathered rock
Gaucha Island
Zone 2 & 3
Zone 4
100
0
-100
35
40
45
50
55
60

PROFILE
Scale : 1" = 100'

LEGEND
Random fill (Zones 2 & 3).
Recent lake deposits : Silt, clay, soft overburden average thickness 3 feet.
Original deposits prior to flooding Gatun Lake : Silt, sand, clay, pebbl (average thickness 20 feet).
Weathered conglomerate average thickness 10 feet.
Foundation mat, 8" minus material (Zone 1)

NOTE :
Zone 4 is not included in this contract.

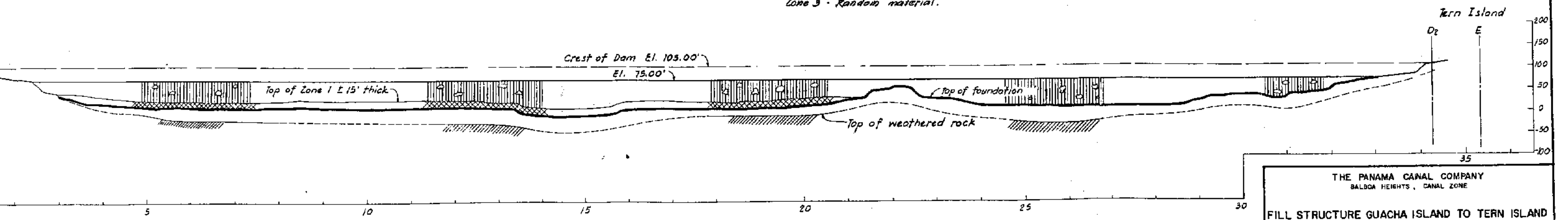


PLAN
Scale : 1" = 200'

NOTES:
1. This map is reduced from topographic maps furnished by Panama Canal Company.
2. Marker line offsets shown indicate embankment slope changes measured North and South from ℄ of Dam.
3. All berm elevations are those expected after completion of the fill to El. +75.00'
4. All elevations refer to P.L.D.
5. Zone 1 - Mat, 8" minus material, screened and/or crushed.
   Zone 2 - Random material, 30 to 50% minus 6" visual classification.
   Zone 3 - Random material.

LEGEND

- Random fill (Zones 2 & 3)
- Recent lake deposits : Silt, clay, soft overburden average thickness 3 feet.
- Original deposits, prior to flooding Gatun Lake : Silt, sand, clay, pebbles (average thickness 20 feet)
- Weathered conglomerate average thickness 10 feet.
- Foundation mat, 8" minus material (Zone 1)



PROFILE
Scale : 1" = 100'

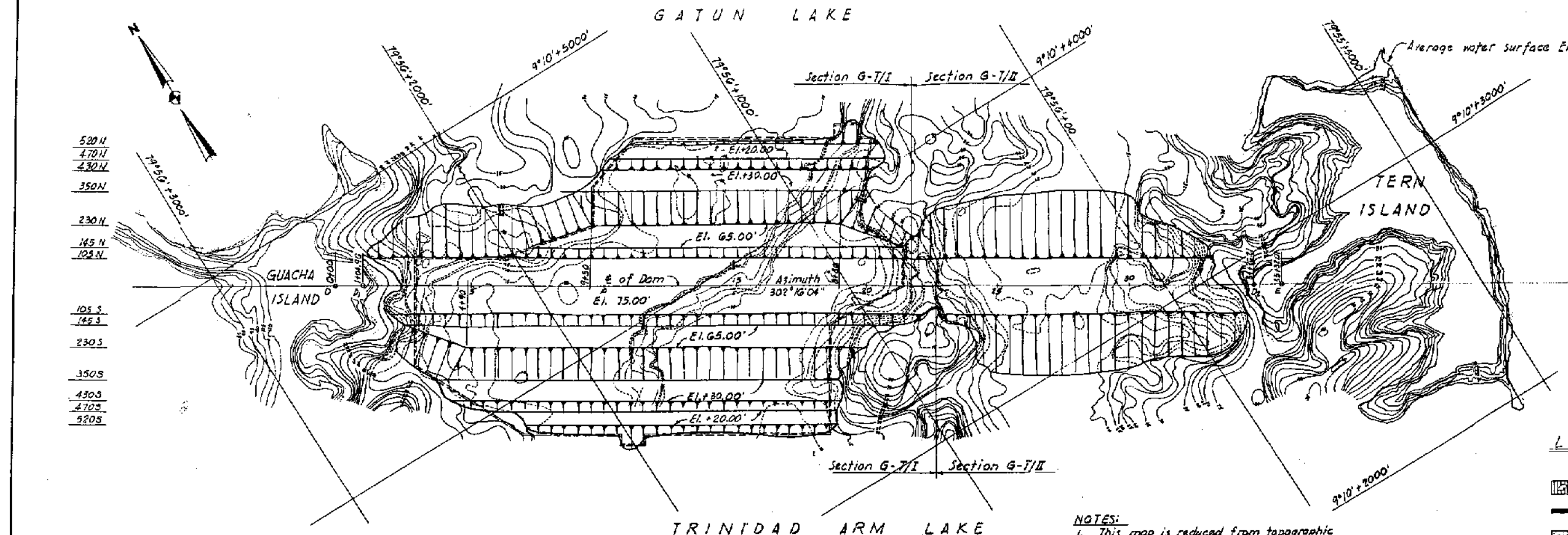
THE PANAMA CANAL COMPANY
BALBOA HEIGHTS, CANAL ZONE

FILL STRUCTURE GUACHA ISLAND TO TERN ISLAND

PLAN & PROFILE

DESIGNED	TUDOR ENGINEERING COMPANY SAN FRANCISCO, CALIF.	DRAWING NUMBER
DATE		OF

FIGURE NO. 7



PLAN
Scale : 1" = 200'

NOTES:
1. This map is reduced from topographic maps furnished by Panama Canal Company.
2. Marker line offsets shown indicate embankment slope changes measured North and South from ℄ of Dam.
3. All berm elevations are those expected after completion of the fill to El. +75.00'
4. All elevations refer to P.L.D.
5. Zone 1 - Mat. 8" minus material, screened and/or crushed.
   Zone 2 - Random material, 30 to 50% minus 6" visual classification.
   Zone 3 - Random material.

LEGEND
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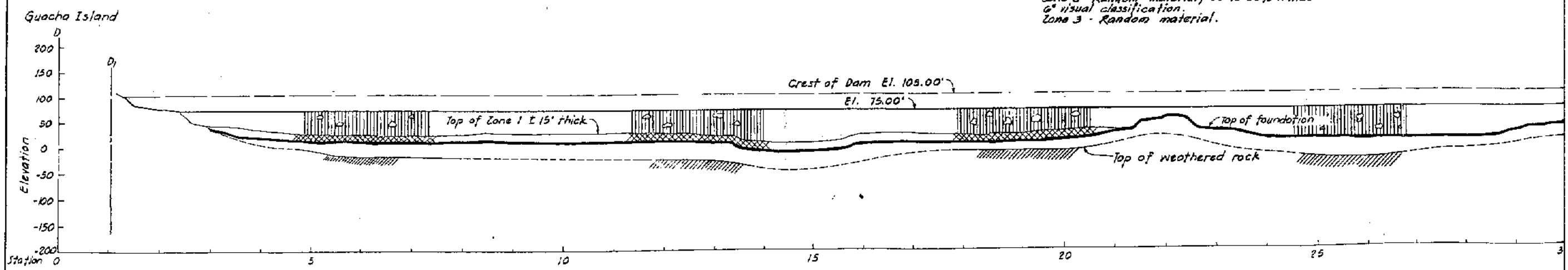
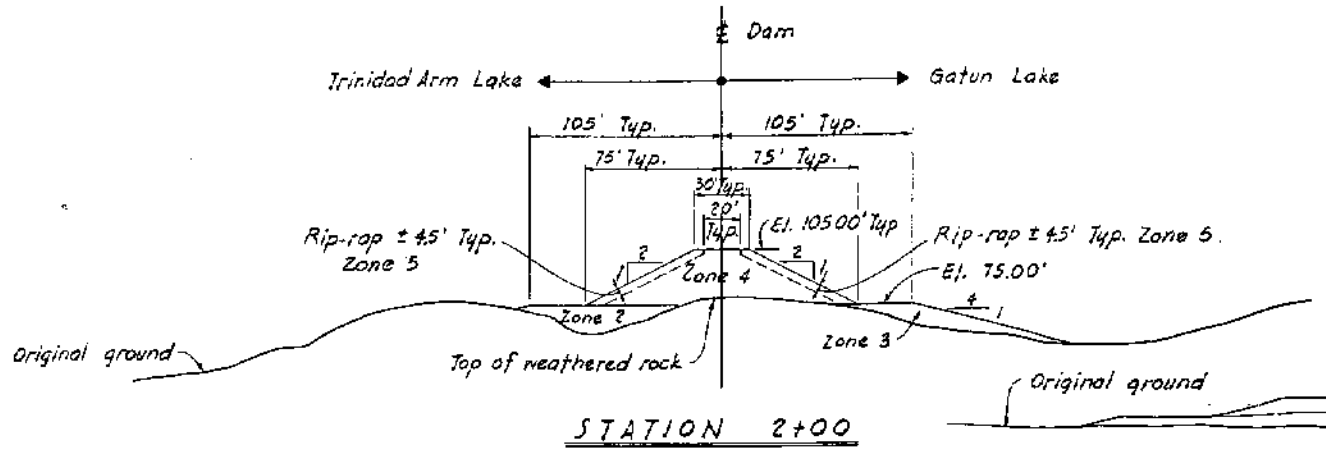
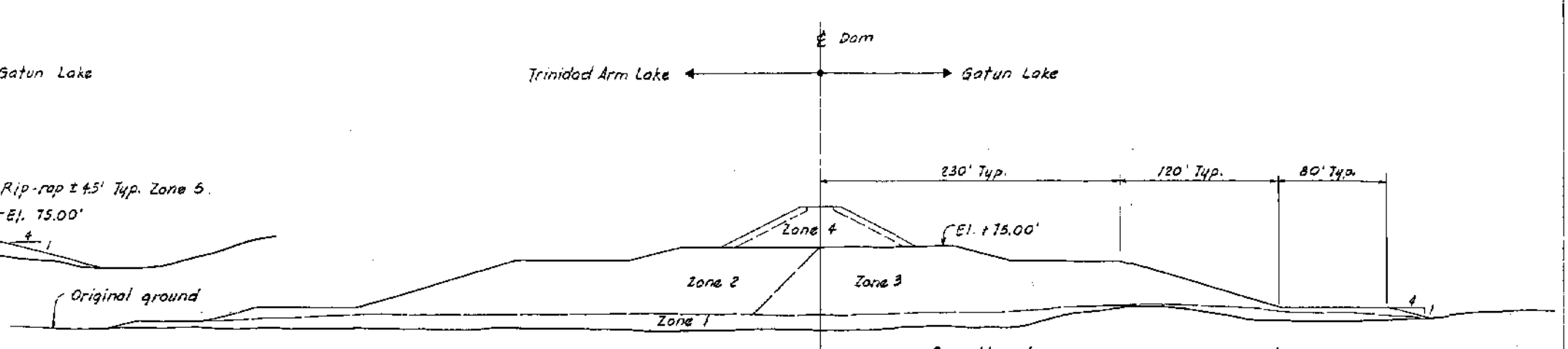


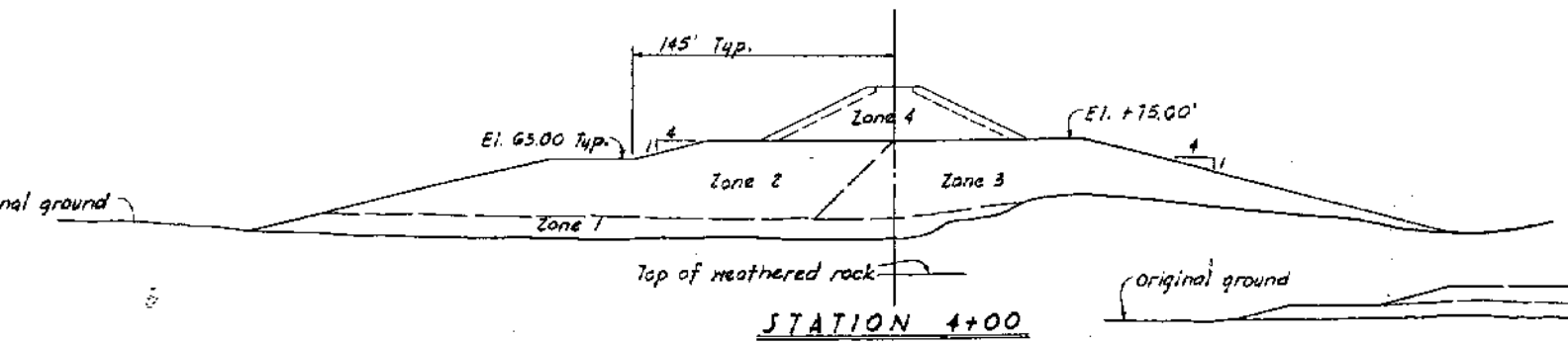
PROFILE
Scale: 1" = 100'



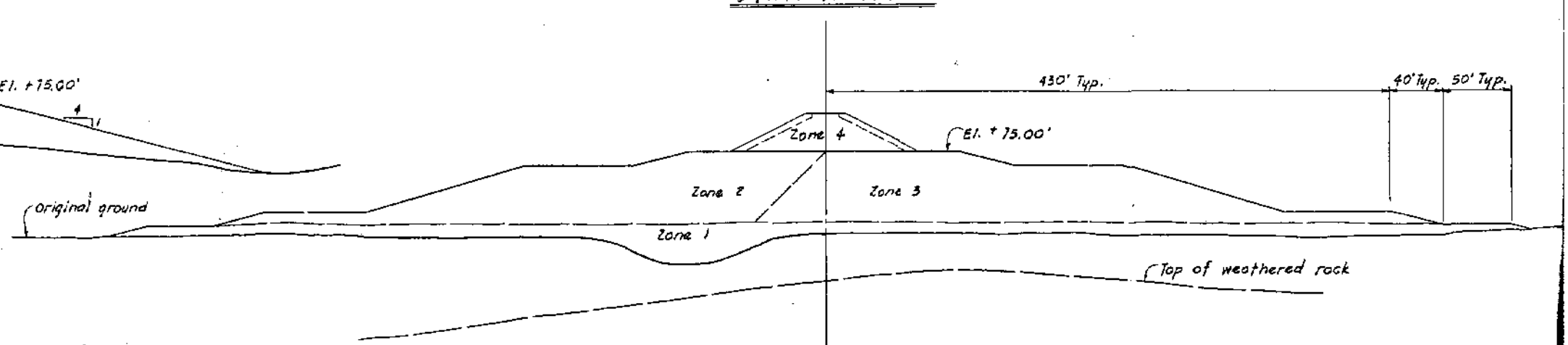
STATION 2+00



STATION 10+00

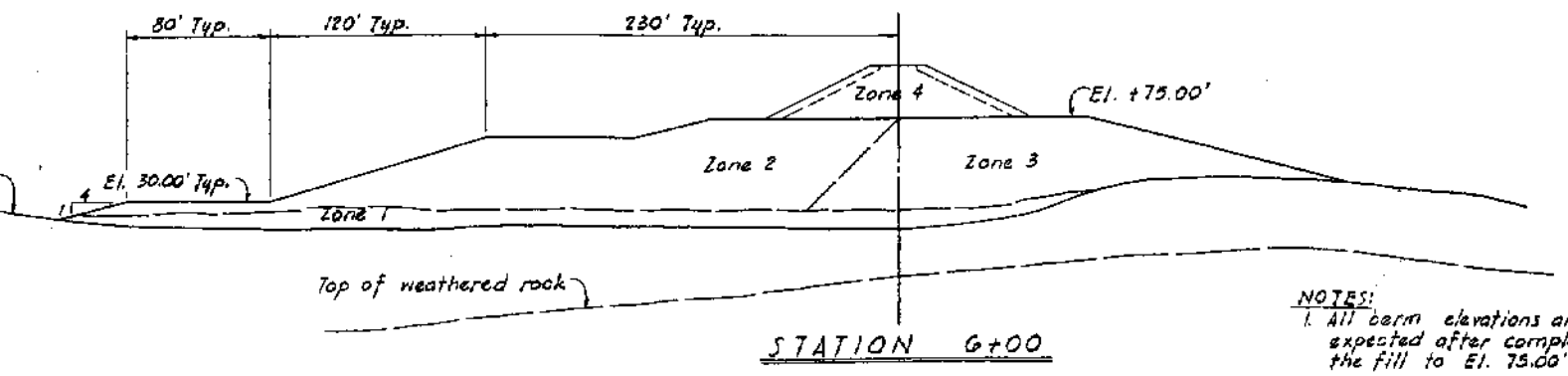


STATION 4+00



STATION 12+65

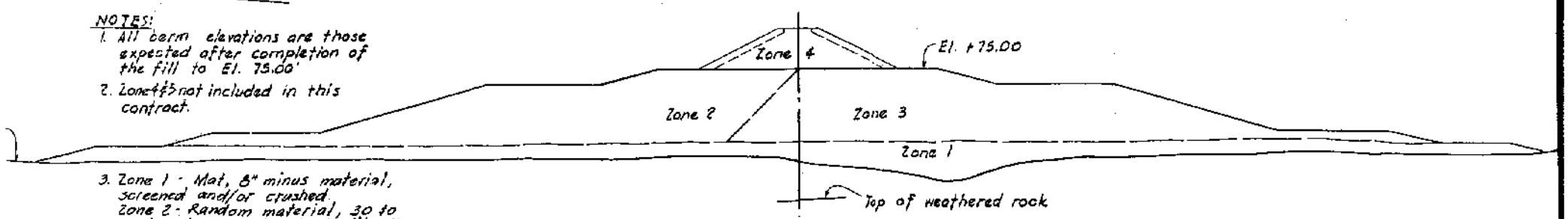
Typical From Station 11+00 to Station 18+50



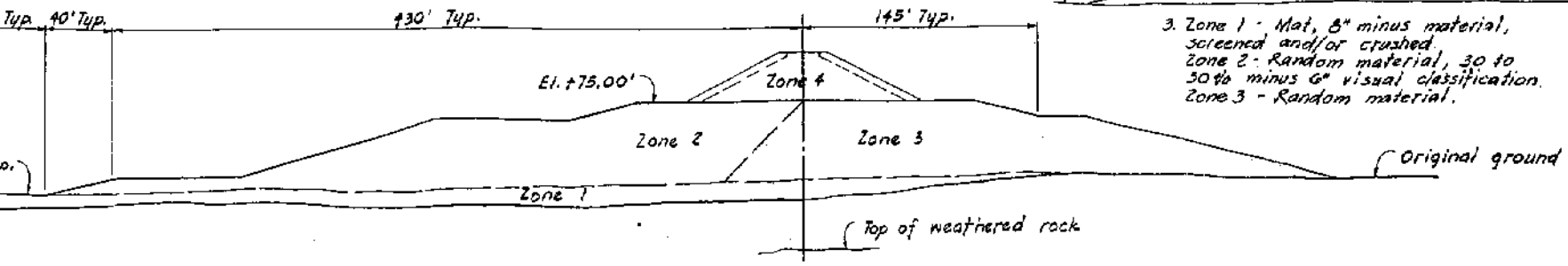
STATION 6+00

NOTES:

1. All berm elevations are those expected after completion of the fill to El. 75.00'
2. Zone 4 & 5 not included in this contract.
3. Zone 1 - Mat, 8" minus material, screened and/or crushed.
   Zone 2 - Random material, 30 to 50% minus 6" visual classification.
   Zone 3 - Random material.



STATION 16+00



STATION 8+00

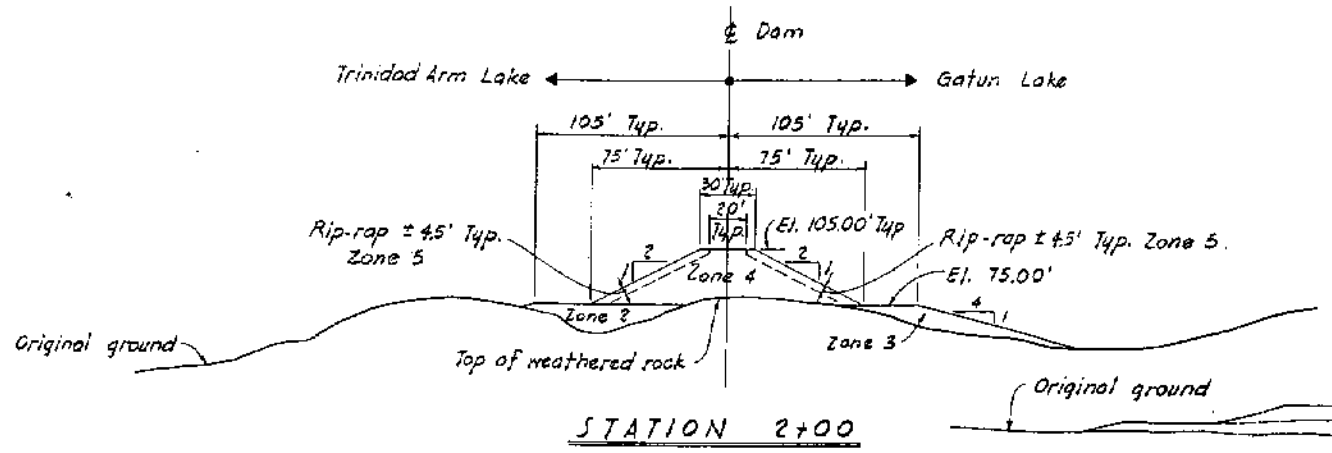
THE PANAMA CANAL COMPANY
BALBOA HEIGHTS, CANAL ZONE

FILL STRUCTURE GUACHA ISLAND TO TERN ISLAND

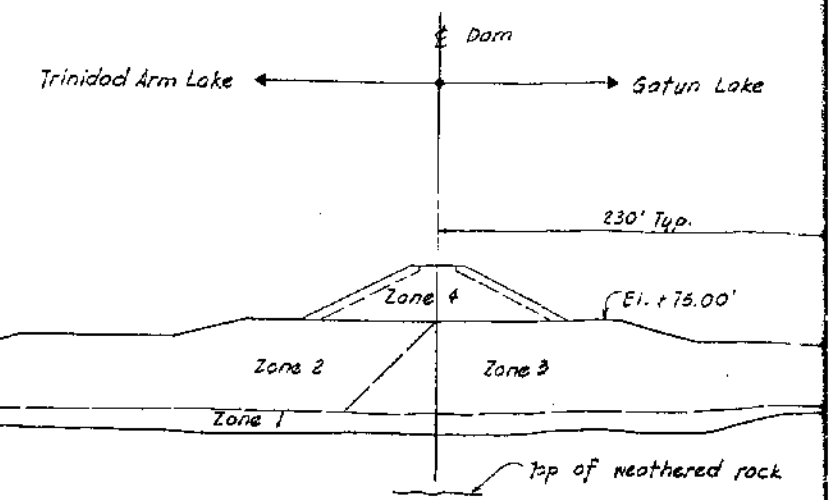
CROSS SECTIONS

DESIGNED	TUDOR ENGINEERING COMPANY	DRAWING NUMBER
DATE	SAN FRANCISCO, CALIF	OF

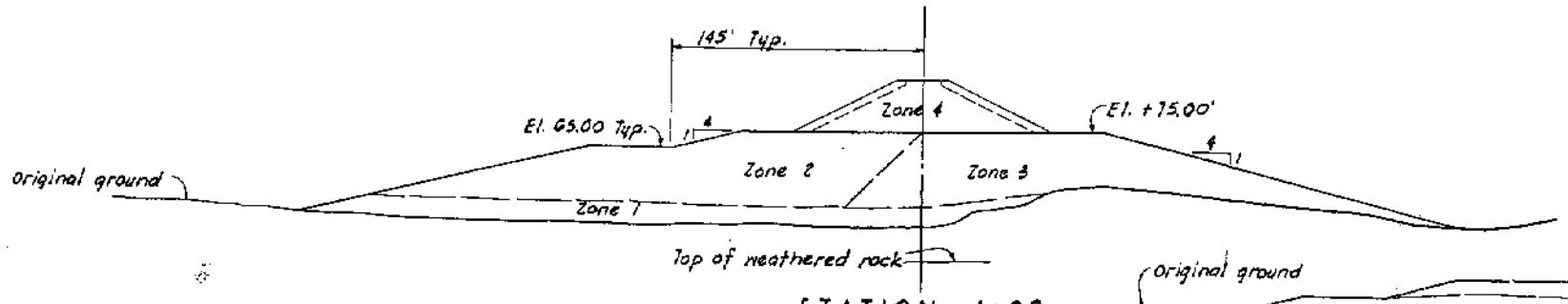
FIGURE NO.



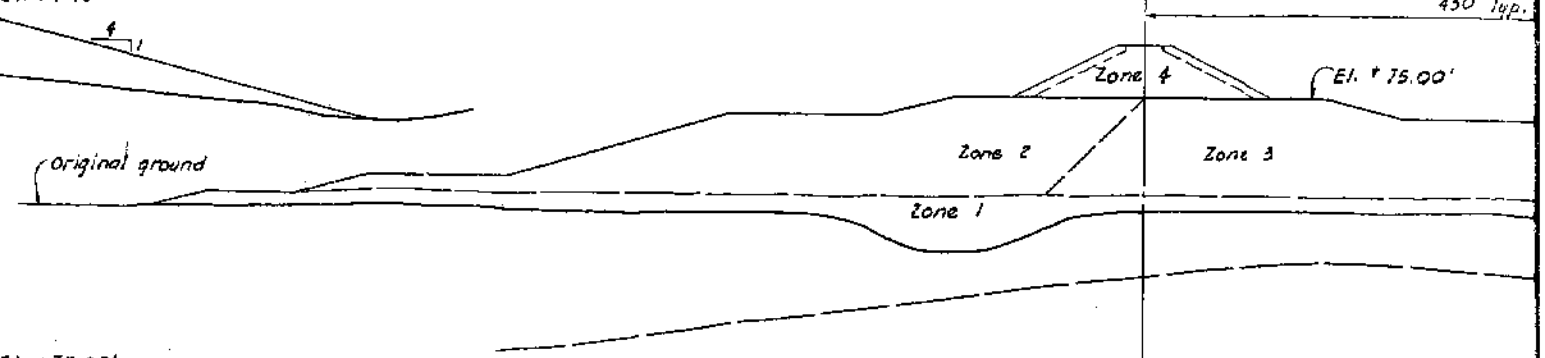
STATION 2+00



STATION 10+00

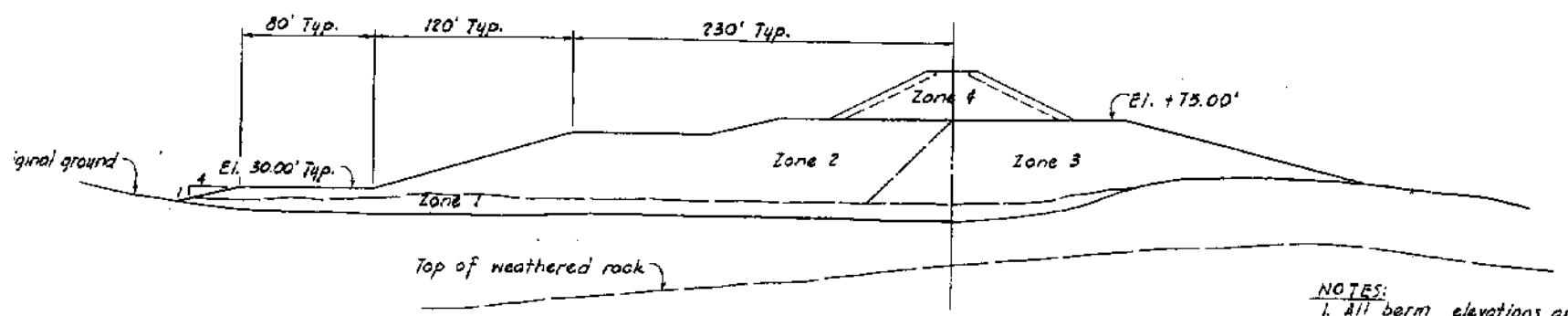


STATION 4+00



STATION 12+65

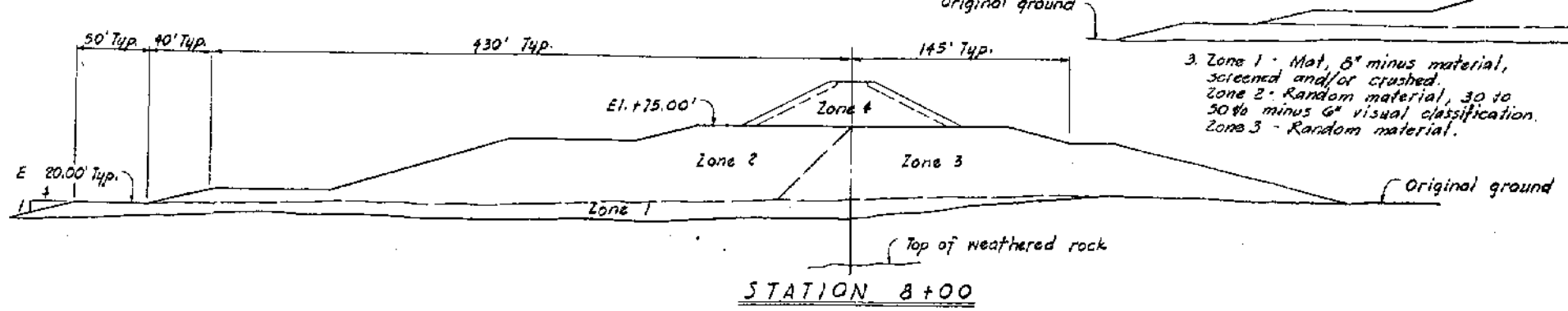
Typical From Station 11+00 to Station 18+50



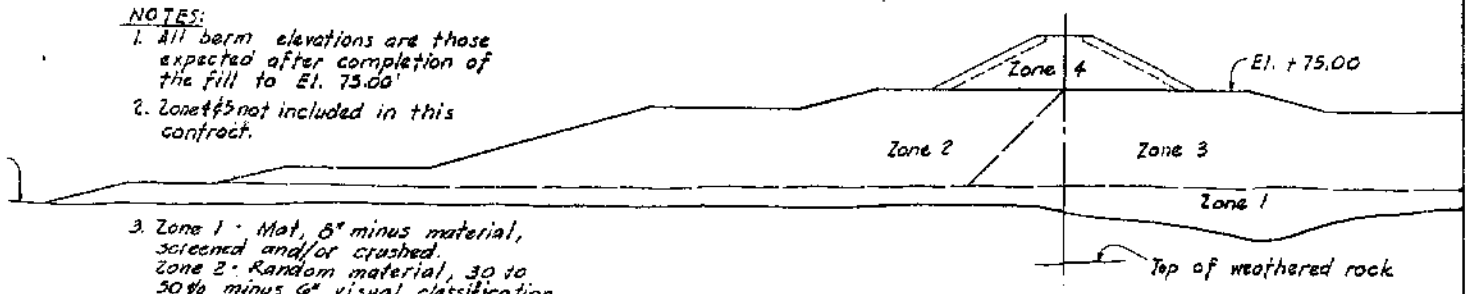
STATION 6+00

NOTES:

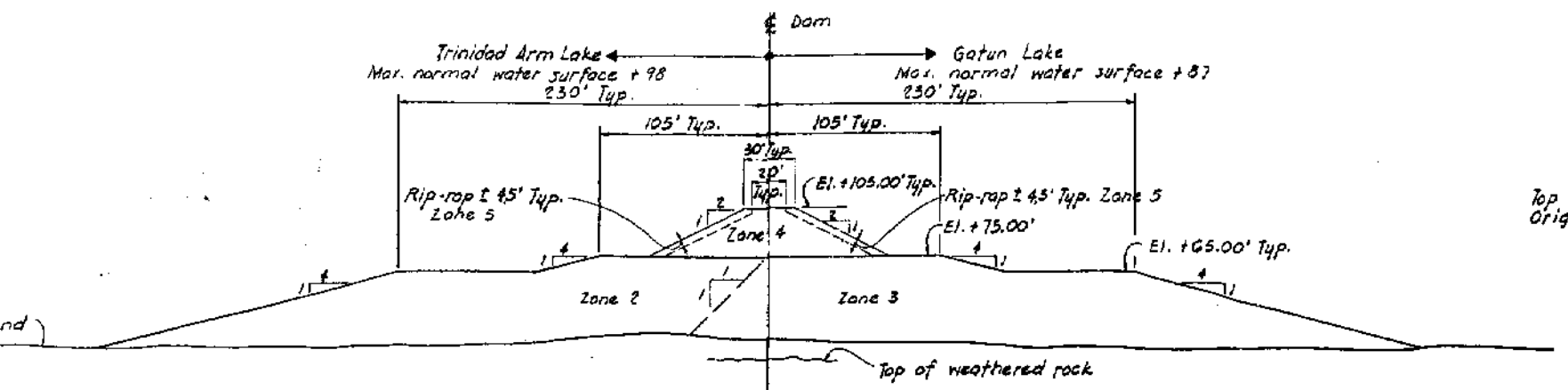
1. All berm elevations are those expected after completion of the fill to El. 75.00'
2. Zone 4 & 5 not included in this contract.
3. Zone 1 - Mat, 8" minus material, screened and/or crushed.
   Zone 2 - Random material, 30 to 50% minus 6" visual classification.
   Zone 3 - Random material.



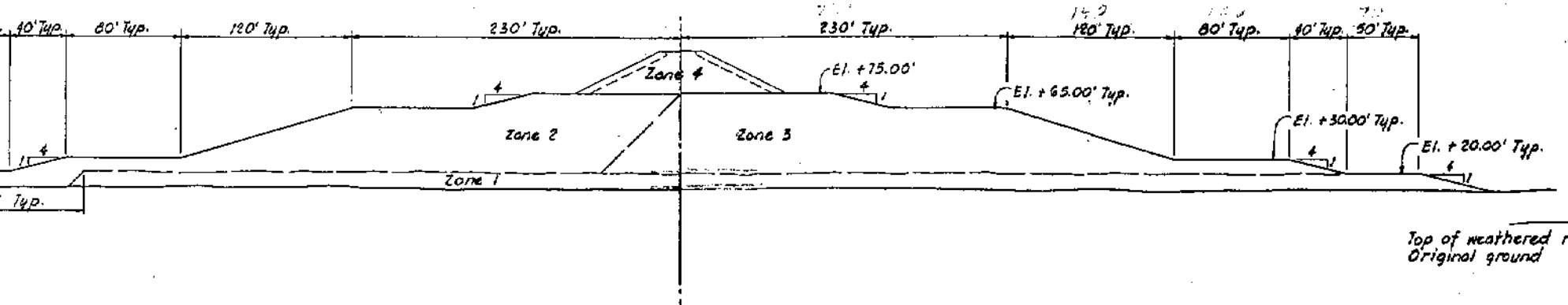
STATION 8+00



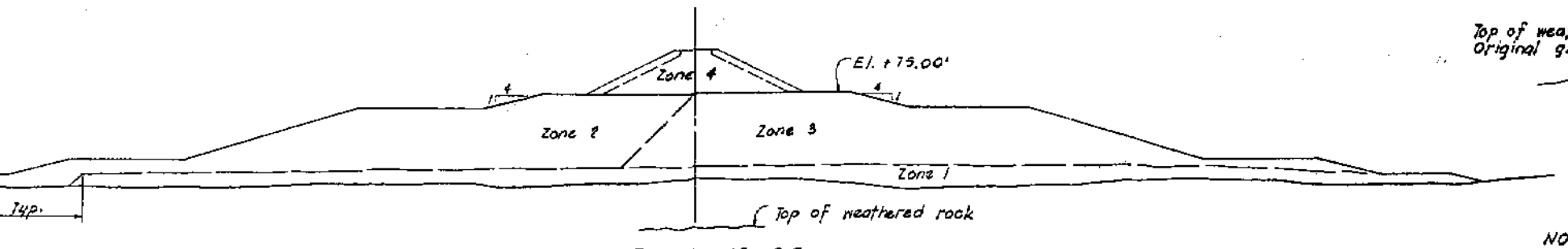
STATION 16+00



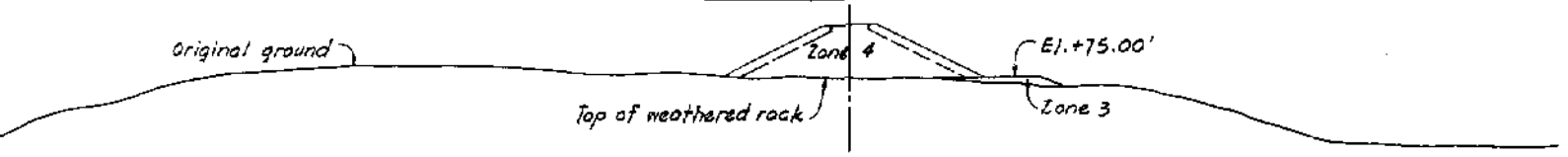
STATION 7+00



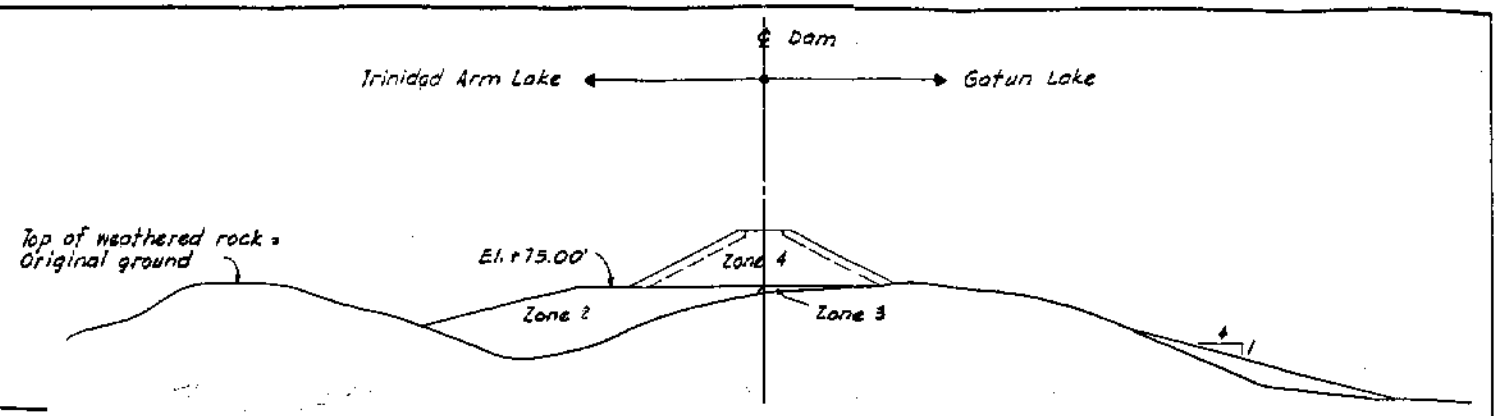
STATION 25+00
Typical From Station 8+50 to Station 45+00



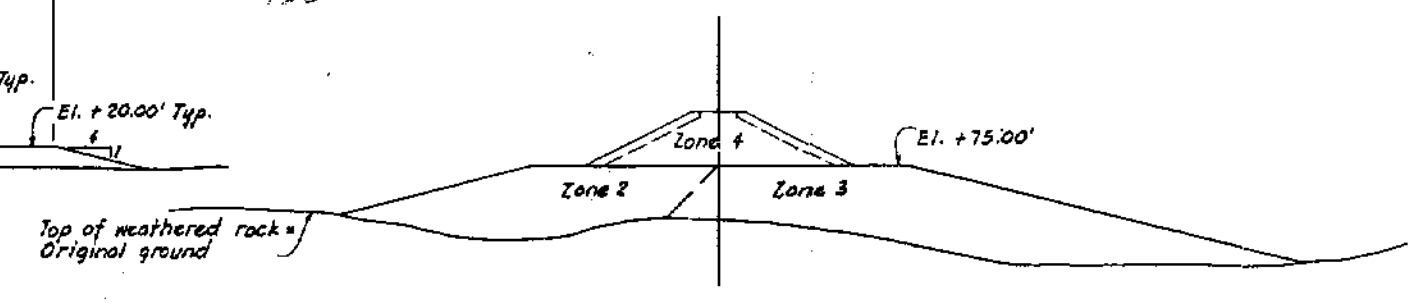
STATION 45+00



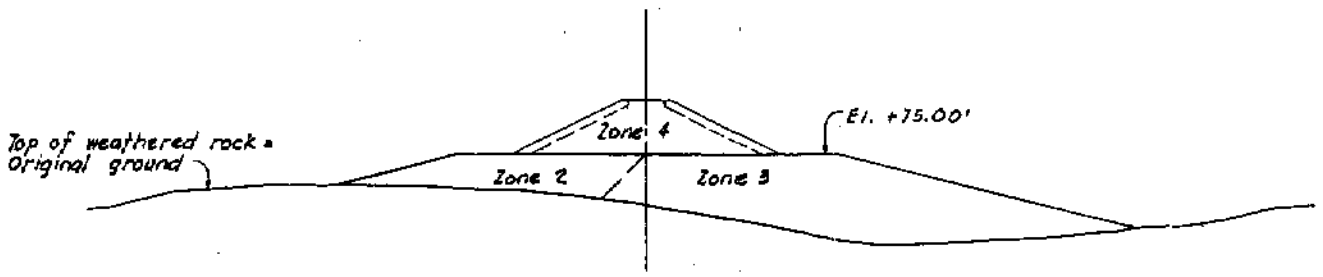
STATION 50+00
Scale : 1" = 50'



STATION 51+50



STATION 53+75



STATION 55+00
Scale : 1" = 50'

NOTES :
1. Zone 1 - Mat, 8" minus material, screened and/or crushed.
   Zone 2 - Random material 30 to 50% minus 6" by visual classification
   Zone 3 - Random material.
2. All berm elevations are those expected after completion of the fill to elevation +75.00'
3. Zone 4 & 5 not included in this contract
4. Refer to figures 3-1, 3-2, 3-3 in "Foundation Investigation, Proposed Rock & Earth Fill Embankment Across Trinidad Arm of Gatun Lake" by Shannon and Wilsen, Inc. for geologic sections of foundation, Mainland to Guacha Island.

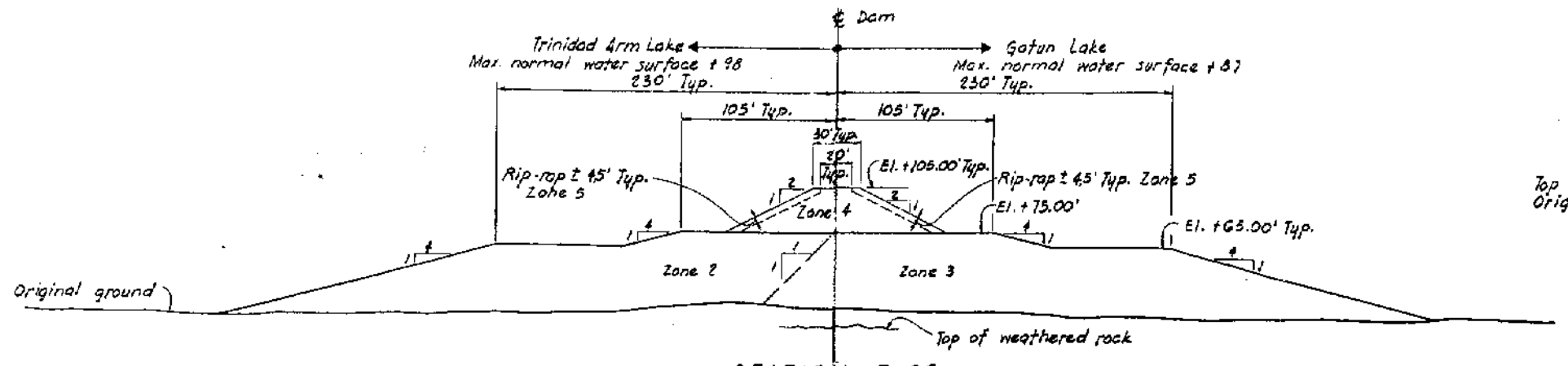
THE PANAMA CANAL COMPANY
BALBOA HEIGHTS, CANAL ZONE

FILL STRUCTURE MAINLAND TO GUACHA ISLAND

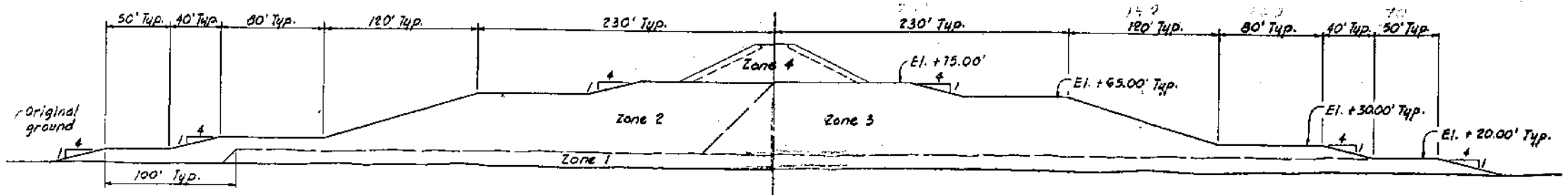
CROSS SECTIONS

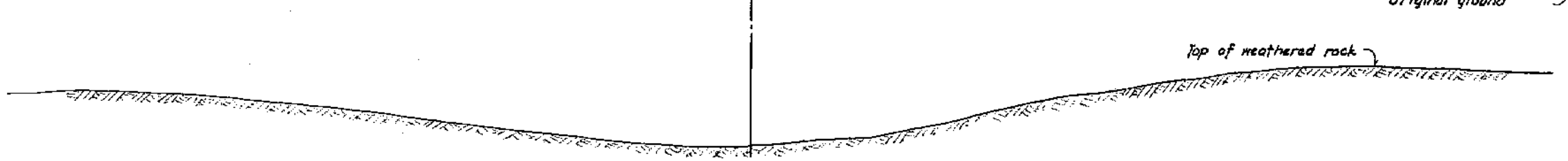
DESIGNED	TUDOR ENGINEERING COMPANY	DRAWING NUMBER
DATE	SAN FRANCISCO, CALIF.	OF

FIGURE NO. 6



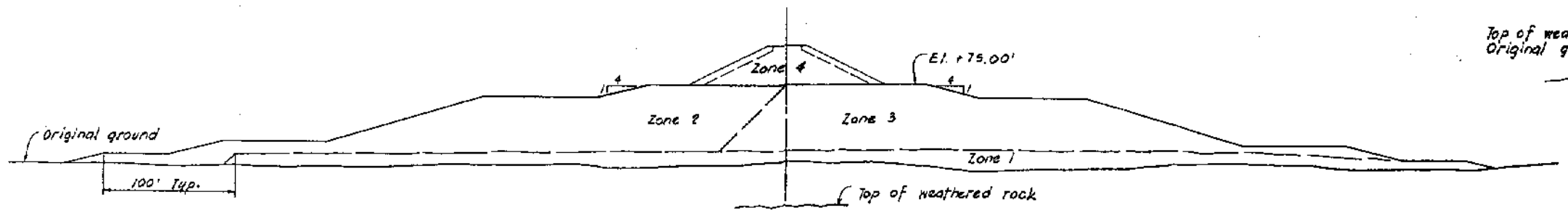
STATION 7+00



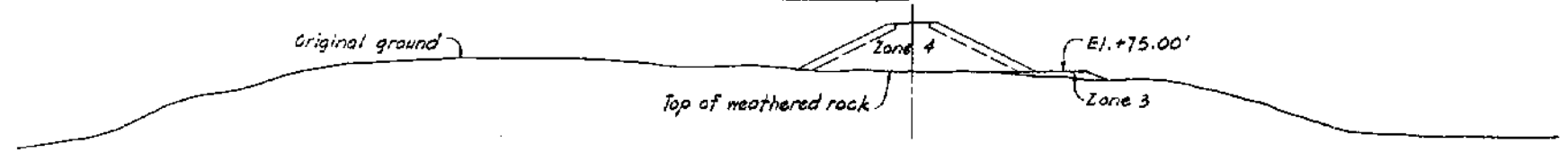


STATION 25+00

Typical From Station 8+50 to Station 45+00

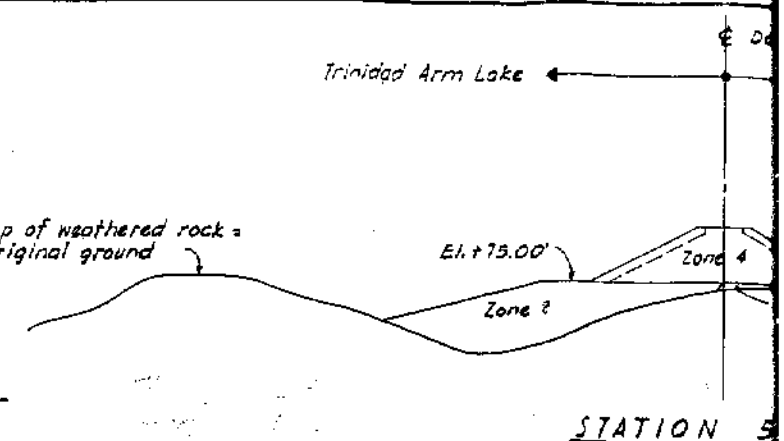


STATION 45+00

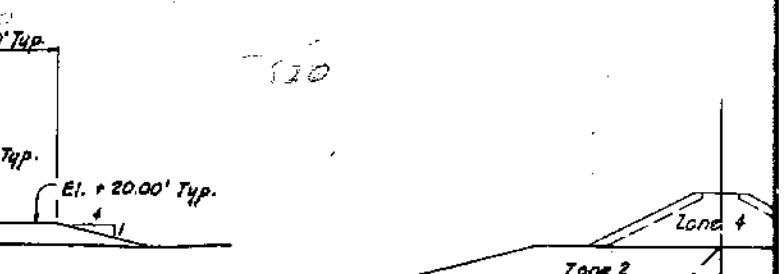


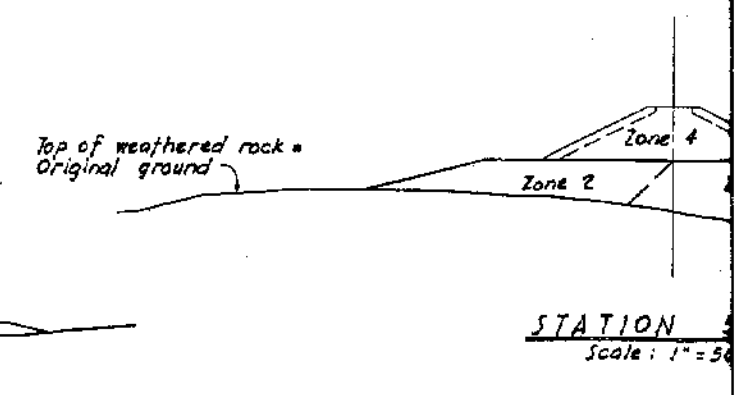
STATION 50+00

Scale : 1" = 50'



STATION 5



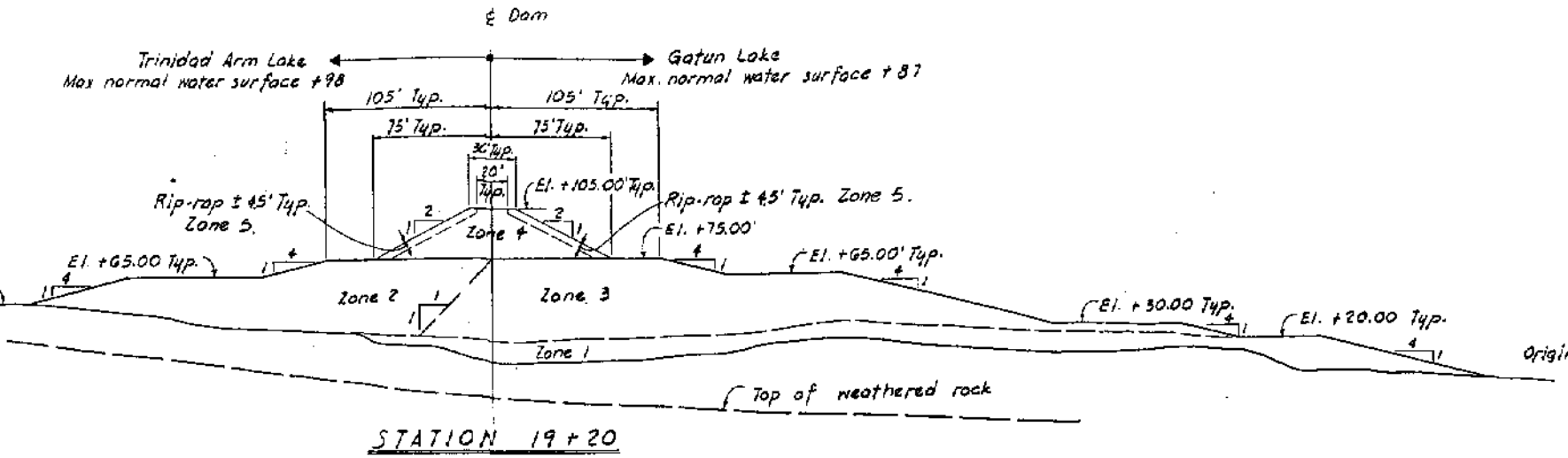


STATION

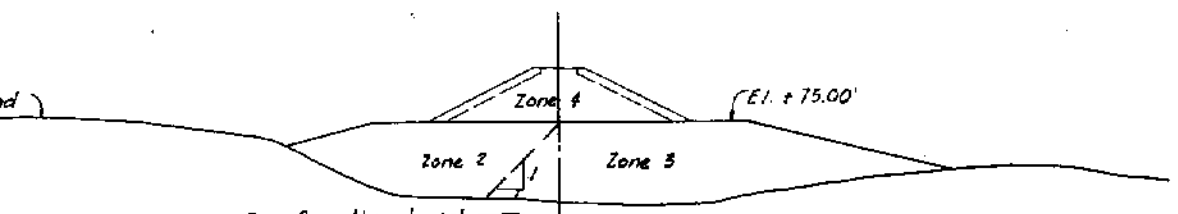
Scale : 1" = 5

NOTES:

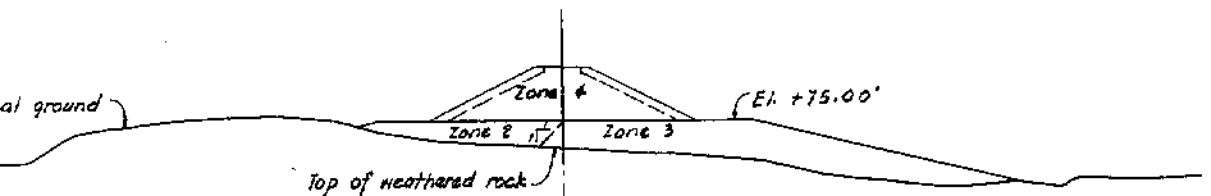
1. Zone 1 - Mat, 8" minus material, screened and/or crushed.
   Zone 2 - Random material 30 to 50% minus 6" by visual classification
   Zone 3 - Random material.
2. All berm elevations are those expected after completion of the fill to elevation' +75.00'
3. Zone 4 & 5 not included in this contract
4. Refer to figures 3-1, 3-2, 3-3 in "Foundation Investigat Proposed Rock & Earth Fill Embankment Across Trini Arm of Gatun Lake" by Shannon and Wilson, Inc. f geologic sections of foundation, Mainland to Guach Island.



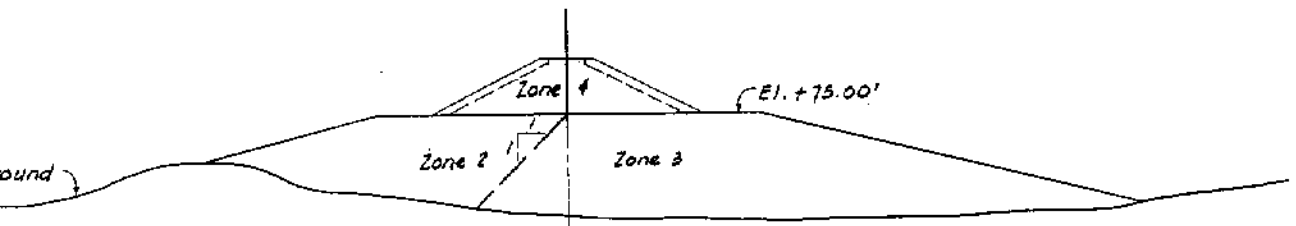
STATION 19+20



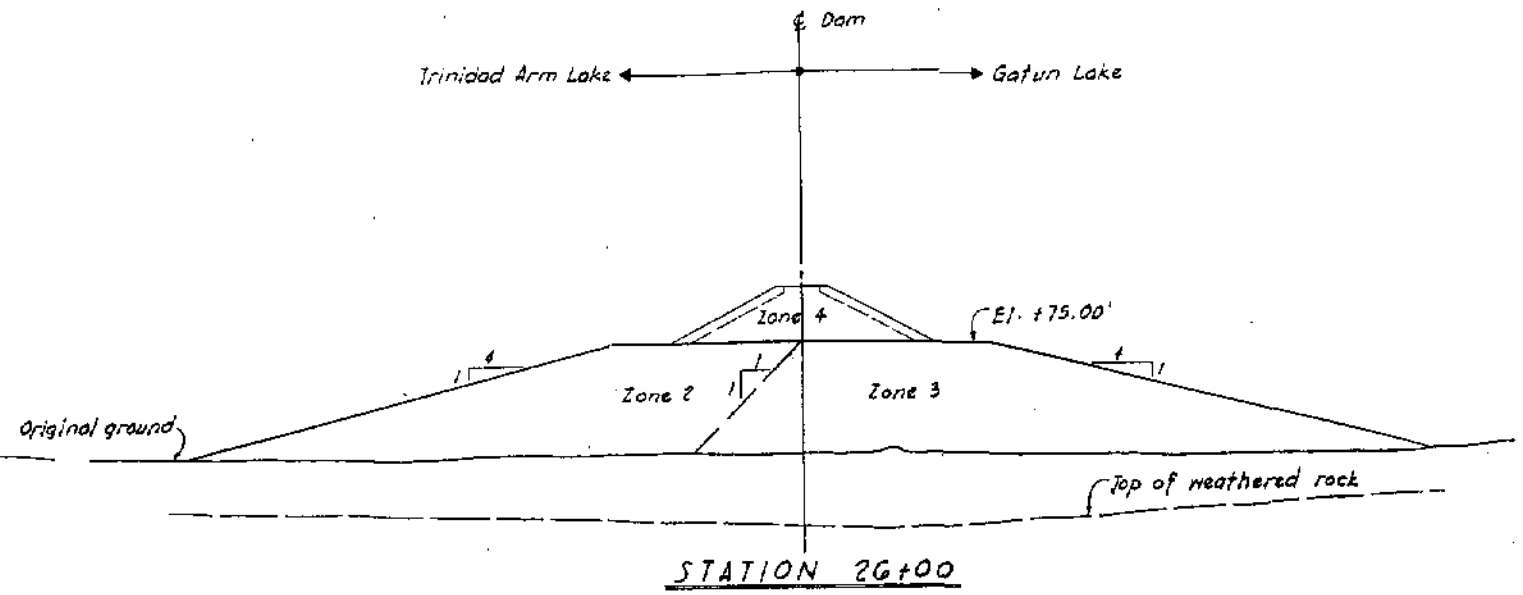
STATION 21+00



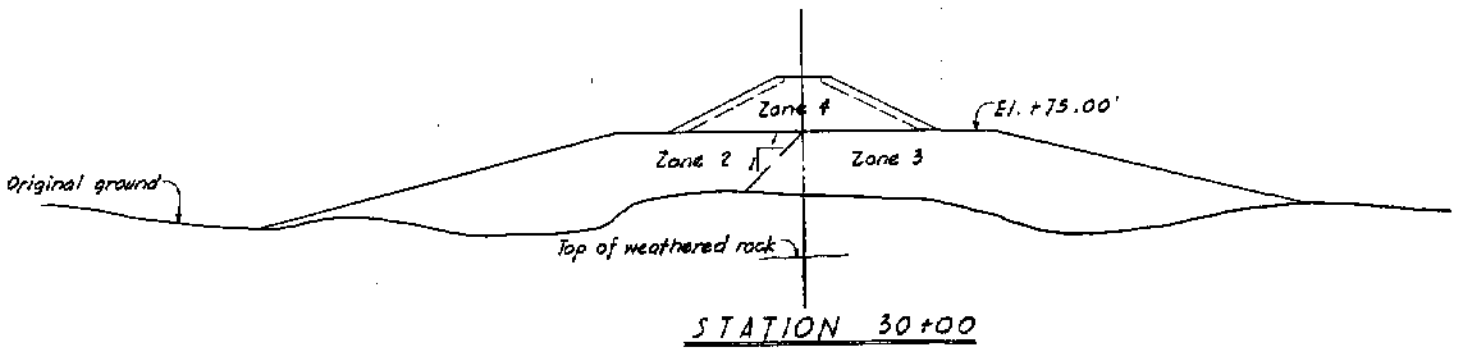
STATION 22+00



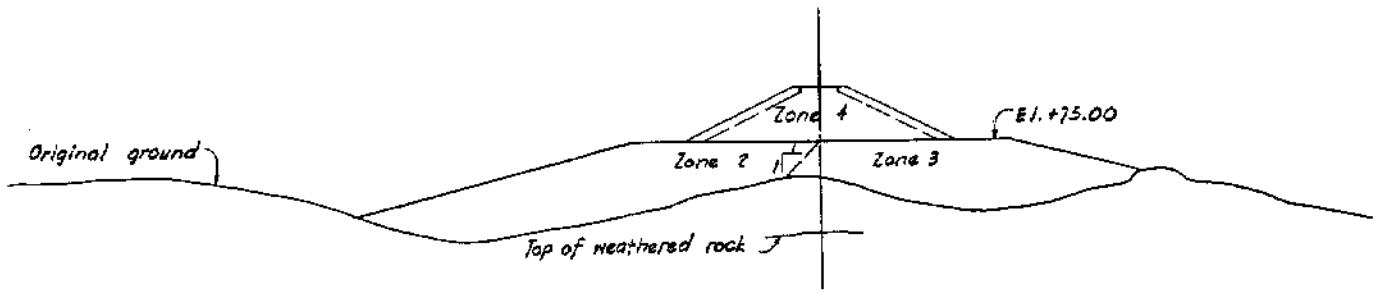
STATION 24+00
Scale : 1" = 50'



STATION 26+00



STATION 30+00



STATION 32+00
Scale : 1" = 50'

NOTES :
1. All berm elevations are those expected after completion of the fill to elevation +75.00'
2. Zone 4 & 5 not included in this contract.
3. Zone 1 - Mat, 8" minus material, screened and/or crushed.
   Zone 2 - Random material 30 to 50% minus 6" by visual classification.
   Zone 3 - Random material.

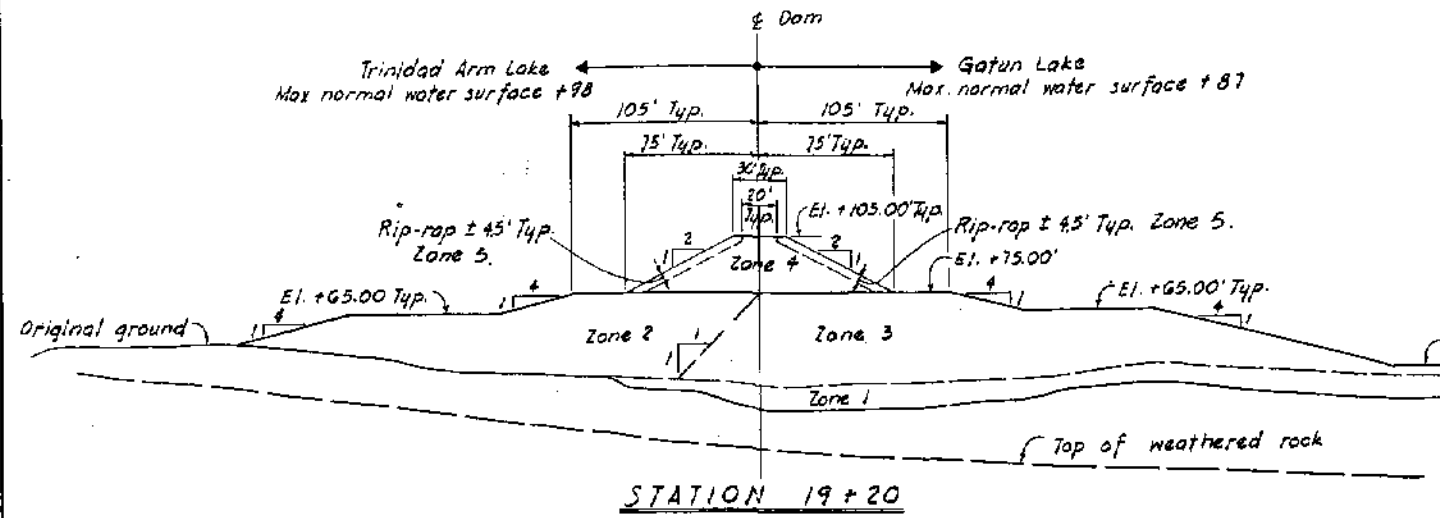
THE PANAMA CANAL COMPANY
BALBOA HEIGHTS, CANAL ZONE

FILL STRUCTURE GUACHA ISLAND TO TERN ISLAND

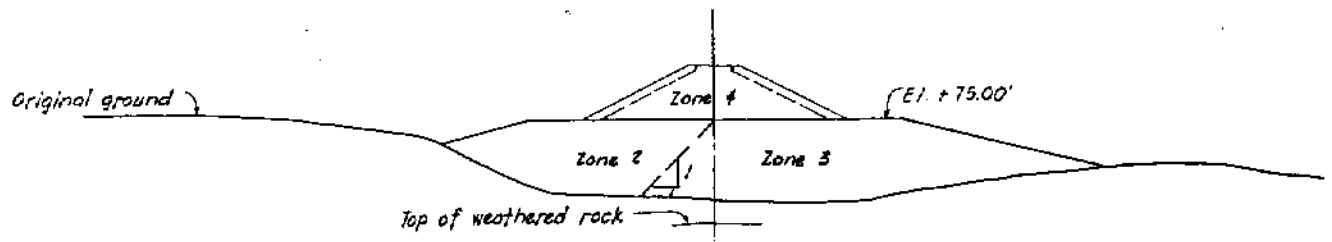
CROSS SECTIONS

DESIGNED	TUDOR ENGINEERING COMPANY	DRAWING NUMBER
DATE	SAN FRANCISCO, CALIF	OF

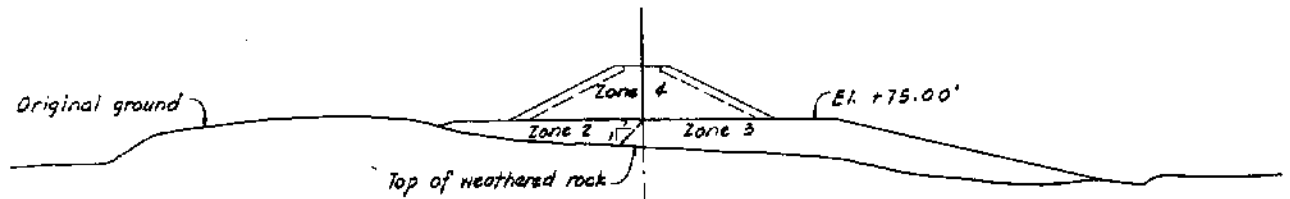
FIGURE NO. 9



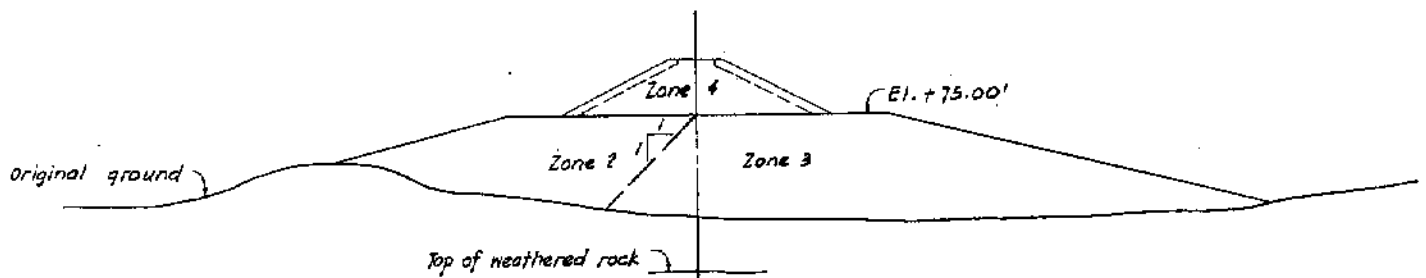
STATION 19+20



STATION 21+00

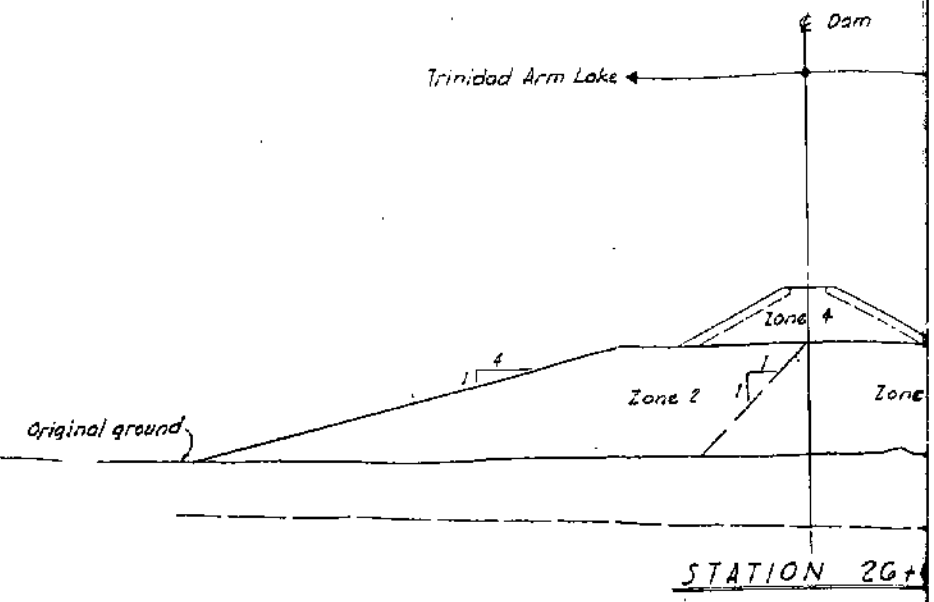


STATION 22+00

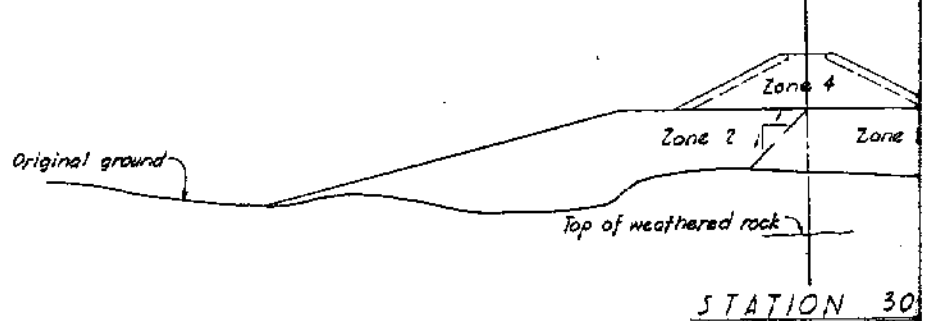


STATION 24+00

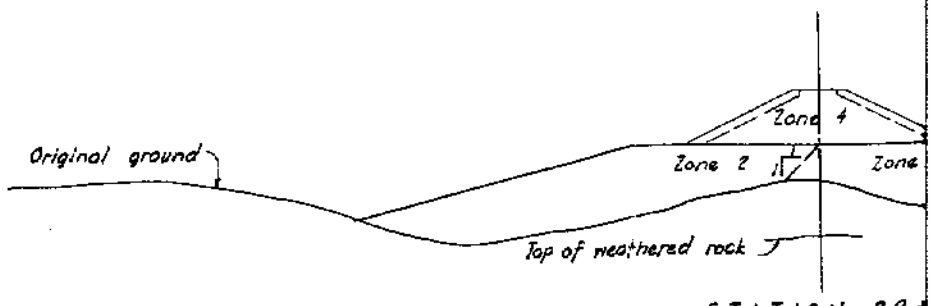
Scale : 1" = 50'



STATION 26+



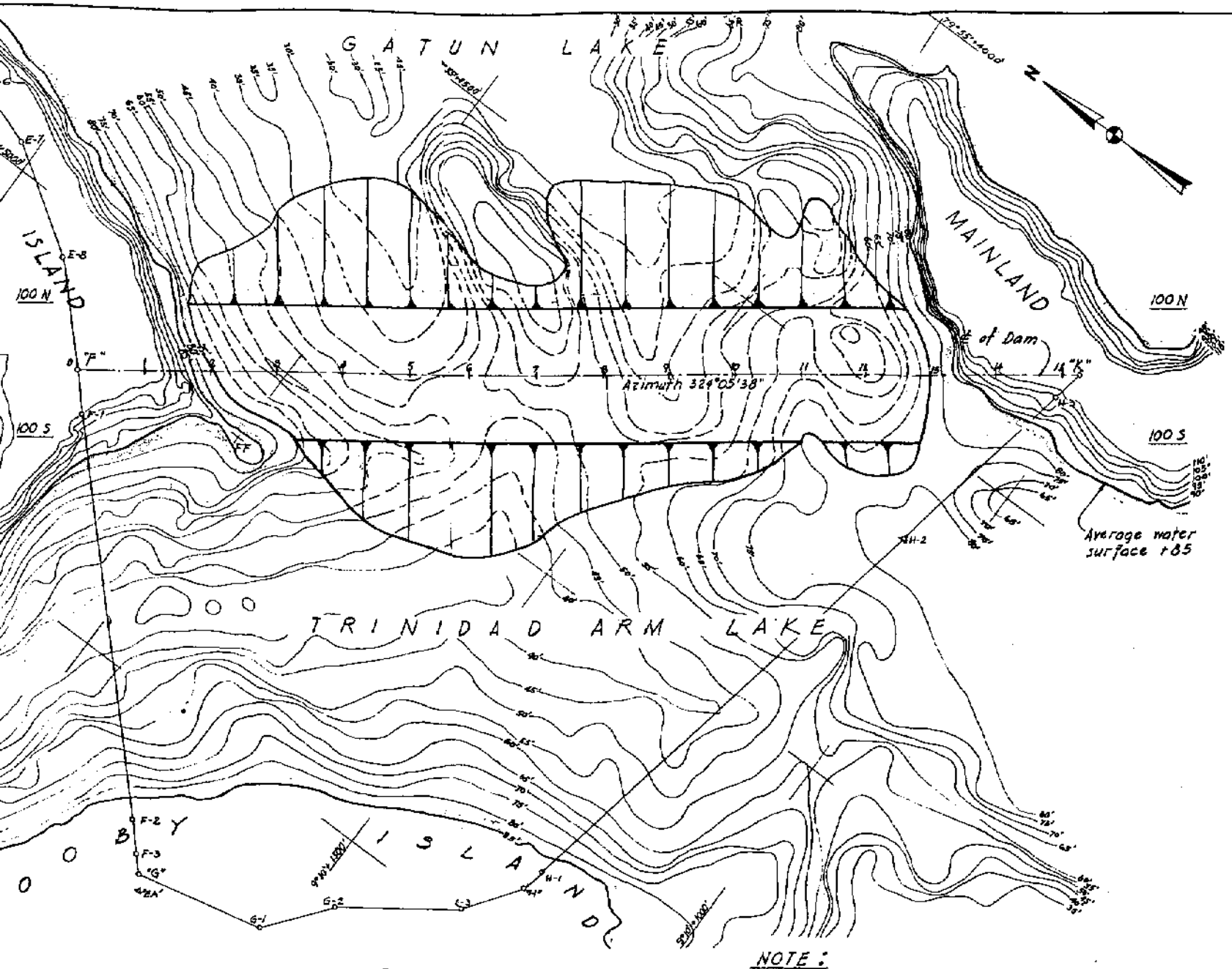
STATION 30



STATION 32+

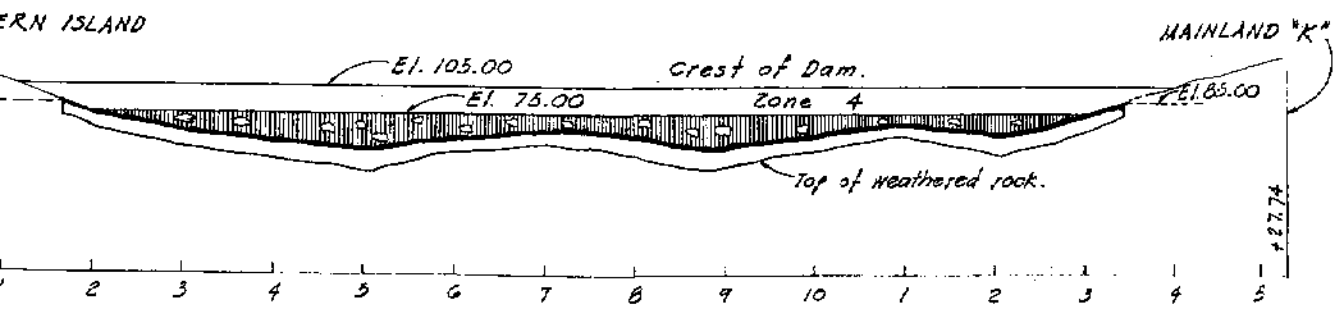
Scale : 1" = 50'

NOTES :
1. All berm elevations are those expected after completion of the fill to elevation +75.00'
2. Zone 4 & 5 not included in this contract.
3. Zone 1 - Mat, 8" minus material, screened and/or crushed.
   Zone 2 - Random material 30 to 50% minus 6" by visual classification.
   Zone 3 - Random material.

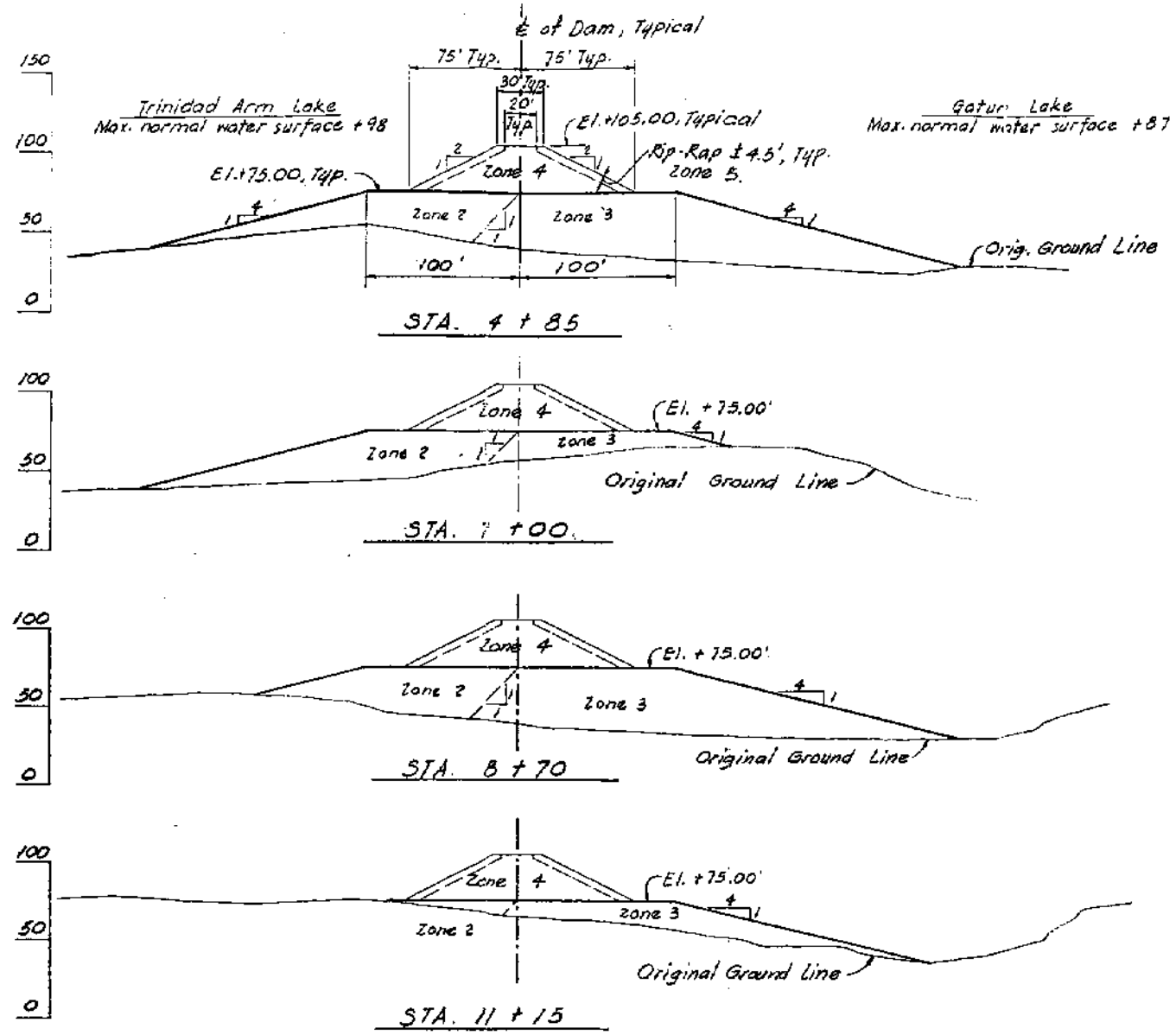


PLAN
Scale: 1" = 100'

NOTE:
This map reduced from scale 1:1000 DWG. No. X G21-20B, Prepared by Panama Canal Company.



PROFILE
Scale: 1" = 100'



TYPICAL CROSS SECTIONS
Scale: 1" = 50'

NOTES:
1. All berm elevations are those expected after completion of the fill to elevation +75.0.
2. Zone 4 is not included in this contract.
3. Zone 1 - Mat, 8" minus material, screened and/or crushed.
   Zone 2 - Random material, 30 to 50% minus 6" visual classification.
   Zone 3 - Random material.

LEGEND:

Dumped Fill. (Zones 2 & 3)

Recent Lake Deposits: Silt, clay, soft Overburden aver. thickness 3 feet.

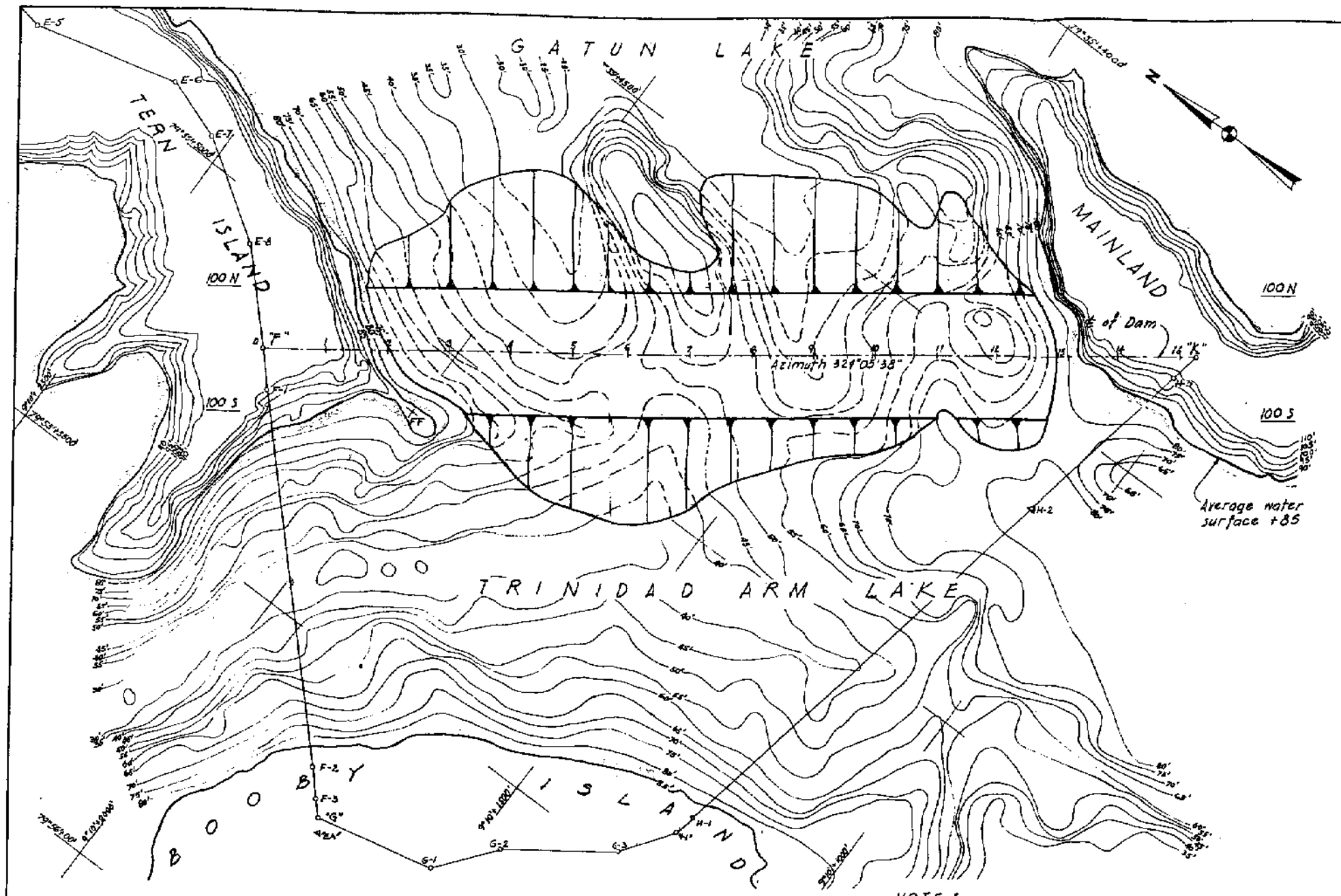
THE PANAMA CANAL COMPANY
BALBOA HEIGHTS, CANAL ZONE

FILL STRUCTURE TERN ISLAND TO MAINLAND

PLAN & SECTIONS

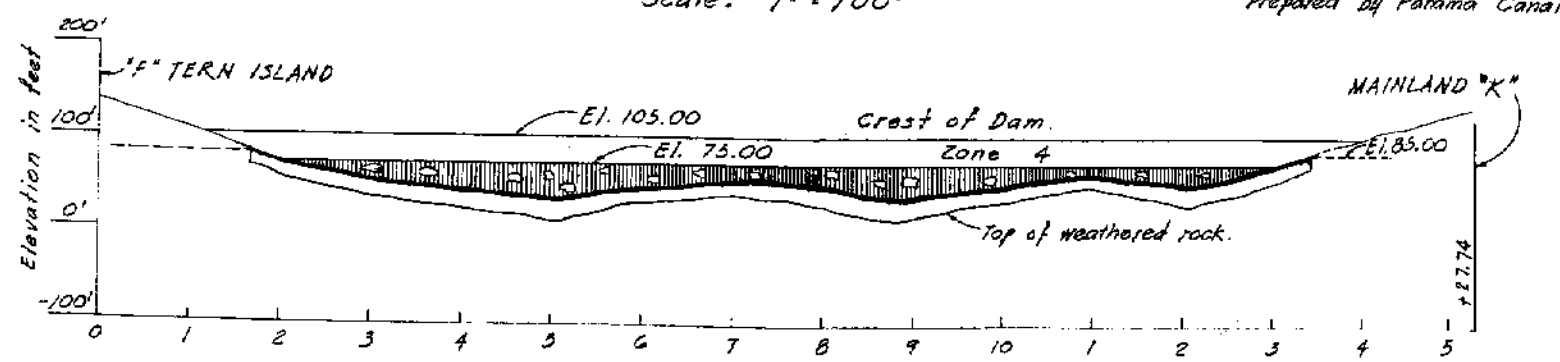
DESIGNED	TUDOR ENGINEERING COMPANY	DRAWING NUMBER
DATE	SAN FRANCISCO, CALIF.	OF

FIGURE NO. 10

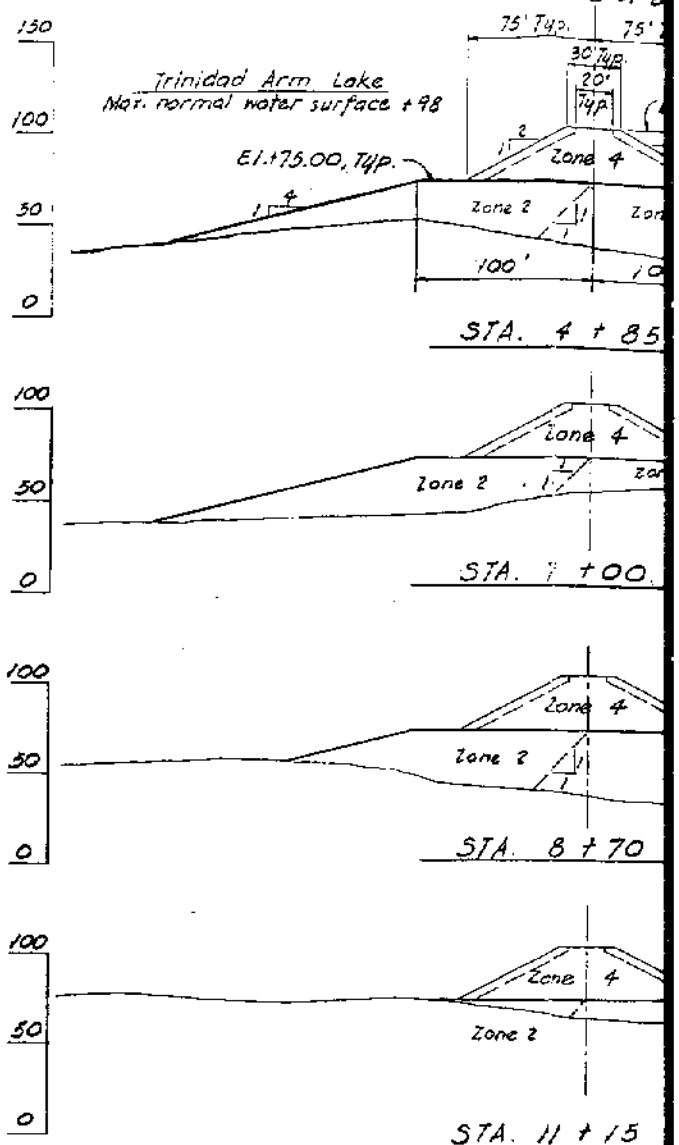


PLAN
Scale: 1" = 100'

NOTE:
This map reduced from scale 1:1000 DWG. No. X G21 - 20B, Prepared by Panama Canal Company.



PROFILE
Scale: 1" = 100'



TYPICAL CROSS
Scale: 1" = 5

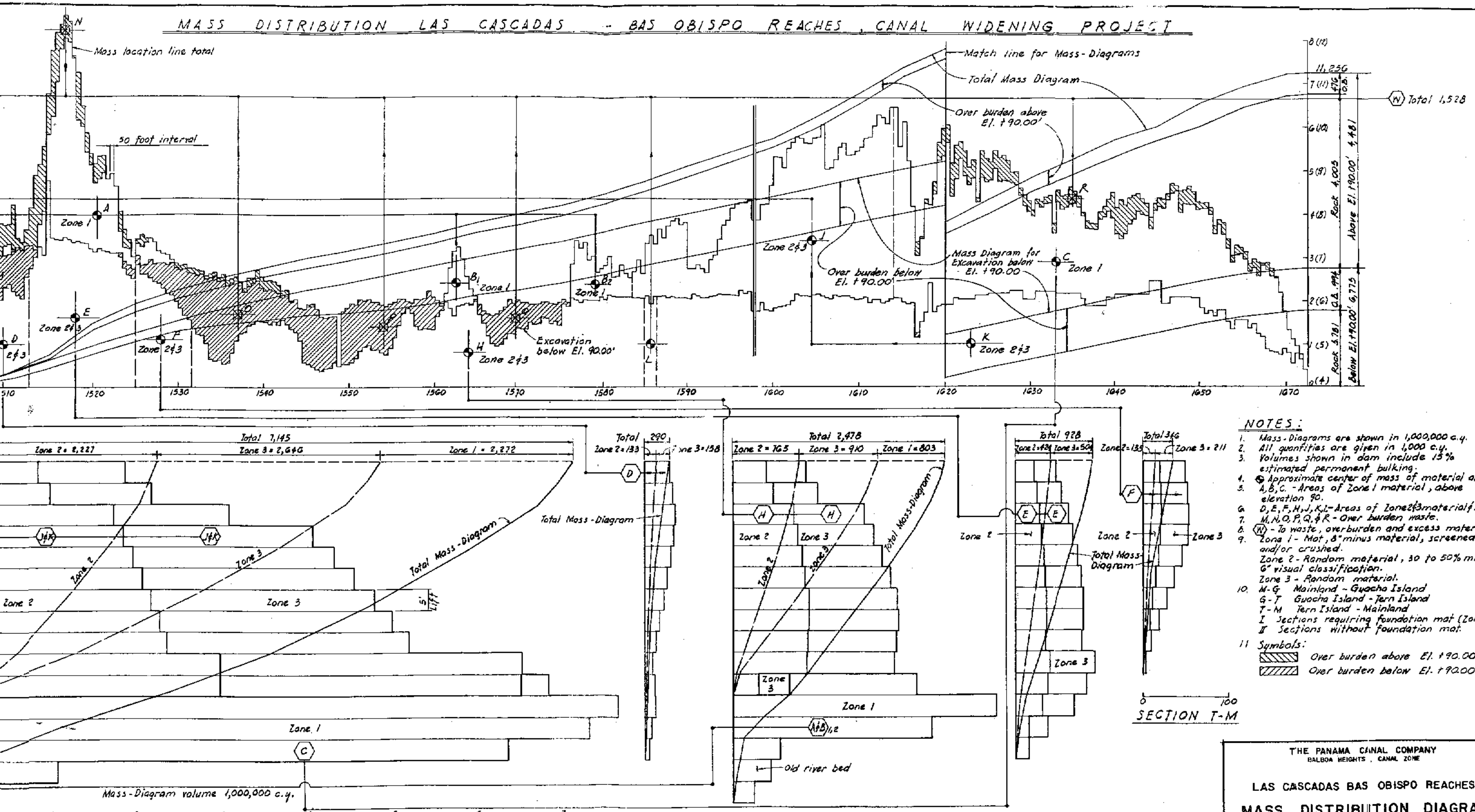
NOTES:
1. All berm elevation
compltion of the
2. Zone 4 & 5 not includ
3. Zone 1 - Mat, 6" m
and/or crushed.
Zone 2 - Random,
6" risua, classifica
Zone 3 - Random

LEGEND:

Dumped Fill. (Zones 2 & 3)

Recent Lake Deposits: Silt, Clay, soft Overburden aver. thickness 3 feet.

MASS DISTRIBUTION LAS CASCADAS – BAS OBISPO REACHES, CANAL WIDENING PROJECT



SECTION M-G/I

SECTION M-G/II

SECTION G-T/I

SECTION G-T/II

SECTION T-M

NOTES:

1. Mass-Diagrams are shown in 1,000,000 c.y.
2. All quantities are given in 1,000 c.y.
3. Volumes shown in dam include 15% estimated permanent bulking.
4. ⊕ Approximate center of mass of material areas.
5. A, B, C. - Areas of Zone 1 material, above elevation 90.
6. D, E, F, H, J, K, L - Areas of Zone 2&3 material of waste.
7. M, N, O, P, Q, & R - Over burden waste.
8. (W) - To waste, overburden and excess material.
9. Zone 1 - Mat, 8" minus material, screened and/or crushed.
   Zone 2 - Random material, 30 to 50% minus 6" visual classification.
   Zone 3 - Random material.
10. M-G Mainland - Gaucha Island
    G-T Gaucha Island - Tern Island
    T-M Tern Island - Mainland
    I Sections requiring foundation mat (Zone 1)
    II Sections without foundation mat.
11. Symbols:
    Over burden above El. +90.00'
    Over burden below El. +90.00'.

THE PANAMA CANAL COMPANY
BALBOA HEIGHTS, CANAL ZONE

LAS CASCADAS BAS OBISPO REACHES

MASS DISTRIBUTION DIAGRAM

DESIGNED	TUDOR ENGINEERING COMPANY SAN FRANCISCO, CALIF.	DRAWING NUMBER
DATE		OF

FIGURE NO. 11

MASS DISTRIBUTION – DAM FILL SECTIONS

MASS DISTRIBUTION LAS CASCADAS - BAS OBISPO REACHES, CANAL WIDENING PROJECT

Excavation in 1,000 c.y. for 50 foot intervals

Mass location line total

50 foot interval

Match line for Mass-Diagrams

Total Mass Diagram

Over burden above El. +90.00'

Mass Diagram for Excavation below - El. +90.00

Over burden below El. +90.00'

Excavation below El. 90.00'

Zone 1

Zone 2&3

Elevation - ft.

Total 7,145 — Zone 1 = 2,272 — Zone 2 = 2,227 — Zone 3 = 2,646

Total Mass-Diagram

5' Lift

Mass-Diagram volume 1,000,000 c.y.

Volume per 5' lift 1,000 c.y.

SECTION M-G/I

Total 290 — Zone 2=133 — Zone 3=158

SECTION M-G/II

Total 2,478 — Zone 1=803 — Zone 2=1065 — Zone 3=910

Old river bed

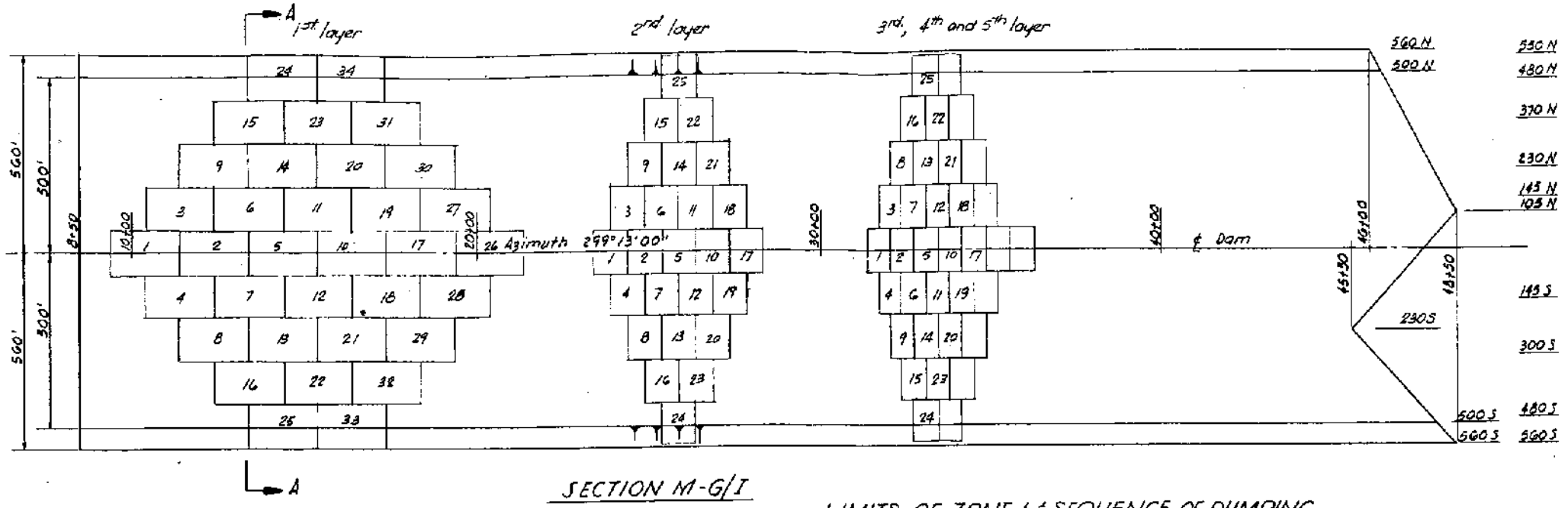
SECTION G-T/II

Total 928 — Zone 2=424 — Zone 3=504

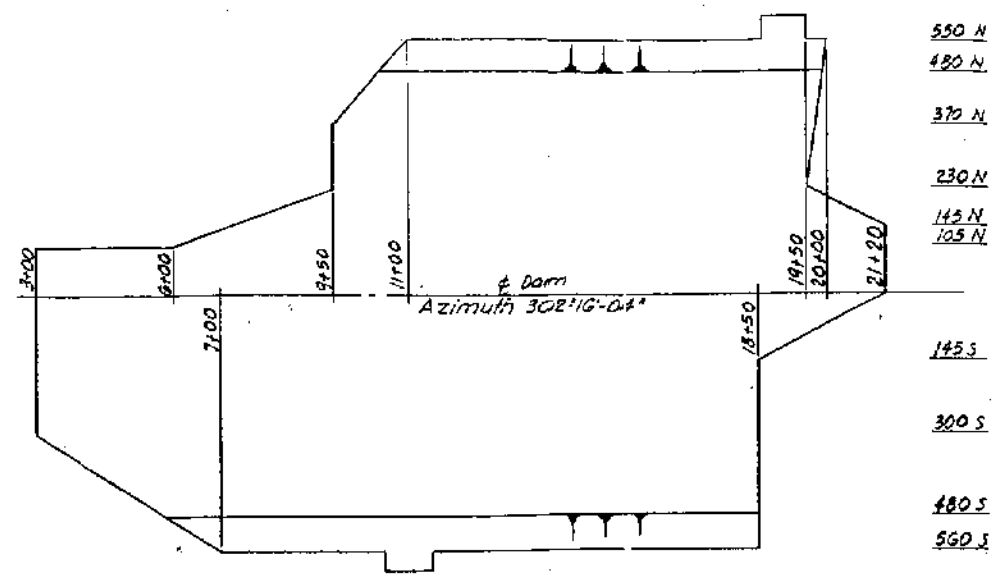
Total 346 — Zone 2=135

SECTION

MASS DISTRIBUTION — DAM FILL SECTIONS



SECTION M-G/I



SECTION G-T/I

LIMITS OF ZONE I & SEQUENCE OF DUMPING

scale 1" = 200'

...TION	CANAL WIDENING AREA	DAM SECTION	DAM ZONE	QUANTITIES (1000 C.Y.)
...the Crushing	A			
...erburden	M,N,O.			910
...d Placing	A, B_1, B_2	G-T/I	1	698
...n of the ...nt.	C			
...verburden.	R			248
...nd Placing	C	M-G/I	1	1976
...nd Placing	D,E,F	M-G/II G-T/II T-M	2, 3	1360
...verburden	P, Q			312
...nd Placing	H	G-T/I	2,3	1,457
...and Placing	J			1,332
...nd Placing	K	M-G/I	2,3	2905
...nd Removal	L		Sur-plus	58
...NNEL EXCAVATION				11,256
Overburden				1,470
Zone 1				2,674
Zones 2 and 3				7,054
Surplus				58

MONTHLY SEQUENCE

1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25 26 27 28 29 30 31 32 33 34 35 36 37 38 39 40 41 42 43 44 45 46 47 48 49 50 51 52 53 54

NOTES: 1. DAM SECTIONS:
M-G = Mainland - Guacha Island
G-T = Guacha Island - Tern Island
T-M = Tern Island - Mainland
I = Sections requiring Foundation Mat (Zone 1)
II = Sections not requiring Foundation Mat.

2. DAM ZONES:
Zone 1 - Mat; 8" minus material screened and or crushed.
Zone 2 - Random material; 30 to 50 % minus 6" by visual classification.
Zone 3 - Random material;

3. Place Zone 1 material in each area so that entire area is covered by single 5' or less mat before placing next layer of material.

4. As far as is practical, place Zone 2 and 3 materials in the same manner as Zone 1 material.

5. All quantities expressed as unexcavated amounts from Canal widening areas.

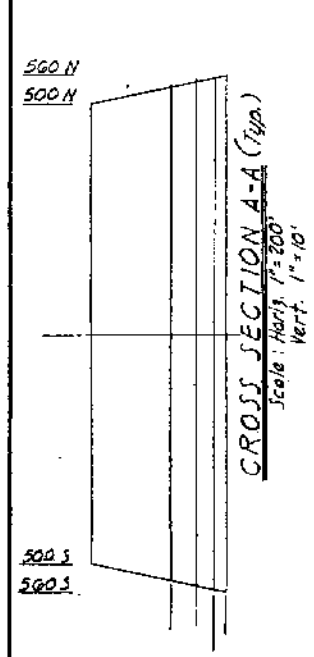
THE PANAMA CANAL COMPANY
BALBOA HEIGHTS, CANAL ZONE

DAM ACROSS TRINIDAD ARM OF GATUN LAKE

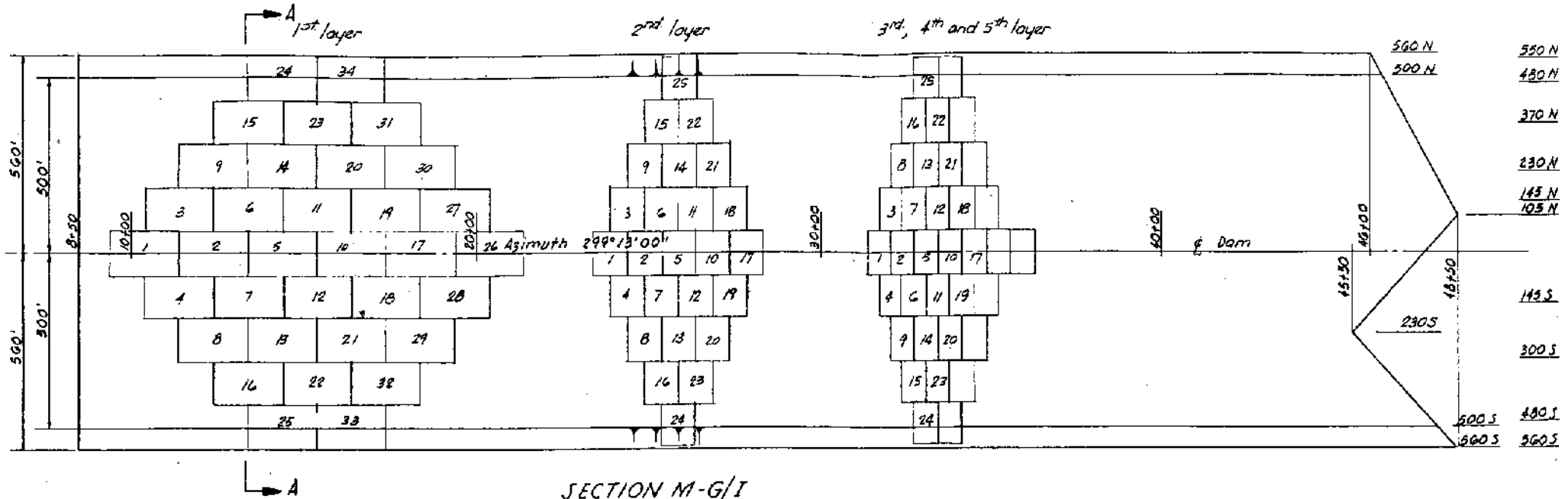
CONSTRUCTION SCHEDULE

DESIGNED	TUDOR ENGINEERING COMPANY SAN FRANCISCO, CALIF.	DRAWING NUMBER
DATE		OF

FIGURE NO. 12



CROSS SECTION A-A (Typ.)
Scale: Horiz. 1"=200'
Vert. 1"=10'



SECTION M-G/I

SECTION

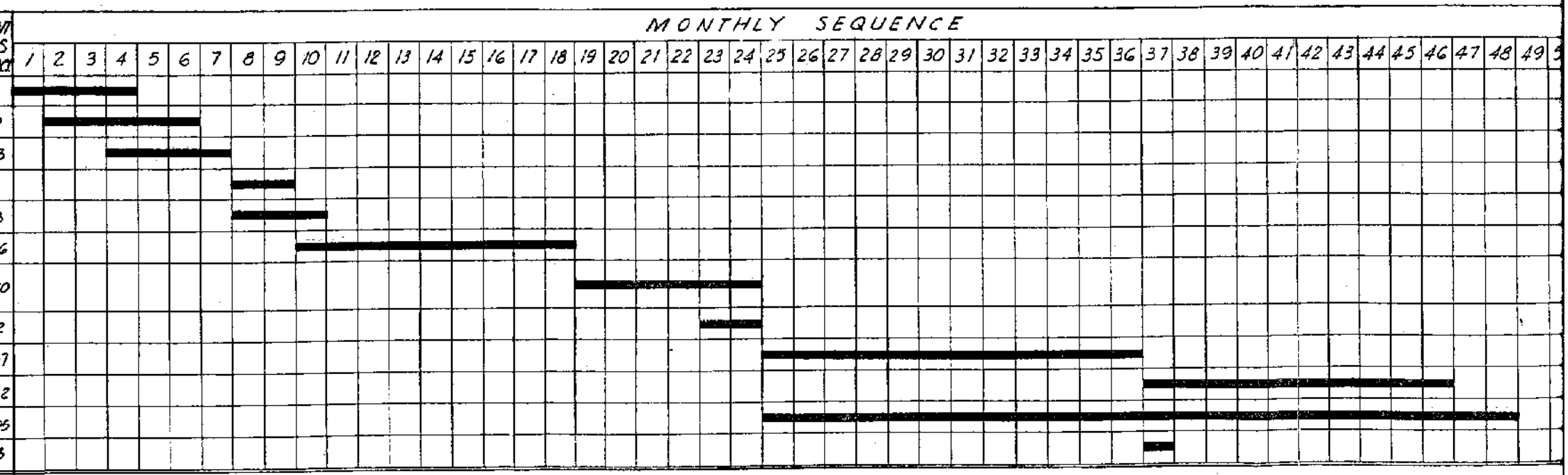
LIMITS OF ZONE I & SEQUENCE OF DUMPING

Scale 1"=200'

NO.	DESCRIPTION	CANAL WIDENING AREA	DAM SECTION	DAM ZONE	QUANTITIES (000CY)
1	Installation of the Crushing Plant	A			
2	Removal of Overburden	M,N,O.			910
3	Excavation and Placing	A,B,Be	G-T/I	1	698
4	Reinstallation of the Crushing Plant.	C			
5	Removal of Overburden.	R			248
6	Excavation and Placing	C	M-G/I	1	1976
7	Excavation and Placing	D,E,F	M-G/II G-T/II T-M	2, 3	1360
8	Removal of Overburden	P, Q			312
9	Excavation and Placing	H	G-T/I	2,3	1,457
10	Excavation and Placing	J			1,332
11	Excavation and Placing	K	M-G/I	2,3	2,905
12	Excavation and Removal	L		Sur-plus	58
	TOTAL CHANNEL EXCAVATION				11,256

SUBTOTALS:		
	Overburden	1,470
	Zone 1	2,674
	Zones 2 and 3	7,054
	Surplus	58

MONTHLY SEQUENCE



NOTES:

1. DAM SECTIONS:
   M-G = Mainland - Guacha Island
   G-T = Guacha Island - Tern Island
   T-M = Tern Island - Mainland
   I = Sections requiring Foundation Mat (Zone 1)
   II = Sections not requiring Foundation Mat.
2. DAM ZONES:
   Zone 1 - Mat; 8" minus material screened and or crushed.
   Zone 2 - Random material; 90 to 50 %, minus 6" by visual classification.
   Zone 3 - Random material;
3. Place Zone 1 material in each area so that entire area is covered by single 5' or less mat before placing next layer of material.
4. As far as is practical, place Zone 2 and 3 materials in the same manner as Zone 1 material.
5. All quantities expressed as unexcavated amounts from Canal widening areas.

APPENDIX A

site was generally about 70 feet. The borings were advanced into the foundation materials to depths of as much as 176 feet below lake bottom. Several hundred large diameter, undisturbed soil samples were recovered from the borings. Most of the samples were examined and tested in a field laboratory set up for the project at Gatun. A substantial percentage of the samples was shipped via airfreight to Seattle for detailed testing and analysis.

The foundation material found to underlie the site of the proposed Dam consists predominantly of normally consolidated organic clay interbedded with layers and seams of fibrous peat. The clay and peat materials comprise the principal constituents of the Atlantic Muck formation. This formation exists over most of the site and forms a thick mantle of sediments over more competent residual soil and bedrock materials. These sediments are relatively weak and highly compressible and they will, consequently, be a major factor in the stability and settlement of the proposed Dam.

The thickness and extent of the Atlantic Muck formation is controlled by the erosional surface upon which it was deposited. The Atlantic Muck formation was not detected in this foundation investigation above approximately elevation +15 feet (P.L.D.).

Within the site area, the thickest section of Atlantic Muck was encountered at station 25+00 on the Axis and at station 25+00 on grid line "C", 1000 feet upstream. Borings at these locations intersected the old meandering stream channel which generally trends in a northerly direction, more or less perpendicular to the axis of the proposed damsite. The maximum thickness of Atlantic Muck along this channel is 160 feet. Since the original valley was "V-shaped," thicknesses of the Muck decrease in both directions from station 25+00 along the Axis.

All materials of the Atlantic Muck formation are mantled by a layer of peat varying in thickness from one to ten feet. The peat is nearly liquid to very soft, decayed to semi-decayed, and somewhat fibrous. Often the peat is clayey and interbedded with lenses of very soft organic clay.

SUMMARY OF SHANNON & WILSON, INC. REPORT ON

FOUNDATION INVESTIGATION PROPOSED ROCK AND EARTH FILL EMBANKMENT ACROSS TRINIDAD ARM OF GATUN LAKE PANAMA CANAL ZONE

The report presents the results of a foundation investigation conducted at the site of the main section of the earth and rock fill dam proposed to be constructed across the Trinidad Arm of Gatun Lake, near Escobal on the Atlantic side of the Isthmus of Panama. The proposed dam will extend from Punta Mala on the west shore of Gatun Lake to Guacha Island, thence to Tern Island and from Tern Island to the mainland on the east shore of Gatun Lake. The main portion of the Dam at which the foundation investigation was undertaken is that which extends from near Punta Mala to Guacha Island.

The purpose of the foundation investigation was to explore and evaluate the shear strength and consolidation properties of the soft foundation materials in order that an earth and rock fill dam section could be designed with an adequate factor of safety against failure. None of the foundation explorations treated in this report deals with foundations for proposed concrete structures such as locks and spillways.

Three phases of the project investigations, are covered, as follows:

(a) Exploratory borings in the foundation;

(b) Laboratory soil tests on foundation materials;

(c) Engineering review and analysis of laboratory data as related to proposed embankment design.

The field explorations were relatively extensive and involved making 118 borings of various types. The borings were made by barge-mounted drill rigs operating on the surface of Gatun Lake. The lake depth over the

Underlying the top layer of peat is a layer of very soft, light to dark gray, organic clay with numerous pockets of decayed organic material and with occasional pockets of clayey sand, yellow clayey silt, and siltstone nodules. This clay is fairly continuous over the damsite except in the eastern portion of the site where it becomes soft to stiff. It is believed that the zones of stiffer clay are the result of local desiccation of the existing clay beds.

Underlying these clays is a nearly continuous stratum of interbedded peat and clay. The peat is usually firm, fibrous, and generally somewhat clayey. It parts readily along horizontal planes. The constituents of the peat are easily identified as leaves, twigs, stems, vines, and other organic debris and are quite fresh in appearance. The clay layers are very soft to soft, organic, and silty, with pockets, layers, and lenses of peat, and occasionally with sand partings and lenses, and siltstone nodules.

The material underlying the clay and peat is soft to medium organic silty clay which is stratified with sand layers and partings, occasional peat layers and lenses, silt layers and siltstone nodules. This material can be separated into two distinct layers; one soft and one medium. The soft layer grades into medium toward the abutments of the proposed dam.

Underlying the soft to medium clays is a layer of medium sand with interbedded medium organic silty clay and firm fibrous peat materials. The sand is silty and clayey and overlies the sands and gravels of the old river channel.

The channel sands are dense, silty, and clayey and occasionally contain gravel. This sand is the oldest member of the Atlantic Muck formation.

Detailed engineering studies were undertaken to investigate the existing strength of the formation, the rate of gain in shear strength due to consolidation under construction loadings, and the probable settlements at various sections of the Dam. These studies required the use of basic data on fill materials which are planned to be used and on the proposed outline of the final embankment. Such data were developed jointly by the Panama Canal Co., Tudor Engineering Co. and our staff.

Results of the engineering studies indicated that a moderate gain in foundation shear strength will occur, during construction, at shallow depths below the base of the fill. Since values of in-situ shear strength are low, this strength gain becomes significant in designing the dam section.

The settlement studies revealed that substantial settlement will continue for the design life of the Dam and that periodic additions to the rolled-filled portion of the dam, therefore, will probably be required to maintain the design crest elevation.

The report presents the findings on shear strength of the foundation materials in the form of graphs of "Depth vs Shear Strength" for various dates after start of construction. Copies of the graphs, identified as Figures 7-1 through 7-3 are attached. The shear strength curves are based upon concepts incorporating laboratory test results as well as assumptions relating to drainage layer thicknesses and drainage conditions. These curves, therefore, may be at some variance with actual field conditions; however, any deviation will, in our opinion, be on the side of safety. Field measurements during construction to discern variations from assumed conditions are recommended.

Values of shear strength determined in the study do not reflect any consideration of loss in shear strength resulting from material disturbance. The curves are not applicable, therefore, if disturbance or remolding of the foundation materials occurs as a result of uncontrolled barge dumping operations or fill stability failures. To minimize possible foundation disturbance, the recommendation is made that a select fine rock (minus 8 inch) blanket be initially placed over the foundation in the thinnest practicable layers. It is considered of utmost importance to control both materials and procedures used in the recommended initial blanketing phases of embankment construction to reduce, as much as practical, loss in shear strength resulting from foundation disturbance.

The report presents estimates of foundation settlements in the form of a graph entitled "Predicted Foundation Settlements." A copy of this graph, identified as Figure 6-1, is attached.

Large post-construction settlements can be expected to continue, at a decreasing rate, over a long period of time. As time proceeds, variations in the existing foundation and loading conditions will result in substantial differential settlements.

The settlement analyses indicate that differential foundation settlements between the Axis of the dam and the proposed berm at elevation +30, a horizontal distance of approximately 350 feet, will be of the following order of magnitude:

at the end of construction	1 to 3 feet
5 years after construction	3 to 5 feet
20 years after construction	5 to 7 feet
50 years after construction	7 to 10 feet

Along the axis, the anticipated differential settlements will be greater where the compressible stratum thins toward the Guacha Island abutment than those anticipated near the Mainland abutment. The total foundation settlement at station 40+00 is represented approximately by the curve in Figure 6-1 for the compressible stratum 65 feet thick, whereas the settlement at station 48+00 will be practically zero. The difference in settlement over this distance of approximately 800 feet may reach somewhere in the order of 8 feet by the end of construction and as much as 15 feet in 50 years after the dam is constructed. In the areas near station 40+00 and station 35+00, where stiff desiccated clays mantle the thick compressible materials, greater differential settlements may develop. It is believed, however, that the mode and magnitude of such large differential settlements will not impair the performance of the Dam because of its expected high degree of flexibility.

Settlements will require placement of additional rolled fill material at periodic intervals of say five years to maintain the design crest elevation

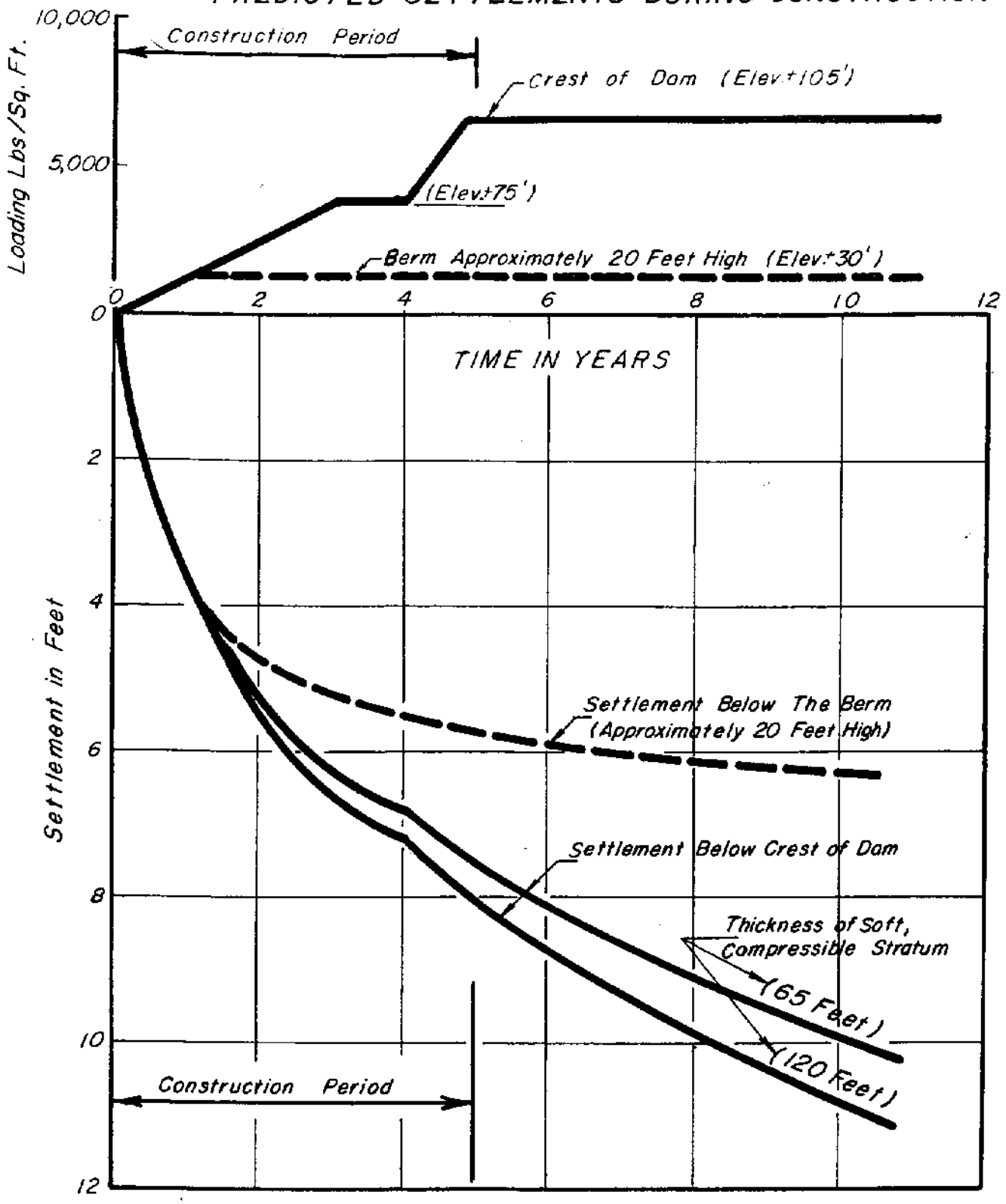
of the dam. The amount of fill material required and the time intervals for placement can be estimated from Figure 6-1. Additional settlements caused by the weight of such added fill material are estimated to be negligible.

It is recognized that, to provide for placing additional fill at the crest to compensate for settlement, provision will have to be made in the design for an initial crest width which is wider than the nominal design width. To provide additional width economically, it would be permissible to steepen the embankment slopes for the upper ten feet of the dam to perhaps a slope of 2 Horiz. to 1 Vert.

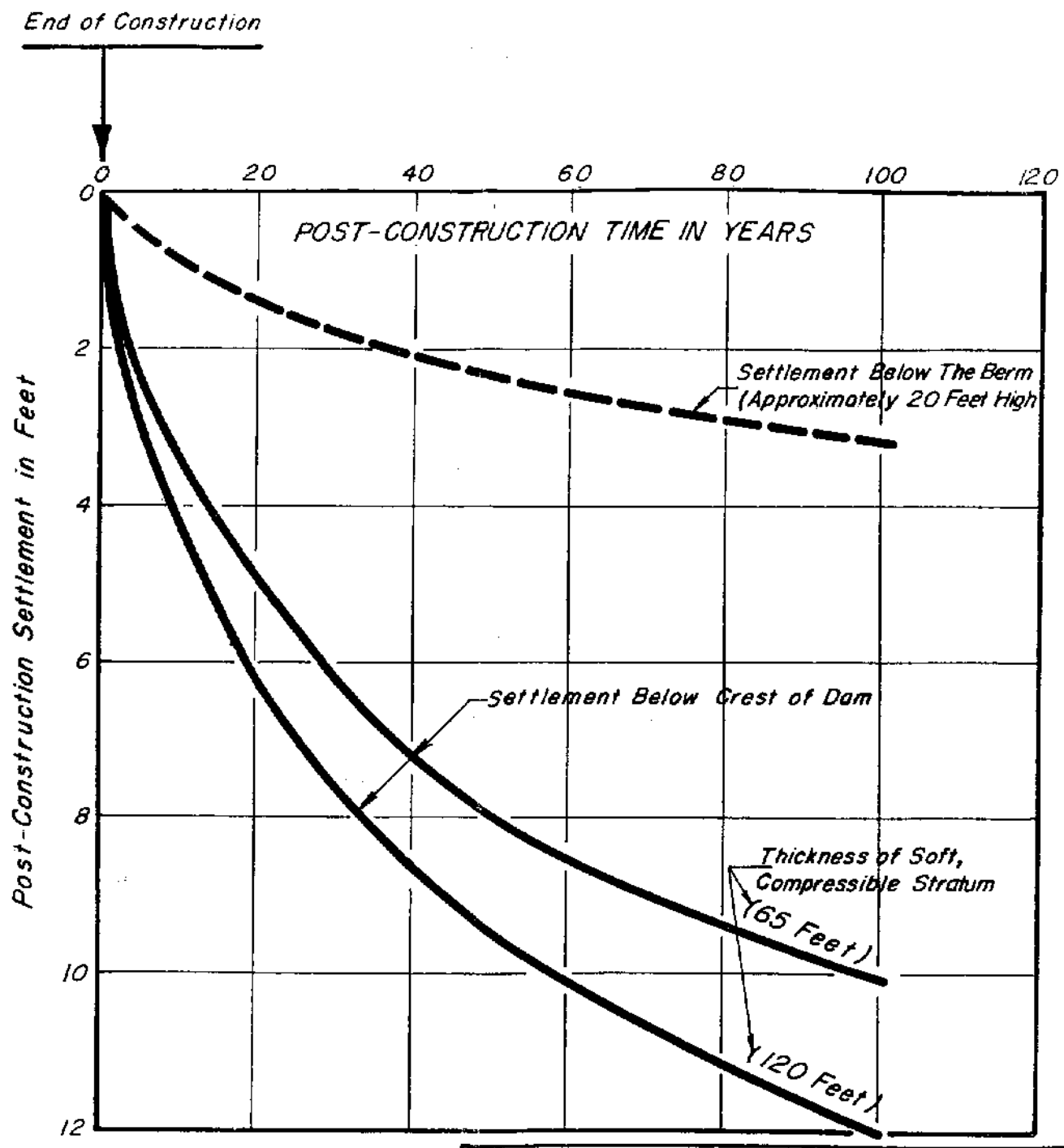
The report concludes with general comments related to the desirability and possible means for checking foundation strength and settlements during construction of the proposed embankment, on the premise that the most critical period for the embankment, stability-wise, will be that time when the embankment will just be topped out at elevation 105. Such attention to performance of the foundation and fill during construction would permit altering the cross-section of the embankment as construction proceeds, where ever justification for such alteration existed.

The report also points out that, from a practical standpoint, considering the sources and significant variations in geologic properties and blast-fracturing of the proposed fill materials, it should be most feasible to check assumed design properties of the materials as the fill construction is in progress. A procedure for making such checks is suggested.

PREDICTED SETTLEMENTS DURING CONSTRUCTION



PREDICTED POST-CONSTRUCTION SETTLEMENTS



PROPOSED DAM - TRINIDAD ARM
GATUN LAKE, PANAMA CANAL ZONE

PREDICTED FOUNDATION SETTLEMENTS

W-62-147
FEBRUARY, 1963

SHANNON & WILSON
SOIL MECHANICS & FOUNDATION ENGINEERS

FIG. 6-1

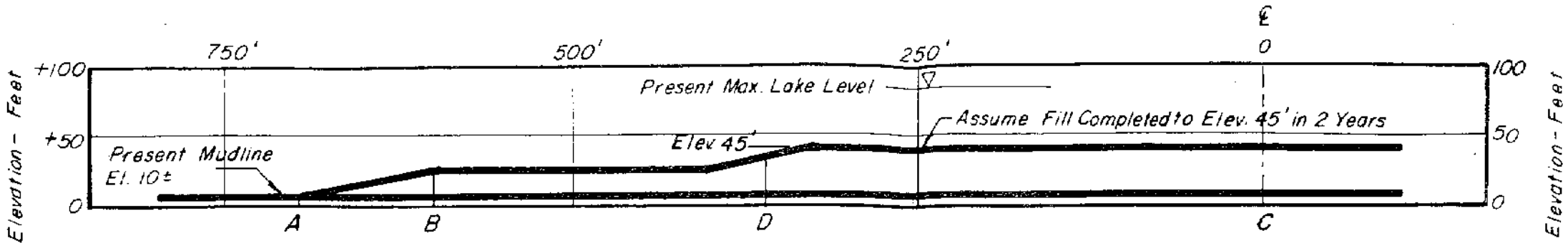


DIAGRAM III

(Shear Strength Between B and D)

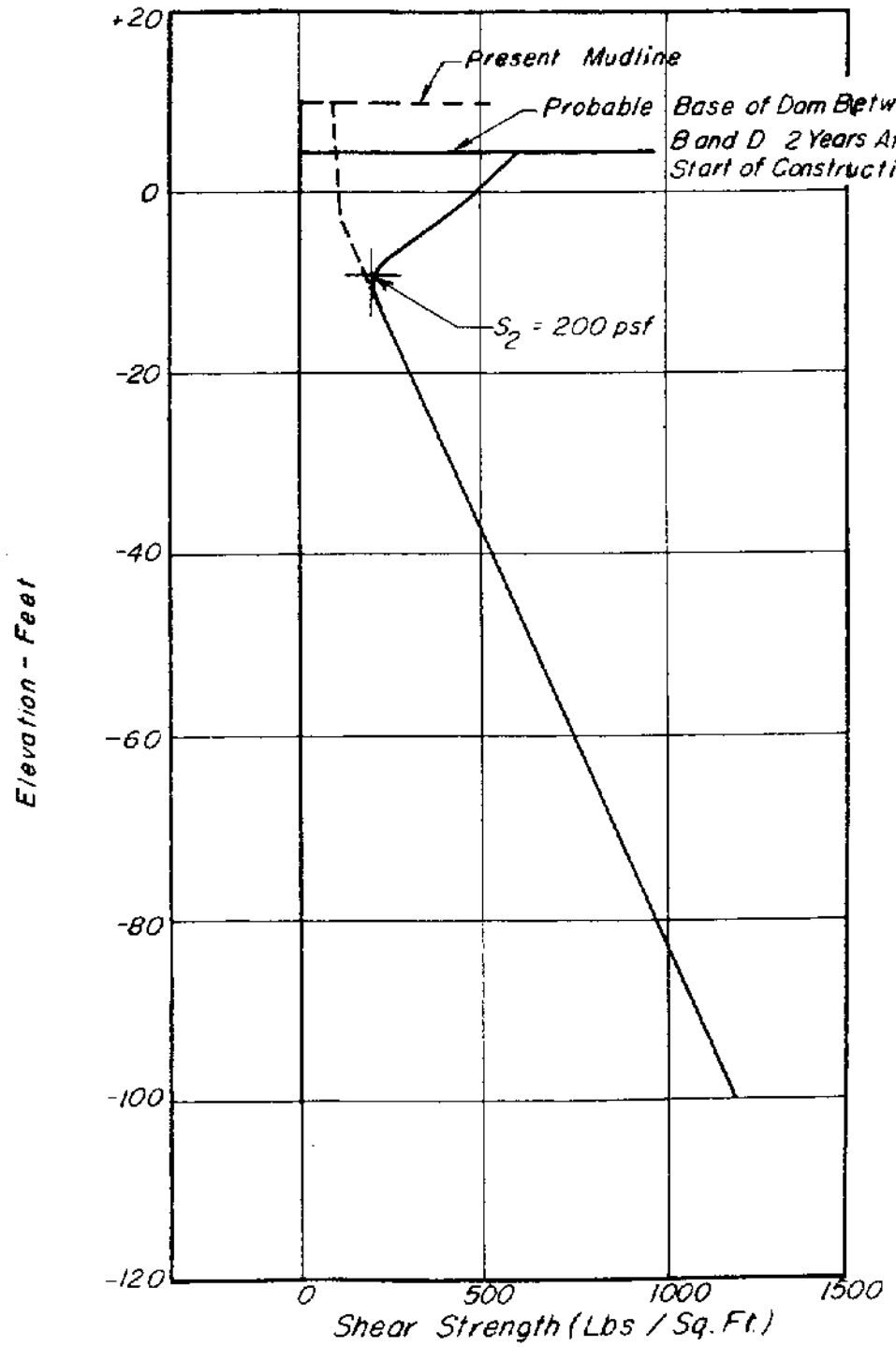
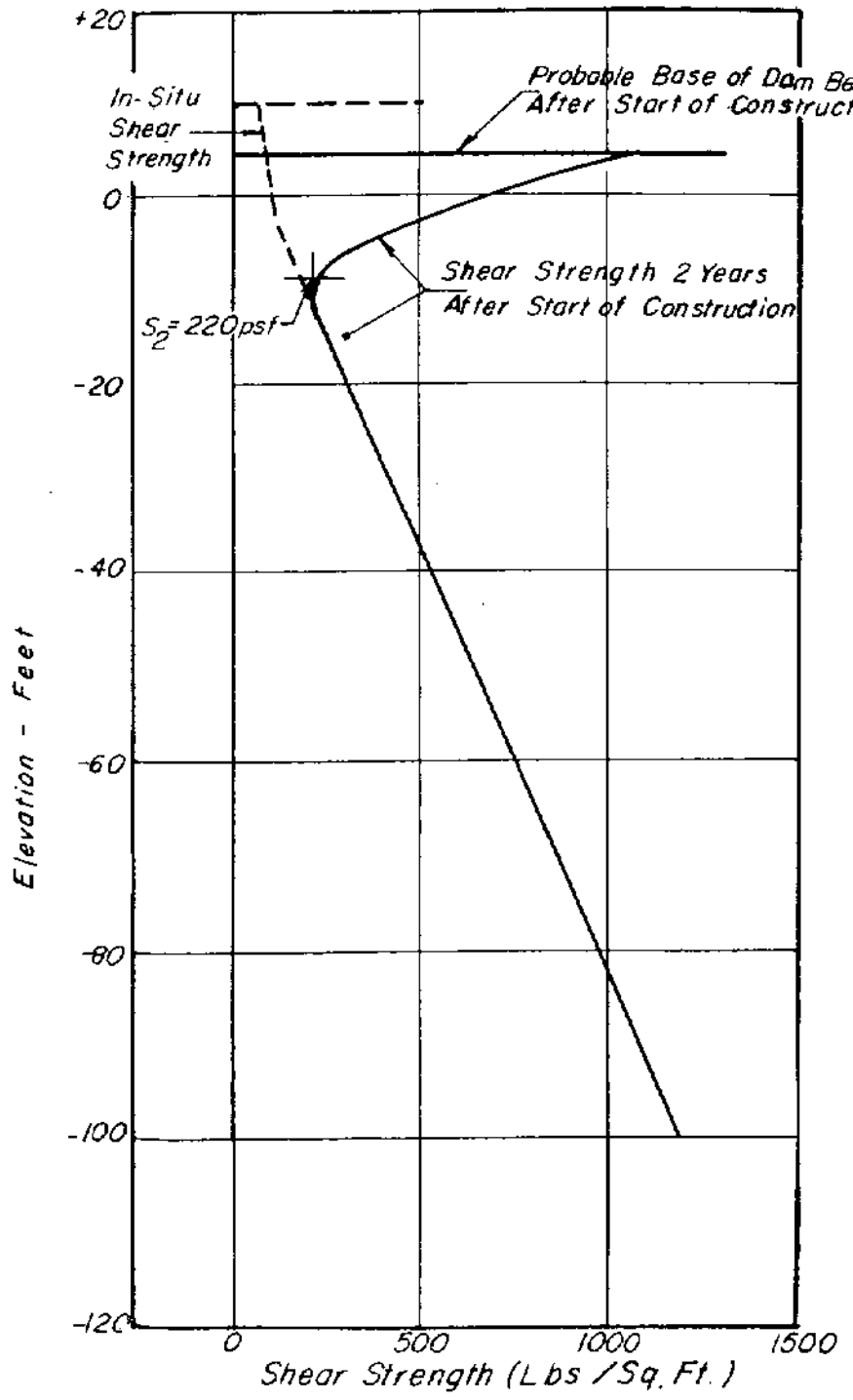


DIAGRAM IV

(Shear Strength Between D and C)



NOTES

1. Between A and B, Use Shear Strength interpolated From Diagrams I (Fig. 7-1) and III
2. Between B and D, Use Diagram III
3. Between D and C, Use Diagram IV
4. S_2 = Calculated Minimum Shear Strength 2 Years After Start of Construction.

PROPOSED DAM - TRINIDAD ARM
GATUN LAKE, PANAMA CANAL ZONE

DATA FOR STABILITY ANALYSES

Depth Vs. Shear Strength

2 YEARS

After Start of Construction

W-62-147
FEBRUARY, 1963

SHANNON & WILSON
SOIL MECHANICS & FOUNDATION ENGINEERS

FIG. 7-2

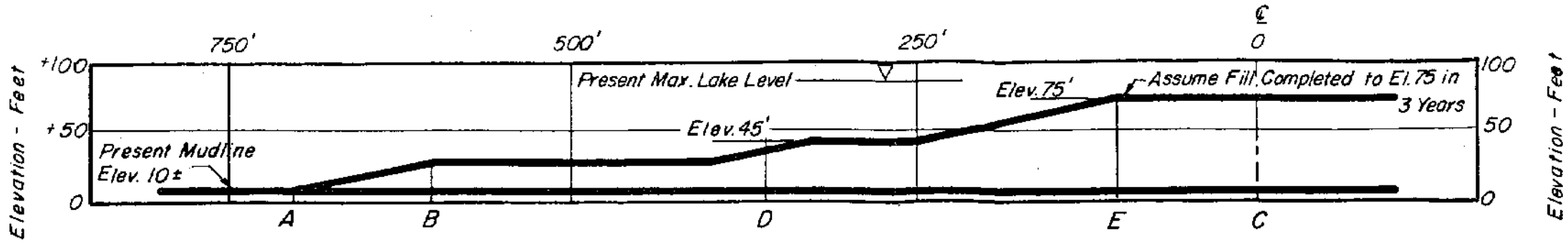


DIAGRAM V
(Shear Strength Between B and D)

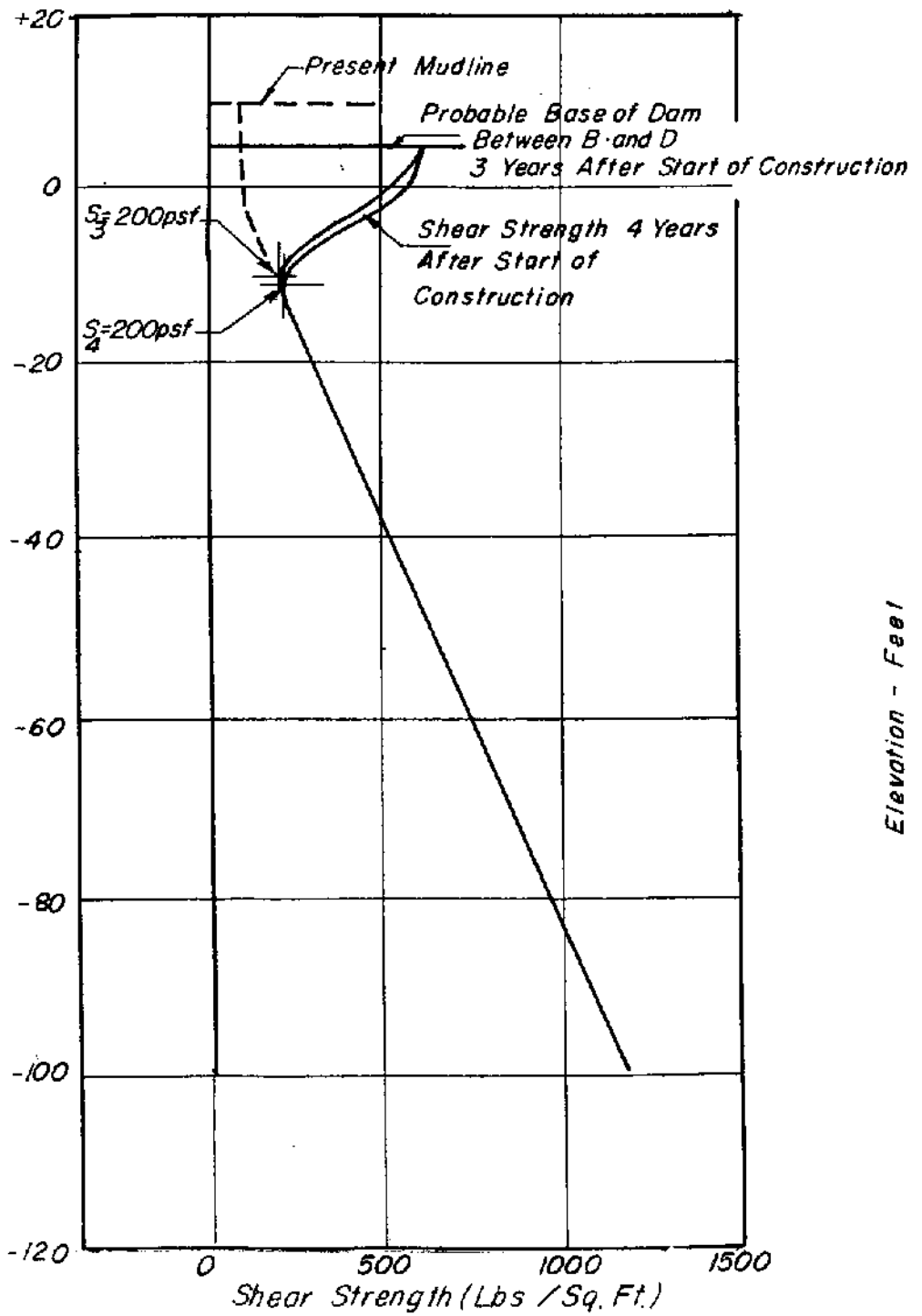
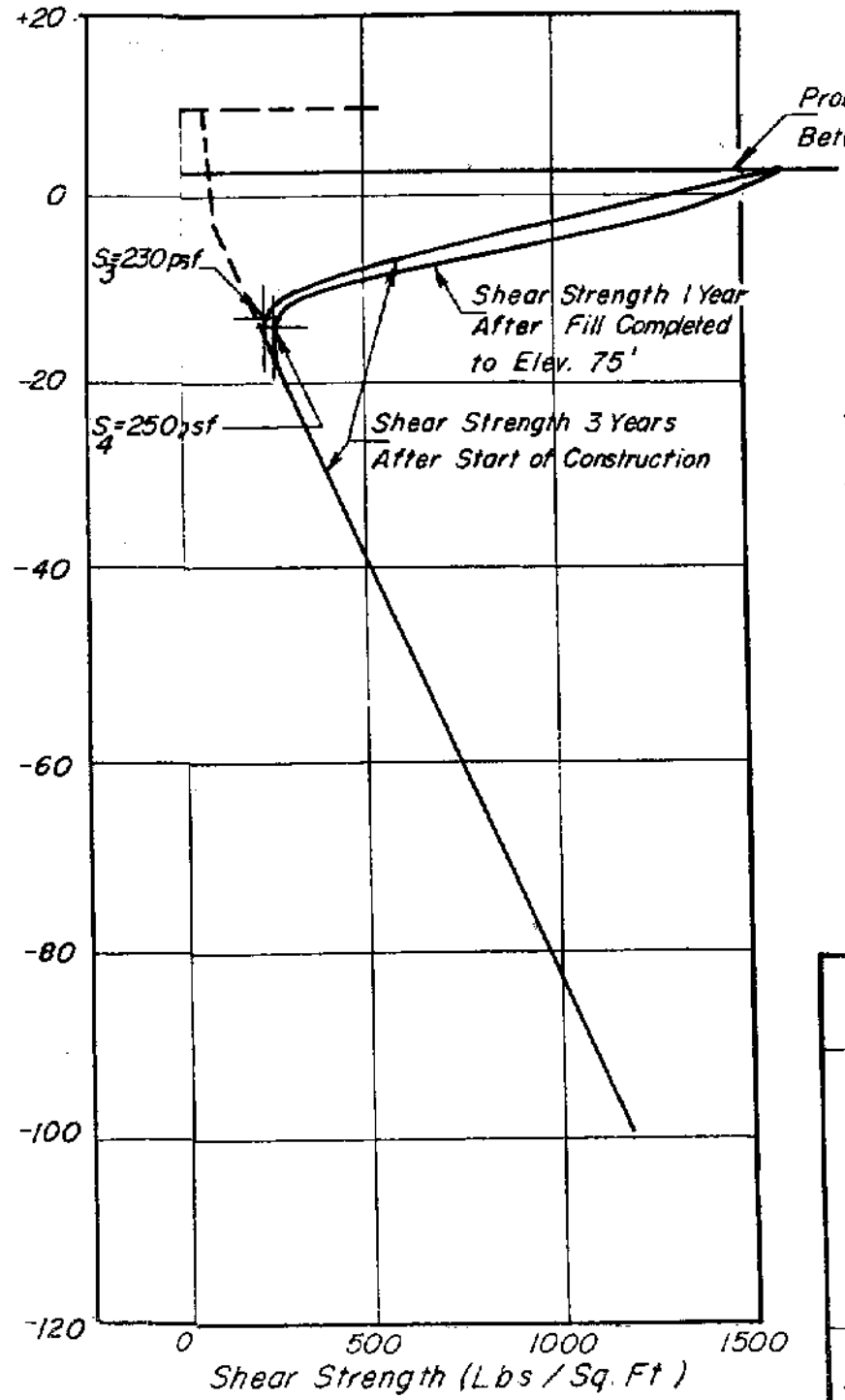


DIAGRAM VI
(Shear Strength Between E and C)



NOTES

1. Between A and B, Use Shear Strength Interpolated From Diagrams I (Fig. 7-1) and V
2. Between B and D, Use Diagram V
3. Between D and E, Use Shear Strength Interpolated From Diagrams V and VI
4. Between E and C, Use Diagram VI
5. S_3, S_4 = Calculated Minimum Shear Strength 3 and 4 Years After Start of Construction, Respectively.

PROPOSED DAM - TRINIDAD ARM
GATUN LAKE, PANAMA CANAL ZONE

DATA FOR STABILITY ANALYSES
Depth Vs. Shear Strength
3 AND 4 YEARS
After Start of Construction

W-62-147
FEBRUARY, 1963

SHANNON & WILSON
SOIL MECHANICS & FOUNDATION ENGINEERS

FIG. 7-3