REPORT OF

FOUNDATION INVESTIGATION

TWO PROPOSED EARTH-FILL DAMS

LORDS LAKE

JEFFERSON COUNTY, WASHINGTON

for the

CROWN ZELLERBACH CORPORATION

SCOPE

The scope of this foundation investigation was intended to, (1) determine the nature of the soils underlying each dam site and the borrow areas, (2) determine if seepage at either site would require special consideration, and (3) provide general recommendations for design and construction.

The locations of the Proposed Earth-fill Dams with respect to Lords Lake and the surrounding area are shown on the Map of Area, Plate 1.

DESIGN CONSIDERATIONS

The dams will be approximately 35 feet in height and will be earth-fill, constructed of natural local borrow. The East Dam will be about 530 feet long at the crest and the North Dam about 170 feet long. The crests of both dams will be at elevation 926.0. The intake structure for the 30-inch supply line will be located at the East Dam site. There will be no provisions for a spillway or overflow at the East Dam site. There will be a spillway section located at the North Dam site. The crest of the spillway will be at elevation 919.5.

SITE CONDITIONS

Lords Lake is located in the foothills of the Olympic Mountains northwest of the town of Quilcene, Washington. The water elevation at the lake is approximately 890. The area surrounding the lake consists of steep slopes covered with a dense growth of timber and brush. Clearing operations had been started and, at the time of the investigation, all timber below elevation 930 had been cut down.

EAST DAM SITE

The site of the East Dam is readily accessible by road. The present outlet from the lake is at this location. The soils evident on the ground surface at this site consist of sandy loam and sandy clay loam with appreciable amounts of gravel and broken rock. To determine the nature of the underlying soils, five test pits were dug within the area to be occupied by the dam. Three additional test pits were dug in the borrow areas to ascertain the nature of the proposed fill soils. The pits were inspected by one of our engineers who obtained samples of the soils and prepared a log of soils encountered in each test pit. The locations of the test pits with respect to the East Dam and the adjacent borrow areas are shown on the Plot Plan which, together with the logs of the test pits at the East site, appears on Plate 2, East Dam Site. The investigation revealed that the sandy loam, evident at the surface was continuous to the depths explored. In test pits E-1, E-2, E-3, and E-8, those located within the area of the dam, the surface layer of reddish-brown sandy loam with gravel was two feet thick. This layer thinned to a thickness of one-foot in the vicinity of test pit E-9 which was located adjacent to the outlet. Underlying the surface layer was a formation of dense gray sandy loam with gravel and occasional boulders. This formation was continuous to the bottom of all test pits. In test pits E-1 and E-2 steel rods were driven to a

penetration of two and one-half feet below the bottom of the pits. In both instances the rods drove with difficulty, indicating that no soft soils existed within the depths penetrated.

The soils encountered in the pits located in the borrow areas, test pits E-4, E-5, and E-7, were similar to those in the area of the dam. The reddish-brown formation of sandy loam with gravel was about one-foot thicker, otherwise there was no change.

NORTH DAM SITE

The North Dam site lies in a narrow, steep sided valley at the north end of the lake. There was no road to this site -- access was by means of a small boat on the lake or by hiking around the lake shore. Due to the tangled mass of fallen timber, access by both land and water was difficult. The site itself was covered with water and fallen timber. The water was relatively shallow in some places, but in some areas it was several feet deep.

Six test pits were located within the area of the proposed dam location and two pits were located approximately 200 feet further north. The locations of the test pits are shown on the Plot Plan which appears, together with the logs of the test pits, on Plate 3, North Dam Site.

Test pits N-1 and N-3 were located in the lowest portion of the site not under water. The logs of these two pits were nearly identical. Soft, black silty loam with a high organic content occurred within the top two feet. Underlying the soft soil was a formation consisting of a large amount of broken, angular rock ranging in size from one inch minus to small boulders, with a matrix of brown silty loam. This formation was four feet thick and was underlain, at a depth of six feet, by gray coarse sand with boulders of broken rock. Test pit N-1 was approximately eight and one-half feet deep. A steel drive rod penetrated seven feet below the bottom of the pit and drove

easily all the way. Test pit N-3 was seven feet deep. In this pit, the drive rod penetrated four and one-half feet below the bottom encountering refusal at that point. It was impossible to determine whether refusal was due to a solid formation or an isolated boulder. Water seeped into these two pits rapidly and the water level was at the ground surface after the pits had been open over night.

Two test pits were located on each side slope -- N-2 and N-7 on the West side with N-4 and N-8 on the East side. The logs of these pits were similar to each other. Angular broken rock with silty loam binder, similar to the formation occurring at a depth of two feet in test pits N-1 and N-3, was the only material encountered in the test pits on each side slope. Test pit N-2 was dug to a depth of ten feet and the drive rods penetrated an additional six feet before meeting refusal. No water was present in this pit at the time of our inspection; however, we were informed that water was flowing rapidly into the pit below a depth of eight feet when it was dug. The remaining pits in the area of the dam, N-4, N-7, and N-8 were each approximately three feet deep. No water was encountered in N-4 and N-8 but N-7 was terminated due to a rapid flow of water from the up hill side. A drive rod penetrated ten feet below the bottom of pit N-4, driving easily all the way and meeting no refusal. At test pit N-8, the drive rod penetrated three feet below the bottom and met refusal, presumably on a boulder.

Test pits N-5 and N-6 were located nearly 200 feet North of the proposed dam site. The soils encountered in test pit N-5 were similar to that in the pits within the area of the dam. In N-6, about 75 feet North of N-5, gravel and broken rock were present but the matrix was sandy clay and sandy clay loam and was much more impervious than the silty loam matrix in the other pits. The surface soil was dark brown loam with vegetation. Underlying the

six-inch surface layer was a formation of reddish-brown sandy clay loam with angular broken rock and gravel. At a depth of one and one-half feet the matrix changed color to yellowish gray; otherwise, the formation was the same to a depth of four and one-half feet. At this depth and continuing to the bottom of the test pit was found a formation of brown sandy clay with broken rock and gravel. At test pit N-5 the water level rose to about one-foot below the ground surface after the pit stood over night. At N-6 no static level was obtained; however, only small amounts of water seeped in as the pit was being dug and this in the bottom two and one-half feet.

DISCUSSIONS AND RECOMMENDATIONS

EAST DAM SITE

The investigation revealed that dense relatively impervious soils occurred at a depth of two feet, generally, throughout the East site. After stripping operations have been completed in this area it is probable that the lower formation of dense gray sandy loam with gravel and boulders would be exposed throughout the site. The proposed cut off wall will extend well into this formation so we expect no difficulty due to excess seepage at this site. Adequate provisions must be made to keep the cut off excavation dry at the time fill is placed otherwise adequate compaction will be difficult to obtain.

NORTH DAM SITE

The soils at the North Dam site contain large quantities of broken rock and boulders. The matrix was predominantly silty loam and the formations were quite porous. Water flowed freely into most of the test pits dug at the north site but it was possible to keep the pits free of water by constant bailing. The presence of boulders and necessity of constant bailing made these pits difficult to dig. In test pits N-1 and N-3, there was a two-foot layer of

soft soil overlying the broken rock and silty loam binder. At a depth of six feet in each pit the formation changed to gray coarse sand and broken rock. It was impossible to dig these pits deep enough with the available hand equipment to determine the depth of this sand and rock layer; however, in pit N-1 drive rods penetrated to a depth of seven feet below the bottom of the pit-driving with ease all the way. In pit N-3 the drive rod met refusal, possibly a boulder, at four and one-half feet below the bottom of the pit. This sand and broken rock deposit could be localized as it was not encountered in any other test pit; however, the test pits and drive rod records for these pits on either side slope all terminated above the elevation at which this sand and rock deposit occurred in test pits N-1 and N-3. Based on the typical cross section for the dam and the contours on the Plot Plan, it is our opinion that seepage losses through this formation would be excessive if either the cut off wall did not extend below this formation or if an upstream imperious blanket was not provided. Consequently, recommendations as to the type and depth of seepage restraining structures can not be made at this time without additional subsurface information.

Two test pits, N-5 and N-6, were located to the north of the proposed North Dam site. The soils in pit N-5 were similar to those found in the immediate vicinity of the dam. In pit N-6 the soil matrix was sandier and contained clay. There were fewer boulders and large cobbles in the area of this pit and water seeped in quite slowly. Due to the clay, the soils in this area were much more imperious than those at the proposed site. Since the coarse sand and broken rock encountered in test pits N-1 and N-3 were not found at the location of N-6, it is our opinion that further investigation in this area is required. This additional information is necessary in order to make recommendations for the seepage restraining structures. We believe that the additional

investigation could be best accomplished after access to the north site with motorized equipment is possible. The additional investigation would be directed toward determining the extent of the sand and rock deposit encountered in test pits N-1 and N-3 and to further exploration in the area of test pits N-5 and N-6. On the basis of the information obtained in N-6, this area seems to be a more favorable dam location from a soils standpoint.

BORROW AREAS

Test pits in the borrow areas revealed that the soils in these areas were predominantly sandy loam with gravel and broken rock the same as was found at the East Dam site. Disturbed bulk samples of these borrow soils were taken to our laboratory for testing and analyses. Tests performed included compaction tests, sieve analyses and direct shear tests on samples compacted to 90 per cent and 95 per cent of maximum density. The methods used in performing the tests are described in Appendix A. The test results are presented graphically on Plate A-1, Compaction Test Data.

Compaction tests were performed on samples of each soil type encountered. The upper soil, dark brown sandy loam with gravel, had a maximum dry density of 118 pounds per cubic foot at an optimum moisture content of 13.5 per cent. The lower soil, gray sandy loam and gravel had a maximum dry density of 131 pounds per cubic foot at an optimum moisture of 11.5 per cent.

Sieve analyses on these samples showed that both were well graded but that the lower soil contained a smaller percentage of fines.

The test results show that the soils in the proposed borrow areas are quite suitable for fill purposes. The upper soils, containing a higher percentage of fines, would be more suitable for use in the cut off walls and the upstream portion of the dam. Due to the larger amount of fines the upper soil will be more sensitive to moisture variation. Careful moisture control should

be maintained during filling operations and we recommend that the moisture content be held to a few per cent below optimum. For the proposed upstream and downstream dam slopes of one on three and one on two respectively, we recommend that the fills be compacted to 90 per cent of the maximum density obtained by the Modified A.A.S.H.O. Method of Compaction. In order to obtain this compaction it will be necessary to remove the cobbles and small boulders from the fill soils. We recommend that all rock larger than six inches be removed.

Respectfully submitted,

DAMES & MOORE

Irving M. Olsen

Registered Professional Engineer No. 4734
State of Washington

LORDS LAKE

N

Existing Road

Cabin

Cutoff trench

TEST PIT E-1

TEST PIT E-9

TEST PIT E-8

TEST PIT E-2

TEST PIT E-3

"D" Line

Rock Toe

TEST PIT E-7

TEST PIT E-4

DEPTH IN FEET

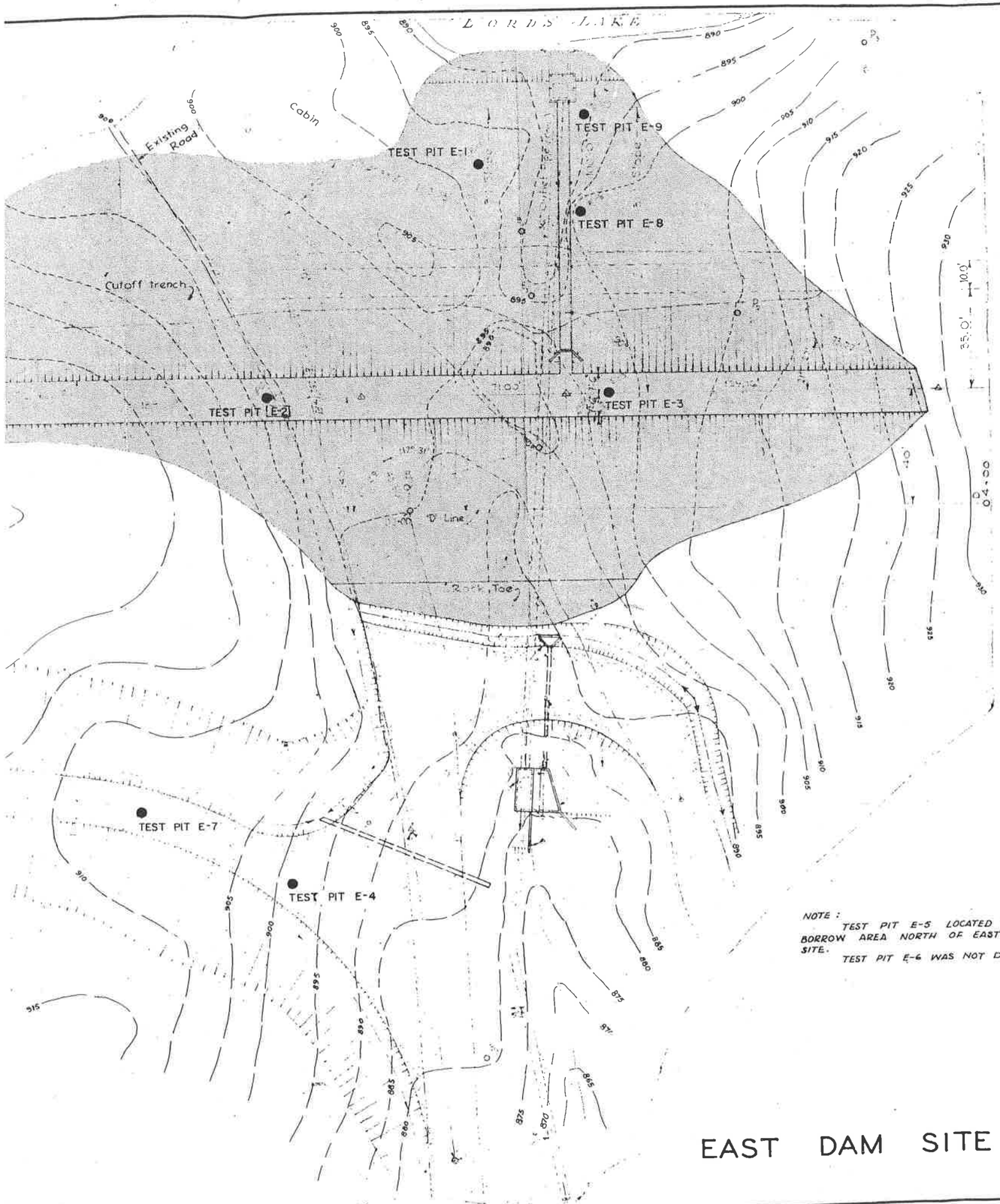
NOTE :
TEST PIT E-5 LOCATED IN BORROW AREA NORTH OF EAST DAM SITE.
TEST PIT E-6 WAS NOT DUG.

PLOT PLAN

FEET
10 5 0 10 20 30 40 50

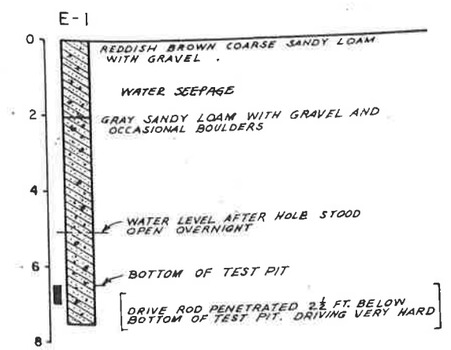
REFERENCE : DWG. NO. 670-A-3 3943 ENTITLED "EAST DAM" BY JOHN W. CUNNINGHAM & ASSOCIATES. DATED: JAN, 1956

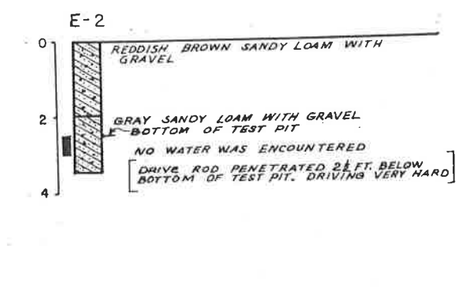
EAST DAM SITE

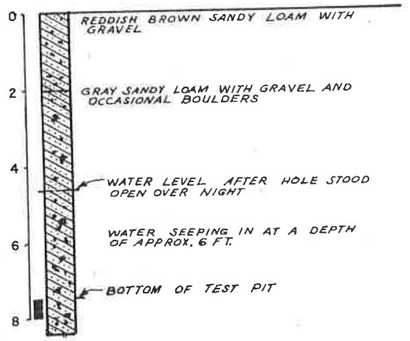


NOTE :
TEST PIT E-5 LOCATED IN BORROW AREA NORTH OF EAST DAM SITE.
TEST PIT E-6 WAS NOT DUG.

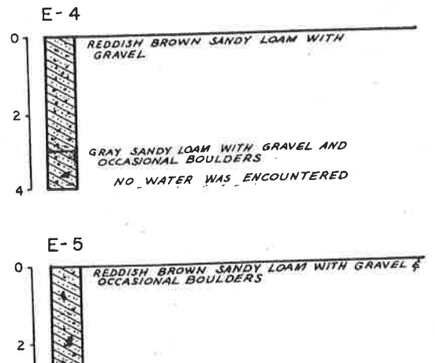
EAST DAM SITE

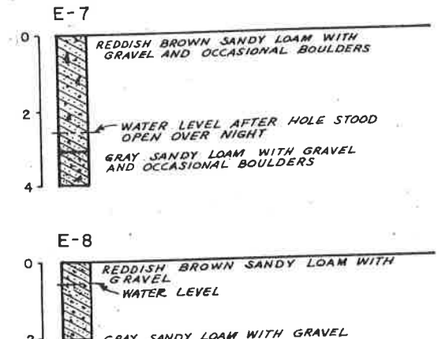




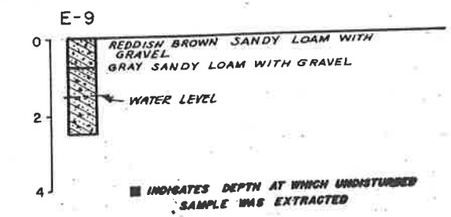


DEPTH IN FEET





DEPTH IN FEET

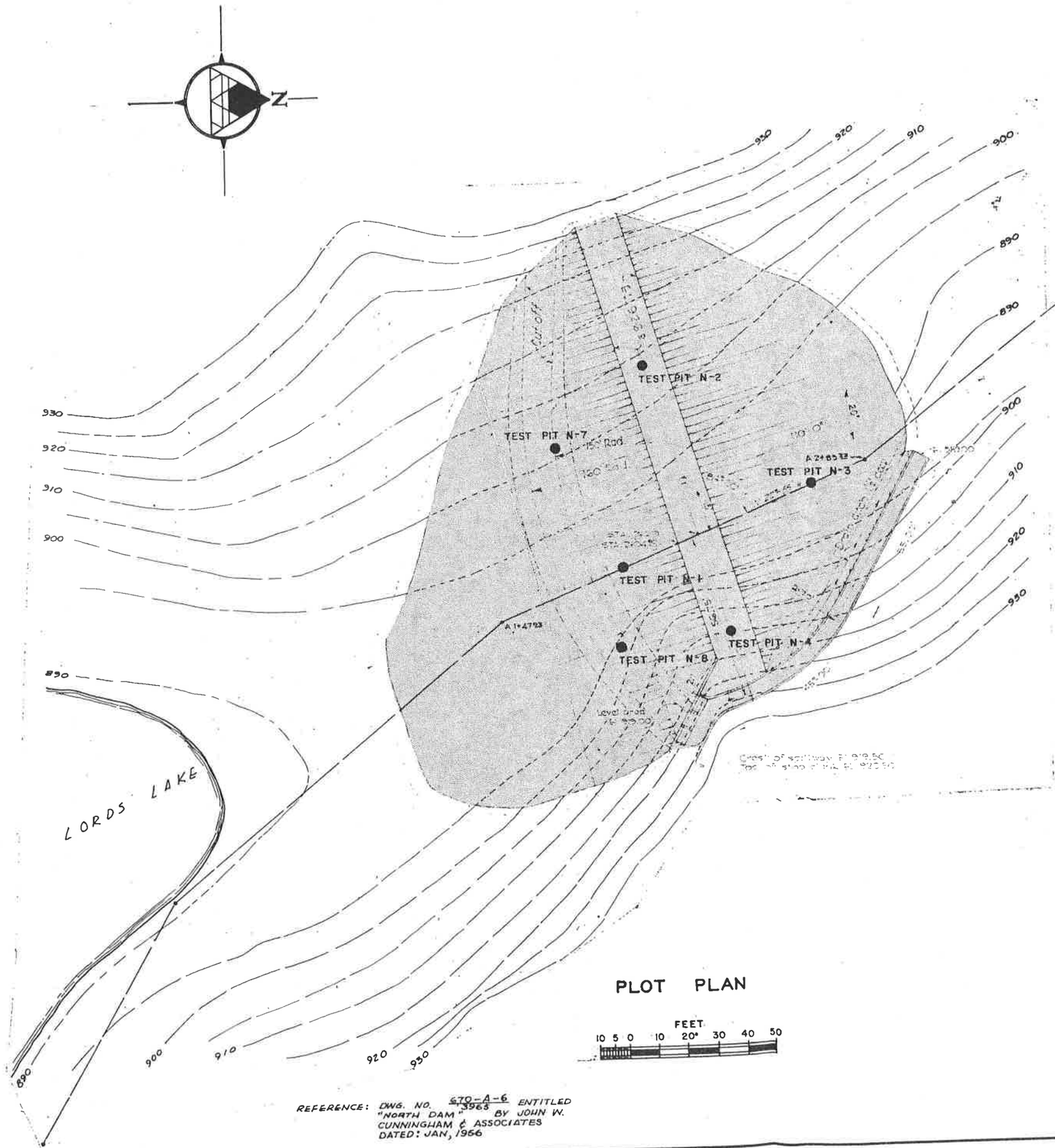


■ INDICATES DEPTH AT WHICH UNDISTURBED SAMPLE WAS EXTRACTED

LOG OF TEST PITS

DAMES & MOORE
SOIL MECHANICS ENGINEERS

PLATE 2

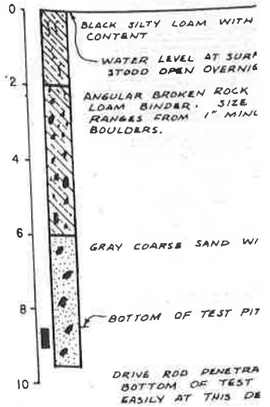


PLOT PLAN

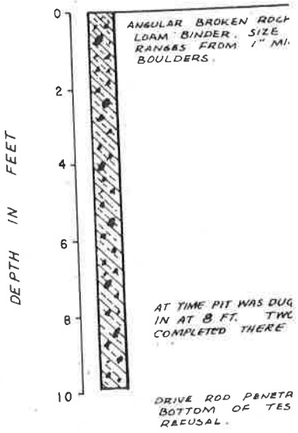
FEET
10 5 0 10 20 30 40 50

REFERENCE: DWG. NO. 570-A-6 ENTITLED "NORTH DAM" 1963 BY JOHN W. CUNNINGHAM & ASSOCIATES DATED: JAN, 1956

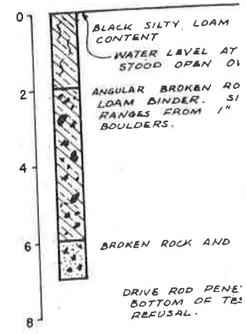
N-1



N-2



N-3



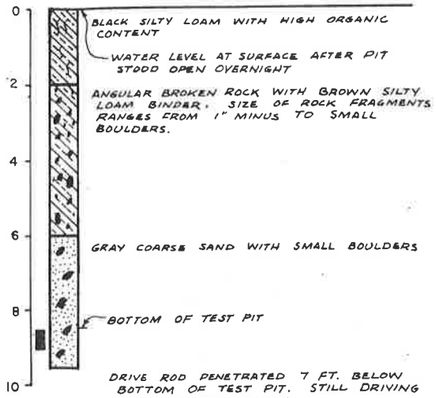
■ INDICATES DEPTH AT WHICH UNDISTU SAMPLE WAS EXTRACTED

NORTH DAM SITE

LOCATION)

DEPTH IN FEET

N-1



BLACK SILTY LOAM WITH HIGH ORGANIC CONTENT

WATER LEVEL AT SURFACE AFTER PIT STOOD OPEN OVERNIGHT

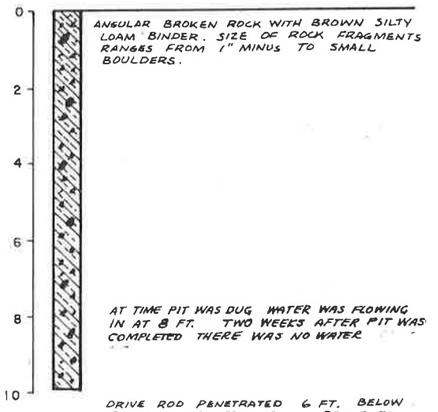
ANGULAR BROKEN ROCK WITH BROWN SILTY LOAM BINDER. SIZE OF ROCK FRAGMENTS RANGES FROM 1" MINUS TO SMALL BOULDERS.

GRAY COARSE SAND WITH SMALL BOULDERS

BOTTOM OF TEST PIT

DRIVE ROD PENETRATED 7 FT. BELOW BOTTOM OF TEST PIT. STILL DRIVING EASILY AT THIS DEPTH.

N-2

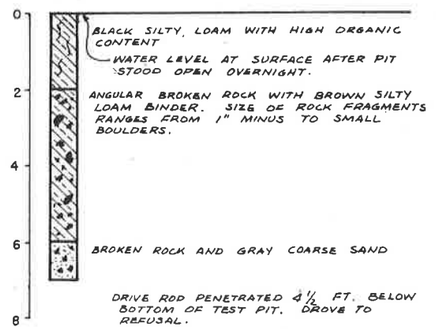


ANGULAR BROKEN ROCK WITH BROWN SILTY LOAM BINDER. SIZE OF ROCK FRAGMENTS RANGES FROM 1" MINUS TO SMALL BOULDERS.

AT TIME PIT WAS DUG WATER WAS FLOWING IN AT 8 FT. TWO WEEKS AFTER PIT WAS COMPLETED THERE WAS NO WATER.

DRIVE ROD PENETRATED 6 FT. BELOW BOTTOM OF TEST PIT. DROVE TO REFUSAL.

N-3



BLACK SILTY LOAM WITH HIGH ORGANIC CONTENT

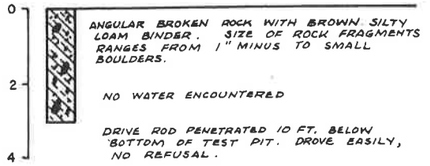
WATER LEVEL AT SURFACE AFTER PIT STOOD OPEN OVERNIGHT.

ANGULAR BROKEN ROCK WITH BROWN SILTY LOAM BINDER. SIZE OF ROCK FRAGMENTS RANGES FROM 1" MINUS TO SMALL BOULDERS.

BROKEN ROCK AND GRAY COARSE SAND

DRIVE ROD PENETRATED 4½ FT. BELOW BOTTOM OF TEST PIT. DROVE TO REFUSAL.

N-4

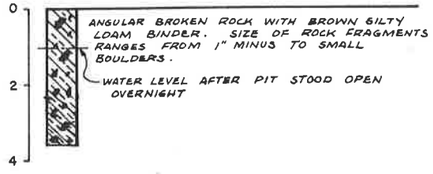


ANGULAR BROKEN ROCK WITH BROWN SILTY LOAM BINDER. SIZE OF ROCK FRAGMENTS RANGES FROM 1" MINUS TO SMALL BOULDERS.

NO WATER ENCOUNTERED

DRIVE ROD PENETRATED 10 FT. BELOW BOTTOM OF TEST PIT. DROVE EASILY, NO REFUSAL.

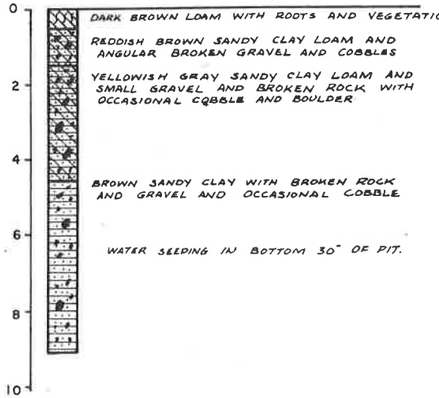
N-5



ANGULAR BROKEN ROCK WITH BROWN SILTY LOAM BINDER. SIZE OF ROCK FRAGMENTS RANGES FROM 1" MINUS TO SMALL BOULDERS.

WATER LEVEL AFTER PIT STOOD OPEN OVERNIGHT

N-6



DARK BROWN LOAM WITH ROOTS AND VEGETATION

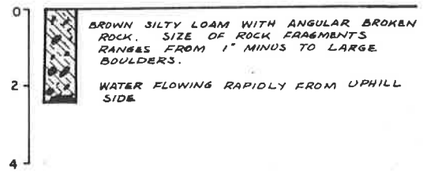
REDDISH BROWN SANDY CLAY LOAM AND ANGULAR BROKEN GRAVEL AND COBBLES

YELLOWISH GRAY SANDY CLAY LOAM AND SMALL GRAVEL AND BROKEN ROCK WITH OCCASIONAL COBBLE AND BOULDER

BROWN SANDY CLAY WITH BROKEN ROCK AND GRAVEL AND OCCASIONAL COBBLE

WATER SEEPING IN BOTTOM 30" OF PIT.

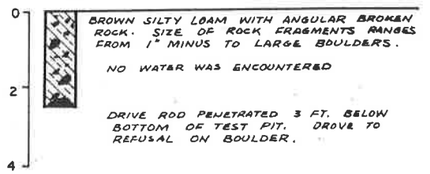
N-7



BROWN SILTY LOAM WITH ANGULAR BROKEN ROCK. SIZE OF ROCK FRAGMENTS RANGES FROM 1" MINUS TO LARGE BOULDERS.

WATER FLOWING RAPIDLY FROM UPHILL SIDE

N-8



BROWN SILTY LOAM WITH ANGULAR BROKEN ROCK. SIZE OF ROCK FRAGMENTS RANGES FROM 1" MINUS TO LARGE BOULDERS.

NO WATER WAS ENCOUNTERED

DRIVE ROD PENETRATED 3 FT. BELOW BOTTOM OF TEST PIT. DROVE TO REFUSAL ON BOULDER.

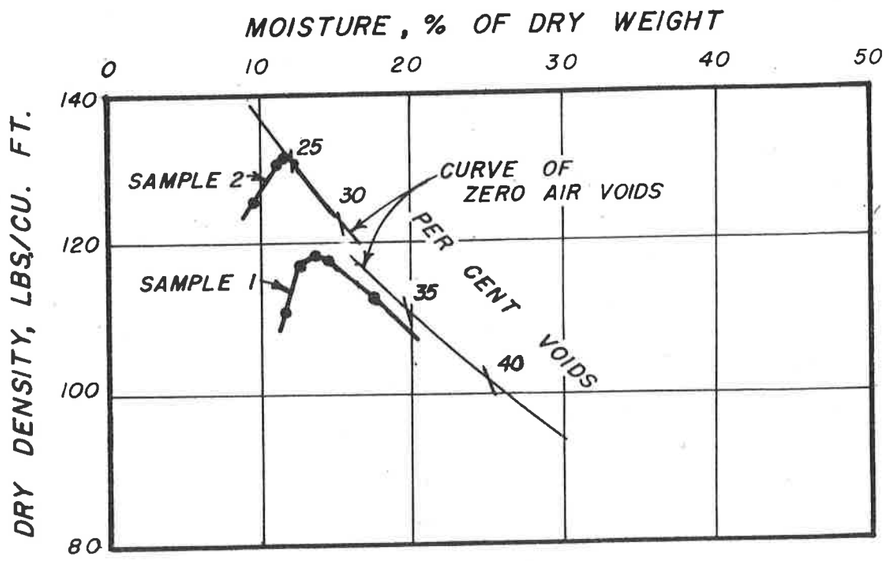
■ INDICATES DEPTH AT WHICH UNDISTURBED SAMPLE WAS EXTRACTED

LOG OF TEST PITS

DAMES & MOORE
SOIL MECHANICS ENGINEERS

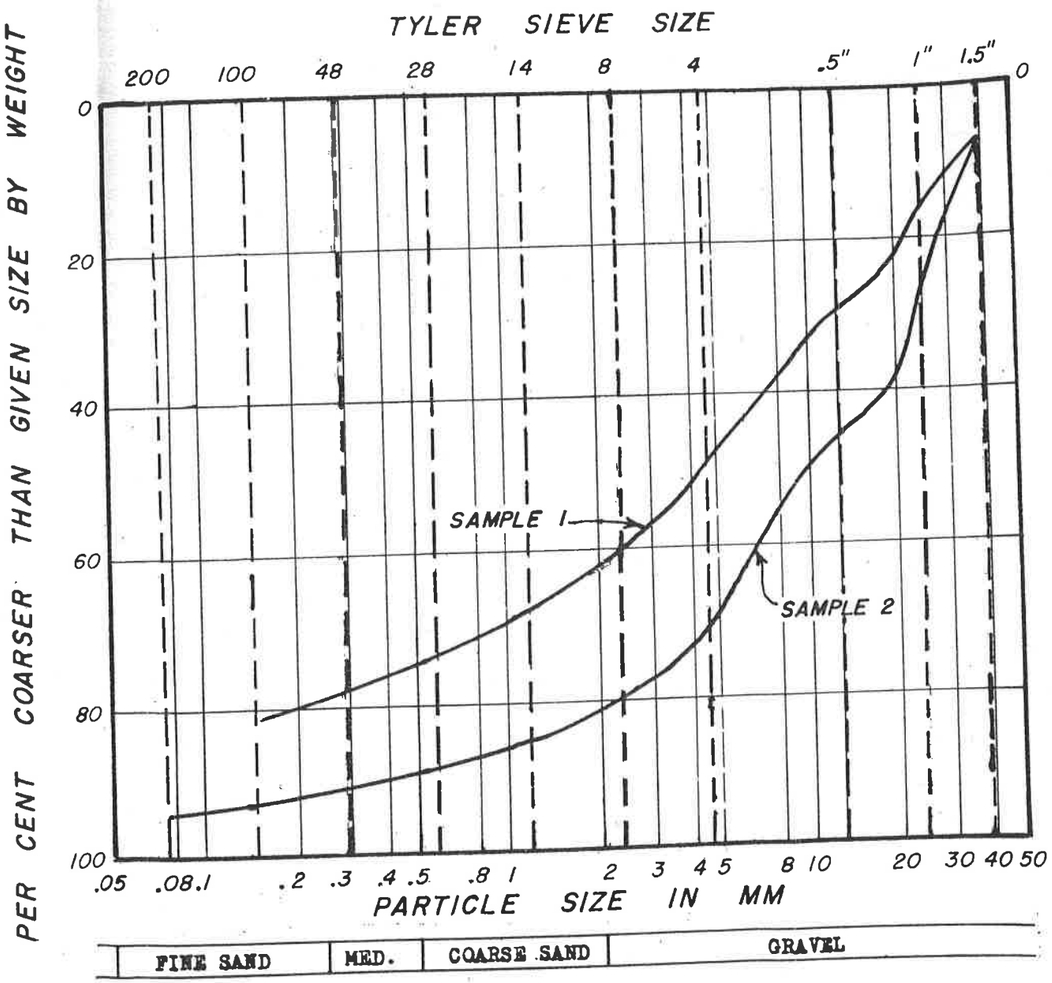
PLATE 3

COMPACTION TEST CURVES

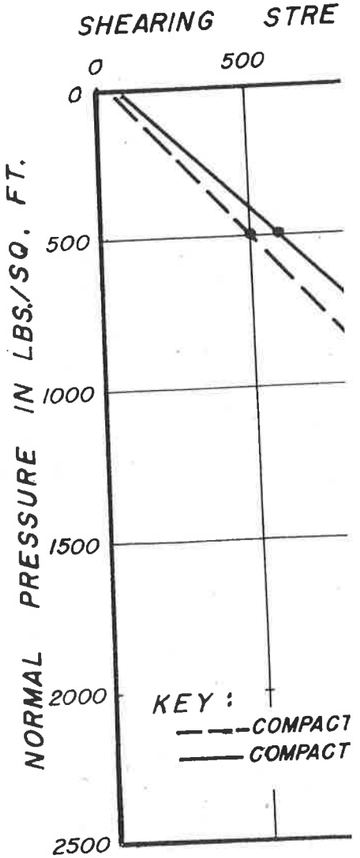


SAMPLE NUMBER	SOIL TYPE	MAXIMUM DENSITY	OPTIMUM MOISTURE
1	DARK BROWN SANDY LOAM WITH GRAVEL	118	13.5 %
2	GRAY SANDY LOAM WITH GRAVEL	131	11.5 %

PARTICLE-SIZE DISTRIBUTION

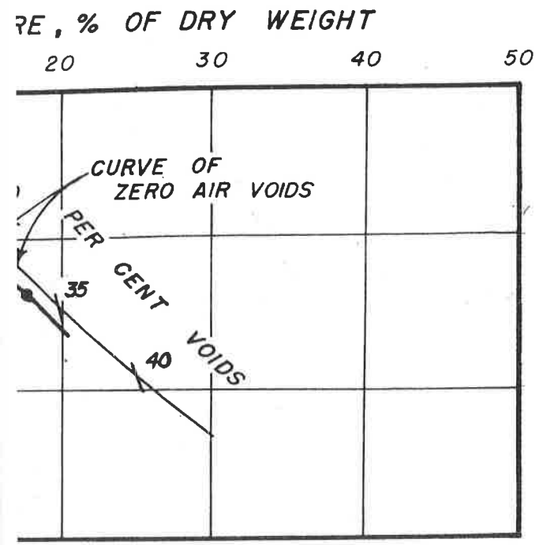


SUMMARY OF



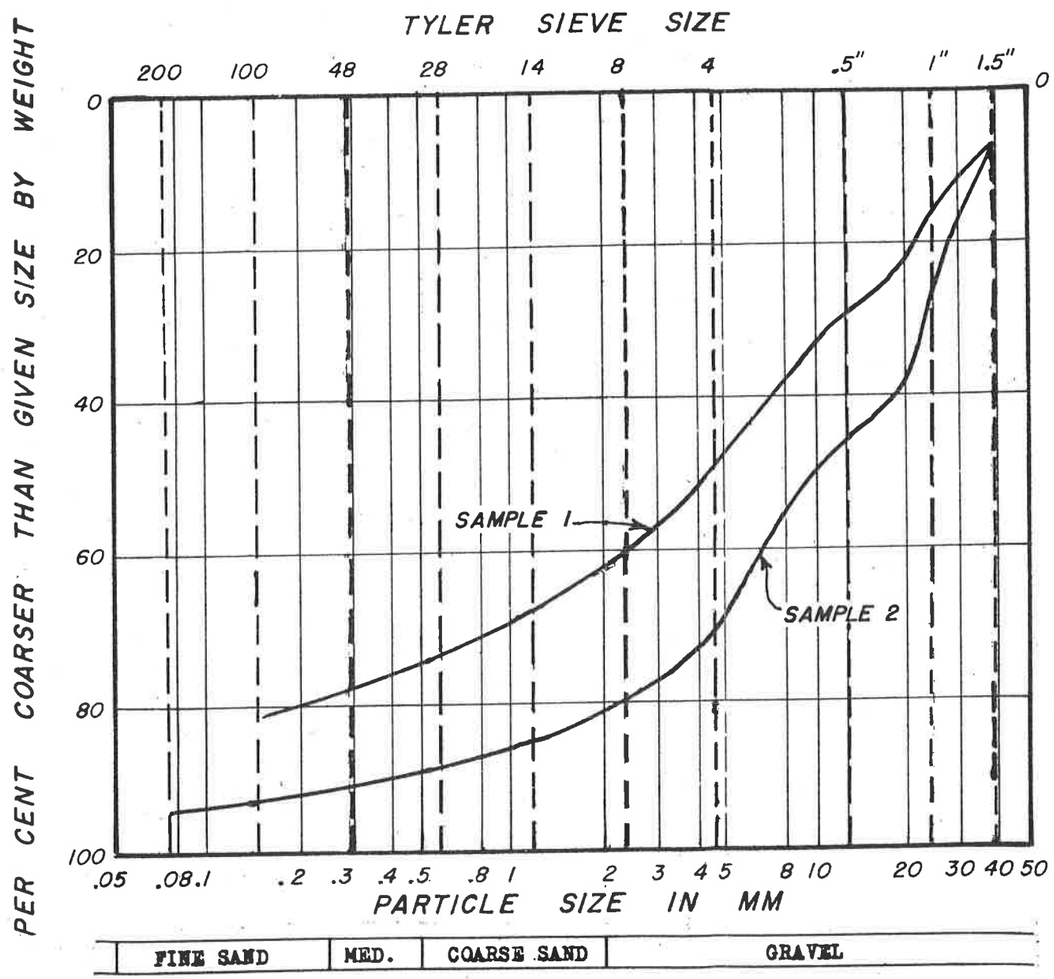
COMPACTION TEST DATA

ON TEST CURVES

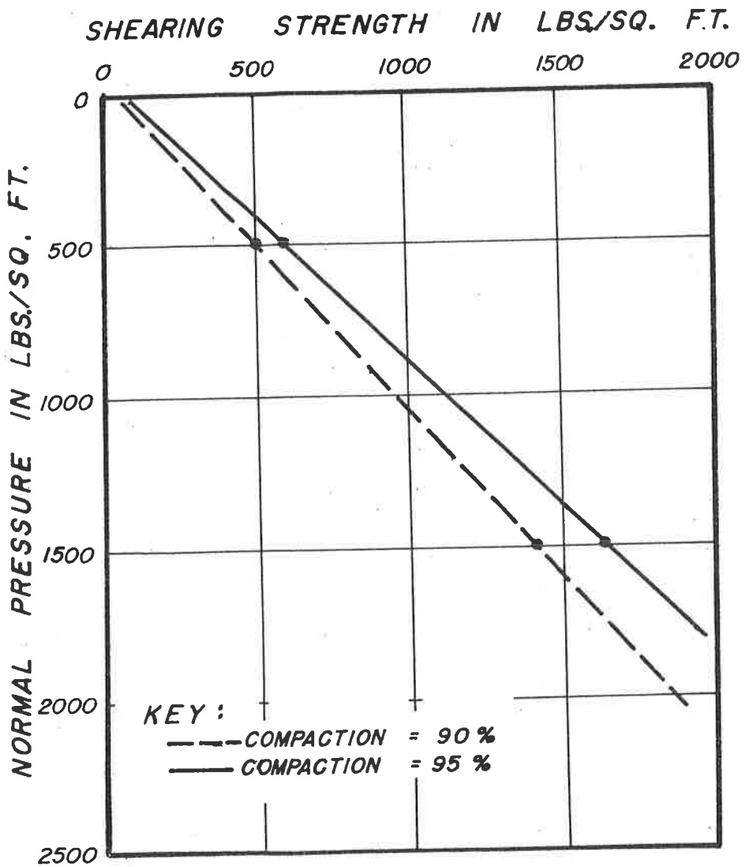


IL TYPE	MAXIMUM DENSITY	OPTIMUM MOISTURE
ROWN SANDY ITH GRAVEL	118	13.5 %
INDY LOAM RAVEL	131	11.5 %

PARTICLE - SIZE DISTRIBUTION



SUMMARY OF SHEAR TEST DATA



COMPACTION TEST DATA

DAMES & MOORE
SOIL MECHANICS ENGINEERS

PLATE A-1