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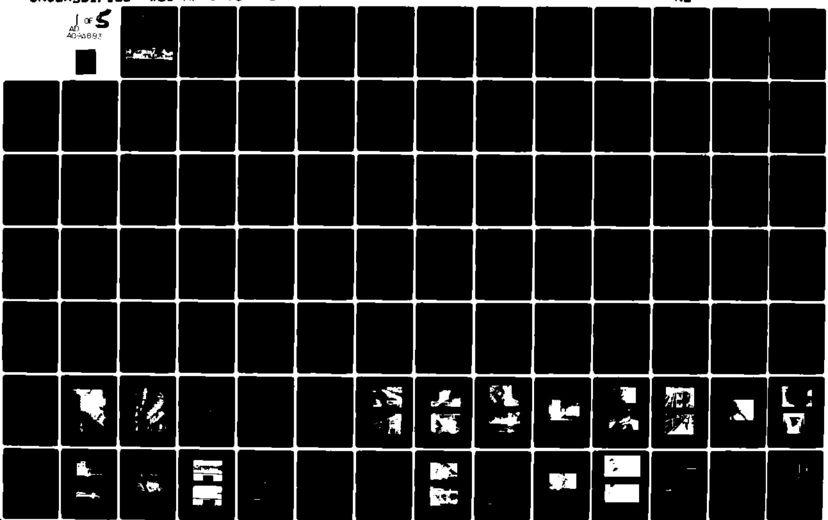

LEVEL II

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MISCELLANEOUS PAPER C-78-6

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ENGINEERING CONDITION SURVEY AND EVALUATION OF TROY LOCK AND DAM HUDSON RIVER, NEW YORK

Report 2

EVALUATION AND REHABILITATION

by

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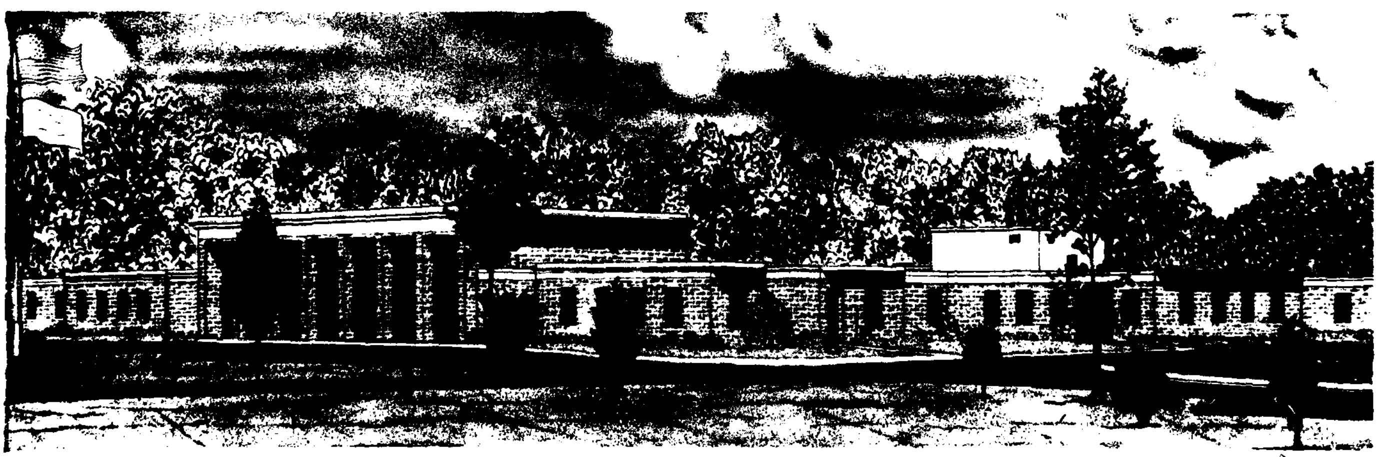

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The monoliths of Troy lock, dam, and headgate section must be rehabilitated in the near future or the concrete deterioration will progress to the point that the total structure will have to be replaced. Two specific areas of the structure are now in such a state of deterioration that they essentially will have to be replaced. The concrete in the land wall monoliths upstream of the upper gate have depths of deteriorated concrete in excess of 5 ft. The upper sections of the gated spillway to the powerhouse are so deteriorated that

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20. ABSTRACT (Continued)

enough sound concrete would not remain for rehabilitation; replacement of the upper sections will be more efficient. The other portions of the lock and dam are generally sound (4000- to 5000-psi concrete interiors) and are adequate for effective and economical rehabilitation. The concrete tensile strength is low because of minor alkali-silica reaction products and ettringite coating of aggregates but it is adequate and is expected to remain adequate.

The compressive (900 psi) and tensile (43 psi) strengths of the foundation material are very low but are adequate to resist bearing pressures and give excellent resistance for foundation anchors. There are no soft seams in the slaty-shale foundation. The foundation was very consistent. The predominant geological feature is bedding planes which dip downstream at 30 to 90 deg. This does not present any potential stability problems.

Even though the construction joints leak badly, the second phase of study established that they are not deteriorated and do not require rehabilitation (except one in the river face of the river wall).

The monoliths of the lock and dam are very inadequate in relation to stability requirements. The stability analysis and proposed remedial measures are presented. Recommendations are made for posttensioning and reaction block designs. After posttensioning, base pressures are within allowables.

Remedial actions for Troy lock, dam, and headgate section are recommended. The headgate monolith could fail when subjected to extreme ice loading unless remedial measures are accomplished. It is essential that the rehabilitation of Troy lock, dam, and headgate section be accomplished in the near future or they will become deteriorated to the extent that replacement will be necessary.

PREFACE

An engineering condition survey and evaluation of Troy Lock and Dam was conducted for the U. S. Army Engineer District, New York, (NYD), by the Structures Laboratory (SL) of the U. S. Army Engineer Waterways Experiment Station (WES). Authorization for this investigation was given in Intra-Army Order for reimbursable services No. NYD-78-52(c) dated 16 February 1978.

The contract was monitored by the NYD Office with main assistance from Mr. Tony Barbero, whose cooperation was greatly appreciated. The assistance of Mr. Roselle and other lock personnel was outstanding.

The study was performed under the direction of Messrs. Bryant Mather, William Flathau, and John Scanlon, SL.

The structural analysis was performed by Dr. C. E. Pace and Mr. Roy Campbell. Material property tests were performed under the direction of Messrs. F. S. Stewart and J. B. Eskridge. The instrumentation was performed by Messrs. Dale Glass and Dan Wilson. The core logging was performed in the field by Mr. Steve Johnson and in the laboratory by Messrs. Sam Wong and J. Rhoderick. The core drilling was under the direction of Mr. Mark Vispi. Dr. Pace and Messrs. Campbell and Wong prepared this report.

Commanders and Directors during the conduct of the program and the preparation and publication of this report were COL John L. Cannon, CE, and COL Nelson P. Conover, CE. Mr. F. R. Brown was Technical Director.

CONTENTS

CONVERSION FACTORS, INCH-POUNDS TO METRIC (SI) UNITS OF MEASUREMENT

Inch-pounds units of measurement used in this report can be converted to metric (SI) units as follows:

Multiply	By	To Obtain
cubic yards	0.7645549	cubic metres
feet	0.3048	metres
$feet^4$ (second moment of of area)	0.008630975	metre to the fourth power
feet per second	0.3048	metres per second
inches	0.0254	metres
kips (force)	4448.222	newtons
kips (force) per square foot	47.88026	kilopascals
miles (U. S. statute)	1609.347	metres
pounds (force)	4.448222	newtons
pounds (force) per square inch	6.894757	kilopascals
pounds (mass)	0.4535924	kilograms
pounds (mass) per cubic foot	16.01846	kilograms per cubic metre
pounds per foot	14.5939	newtons per metre
square inches	0.00064516	square metres
tons (force) per square foot	95.76052	kilopascals

ENGINEERING CONDITION SURVEY AND EVALUATION OF TROY LOCK AND DAM, HUDSON RIVER, NEW YORK

EVALUATION AND REHABILITATION

PART I: INTRODUCTION

Background

Significance of lock and dam

1. Troy Lock and Dam (Figure 1) is a vital link in the navigation on the Hudson River, the New York State Barge Canal System, and the Great Lakes, allowing access to many cities. The lock is essential for the transportation of commodities by tugs, tows, tank barges, self-propelled tank barges, and dry-cargo barges. Not only is it essential for commodity transportation, but it has become the means by which many pleasure craft travel up and down the river.

2. With the increase in leisure time and the interest in recreational boating, the use of the waterway by pleasure craft has increased with time and this trend is expected to continue in the future. Many boats in both the spring and fall make seasonal trips from the sunny south to the more mountainous, wooded north, as well as completing many short trips within the system during the summer navigation season.

3. Interruptions to the passage of vessels to accomplish any repair work, either emergency or scheduled, have been practically nil during the lifetime of the lock. The lock and dam was completed in the fall of 1915 and became officially operational with the beginning of the navigation season in 1916. This makes the facility more than 65 years old. An example of the original construction of Troy Lock and Dam is presented in Figures 2 and 3, respectively. Surface wearing, spalling, cracking, and general deterioration of the concrete have occurred and will continue to occur at accelerated rates. Preventative maintenance procedures are being implemented to preserve the integrity of the structure.

4. The present Troy Lock and Dam connects the lower Hudson River and the New York Canal System, primarily consisting of the Erie, Oswego, and Champlain canal branches, with a total canal length of about 525 miles* with 57 locks.

5. The "system" of inland waterways provides a direct link between the Port of New York and the Great Lakes as well as providing access to Lake Champlain and the northeast section of New York State, the western section of the State of Vermont, and Canada.

6. If for any reason, Troy Lock could not be kept operational, the whole Federal and State systems would fail completely since the facility is the entrance from the Hudson River to the rest of the extensive State Barge Canal System. The importance of the Hudson River lock for transportation, as well as recreational aspects, makes it imperative that rehabilitation of the lock and dam be accomplished. The point in time has arrived when a decision must be made to either refurbish the structures at a substantial cost in the immediate future, or to allow further deterioration to the point where a complete rebuilding, at a considerably greater cost, will be required. The replacement of the lock and dam would bring on a further complication of requiring a consideration of the fate of the public-owned electric power plant at the dam.

7. It is believed that restoration of the lock and dam can extend its useful life for many years. This is very important in light of the importance of the lock and dam, as has already been explained, and in light of the vast amount of money which is now necessary for the replacement of a large structure of this kind. In fact, the cost of large construction projects is becoming exorbitant, and the funding for their replacement is increasingly difficult to obtain. Troy lock, dam, and gated spillway can deteriorate to the point where replacement is necessary; a few portions already have reached this stage.

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* A table of factors for converting inch-pound units of measurement to metric (SI) units is presented on page 4.

Historical background of Troy Lock and Dam

8. The Hudson River originates in the Adirondack Mountains in northern New York State among the highest peaks of the Adirondack range near Mount Marcy (5344 ft above mean sea level (msl)). It flows generally south into the ocean at New York City and is over 300 miles in length.

9. First improvements of the Hudson River were made by the State of New York in 1797. Shortly thereafter, construction of a State Barge Canal System was proposed and the original canal was completed in 1825 linking Buffalo, in the western part of the state, with New York City.

10. First improvements of the Hudson River were started by the Federal Government in 1834 (House Document No. 189--22nd Congress, First Session), and the work has been continued by subsequent modifications to the present navigation project by the U. S. Army Engineer District, New York (NYD).

11. The Hudson River Lock at Troy, N. Y., is located in the section of the Hudson River under improvement, extending from New York City to Waterford, N. Y., a distance of about 156 miles. The Hudson River is tidal to Troy Lock and Dam with a mean tidal range downstream of the lock of 4.8 ft during the navigation season, which has an average duration of approximately 250 days (from about 31 March to 15 December).

12. The present improvement of the Hudson River provides for a 32-ft-deep channel from New York City to the Port of Albany, a distance of about 150 miles. This allows deep draft, oceangoing vessels access to a major inland port with modern facilities, including tank farms, a lumber yard, a large grain elevator, and a rail yard. Shallow draft vessels ply the remaining system of rivers, lakes, and canal sections to deliver various products throughout not only the tributary areas, but also the Great Lakes.

Objectives

13. The first phase of study consisted of a condition survey (Pace 1978). The second phase was to determine in more detail the

actual condition of the lock and dam. This was accomplished by:

a. A coring program which gave profile depths of deteriorated concrete and representative engineering properties of:

   (1) Concrete in the lock, dam, and headgate section.

   (2) The foundation under the lock and dam.

b. The profile depths of deteriorated concrete allow:

   (1) An evaluation of rehabilitation or replacement of each part of the structure.

   (2) Accurate means of making estimates for the rehabilitation process.

c. A detailed stability analysis which permits an evaluation of the stability of representative monoliths of the structure in relation to present-day criteria and to develop remedial actions.

d. An evaluation of any areas of critical stress.

e. General recommendations for the rehabilitation of the lock and dam. The recommendations include:

   (1) Cause of deterioration and depth of removal of deteriorated concrete.

   (2) Method of removing deteriorated concrete.

   (3) Methods of bonding and replacement of deteriorated concrete.

   (4) Rehabilitation necessary to eliminate stability inadequacies.

Scope

14. This report makes conclusions about the condition of Troy Lock and Dam and gives general recommendations concerning its rehabilitation.

PART II: CONDITION SURVEY RESULTS

15. The geometry of Troy Lock and Dam is presented in Figures 4 through 6.

16. Initial observations of Troy Lock and Dam give misleading impressions of structural deficiencies (Figures 7 through 17). As is apparent, there are significant deterioration deficiencies which are important in relation to structure rehabilitation. The Phase I study revealed (by ultrasonic investigation) that in general the interior concrete of the lock is sound and of sufficient strength. The concrete cracking in the lock and dam is negligible and is insignificant in the headgate section except for:

- a. The pier which allows access to the dam tunnel on the powerhouse side of the river.
- b. The piers of the gated section which allow water to enter the powerhouse.

17. The lock and dam monoliths show no signs of stability problems.

18. The water below Troy Lock and Dam was tested, and it did not contain any substances which would be detrimental to the concrete.

19. Detailed analysis of the cause of the concrete deterioration will be presented in Part IV of this report. Conclusions are drawn based on the findings of concrete deterioration, stability analysis, and stress analysis. Engineering judgment is then used to ascertain the needs for rehabilitation of the lock, dam, and headgate section in Parts VI, VII, VIII, and IX.

PART III: CORING PROGRAM

Introduction

20. The condition survey (Pace 1978) determined from ultrasonic test results and visual observations that in all probability the interior concrete in Troy Lock and Dam is of good strength and cracking in the lock and dam is structurally insignificant. The ultrasonic results gave a general indication of the quality of the concrete in locations where each side of the structure was accessible and the characteristics of a pulse could be determined when sent on one side of the structure and received on the other. The velocities of the ultrasonic pulse must be correlated with results from concrete core tests that are in the same general location to accurately relate the ultrasonic data to given concrete strengths; therefore, representative cores were obtained to verify the properties of the concrete and foundation.

21. The main objective of the coring program was to obtain representative samples of concrete, foundation, and backfill, which were used to determine the engineering and characteristic properties and the degree of uniformity for representative areas of the structure, backfill, and foundation.

Plans for Coring Program

22. From the condition survey determinations, the 6-in. coring program was oriented toward the following considerations:

- a. Coring in the backfill behind the land wall monoliths to obtain samples for determining average backfill density and characteristics. Backfill characteristics will be used to estimate reasonable horizontal pressure coefficients.
- b. Six-inch cores of the concrete to determine:
  - (1) The depths of deteriorated concrete over the lock, dam, and gated spillway by representative coring. The representative depths of deteriorated concrete determined from the concrete cores allow depths of deteriorated concrete removal to be determined.

This gives necessary information to determine if it is better to rehabilitate or replace various parts of the lock, dam, and gated spillway and gives accurate data for making estimates for replacement or rehabilitation.

(2) Representative samples of deteriorated concrete for analysis and a determination of the cause of deterioration.

(3) Engineering properties of the concrete, below that which is deteriorated and will be removed in the lock, dam, and headgate section, for stability and stress considerations.

(4) Interaction properties of the concrete and foundation for stability analysis.

(5) In general the as-built imbedment depths of the concrete monoliths into the foundation material.

(6) Remedial action for the concrete in the lock, dam, and headgate section.

c. Six-inch cores of the foundation to determine:

(1) Engineering properties of the foundation material under the lock, dam, and gated spillway for use in stability and stress analyses and for a determination of remedial stability measures.

(2) Geological characteristics of the foundation material (discontinuities, bedding planes, and their orientation, weak seams, etc.).

(3) Properties to judge the adequacy of the foundation for the next 100 years.

23. Because of the deterioration and rock size in the mass concrete structure, it was decided to obtain 6-in. cores. Many times, smaller cores cannot be recovered and even if they are recovered, property determinations are at best questionable. As the coring program progressed, it became apparent that 6-in. coring was essential for sampling both the concrete and foundation.

24. An overall view giving the core locations in the backfill, lock, dam, and gated spillway is presented in Figure 18. The core locations, which are presented, are those that were finally drilled after reflections and evaluations as the program proceeded. The initial coring plan was analyzed and updated to reflect information learned from

previous cores. A more detailed location of the coring is presented in Part V.

25. Certain cores were taken through representative lock and dam monoliths and into the foundation, and others were taken for a depth sufficient to extend below the deteriorated concrete.

26. Due to uniformity of concrete in certain portions of the lock and dam, certain cores were eliminated and due to nonuniformity of concrete in other locations, additional cores were taken.

27. Table 1 gives the purpose of the core obtained from the various core holes.

28. The final coring plan gives what is considered a minimum but adequate coverage of the backfill, lock, dam, and gated spillway to make the evaluation and plans for rehabilitation of Troy Lock and Dam.

29. The petrographic analysis and core logs are presented in Part IV. The test specimen selection, engineering properties, and test results are presented in Part V. The analysis of the backfill, concrete, and foundation properties are presented in Part VI.

Coring Operations

30. Core drilling began on 1 October 1979. Drilling equipment consisted of two skid-mounted rotary drill rigs (a Toredo Mark II-Acker and a Sprague and Henwood, Model 40-CL). Six-inch ID by 7-3/4-in. OD diamond core bits and 5-ft-long double-tube, swivel-head core barrels were used to drill the vertical concrete and bedrock cores. An electric-motor-driven Concore Model 110 rig (6-in. ID by 6-1/2-in. OD single-tube core barrel) was used to drill the horizontal cores.

31. Typical drilling operations are shown in Figures 19 and 20.

32. The holes in the backfill material were drilled with the skid-mounted rotary drill rigs. The backfill was mainly of cohesionless material with the inclusion of large rocks that made it almost impossible to obtain undisturbed samples for testing. The backfill material was sampled and the samples preserved.

Preparation of Cores to Preserve In Situ Characteristics

33. After the concrete and foundation cores were drilled, they were logged, photographed (a complete set of photographs is available at the NYD office), and then wrapped with plastic and waxed with a lukewarm mixture of 50:50 microcrystalline and paraffin wax. Examples of the cores as sampled are given in Figures 21 and 22; a complete set of photographs was obtained of the cores. The cores were then embedded in sawdust inside a core box. The core boxes were stored in a building where the temperature was kept well above freezing. The above measures were taken because it is necessary that the cores be prepared and stored such that their engineering and characteristic properties are preserved as sampled in the field.

34. The backfill material was sampled and preserved in the same manner as the concrete and foundation. Only enough undisturbed backfill material was obtained to get in-place densities. The backfill is very random including rocks and varying amounts of sand, shale, slate, and other materials. The large rocks and cohesionless characteristics of the backfill material made it impossible to obtain representative undistrubed samples for testing.

35. After all cores were drilled, logged, and stored, they were then transported from Troy, N. Y., to the U. S. Army Waterways Experiment Station (WES) in a 40-ft covered van. The 40-ft van was filled with approximately 30 cu yd of sawdust before leaving WES. The core boxes were loaded in the van on top of a foot or more of sawdust and then they were covered with a foot or more of sawdust. The core boxes were loaded in the morning, and the van was driven back south the same day to avoid the chance of being caught in freezing weather. The cores were kept well above freezing while being shipped and were placed in the controlled environment of the laboratory upon arrival at WES. From all indications, the care taken with the core was adequate.

Core Logging

36. The cores had been logged in the field but for an independent evaluation they were logged in the laboratory. The two loggings were necessary because each environment has its advantages and disadvantages. The best effort can be obtained by a combination of the advantages and by an evaluation of the field logs in the laboratory.

37. The field environment allows:

- a. Drilling conditions as have affected the core to be noted.
- b. Immediate evaluation of the core in relation to drilling conditions.
- c. Immediate evaluation of a core when characteristic features are as just sampled.
- d. Mapping of all cores immediately after sampling by photographs to give the opportunity for later study.
- e. Immediate evaluation of breaks, core losses, etc., in relation to drilling operations.

38. The laboratory environment allows:

- a. A concentrated analysis by personnel skilled in logging, deterioration evaluation, and representative specimen selection.
- b. Laying several concrete cores out at the same time for observation, comparison, logging, and test specimen selection.

39. During logging, specimen selection, and geological feature evaluation, the foundation material was kept damp at all times and not allowed to be exposed to the environment except for short periods of time.

40. Before logging, to determine how sensitive the foundation material was to deterioration in the atmosphere and deterioration in the fog room environment, samples were placed in the air and in the fog room, and detailed observations were made of the specimens during the day to check for slacking or any other deterioration effects. The slaty-shale is very competent to deterioration and showed no detrimental effects within a day while subjected to either environment. After

several days, some deterioration could be denoted of the specimens exposed to air. No deterioration of the specimens after several days' exposure in the fog room environment could be detected.

41. The foundation material was not real sensitive to environmental changes; therefore, it was concluded that only several minutes' exposure for logging, then wrapping with a damp cloth, and then resealing the specimens after an hour should be adequate to preserve their in situ characteristics.

PART IV: CORE LOGS AND PETROGRAPHIC REPORT

Samples

42. Fifty-seven cores were taken from concrete at the Troy Lock and Dam on the Hudson River, N. Y.

43. Thirty-two of the cores were taken from either horizontal or inclined holes. The remaining 25 cores were taken from vertical holes. Eight of the vertical cores were drilled through concrete and into foundation material. The cores are identified in Table 2.

Test Procedure

44. All of the material shipped from the 57 core holes was examined. The quality and the condition of the concrete and foundation rock were noted. Representative pieces of concrete that contained visual evidence of poorer quality concrete or significant reaction products were taken for more detailed examination.

45. Samples for physical tests of concrete were taken from sound material. The concrete was considered deteriorated when the concrete appeared cracked and fragmented. If the core fell into fragments when struck gently several times with a hammer it was considered deteriorated.

46. Samples of foundation rock for physical property determinations were taken from near the top of the rock contact with the concrete, from the middle of the rock portion of the core, and near the lower end of the rock.

47. Detailed examination of the rock included examination of samples of rock from each core that contained foundation rock by X-ray diffraction and with a stereomicroscope. Samples from the top, middle, and bottom of the rock in core RW-37 were also examined by X-ray diffraction to determine the ranges in composition.

48. Cement paste concentrates were prepared and examined by X-ray diffraction. These were obtained from samples judged to represent deteriorated and nondeteriorated concrete. The paste was concentrated

by gentle crushing of concrete and passing the fragments over a 150-μm (No. 100) sieve. The material finer than the sieve is then ground before examination. Samples of the white reaction product found in some voids and lining open fractures in the concrete were examined using a stereomicroscope, by X-ray diffraction, and as powder immersion mounts using a polarizing microscope.

49. All X-ray patterns were made with an X-ray diffractometer using nickel-filtered copper radiation.

Results

50. Original concrete representing the concrete used in constructing the lock was easily distinguished from later concrete used in overlay repair work. The features that were used to make this distinction will be reported later. The coarse aggregate in the original concrete was a natural river gravel of mixed composition, consisting of silica-bonded sandstone, vein quartz, graywacke, siltstone, gneiss, and miscellaneous fine-grained, dark rock particles. Impurities included pieces of coal and wood.

Vertical cores, land wall

51. The general physical condition of the six concrete cores (LS-1, LW-1, LW-4, LW-5, LW-18, LW-22) from the top of the land wall are shown in Figure 23. Three of the six cores in this group were from an area that had been resurfaced with air-entrained concrete. The overlay concrete was made using a 3/4-in.-max size crushed igneous rock, probably dacite, as coarse aggregate. In all cases the old concrete directly below the overlay was damaged due to frost action.

52. The concrete from cores LW-18 and LW-22 did not show damage other than a vertical crack to a depth of 0.4 ft in LW-18. One of the other four cores in this group contained deteriorated concrete to a depth greater than 5 ft (LS-1). The other three cores (LW-1, -4, and -5) which contained the concrete overlay showed damage from 0.7 to 3 ft deep.

Horizontal cores, vertical face of land wall

53. Of the six higher elevation cores (Figure 24), three (LS-2,

LW-17, and LS-21) did not reveal any deterioration. Two of these cores (LW-17 and LS-21) were old concrete while core LS-2 consisted entirely of overlay concrete. Core LW-3 in this group contained deteriorated concrete to a depth greater than 2.6 ft. The other two cores (LW-7 and -9) contained deteriorated concrete to a depth less than 1.0 ft. Core LW-3 contained a longitudinal crack at the bottom of the core with no surface trace of the crack. Stress causing this crack was normal to the stresses generated by freezing and thawing. Figure 25 illustrates the deterioration of the concrete in the upper land wall gate monolith (monolith 3).

54. All of the four horizontal concrete cores (LW-8, -10, -16, and -20) in the lower portion of the land wall were in good condition. The surface of the concrete appeared to be slightly roughened resulting in coarse aggregate standing in relief as illustrated in Figure 26. The removal of the surface aggregate particles may be the result of either physical weathering or chemical solution, or both.

Vertical cores,river wall

55. The six river wall cores (Figure 27) were identified as RW-CON, RW-27TS, RW-37, RW-55, RW-60TS, and RW-65TS. Cores RW-CON, RW-27TS, and RW-37 were topped with a concrete overlay. RW-CON was the only one of the three that did not show deterioration below the overlay. Core RW-27TS, aside from its intact overlay, showed damage for its depth of 3.0 ft while core RW-37 showed about 1 ft of damage beneath its intact overlay. The type of damage is shown in Figure 28 and is believed to be due to frost action.

56. Core RW-37 also contained some white alkali-silica reaction gel in fractures at various depths. The gel was associated with silica bonded sandstone. Most of the white secondary reaction product coating these cracks was ettringite.

57. Most of core RW-27TS was recovered as rubble.

58. The other three cores in this group (RW-55, RW-60TS, RW-65TS) did not contain an overlay. RW-55 contained a shallow longitudinal crack at the top surface which may have been due to drying shrinkage. While inspection of this core did not indicate significant damage to

the concrete, examination of Figures 29 and 30 shows cracking. These pictures show adjacent pieces of RW-55 at about 12 in. down from the top concrete surface. The sawed and ground surfaces were impregnated with epoxy resin containing a fluorescent dye. The use of ultraviolet light as illustrated in the photographs revealed fine cracking for the full depth shown. In addition to providing additional information about cracking in the concrete this technique suggests that there is probably some frost damage cracking in all of the old concrete.

59. The concrete in cores RW-60TS and RW-65TS was deteriorated to depths of 1 ft and 2.7 ft, respectively. The deterioration of this concrete is assumed to have been caused by frost action.

Horizontal cores,
land face of river wall

60. A total of 11 cores (Figure 31) came from the face of the river wall. Six of the cores were from higher elevations of 14 to 21 ft (RW-27, RW-34, RW-35UP, RW-37UP, RW-44UP, and RW-50UP). Two of those cores were drilled completely through the wall (RW-27 and RW-50UP), and the river wall side of these will be described later. Cores RW-27 and RW-44UP were the only two from the group that did not show deteriorated concrete; RW-27 did contain a longitudinal crack from its surface to a depth of 1 ft, which may have been due to drying shrinkage. The other four cores from the upper elevation show different depths of deterioration with a maximum of 4 ft for core RW-50UP. Cores RW-27, RW-34, and RW-35UP had white alkali-silica reaction gel coating some of the cracked surfaces.

61. The other five cores were from lower elevations of 3 to 6 ft (RW-37LP, RW-44LP, RW-50LSL, RW-60LS, and RW-65LS). Core RW-50LSL was in the worst condition with about 1 ft of damaged concrete. This appeared to be air-entrained. The other four cores contained less than 0.4 ft of damaged outer surface concrete. White alkali-silica gel was present along cracks in cores RW-37LP, RW-44LP, and RW-50LSL.

Horizontal and inclined
cores, river face of river wall

62. Figure 32 illustrates the condition of the four concrete cores

from two elevations in this wall (RW-27, RW-45, RW-50UP, and RW-62RS) with cores RW-27 and RW-50UP being the longer cores mentioned earlier. Depths of deteriorated concrete ranged from 0.8 ft for cores RW-27 and RW-45, 3 ft for core RW-62RS, to 6.8 ft for core RW-50UP. The deterioration of the first 4 ft of concrete in core RW-50UP was apparently caused by frost damage. The remainder of the damage was believed to be due to a combination of frost damage and alkali-silica reaction. The criterion used for this distinction was that frost damage tends to develop cracking parallel or sub-parallel to the exposed surface whereas the chemical reaction does not tend to develop this oriented cracking pattern. Inspection of this long core in Figure 32 shows that only about 2 ft of its interior was classed as intact. Cores RW-45 and RW-62RS were inclined 60 deg.

Vertical cores, top of dam

63. Ten cores (Figure 33) were taken from this general location (D-6, D-10, D-12, D-14, D-16, D-33, D-42, D-52, and D-59). Two of them went through the concrete and into the foundation rock (D-14, D-33). Core D-6 was the only one that showed significant deterioration of the subsurface concrete; this was 1.2 ft. All of the surface concrete had exposed coarse aggregate.

Vertical and inclined cores, toe of dam and headgate tunnel entrance

64. Six cores were taken from the toe of the dam (DA-1, DF-4, DF-8, DF-14, DF-27, and DA-48) and one from the east side of the monolith at the end of the dam on the powerhouse side of the river (HG-1) (Figure 34). Cores DF-4, -8, -14, and -27 were drilled at an angle of 30 deg. Core DA-1 extended into the foundation rock. All of the surface concrete showed etching of the paste; otherwise, the concrete was essentially undamaged except that core DA-48 showed some vertical cracking near its bottom. Some alkali-silica reaction gel was present in DF-14, and core DA-48 appeared to be air-entrained.

Horizontal and vertical cores, dam spillway piers

65. Five cores were taken from the headgate section of the dam

(Figure 35). Four of the cores were horizontal cores drilled into the piers (DSPL-1, -2, -3, and -4) and one was a vertical core drilled into the pier next to the ice chute (HG-2). All of the cores had some deterioration except for core DSPL-2. The depths of deterioration ranged from 0.6 ft (DSPL-1) to 3.7 ft (HG-2). Deterioration of the concrete was also observed in core HG-2 between depth 6.2 ft and 7.4 ft, below an old mortar-filled 6-in.-diam horizontal boring. A white reaction product coated most crack surfaces. Most of this coating was ettringite.

66. White alkali-silica gel was either layered or not in layers. The indices of refraction of some of the gel were below 1.488 while some were higher than this. The association of reaction product gel and reactive particles was difficult to establish. The white gel usually covered a crack surface and coated numerous particles. Silica-bonded sandstone and dark, fine-grained rock particles tended to be more often cracked and coated with gel than other particles, so they may be the reactive aggregates.

Foundation rock

67. The general condition of the foundation rock in seven cores is shown in Figure 36 (LW-1, LW-22, RW-37, RW-55, D-14, D-33, and HG-2). Cores RW-37 and HG-2 were the only cores in which some of the rock in the upper 5 ft was fragmented.

68. Fracture near the contact of concrete and foundation rock was always in the rock. Some foundation rock was embedded in the concrete as shown in Figure 37.

69. The foundation rock was a slaty-shale composed primarily of chlorite, vermiculite, clay-mica, quartz, plagioclase feldspars, and dolomite. Some calcite, pyrite, and potassium feldspar were present in some of the samples that were examined. The composition of the rock samples was homogeneous within the cores and between the cores. No soft clay seams were observed.

70. Most of the fractures in the rock were along bedding planes as shown in Figures 38 and 39. The bedding dipped between 30 deg and 90 deg, but more commonly the beds dipped about 40 deg. Some of the beds

are deformed as shown in Figure 39. Many breaks were along slicksided, smooth, shiny bedding planes.

71. Some of the rock had a well developed closely spaced joint system perpendicular to the bedding plane. This joint pattern seemed to be isolated and was not continuous either vertically or horizontally.

Discussion

72. Since the structure was built before air-entrainment of concrete was required, it would be anticipated that cracking due to frost damage would be present. Such cracking and associated deterioration of the concrete was present and has been described for the cores by areas (Figures 23, 24, 27, and 31 through 35). An attempt was made to make a visual determination in each case of the amount of deteriorated concrete that was present. In addition, it was shown by the use of fluorescent dye and ultraviolet light on part of one core that some cracking damage was present even though the cracking was not readily detectable. Therefore, it seems probable that this would also be true for the other cores that did not show damaged concrete as defined in this report.

73. Examination of the groups of cores from the land wall, from the river wall, and from various parts of the dam indicated that about half of the 57 cores showed significant damage and deterioration of the concrete. This damage was usually confined to the upper foot of core, but in some cases ranged up to several feet. These depths of deteriorated concrete are shown in Figures 23, 24, 27, and 31 through 35. In several cases there appears to have been frost damage to the original concrete after it was covered with air-entrained concrete.

74. The surfaces of some cores were roughened by the erosion of mortar between coarse aggregate particles. This is regarded as the result of physical or chemical action, or a combination of the two. The damage is not significant.

75. Alkali-silica reaction was indicated by the presence of white gel coating some crack surfaces. It was not clear in many cases whether significant deterioration was caused by this reaction. The

presence of this reaction associated with interior longitudinal cracking in core RW-50UP indicated that the cracking was probably due to the reaction. There is thus some evidence that alkali-silica reaction has played a part in damaging the concrete in this structure. There was abundant ettringite coating most crack surfaces. No evidence of damaging sulfate attack was found.

76. Aside from damage due to frost action and possibly to alkali-silica reaction the concrete was generally uniform, well consolidated, and appeared to be in good condition.

77. The contact of concrete and foundation rock appeared to be tight and uniformly good as judged by the contacts that were seen. The foundation rock itself was a uniform, black slaty shale whose bedding was generally dipping about 40 deg.

78. No soft clay seams were found in any of the rock that was examined.

PART V: TEST SPECIMENS, ENGINEERING PROPERTIES, AND TEST RESULTS

Test Specimen Selection and Preparation

79. The selection of test specimens was first planned from the background knowledge of the structure and the coring. The concrete core from several core holes was laid out in the laboratory for an overall view and a comparative analysis. At this time the concrete core test specimens were selected. The foundation core was analyzed separately because it was kept unexposed to the atmosphere (except for short periods of time), kept damp, and then resealed.

80. Test specimen locations from the core which were drilled through the concrete and into the foundation are presented in Figure 40. Figure 40 presents all the test specimens from the deep holes except those which were selected for shear testing. To give a more detailed understanding of the locations of the core, the depth of deteriorated concrete, and the compressive strength in the approximately 3-ft-deep holes, Figures 18 and 41 through 45 are presented. The general locations of the cores are given in Figure 18. More detailed locations of the core for the land wall, river wall, and dam are given in Figures 41, 42, and 43, respectively. The depth of deteriorated concrete and the compressive strength below the deteriorated concrete are given next to the core hole number for the 3-ft-deep holes. Detailed locations of the core holes on the dam monoliths are given in Figures 44 and 45. Detailed locations of the core holes in the backfill are presented in Figures 46, 47, and 48.

81. Representative specimens in relation to structure and depth below the concrete surface were selected to give an overall view of the material properties of both the concrete and foundation. Test specimens from the approximately 3-ft core were selected just below the deteriorated concrete and were tested for unconfined compressive strength.

82. After the test specimens were selected:

a. The concrete core specimens were left unwrapped and kept in the fog room. They were soaked 40 hr before testing.

b. The foundation core specimens were sealed and kept in the fog room. They were kept and tested in their in situ condition.

83. The test specimens were then cut to orientation, size, and geometry for testing. For the compression, triaxial compression, and tension test, the specimens were cut with a diamond-blade saw and the cut surfaces were ground flat to 0.001 in.; specimens were checked for parallel ends and the perpendicularity of ends to the axis of the specimen. Electrical resistance strain-gages were used for strain measurements. Two each were employed in the axial (vertical) and horizontal (circumferential) directions. The modulus of elasticity, Poisson's ratio, and shear modulus were computed from the strain measurements. Axial specimen load was applied with a 440,000-lb capacity Universal testing machine. An example of a concrete core specimen being prepared for testing is given in Figure 49. An example of a foundation core specimen which has been tested is presented in Figure 50.

84. The shear specimens were prepared according to the testing and properties which were to be obtained:

a. Sliding friction shear tests - Concrete and foundation specimens were obtained as close to the concrete-foundation interface as possible. Horizontal planes on each were cut and ground flat. They were then tested in a direct shear apparatus under 2-, 4-, and 8-tsf confining pressure. This gave lower bound ϕ and c values for the analysis of sliding at the interface. No intact interface specimens could be obtained for testing. This was not due to poor contact at the interface; in fact, usually some shale was broken off and remained in the concrete at the interface (Figure 37, Part IV). Because of the difference in material properties, the drilling operation could not keep the two materials from breaking apart at the interface. An example of a specimen cut and prepared for testing is given in Figure 51.

b. Shear along bedding planes - The specimens were cut perpendicular to the bedding planes and prepared for testing. They were tested with 2-, 4-, and 8-tsf confining pressure. An example of this prepared specimen is presented in Figure 52.

c. Horizontal shear - Vertical core specimens were cut, ground flat, and sheared perpendicular to the axis of the core.

85. After the specimens were prepared for testing, the concrete specimens were placed in the fog room. The foundation specimens were coated with Protexo-Cote to seal them from atmospheric deterioration and also placed back in the fog room.

Concrete, Foundation, and Backfill Properties

Concrete and foundation properties

86. The engineering properties obtained and the standard tests used for testing both the concrete and foundation are as follows:

Property	Test Method
Triaxial strength	RTM* 202 (ASTM D 2664)**
Direct shear strength	RTM 203
Elastic moduli, E	RTM 201 (ASTM D 3148)
Poisson's ratio, μ	ASTM D 3148-72
Shear modulus	ASTM D 3148-72

* Proposed rock test method, Corps of Engineers, in review prior to publication.
** See appropriate, ASTM 1979 Book of ASTM Standards.

These properties should be obtained in order that sufficient data are available for any necessary stability or stress analysis which is presently required or for requirements which may develop as the analysis and rehabilitation progress. The index properties obtained for both concrete and foundation and the appropriate test methods used are as tabulated below:

Property	Method
Compressive strength, UC	RTM 111 (ASTM D 2938) (CRD-C 150)*
Direct tensile strength, T_s	RTM 112 (ASTM D 2936)
Tensile splitting strength, T_d	
Compressional wave velocity, V_p	RTM 110 (ASTM D 2845) (CRD-C 151)

(Continued)

* U. S. Army Engineer Waterways Experiment Station, CE, Handbook for Concrete and Cement, Aug 1949 (with quarterly supplements), Vicksburg, Miss.

Property	Method
Effective unit weight (as received), γ_m	RTM 109
Dry unit weight, γ_d	RTM 109
Water content, w	RTM 106

87. The structure-foundation interaction must be considered; therefore, the following properties and characteristics were obtained.

- a. Sliding friction and cohesion between concrete and foundation.
- b. Shear strength properties in relation to geological characteristics of the foundation.
  - (1) Shear strength along bedding planes.
  - (2) Horizontal and cross-bed shear strength.

88. The material properties of the test specimens from the deep holes are given beside the location of the test specimens in Figure 40. The type of test performed on each specimen is indicated to the left of the specimen location in Figure 40. The location of the cores which were drilled below the deteriorated concrete and their compressive strengths are given in Figures 41, 42, and 43. As can be seen from these figures, the testing program will give representative properties for any stability or stress analysis. The test data for not only the deep core but also the approximately 3-ft-long core are presented in Table 3. The test data for the shear friction, shear-along bedding planes, and horizontal or cross-bed shear are given in Tables 4, 5, and 6, respectively.

89. The Mohr circles for the triaxial tests on the foundation material are presented in Figures 53 and 54.

90. The unconfined compressive stress-strain curves for concrete tests are presented in Figures 55, 56, 57, and 58. The unconfined compressive stress-strain curves for the foundation material are presented in Figures 59 and 60. The stress-strain curves for the direct tension tests are presented in Figures 61 and 62 for the concrete and slaty-shale material, respectively. The deviator stress versus strain for the triaxial test of foundation material is presented in Figures 63 and 64.

91. The test setup for pullout resistance is sketched in Figure 65. Nine specimens were prepared obtaining representative samples of

foundation material of various predominant bedding plane angles.

92. The specimens were prepared as follows:

- a. A 6-in.-diam by ≈3.1-in.-long core (allowing ≈45 deg failure cone in the foundation material) was placed upright in the center of a 1-ft square mold.
- b. A concrete mixture having the average compressive strength of the slaty-shale foundation was placed into the mold embedding the core to its full height.
- c. The concrete acted as a resistance block allowing the rebar to be pulled.
- d. After the concrete had cured and attained the desired strength, a 1-in.-diam hole was drilled in the center of the foundation core.
- e. A No. 4 rebar was grouted the full depth of the core using a commercially available premix grout for anchoring bolts and dowels. (Prepared specimens are shown in Figure 66.)

93. After the grout had cured sufficiently the bars were pulled using the setup depicted in Figure 65. A specimen after being tested is shown in Figure 67.

94. From careful observations of the foundation core, it was found that even though there was a predominant bedding plane angle the orientation of the planes changed a great deal within a single specimen. The predominant bedding planes dip downstream, which causes posttensioning in an upstream or transverse direction to the river to have relatively large angles with the bedding planes. For example, a 60-deg bedding plane with a 45-deg posttensioning upstream would result in a 75-deg angle between the posttensioning and the bedding plane. Transverse posttensioning is not as straightforward in its embedment but due to the random orientation of bedding planes and the three-dimensional shear environment producing stress fields radially across bedding planes, the pullout tests give allowable resistances which are applicable.

95. As seen from Table 7 the pullout strength decreases as the angle of embedment steepens. The mode of specimen failure is given in Table 8. Using a pullout resistance of 18,000 lb/ft and a safety factor of 2, an allowable of 9000 lb/ft is obtained for the specimens tested. The pullout resistance of the slaty-shale foundation material is

$$\frac{9000\ \text{lb/ft}}{\text{Area between grout and foundation}} = \frac{9000\ \text{lb/ft}}{37.68\ \text{sq in.}} = 240\ \text{psi}$$

96. The backfill was mainly of cohesionless material with the inclusion of large rocks which made it impossible to obtain undisturbed samples for testing. The backfill material was sampled and only enough undisturbed material was recovered to obtain various densities of the random backfill material. The dry unit weight of the backfill material varied from 100 to 122 lb/ft^3. The greater unit weights had rocks in the sample. An average dry unit weight of 115 lb/ft^3 was used in the analysis. The saturated unit weights varied from 115 to 144 lb/ft^3. Most values were between 140 and 144 lb/ft^3. A value of 144 lb/ft^3 was used in the stability analysis to be conservative.

PART VI: CONCRETE INTEGRITY, FOUNDATION INTEGRITY, AND MATERIAL PROPERTIES TO USE IN ANALYSIS

Concrete Integrity

Introduction

97. In general, the nondeteriorated concrete is uniform in quality, but certain distinct areas of lock, dam, and headgate section comparatively have more deteriorated concrete. The cores were used to locate and quantify the strength and deterioration in various areas. The compressive strengths are presented with depths for the cores which extended through the entire monolith in Figure 40. The unconfined compressive strengths for the core tests below the deteriorated concrete are presented in Figures 41, 42, and 43. The listing of material properties, except shear strengths, is given in Table 3. The shear strength data are given in Tables 4, 5, and 6.

98. Four specimens (31, 51, 53, and 63) were selected within depths of concrete which were later considered deteriorated. Specimen 31 (2910 psi), 51 (4000 psi), 53 (3190 psi) and 63 (5850 psi) had compressive strengths from below to above the average value and, therefore, had little effect on the average compressive strength. The compressive strengths of the interior nondeteriorated concrete, in general, varies from 4000 to 5000 psi and are very adequate for the gravity structure. When the compressive strengths of the above four specimens are eliminated, there is no trend of concrete strength variation with depth or for various sections of the lock and dam. With the above four specimens eliminated, the average compressive strength of the concrete just below that which is deteriorated for the lock and dam is approximately 4400 psi.

99. For the concrete core which was drilled through the concrete monoliths, the compressive strengths do not vary significantly with depth; therefore, if the deteriorated surface concrete is removed, a consistent durable concrete interior is left for effective rehabilitation. In Troy Lock and Dam, where frost action is the major cause of deterioration, the modulus of elasticity and Poisson's ratio are probably

better indications of deterioration than compressive strengths and can be seen (Table 3) to indicate deterioration at the surface in core LW-22 and especially in core HG-2. The concrete properties which were used in the analysis are presented in Table 9.

100. The tensile strength of the concrete is low and is less than 10 percent ($\approx$6 percent) of the unconfined compressive strength. This is mainly because of the large aggregate in the cores and because of a development of poor bond between aggregate and matrix because of a white reaction product (alkali-silica reaction and ettringite). An example of a specimen failed in direct tension is presented in Figure 68. The average tensile strength is 247 psi and the average compressive strength is 4400 psi. This indicates that pullout tests should be performed in the field for dowels used to securely anchor overlays to be sure of a depth which will develop the strength of the reinforcement.

101. For the comparative results some tensile-splitting tests were performed as well as direct tension tests. The average value for the direct tension tests was 198 psi and for the tensile-splitting test was 295 psi. The tensile strength of the nondeteriorated concrete is adequate for the gravity structure and is expected to remain adequate.

102. Frost damage is the main deteriorating effect on the lock, dam, and gated spillway. If the headgate monoliths on the power house side of the river are made structurally sound and durable they should be in excellent condition for future service.

103. The sliding friction of precut concrete on shale gives lower bound values of ϕ and c. Since the actual sliding friction value cannot be obtained these values should be used in the stability analysis because they are on the conservative side. The values are given in Table 4. From this table the values to use in this analysis are

$$\phi = 30 \text{ deg} - 24 \text{ min}$$
$$\text{and } c = 0.04 \text{ ksf}$$

These values are probably very close to residual values and are, therefore, adequate for analysis purposes.

104. The ϕ and c of the foundation material as obtained from triaxial tests range as follows:

ϕ between 42 and 50 deg

c between 10 and 230 psi

From shear tests along the bedding plane, ϕ is approximately 59 deg at ultimate, and c is approximately 9.4 ksf. The intact specimens of foundation tested in direct shear had a ϕ of approximately 63 deg and a c of approximately 27 ksf. The ϕ and c along the bedding planes under normal load have competent values. The bedding planes are steep and, therefore, do not pose a threat to stability. There were no seams of weak material within the foundation.

105. The sonic velocities as obtained in the field are presented in Pace (1978). They are in very good agreement with those obtained from the core in the laboratory. They correlate with compressive strengths between 4000 and 5000 psi. No ultrasonic data were obtained for the monoliths upstream of the upper gate on the landside or for the headgate section where some badly deteriorated concrete was found to exist by the coring program. The ultrasonic results are somewhat lower than normal through the top of monoliths R-46 through R-50 which indicates that the concrete in this area is of lower quality and is in agreement with the extreme deterioration of 6.8-ft found on the riverside of monolith R-50.

Deteriorated concrete

106. Land wall. Certain portions of the lock, dam, and gated spillway have greater depths of deteriorated concrete than others. The deterioration of the upstream land wall monoliths (L-1, L-2, and L-3) is 1 ft for the top surface and 3 ft or greater for the riverside surface. Core LS-1 was 3 ft from the river face of L-1 and, therefore, the 5-ft deterioration depth was probably reflecting a 3-ft depth from the river face. The concrete in the upper gate monolith L-3 must retain its integrity at the location of the gate anchors or problems will begin to occur with the operation of the upper gate. In the area of core hole LW-3, it was not possible to get intact concrete. The depths of

deteriorated concrete decrease with an increase in distance downstream of the upper gate monolith. The probable depths of deteriorated concrete are presented in Table 10.

107. Water and backfill material are coming through the landside culvert wall of monolith L-5 (Figure 69) which indicates that some portion of the concrete in this culvert wall is not of sufficient quality and must be evaluated and replaced as the rehabilitation progresses.

108. The construction joints and the few cracks which exist in the land wall monoliths are not a problem and need not be repaired (Figures 70 and 71). A core (LW-1) was taken next to a construction joint and it was found that the interior concrete at the joint was as sound as the interior concrete away from the construction joint. The replacement of the deteriorated concrete surfaces and the preparing of good construction joints in the overlay should be sufficient. There is some problem with pieces of surface concrete coming loose and posing a potential hazard by the possibility of falling on people passing through the lock; the surface concrete rehabilitation will eliminate this problem.

109. The deterioration at the filling and emptying culverts and along the base of the monoliths (Figure 9) will be eliminated by surface concrete rehabilitation and reaction block construction at the base of the monoliths.

110. River wall. The same general condition exists for the river wall monoliths in that there are greater depths of deteriorated concrete in the upstream portion of the wall. There is one difference in that the exposure of the river face of the wall has caused deterioration to range from about 1 ft to over 6 ft. The probable depths of deteriorated concrete are given in Table 10.

111. The construction joints (except as noted below), deteriorated concrete at the monolith base inside lock chamber, and cracking should be treated the same as for the land wall.

112. There is one construction joint in the river face of the river wall (Figure 12) which is leaking and should be filled with a nonshrink mortar.

113. Dam. The exterior surface of the dam has very little deteriorated surface concrete. What deterioration has occurred has been eroded away. The rehabilitation of the surface by cleaning, preparing, and patching holes with nonshrink concrete, reinforcing, and placing a durable 3-in. reinforced overlay over the surface will be adequate.

114. Headgate section. The concrete in the gated spillway of the headgate section is cracked and badly deteriorated. These sections are not of sufficient thickness to have deteriorated concrete removed and replaced. The sections of the total headgate starting at the end of the dam should be removed to an elevation where the concrete is not deteriorated and should be replaced using doweled connections between the old and new concrete. These replaced sections should be adequately reinforced. Replacing the upper portion of these sections will give a rehabilitation of sound engineering background.

115. All compressive strengths of nondeteriorated concrete are more than adequate for the gravity structure and will serve adequately as a basis for an effective rehabilitation.

116. It is recommended that control blasting be used to remove 1-ft deteriorated concrete from the chamber faces of the land and river walls except for areas below the tops of filling and emptying culverts. Where the concrete thickness is 5 ft or less, a chipper must be used. Blasting cannot be used in locations where water can act as a confining pressure because the water will cause coupling of energy into the concrete monolith and cause damage to the nondeteriorated concrete. If any isolated area of deterioration remains, it can be removed by a chisel point chipper. (For more details see Part VIII.) It is not necessary to remove the total depth of deteriorated concrete from the horizontal surface of the land and river walls. A 1-ft-deep removal of concrete and a reinforced overlay will be adequate (see Part VIII for more details). For the remainder of the lock, the deteriorated depth of concrete is variable (Figures 41 and 42) and it is suggested that the contract allow this removal to be bid on a per-cubic-yard basis.

117. The dam has almost no deteriorated concrete; therefore, the surface can be cleaned with some removal of concrete and an erosion

resistant overlay applied. Some of the dam surface has been eroded away; therefore, a 3-in. overlay will not raise the pool higher than that which existed originally.

Foundation Integrity

118. There is very little information concerning the foundation material below Troy Lock and Dam. The borings taken before the lock and dam was constructed were through the overburden material and only down to the slaty-shale foundation. Previously determined properties of the foundation material could not be found. The foundation cores were evaluated as the coring program progressed and a minimum number of cores were obtained because of the uniformity of the foundation material. The bedding planes and their orientation is not a problem. Adequate properties for evaluation were obtained during the present coring programs. The unconfined compressive strength of the foundation material is very low and is very consistent with depth. An average unconfined strength is 902 psi, with a standard deviation of 482. A lower bound would be about 900 psi because with a confinement pressure of 100 psi its compressive strength is a little greater than 2000 psi. The tensile strength of the foundation material is very low. The average value is 43 psi.

119. The tensile strength of the foundation material is almost negligible from the 6- by 12-in. core tests and will be somewhat higher in its three-dimensional in situ condition; but, it will still be low and any posttensioning should be tested in the field for adequacy. Part VII determines that the bearing stresses and foundation properties are adequate.

PART VII: STABILITY ANALYSIS

Introduction

120. Even though structures have been in service for long periods of time, it is important that they be examined in view of present-day criteria and in relation to any deterioration experienced to assure continued structural adequacy. If the design or the deterioration makes the structures fail to satisfy current criteria, thereby producing unsafe or doubtful conditions of safety, the structure must be modified to conform to good engineering practice.

121. One of the main considerations for structural adequacy of a dam is stability of the various monoliths when subjected to possible loading conditions. The stability study involves analyzing selected monoliths to determine if they have adequate resistance against overturning, sliding, and base pressures. Only one monolith of each configuration and loading was analyzed; the conclusions based on these analyses are adequate for an evaluation of all monoliths.

122. In general, the stability study was done in accordance with the applicable portions of the following Engineer Manuals and Engineer Technical Letters.

- a. EM 1110-2-2502, Retaining Walls.
- b. EM 1110-2-2602, Planning and Design of Navigation Lock Walls and Appurtenances.
- c. EM 1110-2-2607, Navigation Dam Masonry.
- d. ETL 1110-2-22, Design of Navigation Lock Gravity Walls.
- e. ETL 1110-2-184, Gravity Dam Design Stability.

123. The adequacy of the structure to resist overturning can be judged by the location of the resultant with respect to the base of the section where stability is being considered, within the monolith, or at the base-foundation interface. In general, the gravity monoliths where stability against overturning is being considered are required to have the resultant of applied loads fall within the kern of the base of the section being analyzed when subjected to active earth pressures or for

monoliths not subjected to earth pressures. Resistance to overturning was considered adequate if the resultant fell outside the kern but 75 percent of the base was still in compression for normal operation, extreme maintenance or maximum flood case loadings using "at-rest" earth pressure coefficients. For operating conditions with earthquake, the resultant only has to fall within the base, but the allowable foundation stresses should not be exceeded.

124. The percent effective base (percent of the base which is in compression) is a good way to present where the resultant falls in a rectangular base section. It is a good guide for representing overturning resistance for any shape base. For example, for a rectangular base:

Percent Effective Base	Resultant Location Within Base
100	Within middle 1/3 or in kern area
75	At 1/4 points of base
50	At 1/6 points of base

125. Sliding resistance of a monolith is calculated by choosing a trial failure plane or combination of planes and calculating the resistance along this path. The critical section for sliding must be determined. It may be within the monolith, at the base-foundation interface, or at a plane or combination of planes below the base.

126. The resistance may be composed of several types. The sliding resistance due to friction and cohesion for horizontal surfaces between the monolith and its foundation is calculated by the shear-friction formula given in ETL 1110-2-184. The safety factor is obtained by dividing the horizontal resistance by the horizontal driving force. These formulas are inadequate for evaluating structural sliding on inclined planes. For inclined planes the safety factor is obtained by dividing the resistance along the plane by the driving force along the plane with any passive resistance taken into consideration to obtain the sliding safety factor. The sliding resistance due to all or any part of the failure plane extending through either the concrete monolith or the foundation is calculated from the shearing strength of the material acting over the length in which shearing occurs. If other restraints, such as strut action, exist, they must also be considered in the evaluation. An allowable

safety factor against sliding for the normal operation case is considered to be 2. For normal operation with earthquake, the safety factor should be equal to or greater than 1-1/3. Existing criteria (ETL 1110-2-184) require a safety factor of 4 for sliding in all cases except normal operation plus earthquake and construction conditions. For these case loadings the safety factor for sliding was reduced from 4 to 2. The safety factor for the normal operation plus earthquake condition was reduced from 2-2/3 to 1-1/3. Since the monoliths have not shown signs of instability during 65 years of service, it is felt that this reduction is satisfactory but that the safety factors of 2 and 1-1/3 are necessary for the assurance of safety under any unusual loading conditions.

127. The base pressures are the sum of the contact and uplift pressures on the concrete-foundation interface.

128. The allowable base pressures are goverened by the slaty-shale foundation. For this foundation, the conventional base pressure calculation should be within allowables because the foundation is relatively weak in bearing. The average unconfined compressive strength is approximately 900 psi. Using a safety factor of 4, the allowable bearing pressure is 225 psi or approximately 33 ksf. The safety factor of 4 is considered necessary for this weak, closely spaced bedding plane foundation. The triaxial test data show that there is a significant increase in foundation strength with increases in confining pressure (100, 200, 400, 500, 1000, and 1500 psi). The actual pressure created by a 40-ft height of concrete is 41.7 psi or 3 tsf. From an examination of the triaxial data and a consideration of the 41.7-psi actual pressure, it is still concluded that the allowable from the unconfined compressive strengths is the value which should be used in the bearing pressure evaluation.

Applied Loads

129. The lock and dam monoliths were investigated for three case loadings unless it was apparent that certain cases were not critical. The three case loadings are:

a. Normal operating condition:

(1) Upper guide, land wall, and lower guide wall monoliths: The most critical loadings of upper pool, lower pool, and saturation level in backfill were considered. Also, dead load, uplift, tow impact, hawser pull, wind, and gate loads were used when applicable.

(2) River wall monoliths: Normal lower and upper pools, uplift, impact, hawser pull, wind, and gate loads as applicable were considered in this case.

(3) For the dam, the most critical monoliths were analyzed. Normal operation plus accidental boat impact was also considered for the dam monoliths. A picture showing an actual case of accidental boat impact at Troy Dam is given in Figure 72.

b. Maintenance or dewatered condition: Backfill, gate, dead loads, and uplift were considered. The saturation levels in the backfill were considered as presented in Table 11. Impact, hawser pull, and wind loads were applied according to the situation.

c. Flood condition: Monoliths were checked for stability during maximum flood conditions. A picture of the lock during a flood is given in Figure 73.

130. The standard procedure was to analyze two-dimensional sections of unit depth except for a three-dimensional analysis of monoliths of nonuniform geometry and/or loading. All sections were viewed from upstream looking downstream. Forces acting toward the left, downward, and counterclockwise moments are considered positive.

131. The random backfill was mainly noncohesive, which made obtaining an intact sample virtually impossible. Tests on a remolded sample for "at-rest" pressure coefficients would not be reliable. This is partially true because of large pieces of rock in the fill, the effect of which would be hard to determine in any reasonable size test sample. The only way to get experimental values would be to make a number of tests at the lock and dam site, testing the actual backfill material in situ. The scope of this work in time and/or funding was such that this type of testing was impossible. On this basis, it was decided to estimate a lower bound value as follows. This lower bound was obtained by considering the value for sand from dense to loosely compacted as

0.45 to 0.55; for silt, 0.6; and for clay, from 0.7 to 1.0. The backfill behind Troy land wall monoliths contains some clay. It is reasonable, therefore, to use a lower bound but reasonable "at-rest" earth coefficient of 0.5.

132. Boat impact loads were applied on the basis of design loads used for locks previously constructed with considerations given in EM 1110-2-2602. The loads which were used are:

a. Lock chamber walls: 800 lb/ft but not less than 40,000 lb per monolith.

b. Other walls: 2500 lb/ft but not less than 120,000 lb per monolith.

The boat impact was considered as acting 5 ft above the waterline and was combined with the most severe normal loading conditions.

133. A hawser pull of 24,000 lb was applied 5 ft above pool height and was considered distributed over a monolith length of about 30 ft.

134. When considering gate load, hawser pull, impact loads, etc., which act on a localized area of the monolith, the loads were distributed on a per foot basis for the two-dimensional stability but is not accurate enough when considering stress because of localized stresses which may become critical in certain cases.

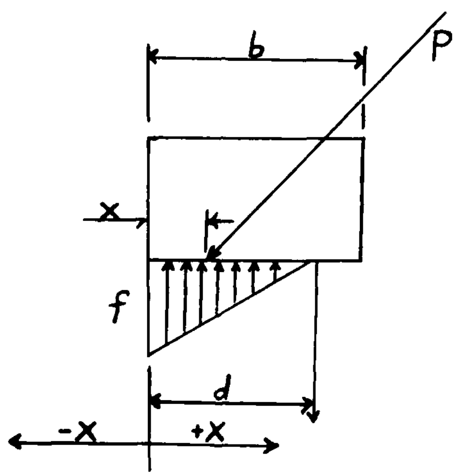
135. Ice load was considered as 5000 psi per sq ft and a 1-ft ice thickness used for the dam monoliths and a 2-ft thickness used for the headgate analysis. Ice loading during times of extreme ice jams and breakups can be as much as 2 ft on the headgate section due to sheets riding one over the top of the other and building up in thickness against the monoliths. The 2-ft ice thickness will not occur every year but if it does occur or if the dam experiences such a load by flowing pieces of ice breaking up and hitting a monolith as it passes downstream, the monoliths will have experienced this loading.

Analysis Considerations

136. There is no problem in engineering concepts if the total

base pressure is compressive because for massive-rigid structures it can be obtained rather accurately by $f = \frac{P}{A} \pm \frac{Mc}{I}$ considering the total area of the base. The problem arises when the monolith just rests on a foundation and part of the base is not in compression (tension in reality cannot exist). If the total base is used in the analysis when part of the area is noneffective (shows tension), the equilibrium equations are not even satisfied. The way to determine the base pressures is to consider only the effective part of the monolith base - that which is in compression. This will be done and the effective stress is derived below for a two-dimensional flat base structure.

137. Consider the resultant force "x" distance from the left toe of the monolith and solve the equation $f = \frac{P}{A} - \frac{Mc}{I}$ when the stress (f) equals zero.



$$\frac{P_y}{A} - \frac{Mc}{I} = 0 \tag{1}$$

$$\frac{P_y}{d} - \frac{\left(\frac{d}{2} - x\right) P_y \frac{d}{2}}{\frac{d^3}{12}} = 0 \tag{2}$$

solving $d = 3x$ valid for $b > d > 0$.

138. The above derivation is for a two-dimensional section with a unit depth of 1 ft. The stress is then:

$$(P_y)(x) = \frac{f(3x)}{2}\left(\frac{1}{3}\right)(3x) \tag{3}$$

$$f = \frac{2}{3}\ \frac{P_y}{x} \tag{4}$$

If the resultant falls outside the base, the monolith should begin overturning.

139. There are factors which are not sufficiently known to be dependable enough at this time to be justified in good engineering design. For example, such factors are:

- a. The force required to shear a failure wedge from behind the land wall monoliths as would have to happen for tilting of the monolith to begin.
- b. The base of the structure-foundation interface is assumed flat when in fact, it may be irregular and keyed together.
- c. A refinement in calculation and test method to obtain actual horizontal backfill pressure coefficients should be developed to more accurately obtain a horizontal soil force against the monoliths.
- d. The degree of uplift which is being used in the analysis may not be that which actually exists, although the actual value could be less or greater than that used in analysis. Full uplift of that at the edge of the monolith where noncompression began to develop must be applied under the noncompression area of the base. The same type analysis has to be performed for three-dimensional monoliths but the derivations get very complicated. For the analysis of the three-dimensional monoliths of Troy, computer programs were developed which would iterate and obtain solutions with full uplift under the nomcompressive area of the base.

140. There is no rigid body analysis criteria for calculating pressures when the resultant falls outside the base; all the pressure would be on the toe of the monolith, giving large pressures; therefore, a value of ∞ is given for these base pressures in Table 12. From past experience, the base pressures which are calculated by normal conventional design compare relatively well with those calculated at the

base-foundation interface by the finite element method when greater than 50 percent of the base is in compression. The comparisons become increasingly worse when a lesser portion of the base is in compression. The conventional analysis begins to give larger base pressures because the deformation characteristics of the structure and foundation are not considered.

Results of Stability Analysis

141. The summary of the results of the stability analysis is presented in Table 12. The stability analysis calculations are presented in Appendix A. The summary of the stability analysis after remedial measures is presented in Table 13. Table 14 presents the monoliths for which stability computations were performed and those for which these computations represent.

142. Certain monoliths of the lock and dam are inadequate for overturning and bearing pressures. Many monoliths for which stability was figured are very inadequate in their resistance to sliding.

143. A discussion of the stability of the individual monoliths is given below.

- a. Monolith L-1 is very inadequate in its resistance to overturning, sliding, and base pressures.
- b. Monolith L-2 is almost adequate in its resistance to overturning, but very inadequate in its resistance to sliding. The base pressures are below allowables.
- c. Monolith L-3 is inadequate in resistance to overturning, very inadequate in resistance to sliding, but the actual base pressures are adequate. The actual factor of safety against sliding is 0.84 versus an allowable of 2 for the dewatered condition with surcharge loads behind the monolith.
- d. Monolith L-5 is inadequate in resistance to overturning, very inadequate in resistance to sliding, and actual base pressure is inadequate. Even for the normal operation case with hawser pull, the actual percent effective base is 22 percent versus an allowable of 75 percent. The safety factor against sliding is 1.28 versus an allowable of 2 for the normal operation case with hawser pull and is 0.61 versus an allowable of

1.33 for the dewatered case with surcharge. Base pressures are not too bad except for the dewatered cases where the base pressure as calculated by conventional methods is ∞ .

e. Monolith L-12 is almost adequate for overturning but is very inadequate for resistance to sliding. Normal operation plus hawser has an actual safety factor against sliding of 1.42 compared to an allowable of 2. When the chamber is dewatered and surcharge loading is used, the actual safety is 0.83 compared to an allowable of 1.33. This is very critical. Bearing pressures are within allowables.

f. Monolith L-16 is inadequate in its resistance to overturning and sliding. Base pressures are below allowables.

g. Monolith L-20 is inadequate for overturning and very inadequate for sliding. Base pressures are adequate. Even for the normal operation plus hawser case the actual factor of safety for sliding is 1.30 compared to an allowable of 2.

h. Monolith L-24 is somewhat inadequate for overturning and very inadequate for sliding resistance. The base pressures are above allowables except for the normal operation plus earthquake case.

i. Monolith R-36 is inadequate in its resistance to overturning. The monolith is very inadequate in its resistance to sliding. It has an actual safety factor of 1.45 compared to an allowable of 2 for the normal operation plus hawser case and 1.14 compared to an allowable of 1.73 for the chamber dewatered case. Base pressures are below the allowable.

j. Monolith R-44 is adequate for overturning. It is very inadequate in its resistance to sliding. The case of normal operation plus impact has a safety factor of 1.58 compared to an allowable of 4. Base pressures are within allowables.

k. Monolith R-50 is almost adequate for its resistance to overturning. It is very inadequate in its resistance to sliding. It has a safety factor of 1.57 compared to an allowable of 4 for normal operation plus impact. Base pressures are within allowables.

l. Monoliths D-1 through D-33 are adequate in overturning (assuming apron not overstressed), inadequate in resistance to sliding, and have base pressures below allowables.

m. Monoliths D-34 through D-66 are adequate in overturning (assuming apron not overstressed), inadequate in resistance to sliding, and have base pressures below allowables.

n. The headgate monolith is adequate in stability.

144. The upper and lower river guide walls were adequate in stability.

145. During the coring program a piece of the rock anchor from under the dam (Monolith D-36) was obtained (Figure 74). It showed no signs of deterioration of the steel, grout or of the bond between the grout and foundation material. The cores showed good contact between the concrete monoliths and the foundation (Figure 28). With these facts in mind it was assumed that the rock anchors under the dam are effective.

146. Many monoliths are:

a. Very inadequate in their resistance to sliding.

b. Inadequate in their resistance to overturning.

c. Some have excessive base pressures.

147. The small inadequacies in base pressures were eliminated in the process of correcting overturning instability. Remedial measures are recommended in Part IX.

148. The monoliths are not adequate for sliding. Posttensioning could be used to provide the monoliths with adequate sliding resistance, but to keep the tensile stress in the monoliths as low as possible posttensioning should only be used to correct overturning deficiences while a reaction block is used to give adequate sliding resistance. The reaction block concept is presented in Part IX.

149. The remedial measures for overturning deficiencies will have to be accomplished by posttensioning. Only a portion of the actual posttensioning required is stressed into the anchors. The reason for not applying the total posttensioning is that, when and if the monoliths have a tendency to move, the strand will then develop the necessary resistance for adequacy in overturning. This way large stresses are not induced in the monoliths or culvert walls by posttensioning which could have a tendency to produce cracking and problems.

150. Soundings directly in front of the dam show some erosion which should be evaluated as the rehabilitation progresses and filled to prevent stability problems by undermining of the dam foundation. The scourer holes are as follows:

Monoliths	Scourer Depth Below Sill, ft
D-33 to D-35	8 to 9
D-44 to D-45	10
D-46 to D-66	8 to 10

PART VIII: FINITE ELEMENT STRESS ANALYSIS

Introduction

151. It is becoming increasingly important to understand the phenomenon of stress distribution in structures and not depend entirely on average stress approximations as has been done in conventional design. Knowledge of the total stress field is important in order that stress concentrations and decisions about stresses in the concrete as well as concrete reinforcement can be handled wisely and economically. Conventional analysis usually leads to a safe design but is inadequate in determining stress concentrations; therefore, regions may not be reinforced adequately to prevent undesirable cracking. In conventional analysis the whole stress field is not known and observations of stress concentrations cannot be delineated, studied, and reacted to properly. The finite-element analysis adds a new dimension or advantage in this respect. A finite element study does not make conventional design obsolete; in fact, it is a supplement, making a combination which is much better than either separately. It is important to consider stress distribution in areas of stress concentration when evaluating old structures which have cracked and are deteriorating. The finite element solution gives good results as long as the model adequately represents the actual situation and as long as any assumptions made can be seen to be logical or proven to be adequate.

152. The finite element analysis is used to get some idea of the magnitude of compressive- and tensile-stress concentrations within the monoliths before and after posttensioning to be sure the additional stressing does not adversely affect the structural integrity of the monoliths. Even though the total posttensioning is not stressed into the monoliths, it is assumed that it may be needed and the total load is induced into the monoliths for stress evaluations.

153. An important concept is that conventional posttensioning loads along the monolith length make the problem a three-dimensional analysis.

Finite Element Analysis Program

Introduction

154. A finite element analysis program called "SAP V" was used to compute the stresses in the structure and foundation. This program was designed and programmed to be an effective and efficient computer program for analyzing very large, complex, three-dimensional structural systems with no loss of efficiency in the solution of small problems. Twelve structural element types were included to increase the usability and flexibility of the program.

155. The capacity of the program is controlled by an "A" array containing 10,000 double precision words of storage for computers with large storage capacities. The size of this array can be changed to increase efficiency and the capacity of the program by increasing the value of "MTOT1" in a routine labeled SAP V of the program.

Input

156. Each node in the system is described by a location and a set of boundary conditions. The location is input as either cartesian (x, y, z) or cylindrical (r, z, θ) coordinates. The boundary conditions are defined by three translations and three rotations.

157. Each element in the system is described by a set of nodes and a material type. Other element input includes material properties such as Young's modulus of elasticity, weight density, coefficient of thermal expansion, material axis orientation, Poisson's ratio, and shear modulus.

158. Structural loadings are input as nodal and element loads. The nodal loads are applied as forces and moments. The element loads include thermal, gravity, distributed surface, and hydrostatic loadings.

Output

159. The solution output includes displacements and rotations for each unrestrained node and normal and shearing stresses at selected points for each element. Undeformed or deformed finite element grids can be obtained. The output units are the same as the input units.

Loads

160. In making stress calculations, the backfill was not used as part of the gridded medium. There were three reasons for this:

- a. Elaborate and costly tests of backfill material would be required to define the backfill properties precisely. This was not done because of the expense which would have been incurred and because of the random nature of the backfill. Also, at the time of sampling, the material properties for analysis were being obtained and the instability of the monoliths was not known; therefore, a costly evaluation could have been useless. Without a precise definition of the backfill, the vertical and horizontal backfill loads, which are obtained by using unit weights and a coefficient of at-rest-earth pressure, are within the accuracy of the study.
- b. The three-dimensional finite element grid would become very large.
- c. SAP V does not have the capacity to ignore tension between the structure and the backfill and with the backfill and structure gridded together, unrealistic tension may be created.

161. The density of the backfill material was used to get vertical loads. The coefficient of at-rest-earth pressure and the density of the backfill material were used to obtain the horizontal loads. The water pressure from saturation level was taken into account. The loads are then applied at node points of the finite element grid.

162. One consideration which must be made in the stress analysis is the effect of uplift on the base of the monolith. In certain cases the effect will be negligible, but in others it could be substantial. The important concept concerning uplift is that it is a support condition, and its effect (small or large) is dependent on its distribution and the thickness of the supporting element over which it is distributed. Specific loadings on a structure cause a specific distribution of pressure under the monolith base. The uplift will change this distribution, thereby affecting the support condition of the monolith. It can be seen that the pressure distribution under the monolith affects the stress in the structure only by deformations resulting from the support condition. By looking at free body force diagrams of a

monolith, in fact, a section an infinitesimal distance above the base (in rigid body analysis) can be taken and the upper part of the monolith considered as a free body. The analysis will then not even see the pressure distribution at the base; therefore, the distribution affects the stress analysis through deformations which are taken into account in the finite element study. Uplift could have significant effect where there are large culverts close to the base of the monolith and the distribution is such as to load the slab to increase stresses. The total distribution including uplift was used in the three-dimensional stress analysis.

Analysis and Results

163. A three-dimensional analysis was used to evaluate the stress distribution in Monolith L-5. Figure 75 presents a two-dimensional end view of the three-dimensional finite element grid. Monolith L-5 requires more posttensioning than any of the other monoliths which are to be posttensioned through the culvert wall and has the most irregular and thinnest section at the filling and emptying culvert where the posttensioning forces are to be applied. If Monolith L-5 is not overstressed, the other monoliths which are to be posttensioned through the filling and emptying culverts will not be either. From experience (Pace and Campbell 1978) the monoliths which are to be posttensioned vertically through the total monolith will not be overstressed with the required posttensioning loads.

164. Enough foundation material was gridded with the structure to allow adequate structure-foundation interaction to give accurate results. The boundary conditions are as presented in Figure 75. A three-dimensional slice of the finite element grid is presented in Figure 76. The total three-dimensional grid is composed of these sections which act monolithically.

165. The finite element analysis was performed with and without the posttensioning loads to see what effect the additional stressing produced. The case loadings analyzed were the normal operation condition and the dewatered condition with surcharge. Two posttensioning

situations were analyzed. Maximum stresses were found and evaluated. Figure 75 presents the elements which have maximum stresses. Maximum stresses before posttensioning are summarized in Tables 15 and 16. Maximum stresses after posttensioning for the normal operation and the dewatered case with surcharge are presented in Tables 17 and 18, respectively, for the condition of soil anchors through the top of the monolith. Maximum stresses after posttensioning for the normal operation and the dewatered case are presented in Tables 19 and 20, respectively, for the condition of posttensioning through the culvert walls.

166. The first posttensioning situation analyzed was to have the tendons placed through the top of the monoliths (Figure 77) and extend horizontally to soil anchors embedded a sufficient distance behind the monoliths. The finite element analysis (Tables 15-18) shows that this design is unacceptable because it created tensile stresses in the concrete of the lock face in the area of the filling and emptying culvert of approximately 152 psi, which is excessive in relation to $0.01\ f'_c$.

167. The second consideration (Figure 78) was to posttension vertically through the back of the monoliths when possible and to use anchors through the filling and emptying culvert walls when not possible. From experience (Pace and Campbell 1978), it is known that the stresses produced by posttensioning vertically through the monoliths will not be excessive for the required posttensioning loads. The finite element analysis showed that tensile stresses will only be increased by about 11 psi (Tables 15, 16, 19, and 20) by the maximum posttensioning loads stressed in the culvert walls. The tensile stress increased from 28 to 39 psi. This is considered acceptable when considering an allowable tension of $0.01\ f'_c$ giving maximum allowable tensile stresses of approximately 44 psi. The posttensioning does not cause excessive tensile stresses in the foundation. This assumes that the culvert wall is in contact with the rock. This situation should be checked as the rehabilitation progresses.

168. This analysis confirms that the required posttensioning through the culvert walls will be acceptable for the land and river-wall monoliths where it is required.

PART IX: RECOMMENDATIONS

Introduction

169. The three main objectives of rehabilitation at Troy lock, dam, and headgate are:

- a. To render the monoliths adequate with regard to stability.
- b. To remove and replace the deteriorated concrete with concrete of appropriate quality.
- c. To rehabilitate the headgate monoliths in such a manner as to make the stresses in the structure below allowables.

Recommended Remedial Action for Stability Inadequacies

170. The monoliths of Troy lock, dam, and headgate sections should be adequate in stability. The background information concerning the stability analysis and the criteria used to judge the adequacy of monoliths stability are presented in Part VII. Summaries of the stability of the various monoliths before and after posttensioning are presented in Tables 12 and 13, respectively, of Part VII.

171. As shown Part VII, many monoliths are very inadequate in stability and require remedial action to achieve continued operational success.

172. It is desirable to posttension the monoliths as little as possible to meet the stability criteria as presented in Part VII. To do this, the monoliths were posttensioned to meet overturning requirements and reaction blocks were used at the monolith base to meet any remaining deficiency in sliding criteria. Furthermore, it is advantageous to reduce the applied posttensioning by applying a minimal amount of stress in the tendons (Table 21). The tendons will have the capacity to resist the full requirement but will not experience the force unless forces on the monolith require the tendons to develop the resisting force. This is considered adequate because small strains will develop the required

posttensioning forces in the tendons. The posttensioning force will be available but not used unless it is necessary. This will reduce any tendency for stress problems from the posttensioning.

173. Two considerations of posttensioning were evaluated using the finite element analysis of Part VIII. The first one was to have the posttensioning cables go through the top of the monoliths (Figure 77) and extend horizontally to soil anchors embedded a sufficient distance behind the monoliths. The finite element analysis (Part VIII) showed that this design was unacceptable because it created tensile stresses in the concrete of approximately 152 psi, which is excessive. The second consideration (Figure 78) was to either posttension vertically through the back of the monoliths when possible or, when not possible, to use anchors on a 45-deg angle through the filling and emptying culvert walls (Figure 79). From experience (Pace and Campbell 1978) it is known that the stresses produced by posttensioning vertically through the monoliths will not be excessive for the required posttensioning loads. The finite element analysis showed that tensile stresses will only be increased by about 11 psi by the maximum posttensioning loads applied in the culvert walls. The tensile stress increased from 28 to 39 psi. This is considered acceptable when considering an allowable tension of 0.01 f' giving maximum allowable tensile stress of approximately 44 psi.

174. A specific example of how posttensioning is figured is presented below for Monolith L-5. This presentation is for a 1-ft length of monolith.

175. Horizontal posttensioning (soil anchorage) which is required to meet sliding stability for Monolith L-5 is as obtained below.

$$\frac{R}{F_H} = FSR$$

$$R = FSR \, {*}F_H$$

$$F_V{*} \tan \phi + A{*}C + PS = FSR{*}F_H$$

$$PS = FSR{*}F_H - F_V{*} \tan \phi - A{*}C \qquad (5)$$

where

FSR = factor of safety against sliding required to meet stability criteria

F_H = resultant horizontal force (kips)

F_V = resultant vertical force (kips)

ϕ = angle of internal friction (deg)

A = area of base in which the foundation-structure interface is still considered bonded (ft^2)

C = cohesion at interface (ksf)

PS = posttensioning force required to meet sliding stability (kips)

Given: Dewatered condition with surcharge

$FSR = 2$

$F_H = 64.96$

$F_V = 67.38$

$\phi = 30.4$

$A = 0.0$

$C = 0.04$

$PS = 2*64.96 - 67.38*\tan 30.4 - 0.0*0.04$

$PS = 90.39$ kips/ft of monolith

Use two rows of posttensioning with tendons located 5 ft on centers. Top row of tendons is at elevation 19.0 ft and bottom row at elevation 13.0 ft.

$$PS_{hole} = \frac{90.39 *5}{2}$$

$$PS_{hole} = 226 \text{ kips/hole}$$

176. The posttensioning of 226 kips/hole was used in the finite element analysis and was found to overstress the concrete in tension.

177. Posttensioning through the filling and emptying culvert walls to meet overturning requirements for Monolith L-5 is obtained below.

Let

$$A = \frac{BW*PEBR}{300}$$

$$B = \cos\theta *(Y1 + Y2) + \sin\theta *(X1 + X2)$$

$$\frac{3*e}{BW} * 100 = PEBR$$

$$e = \frac{BW*PEBR}{300}$$

$$e = A$$

$$\frac{M}{F} = A$$

$$M = F*A$$

$$M_o + PS* [Y1* \cos\theta + X1* \sin\theta] + PS* [Y2* \cos\theta + X2* \sin\theta] = [F_V + 2*PS* \sin\theta] *A$$

$$M_o + PS* [\cos\theta *(Y1 + Y2) + \sin\theta *(X1 + X2)] = A* F_V + 2*A*PS* \sin\theta$$

$$M_o + B*PS = A*F_V + 2*A*PS* \sin\theta$$

$$PS* \ B - 2*A* \sin\theta = A*F_V - M_o$$

$$PS = \frac{A*F_V - M_o}{B - 2*A* \sin\theta} \qquad (6)$$

where

BW = base width of monolith (ft)

PEBR = percent effective base required (percent)

θ = angle posttensioning tendons makes with horizontal (deg)

X1 = X-moment arm of top row of posttensioning (ft)

X2 = X-moment arm of bottom row of posttensioning (ft)

Y1 = Y-moment arm of top row of posttensioning (ft)

Y2 = Y-moment arm of bottom row of posttensioning (ft)

e = moment arm for force, F_V (ft)

F_V = resultant vertical force (kips)

M_o = moment due to applied forces (ft-kips)

F = resultant force after posttensioning (kips)

M = moment due to force, F (ft-kips)

PS = required posttensioning force per row per ft of monolith (kips)

Given: Dewatered condition with surcharge

$BW = 15$ ft

$PEBR = 75$ percent

$\theta = 45$ deg

$X1 = 12.71$ ft

$X2 = 12.71$ ft

$Y1 = 7.0$ ft

$Y2 = 4.0$ ft

$F_V = 67.38$ kips

$M_O = -189.09$ ft-kips

$$A = \frac{15*75}{300}$$

$$A = 3.75 \text{ ft}$$

$$B = \cos 45*(7 + 4) + \sin 45(12.71 + 12.71)$$

$$B = 25.75$$

$$PS = \frac{3.75*67.38 - (-189.09)}{25.75 - 2*3.75* \sin 45} = \frac{441.77}{20.45} = 21.6 \text{ kips/ft monolith}$$

$$PS_{hole} = \frac{21.6 \text{ kips/ft monolith}*32 \text{ ft}}{6} = 115.2 \text{ kips/hole}$$

178. The strut resistance needed for Monolith L-5 to meet sliding stability after posttensioning through the filling and empting culvert walls to satisfy overturning requirements is obtained below.

$$\frac{R}{F_H} = FS$$

$$R = FSR*F_H$$

$$(F_V + PS* \sin \theta)* \tan \emptyset + PS* \cos + A*C + SR = FSR*F_H$$

$$SR = FSR*F_H - \left[(F_V + PS* \sin \theta) * \tan \emptyset + PS* \cos \theta + A*C\right] \quad (7)$$

where

FSR = factor of safety against sliding required to meet stability criteria

F_H = resultant horizontal force (kips)

F_V = resultant vertical force (kips)

PS = posttensioning force required to meet present-day overturning stability (kips)

θ = angle posttensioning tendons makes with horizontal (deg)

$\emptyset$ = angle for sliding friction (deg)

A = area of base in which the foundation-structure interface is still considered bonded (ft^2)

C = cohesion at interface (ksf)

SR = strut resistance required to meet sliding stability (kips/ft of monolith)

179. The calculations for strut resistance are for the dewatered condition with surcharge behind the monolith.

Given:

FSR = 2

F_H = 64.96 kips

F_V = 67.38 kips

PS = 21.6*2 = 43.2 kips/ft monolith

θ = 45 deg

A = 0.0

C = 0.04

SBR = 2*64.96 - [(67.38 + 43.2* sin 45) tan 30.4 + 43.2* cos 45 + 0.0*0.04]

SBR = 41.92 kips

180. The posttensioning and strut action were obtained for all monoliths using concepts similar to those used in the sample calculations for Monolith L-5.

181. The posttensioning for the three-dimensional monoliths had to be determined by iteration because of the irregular base geometry causing the kern to be of irregular shape. The posttensioning requirements for the governing cases are presented in Table 21.

182. For vertical tendons through the entire monolith depth (example Monolith L-1) the posttensioning force per tendon could be increased, and the number of holes decreased. A judgment was made to posttension as given in Table 21 in order to keep the stresses in the monoliths as low as possible. Table 21 can be used to make the actual rehabilitation plans for posttensioning. General locations for posttensioning are presented in Figure 78.

183. The strut resistance necessary for the additional sliding resistance is presented in Table 22. Strut resistance is to be provided by a reaction block using rock anchors to secure the block to the foundation. Rock anchors are inclined downward and toward the monolith at 45 deg. Required capacities for the anchors per monolith are presented in Table 22. The rock anchor selection and spacing can also be made by using the requirements presented in Table 22. The recommended size and reinforcing for the reaction block are presented in Figure 80.

184. After posttensioning, the base pressures are below the allowables of 33 ksf.

185. Dam Monoliths D-1 through D-62 require posttensioning to make their resistance adequate in stability. No strut resistance was assumed because of the construction (Figure 3). The required posttensioning is presented in Table 21. Different posttensioning loads were required for D-1 through D-33 than were required for D-34 through D-62. The posttensioning for Monoliths D-34 through D-62 is greater than for D-1 through D-33 as shown in the calculations presented below.

186. The stability was calculated using the entire monolith. This assumes that the apron is not overstressed in tension. The following calculations show that for the more critically stressed monoliths (D-34 through D-62) the apron has 50-psi tension before posttensioning and 41-psi tension afterward. The posttensioning decreases the stress in the apron, therefore, the above analysis is adequate.

187. Any cracks which exist in the headgate monolith after deteriorated concrete is removed should be epoxy injected.

Depth of Posttensioning Anchor

188. The failure mode of the posttensioning tendon in the foundation can be in any of the following ways:

a. By failure within the rock mass.

b. By failure of the bond between rock and grout.

c. By failure of the bond between the grout and the tendon.

d. By failure of the steel tendon or top anchorage.

189. The most critical failure mode must be determined and used in obtaining the length of posttensioning.

a. Failure within rock mass. From pullout data the failure within the rock mass was about 18 kips per foot (Part V). Using a safety factor of 2 the allowable resistance will be 9 kips per foot of hole.

b. Rock/grout bond. From the pullout tests it was found that the bond between rock and grout can withstand a maximum stress of 480 psi. Using a safety factor of 2 the allowable bond stress is 240 psi. The maximum hole diameter for posttensioning tendons is 2-1/2 in. Using the 2-1/2 in.-diam hole, the pullout resistance per foot of tendon is (12 in.) (3.14) (2.5 in.) (240 psi) (1 kip/1000 lb) = 22.6 kips per foot of hole. This allowable is greater than the 9 kips per foot of tendon for the foundation material itself; therefore, the bond between rock and grout does not govern the design.

c. Grout/tendon interface. If an allowable stress of 145 psi is used for the bond between the grout and tendon, the allowable force per foot of tendon is as calculated below for the various tendons.

ER5-3(3 strand)(steel area = 0.459 in.^{2})

$$\text{Allowable load per foot of tendon} = \sqrt{\frac{(4)(0.459)}{3.14}}\ (3.14)(304.5)(12)(1/1000) = 8.77 \text{ kips}$$

ER5-6(5 strand)(steel area = 0.765 in.^{2})

$$\text{Allowable load per foot of tendon} = \sqrt{\frac{(4)(0.765)}{3.14}}\ (3.14)(304.5)(12)(1/1000) = 11.33 \text{ kips}$$

ER5-9(7 strand)(steel area = 1.071 in.^{2})

$$\text{Allowable load per foot of tendon} = \sqrt{\frac{(4)(1.071)}{3.14}}\ (3.14)(304.5)(12)(1/1000) = 13.40 \text{ kips}$$

The above values are conservative because the calculations assume only one circular tendon and the multiple strand tendons will have more surface area. The allowable of 9 kips per foot for the foundation is still a good value to use in the design.

d. Steel tendon. The allowable load given by the tendon manufacturer will be used. This will give a tendon which will perform successfully.

190. The allowable load per foot of tendon will be 9 kips per foot of embedment depth. For effective placement and good engineering practice a depth of tendon embedment less than 15 ft will not be used. The depth of tendon embedments is given in Table 21.

191. Several tests will be performed in the field pulling the tendons to maximum load to be sure that the embedment depths are sufficient.

Removal and Replacement of Deteriorated Concrete

192. The main factors involved in the concrete removal and overlay replacement are:

a. Means of concrete removal.

b. Depths of concrete removal.

c. Preparing surface for overlay replacement.

d. Bonding agent.

e. Reinforcement.

f. Type overlay and its main engineering properties.

193. The probable depths of concrete removal are presented in Part VI. Table 23 presents the recommended repair of deteriorated concrete.

Land wall

194. Deteriorated concrete especially in the location of gate

anchors must be removed and replaced by a properly reinforced, air-entrained overlay.

195. Water and backfill material are coming through the landside culvert wall of monolith L-5 (Figure 69), which indicates that some portion of the concrete in this culvert wall is not of sufficient quality and must be evaluated and replaced as the rehabilitation progresses.

196. The construction joints and the few cracks which exist in the land wall monoliths are not a problem and need not be repaired.

197. Danger from the falling of loose pieces of concrete will be eliminated by the surface concrete rehabilitation.

198. The deterioration at the filling and emptying culverts and along the base of the monoliths (Figure 9) will be eliminated by surface concrete rehabilitation and reaction block construction at the base of the monoliths.

River wall

199. The same general recommendations apply for the river wall monoliths. One leaking construction joint in the river face of the river wall (Figure 12) should be cleaned and filled with nonshrink mortar.

Dam

200. The dam has almost no deteriorated concrete; therefore, the surface can be cleaned with some removal of concrete and an erosion-resistant overlay applied. All holes should first be patched with nonshrink concrete before an overlay is applied. Some of the dam surface has been eroded away; therefore, a 3-in. overlay will not raise the pool higher than that which existed originally.

201. Scour in front of the dam should be eliminated to prevent undermining of the dam foundation (Part VII).

Headgate

202. The deteriorated concrete in the headgate section should be removed to an elevation of sound nondeteriorated concrete. Dowels should be used to anchor the old concrete to the new. After the deteriorated and cracked concrete is removed from the headgate monolith, the new concrete should be reinforced to take the loads for the normal operation plus ice condition which was used in the stability analysis.

If the concrete below that which is removed is still overstressed, post-tensioning tendons can be used to carry the tensile stresses.

203. The gated spillway should be reinforced to have adequate resistance to ice loadings. The handrail on the gated spillway should be light and removable because ice loading against it can cause cracks in the gated spillway (Figure 15).

204. It is recommended that controlled blasting be used to remove 1-ft deteriorated concrete from the chamber faces of the land and river walls except for areas below the tops of filling and emptying culverts. Where the concrete thickness is 5 ft or less, a chipper must be used. If any isolated areas of deterioration remain, they can be removed by a chisel point chipper. Blasting in a location where water can act as a confining pressure should not be used because the water will cause coupling of energy into the concrete monolith and cause damage to the nondeteriorated concretes. It is not necessary to remove the total depth of deteriorated concrete from the horizontal surface of the land and river wall. A 1-ft-deep removal of concrete and a reinforced overlay will be adequate. For the remainder of the lock, the deteriorated depth of concrete is variable (Figures 41 and 42), and it is suggested that the contract allows this removal to bid on a per cubic yard basis.

205. In all cases (except the top surface of the land and river walls) deteriorated material shall be completely removed. In a few cases sound material must be removed so as to accommodate a specific repair procedure requiring a given thickness (depth) of new concrete so as to allow proper placement of reinforcing so that the required minimum cover over steel in the repair concrete is achieved (1 in. for wire mesh and 3 in. for reinforcement).

206. The No. 5 bars at 12 in. on center over the dowels are for crack control in the overlay. The mat reinforcement will decrease cracking, entry of water into the concrete, and decrease concrete deterioration. No bonding agent should be used. The overlay should be placed on the dry concrete surface to get a minimum discontinuity between the overlay and the interior concrete. This will minimize the collection of water in sufficient quantities at the interface of the

overlay to cause debonding when freezing occurs.

207. The remedial stability measures should be accomplished in the following manner.

a. Use reaction blocks to correct for sliding stability.

b. Use posttensioned tendons as specified to correct for overturning stability. The tendons will be checked for the specified strength development capacity in the field. If there is any tendency for the monolith to move, the tendon will then become active and resist the movement.

208. The depths of posttensioning anchorage are presented in Table 19.

209. In concrete placement, good concrete practices for batching, transportation, and placement in a cold weather environment should be used.

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U. S. Army Engineer Waterways Experiment Station. 1949 (Aug). "Handbook for Concrete and Cement," Aug 1949 (with quarterly supplements), CE, Vicksburg, Miss.

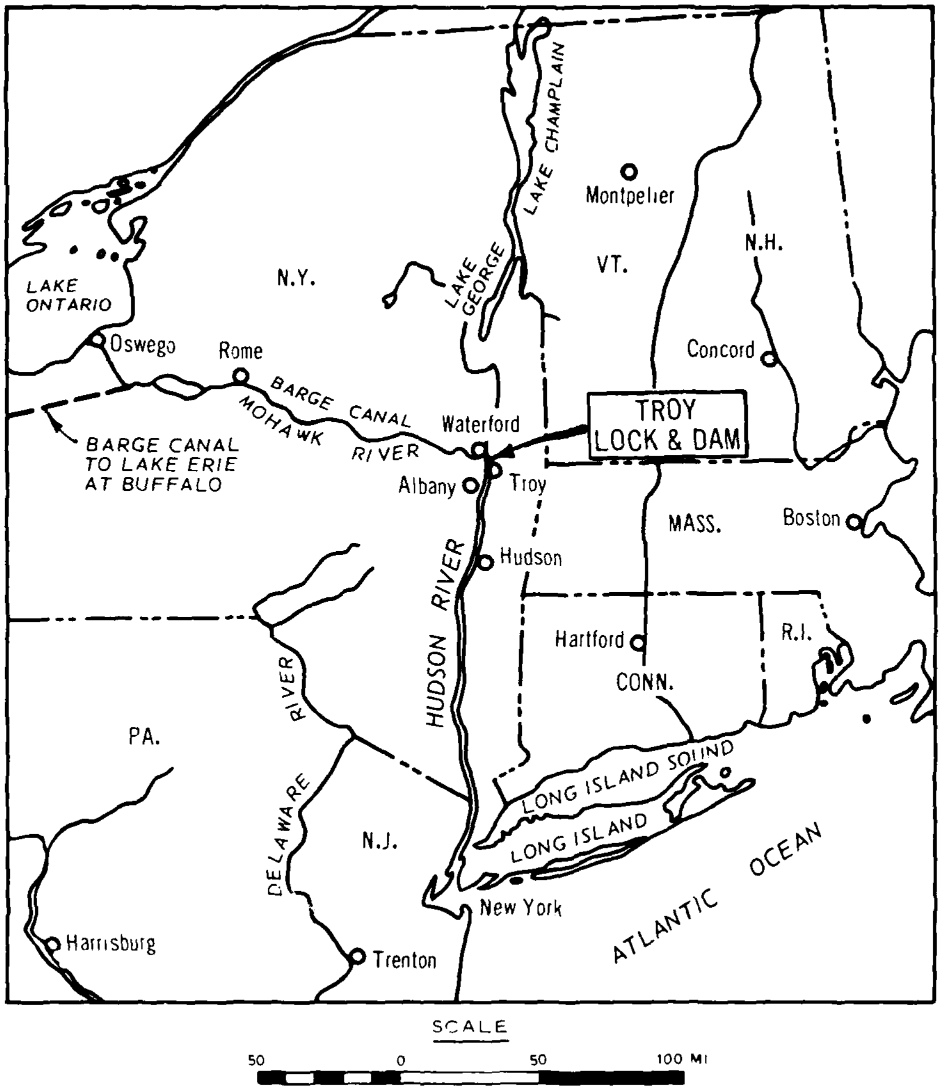


Figure 1. Geographical location of Troy Lock and Dam

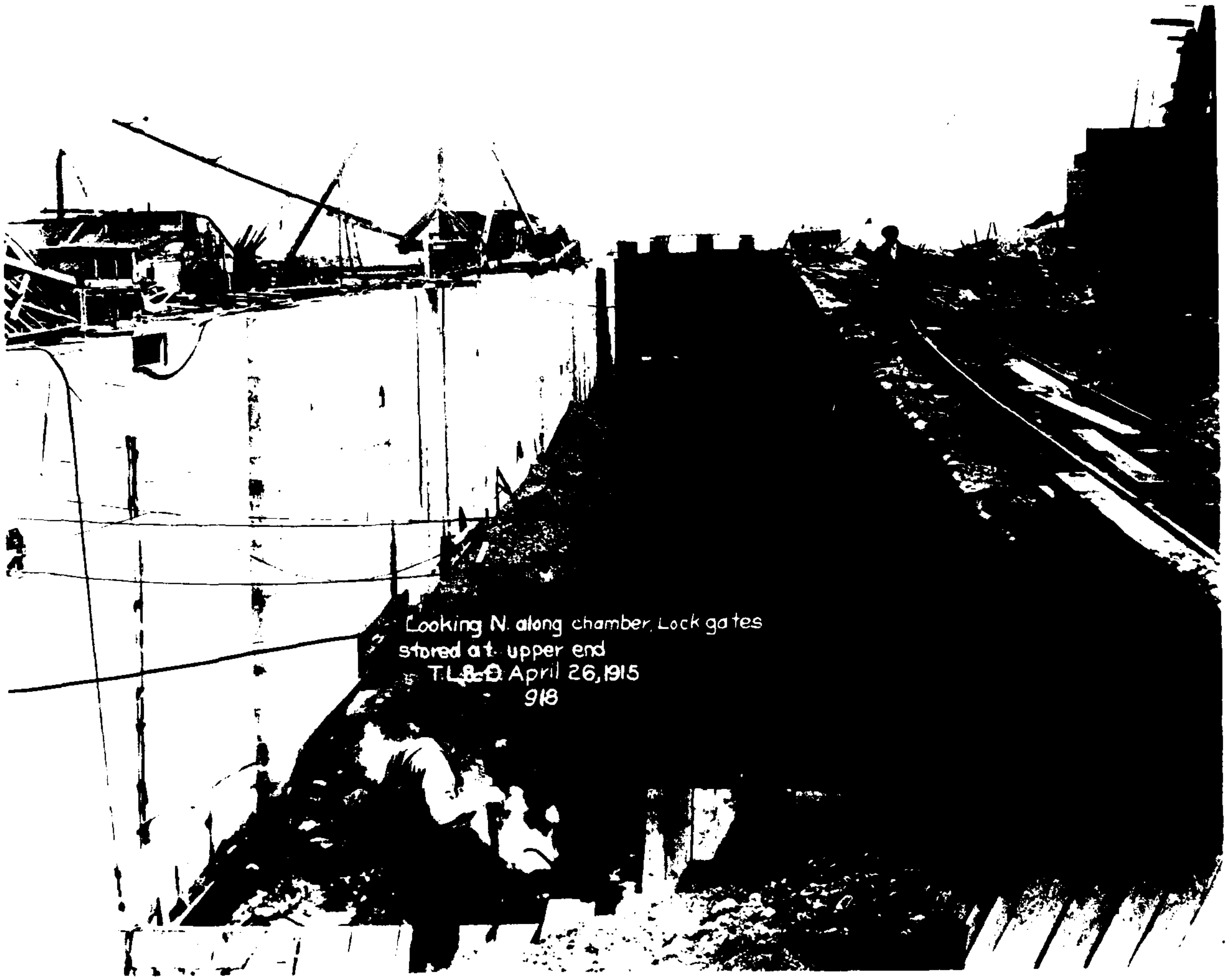


Figure 2. Original construction, Troy Lock

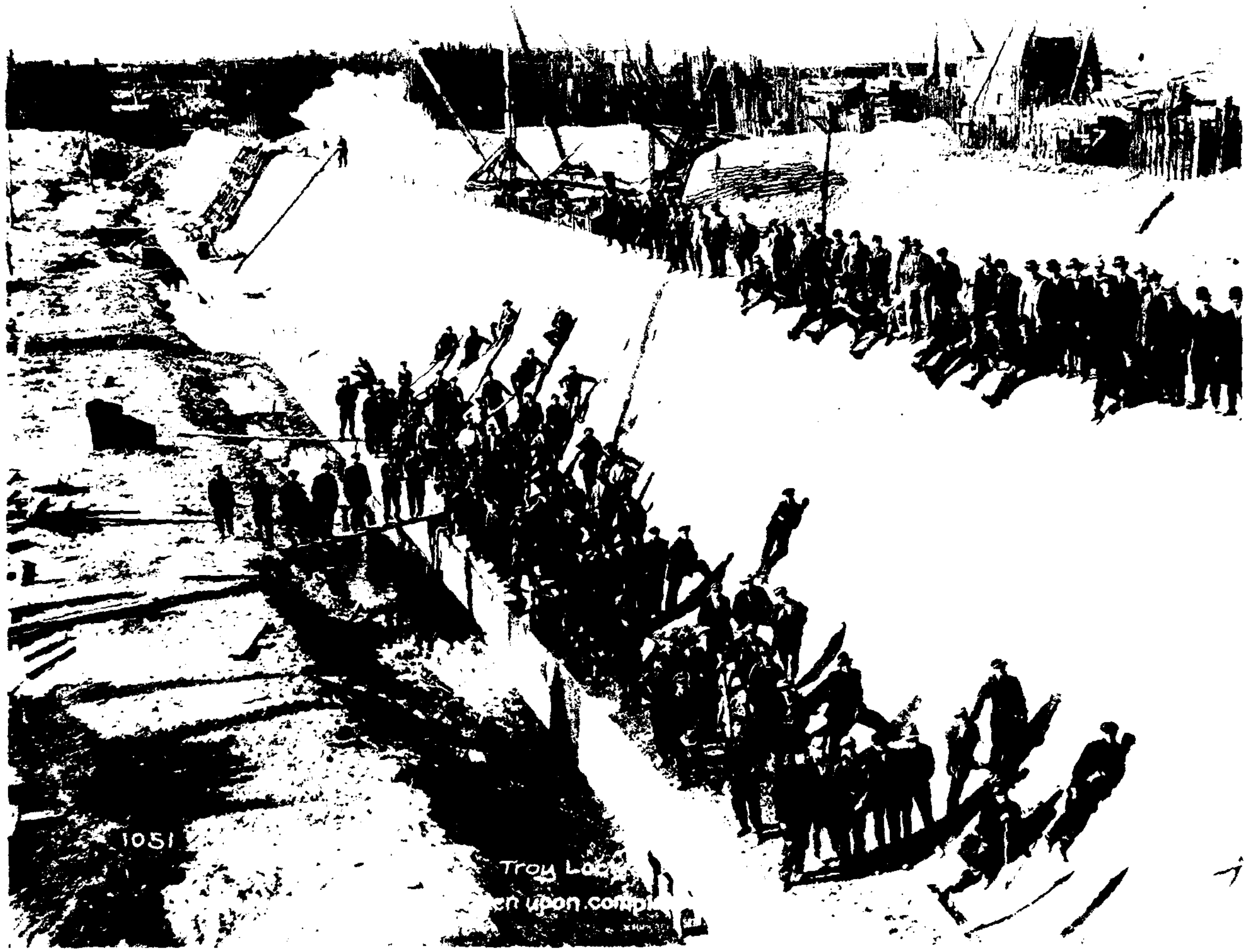


Figure 3. Original construction, Troy Dam

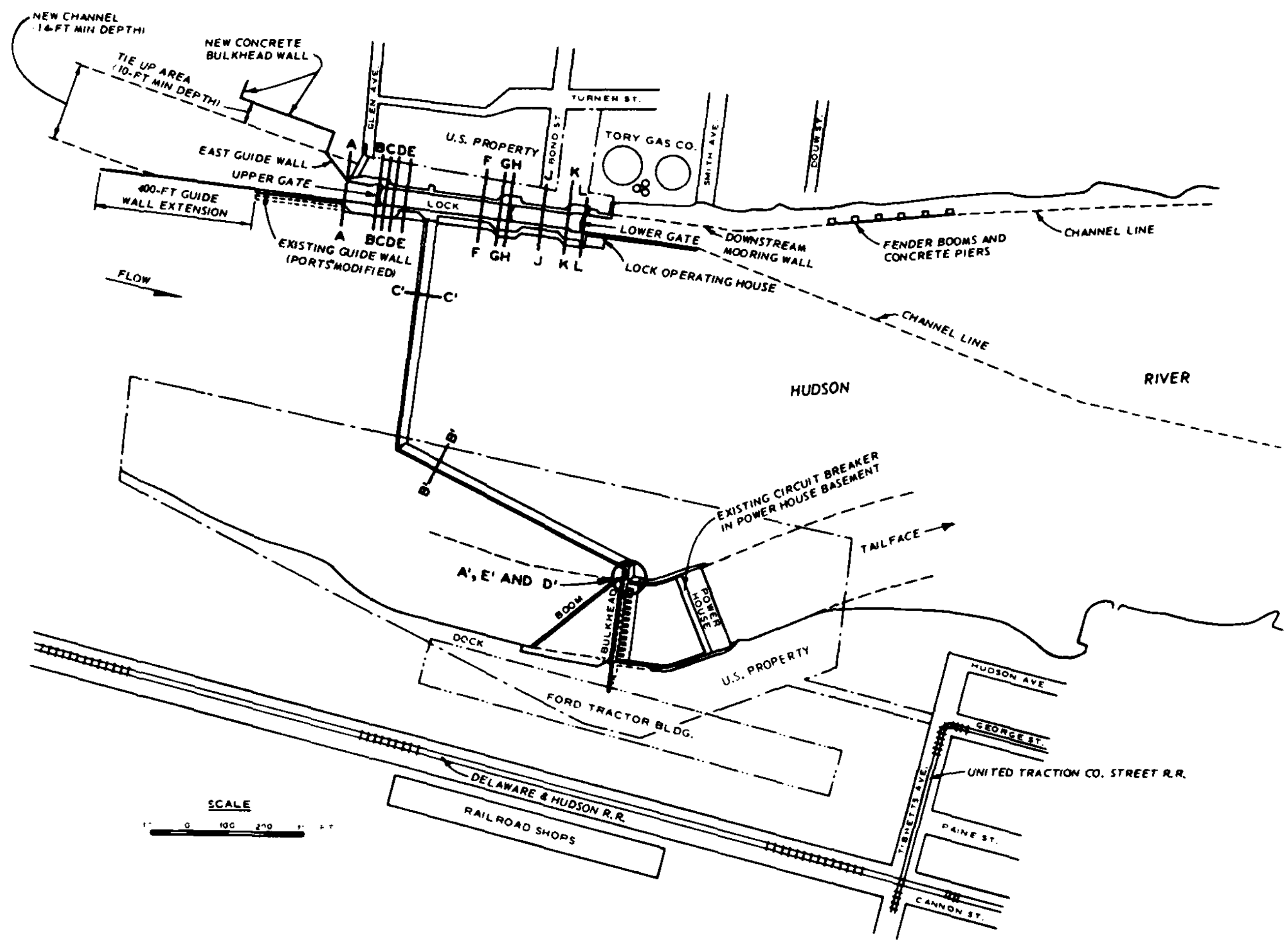


Figure 4. Schematic presentation of lock, dam, and power plant

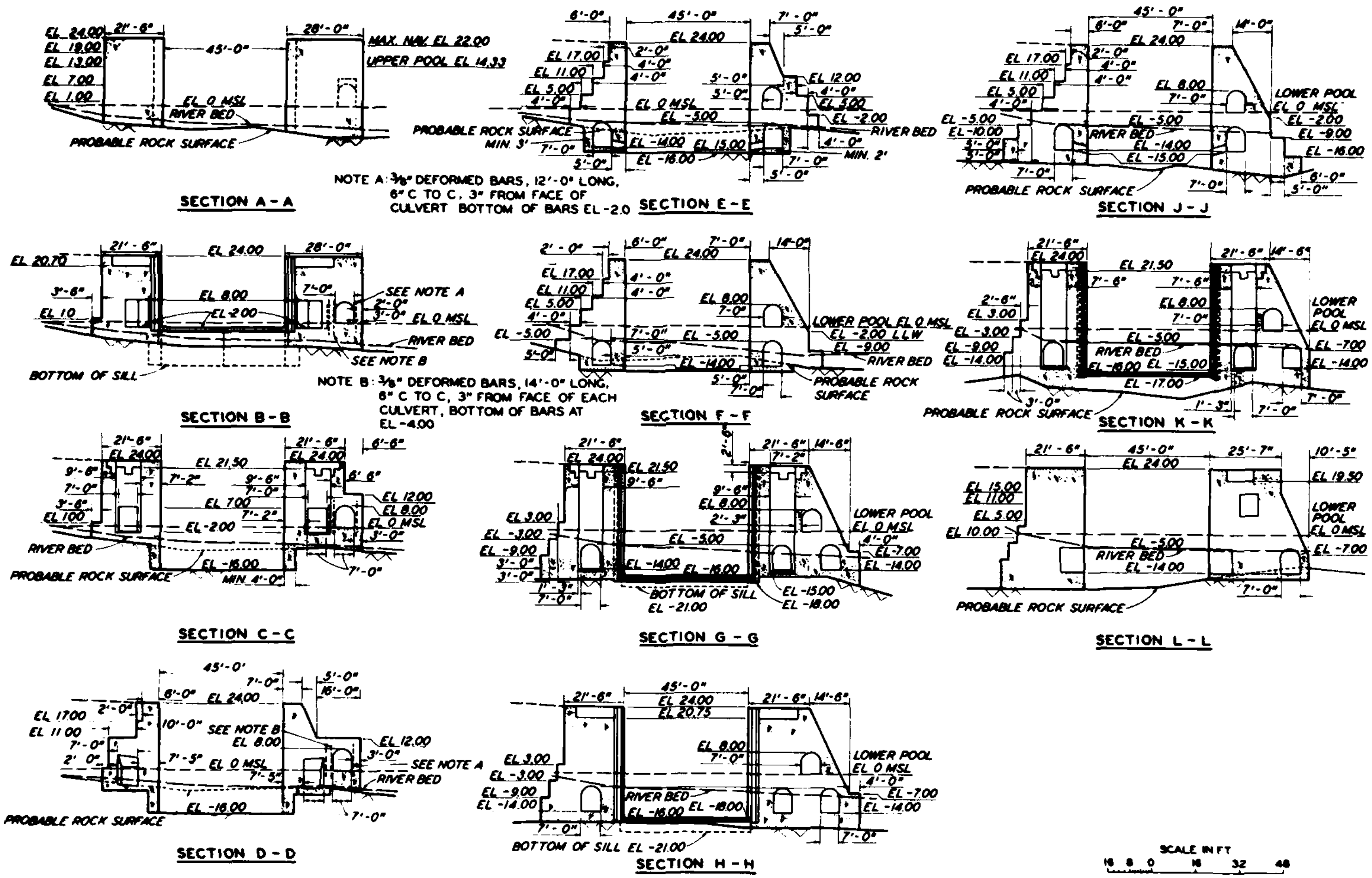


Figure 5. Sections through lock as indicated in Figure 4

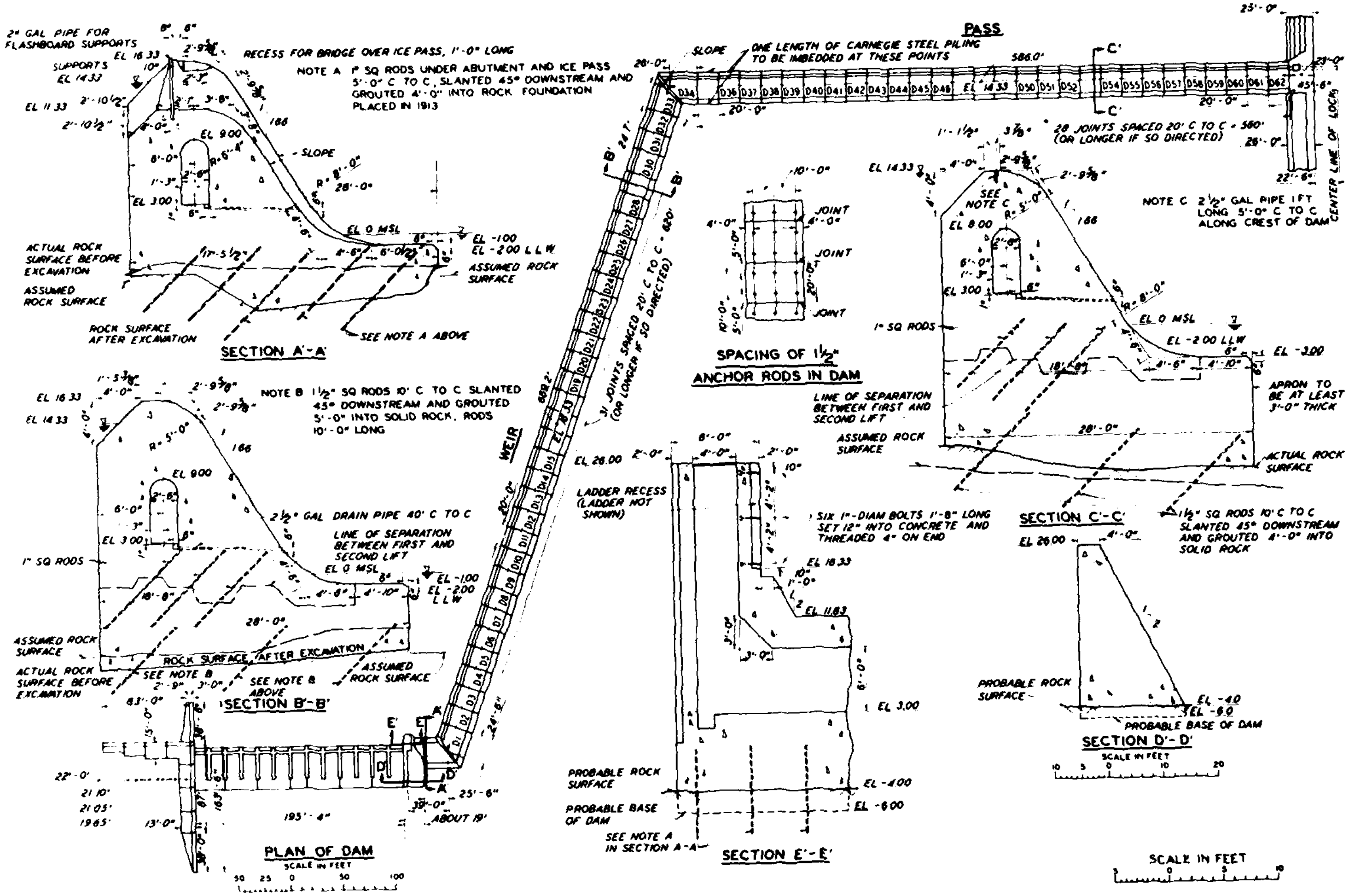


Figure 6. Details of dam construction

Figure 7. Overview of upstream portion, Troy Lock

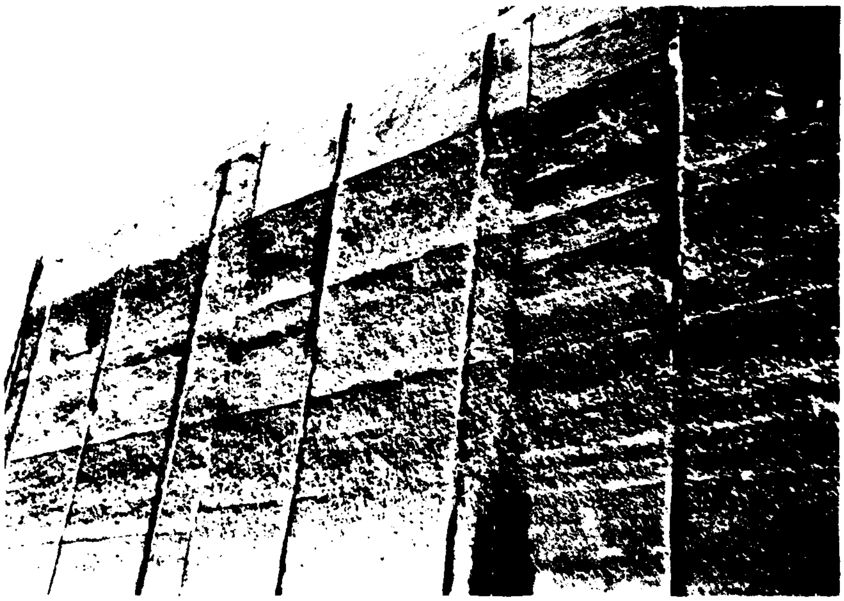


Figure 8. Typical view of lock chamber walls

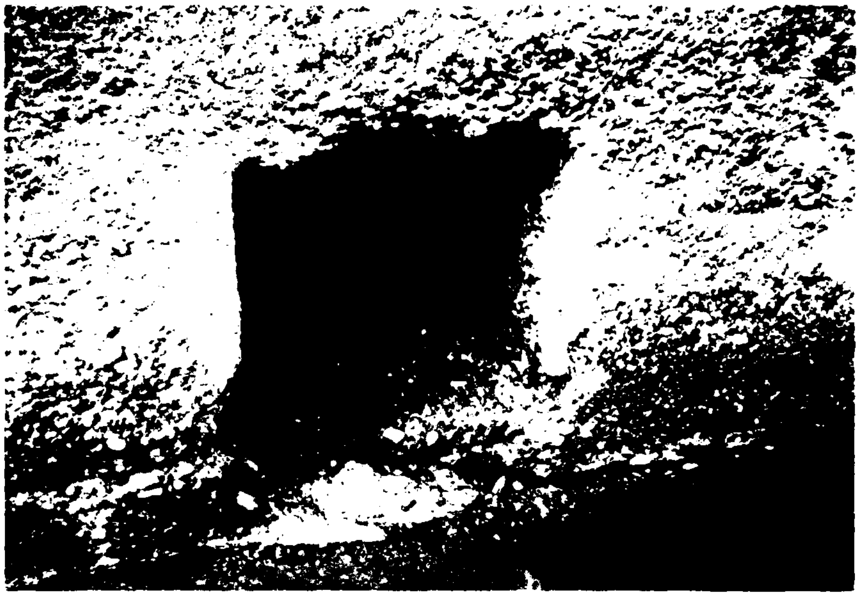


Figure 9. Typical view of filling and emptying culverts

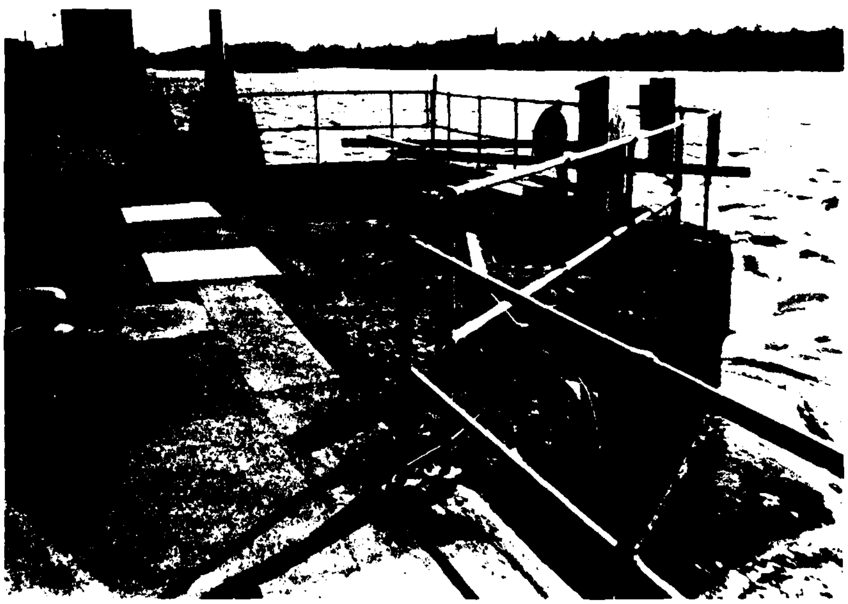


Figure 10. River wall-location where dam joins river wall

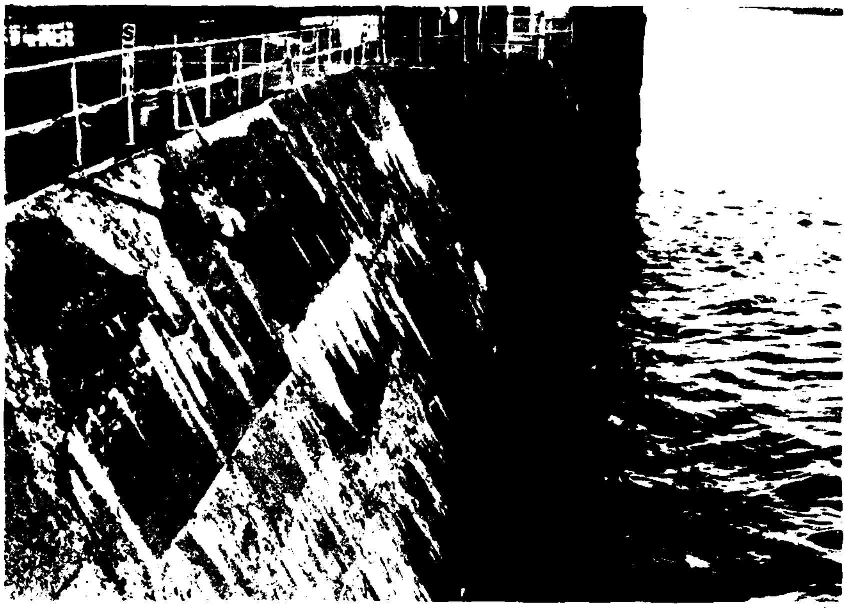
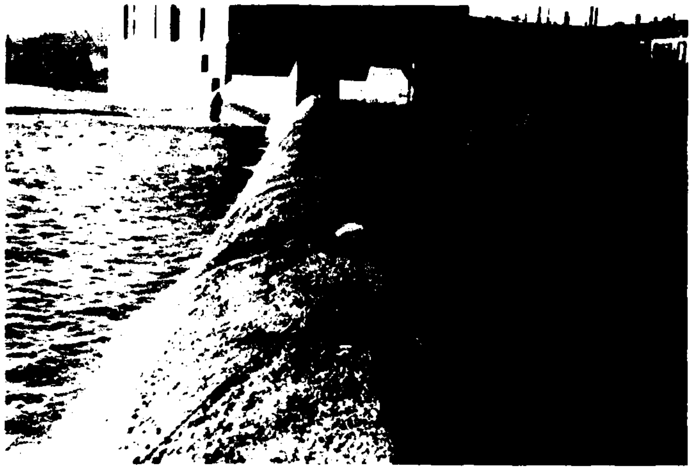


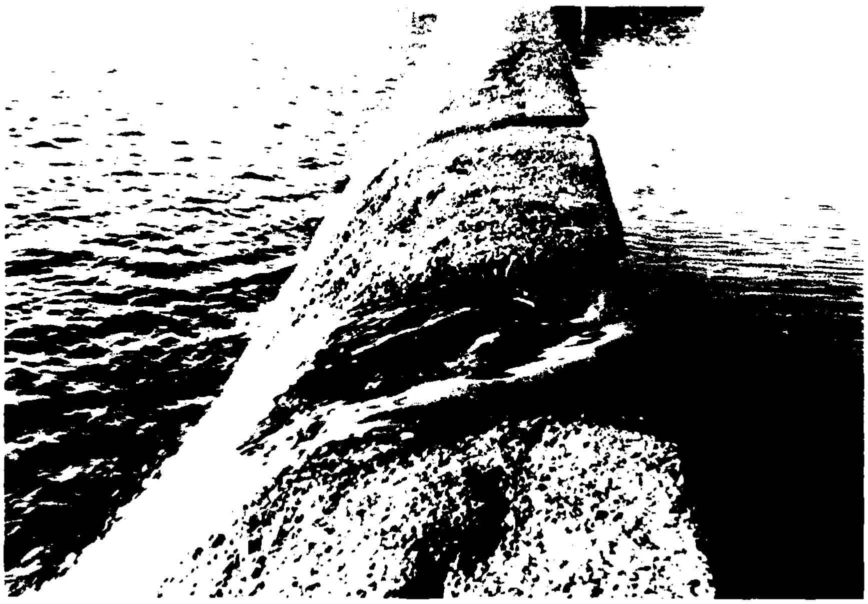
Figure 11. Riverside of river wall

Figure 12. Riverside river wall showing deterioration, undercutting at water level, and water flowing from construction joint

Figure 13. Undercutting of concrete at base of control building



a. Overall view



b. Closeup view

Figure 14. Deterioration of concrete of dam

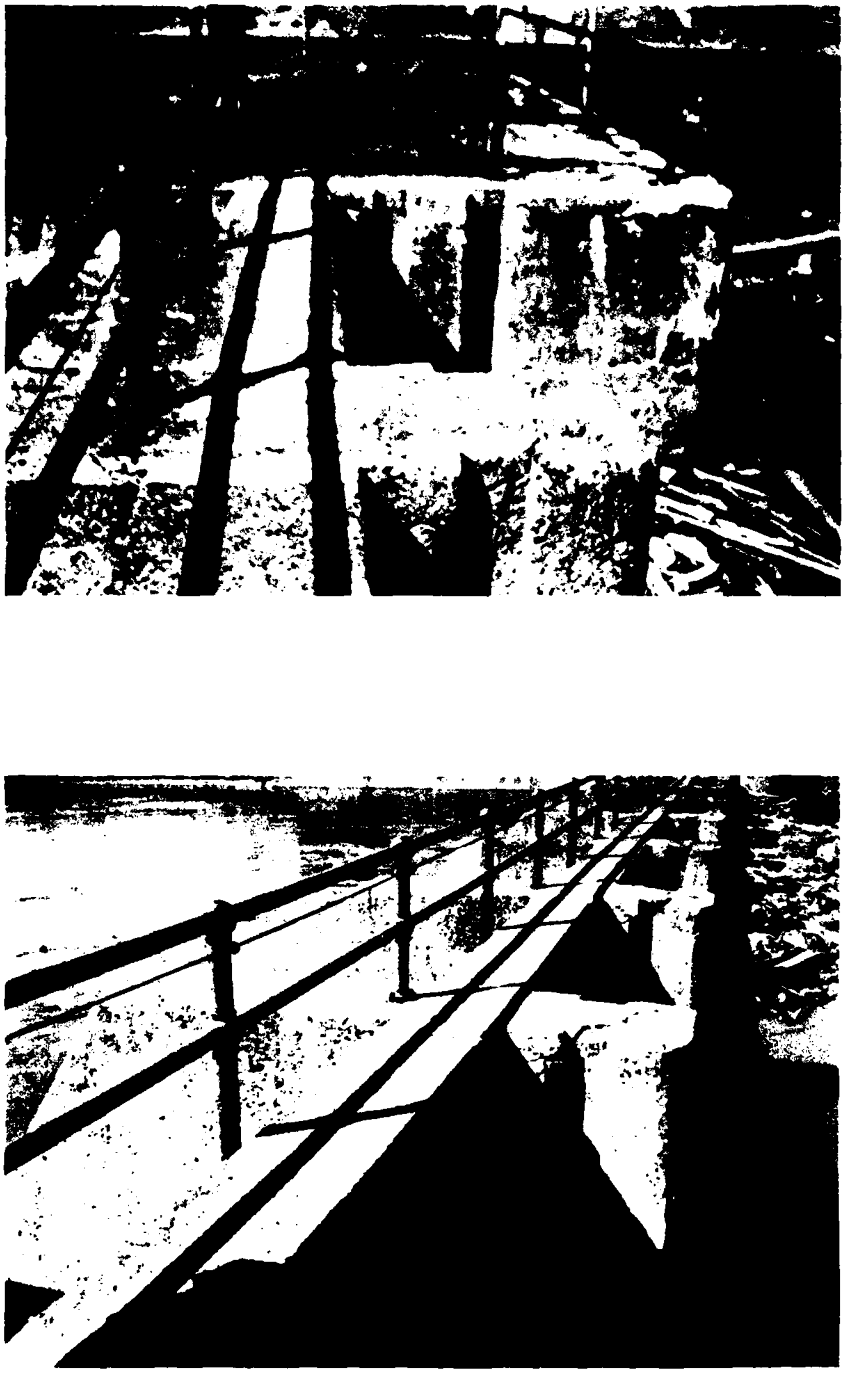


Figure 15. Cracking and deteriorated surface concrete in the piers of the gated section near powerhouse

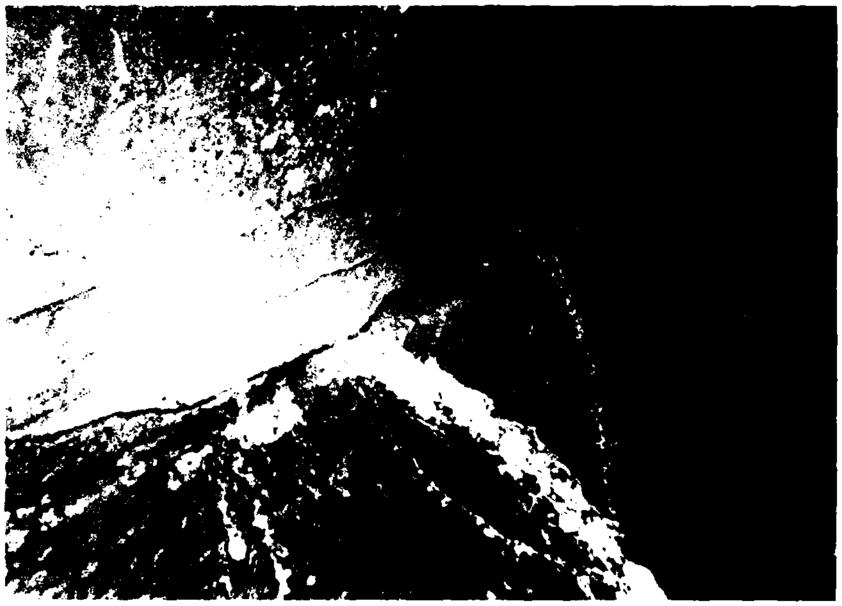


Figure 16. Leaking construction joint in the shaft which allows entrance into the dam tunnel

Figure 17. Cracking in the shaft which allows entrance to the dam tunnel

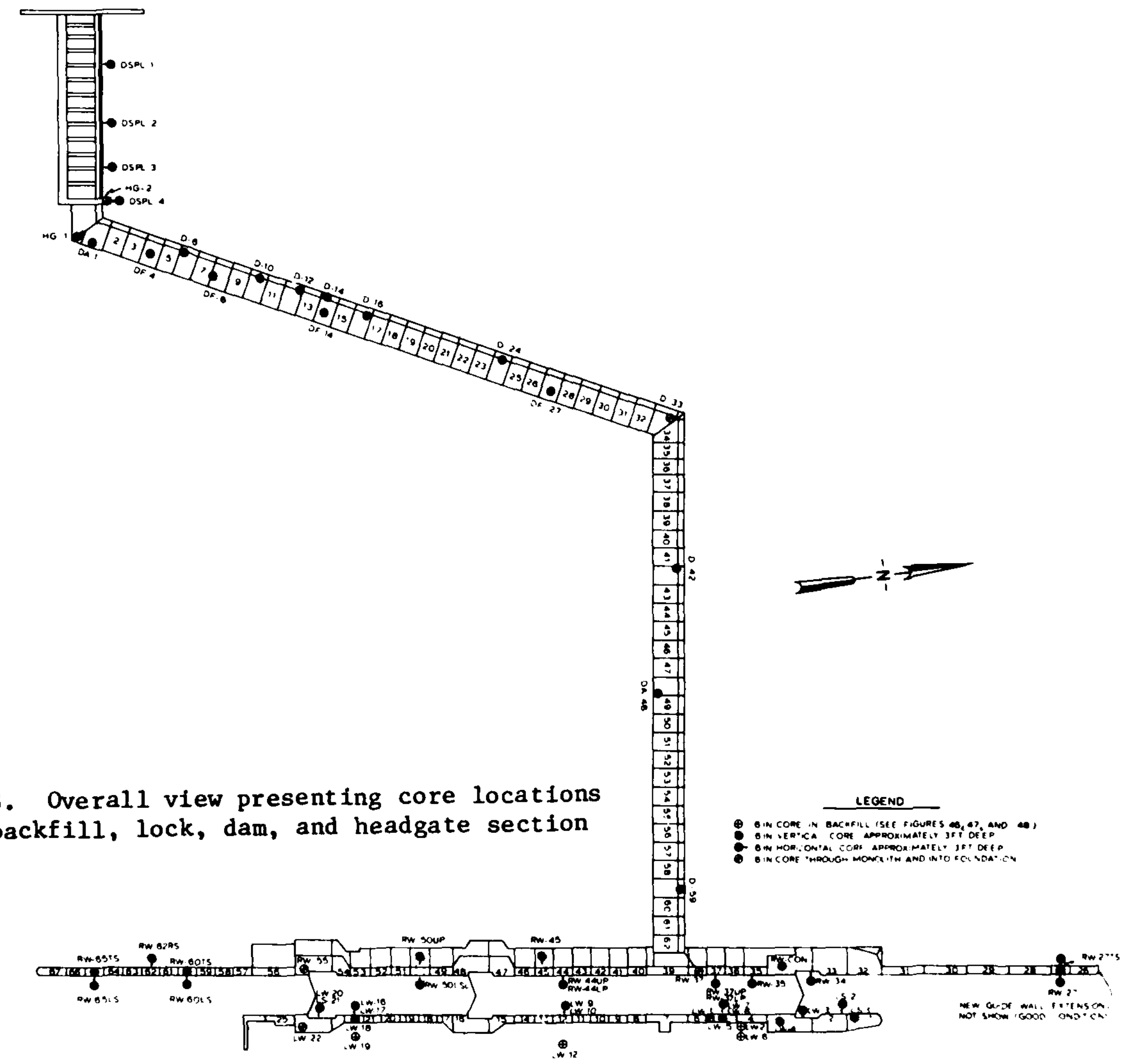
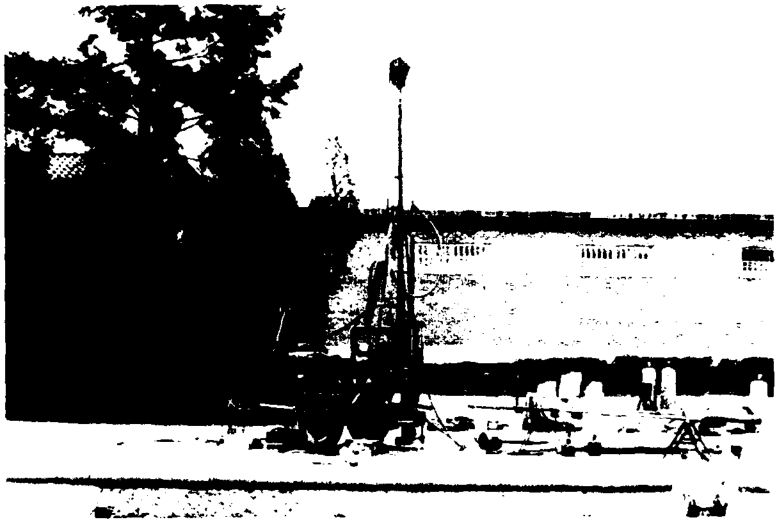


Figure 18. Overall view presenting core locations in the backfill, lock, dam, and headgate section



a. On land wall monolith

b. On dam monolith

Figure 19. Vertical core drilling

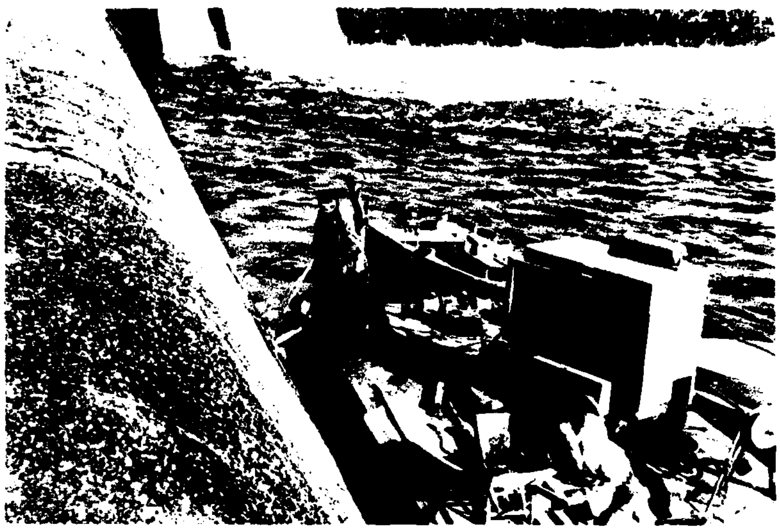


Figure 20. Closeup view of 3-ft core drilling in dam face

Figure 21. Concrete core immediately after being sampled

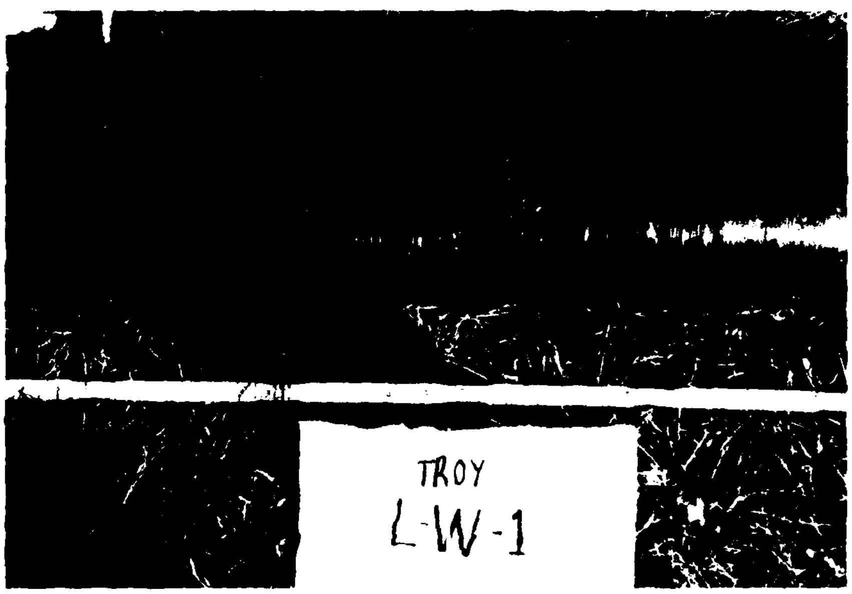


Figure 22. Foundation core immediately after being sampled

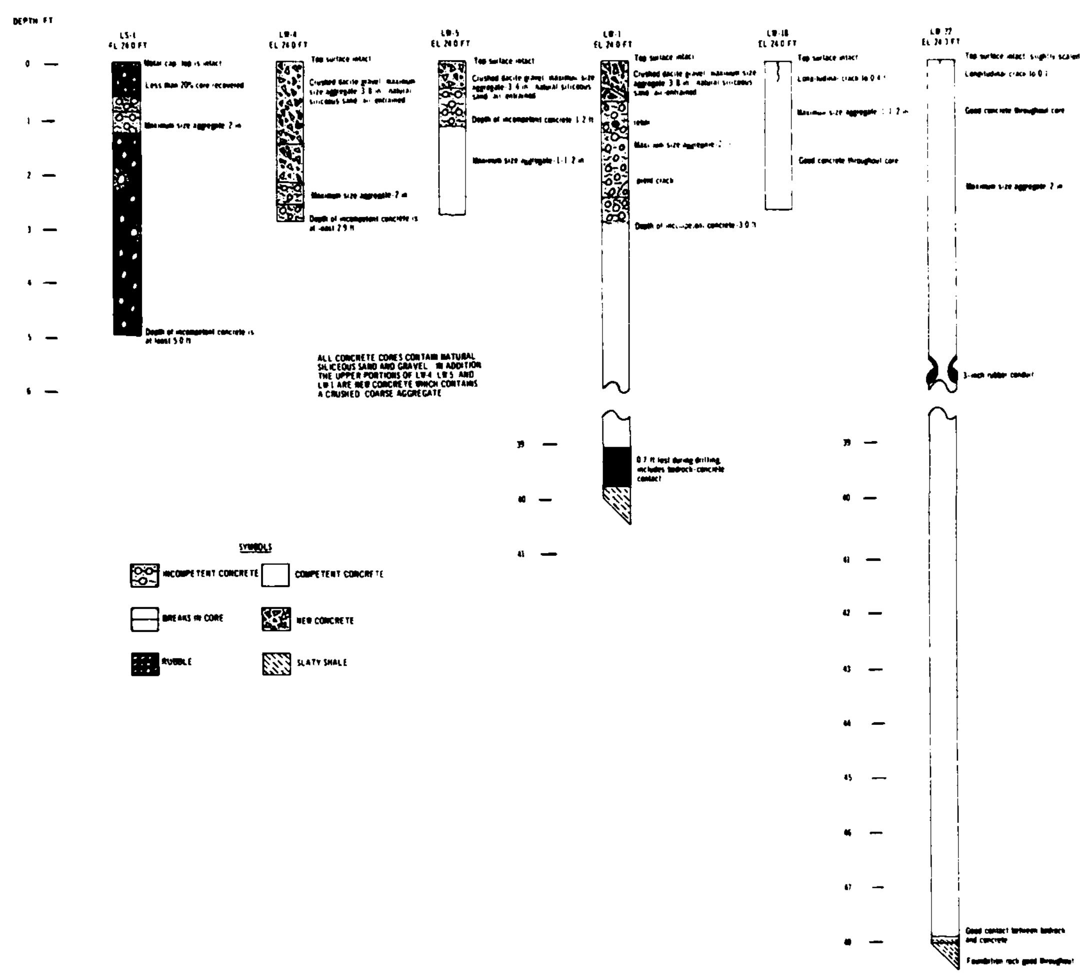


Figure 23. Vertical cores, land wall

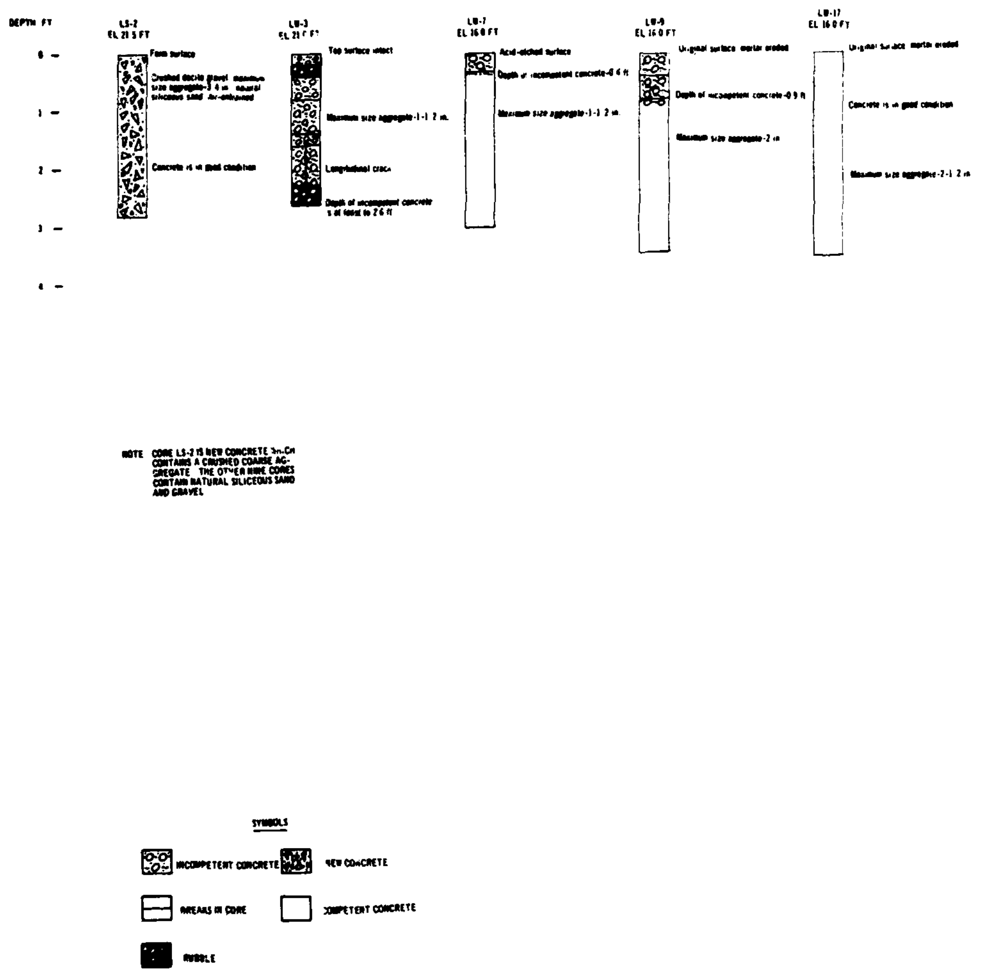


Figure 24. Horizontal cores, vertical face of land wall (Continued)

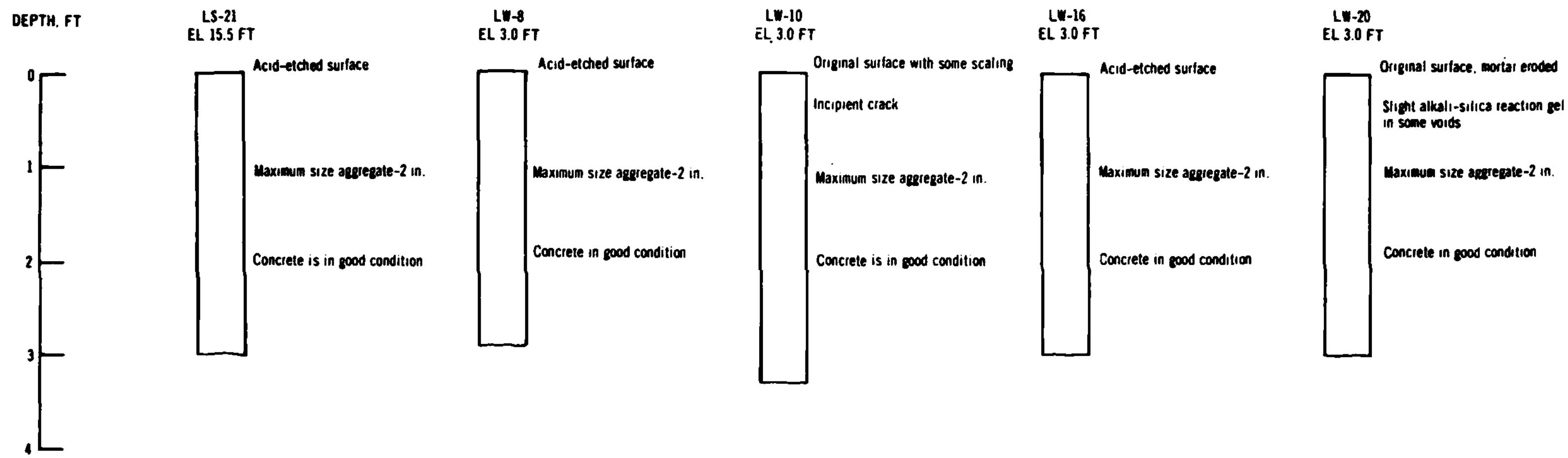


Figure 24. (Concluded)

Figure 25. Subsurface deterioration of concrete in upper vertical face of the upper land wall gate monolith (monolith 3)

Figure 26. Surface of concrete core from vertical face of land wall showing typical etching away of mortar leaving coarse aggregate in relief

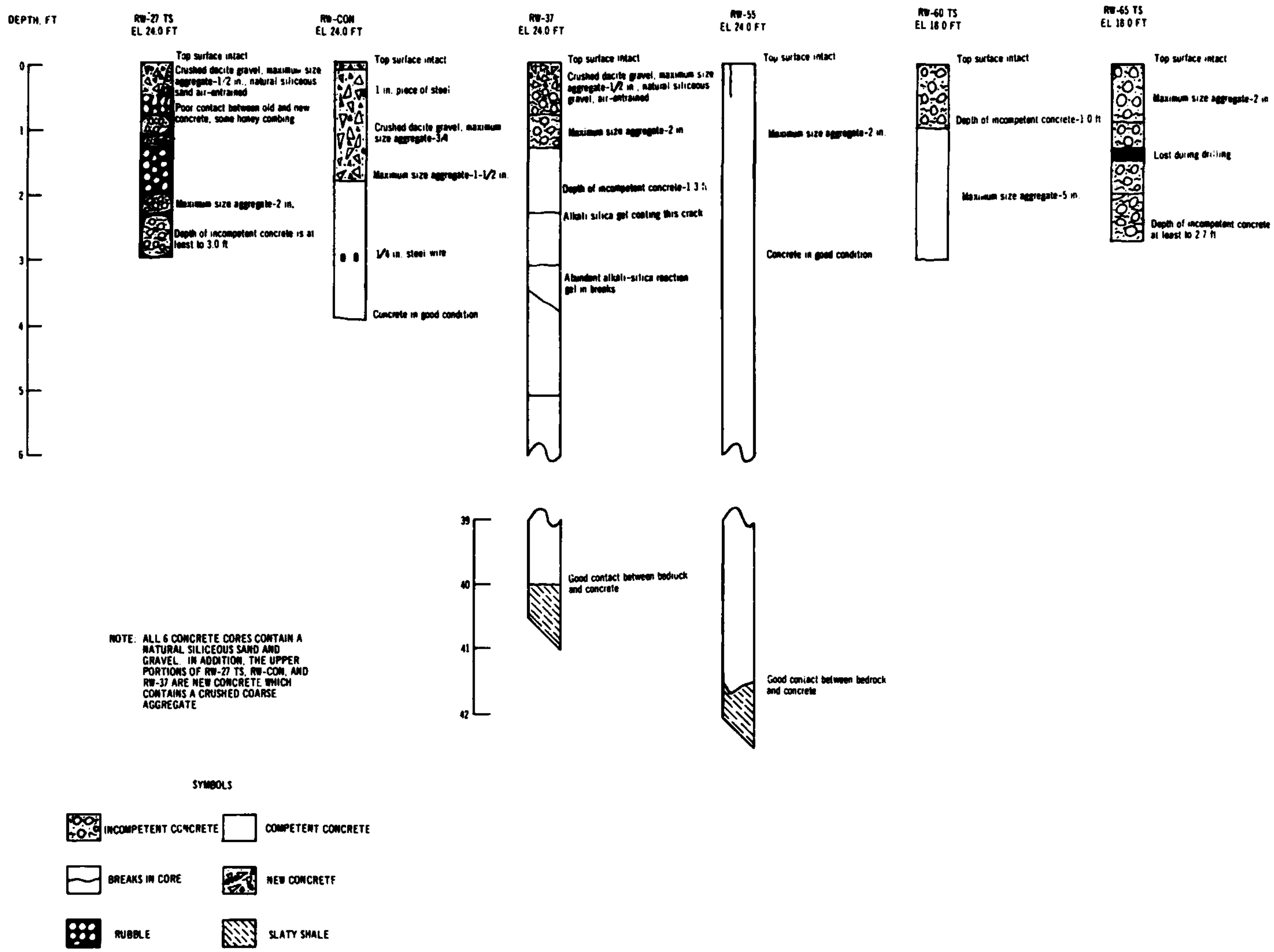


Figure 27. Vertical cores, river wall

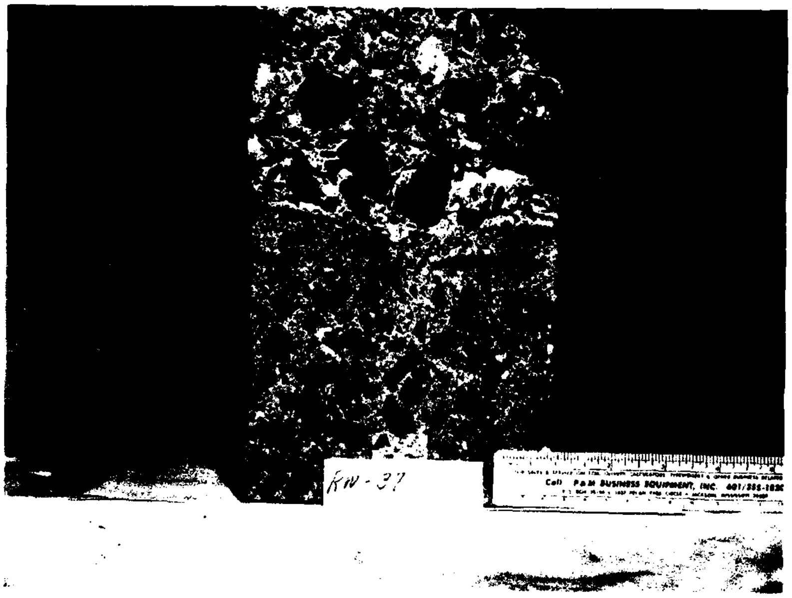


Figure 28. Core RW-37 from top of river wall showing subparallel cracking of older concrete below overlay (the core was photographed upside down so it would stand alone)

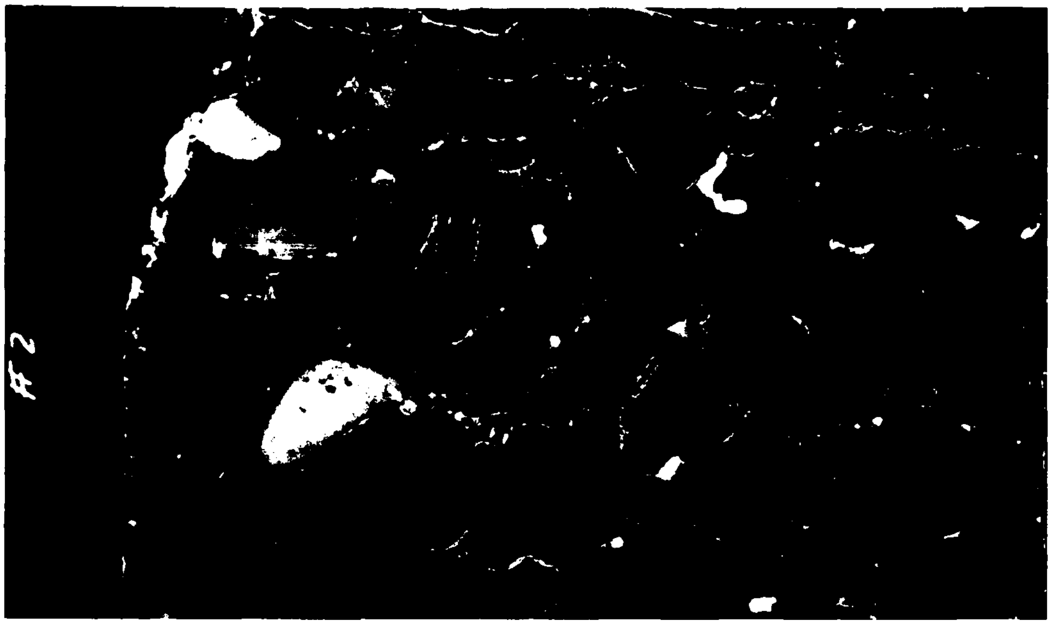


Figure 29. Sawed surface of core RW-55 impregnated with epoxy resin containing fluorescent dye and photographed using ultraviolet light to show the presence and amount of cracking, ×0.9

Figure 30. Ground surface of core RW-55 impregnated with epoxy resin containing fluorescent dye and photographed using ultraviolet light to show the presence and amount of cracking, ×0.9

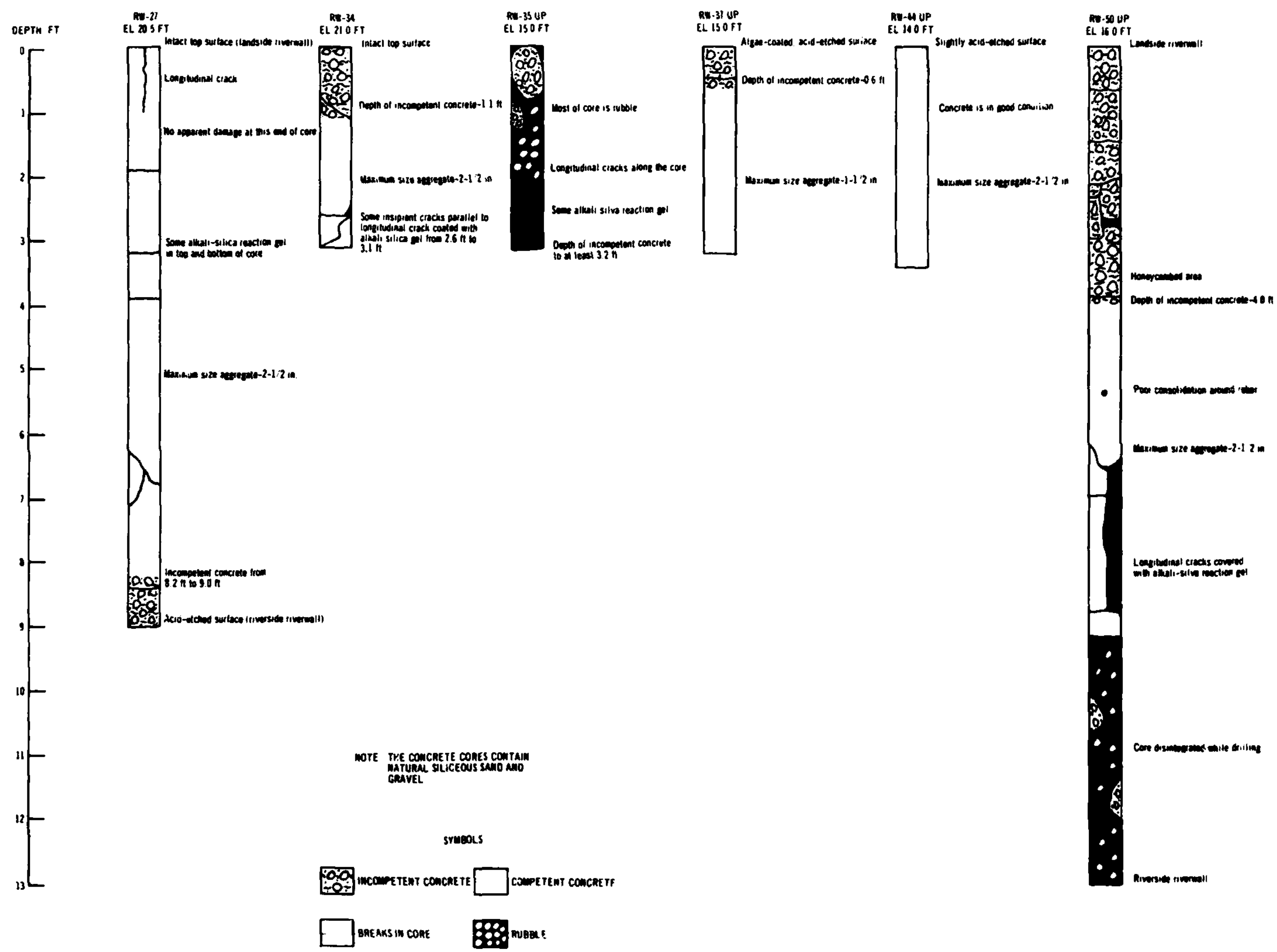


Figure 31. Horizontal cores, land face of river wall (Continued)

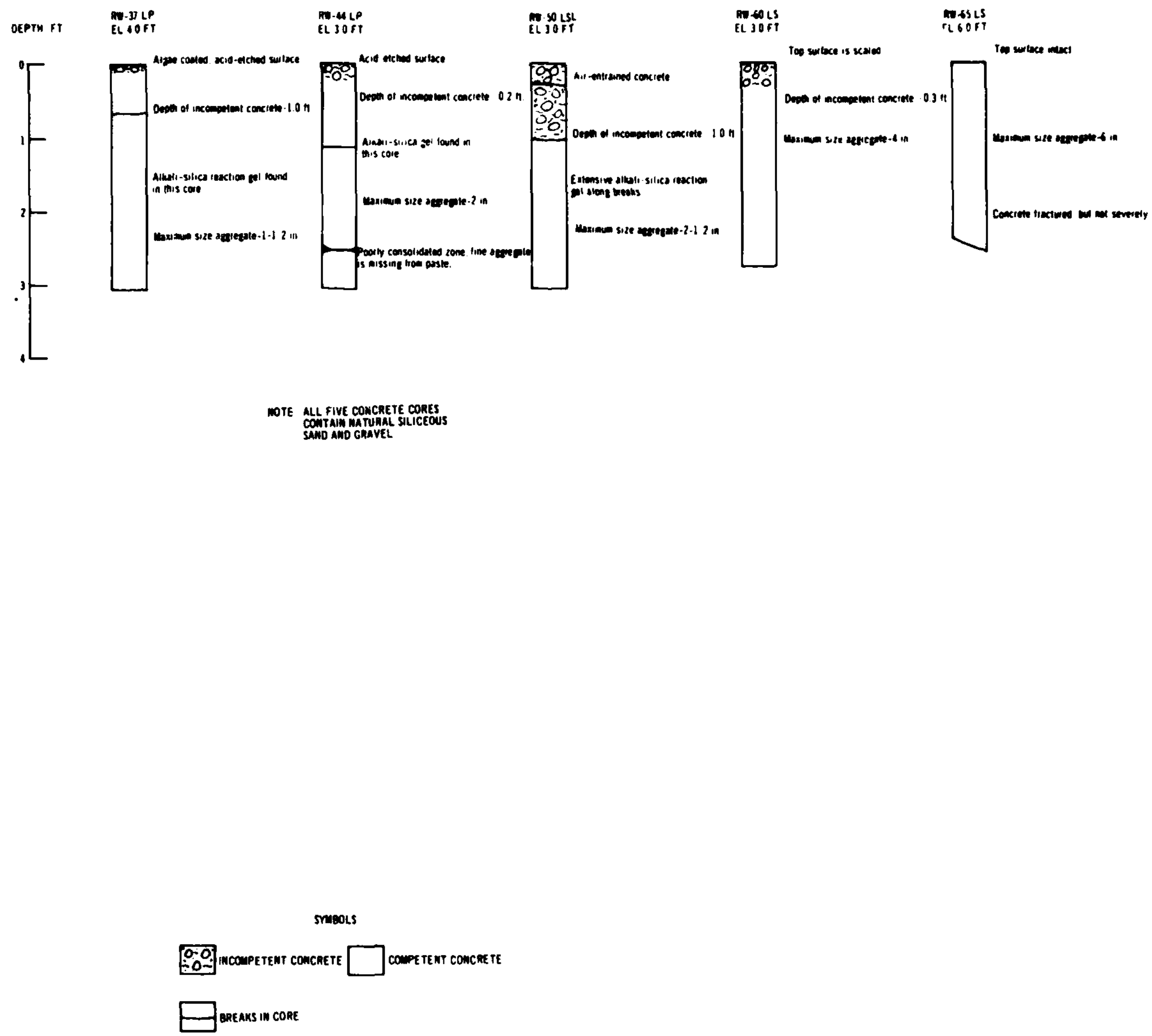


Figure 31. (Concluded)

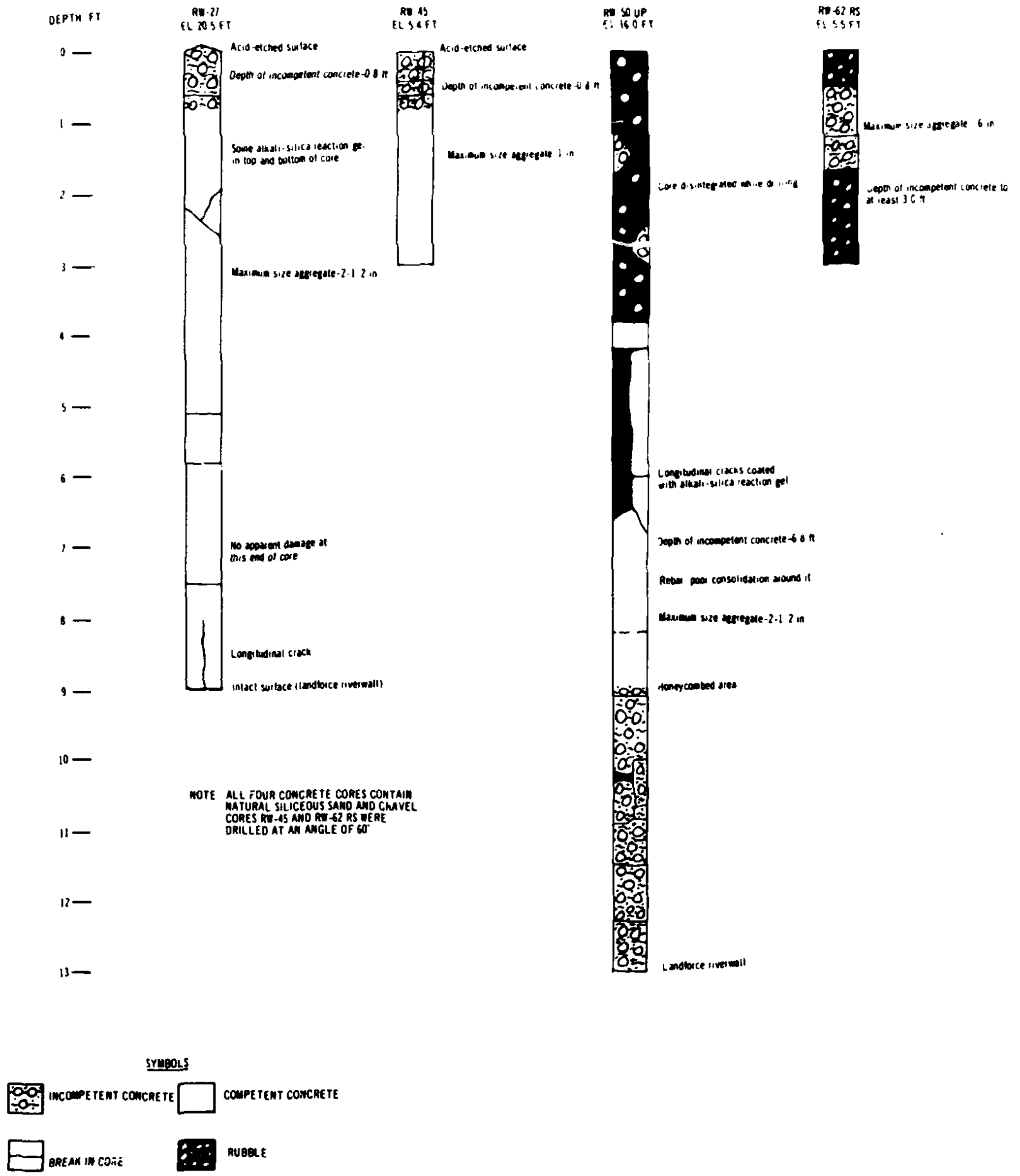


Figure 32. Horizontal and inclined cores, river face of river wall

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ENGINEERING CONDITION SURVEY AND EVALUATION OF TROY LOCK AND DA--ETC(U)
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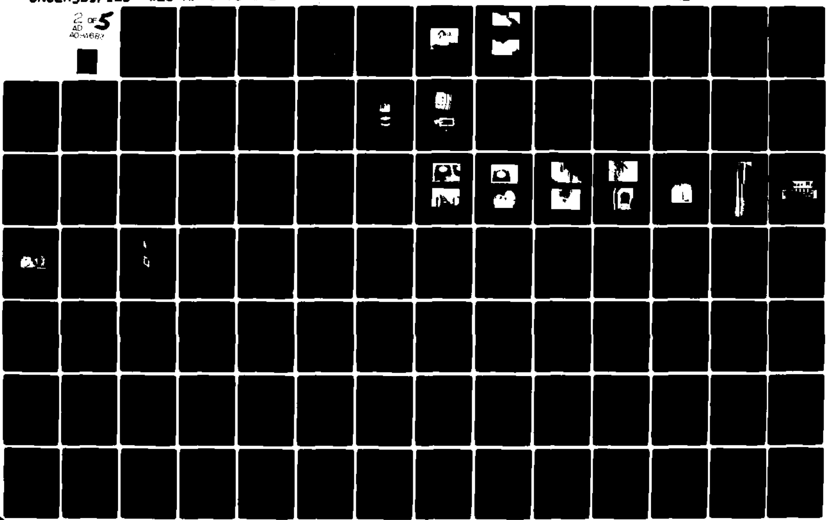


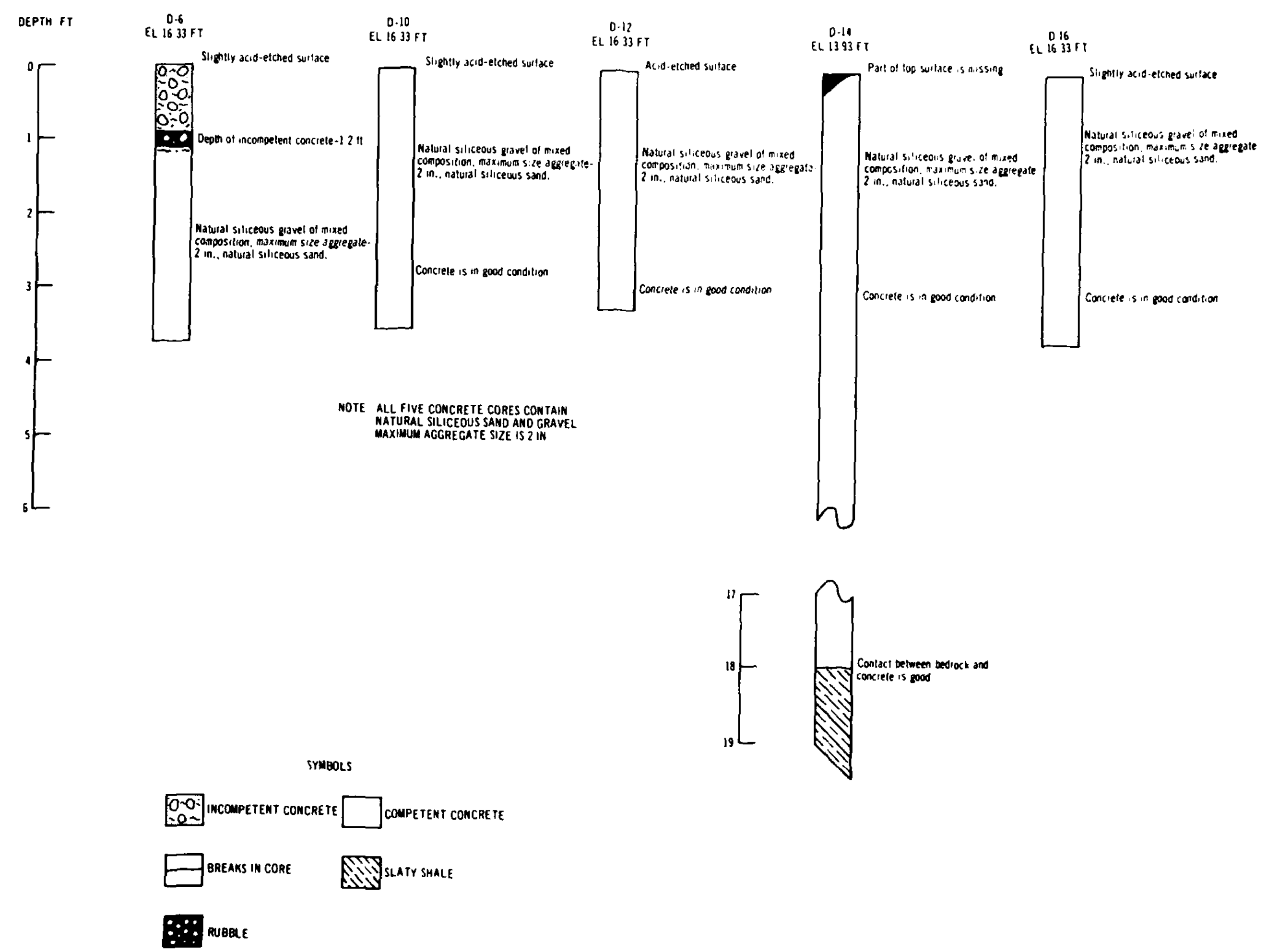


Figure 33. Vertical cores, top of dam (Continued)

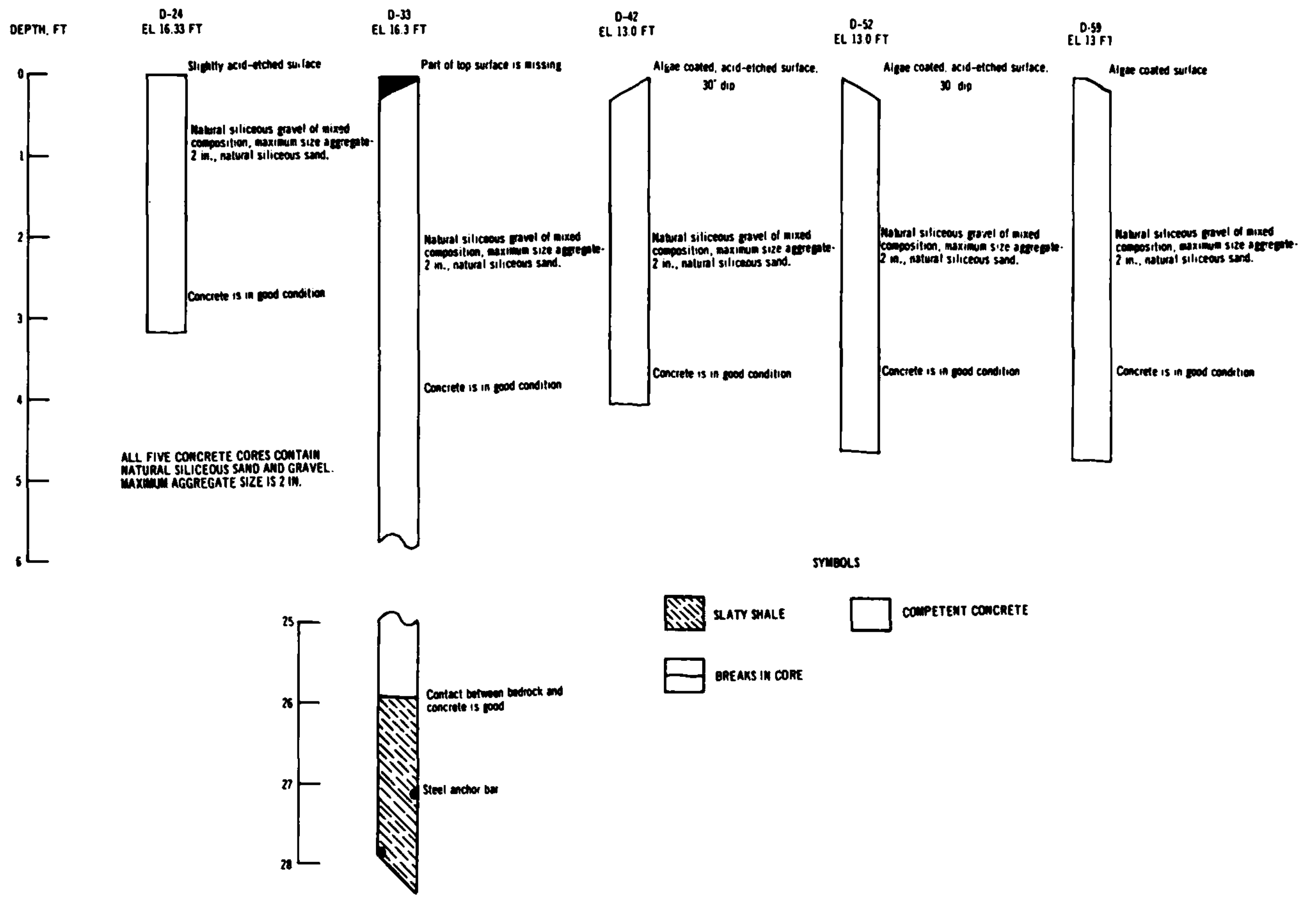


Figure 33. (Concluded)

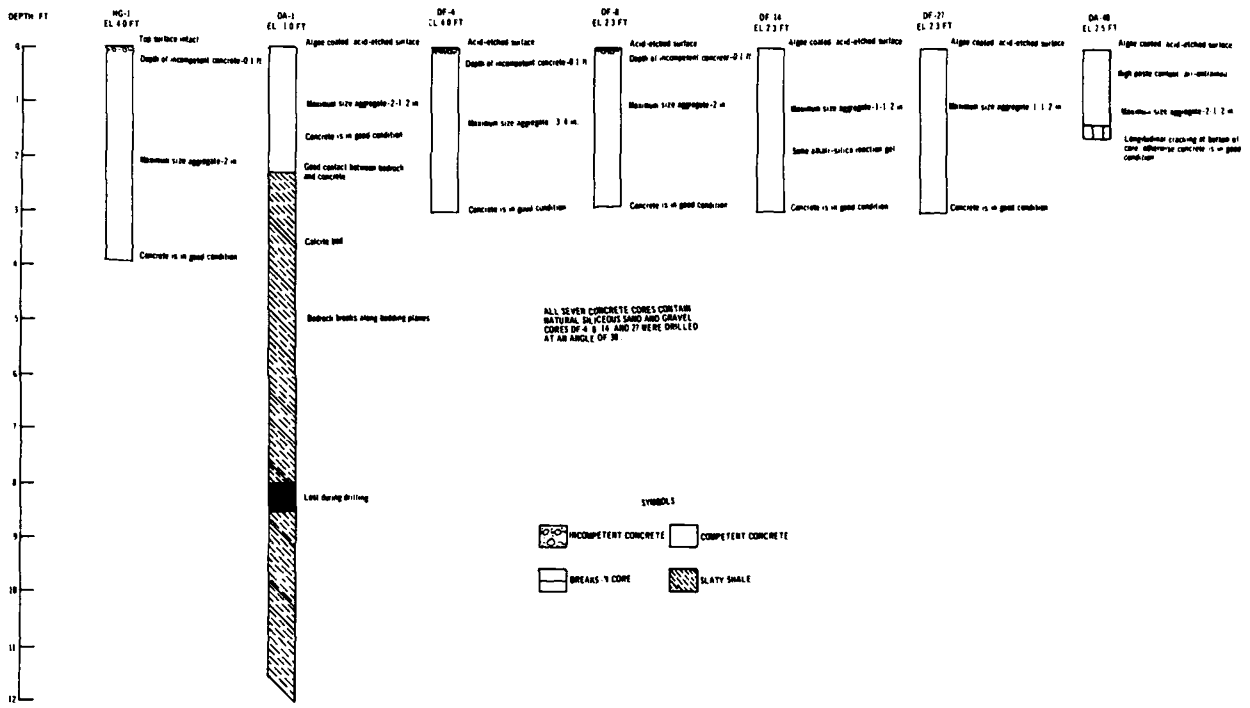


Figure 34. Vertical and inclined cores, toe of dam and headgate tunnel entrance

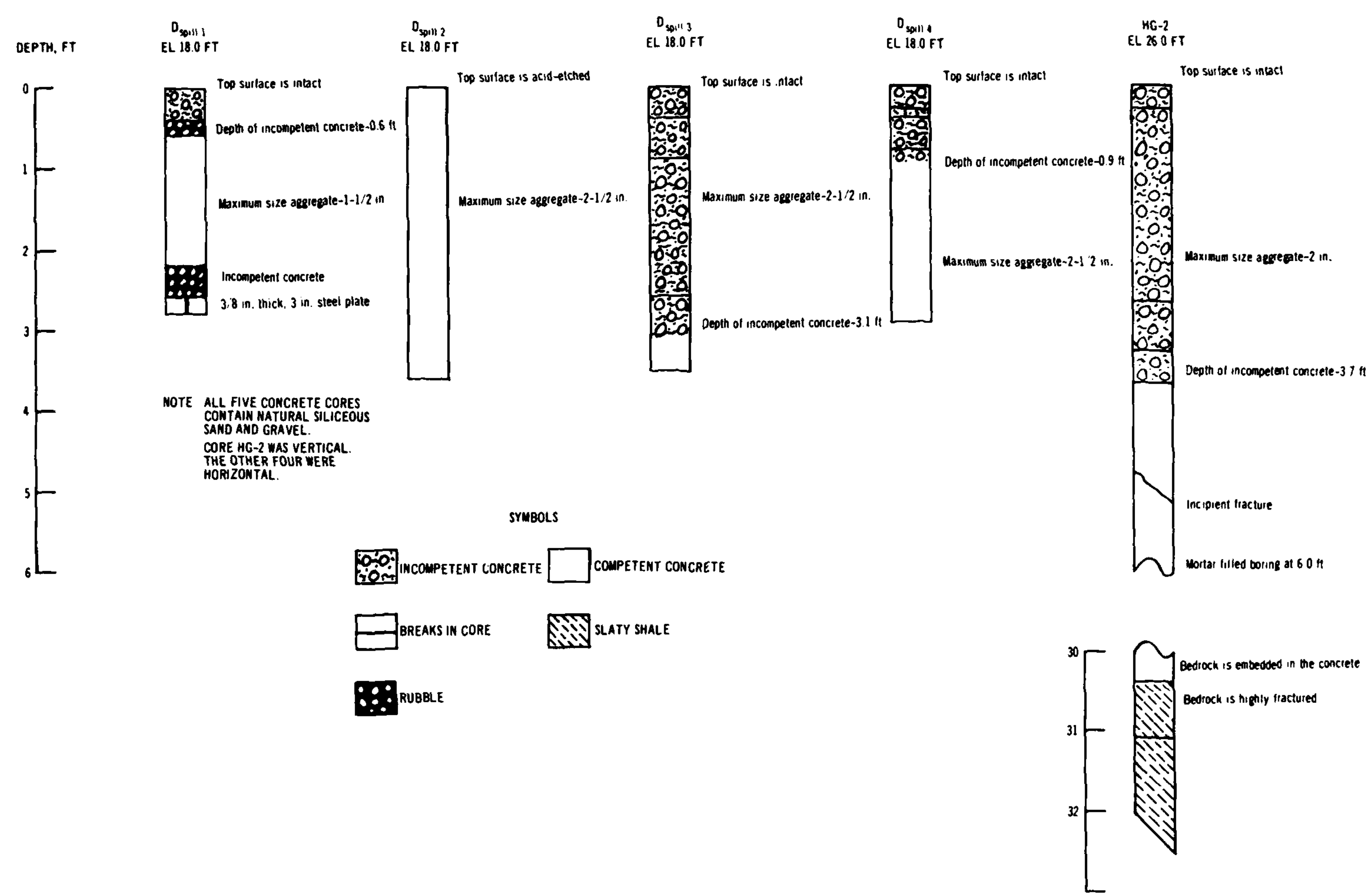


Figure 35. Horizontal and vertical cores, dam spillway piers

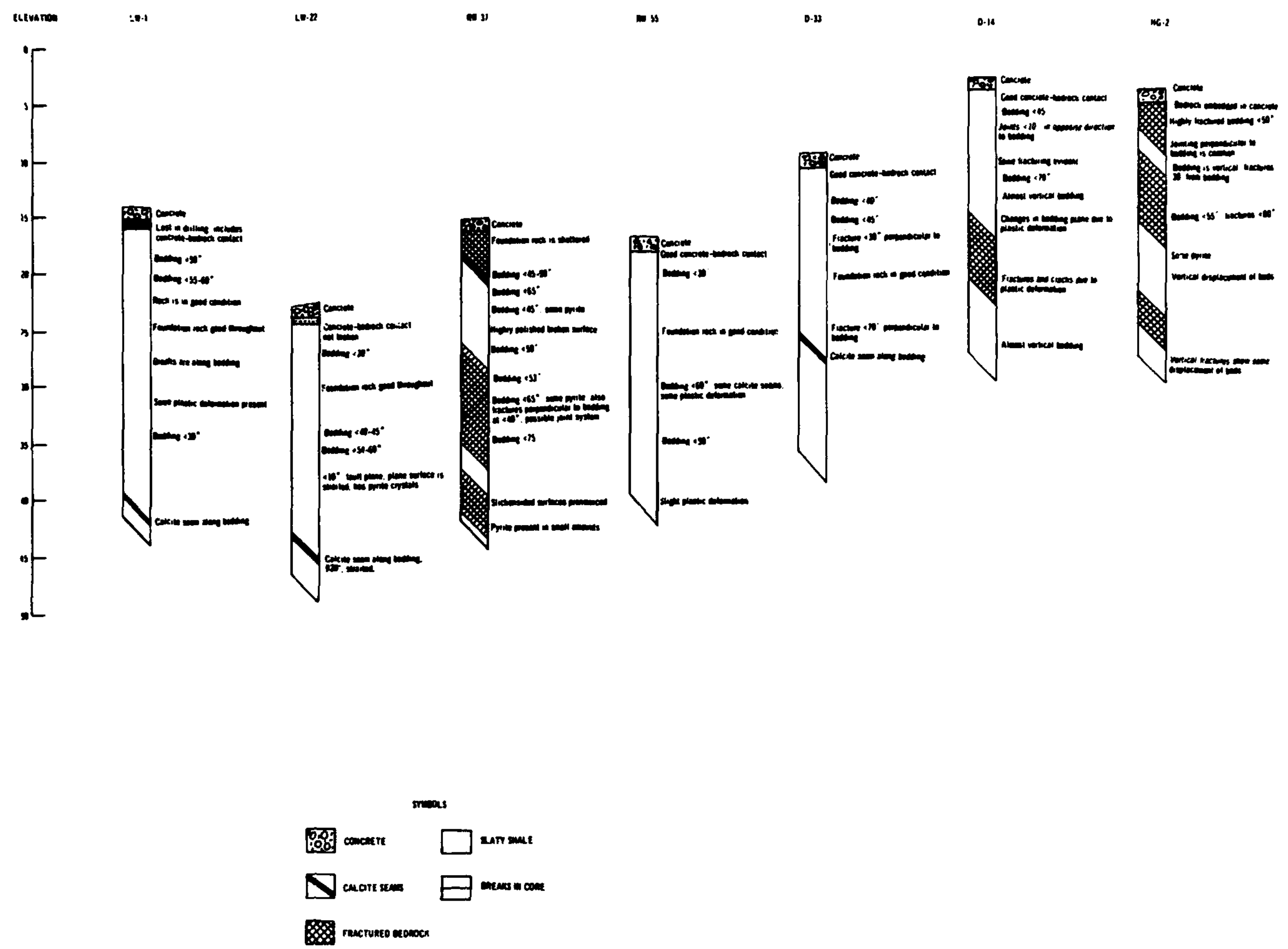


Figure 36. Foundation rock

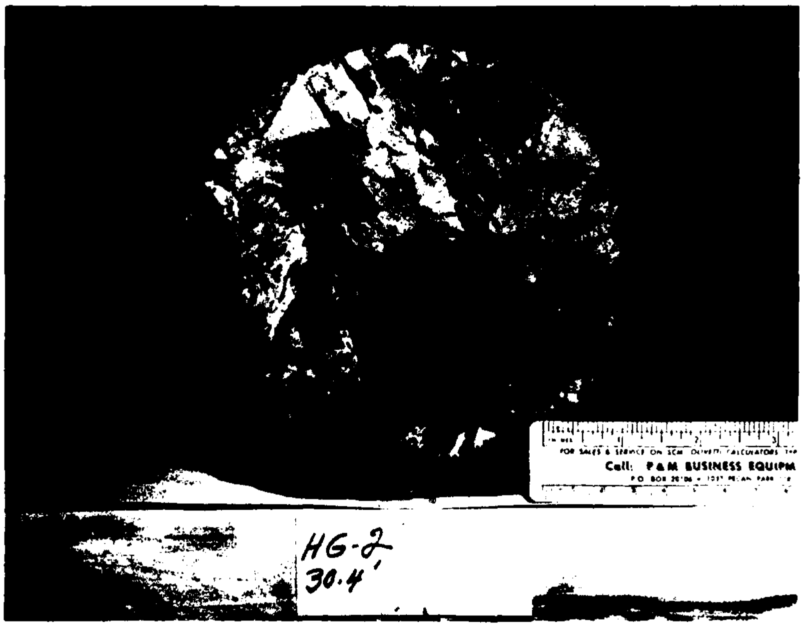


Figure 37. Base of concrete in Boring HG-2
showing embedded black foundation rock

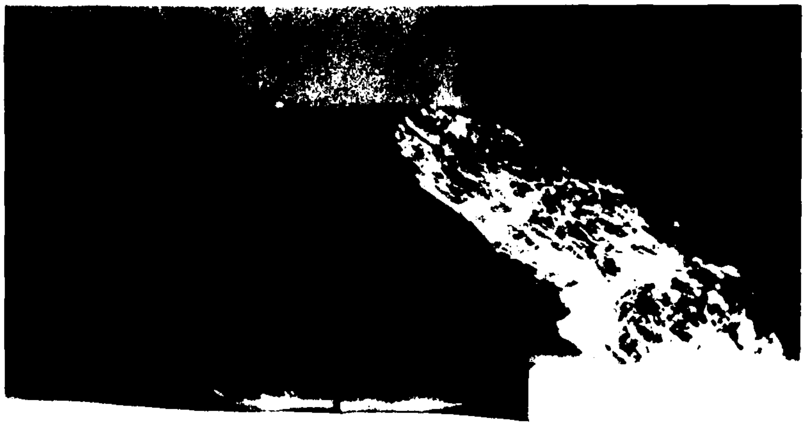


Figure 38. Short length of foundation rock from Core RW-37 lying on its side to show typical high angle breaks, ×0.2

Figure 39. Sawed surface from short length of foundation rock from Core RW-55. The broken surfaces and the sloping bedding traces on the sawed surface are typical, approximately ×0.5

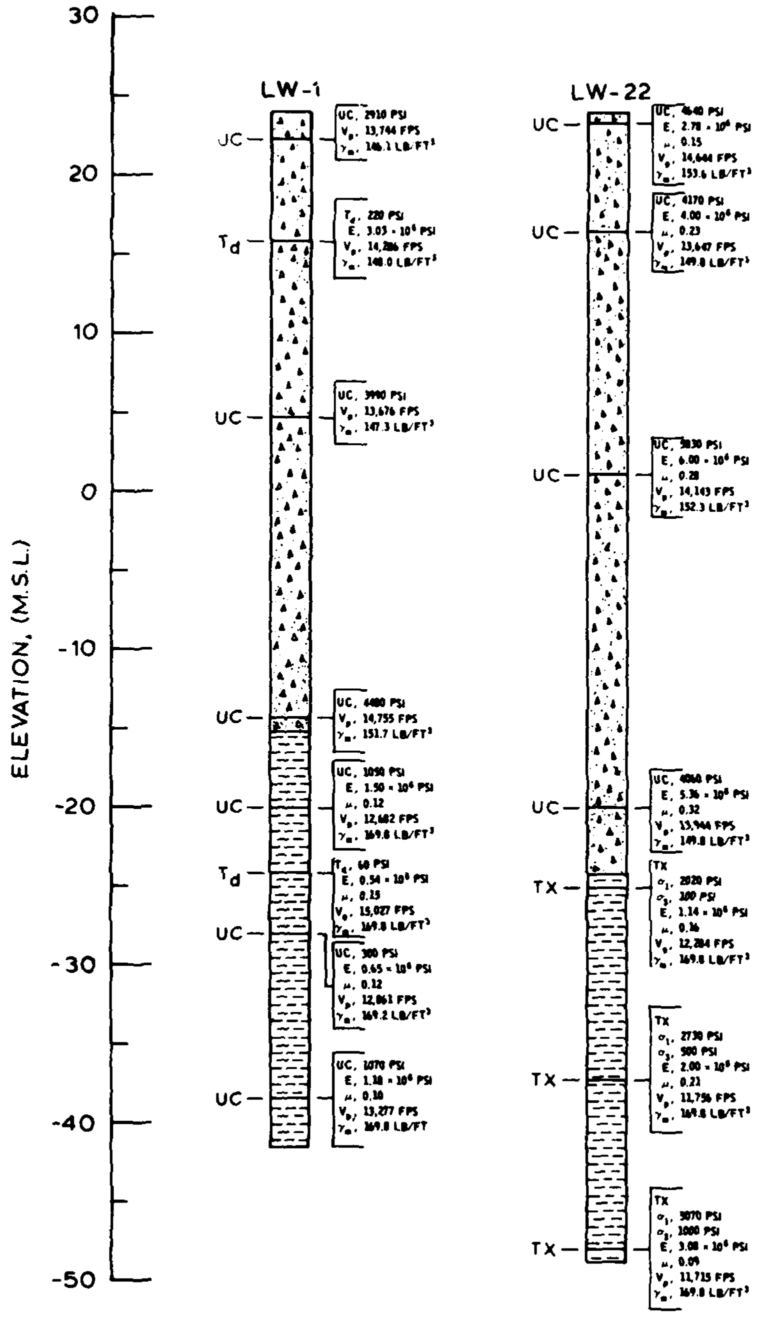


Figure 40. Test results from vertically drilled concrete and foundation cores (core No., type test, specimen location, and material properties) (Sheet 1 of 3)

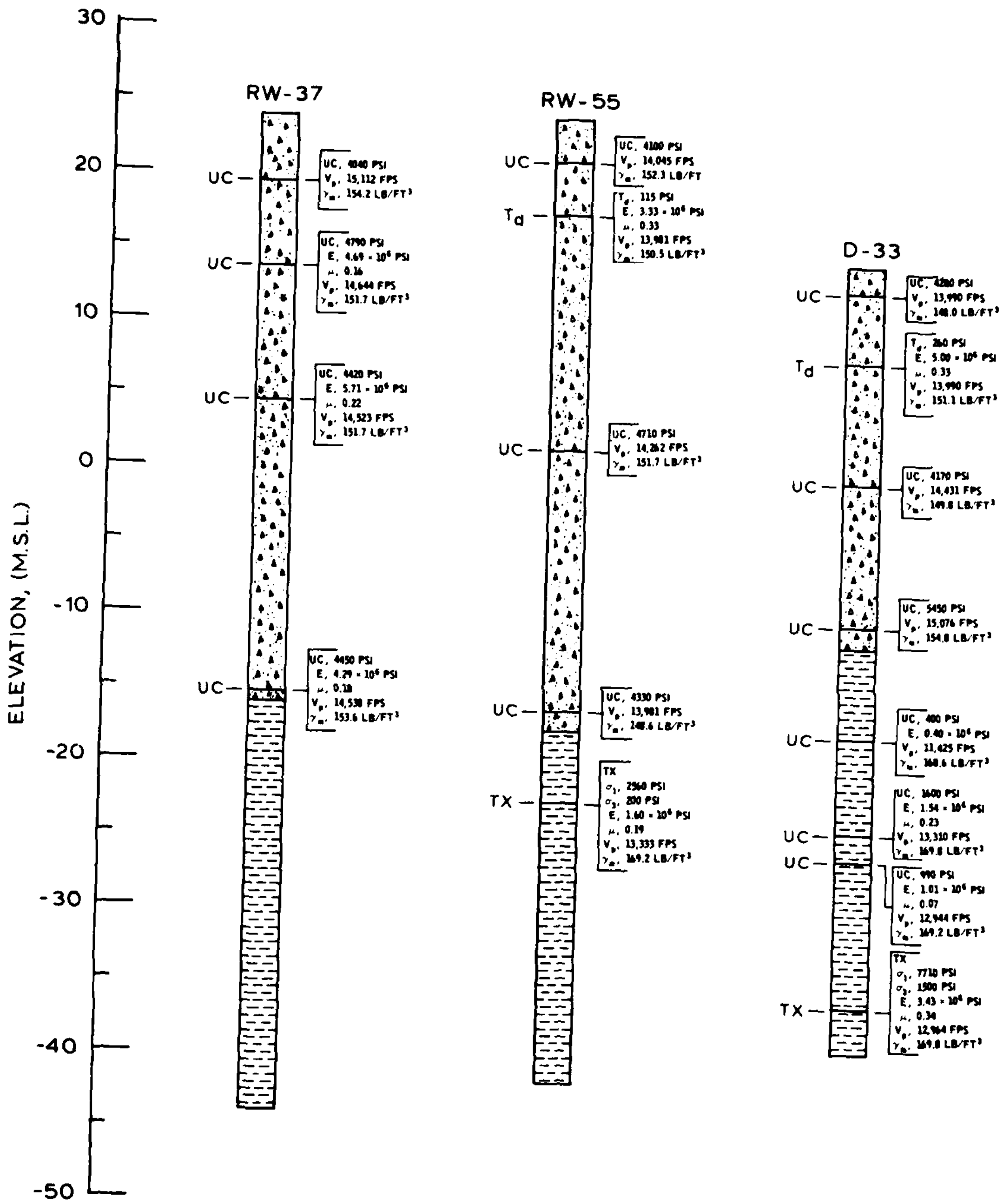


Figure 40. (Sheet 2 of 3)

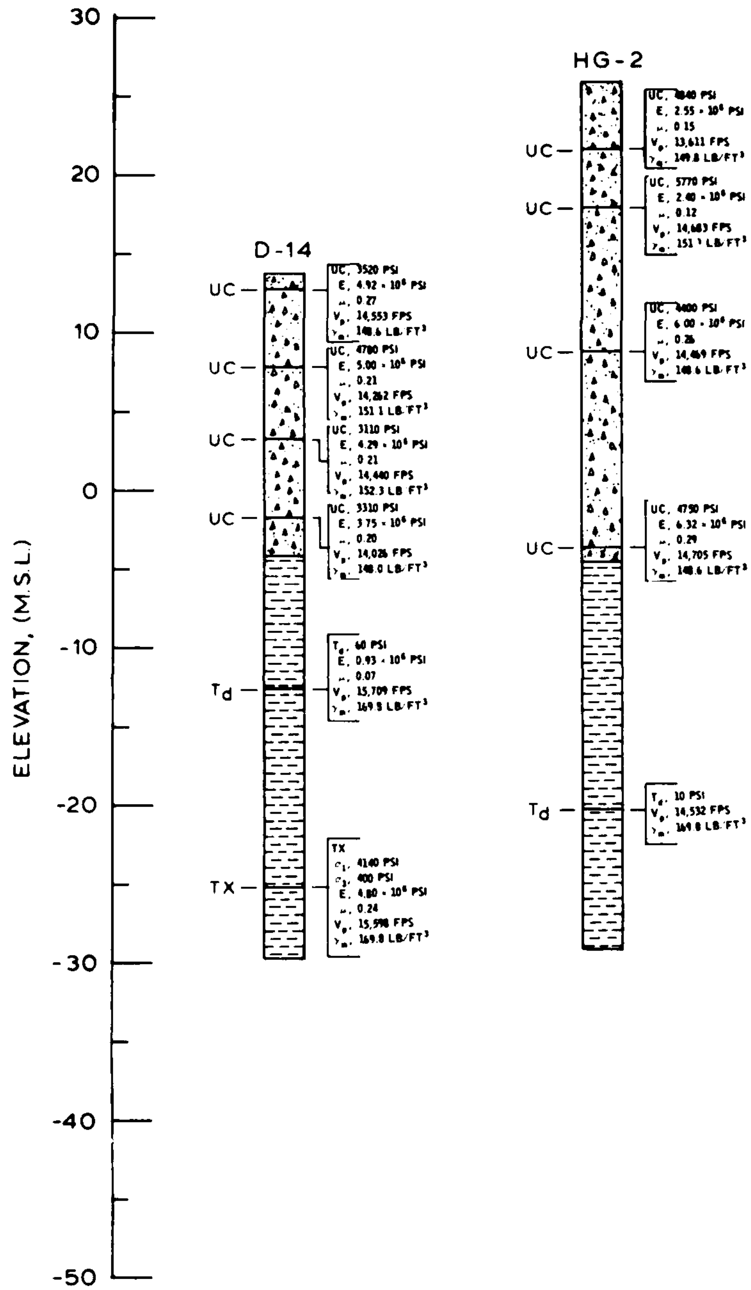


Figure 40. (Sheet 3 of 3)

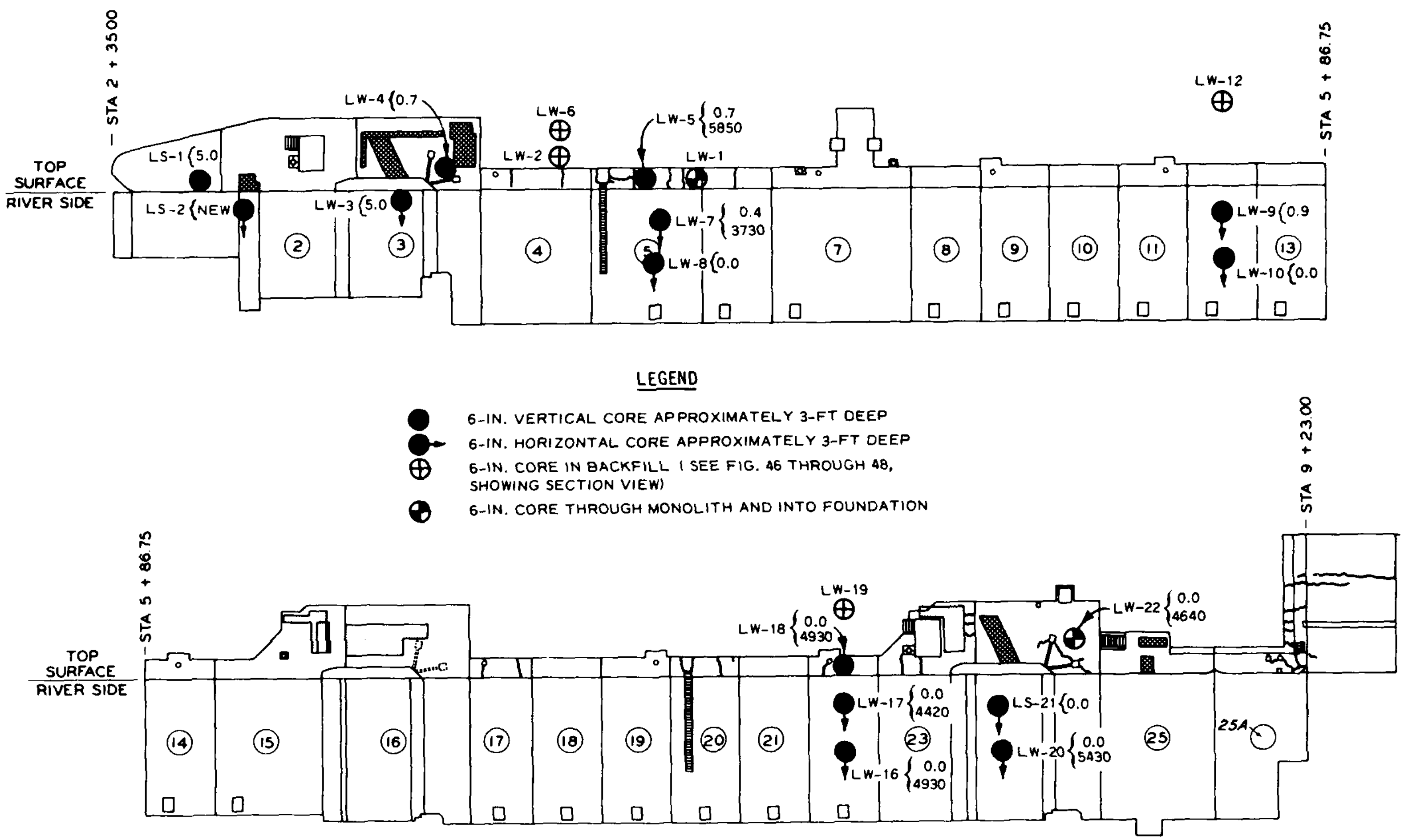


Figure 41. Core locations, depth of deteriorated concrete, and compressive strength below deteriorated concrete--land wall

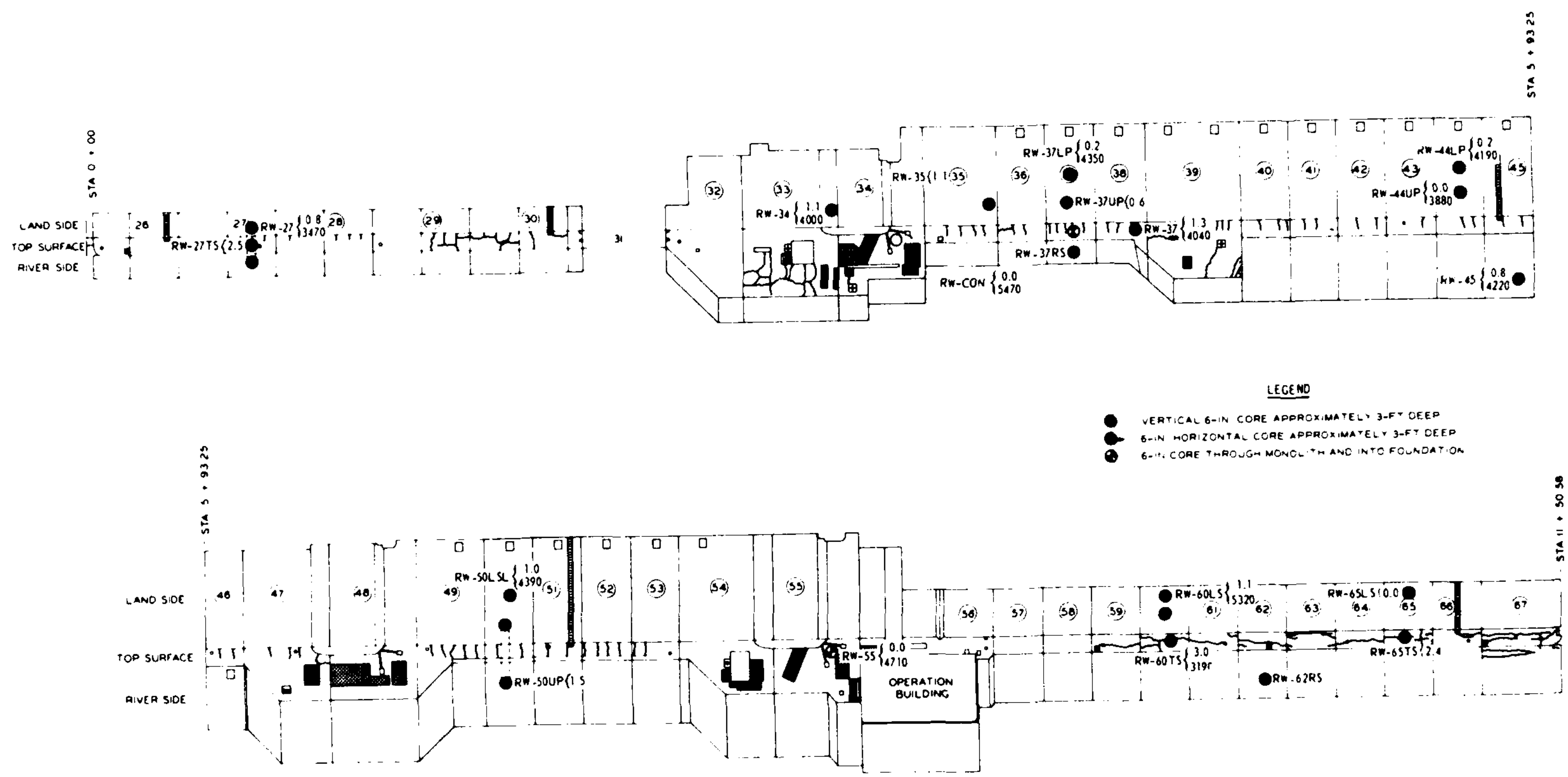


Figure 42. Core locations, depth of deteriorated concrete, and compressive strength below deteriorated concrete--river wall

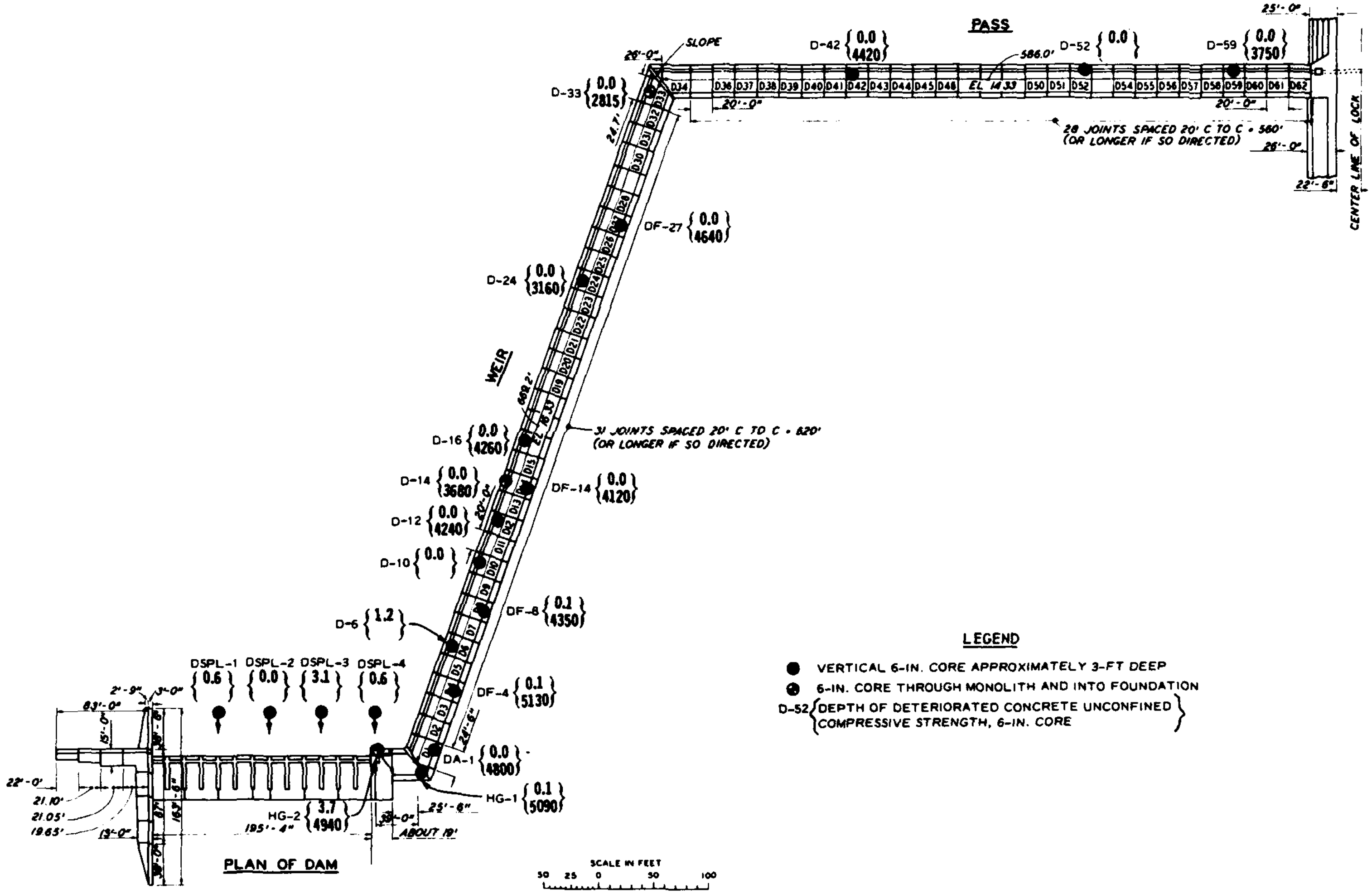


Figure 43. Core locations, depth of deteriorated concrete, and compressive strength below deteriorated concrete--dam

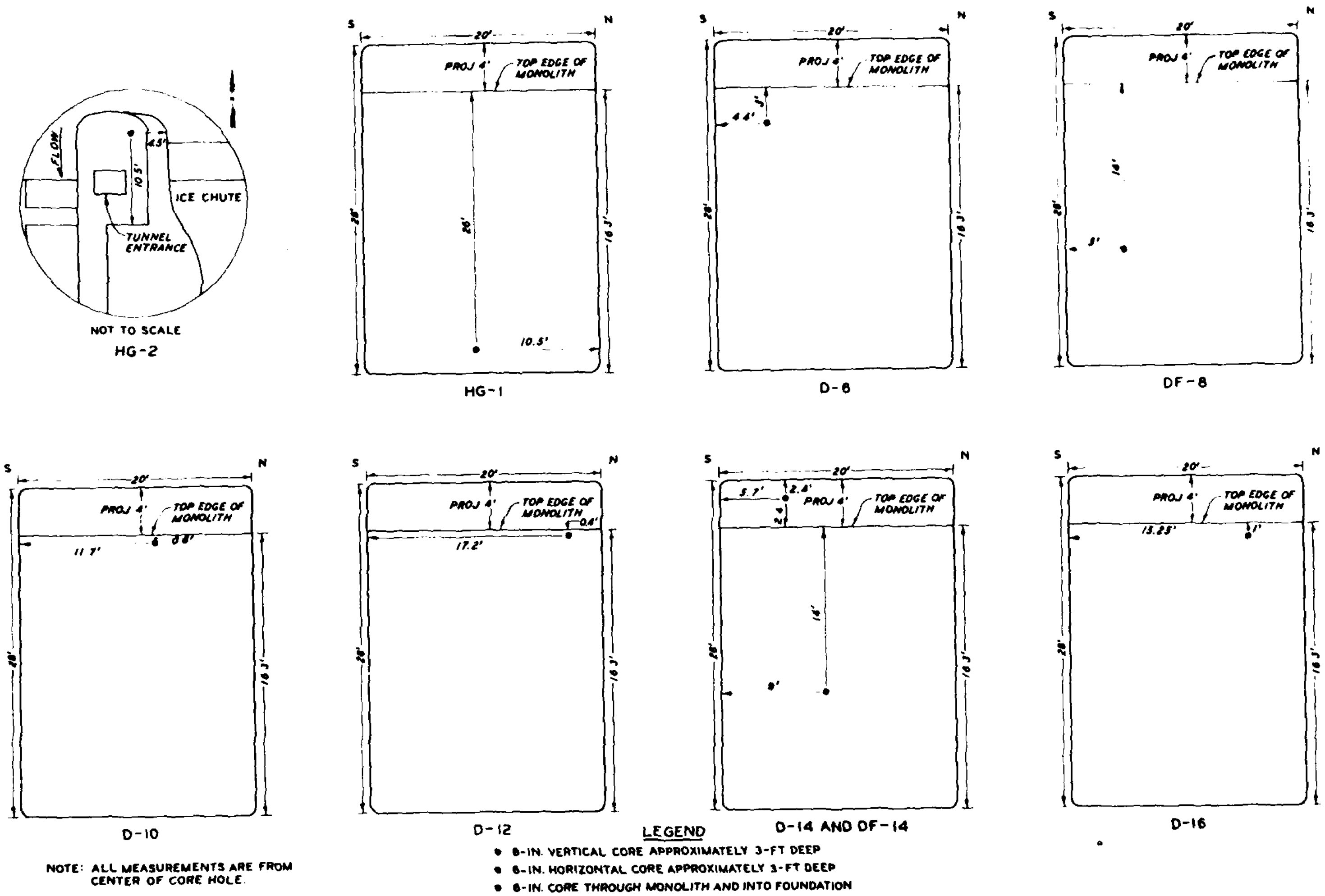


Figure 44. Detail core locations on dam, Monoliths HG-2, HG-1, D-6, DF-8, D-10, D-12, D-14, DF-14, and D-16

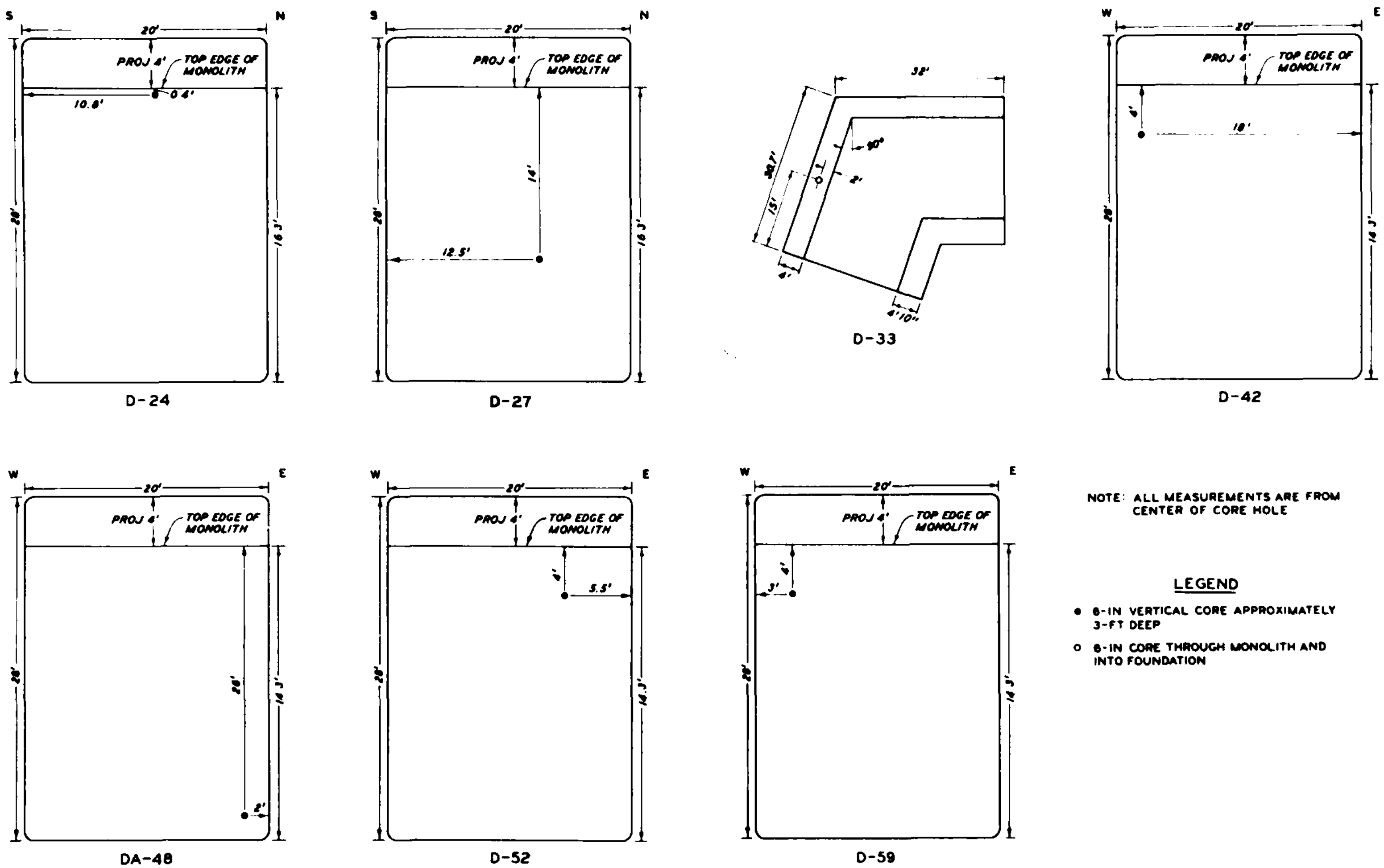


Figure 45. Detail core locations on dam, Monoliths D-24, D-27, D-33, D-42, DA-48, D-52, and D-59

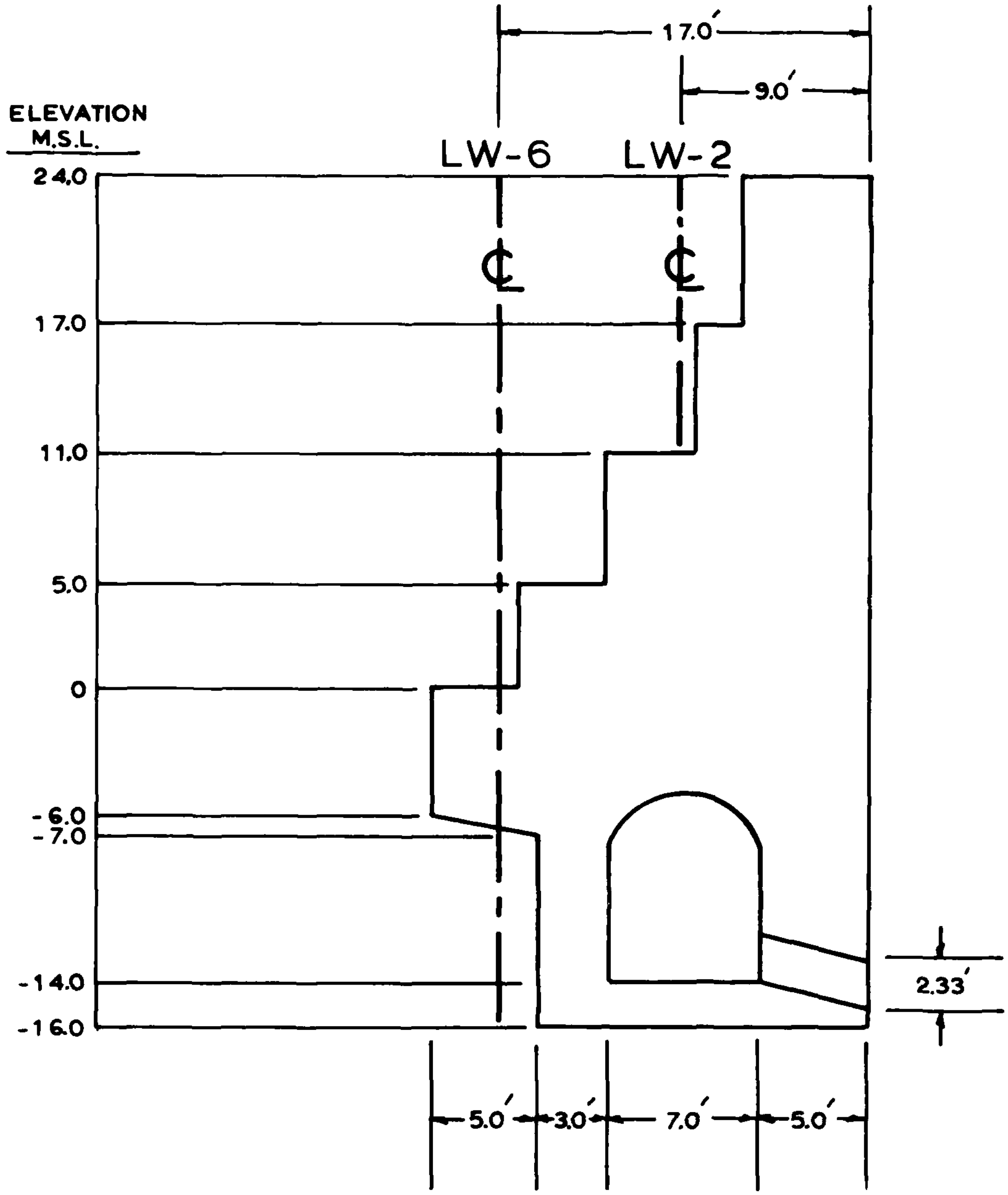


Figure 46. Elevation view presenting core locations behind Monolith 4

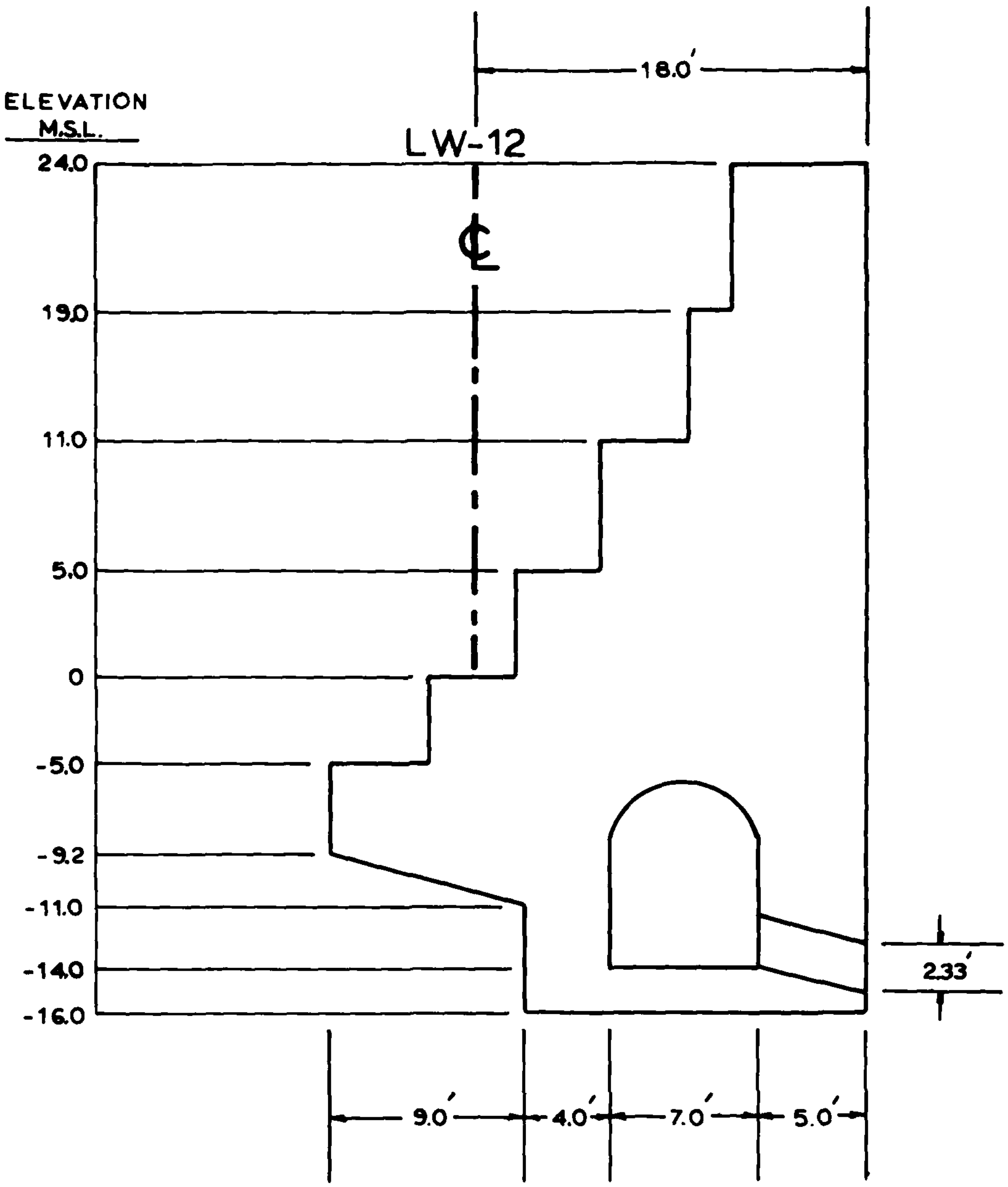


Figure 47. Elevation view presenting core hole location behind Monolith 12

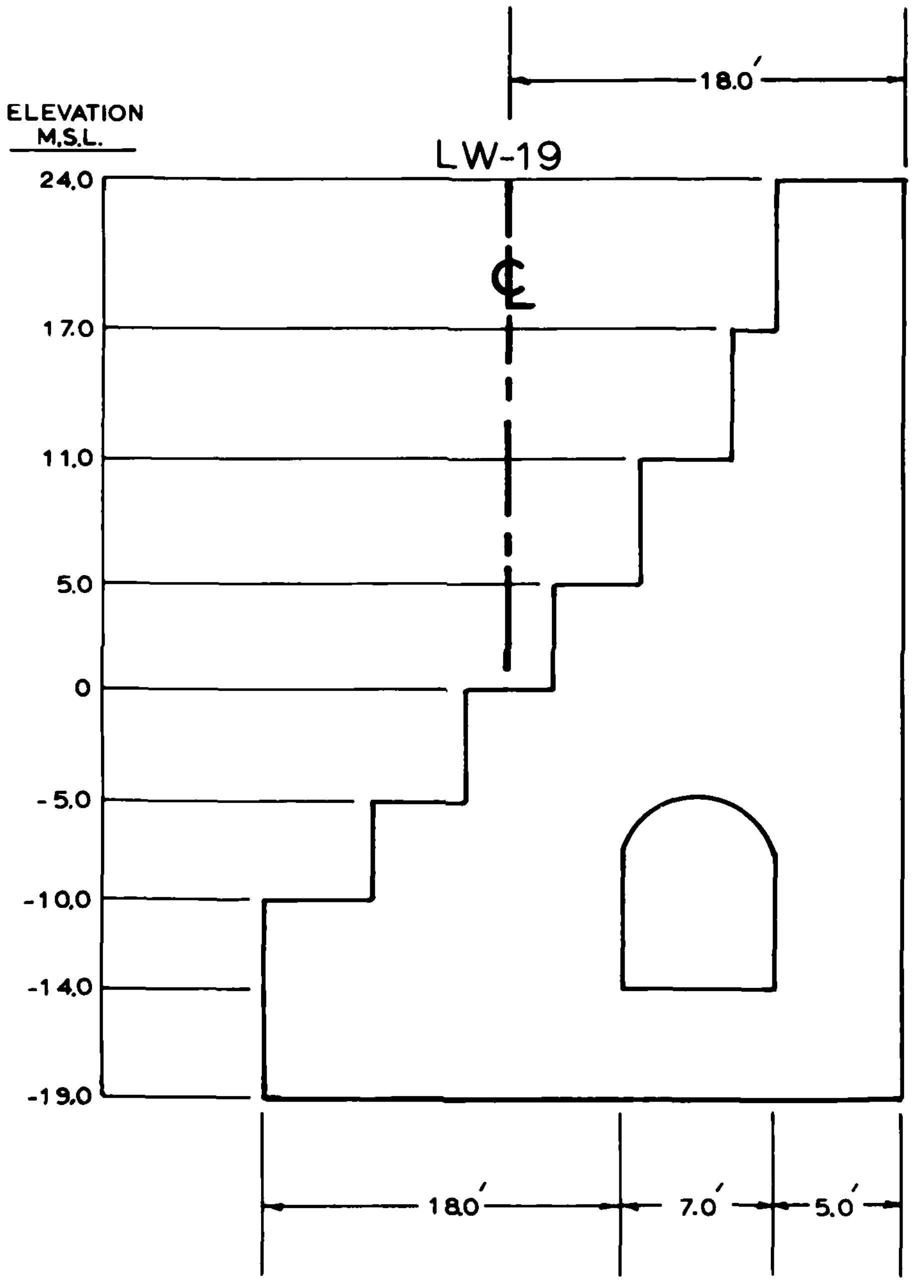


Figure 48. Elevation view presenting core hole location behind Monolith 22

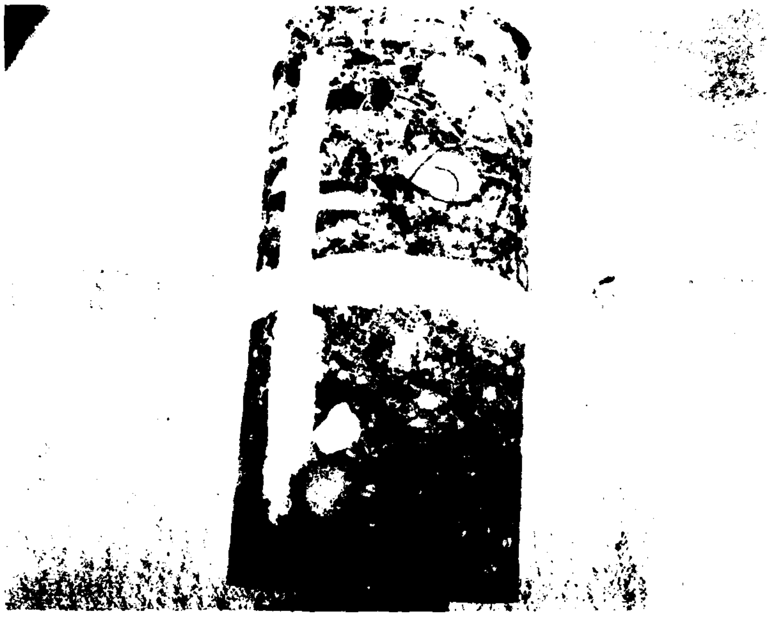


Figure 49. Core in preparation stage for testing

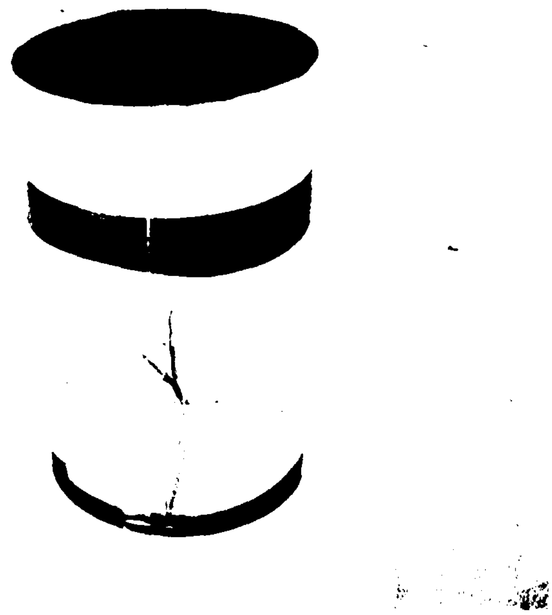


Figure 50. Foundation core after triaxial test

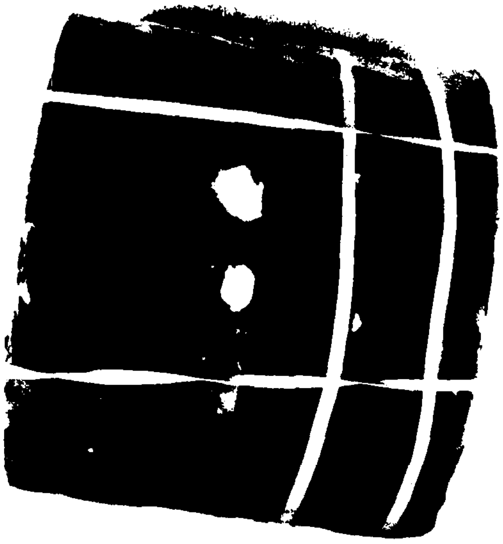


Figure 51. Specimen of concrete and foundation prepared for sliding friction shear tests

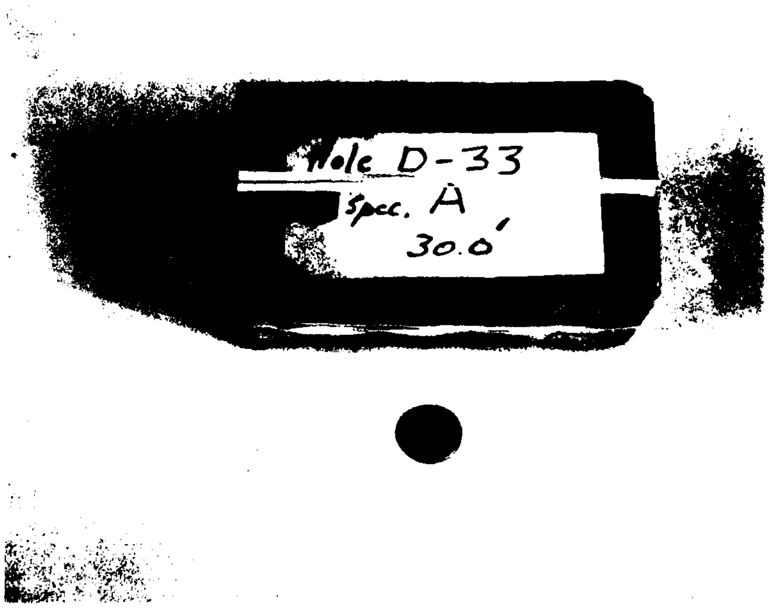


Figure 52. Prepared specimen for testing in shear along bedding plane

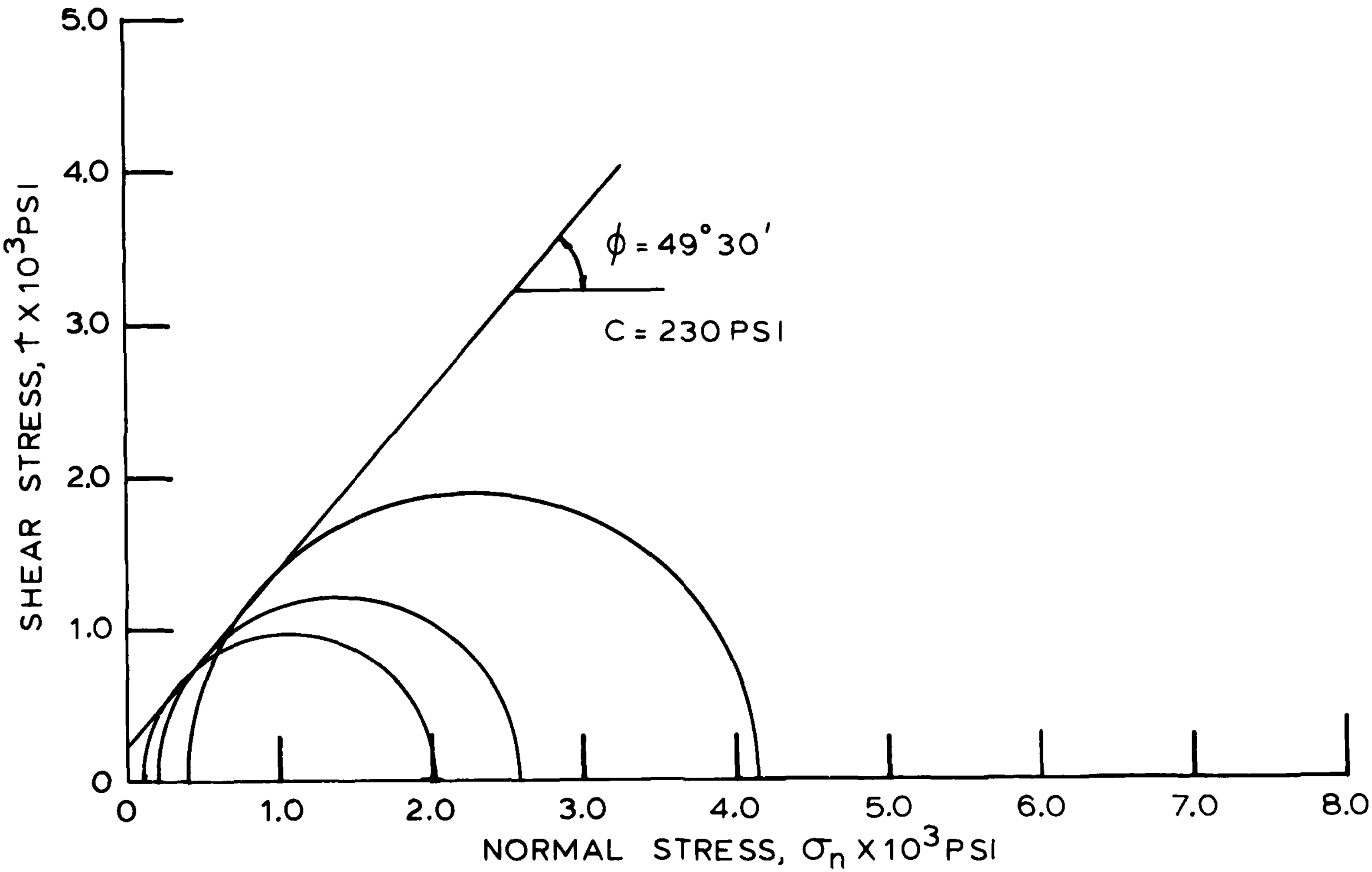


Figure 53. Triaxial test data, foundation Specimens G-1, P-2, and N

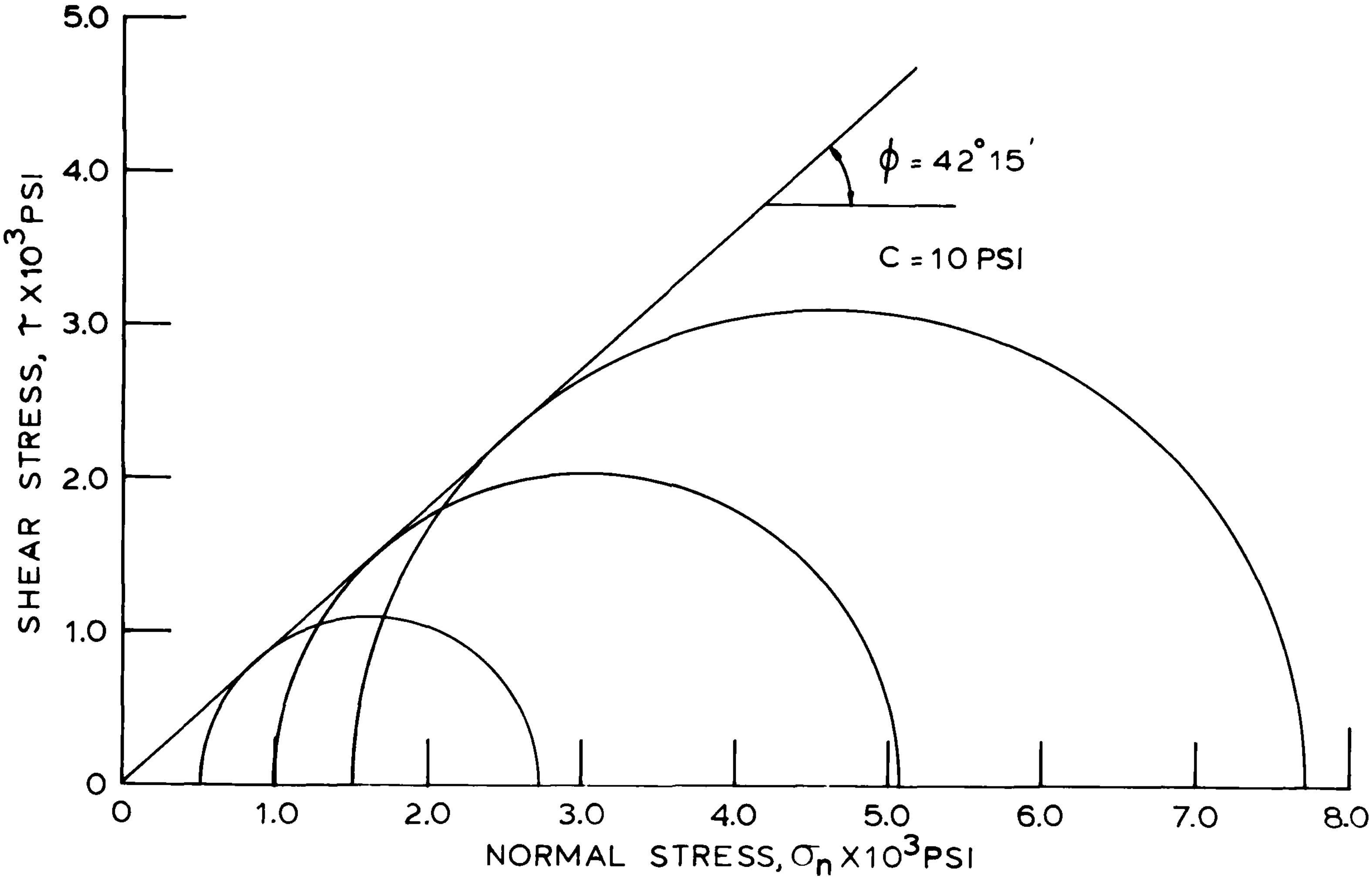


Figure 54. Triaxial test data, foundation Specimens H, I, and C

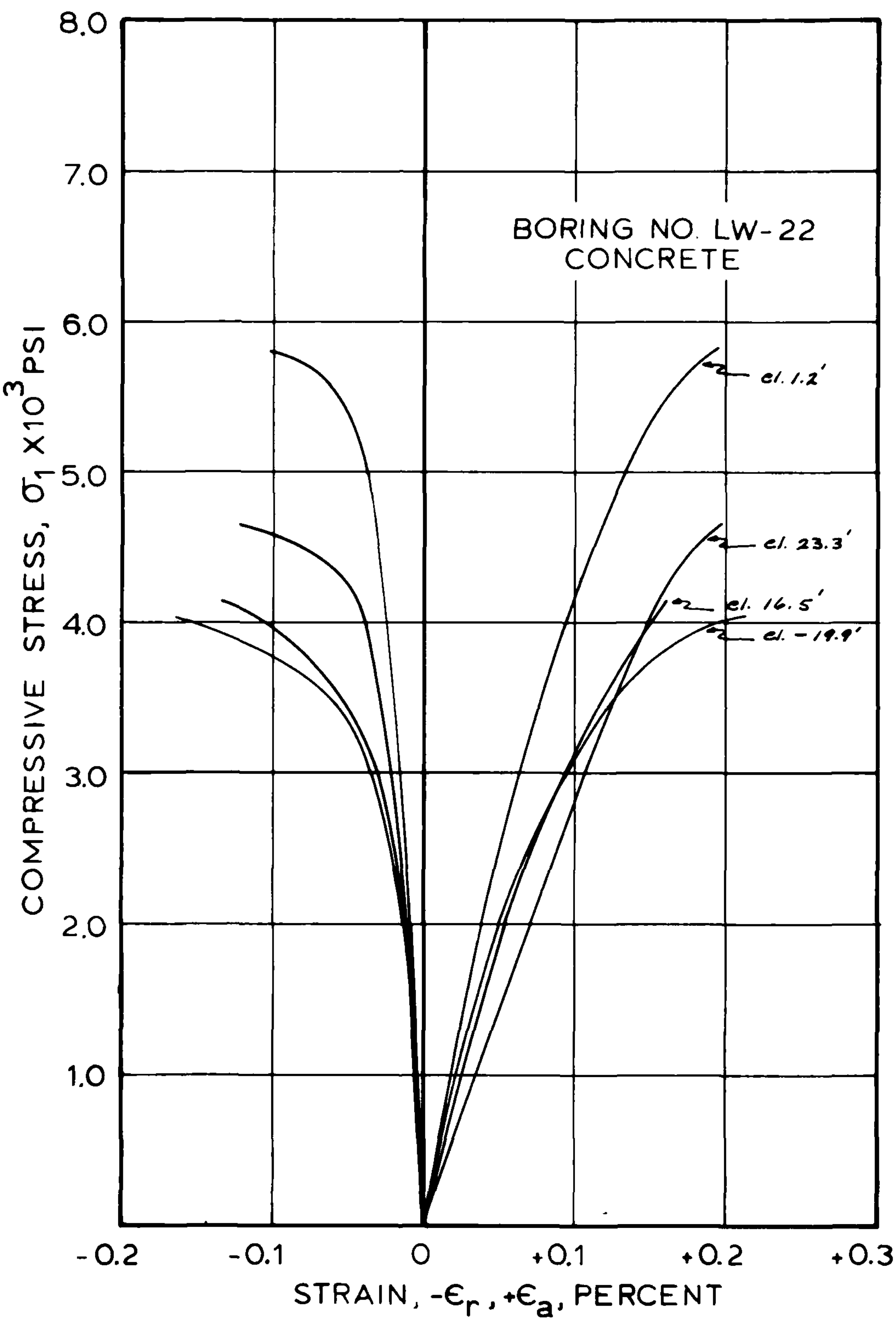


Figure 55. Unconfined stress-strain results of concrete Specimens 11, 12, 13, and 14

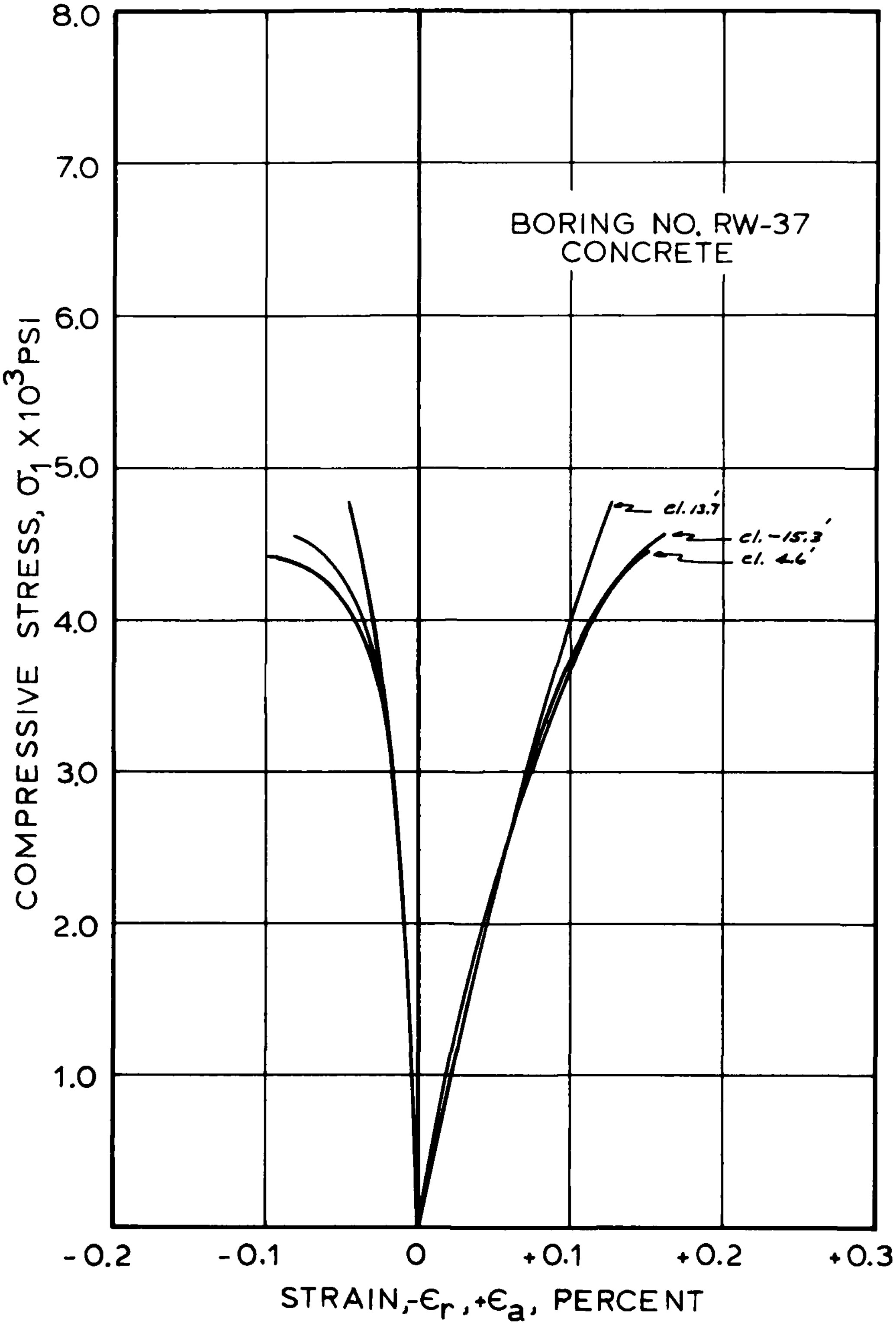


Figure 56. Unconfined compression test results of concrete Specimens 7, 8, and 9

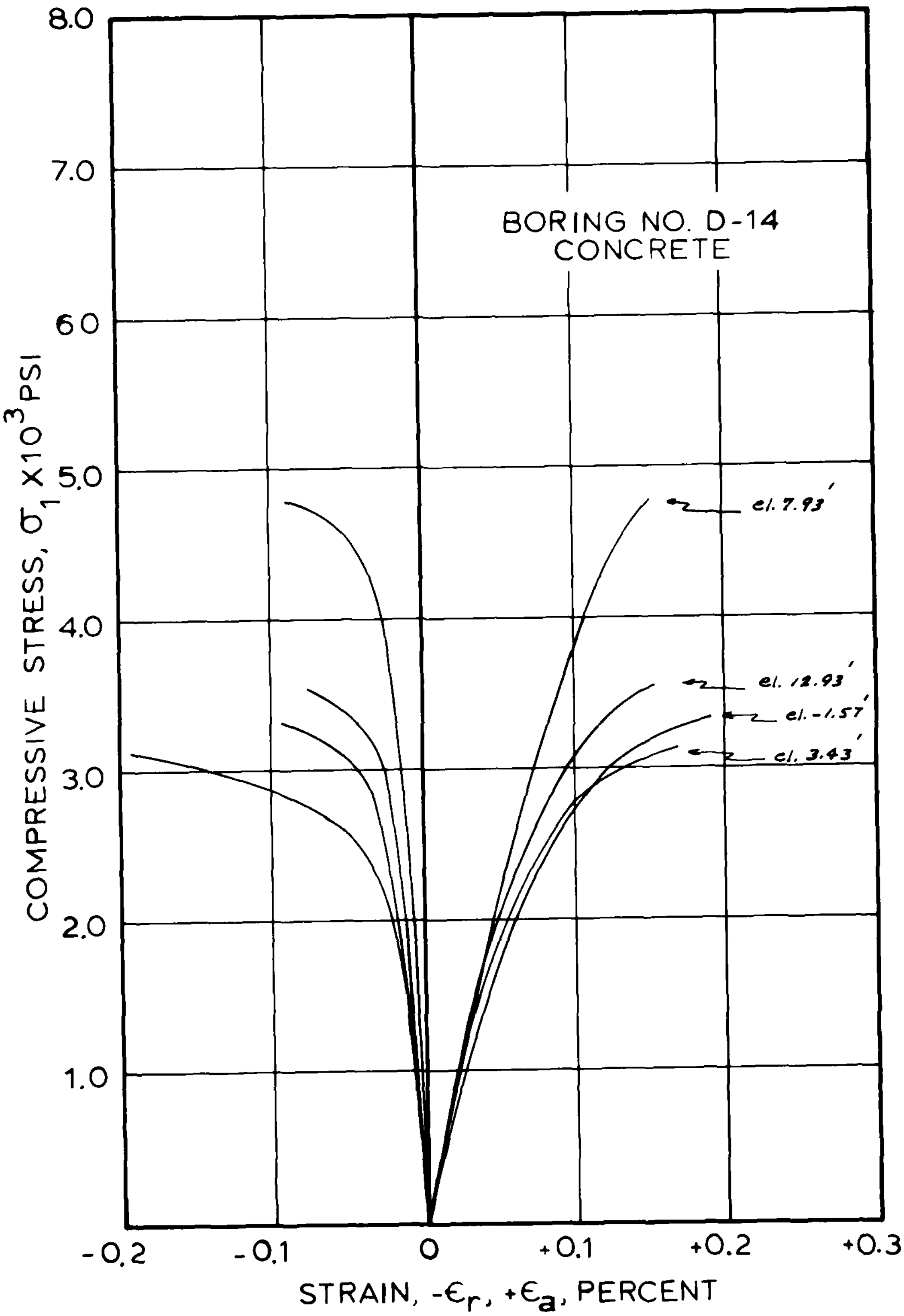


Figure 57. Unconfined compression test results of concrete
Specimens 21, 22, 23, and 24

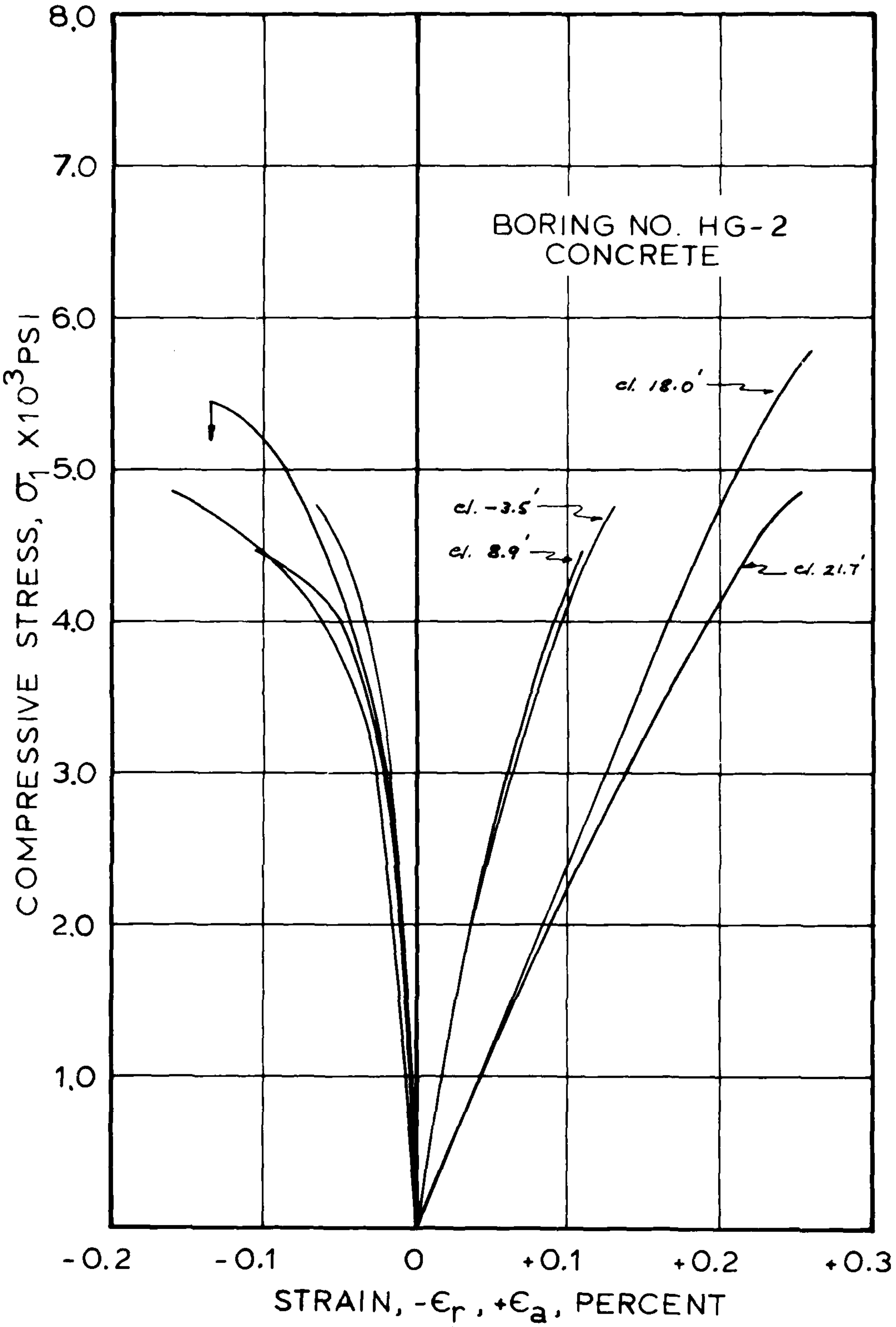


Figure 58. Unconfined compression test results of concrete Specimens 16, 17, 18, and 19

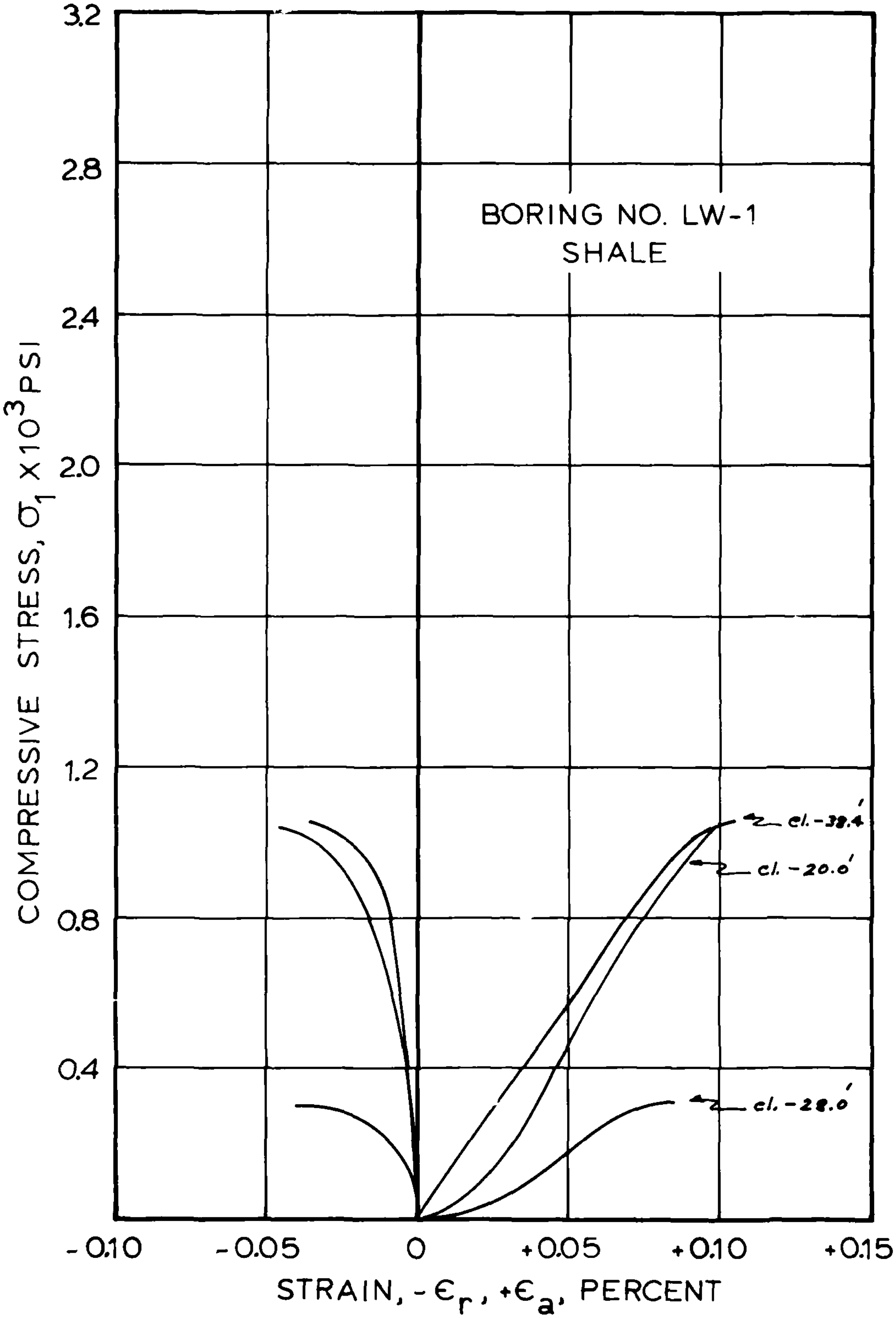


Figure 59. Unconfined compression test results of foundation Specimens U, S-1, and T

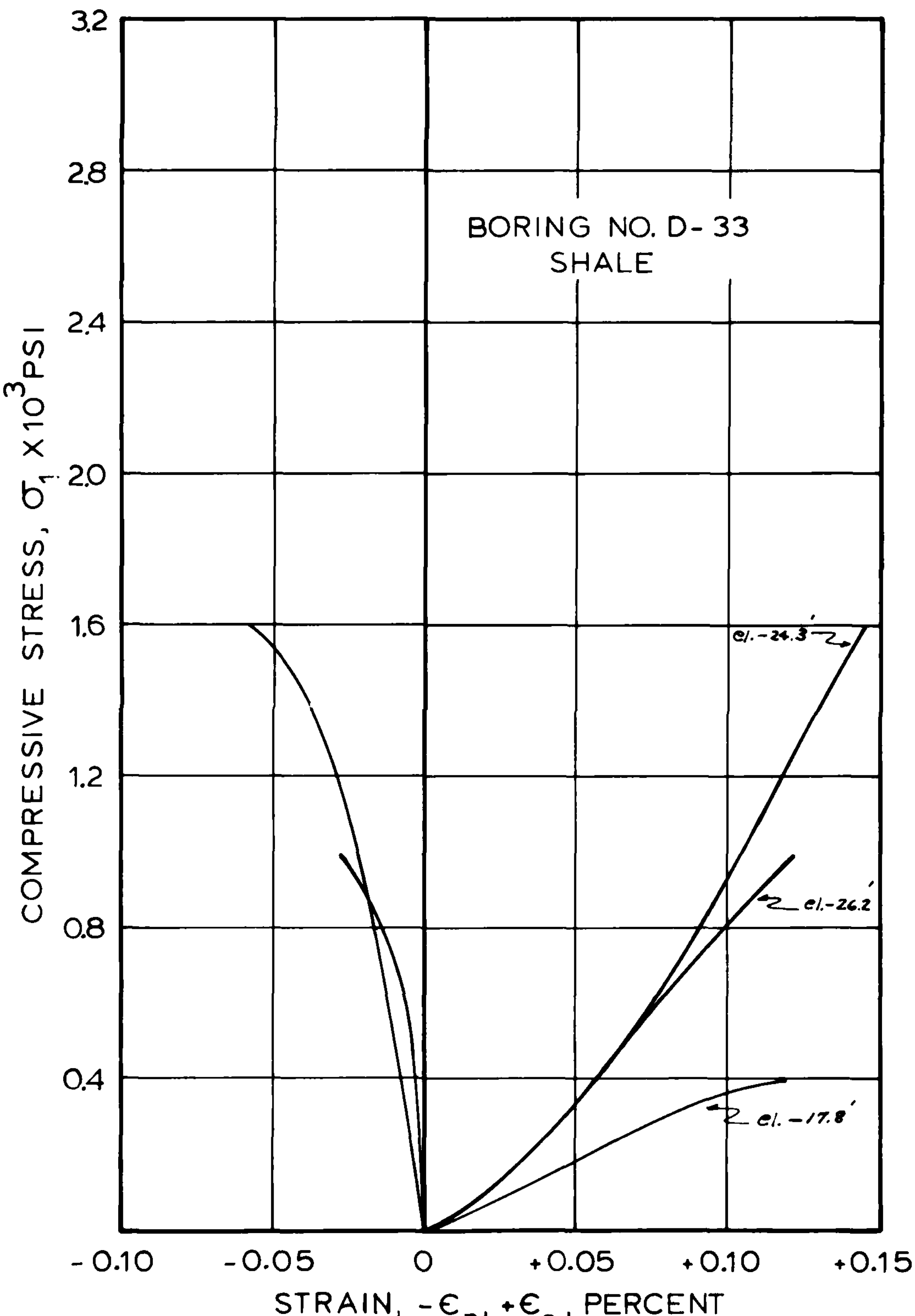


Figure 60. Unconfined compression test results of foundation Specimen A-3, A-4, and B

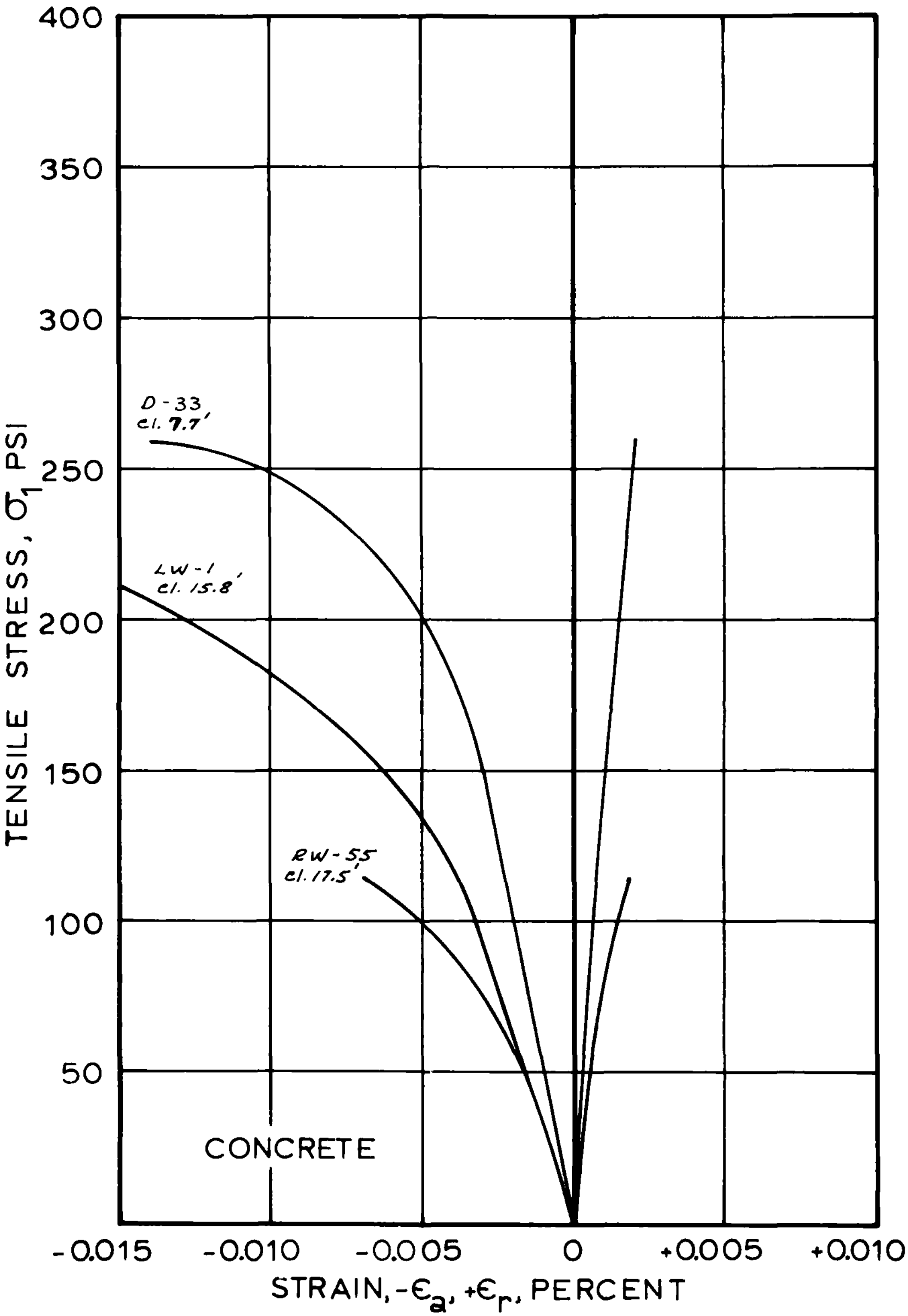


Figure 61. Tension test results of concrete
Specimens 2, 27, and 32

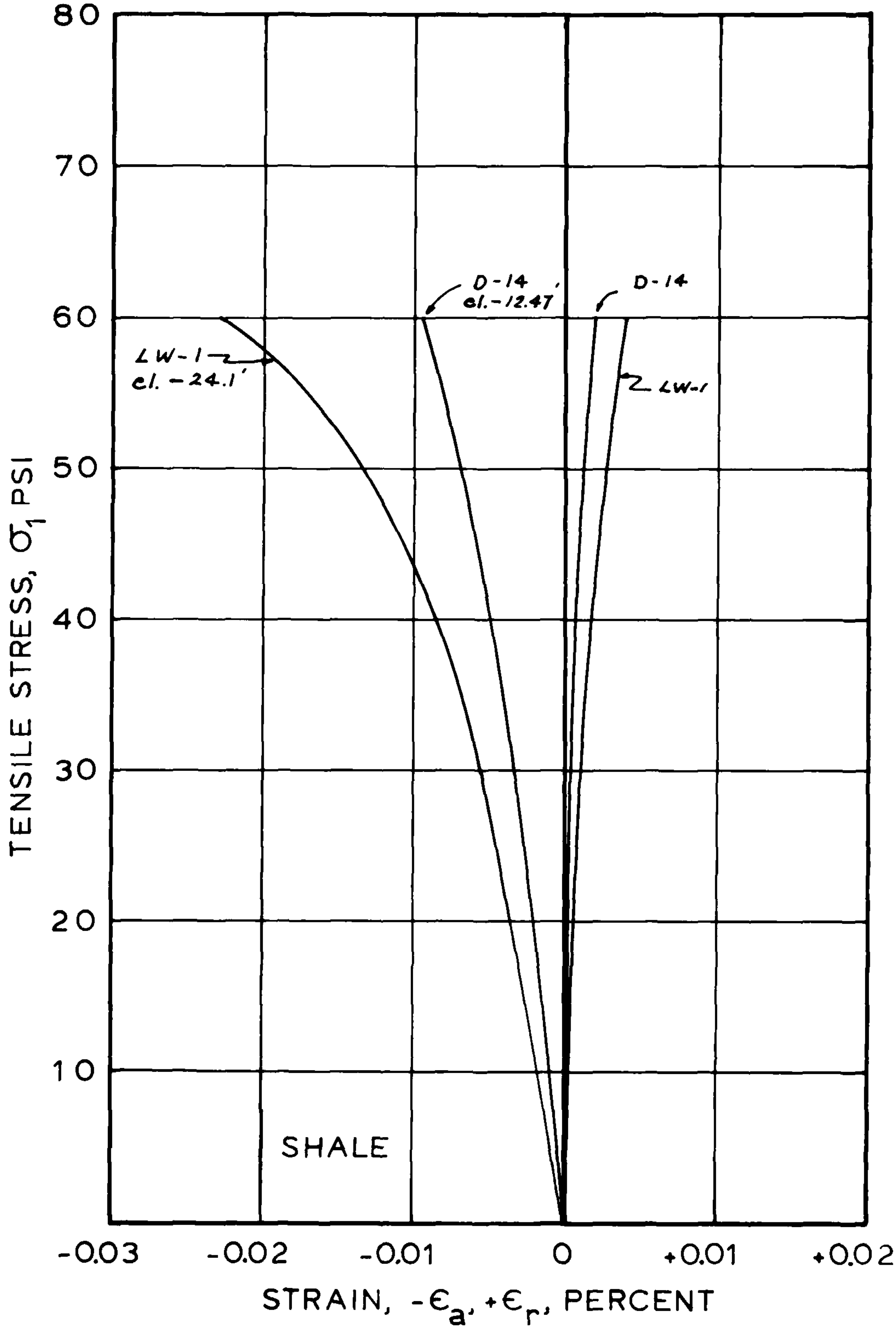


Figure 62. Tension test results of foundation Specimens S-3 and M-3

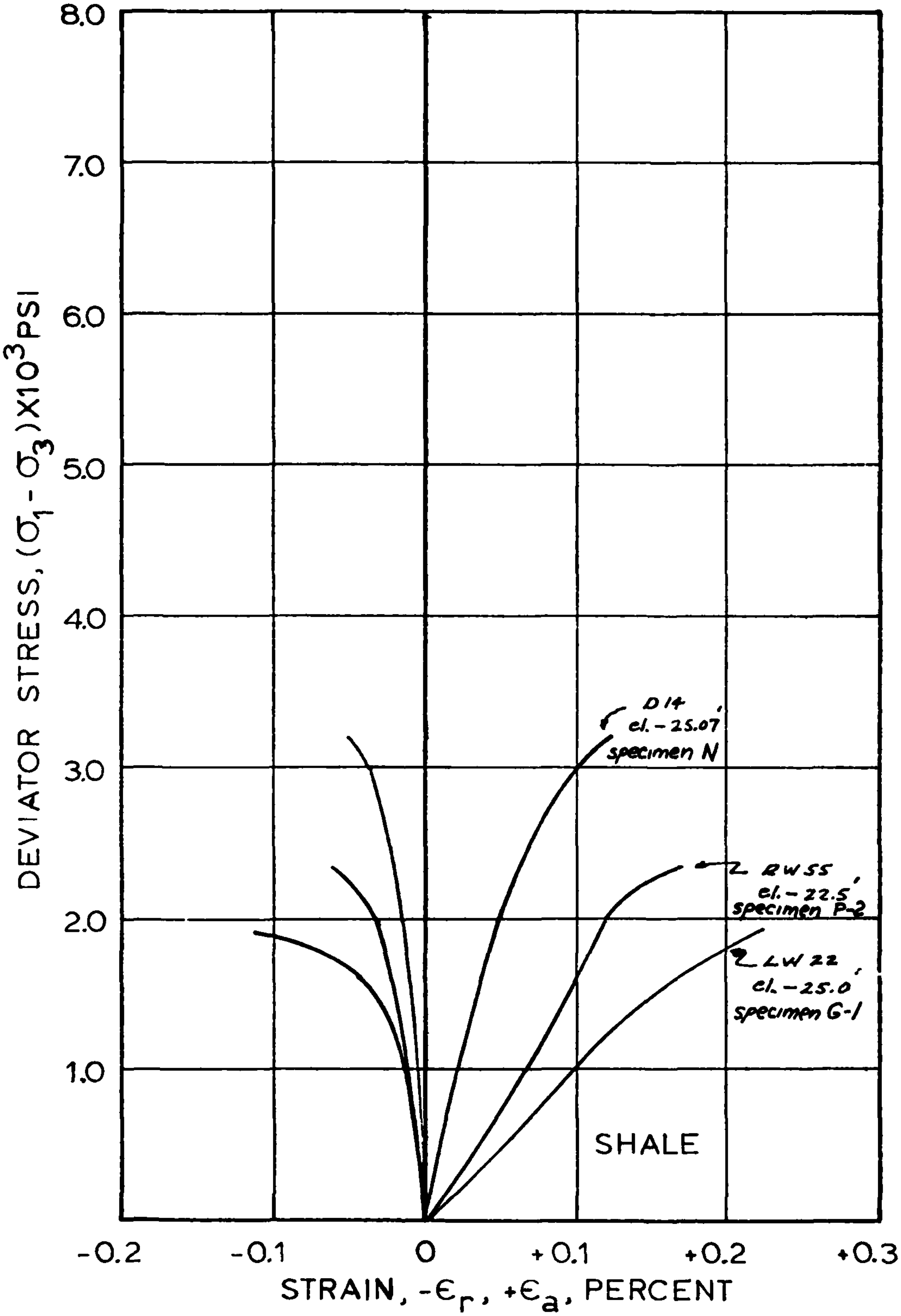


Figure 63. Triaxial test results of foundation Specimens G-1, N, and P-2

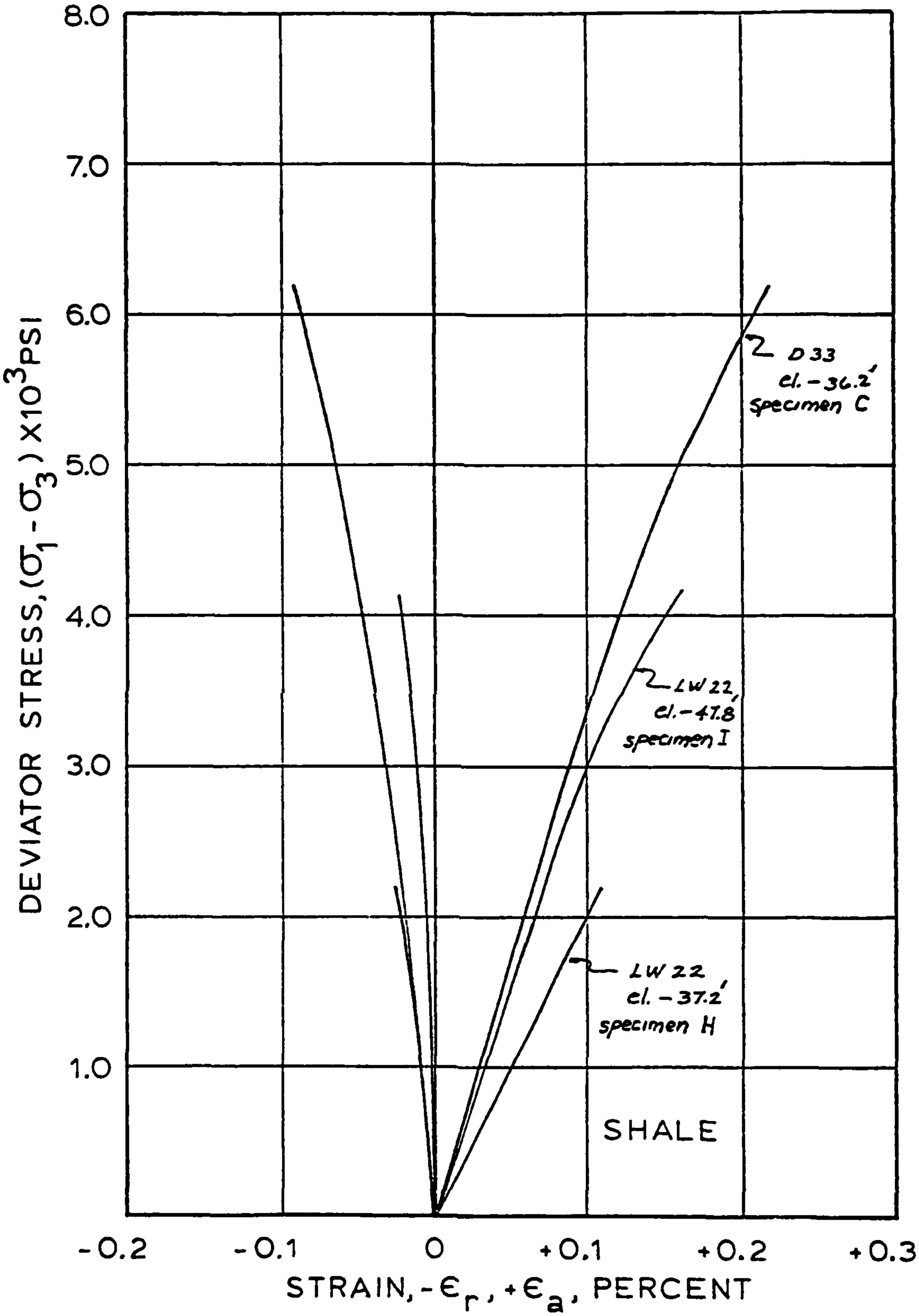


Figure 64. Triaxial test results of foundation Specimens C, I, and H

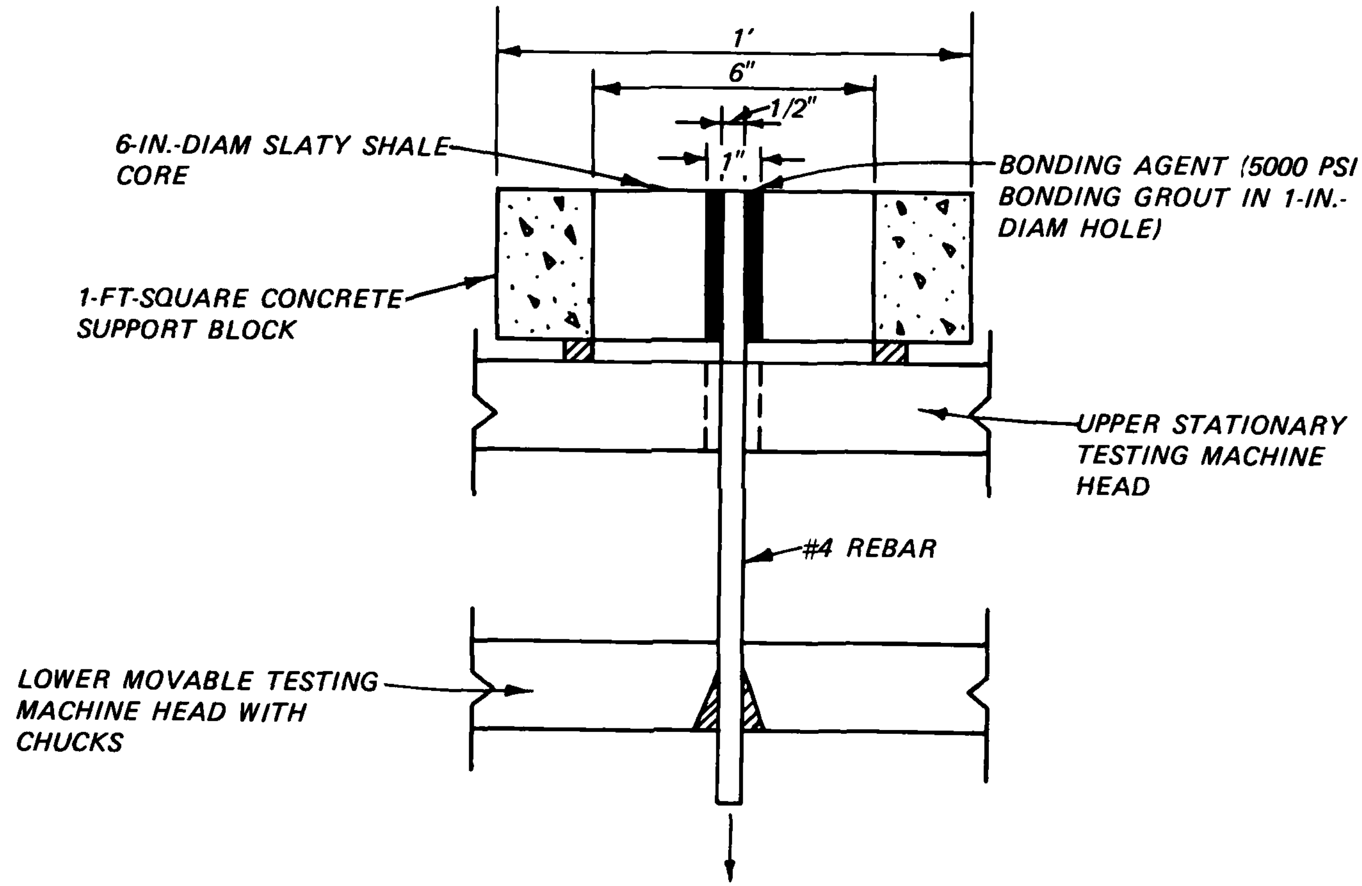


Figure 65. Pullout test setup

a. Closeup view

b. Overall view

Figure 66. Specimens prepared for pullout testing

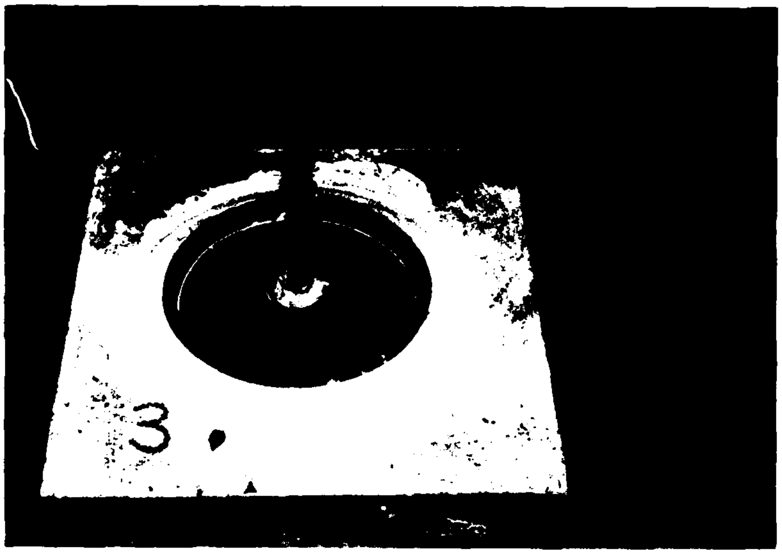


Figure 67. Pullout specimen after failure

Figure 68. Specimen failed in direct shear

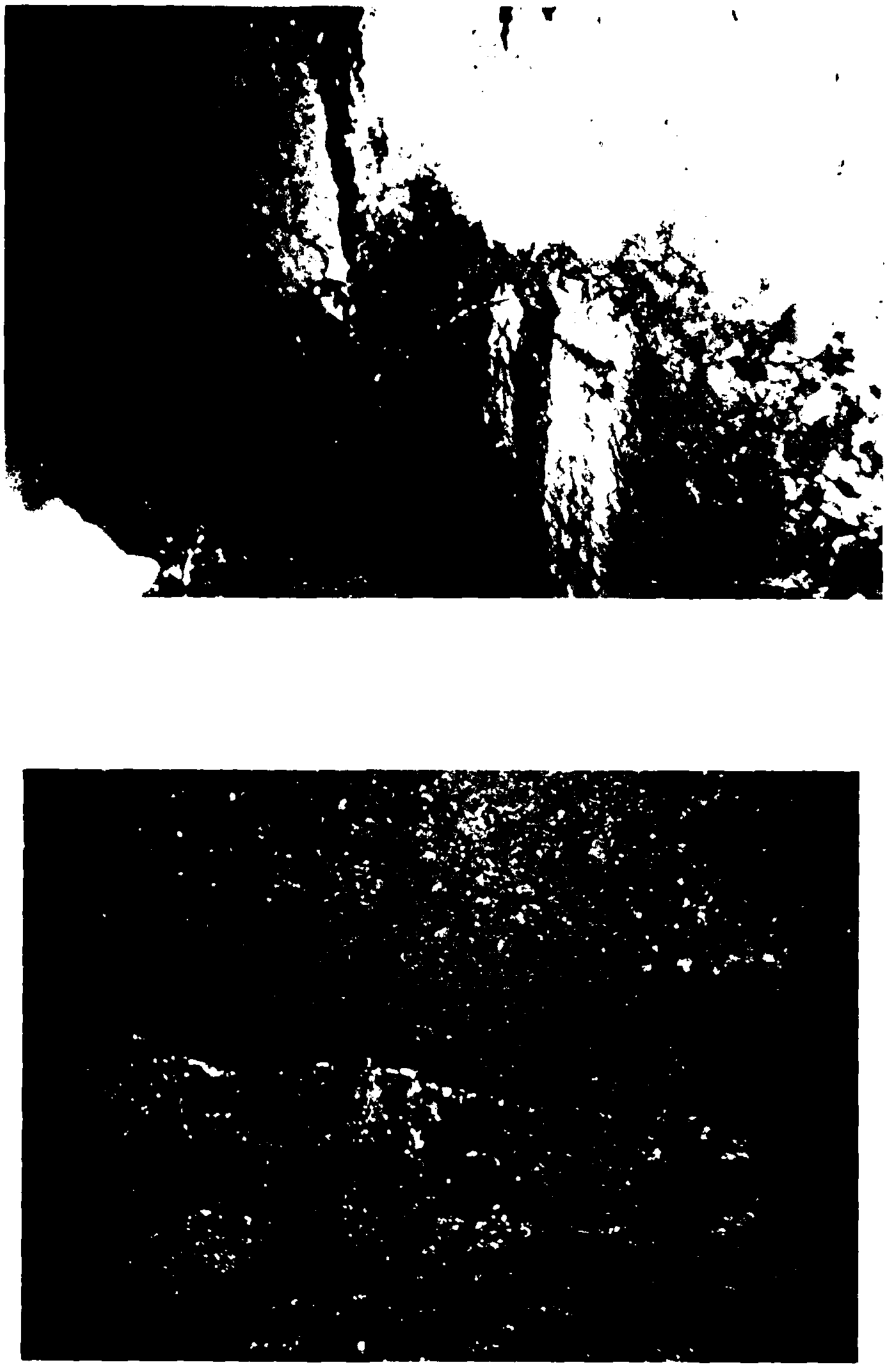


Figure 69. Mud and water flow through the wall of Monolith 5 into the filling and emptying culvert of the land wall

a. Leakage in construction joint of dam tunnel

b. Ice sheets from leakage in land wall filling and emptying culverts

Figure 70. Construction joints

Figure 71. Cracking in top of downstream land wall filling and empyting culvert

Figure 72. Accidental boat impact against Troy Dam

Figure 73. Flood conditions at Troy Lock and Dam

Figure 74. Core showing rock anchor of dam monoliths

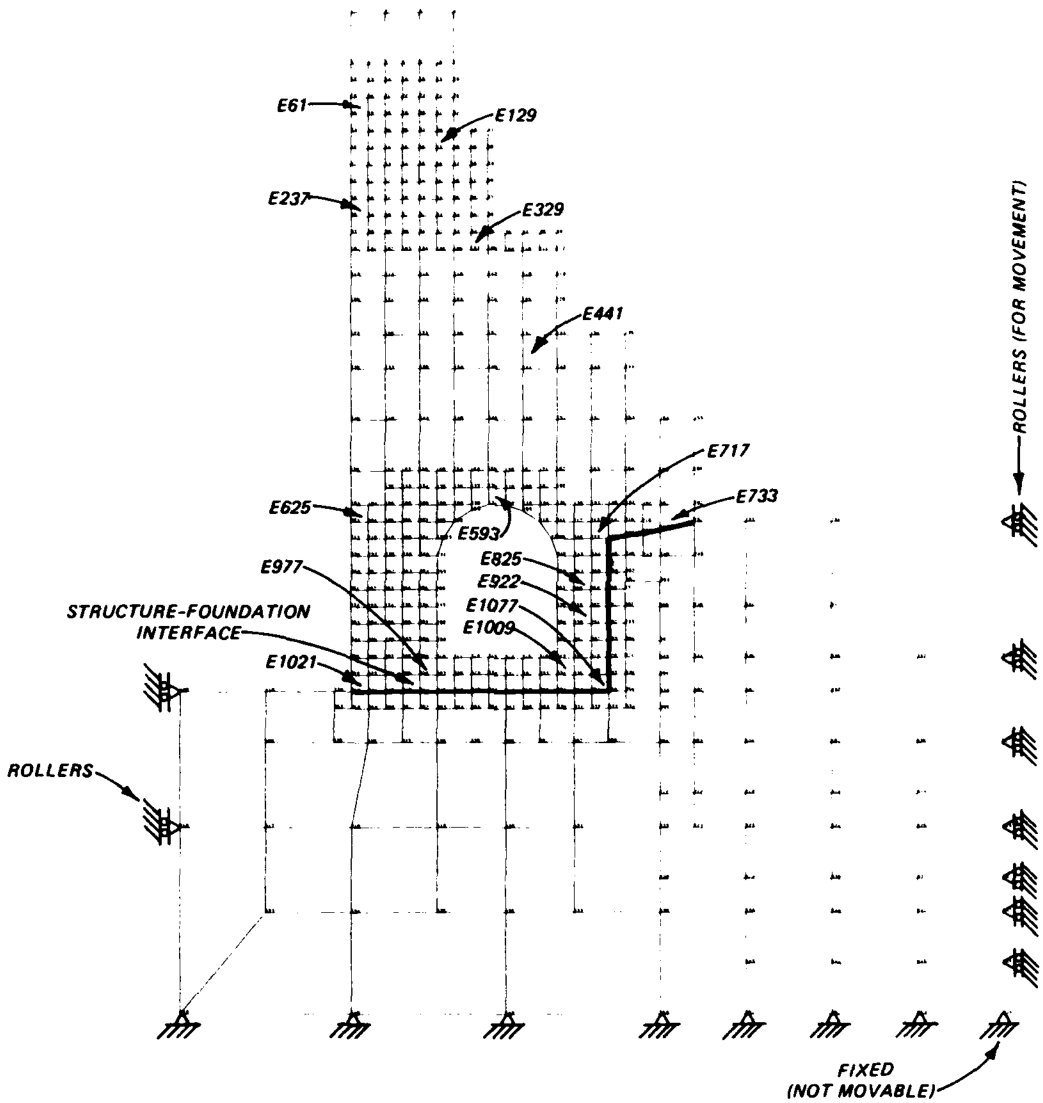


Figure 75. Monolith 5, Troy Lock and Dam, two-dimensional end view of three-dimensional finite element grid

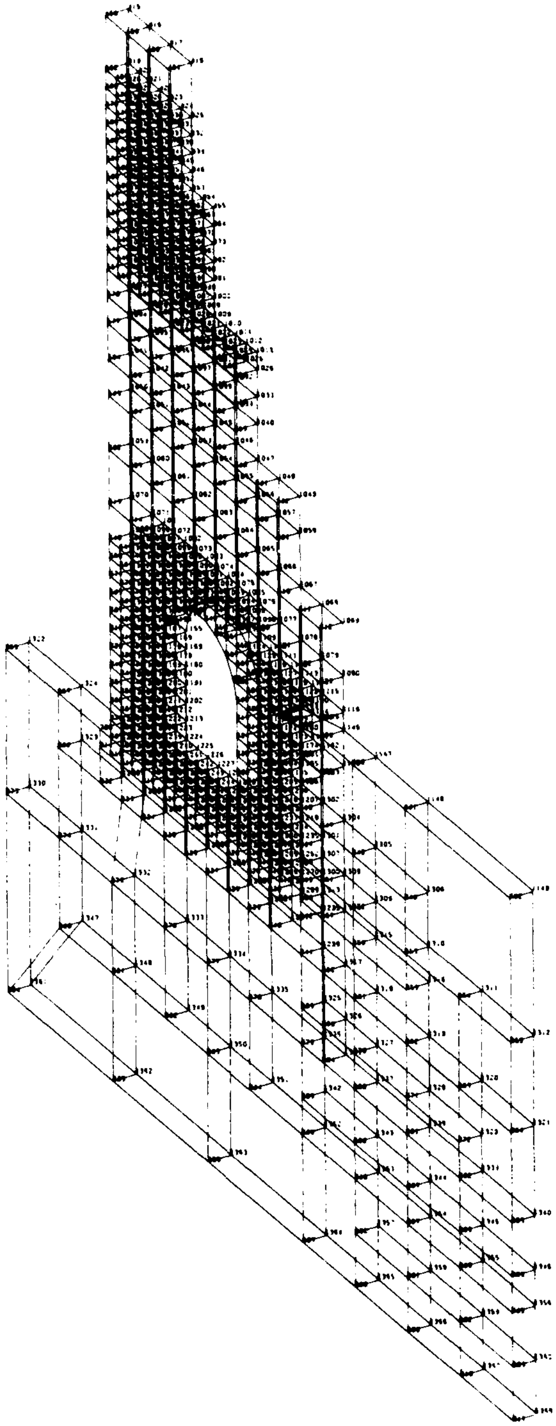


Figure 76. Monolith 5, Troy Lock and Dam, three-dimensional slice of finite element grid

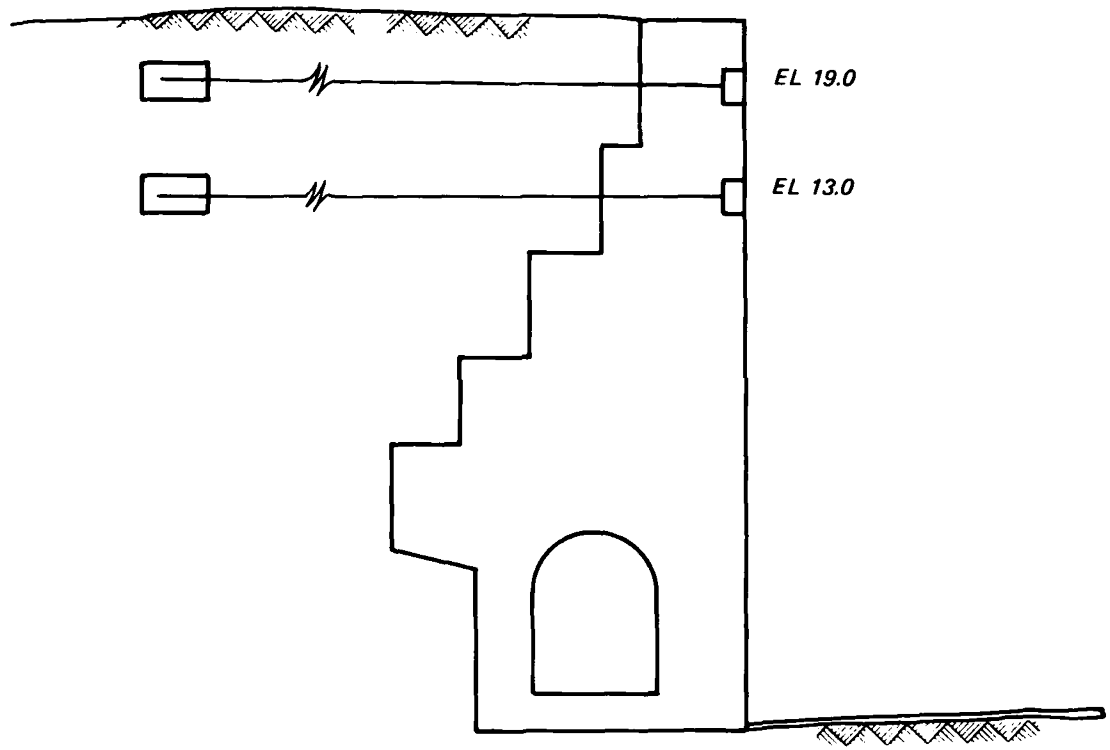


Figure 77. Posttensioning horizontally through the top of the monoliths (soil anchorage)

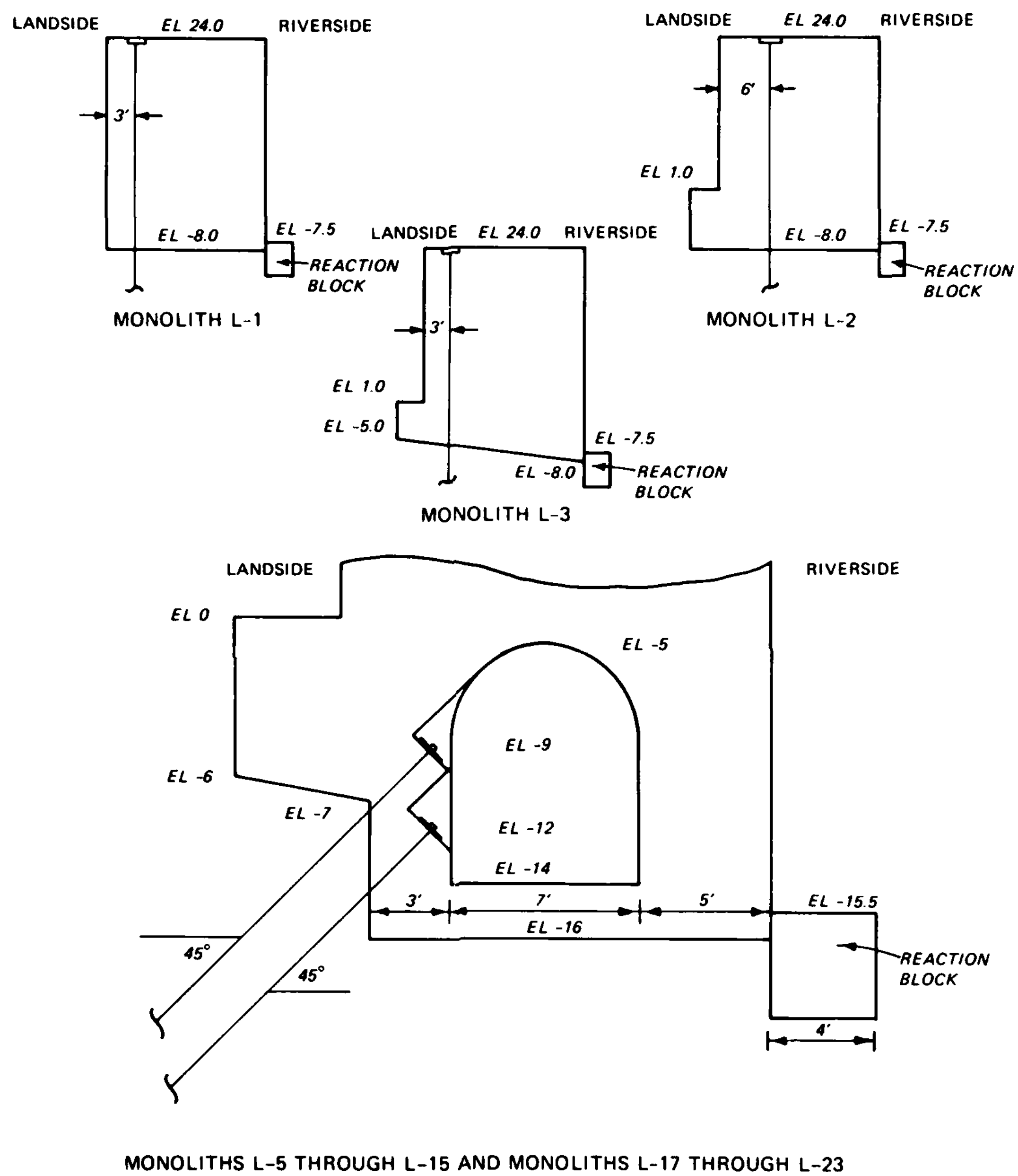


Figure 78. Posttensioning locations (Sheet 1 of 5)

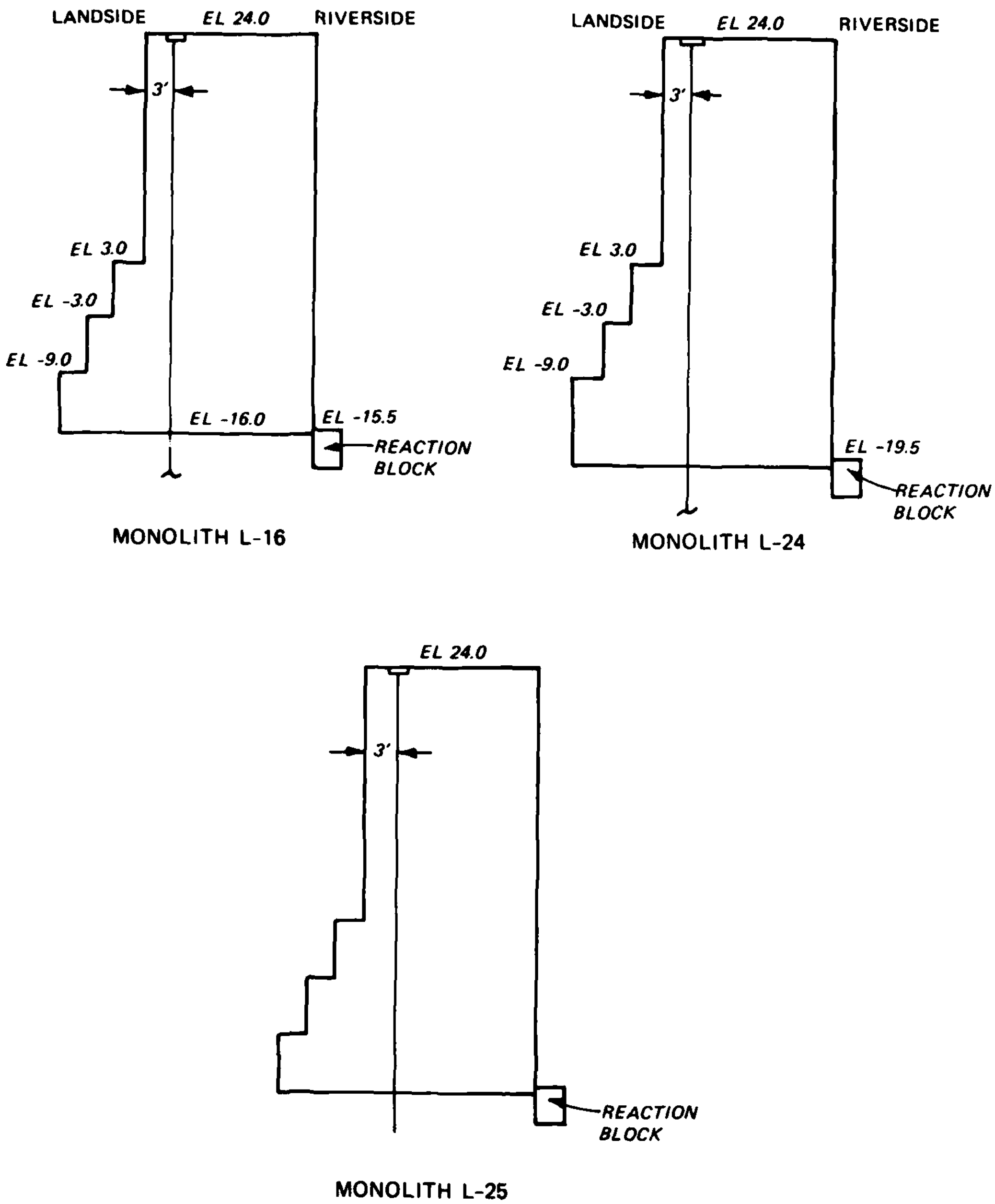
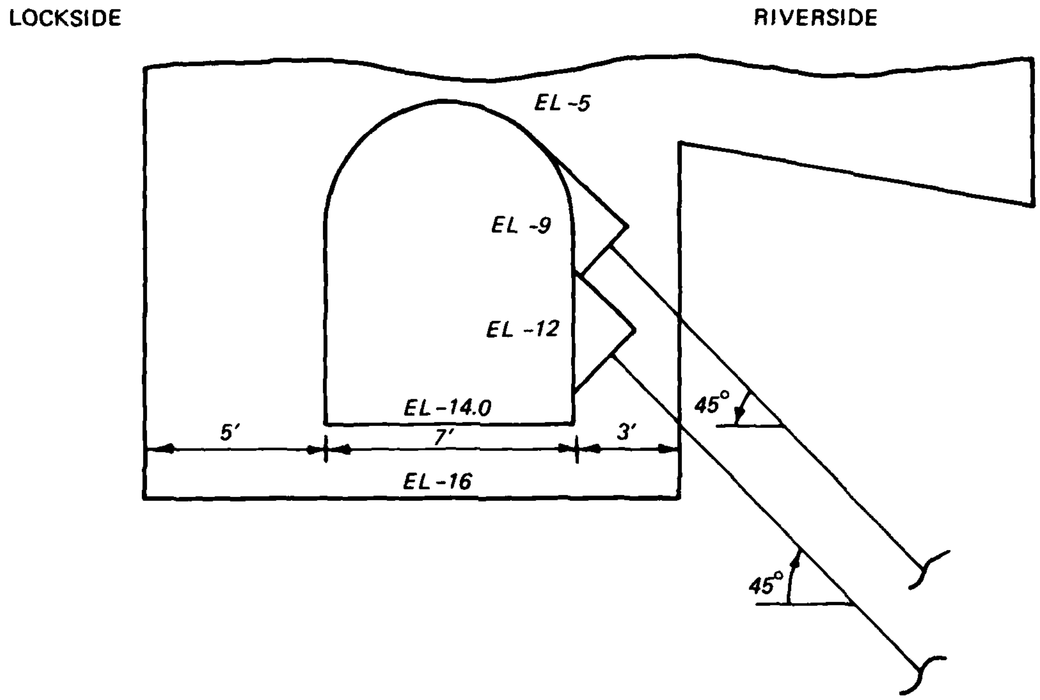
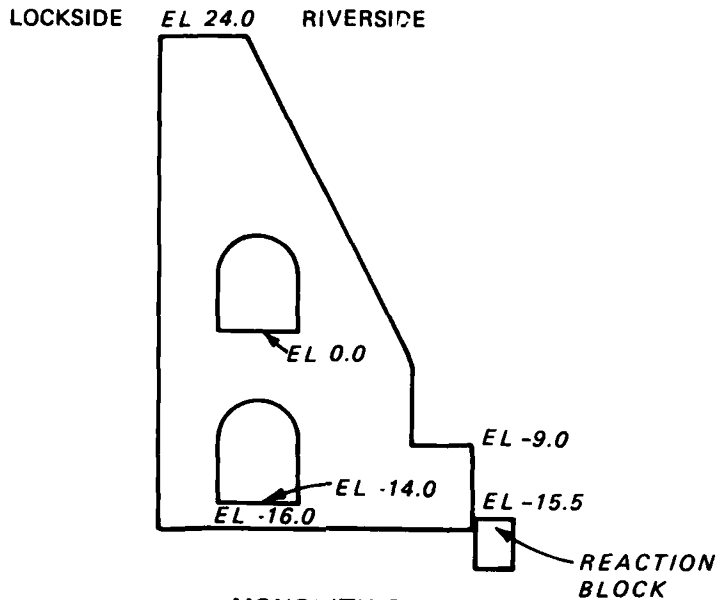


Figure 78. (Sheet 2 of 5)

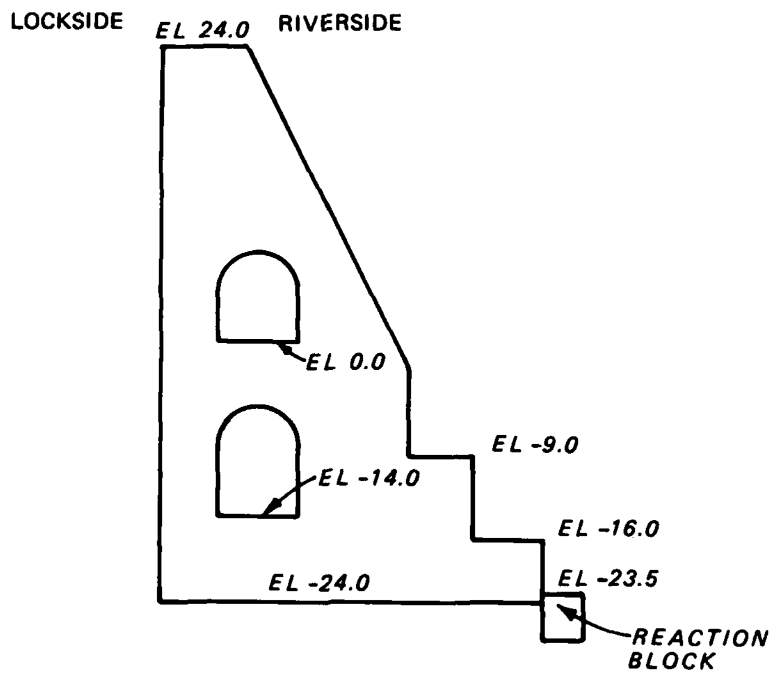


MONOLITH R-36

Figure 78. (Sheet 3 of 5)

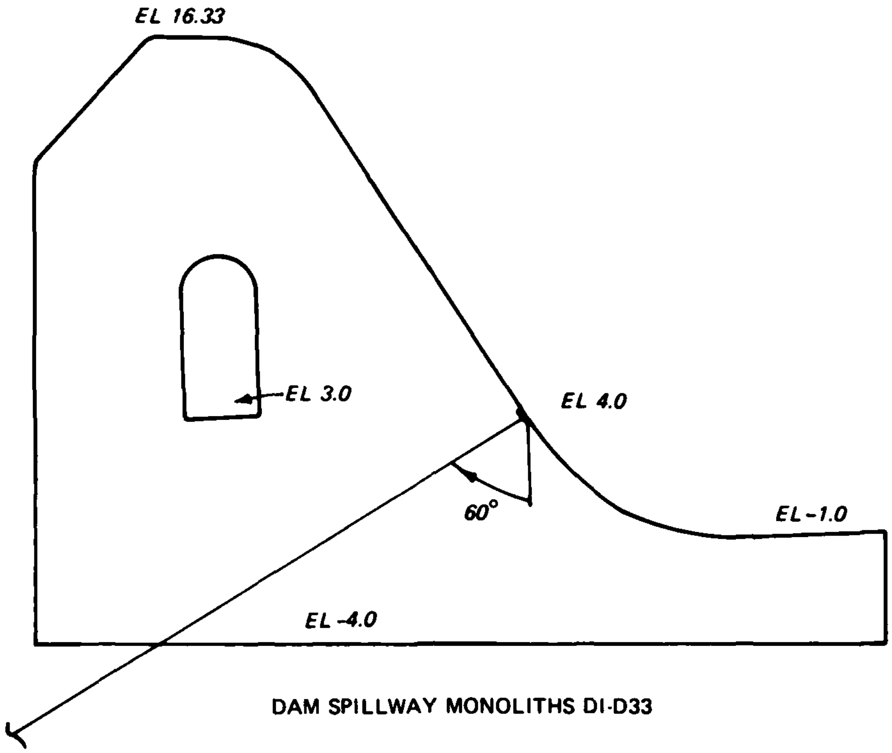


MONOLITH R-44

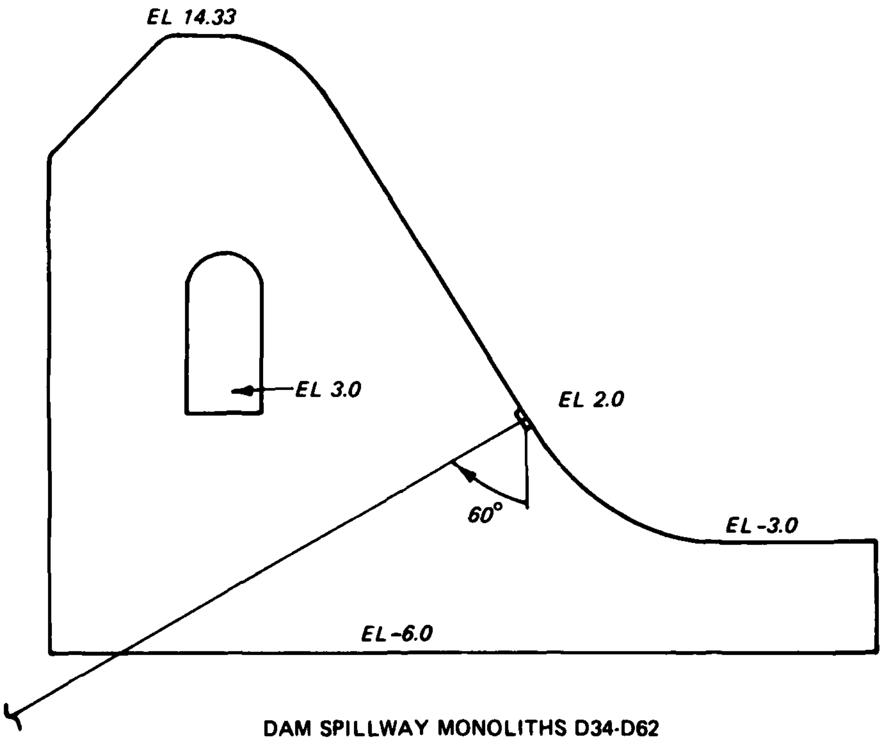


MONOLITH R-50

Figure 78. (Sheet 4 of 5)

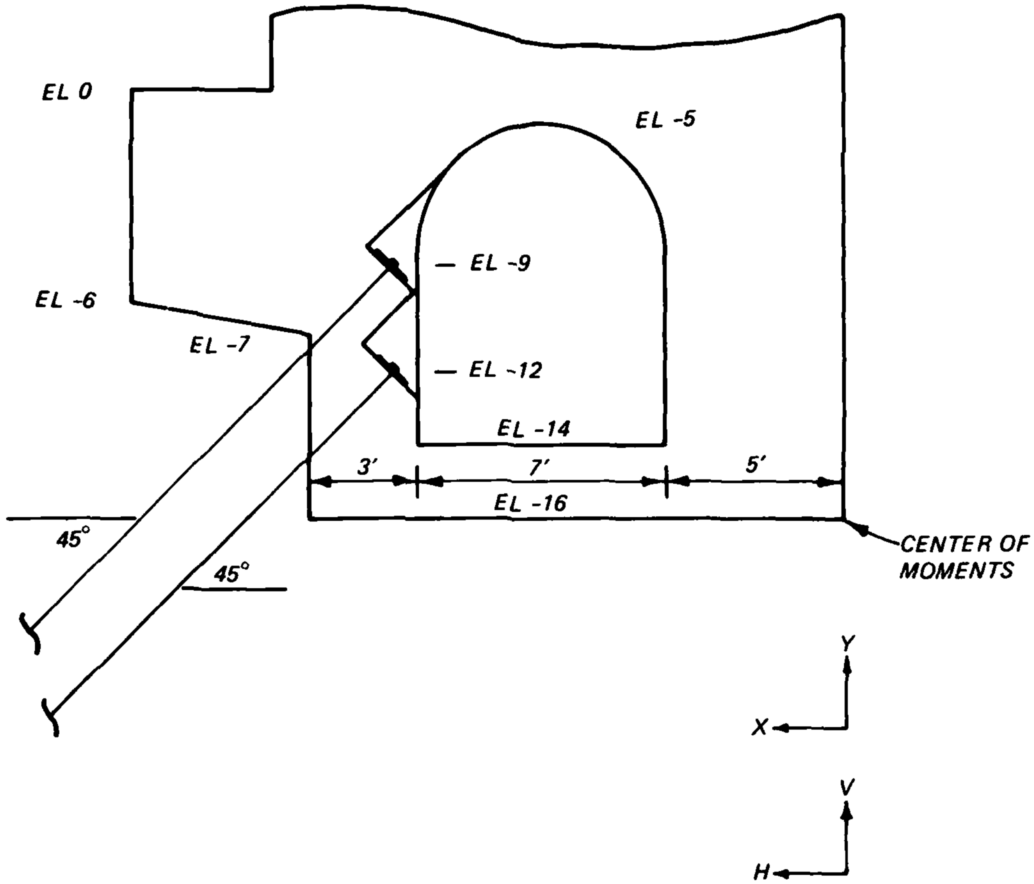


DAM SPILLWAY MONOLITHS DI-D33



DAM SPILLWAY MONOLITHS D34-D62

Figure 78. (Sheet 5 of 5)



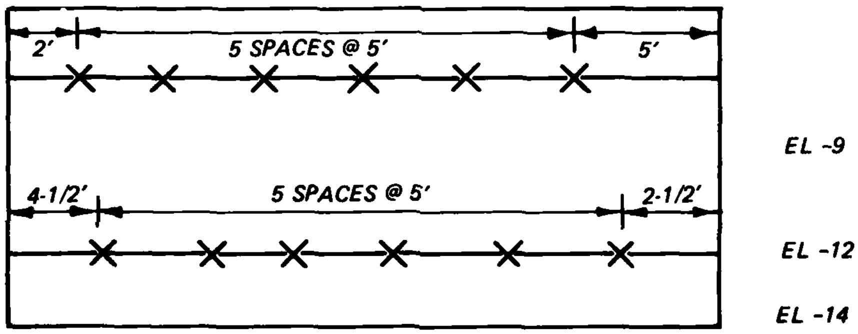


Figure 79. Monolith L-5, posttensioning through the filling and emptying culvert walls to meet overturning requirements

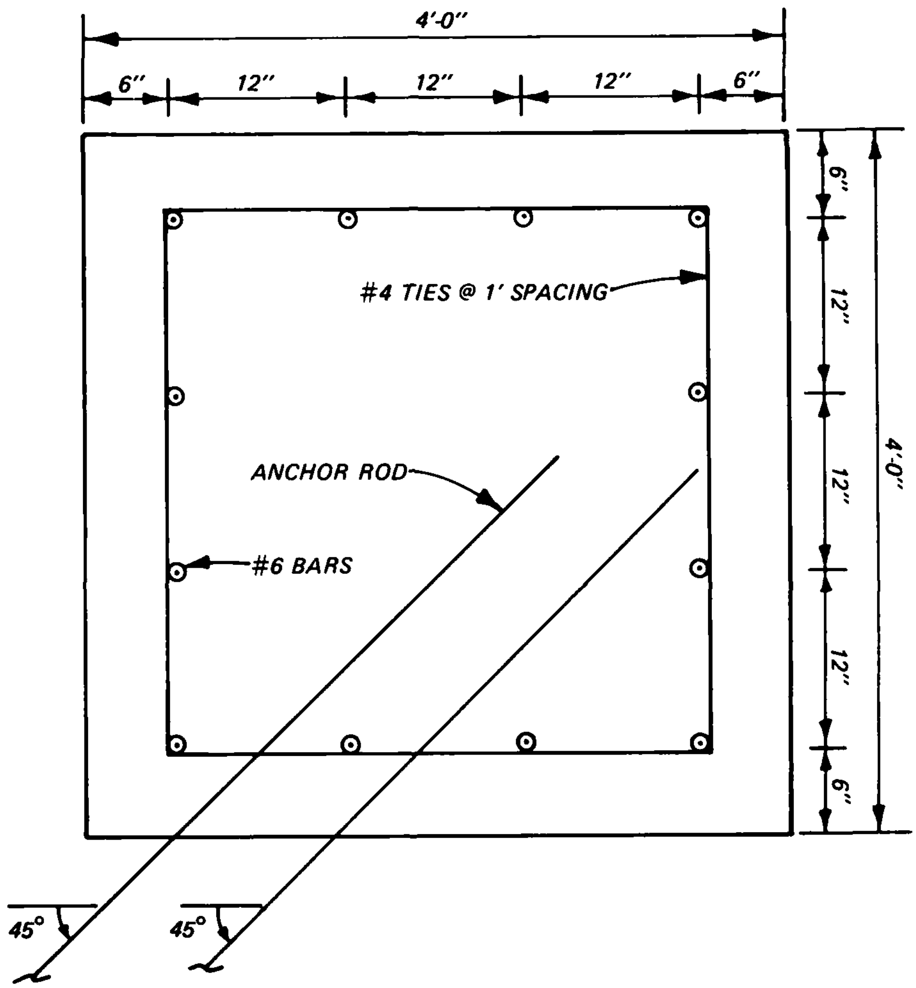


Figure 80. Reaction block, size and reinforcement

Table 1

Location and Purpose for Cores

Location	Purpose	Core Hole No.
Backfill	To determine: (1) backfill densities (2) horizontal pressure coefficients	LW-2, LW-6, L-12, and LW-19
Land wall		
Concrete	To determine: (1) depth of deteriorated concrete (2) cause of concrete deterioration	LS-1, LS-2, LW-3, LW-4, LW-5, LW-7, LW-8, LW-9, LW-10, LW-16, LW-17, LW-18, LW-20, LW-21
	To determine: (1) depth of deteriorated concrete (2) cause of concrete deterioration (3) engineering properties of concrete (4) monolith embedment depths	LW-1 and LW-22
Foundation	To determine: (1) engineering properties (2) concrete-foundation interface properties (3) any significant geological features	LW-1 and LW-22
River wall		
Concrete	To determine: (1) depth of deteriorated concrete (2) cause of concrete deterioration	RW-27, RW-27TS, RW-35, RW-37LP, RW-37UP, RW-37RS, RW-44LP, RW-44UP, RW-45, RW-50LS, RW-50UP, RW-62RS, RW-65LS, RW-65TS
	To determine: (1) depth of deteriorated concrete (2) cause of concrete deterioration (3) engineering properties of concrete (4) monolith embedment depths	RW-55 and RW-37

(Continued)

Table 1 (Concluded)

Location	Purpose	Core Hole No.
River wall (Continued)		
Foundation	To determine: (1) engineering properties (2) concrete-foundation interface properties (3) any significant geological features	RW-55 and RW-37
Dam		
Concrete	To determine: (1) depth of deteriorated concrete (2) cause of concrete deterioration	HG-1, DF-4, D-6, D-10, D-12, DF-8, D-16, D-24, D-27, D-42, DA-48, D-52, and D-59
	To determine: (1) depth of deteriorated concrete (2) cause of concrete deterioration (3) engineering properties of concrete (4) monolith embedment depths	HG-2, D-14, and D-33
Foundation	To determine: (1) engineering properties (2) concrete-foundation interface properties (3) any significant geological features	HG-2, D-14, and D-33
Gated spillway		
Concrete	To determine: (1) depth of deteriorated concrete (2) cause of concrete deterioration	DSPL-1, DSPL-2, DSPL-3, and DSPL-4

Table 2

Core Identification

Core No.	Elevation ft*	Depth ft	Orientation	Location	Material
LS-1	24.0	5.0	Vertical	Monolith No. 1, land wall	Concrete
LW-4	24.0	3.0	Vertical	Monolith No. 3, land wall	Concrete
LW-5	24.0	2.8	Vertical	Monolith No. 4, land wall	Concrete
LW-1	24.0	39.8 65.5	Vertical	Between Monoliths No. 5 & 6	Concrete Rock
LW-18	24.0	2.7	Vertical	Monolith No. 22, land wall	Concrete
LW-22	24.0	48.15 72.8	Vertical	Monolith No. 24, land wall	Concrete Rock
LS-2	21.5	2.8	Horizontal	Monolith No. 2, land wall	Concrete
LW-3	21.0	3.1	Horizontal	Monolith No. 3, land wall	Concrete
LW-7	16.0	3.3	Horizontal	Monolith No. 5, land wall	Concrete
LW-9	16.0	3.4	Horizontal	Monolith No. 12, land wall	Concrete
LW-17	16.0	3.45	Horizontal	Monolith No. 22, land wall	Concrete
LW-21	15.5	3.0	Horizontal	Monolith No. 24, land wall	Concrete
LW-8	3.0	2.9	Horizontal	Monolith No. 5, land wall	Concrete
LW-10	3.0	3.3	Horizontal	Monolith No. 12, land wall	Concrete
LW-16	3.0	3.0	Horizontal	Monolith No. 22, land wall	Concrete
LW-20	3.0	3.2	Horizontal	Monolith No. 24, land wall	Concrete
RW-27TS	24.0	3.0	Vertical	Monolith No. 27, river wall	Concrete

(Continued)

* Elevations are plus unless preceded by a minus sign.

(Sheet 1 of 4)

Table 2 (Continued)

Core No.	Elevation ft*	Depth ft	Orientation	Location	Material
RW-CON	24.0	3.9	Vertical	Monolith No. 34, river wall	Concrete
RW-37	24.0	40.0 68.0	Vertical	Monolith No. 37, river wall	Concrete Rock
RW-55	24.05	41.65 65.7	Vertical	Monolith No. 55, river wall	Concrete Rock
RW-60TS	18.0	3.0	Vertical	Monolith No. 60, river wall	Concrete
RW-65TS	18.0	3.0	Vertical	Monolith No. 65, river wall	Concrete
RW-27	20.5	9.0	Horizontal	Monolith No. 27, river wall	Concrete
RW-34	21.0	3.1	Horizontal	Monolith No. 34, river wall	Concrete
RW-35UP	15.0	3.2	Horizontal	Monolith No. 35, river wall	Concrete
RW-37UP	15.0	3.2	Horizontal	Monolith No. 37, river wall	Concrete
RW-44UP	14.0	3.4	Horizontal	Monolith No. 44, river wall	Concrete
RW-50UP	16.0	13.0	Horizontal	Monolith No. 50, river wall	Concrete
RW-37LP	4.0	3.2	Horizontal	Monolith No. 37, river wall	Concrete
RW-44LP	3.0	3.3	Horizontal	Monolith No. 44, river wall	Concrete
RW-50LSL	3.0	3.2	Horizontal	Monolith No. 50, river wall	Concrete
RW-60LS	2.9	3.0	Horizontal	Monolith No. 60, lower guide wall	Concrete
RW-65LS	6.0	2.7	Horizontal	Monolith No. 65, lower guide wall	Concrete
RW-45	5.4	3.0	Inclined 60°	Monolith No. 45, river wall	Concrete

(Continued)

(Sheet 2 of 4)

Table 2 (Continued)

Core No.	Elevation ft*	Depth ft	Orientation	Location	Material
RW-62RS	5.5	3.0	Inclined 60°	Monolith No. 62, river wall	Concrete
D-6	16.33	3.7	Vertical	Monolith No. 6, spillway	Concrete
D-10	16.33	3.5	Vertical	Monolith No. 10, dam	Concrete
D-12	16.33	3.2	Vertical	Monolith No. 12, dam	Concrete
D-14	15.33	18.0 43.5	Vertical	Monnolith No. 14, dam	Concrete Rock
D-16	16.33	3.6	Vertical	Monolith No. 16, dam	Concrete
D-24	16.33	3.3	Vertical	Monolith No. 24, dam top	Concrete
D-33	16.3	26.0 53.7	Vertical	Monolith No. 33, dam	Concrete Rock
D-42	13.0	4.2	Vertical	Monolith No. 42, dam	Concrete
D-52	13.0	4.7	Vertical	Monolith No. 52, dam	Concrete
D-59	13.0	4.9	Vertical	Monolith No. 59, dam	Concrete
HG-1	4.0	3.4	Horizontal	Head gate	Concrete
DA-1	-1.0	2.3 11.5	Vertical	Monolith No. 1, dam toe	Concrete Rock
DF-4	-1.0	3.0	Inclined 30°	Monolith No. 4, dam toe	Concrete
DF-8	2.3	2.9	Inclined 30°	Monolith No. 8, dam toe	Concrete
DF-14	2.3	3.05	Inclined 30°	Monolith No. 14, dam toe	Concrete
DF-27	2.3	3.0	Inclined 30°	Monolith No. 27, dam toe	Concrete
DA-48	2.5	1.6	Vertical	Monolith No. 48, dam toe	Concrete

(Continued)

Table 2 (Concluded)

Core No.	Elevation ft*	Depth ft	Orientation	Location	Material
D spill-1	18.0	3.2	Horizontal	Fourth pier from west	Concrete
D spill-2	18.0	3.6	Horizontal	Seventh pier from west	Concrete
D spill-3	18.0	3.5	Horizontal	Tenth pier from west	Concrete
D spill-4	18.0	2.9	Horizontal	Last pier from west	Concrete
HG-2	26.0	30.4 55.0	Vertical	Head gate pier next to ice chute	Concrete Rock

(Sheet 4 of 4)

Table 3

Material Properties of Concrete and Foundation

Core Hole	Core Descrip- tion, Orienta- tion	Specimen No.	Depth from Concrete Surface to Center of Specimen, ft	Depth of Deterio- rated Concrete, ft	Type Test	Compression σ_1 psi	Compression σ_3 psi	Tension: Di- rect Ten- sion psi	Tension: Ten- sile Split- ting, psi	Modulus of Elas- ticity, E 10^6 psi	Poisson's Ratio, μ	Density: Effec- tive Unit Weight pcf	Density: Dry Unit Weight pcf	Water Content, %	Ultra- sonic Velocity, fps
LS-1	C, V			5.0											
LW-4	C, V	62	0.50	0.7											
LW-5	C, V	63	1.90	0.7	UC	5850						148.0	136.9	8.1	13,944
LW-7	C, H	36	0.90	0.4	UC	3730						149.2	137.8	8.3	12,066
LW-8	C, H			0.0											
LW-1	C, V	31	2.20	3.0	UC	2910						146.1	134.5	8.6	13,744
	C	33	19.80		UC	3990						147.3	134.6	9.4	13,676
	C	34	38.50		UC	4480						151.7	140.2	8.2	14,755
	F	S-1	44.50		UC	1050				1.50	0.12	169.8	167.8	1.2	12,682
	F	T	52.50		UC	300				0.65	0.12	169.2	167.2	1.2	12,861
	F	U	62.90		UC	1070				1.18	0.10	169.8	168.1	1.0	13,277
	C	32	8.70		T_d			220		3.03		148.0			14,286
	F	S-3	48.60		T_d			60		0.54	0.15	169.8			15,027
	C	35	37.20												
	F	S-4	50.00												
	F	S-2	46.70												
LW-9	C, H	39	1.50	0.9	TS			325				151.7	141.4	7.3	13,480
LW-10	C, H	40	1.30	0.0	UC	4710						148.0	136.0	8.8	13,889
LW-18	C, V	64	1.00	0.0	UC	4600						151.1	141.7	6.6	13,889
LW-17	C, H	37	0.90	0.0	UC	4420						149.2	139.2	7.2	14,765
LW-16	C, H	38	2.10	0.0	UC	4930						150.5	139.0	8.3	14,536
LS-2	C, H	43	0.50	0.0											
LW-3	C, H			>2.6											
LS-21	C, H	41	0.50	0.0	UC	3800						149.2	137.8	8.3	14,085

(Continued)

Note: C - concrete specimen; F - foundation specimen; V - vertical core; H - horizontal core; I - inclined core; UC - unconfined compression; T_d - direct tension; TS - tensile splitting; TX - triaxial.

(Sheet 1 of 5)

Table 3 (Continued)

Core Hole	Core Description, Orientation	Specimen No.	Depth from Concrete Surface to Center of Specimen, ft	Depth of Deteriorated Concrete, ft	Type Test	Compression σ_1 psi	Compression σ_3 psi	Tension: Direct Tension psi	Tension: Tensile Splitting, psi	Modulus of Elasticity, E 10^6 psi	Poisson's Ratio, μ	Density: Effective Unit Weight pcf	Density: Dry Unit Weight pcf	Water Content, %	Ultrasonic Velocity, fps
LW-22	C, V	11	1.20	0.0	UC	4640				2.78	0.15	153.6	144.5	6.3	14,644
	C	12	8.00		UC	4170				4.00	0.23	149.8	139.6	7.3	13,647
	C	13	23.30		UC	5830				6.00	0.28	152.3	141.3	7.8	14,143
	C	14	44.40		UC	4060				5.36	0.32	149.8	139.7	7.2	13,944
	F	G-1	49.50		TX	2020	100			1.14	0.16	169.8			12,284
	F	H	61.70		TX	2730	500			2.00	0.21	169.8			11,756
	F	I	72.30		TX	5070	1000			3.08	0.09	169.8			11,715
	C	15	42.50												
	F	G-2	50.40												
	F	G-4	56.50												
LW-20	C, H	42	0.50	0.0	UC	5430						151.1	140.7	7.4	14,706
RW-27(LF)	C, H	49	4.50	0.0	UC	3470						148.6	138.6	7.2	13,931
RW-27(RF)	C, H	50	7.60	0.8	TS				215			146.1	134.5	8.6	11,663
RW-27TS	C, V			2.5											
RW-CON	C, V	66	2.50	0.0	UC	5470						152.3	143.0	6.5	14,432
RW-34	C, H	51	1.70	1.1	UC	4000						147.3	134.8	9.3	13,581
RW-35UP	C, H			1.1											
RW-37LP	C, H	44	1.30	0.2	UC	4350						149.8	139.5	7.4	13,568
RW-37UP	C, H	45	1.20	3.5	TS				345			149.2	137.1	8.8	13,393
RW-37	C, V	6	5.00	1.3	UC	4040						154.2	144.4	6.8	15,112
	C	7	10.80		UC	4790				4.69	0.16	151.7	141.4	7.3	14,644
	C	8	19.90		UC	4420				5.71	0.22	151.7	142.3	6.6	14,523
	C	9	39.80		UC	4450				4.29	0.18	153.6	143.8	6.8	14,538
	C	10	37.00												
	F	E	49.00												
	F	D	43.70												

(Continued)

Table 3 (Continued)

Core Hole	Core Description, Orientation	Specimen No.	Depth from Concrete Surface to Center of Specimen, ft	Depth of Deteriorated Concrete, ft	Type Test	Compression σ_1 psi	Compression σ_3 psi	Tension: Direct Tension psi	Tension: Tensile Splitting, psi	Modulus of Elasticity, E 10^6 psi	Poisson's Ratio, μ	Density: Effective Unit Weight pcf	Density: Dry Unit Weight pcf	Water Content, %	Ultrasonic Velocity, fps
RW-44LP	C, H	47	1.80	0.2	UC	4190						150.5	140.1	7.4	14,718
RW-44UP	C, H	48	1.50	0.0	UC	3880						148.6	137.3	8.2	12,094
RW-45	C, I	54	1.40	0.8	UC	4220						144.8	132.6	9.2	12,048
RW-50LSL	C, H	46	1.90	1.0	UC	4390						148.0	136.2	8.7	13,263
RW-50UP (LF)	C, H			1.0											
RW-50UP (RF)	C, H			1.5											
RW-60TS	C, V	53	0.50	0.0	UC	3190						148.6	138.4	7.4	8,690
RW-60LS	C, H	52	1.10	<0.4	UC	5320						150.5	139.7	7.7	13,343
RW-62RS	C, H			3.0											
RW-65TS	C, V			2.4											
RW-65LS	C, H			<0.4											
RW-55	C, V	28	23.00	0.0	UC	4710						151.7	142.3	6.6	14,262
	C	26	3.40		UC	4100						152.3	142.5	7.0	14.045
	C, V	27	7.00		T_d			115		3.33	0.33	150.5			13,981
	C	29	40.80		UC	4330						148.6	135.6	9.6	13,981
	F	P-2	47.00		TX	2560	200			1.60	0.19	169.2			13,333
	C	30	38.50												
	F	P-1	44.10												
D-59	C, V	74	1.50	0.0	UC	3750						146.1	135.0	8.2	13,080
DA-48	C, V	61	0.70	0.0	UC	3880						143.0	130.5	9.6	13,136
D-42	C, V	72	1.80	0.0	UC	4420						148.0	136.9	8.1	14,329
D-33	C, V	1	2.30	0.0	UC	4280						148.0	134.5	10.0	13,990
	C	3	15.30		UC	4170						149.8	139.2	7.6	14,431
	C	4	25.00		UC	5450						154.8	146.0	6.0	15,076
	F	A-3	32.60		UC	400				0.40		168.6	166.8	1.1	11,425

(Continued)

Table 3 (Continued)

Core Hole	Core Description, Orientation	Specimen No.	Depth from Concrete Surface to Center of Specimen, ft	Depth of Deteriorated Concrete, ft	Type Test	Compression σ_1 psi	Compression σ_3 psi	Tension Direct Tension psi	Tension Tensile Splitting, psi	Modulus of Elasticity, E 10^6 psi	Poisson's Ratio, μ	Density Effective Unit Weight pcf	Density Dry Unit Weight pcf	Water Content, %	Ultrasonic Velocity, fps
D-33	F	A-4	39.10		UC	1600				1.54	0.23	169.8	167.0	1.1	13,310
(Continued)	F	B	41.00		UC	990				1.01	0.07	169.2	167.4	1.1	12,944
	F	C	51.00		TX	7710	1500			3.43	0.34	169.8			12,964
	C	2	7.10		T_d			260		5.00	0.33	151.1			13,990
	C	5	23.10												
	F	A-2	31.60												
	F	A	30.50												
DF-27	C, I	60	0.70	0.0	UC	4640						150.5	140.1	7.4	13,387
D-24	C, V	71	0.50	0.0	UC	3160						144.2	130.6	10.4	13,589
D-16	C, V	70	1.20	0.0	UC	4260						149.2	138.8	7.5	13,843
D-14	C, V	21	1.50	0.0	UC	3520				4.92	0.27	148.6	137.3	8.2	14,553
	C	22	6.50		UC	4780				5.00	0.21	151.1	140.8	7.3	14,262
	C	23	11.00		UC	3110				4.29	0.21	152.3	143.7	6.0	14,440
	C	24	16.00		UC	3310				3.75	0.20	148.0	135.5	9.2	14,026
	F	N	39.50		TX	4140	400			4.80	0.24	169.8			15,598
	F	M-3	26.90		T_d			60		0.93	0.07	169.8			15,708
	C	25	15.50												
	F	M-1	20.30												
	F	M-2	24.50												
	F	0	42.90												
DF-14	C, I	59	0.60	0.0	UC	4120						149.2	138.7	7.6	13,796
D-12	C, V	69	0.70	0.0	UC	4240						149.2	137.5	8.5	13,373
D-10	C, V			0.0											
DF-8	C, I	58	1.40	0.1	UC	4350						152.3	139.0	9.6	14,372
D-6	C, V			1.2											
DF-4	C, I	57	0.70	0.1	UC	5130						148.0	136.0	8.8	13,081

(Continued)

Table 3 (Concluded)

Core Hole	Core Description, Orientation	Specimen No.	Depth from Concrete Surface to Center of Specimen, ft	Depth of Deteriorated Concrete, ft	Type Test	Compression σ_1 psi	Compression σ_3 psi	Tension: Direct Tension psi	Tension: Tensile Splitting, psi	Modulus of Elasticity, E 10^6 psi	Poisson's Ratio, μ	Density: Effective Unit Weight pcf	Density: Dry Unit Weight pcf	Water Content, %	Ultrasonic Velocity, fps
DA-1	C, V	56	0.50	0.0	UC	4800						149.2	138.3	7.9	14,061
D Spill-1	C, H	67	1.30	0.6	UC	3630						149.2	140.5	6.2	13,619
D Spill-2	C, H	68	2.80	0.0	UC	3670						148.6	138.2	7.5	14,286
D Spill-3	C, H			3.1											
D Spill-4	C, H			0.9											
D-52	C, V	73	4.00	0.0	UC	4280						151.1	139.5	8.3	14,197
HG-1	C, H	55	1.50	0.1	UC	5090						149.2	136.9	9.0	12,550
HG-2	C, V	16	4.80	3.7	UC	4840				2.55	0.15	149.8	137.1	9.3	13,611
	C	17	8.50		UC	5770				2.40	0.12	151.1	141.5	6.8	14,683
	C	18	17.60		UC	4400				6.00	0.26	148.6	139.4	6.6	14,469
	C	19	30.00		UC	4750				6.32	0.29	148.6	138.6	7.2	14,705
	F	L	46.60		T_d			10				169.8			14,532
	C	20	28.00												
	F	J-2	38.00												
	F	J-3	41.10												
	F	J-1	35.20												
	F	K	43.60												

(Sheet 5 of 5)

Table 4

Test Results for Sliding Friction, Precut Concrete on Rock

Material	Core Hole	Elevation msl, ft	Normal Stress tsf	Peak Shear Stress tsf	Ultimate Shear Stress tsf	Shear Test Envelopes: Peak Cohesion, C, tsf	Peak Angle of Friction, Φ, degrees	Ultimate Cohesion, C, tsf	Ultimate Angle of Friction, Φ, degrees
Concrete Slaty shale	D-14 D-14	-1.07 -5.87	2.0	2.45	1.98	1.75	24.70	0.92	23.28
Concrete Slaty shale	D-33 D-33	-8.30 -16.80	4.0	3.92	2.33				
Concrete Slaty shale	HG-2 HG-2	-1.50 -11.50	8.0	5.32	4.46				
Concrete Slaty shale	RW-55 RW-55	-14.30 -19.60	1.0	0.42	0.34	-0.19	33.53	-0.48	33.77
Concrete Slaty shale	RW-37 RW-37	-12.50 -24.50	2.0	1.51	0.79				
Concrete Slaty shale	LW-22 LW-22	-18.00 -25.90	4.0	2.00	2.01				
Concrete Slaty shale	LW-1 LW-1	-12.70 -25.50	8.0	5.26	4.95				
Failure Envelope for All Shear-Friction Data						0.43	31.60	0.02	30.40

Table 5

Test Results for Shear Resistance Along Intact Bedding Planes of Slaty Shale Foundation Material

Material	Core Hole	Elevation msl, ft	Normal Stress tsf	Peak Shear Stress tsf	Ultimate Shear Stress tsf	Shear Test Envelopes: Peak Cohesion, C, tsf	Peak Angle of Friction, Φ, degrees	Ultimate Cohesion, C, tsf	Ultimate Angle of Friction, Φ, degrees
Slaty Shale	RW-37	-19.20	2.0	4.23	3.93	0.61	63.65	0.26	58.65
Slaty Shale	LW-1	-22.20	4.0	9.33	6.26				
Slaty Shale	LW-22	-32.00	8.0	16.56	13.59				
Slaty Shale	D-14	-10.07	2.0	15.64	15.74	8.46	71.18	9.10	58.83
Slaty Shale	D-33	-15.70	4.0	18.23	10.70				
Slaty Shale	HG-2	-14.60	8.0	32.60	23.99				
Failure Envelope for All Shear-Friction Data						4.54	68.02	4.68	58.75

Table 6

Test Results for Horizontal or Cross-Bed Shear of Slaty Shale Foundation Material

						Shear Test Envelopes			
						Peak		Ultimate	
Material	Core Hole	Elevation msl, ft	Normal Stress tsf	Peak Shear Stress tsf	Ultimate Shear Stress tsf	Cohesion, C, tsf	Angle of Friction, ϕ, degrees	Cohesion, C, tsf	Angle of Friction, ϕ, degrees
Slaty shale	HG-2	-8.70	2.0	38.16	14.69	49.54	5.30	13.63	63.07
Slaty shale	HG-2	-17.10	4.0	67.26	25.82				
Slaty shale	D-14	-28.47	8.0	44.50	27.94				

Table 7

Failure Mode of Pullout Specimen

Specimen Number	Failure Mode
1	*
2	**
3	*
4	**
5	†
6	**
7	**
8	*
9	†

* Slaty-shale foundation failed.

** Concrete conditioning specimen failed.

† Failure at bond interface of grout and slaty shale foundation.

Table 8

Characteristics and Pullout Strength of Test Specimens

Specimen Number	Hole Number	Core Depth ft	Core Diameter in.	Angle of Bonding Plane	Hole Diameter in.	Hole Length in.	Hole Surface Area $in.^2$	Pullout Strength Total Land lb	Pullout Strength Pounds per foot
1	LW-1	40.3	5.90	68°	1.294	3.00	12.20	4580	18,000
2	LW-1	41.2		64°		2.99	12.16	6100	24,000
3	LW-22	67.5		50°		3.08	12.52	6250	24,000
4	LW-22	68.8		50°		3.17	12.89	6450	24,000
5	LW-22	70.5		45°		3.18	12.93	7250	27,000
6	D-33	46.5		45°		3.19	12.97	7075	27,000
7	D-33	98.0		50°		3.21	13.05	6800	25,000
8	RW-55	59.5		65°		3.14	12.76	5350	20,000
9	RW-55	63.5		67°		3.19	12.97	5700	21,000

Table 9

Engineering Properties for Use in Analysis

Property	Location	Numerical Value Local	Numerical Value Overall
Coefficient of sliding friction between concrete and foundation (ϕ), deg	Land wall	30° 24'	30° 24'
	River wall		
	Dam		
	Headgate		
Cohesion between concrete and foundation (C), ksf	Land wall	0.04	0.04
	River wall		
	Dam		
	Headgate		
Effective unit weight of concrete (γ_m), pcf	Land wall	149.80	149.59
	River wall		149.93
	Dam	149.19	
	Headgate	149.30	
Dry unit weight of concrete (γ_d), pcf	Land wall	139.06	138.66
	River wall		139.16
	Dam	137.69	
	Headgate	138.89	
Effective unit weight of foundation material (γ_m), pcf	Land wall	169.71	169.60
	River wall		169.20
	Dam	169.50	
	Headgate	169.80	
Dry unit weight of foundation material (γ_d), pcf	Land wall	167.70	167.38
	River wall		-
	Dam	167.07	
	Headgate	-	
Saturated unit weight of backfill material (γ_s), pcf	Land wall	144	144
Dry unit weight of backfill material (γ_d), pcf	Land wall	115	115
Modulus of Elasticity of concrete (E_c), psi	Land wall	4.23×10^6	4.41×10^6
	River wall	4.50×10^6	
	Dam	4.59×10^6	
	Headgate	4.32×10^6	
Poisson's ratio of concrete (μ)	Land wall	0.24	0.23
	River wall	0.22	
	Dam	0.24	
	Headgate	0.21	

(Continued)

Table 9 (Concluded)

Property	Location	Numerical Value Local	Numerical Value Overall
Modulus of elasticity of foundation material (E_f), psi	Land wall	0.97×10^6	0.97×10^6
	River wall		-
	Dam	0.97 × 106	
	Headgate	-	
Poisson's ratio of foundation material (μ)	Land wall	0.12	0.12
	River wall		-
	Dam	0.12	
	Headgate	-	
Foundation material pullout resistance based on area between grout and rock, kips/foot of depth	Land wall	9	9
	River wall		
	Dam		
	Headgate		
Compressive strength from unconfined compressive test of nondeteriorated concrete, psi	Land wall		4400
	River wall		
	Dam		
	Headgate		
Tensile strength from tensile splitting tests of nondeteriorated concrete, psi			295
Tensile strength from direct tension tests of nondeteriorated concrete, psi			198
Average tensile strength from tensile splitting and direct tension tests of nondeteriorated concrete, psi			247
Compressive strength from unconfined compressive test of slaty-shale foundation, psi			900
Tensile strenght from direct tension test of slaty-shale foundation, psi			43
Angle of internal friction, ϕ , from triaxial test of slaty-shale foundation (deg)			42-49
Cohesive strength, c, from triaxial test of slaty-shale foundation, psi			10-230

Table 10

Probable Depths of Concrete Deterioration

Location	Monoliths	Surface	Probable Depths of Deteriorated Concrete ft
Land Wall	L-1→L-3	Top	1
		Riverside	3 or greater
	L-4→L-25A	Top	0 to 3
		Riverside	0 to 1
River Wall	R-28→R-35	Landside	0 to 3.5
	R-36→R-67		0 to 1
	R-28→R-35	Top	0 to 3
	R-36→R-61		0 to 1
	R-62→R-67		0 to 3
	R-28→R-45	Riverside	1 to 2
	R-46→R-50		6
	R-51→R-67		3
Dam	D1 to D62	Exterior Surface	0 to 0.1
Headgate Section	Total Section	Exterior Surface	0 to 3

Table 11

Saturation Levels to Use in the Backfill of the Land Wall Monoliths

Sections of Land Side Lock Wall	Saturation Elevations for Normal Operating Conditions	Saturation Elevations for Extreme Maintenance Conditions
Upper guide wall monolith	One-half way between upper pool and the top of lock wall	--
Upper gate monoliths	Upper pool elevation	Upper pool elevation
Lock chamber monoliths	One-half way between upper pool and lower pool elevations	Three-fourths way between upper pool and lower pool elevations
Lower gate monoliths	One-half way between upper pool and lower pool elevations	Three-fourths way between upper pool and lower pool elevations
Lower guide wall monoliths	One-half way between upper pool and lower pool elevations	One-half way between upper pool and lower pool elevations

Table 12

Summary of Stability Analysis Results before Remedial Measures

Monolith	Case Considered	Percent Effective Base		Factor of Safety Against Sliding		Maximum Base Pressure ksf	
		Allowable	Actual	Allowable	Actual	Allowable	Actual
L-1	Dewatered condition with surcharge behind monolith (critical case loading)	75	0	2	0.74	33	17,400
L-2	Normal operation	75	90.1	2	1.50	33	8.87
	Normal operation with earthquake	0	58.0	1.33	1.09	33	13.34
	Flood condition	75	100.0	2	1.93	33	7.67
	Dewatered condition	75	70.9	2	1.14	33	11.11
	Dewatered condition with surcharge behind monolith	75	62.1	2	1.05	33	12.54
L-3	Normal operation (most critical condition of upper pool in lock chamber and no gate thrust)	75	92.4	2	1.24	33	7.81
	Normal operation with earthquake	0	55.1	1.33	0.93	33	12.30
	Flood condition	75	97.7	2	1.25	33	7.15
	Dewatered condition	75	68.2	2	0.91	33	9.51
	Dewatered condition with surcharge loads behind monolith	75	61.6	2	0.84	33	10.41
L-5	Normal operation	75	29.4	2	1.33	33	35.20
	Normal operation with hawser	75	22.2	2	1.28	33	46.16
	Normal operation with earthquake	0	0	1.33	1.04	33	∞
	Normal operation with impact	75	100.0	2	3.77	33	10.64
	Normal operation with ice	75	100	2	1.06	33	6.56
	Dewatered condition	75	0	2	0.63	33	∞
	Flood condition	75	62.8	2	1.89	33	14.14
	Dewatered condition with surcharge	75	0	2	0.61	33	∞
L-12	Normal operation	75	96.75	2	1.50	33	13.52
	Normal operation with hawser	75	88.31	2	1.42	33	14.66
	Normal operation with earthquake	0	47.81	1.33	1.11	33	26.32

(Continued)

Table 12 (Continued)

Monolith	Case Considered	Percent Effective Base		Factor of Safety Against Sliding		Maximum Base Pressure ksf	
		Allowable	Actual	Allowable	Actual	Allowable	Actual
L-12 (Cont'd)	Normal operation with ice	75	100.0	2	8.46	33	5.76
	Flood condition	75	100.0	2	2.00	33	9.69
	Dewatered condition	75	59.81	2	0.88	33	19.52
	Dewatered condition with surcharge	75	46.31	2	0.83	33	24.72
L-20	Normal operation	75	81.9	2	1.35	33	11.83
	Normal operation with hawser	75	78.0	2	1.30	33	12.33
	Normal operation with earthquake	0	48.4	1.33	1.02	33	19.19
	Flood condition	75	99.8	2	1.66	33	10.02
	Dewatered condition	75	68.3	2	1.10	33	13.24
	Dewatered condition with surcharge	75	62.9	2	1.05	33	14.22
L-24	Normal operation (lower pool in chamber)	75	72.3	2	1.33	33	15.10
	Normal operation with earthquake	0	31.3	1.33	0.99	33	36.88
	Flood condition	75	94.1	2	1.65	33	11.45
	Dewatered condition	75	54.3	2	1.04	33	19.53
	Dewatered condition with surcharge	75	48.8	2	0.99	33	21.69
R-36	Normal operation	100	75.2	2	1.63	33	11.08
	Normal operation with hawser	100	59.0	2	1.45	33	13.60
	Normal operation (with earthquake)	0	38.0	1.33	1.27	33	20.84
	Dewatered condition	75	50.2	2	1.14	33	14.66
	Flood condition	75	100.0	2	∞	33	6.27
	Normal operation with impact	100	100.0	2	15.49	33	5.30
	Normal operation with ice (lockside)	75	100.0	2	3.10	33	4.08
R-44	Normal operation	100	100.0	2	1.73	33	3.99
	Normal operation with ice (lockside)	75	83.8	2	1.13	33	6.30
	Normal operation with earthquake (lockside)	0	100.0	1.33	1.32	33	4.36
	Normal operation with earthquake (riverside)	0	91.7	1.33	8.06	33	6.96
	Normal operation with impact	100	100.0	2	1.58	33	4.11
	Normal operation with hawser	100	98.4	2	21.40	33	6.56
	Flood condition	75	100.0	2	∞	33	6.24
	Dewatered condition	75	98.4	2	5.80	33	6.04

(Continued)

Table 12 (Concluded)

Monolith	Case Considered	Percent Effective Base		Factor of Safety Against Sliding		Maximum Base Pressure ksf	
		Allowable	Actual	Allowable	Actual	Allowable	Actual
R-50	Normal operation (upper pool in chamber)	100	100.0	2	1.70	33	4.71
	Normal operation with ice - lockside (up)	75	100.0	2	1.22	33	6.19
	Normal operation with earthquake - lockside (up)	0	100.0	1.33	1.27	33	4.95
	Normal operation with impact (up)	100	100.0	2	1.57	33	4.59
	Normal operation (lower pool in chamber)	100	96.09	2	∞	33	6.85
	Normal operation with earthquake - riverside (lp)	75	85.31	1.33	7.18	33	7.55
	Normal operation with hawser (lp)	100	90.38	2	25.57	33	7.21
	Flood condition	75	100.0	2	∞	33	7.04
	Dewatered condition	75	86.6	2	4.18	33	6.98
R-55	Normal operation (upper pool in chamber)	100	100.0	2	2.53	33	5.70
	Normal operation with earthquake	0	100.0	1.33	1.89	33	6.53
	Dewatered condition	75	100.0	2	∞	33	6.90
	Flood condition	75	100.0	2	9.70	33	6.91
D-1 - D-33	Normal operation with impact or ice, upper pool at elevation 16.33 and lower pool at elevation -2	100	100	2	1.68	33	1.63
D-34 - D-62	Normal operation (most critical condition with upper pool at elevation 18.0 and lower pool at elevation 0.0)	100	100	2	1.72	33	1.14
	Normal operation with earthquake	0	100	1.33	1.44	33	1.35
	Normal operation with impact	100	99.9	2	1.32	33	1.92
	Flood condition	100	100	2	2.00	33	3.24
Headgate monolith	Normal operation (most critical condition of upper pool el = 18.0 and lower pool = el 0.0	100	100	2	3.66	33	2.65
	Normal operation with earthquake	0	100	1.33	2.71	33	2.42
	Normal operation with ice	100	100	2	2.26	33	3.11
	Flood condition	100	100	2	2.27	33	1.97

Table 13

Summary of Stability Analysis Results after Remedial Measures

Monolith	Case Considered	Percent Effective Base Allowable	Percent Effective Base Actual	Factor of Safety Against Sliding Allowable	Factor of Safety Against Sliding Actual	Maximum Base Pressure ksf Allowable	Maximum Base Pressure ksf Actual
L-1	Dewatered condition with surcharge behind monolith (critical case loading)	75	75.0	2	1.33	33	21.0
L-2	Normal operation	75	99.8	2	1.70	33	8.87
	Normal operation with earthquake	0	73.1	1.33	1.24	33	11.98
	Flood condition	75	100.0	2	2.23	33	7.76
	Dewatered condition	75	82.9	2	1.27	33	10.51
	Dewatered condition with surcharge behind monolith	75	75.2	2	1.18	33	11.43
L-3	Normal operation (most critical condition of upper pool in lock chamber and no gate thrust)	75	99.5	2	1.35	33	7.59
	Normal operation with earthquake	0	70.3	1.33	1.00	33	10.63
	Flood condition	75	100.0	2	1.39	33	6.97
	Dewatered condition	75	81.0	2	0.98	33	8.63
	Dewatered condition with surcharge loads behind monolith	75	75.2	2	0.90	33	9.18
L-5	Normal operation	75	100.0	2	2.80	33	9.29
	Normal operation with hawser	75	100.0	2	2.69	33	9.32
	Normal operation with earthquake	0	75.0	1.33	2.12	33	19.82
	Normal operation with impact	75	100.0	2	8.06	33	4.09
	Normal operation with ice	75	82.6	2	33.38	33	1.90
	Dewatered condition	75	87.4	2	1.41	33	14.94
	Flood condition	75	100.0	2	4.53	33	8.67
	Dewatered condition with surcharge	75	75.0	2	1.36	33	17.42
L-12	Normal operation	75	100.0	2	1.91	33	11.75
	Normal operation with hawser	75	100.0	2	1.81	33	12.74
	Normal operation with earthquake	0	75.1	1.33	1.42	33	18.76
	Normal operation with ice	75	100.0	2	7.48	33	2.81
	Flood condition	75	100.0	2	2.70	33	8.45
	Dewatered condition	75	86.7	2	1.14	33	14.90
	Dewatered condition with surcharge	75	75.0	2	1.07	33	16.92

(Continued)

Table 13 (Concluded)

Monolith	Case Considered	Percent Effective Base		Factor of Safety Against Sliding		Maximum Base Pressure ksf	
		Allowable	Actual	Allowable	Actual	Allowable	Actual
L-20	Normal operation	75	92.3	3	1.77	33	11.73
	Normal operation with hawser	75	98.9	2	1.71	33	12.11
	Normal operation with earthquake	0	62.3	1.33	1.34	33	16.81
	Flood condition	75	100.0	2	2.30	33	10.19
	Dewatered condition	75	79.8	2	1.42	33	12.60
	Dewatered condition with surcharge	75	75.0	2	1.36	33	13.28
L-24	Normal operation (lower pool in chamber)	75	89.6	2	1.69	33	15.74
	Normal operation with earthquake	0	61.8	1.33	1.25	33	22.71
	Flood condition	75	100.0	2	2.21	33	11.89
	Dewatered condition	75	80.1	2	1.31	33	16.32
	Dewatered condition with surcharge	75	75.9	2	1.26	33	17.12
R-36	Normal operation	100	100.0	2	2.82	33	7.09
	Normal operation with hawser	100	100.0	2	2.54	33	8.06
	Normal operation with earthquake	0	100.0	1.33	2.21	33	9.85
	Dewatered condition	75	100.0	2	2.00	33	7.59
	Flood condition	75	100.0	2	∞	33	6.27
	Normal operation with impact	100	100.0	2	15.49	33	5.30
	Normal operation with ice (lockside)	75	100.0	2	3.10	33	4.08
D-1 - D-33	Normal operation with impact or ice, upper pool at elevation 16.33 and lower pool at elevation -2	100	100	2	2.00	33	1.46
D-34 - D-62	Normal operation (most critical condition with upper pool at elevation 18.0 and lower pool at elevation 0.0	100	100	2	2.59	33	0.77
	Normal operation with earthquake	0	100	1.33	2.18	33	0.98
	Normal operation with impact	100	100	2	2.00	33	1.45
	Flood condition	100	100	2	3.08	33	2.86

Table 14

Monoliths as Represented by Stability Computations

Monolith for Which Stability Was Computed	Monoliths Which Are Represented by Stability Computation
L-1	L-1
L-2	L-2
L-3	L-3
L-5	L-4 through L-7
L-12	L-8 through L-15
L-16	L-16
L-20	L-17 through L-23
L-24	L-24
L-25	L-25
L-25A	L-25A
R-34	R-33 and R-34
R-36	R-35 through R-38
R-44	R-40 through R-46
R-48	R-47 and R-48
R-50	R-49 through R-54
R-55	R-55
D-14	D-1 through D-33
D-40	D-34 through D-62
Headgate monolith	Headgate monolith

Table 15

Areas of Critical Stress-Normal Operation

Monolith 5, Troy Lock and Dam

	Normal			Shear		
Element	σ_{xx} ksf	σ_{yy} ksf	σ_{zz} ksf	τ_{xy} ksf	τ_{yz} ksf	τ_{zx} ksf
61-64	-0.01	0.46	1.81	0.00	0.00	-0.06
129-132	-0.24	-0.44	-1.50	0.00	0.00	-0.16
237-240	0.01	-1.17	-4.68	0.00	0.00	-0.11
329-332	0.38	-0.22	-1.25	0.00	0.00	-0.65
593-596	4.06	0.96	-0.24	0.00	0.00	-0.78
625-628	-4.84	-3.19	-12.72	0.00	0.00	-0.31
717-720	-0.06	-2.36	-9.37	0.00	0.00	-2.59
733-736	2.90	0.75	0.10	0.00	0.00	-3.53
825-828	-0.87	-3.86	-14.56	0.00	0.00	-0.93
921-924	-2.91	-4.82	-16.38	0.00	0.00	-2.08
977-980	-2.91	-4.13	-13.60	0.00	0.00	2.01
1009-1012	-4.84	-5.01	-15.20	0.00	0.00	-2.18
1021-1024	-11.01	-11.19	-33.74	0.00	0.00	-9.45
1077-1080	-1.48	-3.53	-12.64	0.00	0.00	2.16

Note: Negative value denotes compressive stress and positive value tensile stress for normal stress values.

Table 16

Areas of Critical Stress-Dewatered Condition

Monolith 5, Troy Lock and Dam

	Normal			Shear		
Element	σ_{xx} ksf	σ_{yy} ksf	σ_{zz} ksf	τ_{xy} ksf	τ_{yz} ksf	τ_{zx} ksf
61-64	-0.01	-0.46	-1.81	0.00	0.00	-0.06
129-132	-0.24	0.44	-1.51	0.00	0.00	-0.16
237-240	0.01	-1.17	-4.68	0.00	0.00	-0.11
329-332	0.35	-0.22	-1.25	0.00	0.00	-0.65
593-596	4.27	1.08	0.04	0.00	0.00	-0.96
625-628	0.31	-3.06	-12.55	0.00	0.00	-0.29
717-720	0.42	-2.31	-9.65	0.00	0.00	-2.71
733-736	3.53	0.95	0.26	0.00	0.00	-3.96
825-828	-0.33	-3.81	-14.93	0.00	0.00	-1.11
921-928	-2.64	-4.93	-17.08	0.00	0.00	-2.71
977-980	-2.45	-4.00	-13.56	0.00	0.00	2.11
1009-1012	-5.45	-5.38	-16.08	0.00	0.00	-2.65
1021-1024	-11.48	-11.82	-35.78	0.00	0.00	-10.58
1077-1080	-1.32	-3.48	-12.60	0.00	0.00	2.02

Note: Negative value denotes compressive stress and positive value tensile stress for normal stress values.

Table 17

Areas of Critical Stress-Normal Operation with Soil Anchors Through Top of Monolith (Figure 77) Monolith 5, Troy Lock and Dam

	Normal			Shear		
Element	σ_{xx} ksf	σ_{yy} ksf	σ_{zz} ksf	τ_{xy} ksf	τ_{yz} ksf	τ_{zx} ksf
61	4.69	2.29	4.65	-0.97	-0.32	-0.91
62	-49.52	-15.40	-12.27	25.19	-1.23	27.39
63	-49.52	-15.40	-12.27	-25.19	1.23	27.39
64	4.69	2.29	4.65	0.97	0.32	-0.91
129	-6.26	-4.43	-11.43	0.01	-0.02	5.90
130	-6.28	-4.41	-11.42	0.01	-0.02	5.94
131	-6.28	-4.41	-11.42	-0.01	0.02	5.94
132	-6.26	-4.43	-11.43	-0.01	0.02	5.90
237	-49.76	-11.10	5.21	-25.20	1.22	27.37
238	4.47	6.61	22.12	0.97	0.31	-0.95
239	4.47	6.61	22.12	-0.97	-0.31	-0.95
240	-49.76	-11.10	5.21	25.20	-1.22	27.37
329	-19.95	-13.19	-32.83	0.00	0.00	8.78
330	-19.94	-13.20	-32.83	0.00	0.00	8.78
331	-19.94	-13.20	-32.83	0.00	0.00	8.78
332	-19.95	-13.19	-32.83	0.00	0.00	8.78
593	2.65	0.45	-0.84	0.00	0.00	-1.20
594	2.65	0.45	-0.84	0.00	0.00	-1.20
595	2.65	0.45	-0.84	0.00	0.00	-1.20
596	2.65	0.45	-0.84	0.00	0.00	-1.20
625	-0.57	5.28	21.69	0.00	0.00	0.85
626	-0.57	5.28	21.69	0.00	0.00	0.85
627	-0.57	5.28	21.69	0.00	0.00	0.85
628	-0.57	5.28	21.69	0.00	0.00	0.85
717	-4.44	-6.01	-19.61	0.00	0.00	1.44
718	-4.44	-6.01	-19.61	0.00	0.00	1.44
719	-4.44	-6.01	-19.61	0.00	0.00	1.44
720	-4.44	-6.01	-19.61	0.00	0.00	1.44
733	-21.30	-12.47	-28.56	0.00	0.00	14.50
734	-21.30	-12.47	-28.56	0.00	0.00	14.50
735	-21.30	-12.47	-28.56	0.00	0.00	14.50
736	-21.30	-12.47	-28.56	0.00	0.00	14.50

(Continued)

Note: Negative value denotes compressive stress and positive value tensile stress for normal stress values.

Table 17 (Concluded)

Element	Normal σ_{xx} ksf	σ_{yy} ksf	σ_{zz} ksf	Shear τ_{xy} ksf	τ_{yz} ksf	τ_{zx} ksf
825	-2.58	-6.48	-23.35	0.00	0.00	0.33
826	-2.58	-6.48	-23.35	0.00	0.00	0.33
827	-2.59	-6.48	-23.35	0.00	0.00	0.33
828	-2.58	-6.48	-23.35	0.00	0.00	0.33
921	-4.22	-7.24	-24.76	0.00	0.00	-4.14
922	-4.22	-7.24	-24.76	0.00	0.00	-4.14
923	-4.22	-7.24	-24.76	0.00	0.00	-4.14
924	-4.22	-7.24	-24.76	0.00	0.00	-4.14
977	4.70	1.79	2.45	0.00	0.00	-1.30
978	4.70	1.79	2.45	0.00	0.00	-1.30
979	4.70	1.79	2.45	0.00	0.00	-1.30
980	4.70	1.79	2.45	0.00	0.00	-1.30
1009	-6.92	-6.82	-20.34	0.00	0.00	-3.90
1010	-6.92	-6.82	-20.34	0.00	0.00	-3.90
1011	-6.92	-6.82	-20.34	0.00	0.00	-3.90
1012	-6.92	-6.82	-20.34	0.00	0.00	-3.90
1021	4.90	4.75	14.09	0.00	0.00	4.49
1022	4.90	4.75	14.09	0.00	0.00	4.49
1023	4.90	4.75	14.09	0.00	0.00	4.49
1024	4.90	4.75	14.09	0.00	0.00	4.99
1077	-0.69	-5.48	-21.22	0.00	0.00	2.30
1078	-0.69	-5.48	-21.22	0.00	0.00	2.30
1079	-0.69	-5.48	-21.22	0.00	0.00	2.30
1080	-0.69	-5.48	-21.22	0.00	0.00	2.30

Table 18

Areas of Critical Stress-Dewatered Condition with Soil Anchors Through Top of Monolith (Figure 77)

Monolith 5, Troy Lock and Dam

	Normal			Shear		
Element	σ_{xx} ksf	σ_{yy} ksf	σ_{zz} ksf	τ_{xy} ksf	τ_{yz} ksf	τ_{zx} ksf
61	4.69	2.29	4.65	-0.97	-0.32	-0.91
62	-49.52	-15.40	-12.27	25.19	-1.23	27.39
63	-49.52	-15.40	-12.27	-25.19	1.23	27.39
64	4.69	2.29	4.65	0.97	0.32	-0.91
129	-6.25	-4.43	-11.43	0.01	-0.02	5.94
130	-6.25	4.41	-11.42	0.01	-0.02	5.94
131	-6.28	-4.41	-11.42	-0.01	0.02	5.94
132	-6.25	-4.43	-11.43	-0.01	0.02	5.94
237	-49.76	-11.10	5.21	-25.20	1.22	27.37
238	4.47	6.61	22.12	0.97	0.31	-0.95
239	4.47	6.61	22.12	-0.97	-0.31	-0.95
240	-49.76	-11.10	5.21	25.20	-1.22	27.37
329	-19.98	-13.20	-32.82	0.00	0.00	8.78
330	-19.97	-13.20	-32.82	0.00	0.00	8.78
331	19.97	-13.20	-32.82	0.00	0.00	8.78
332	19.98	-13.20	-32.82	0.00	0.00	8.78
593	2.87	0.58	-0.56	0.00	0.00	-1.38
594	2.87	0.58	-0.56	0.00	0.00	-1.38
595	2.87	0.58	-0.56	0.00	0.00	-1.38
596	2.87	0.58	-0.56	0.00	0.00	-1.38
625	-0.21	5.41	21.86	0.00	0.00	0.87
626	-0.21	5.41	21.86	0.00	0.00	0.87
627	-0.21	5.41	21.86	0.00	0.00	0.87
628	-0.21	5.41	21.86	0.00	0.00	0.87
717	-3.95	-5.96	-19.89	0.00	0.00	1.32
718	-3.95	-5.96	-19.89	0.00	0.00	1.32
719	-3.95	-5.96	-19.89	0.00	0.00	1.32
720	-3.95	-5.96	-19.89	0.00	0.00	1.32
733	-20.67	-12.27	-28.41	0.00	0.00	14.07
734	20.67	-12.77	-28.41	0.00	0.00	14.07
735	-20.67	-12.77	-28.41	0.00	0.00	14.07
736	-20.67	-12.77	-28.41	0.00	0.00	14.07

(Continued)

Note: Negative value denotes compressive stress and positive value tensile stress for normal stress values.

Table 18 (Concluded)

	Normal			Shear		
Element	σ_{xx} ksf	σ_{yy} ksf	σ_{zz} ksf	τ_{xy} ksf	τ_{yz} ksf	τ_{zx} ksf
825	-2.04	-6.44	-23.72	0.00	0.00	0.15
826	-2.04	-6.44	-23.72	0.00	0.00	0.15
827	-2.04	-6.44	-23.72	0.00	0.00	0.15
828	-2.04	-6.44	-23.72	0.00	0.00	0.15
921	-3.95	-7.35	-25.47	0.00	0.00	-4.78
922	-3.95	-7.35	-25.47	0.00	0.00	-4.78
923	-3.95	-7.35	-25.47	0.00	0.00	-4.78
924	-3.95	-7.35	-25.47	0.00	0.00	-4.78
977	5.19	1.92	2.49	0.00	0.00	-1.19
978	5.19	1.92	2.49	0.00	0.00	-1.19
979	5.19	1.92	2.49	0.00	0.00	-1.19
980	5.19	1.92	2.49	0.00	0.00	-1.19
1009	-7.53	-7.18	-21.19	0.00	0.00	-4.37
1010	-7.53	-7.18	-21.19	0.00	0.00	-4.37
1011	-7.53	-7.18	-21.19	0.00	0.00	-4.37
1012	-7.53	-7.18	-21.19	0.00	0.00	-4.37
1021	4.42	4.12	12.05	0.00	0.00	3.36
1022	4.42	4.12	12.05	0.00	0.00	3.36
1023	4.42	4.12	12.05	0.00	0.00	3.36
1024	4.42	4.12	12.05	0.00	0.00	3.36
1077	-0.52	-5.42	-21.18	0.00	0.00	2.16
1078	-0.52	-5.42	-21.18	0.00	0.00	2.16
1079	-0.52	-5.42	-21.18	0.00	0.00	2.16
1080	-0.52	-5.42	-21.18	0.00	0.00	2.16

Table 19

Areas of Critical Stress-Normal Operation with Posttensioning Through Culvert Wall (Figure 79) Monolith 5, Troy Lock and Dam

	Normal			Shear		
Element	σ_{xx} ksf	σ_{yy} ksf	σ_{zz} ksf	τ_{xy} ksf	τ_{yz} ksf	τ_{zx} ksf
593	5.37	1.34	0.00	0.00	0.00	-1.29
594	5.37	1.34	0.00	0.00	0.00	-1.29
595	5.37	1.34	0.00	0.00	0.00	-1.29
596	5.37	1.34	0.00	0.00	0.00	-1.29
717	-0.60	-2.37	-8.99	0.02	0.04	-2.80
718	-0.61	-2.40	-8.86	-0.01	-0.06	-2.75
719	-0.61	-2.40	-8.86	0.01	0.06	-2.75
720	-0.60	-2.37	-8.99	-0.02	-0.04	-2.80
733	0.98	-0.14	-1.54	0.00	0.00	-2.47
734	0.97	-0.14	-1.54	0.00	0.00	-2.47
735	0.97	-0.14	-1.54	0.00	0.00	-2.47
736	0.98	-0.14	-1.54	0.00	0.00	-2.47
825	-1.35	-5.51	-12.98	0.89	-0.19	-2.11
826	-12.71	-7.19	-23.76	5.60	-5.02	8.50
827	-12.71	-7.19	-23.76	-5.60	5.02	8.50
828	-1.35	-5.51	-12.98	-0.89	0.19	-2.11
921	-14.76	-9.32	-29.05	-5.65	5.17	9.54
922	-3.03	-7.09	-18.80	-0.94	0.36	-1.02
923	-3.03	-7.09	-18.80	+0.94	-0.36	-1.02
924	-14.76	-9.32	-29.05	+5.65	-5.17	9.54
977	-1.80	-4.06	-14.46	0.00	0.00	2.22
978	-1.80	-4.06	-14.46	0.00	0.00	2.22
979	-1.80	-4.06	-14.46	0.00	0.00	2.22
980	-1.80	-4.06	-14.46	0.00	0.00	2.22
1009	-2.80	-5.19	-18.90	-0.02	0.31	-1.89
1010	-3.09	-5.58	-18.30	-0.01	0.26	-1.83
1011	-3.09	-5.58	-18.30	0.01	-0.26	-1.83
1012	-2.80	-5.19	-18.90	+0.02	-0.31	-1.89
1021	-10.11	-11.15	-34.49	0.00	0.00	-9.04
1022	-10.11	-11.15	-34.49	0.00	0.00	-9.04
1023	-10.11	-11.15	-34.49	0.00	0.00	-9.04
1024	-10.11	-11.15	-34.49	0.00	0.00	-9.04

(Continued)

Note: Negative value denotes compressive stress and positive value tensile stress for normal stress values.

Table 19 (Concluded)

Element	Normal σ_{xx} ksf	σ_{yy} ksf	σ_{zz} ksf	Shear τ_{xy} ksf	τ_{yz} ksf	τ_{zx} ksf
1077	-1.30	-4.45	-17.06	-0.04	0.13	4.07
1078	-1.32	-4.68	-16.86	-0.04	0.12	4.01
1079	-1.32	-4.68	-16.86	0.04	-0.12	4.01
1080	-1.30	-4.45	-17.06	0.04	-0.13	4.07

Table 20

Areas of Critical Stress-Dewatered Condition with Posttensioning Through Culvert Wall (Figure 79)

Monolith 5, Troy Lock and Dam

Element	Normal σ_{xx} ksf	σ_{yy} ksf	σ_{zz} ksf	Shear τ_{xy} ksf	τ_{yz} ksf	τ_{zx} ksf
593	5.59	1.47	0.27	0.00	0.00	-1.46
594	5.59	1.47	0.27	0.00	0.00	-1.46
595	5.59	1.47	0.27	0.00	0.00	-1.46
596	5.59	1.47	0.27	0.00	0.00	-1.46
717	-0.11	-2.32	-9.27	0.04	-0.04	-2.91
718	-0.12	-2.34	-9.14	-0.01	-0.06	-2.87
719	-0.12	-2.34	-9.14	0.01	0.06	-2.87
720	-0.11	-2.32	-9.27	-0.02	0.04	-2.91
733	1.60	0.06	-1.38	0.00	0.00	-2.89
734	1.60	0.06	-1.38	0.00	0.00	-2.89
735	1.60	0.06	-1.38	0.00	0.00	-2.89
736	1.60	0.06	-1.38	0.00	0.00	-2.89
825	-0.81	-5.47	-13.35	0.89	-0.19	-2.29
826	-12.17	-7.15	-24.12	5.60	-5.02	8.32
827	-12.17	-7.15	-24.12	-5.60	5.02	8.32
828	-0.81	-5.47	-13.35	-0.89	0.19	-2.29
921	-14.49	-9.43	-29.76	-5.65	-5.17	8.91
922	-2.77	-7.20	-19.51	-0.94	0.36	-1.66
923	-2.77	-7.20	-19.51	0.94	-0.36	-1.66
924	-14.49	-9.43	-29.76	5.65	-5.17	8.91
977	-1.31	-3.93	-14.42	0.00	0.00	2.32
978	-1.31	-3.93	-14.42	0.00	0.00	2.32
979	-1.31	-3.93	-14.42	0.00	0.00	2.32
980	-1.31	-3.93	-14.42	0.00	0.00	2.32
1009	-3.40	-5.56	-19.56	-0.02	0.31	-2.35
1010	-3.70	-5.95	-19.15	-0.01	0.26	-2.30
1011	-3.70	-5.95	-19.15	+0.01	-0.26	-2.30
1012	-3.40	-5.56	-19.76	0.02	-0.31	-2.35
1021	-10.58	-11.78	-36.53	0.00	0.00	-10.17
1022	-10.58	-11.78	-36.53	0.00	0.00	-10.17
1023	-10.58	-11.78	-36.53	0.00	0.00	-10.17
1024	-10.58	-11.78	-36.53	0.00	0.00	-10.17

(Continued)

Note: Negative value denotes compressive stress and positive value tensile stress for normal stress values.

Table 20 (Concluded)

	Normal			Shear		
Element	σ_{xx} ksf	σ_{yy} ksf	σ_{zz} ksf	τ_{xy} ksf	τ_{yz} ksf	τ_{zx} ksf
1077	-1.13	-4.40	-17.01	-0.04	0.13	3.93
1078	-1.15	-4.63	-16.81	-0.04	0.12	3.87
1079	-1.15	4.63	-16.81	0.04	-0.12	3.87
1080	-1.13	-4.40	-17.01	0.04	-0.13	3.93

Table 21

Recommended Posttensioning

Representative Monolith Used For Stability Computations	Monoliths for Which Stability Computations Are Applicable	Actual Posttensioning to Apply per Hole kips	Maximum Posttensioning Requirement per Hole kips	Posttensioning Anchor*	Number of Tendons per Monolith	Depth of Posttensioning Anchor ft
L-1	L-1	85	167	ER5-9 (7 strands)	6	20
L-2	L-2	35	67	ER5-3 (3 strands)	6	15
L-3	L-3	30	58	ER5-3 (3 strands)	4	15
L-5	L-4 and L-5	10	115	ER5-6 (5 strands)	12	15
L-5	L-6	10	123	ER5-6 (5 strands)	7	15
L-5	L-7	10	123	ER5-6 (5 strands)	14	15
L-12	L-8 through L-14	10	70	ER5-3 (3 strands)	4	15
L-12	L-15	10	67	ER5-3 (3 strands)	8	15
L-16	L-16	60	120	ER5-6 (5 strands)	6	15
L-20	L-17	10	129	ER5-6 (5 strands)	3	15
L-20	L-18 through L-22	10	108	ER5-6 (5 strands)	4	15
L-20	L-23	10	123	ER5-6 (5 strands)	5	15
L-24	L-24	80	163	ER5-9 (7 strands)	8	20
L-25	L-25	80	174	ER5-9 (7 strands)	6	20
R-36	R-35	10	74	ER5-3 (3 strands)	9	15
R-36	R-36 through R-38	10	74	ER5-3 (3 strands)	6	15
D-34 through D-62	D-34 through D-62	65	128	ER5-6 (5 strands)	2	15
D-1 through D-33	D-1 through D-33	55	55	ER5-3 (3 strands)	2	15

* Prestressed Rock and Soil Anchors, VSL Corporation or tendons of equivalent capacity.

Table 22

Strut Resistance

Monolith	Required Strut Resistance per Foot of Monolith kips	Side of Monolith Requiring Strut Resistance	Depth of Vertical Contact with Monolith Base Required for Reaction Block* ft	Required Rock Anchor Capacity Needed per Foot of Monolith when Placed at 45° from the Reaction Block into the Foundation kips
L-1	27	Riverside	0.5	38
L-2	39			55
L-3	52			74
L-4 - L-5	42			59
L-6	42			59
L-7	42			59
L-8 - L-14	61			86
L-15	61			86
L-16	40			57
L-17	49			69
L-18 - L-22	49			69
L-23	49			69
L-24	59			83
L-25	45			64
R-40 - R-48	27			38
R-49 - R-54	28			40

* Recommended reaction block size and reinforcing presented in Figure 80.

Table 23

Recommended Repair of Deteriorated Concrete

Location	Means of Removing Deteriorated Concrete	Depth of Removal	Surface Preparation for Placement of New Concrete	Bonding Agent	Reinforcement	Type of Overlay and Its Main Engineering Properties
Top surface of land wall	A chisel point chipper or high pressure water jet	1 ft or to sound concrete	Water jet	None	No. 5 bars 12 in. on center each way	5000 psi concrete 7 percent air 1-1/2-in. aggregate maximum
Riverside of land wall monoliths	Controlled blasting in line drilled holes	To sound concrete or a minimum of 1 ft	Water jet	None	No. 6 dowels 24 in. on center with a 12-in. bend at its end. No. 5 bars 12 in. on center each way	5000 psi concrete 7 percent air 1-1/2-in. aggregate maximum
Landside of river wall monoliths	Controlled blasting in line drilled holes	To sound concrete or a minimum of 1 ft	Water jet	None	No. 6 dowels 24 in. on center with a 12-in. bend at its end. No. 5 bars 12 in. on center each way	5000 psi concrete 7 percent air 1-1/2-in. aggregate maximum
Top surface of river wall monoliths	Same as for top surface of land wall monoliths.					
River face of river wall monoliths	A chisel point chipper or high pressure water jet. Dewater and remove deteriorated concrete then dowel; reinforce and place overlay	To sound concrete	Water jet	None	No. 6 dowels 24 in. on center with a 12-in. bend at its end. No. 5 bars 12 in. on center each way	5000 psi concrete 8 percent air 3/8-in. aggregate maximum
Surface of filling and emptying culverts and ports	A chisel point chipper or high pressure water jet	To sound concrete	Minimum of 3-in. overlay is needed	None	None unless repair area is more than 3 sq ft. If over 3 sq ft, use wire mesh held on by anchors	Shotcrete 5000 psi concrete 7 percent air 3/8-in. aggregate maximum
Surface of dam	A chisel point chipper or high pressure water jet	To sound concrete and very clean. Use a minimum of a 3-in. overlay	Water jet	None	Use wire mesh held on by anchors	Epoxy or acrylic-polymer concrete. 5000 psi concrete 7 percent air 3/8-in. aggregate maximum
Piers of gated spillway	Jackhammer	Complete removal to a depth where sound concrete is reached	Water jet	None	Reinforce adequately for stress and temperature	5000 psi concrete 7 percent air 1-1/2-in. aggregate maximum

APPENDIX A:

STABILITY ANALYSIS

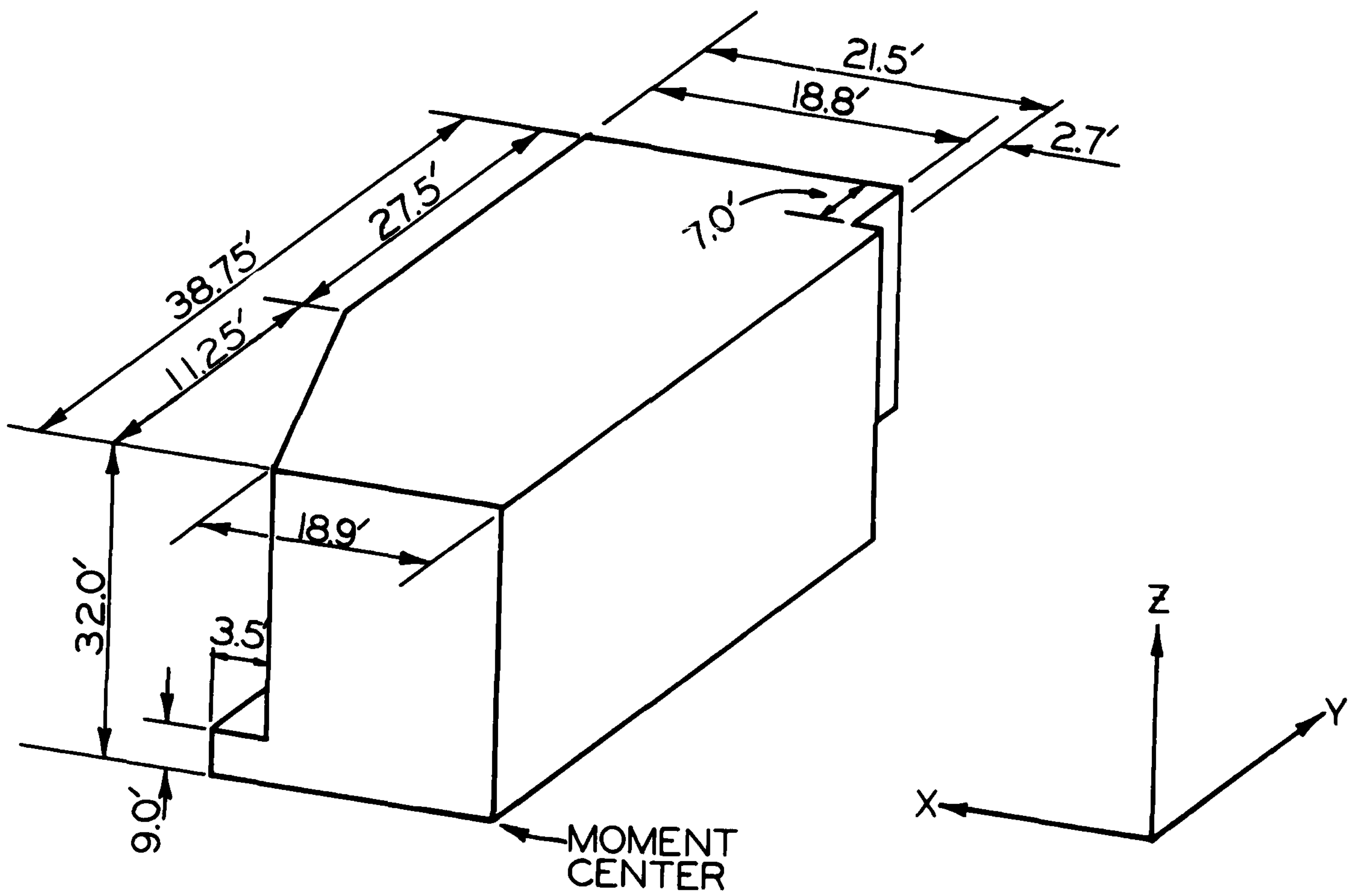
FOR

LOCK MONOLITHS,

DAM MONOLITHS,

AND HEADGATE MONOLITHS

LOCK MONOLITH L-2



Stability analysis, monolith L-2,Troy Lock and Dam

SUBJECT	COMPUTED BY:	DATE:	FILE NO.
Monolith L-2, Troy Lock and Dam Stability Summary - No Posttentioning	CHECKED BY:	DATE:	SHEET NO.

Load Case	Effective Area of Base in Compression (%)	Factor of Safety Against Sliding	Maximum Base Pressure (ksf)
Normal Operation	90.1	1.50	8.87
Normal Operation with Earthquake	58.0	1.09	13.34
Flood Condition	100.0	1.93	7.67
Dewatered Condition	70.9	1.14	11.11
Dewatered Condition with Surcharge Behind Monolith	62.1	1.05	12.54

WES FORM NO. 1253
REV OCT 1960

SUBJECT: Monolith L-2, Troy Lock and Dam Maximum Bearing Pressure - No Posttensioning	COMPUTED BY:	DATE:	FILE NO.
	CHECKED BY:	DATE:	SHEET NO.

Load Case	Height of Water Over Toe (ft)	Hydrostatic Pressure at Toe (ksf)	Maximum Intergranular Pressure at Toe (ksf)	Maximum Base Pressure (ksf)
Normal Operation	22.33	1.40	7.47	8.87
Normal Operation with Earthquake	22.33	1.40	11.94	13.34
Flood Condition	37.70	2.36	5.31	7.67
Dewatered Condition	0.00	0.00	11.11	11.11
Dewatered with Surcharge Behind Monolith	0.0	0.00	12.54	12.54

WES FORM NO. 1253
REV OCT 1968

SUBJECT: Monolith L-2, Troy Lock and Dam Stability Summary - After Posttensioning	COMPUTED BY:	DATE:	FILE NO.
	CHECKED BY:	DATE:	SHEET NO.

Load Case	Effective Area of Base in Compression (%)	Factor of Safety Against Sliding	Maximum Base Pressure (ksf)
Normal Operation	99.8	1.70	8.87
Normal Operation with Earthquake	73.1	1.24	11.98
Flood Condition	100.0	2.23	7.76
Dewatered Condition	82.9	1.27	10.51
Dewatered Condition with Surcharge Behind Monolith	75.2	1.18	11.43

WES FORM NO. 1253
REV OCT 1966

SUBJECT: Monolith L-2, Troy Lock and Dam Maximum Bearing Pressure - After Posttensioning	COMPUTED BY:	DATE:	FILE NO.
	CHECKED BY:	DATE:	SHEET NO.

Load Case	Height of Water Over Toe (ft)	Hydrostatic Pressure at Toe (ksf)	Maximum Intergranular Pressure at Toe (ksf)	Maximum Base Pressure (ksf)
Normal Operation	22.33	1.40	7.47	8.87
Normal Operation with Earthquake	22.33	1.40	10.58	11.98
Flood Condition	37.70	2.36	5.40	7.76
Dewatered Condition	0.00	0.00	10.51	10.51
Dewatered with Surcharge Behind Monolith	0.0	0.00	11.43	11.43

WES FORM NO. 1253
REV OCT 1968

Monolith L-2 , Troy Lock and Dam
Normal Operation

BASE AREA PROPERTIES - Initial

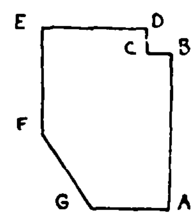
Area (ft^2)	Inertia About Principle X-Axis (ft^4)	Inertia About Principle Y-Axis (ft^4)	X Bar (ft)	Y Bar (ft)	Z Bar (ft)	Angle Principle X-Axis Makes With X-Axis (Degrees)
935.2	113,236	45,573	12.54	-19.30	0.0	5.10

SUMMARY OF FORCES AND MOMENTS - Initial

F_x (kips)	F_y (kips)	F_z (kips)	M_{xx} (ft-k)	M_{yy} (ft-k)	M_{zz} (ft-k)
-1191.3	0	3009.5	58,071	23,293	23,081

BASE PRESSURES - Initial

Pressure Point	X Coordinate	Y Coordinate	Z Coordinate	Pressure (ksf)
A	0.00	0.00	0.00	6.86
B	0.00	-31.75	0.00	7.38
C	2.70	-31.75	0.00	6.53
D	2.70	-38.75	0.00	6.65
E	25.00	-38.75	0.00	-0.40
F	25.00	-11.25	0.00	-0.85
G	22.40	0.00	0.00	-0.22



AD-A094 683 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS F/G 13/13
ENGINEERING CONDITION SURVEY AND EVALUATION OF TROY LOCK AND DA--ETC(U)
JAN 81 C E PACE, R CAMPBELL, S WONG
UNCLASSIFIED WES-MP-C-78-6-2 NL

3 OF 5
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A094683

Monolith L-2 , Troy Lock and Dam
Normal Operation

BASE AREA PROPERTIES - Final*

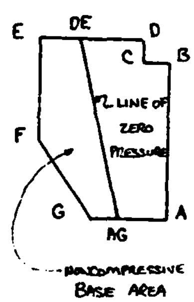
Area (ft^2)	Inertia About Principle X-Axis (ft^4)	Inertia About Principle Y-Axis (ft^4)	X Bar (ft)	Y Bar (ft)	Z Bar (ft)	Angle Principle X-Axis Makes With X-Axis (Degrees)
843.1	103,507	33,354	11.35	-19.33	0.00	4.78

SUMMARY OF FORCES AND MOMENTS - Final*

F_x (kips)	F_y (kips)	F_z (kips)	M_{xx} (ft-k)	M_{yy} (ft-k)	M_{zz} (ft-k)
-1191.3	0.0	2996.0	57,797	23,065	23,081

BASE PRESSURES -

Pressure Point	X Coordinate	Y Coordinate	Z Coordinate	Pressure (ksf)
A	0.00	0.00	0.00	6.92
B	0.00	-31.75	0.00	7.47
C	2.70	-31.75	0.00	6.59
D	2.70	-38.75	0.00	6.71
DE	23.28	-38.75	0.00	0.00
AG	21.21	0.00	0.00	0.00



*Values are after iteration releasing tension at base-foundation interface.

Monolith L-2 , Troy Lock and Dam
Normal Operation with Earthquake

BASE AREA PROPERTIES - Initial

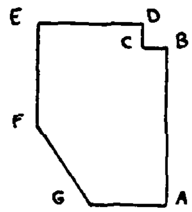
Area (ft^2)	Inertia About Principle X-Axis (ft^4)	Inertia About Principle Y-Axis (ft^4)	X Bar (ft)	Y Bar (ft)	Z Bar (ft)	Angle Principle X-Axis Makes With X-Axis (Degrees)
935.2	113,235	45,573	12.54	-19.30	0.0	5.10

SUMMARY OF FORCES AND MOMENTS - Initial

F_x (kips)	F_y (kips)	F_z (kips)	M_{xx} (ft-k)	M_{yy} (ft-k)	M_{zz} (ft-k)
-1628.7	0.0	2996.0	57,797	15,252	31,556

BASE PRESSURES - Initial

Pressure Point	X Coordinate	Y Coordinate	Z Coordinate	Pressure (ksf)
A	0.00	0.00	0.00	8.82
B	0.00	-31.75	0.00	9.64
C	2.70	-31.75	0.00	8.32
D	2.70	-38.75	0.00	8.50
E	25.00	-38.75	0.00	-2.37
F	25.00	-11.25	0.00	3.08
G	22.40	0.00	0.00	2.10



Monolith L-2 , Troy Lock and Dam
Normal Operation with Earthquake

BASE AREA PROPERTIES - Final*

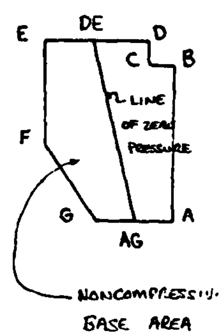
Area (ft^2)	Inertia About Principle X-Axis (ft^4)	Inertia About Principle Y-Axis (ft^4)	X Bar (ft)	Y Bar (ft)	Z Bar (ft)	Angle Principle X-Axis Makes With X-Axis (Degrees)
542.2	65,618	8,974	7.46	-19.32	0.00	3.77

SUMMARY OF FORCES AND MOMENTS - Final*

F_x (kips)	F_y (kips)	F_z (kips)	M_{xx} (ft-k)	M_{yy} (ft-k)	M_{zz} (ft-k)
-1628.7	0.0	2996.0	57,797	15,252	31,556

BASE PRESSURES - Final*

Pressure Point	X Coordinate	Y Coordinate	Z Coordinate	Pressure (ksf)
A	0.00	0.00	0.00	10.56
B	0.00	-31.75	0.00	11.94
C	2.70	-31.75	0.00	9.82
D	2.70	-38.75	0.00	10.12
DE	15.55	-38.75	0.00	0.00
AG	13.41	0.00	0.00	0.00



*Values are after iteration releasing tension at base-foundation interface.

Monolith L-2, Troy Lock and Dam
Flood Condition

BASE AREA PROPERTIES - Initial

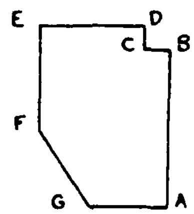
Area (ft^2)	Inertia About Principle X-Axis (ft^4)	Inertia About Principle Y-Axis (ft^4)	X Bar (ft)	Y Bar (ft)	Z Bar (ft)	Angle Principle X-Axis Makes With X-Axis (Degrees)
935.22	113,236	45,573	12.54	-19.30	0.00	5.10

SUMMARY OF FORCES AND MOMENTS - Initial

F_x (kips)	F_y (kips)	F_z (kips)	M_{xx} (ft-k)	M_{yy} (ft-k)	M_{zz} (ft-k)
-808.5	0.0	2605.3	50,289	23,917	15,665

BASE PRESSURES - Initial

Pressure Point	X Coordinate	Y Coordinate	Z Coordinate	Pressure (ksf)
A	0.00	0.00	0.00	5.00
B	0.00	-31.75	0.00	5.31
C	2.70	-31.75	0.00	4.79
D	2.70	-38.75	0.00	4.86
E	25.00	-38.75	0.00	0.59
F	25.00	-11.25	0.00	0.32
G	22.40	0.00	0.00	0.71



Monolith L-2, Troy Lock and Dam
Flood Condition

BASE AREA PROPERTIES - Final*

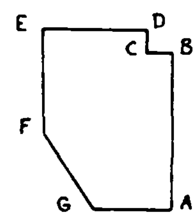
Area (ft^2)	Inertia About Principle X-Axis (ft^4)	Inertia About Principle Y-Axis (ft^4)	X Bar (ft)	Y Bar (ft)	Z Bar (ft)	Angle Principle X-Axis Makes With X-Axis (Degrees)
935.22	113,236	45,573	12.54	-19.30	0.00	5.10

SUMMARY OF FORCES AND MOMENTS - Final*

F_x (kips)	F_y (kips)	F_z (kips)	M_{xx} (ft-k)	M_{yy} (ft-k)	M_{zz} (ft-k)
-808.5	0.0	2605.3	50,289	23,917	15,665

BASE PRESSURES - Final*

Pressure Point	X Coordinate	Y Coordinate	Z Coordinate	Pressure (ksf)
A	0.00	0.00	0.00	5.00
B	0.00	-31.75	0.00	5.31
C	2.70	-31.75	0.00	4.79
D	2.70	-38.75	0.00	4.86
E	25.00	-38.75	0.00	0.59
F	25.00	-11.25	0.00	0.32
G	22.40	0.00	0.00	0.71



*Values are after iteration releasing tension at base-foundation interface.

Monolith L-2 , Troy Lock and Dam
Dewatered Condition

BASE AREA PROPERTIES - Initial

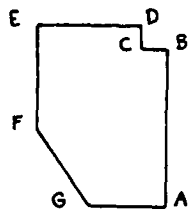
Area (ft^2)	Inertia About Principle X-Axis (ft^4)	Inertia About Principle Y-Axis (ft^4)	X Bar (ft)	Y Bar (ft)	Z Bar (ft)	Angle Principle X-Axis Makes With X-Axis (Degrees)
935.2	113,236	45,573	12.54	-19.30	0.0	5.10

SUMMARY OF FORCES AND MOMENTS - Initial

F_x (kips)	F_y (kips)	F_z (kips)	M_{xx} (ft-k)	M_{yy} (ft-k)	M_{zz} (ft-k)
-1795.1	0.0	3662.2	70,651	24,355	34,780

BASE PRESSURES - Initial

Pressure Point	X Coordinate	Y Coordinate	Z Coordinate	Pressure (ksf)
A	0.00	0.00	0.00	9.36
B	0.00	-31.75	0.00	10.17
C	2.70	-31.75	0.00	8.90
D	2.70	-38.75	0.00	9.08
E	25.00	-38.75	0.00	-1.46
F	25.00	-11.25	0.00	-2.16
G	22.40	0.00	0.00	1.22



Monolith L-2, Troy Lock and Dam
Dewatered Condition

BASE AREA PROPERTIES - Final*

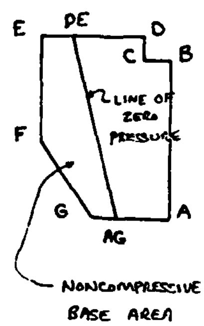
Area (ft^2)	Inertia About Principle X-Axis (ft^4)	Inertia About Principle Y-Axis (ft^4)	X Bar (ft)	Y Bar (ft)	Z Bar (ft)	Angle Principle X-Axis Makes With X-Axis (Degrees)
662.8	80,799	16,284	9.02	-19.34	0.00	4.18

SUMMARY OF FORCES AND MOMENTS - Final*

F_x (kips)	F_y (kips)	F_z (kips)	M_{xx} (ft-k)	M_{yy} (ft-k)	M_{zz} (ft-k)
-1795.1	0.0	-3447.6	66,639	21,166	34,780

BASE PRESSURES - Final*

Pressure Point	X Coordinate	Y Coordinate	Z Coordinate	Pressure (ksf)
A	0.00	0.00	0.00	10.00
B	0.00	-31.75	0.00	11.11
C	2.70	-31.75	0.00	9.47
D	2.70	-38.75	0.00	9.71
DE	18.70	-38.75	0.00	0.00
AG	16.48	0.00	0.00	0.00



*Values are after iteration releasing tension at base-foundation interface and applying full uplift under noncompressive area of base.

Monolith L-2, Troy Lock and Dam
Dewatered Condition with Surcharge Load Behind Monolith

BASE AREA PROPERTIES - Initial

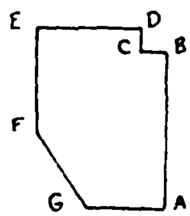
Area (ft^2)	Inertia About Principle X-Axis (ft^4)	Inertia About Principle Y-Axis (ft^4)	X Bar (ft)	Y Bar (ft)	Z Bar (ft)	Angle Principle X-Axis Makes With X-Axis (Degrees)
935.2	113,236	45,572	12.54	-19.30	0.00	5.10

SUMMARY OF FORCES AND MOMENTS - Initial

F_x (kips)	F_y (kips)	F_z (kips)	M_{xx} (ft-k)	M_{yy} (ft-k)	M_{zz} (ft-k)
-1904.0	0.0	3662.2	70,651	22,308	36,890

BASE PRESSURES - Initial

Pressure Point	X Coordinate	Y Coordinate	Z Coordinate	Pressure (ksf)
A	0.00	0.00	0.00	9.87
B	0.00	-31.75	0.00	10.76
C	2.70	-31.75	0.00	9.37
D	2.70	-38.75	0.00	9.56
E	25.00	-38.75	0.00	-1.97
F	25.00	-11.25	0.00	-2.74
G	22.40	0.00	0.00	-1.71



Monolith L-2 , Troy Lock and Dam
Dewatered Condition with Surcharge Load Behind Monolith

BASE AREA PROPERTIES - Final*

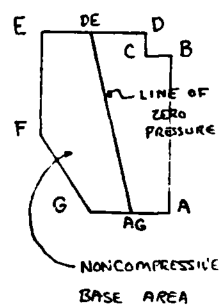
Area (ft^2)	Inertia About Principle X-Axis (ft^4)	Inertia About Principle Y-Axis (ft^4)	X Bar (ft)	Y Bar (ft)	Z Bar (ft)	Angle Principle X-Axis Makes With X-Axis (Degrees)
580.6	70,450	10,988	7.96	-19.34	0.0	3.94

SUMMARY OF FORCES AND MOMENTS - Final*

F_x (kips)	F_y (kips)	F_z (kips)	M_{xx} (ft-k)	M_{yy} (ft-k)	M_{zz} (ft-k)
-1904.0	0.0	3377.6	65,285	18,325	36,890

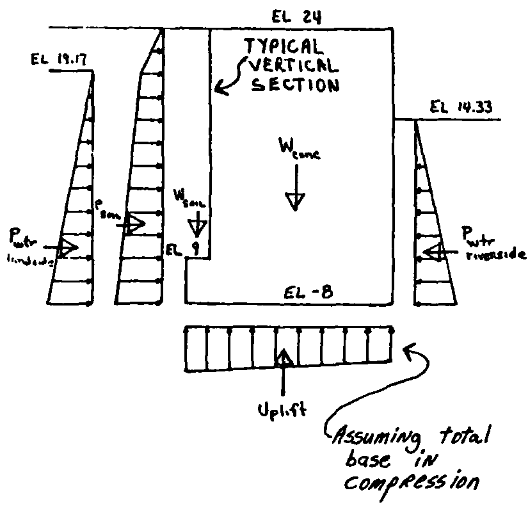
BASE PRESSURES - Final*

Pressure Point	X Coordinate	Y Coordinate	Z Coordinate	Pressure (ksf)
A	0.00	0.00	0.00	11.12
B	0.00	-31.75	0.00	12.54
C	2.70	-31.75	0.00	10.44
D	2.70	-38.75	0.00	10.76
DE	16.58	-38.75	0.00	0.00
AG	14.36	0.00	0.00	0.00



*Values are after iteration releasing tension at base-foundation interface and applying full uplift under noncompressive area of base.

SUBJECT: Monolith L-2, Troy Lock and Dam - Normal Operation	COMPUTED BY:	DATE:
	CHECKED BY:	DATE:



Item	Factors	F_x	F_z	Arm_{xx}	Arm_{yy}	M_{xx}	M_{yy}
W_{conc}	+(0.15)(21.5)(38.75)(32)		3999.0	19.38	10.75	77,501	42,989
	+(0.15)(27.5)(3.5)(9)		+129.9	25.00	23.25	3,248	3,020
	+(0.15)(11.55)(3.5)(9)		+54.6	5.63	21.95	307	1,198
	-(0.15)(2.7)(7)(32)		-90.7	35.25	1.35	-3,197	-122
	-(0.15)(1/2)(2.6)(11.25)(32)		-70.2	3.75	20.63	-263	-1,448
			4022.6			77,596	45,637
P_{soil}	$-(0.5)(24.0-19.17)^2(0.115)(1/2)(38.75)$	-26.0			28.78		-748
	-(0.5)(24.0-19.17)(0.115)(27.17)(38.75)	-292.4			13.59		-3,974
	$-(0.5)(27.17)^2(0.144-0.0625)(1/2)(38.75)$	-582.8			9.06		-5,280
		-901.2					-10,002
P_{wtr} landside	$(27.17)^2(0.0625)(1/2)(38.75)$	-893.9			9.06		-8,099
P_{wtr} riverside	$(22.33)^2(0.0625)(1/2)(38.75)$	603.8			7.44		4,492
Subtotals		-1191.3	4456.2			85,951	42,005
Uplift	-(0.0625)(22.3)(7)(14.33+8)		-217.9	35.25	13.85	-7681	-3,018
	-(0.0625)(1/2)(22.3)(7)(19.17-14.33)		-23.6	35.25	17.57	-832	-415
	-(0.0625)(25)(20.5)(14.33+8)		-715.3	21.5	12.5	-15,379	-3,941
	-(0.0625)(1/2)(25)(20.5)(19.17-14.33)		-77.5	21.5	16.67	-1,666	-1,292
	-(0.0625)(1/2)(22.4)(25)(11.25)(14.33+8)		-372.1	5.63	11.85	-2,095	-4,409
	-(0.0625)(1/2)(22.4+25)(11.25)(19.17-14.33)		-40.3	5.63	15.8	-227	-637
			-1446.7			-27,880	-18,712
W_{soil}	(0.115)(27.5)(24-19.17)(3.5)		53.5	25.0	23.25	1,337	1,244
	(0.115)(24-19.17)(11.55)(3.5)		22.5	5.63	21.95	127	494
	(0.144)(18.17)(27.5)(3.5)		251.8	25.0	23.25	6,295	5,917
	(0.144)(18.17)(11.55)(3.5)		105.8	5.63	21.95	596	2,322
			433.6			8,355	9,977
TOTALS		-1191.3	+3009.5			58,071	23,293

WES FORM NO. 1253A DECEMBER 1964

PAGE OF

SUBJECT: Monolith L-2, Troy Lock and Dam - Normal Operation Plus Earthquake

COMPUTED BY: | DATE:

CHECKED BY: | DATE:

Item	Factors	F_x	F_y	F_z	Arm_{xx}	Arm_{yy}	M_{xx}	M_{yy}
Normal Operation Loads	(Values are after iteration releasing tension at base-foundation interface and applying full uplift under noncompressive area of base.)	-1191.3	0.0	+2996.0			57,797	23,065
Earthquake	$-Pe_1 = -\alpha\omega = -(0.05)(3838.1)$	- 191.9				16.00		-3,070
	$-Pe_2 = [0.7][2/3(51)(0.05)(32)^2](\frac{1}{1000})(38.75)$	- 47.2				10.87		- 513
	$-PE_{soil} = -\Delta K_{EAK}\frac{P_{soil}}{K_{soil}} = -(0.11)(\frac{901.2}{0.5})$	- 198.3				21.33		-4,230
	TOTALS	-1628.7	0.0	2996.0			57,797	15,252

WES FORM NO. 1253A DECEMBER 1964

PAGE OF

SUBJECT:	COMPUTED BY:	DATE:
Monolith L-2, Troy Lock and Dam - Flood Condition	CHECKED BY:	DATE:

Item	Factors	F_x	F_y	F_z	Arm_{xx}	Arm_{yy}	M_{xx}	M_{yy}
W_{conc}	(Values taken from normal operating condition.)			4022.6			77,596	45,637
W_{soil}	(0.144)(23)(3.5)(27.5)			318.8	2.5	23.25	7,970	7,412
	(0.144)(23)(11.55)(3.5)			133.9	5.63	21.95	754	2,939
				452.7			8,724	10,351
W_{wtr}	(0.0625)(21.5)(38.75)(29.7-24)			296.8	19.38	10.75	5,752	3,191
	-(0.0625)(2.7)(7)(29.7-24)			-6.7	35.25	1.35	-237	-9
	-(0.0625)(1/2)(2.6)(11.25)(29.7-24)			-5.2	3.75	20.63	-20	-107
	(0.0625)(3.5)(27.5)(29.7-24)			34.3	25.	23.25	858	797
	(0.0625)(3.5)(11.55)(29.7-24)			14.4	5.63	21.95	81	316
				333.6			6,434	4,188
P_{soil}	$-(0.5)(0.144-0.0625)(24+8)^2(1/2)(38.75)$	-808.5				10.67		-8,626
Subtotals		-808.5		4808.9			92,754	51,550
Uplift	-(0.0625)(22.3)(7)(29.7+8)			-367.8	35.25	13.85	-12,965	-5,094
	-(0.0625)(25)(20.5)(29.7+8)			-1207.6	21.5	12.5	-25,963	-15,095
	-(0.0625)(1/2)(22.4+25)(11.25)(29.7+8)			-628.2	5.63	11.85	-3,537	-7,444
				-2203.6			-42,465	-27,633
Totals		-808.5		2605.3			50,289	23,917

WES FORM NO. 1253A DECEMBER 1964

PAGE OF

SUBJECT

Monolith L-2, Troy Lock and Dam - Dewatered Case

COMPUTED BY: DATE:

CHECKED BY: DATE:

Item	Factors	F_x	F_y	F_z	Arm_{xx}	Arm_{yy}	M_{xx}	M_{yy}
W_{conc}	(Values taken from normal operation condition.)			4022.6			77,596	45,637
W_{soil}				433.6			8,355	9,977
P_{soil}		- 901.2						-10,002
P_{wtr} landside		- 893.9						- 8,099
Subtotals		-1,795.1		4456.2			85,951	37,513
Uplift	-(0.0625)(1/2)(22.3)(7)(19.17+8)			-132.5	35.25	17.57	-4,671	-2,328
	-(0.0625)(1/2)(25)(20.5)(19.17+8)			-435.1	21.50	16.67	-9,355	-7,253
	-(0.0625)(1/2)(18.9+25)(11.25)(1/2)(19.17+8)			-226.4	5.63	15.8	-1,274	-3,577
				-794.0			-15,300	-13,158
Totals		-1,795.1		3662.2			70,651	24,355

WES FORM NO. 1253A DECEMBER 1964

PAGE OF

SUBJECT: Monolith L-2, Troy Lock and Dam - Dewatered Condition with Surcharge Load Behind Monolith

COMPUTED BY: | DATE:

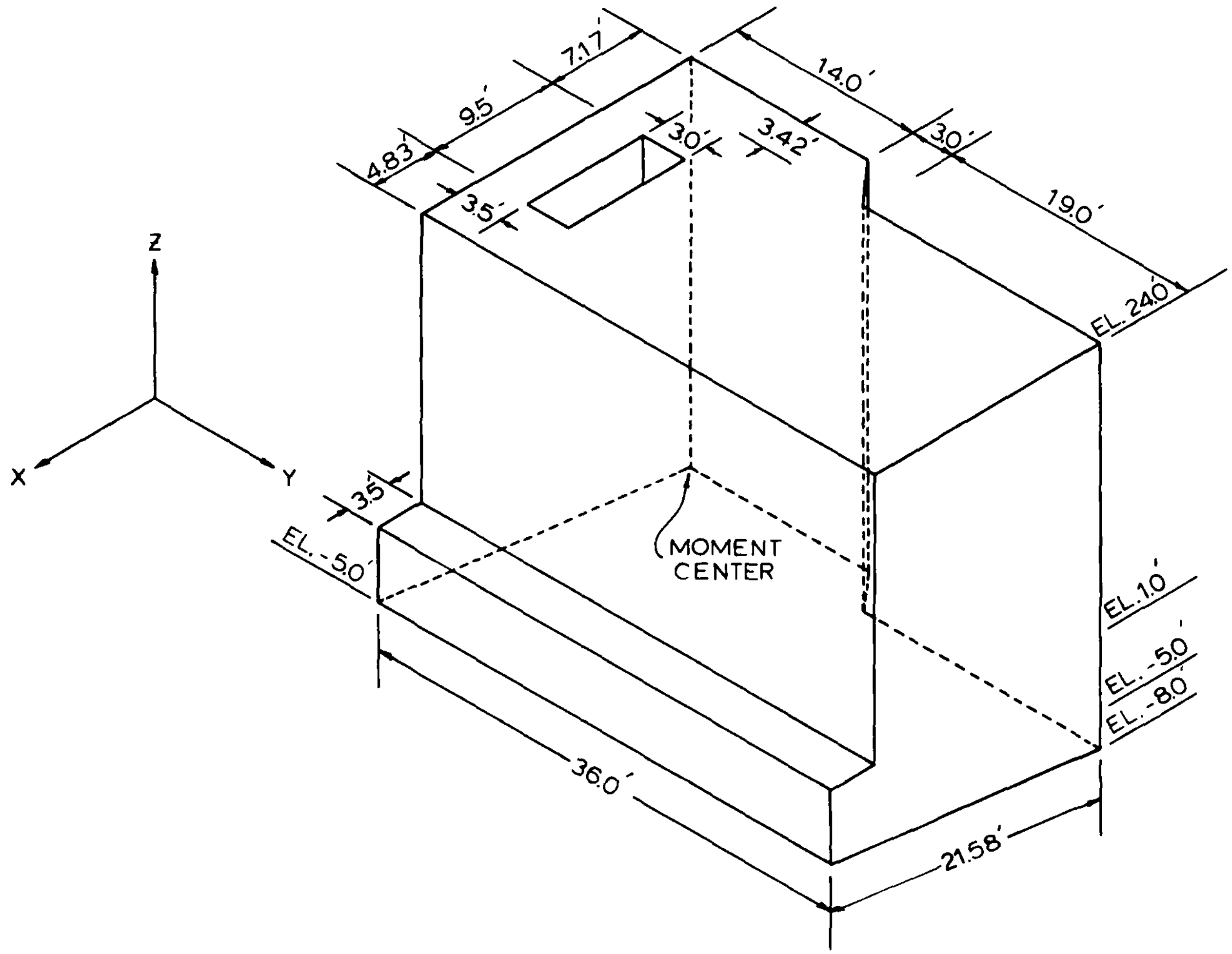
CHECKED BY: | DATE:

Item	Factors	F_x	F_y	F_z	Arm_{xx}	Arm_{yy}	M_{xx}	M_{yy}
Dewatered Loads	Values taken from dewatered condition.	-1795.1		+3,662.2			70,651	24,355
$P_{surcharge}$	Maximum crane surcharge loading of 100 kips on each of the front pads placed behind and symmetrically along the monolith were used. (Calculations made using the distributions as defined on pages 298-299 as presented in Reference 2.)	-108.9				18.79		-2,047
Total		-1904.0		+3,662.2			70,651	22,308

WES FORM NO. 1253A DECEMBER 1964

PAGE OF

LOCK MONOLITH L-3



Stability analysis, monolith L-3, Troy Lock and Dam

SUBJECT: Monolith L-3, Troy Lock and Dam Stability Summary - No Posttensioning	COMPUTED BY:	DATE:	FILE NO.
	CHECKED BY:	DATE:	SHEET NO.

Load Case	Effective Area of Base in Compression (%)	Factor of Safety Against Sliding	Maximum Base Pressure (ksf)
Normal Operation (Most critical condition of upper pool in lock chamber and no gate thrust)	92.4	1.26	7.81
Normal Operation with Earthquake	55.1	0.93	12.30
Flood Condition	97.7	1.29	7.15
Dewatered Condition	68.2	0.91	9.51
Dewatered Condition with Surcharge Load Behind Monolith	61.6	0.84	10.41

WES FORM NO. 1253
REV OCT 1968

SUBJECT: Monolith L-3, Troy Lock and Dam Maximum Bearing Pressure - No Posttensioning	COMPUTED BY:	DATE:	FILE NO.
	CHECKED BY:	DATE:	SHEET NO.

Load Case	Height of Water Over Toe (ft)	Hydrostatic Pressure at Toe (ksf)	Maximum Intergranular Pressure at Toe (ksf)	Maximum Base Pressure (ksf)
Normal Operation (Most critical condition of upper pool in lock chamber and no gate thrust)	22.81	1.43	6.38	7.81
Normal Operation with Earthquake	22.81	1.43	10.87	12.30
Flood Condition	38.18	2.39	4.76	7.15
Dewatered Condition	0.00	0.00	9.51	9.51
Dewatered Condition with Surcharge Load Behind Monolith	0.00	0.00	10.41	10.41

WES FORM NO. 1253
REV OCT 1968

SUBJECT: Monolith L-3, Troy Lock and Dam Stability Summary - After Posttensioning	COMPUTED BY:	DATE:	FILE NO.
	CHECKED BY:	DATE:	SHEET NO.

Load Case	Effective Area of Base in Compression (%)	Factor of Safety Against Sliding	Maximum Base Pressure (ksf)
Normal Operation (Most critical condition of upper pool in lock chamber and no gate thrust)	99.5	1.35	7.59
Normal Operation with Earthquake	70.3	1.00	10.63
Flood Condition	100.0	1.39	6.97
Dewatered Condition	81.0	0.98	8.63
Dewatered Condition with Surcharge Load Behind Monolith	75.2	0.90	9.18

WES FORM NO. 1253
REV OCT 1968

SUBJECT: Monolith L-3, Troy Lock and Dam Maximum Bearing Pressure - After Posttensioning	COMPUTED BY:	DATE:	FILE NO.
	CHECKED BY:	DATE:	SHEET NO.

Load Case	Height of Water Over Toe (ft)	Hydrostatic Pressure at Toe (ksf)	Maximum Intergranular Pressure at Toe (ksf)	Maximum Base Pressure (ksf)
Normal Operation (Most critical condition of upper pool in lock chamber and no gate thrust)	22.81	1.43	6.16	7.59
Normal Operation with Earthquake	22.81	1.43	9.20	10.63
Flood Condition	38.18	2.39	4.58	6.97
Dewatered Condition	0.00	0.00	8.63	8.63
Dewatered Condition with Surcharge Load Behind Monolith	0.00	0.00	9.18	9.18

WES FORM NO. 1253
REV OCT 1968

Monolith L-3 , Troy Lock and Dam
Normal Operation (Upper Pool in Chamber)

BASE AREA PROPERTIES* - Initial

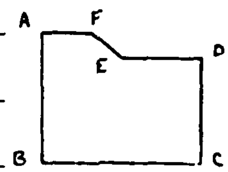
Area (ft^2)	Inertia About Principle X-Axis (ft^4)	Inertia About Principle Y-Axis (ft^4)	X Bar (ft)	Y Bar (ft)	Z Bar (ft)	Angle Principle X-Axis Makes With X-Axis (Degrees)
837.92	91,834	38,205	13.54	17.35	0	-6.96

SUMMARY OF FORCES AND MOMENTS* - Initial

F_x (kips)	F_y (kips)	F_z (kips)	M_{xx} (ft-k)	M_{yy} (ft-k)	M_{zz} (ft-k)
-1096.82	0.00	-2310.66	-40,866.1	20,922.0	19,641.9

BASE PRESSURES* - Initial

Pressure Point	X Coordinate	Y Coordinate	Z Coordinate	Pressure (ksf)
A	0.00	0.00	0.00	5.94
B	25.24	0.00	0.00	-0.89
C	25.24	36.00	0.00	0.11
D	3.45	36.00	0.00	6.01
E	3.45	17.00	0.00	5.48
F	0.00	14.00	0.00	6.33



*Axis rotated to coincide with sliding plane.

Monolith L-3 , Troy Lock and Dam
Normal Operation (Upper Pool in Chamber)

BASE AREA PROPERTIES* - Final**

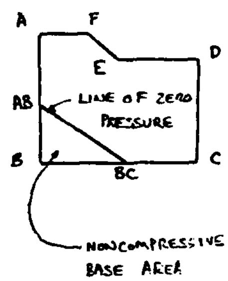
Area (ft^2)	Inertia About Principle X-Axis (ft^4)	Inertia About Principle Y-Axis (ft^4)	X Bar (ft)	Y Bar (ft)	Z Bar (ft)	Angle Principle X-Axis Makes With X-Axis (Degrees)
774.06	86,466	29,378.3	12.68	17.84	0.00	-10.84

SUMMARY OF FORCES AND MOMENTS * - Final**

F_x (kips)	F_y (kips)	F_z (kips)	M_{xx} (ft-k)	M_{yy} (ft-k)	M_{zz} (ft-k)
-1096.82	0.00	-2310.66	-40,866.1	20,922.0	19,641.9

BASE PRESSURES * - Final**

Pressure Point	X Coordinate	Y Coordinate	Z Coordinate	Pressure (ksf)
A	0.00	0.00	0.00	5.96
AB	21.50	0.00	0.00	0.00
BC	25.24	34.14	0.00	0.00
C	25.24	36.00	0.00	0.06
D	3.45	36.00	0.00	6.10
E	3.45	17.00	0.00	5.52
F	0.00	14.00	0.00	6.38



*Axis rotated to coincide with sliding plane.
**Values are after iteration releasing tension at base-foundation interface.

Monolith L-3, Troy Lock and Dam
Normal Operation with Earthquake

BASE AREA PROPERTIES* - Initial

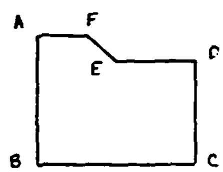
Area (ft²)	Inertia About Principle X-Axis (ft⁴)	Inertia About Principle Y-Axis (ft⁴)	X Bar (ft)	Y Bar (ft)	Z Bar (ft)	Angle Principle X-Axis Makes With X-Axis (Degrees)
837.92	91,834	38,205	13.54	17.35	0	-6.97

SUMMARY OF FORCES AND MOMENTS*- Initial

F_x (kips)	F_y (kips)	F_z (kips)	M_{xx} (ft-k)	M_{yy} (ft-k)	M_{zz} (ft-k)
-1452.41	0.00	-2261.18	-39,976.3	13,874.4	26,042.6

BASE PRESSURES*- Initial

Pressure Point	X Coordinate	Y Coordinate	Z Coordinate	Pressure (ksf)
A	0.00	0.00	0.00	7.92
B	25.24	0.00	0.00	-3.08
C	25.24	36.00	0.00	-1.67
D	3.45	36.00	0.00	7.83
E	3.45	17.00	0.00	7.09
F	0.00	14.00	0.00	8.47



*Axis rotated to coincide with sliding plane.

Monolith L-3, Troy Lock and Dam
Normal Operation with Earthquake

BASE AREA PROPERTIES* - Final**

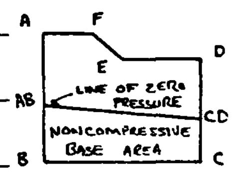
Area (ft^2)	Inertia About Principle X-Axis (ft^4)	Inertia About Principle Y-Axis (ft^4)	X Bar (ft)	Y Bar (ft)	Z Bar (ft)	Angle Principle X-Axis Makes With X-Axis (Degrees)
462.00	52,791	6360	8.34	17.84	0	-8.53

SUMMARY OF FORCES AND MOMENTS*- Final**

F_x (kips)	F_y (kips)	F_z (kips)	M_{xx} (ft-k)	M_{yy} (ft-k)	M_{zz} (ft-k)
-1452.41	0.00	-2261.18	-39,976.3	13,874.4	26,042.6

BASE PRESSURES*- Final**

Pressure Point	X Coordinate	Y Coordinate	Z Coordinate	Pressure (ksf)
A	0.00	0.00	0.00	9.58
AB	12.61	0.00	0.00	0.00
CD	16.99	36.00	0.00	0.00
D	3.45	36.00	0.00	10.29
E	3.45	17.00	0.00	8.53
F	0.00	14.00	0.00	10.87



*Axis rotated to coincide with sliding plane.
**Values are after iteration releasing tension at base-foundation interface.

Monolith L-3, Troy Lock and Dam
Flood Condition

BASE AREA PROPERTIES* - Initial

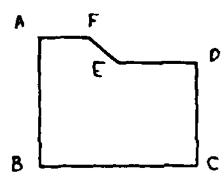
Area (ft^2)	Inertia About Principle X-Axis (ft^4)	Inertia About Principle Y-Axis (ft^4)	X Bar (ft)	Y Bar (ft)	Z Bar (ft)	Angle Principle X-Axis Makes With X-Axis (Degrees)
837.92	91,834	38,205	13.54	17.35	0.00	-6.97

SUMMARY OF FORCES AND MOMENTS* - Initial

F_x (kips)	F_y (kips)	F_z (kips)	M_{xx} (ft-k)	M_{yy} (ft-k)	M_{zz} (ft-k)
-881.36	0.00	-1884.61	-33,686.6	18,228.1	15,831.6

BASE PRESSURES* - Initial

Pressure Point	X Coordinate	Y Coordinate	Z Coordinate	Pressure (ksf)
A	0.00	0.00	0.00	4.41
B	25.24	0.00	0.00	-0.41
C	25.24	36.00	0.00	0.47
D	3.45	36.00	0.00	4.64
E	3.45	17.00	0.00	4.17
F	0.00	14.00	0.00	4.76



*Axis rotated to coincide with sliding plane.

Monolith L-3 , Troy Lock and Dam
Flood Condition

BASE AREA PROPERTIES* - Final**

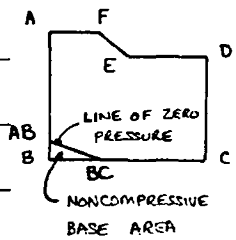
Area (ft^2)	Inertia About Principle X-Axis (ft^4)	Inertia About Principle Y-Axis (ft^4)	X Bar (ft)	Y Bar (ft)	Z Bar (ft)	Angle Principle X-Axis Makes With X-Axis (Degrees)
818.35	89,559	35,070	13.28	17.62	0.00	-9.61

SUMMARY OF FORCES AND MOMENTS* - Final**

F_x (kips)	F_y (kips)	F_z (kips)	M_{xx} (ft-k)	M_{yy} (ft-k)	M_{zz} (ft-k)
-881.36	0.00	-1884.61	33,686.6	18,228.1	15,831.6

BASE PRESSURES* - Final**

Pressure Point	X Coordinate	Y Coordinate	Z Coordinate	Pressure (ksf)
A	0.00	0.00	0.00	4.41
AB	22.99	0.00	0.00	0.00
BC	25.24	17.36	0.00	0.00
C	25.24	36.00	0.00	0.46
D	3.45	36.00	0.00	4.65
E	3.45	17.00	0.00	4.18
F	0.00	14.00	0.00	4.76



*Axis rotated to coincide with sliding plane.
**Values are after iteration releasing tension at base-foundation interface.

Monolith 1-3, Troy Lock and Dam
Dewatered Condition

BASE AREA PROPERTIES* - Initial

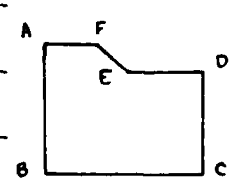
Area (ft^2)	Inertia About Principle X-Axis (ft^4)	Inertia About Principle Y-Axis (ft^4)	X Bar (ft)	Y Bar (ft)	Z Bar (ft)	Angle Principle X-Axis Makes With X-Axis (Degrees)
837.92	91,834	38,205	13.54	17.35	0	-6.97

SUMMARY OF FORCES AND MOMENTS* - Initial

F_x (kips)	F_y (kips)	F_z (kips)	M_{xx} (ft-k)	M_{yy} (ft-k)	M_{zz} (ft-k)
-1629.31	0.00	-2657.63	-47,045.1	20,321.5	29,217.4

BASE PRESSURES* - Initial

Pressure Point	X Coordinate	Y Coordinate	Z Coordinate	Pressure (ksf)
A	0.00	0.00	0.00	8.02
B	25.24	0.00	0.00	-2.29
C	25.24	36.00	0.00	-0.87
D	3.45	36.00	0.00	-8.03
E	3.45	17.00	0.00	7.28
F	0.00	14.00	0.00	8.57



*Axis rotated to coincide with sliding plane.

Monolith L-3, Troy Lock and Dam
Dewatered Condition

BASE AREA PROPERTIES*- Final**

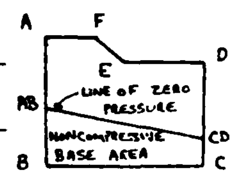
Area (ft^2)	Inertia About Principle X-Axis (ft^4)	Inertia About Principle Y-Axis (ft^4)	X Bar (ft)	Y Bar (ft)	Z Bar (ft)	Angle Principle X-Axis Makes With X-Axis (Degrees)
571.51	64,010	11,916	9.87	17.91	0.00	-9.38

SUMMARY OF FORCES AND MOMENTS*- Final**

F_x (kips)	F_y (kips)	F_z (kips)	M_{xx} (ft-k)	M_{yy} (ft-k)	M_{zz} (ft-k)
-1629.26	0.00	-2495.64	-44,453.6	17,916.6	29,174.2

BASE PRESSURES*- Final**

Pressure Point	X Coordinate	Y Coordinate	Z Coordinate	Pressure (ksf)
A	0.00	0.00	0.00	8.54
AB	15.55	0.00	0.00	0.00
CD	20.12	36.00	0.00	0.00
D	3.45	36.00	0.00	9.15
E	3.45	17.00	0.00	7.83
F	0.00	14.00	0.00	9.51



*Axis rotated to coincide with sliding plane.
**Values are after iteration releasing tension at base-foundation interface and applying full uplift under noncompressive area of base.

Monolith L-3 , Troy Lock and Dam
Dewatered Condition with Surcharge Loads Behind Monolith

BASE AREA PROPERTIES - Initial

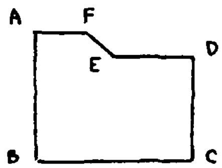
Area (ft^2)	Inertia About Principle X-Axis (ft^4)	Inertia About Principle Y-Axis (ft^4)	X Bar (ft)	Y Bar (ft)	Z Bar (ft)	Angle Principle X-Axis Makes With X-Axis (Degrees)
837.92	91,834	38,205	13.54	17.35	0.00	-6.96

SUMMARY OF FORCES AND MOMENTS - Initial

F_x (kips)	F_y (kips)	F_z (kips)	M_{xx} (ft-k)	M_{yy} (ft-k)	M_{zz} (ft-k)
-1732.67	0.00	-2641.50	46,797.40	19,097.60	31,035.50

BASE PRESSURES - Initial

Pressure Point	X Coordinate	Y Coordinate	Z Coordinate	Pressure (ksf)
A	0.00	0.00	0.00	8.32
B	25.24	0.00	0.00	-2.65
C	25.24	36.00	0.00	-1.16
D	3.45	36.00	0.00	8.31
E	3.45	17.00	0.00	7.52
F	0.00	14.00	0.00	8.90



Monolith L-3, Troy Lock and Dam
Dewatered Condition with Surcharge Loads Behind Monolith

BASE AREA PROPERTIES* - Final**

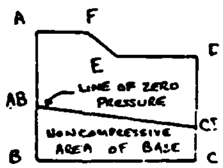
Area (ft^2)	Inertia About Principle X-Axis (ft^4)	Inertia About Principle Y-Axis (ft^4)	X Bar (ft)	Y Bar (ft)	Z Bar (ft)	Angle Principle X-Axis Makes With X-Axis (Degrees)
516.25	57,874	8817	9.10	17.91	0.00	-9.06

SUMMARY OF FORCES AND MOMENTS* - Final**

F_x (kips)	F_y (kips)	F_z (kips)	M_{xx} (ft-k)	M_{yy} (ft-k)	M_{zz} (ft-k)
-1732.67	0.00	-2446.89	-43,596.9	16,302.3	31,035.5

BASE PRESSURES* - Final**

Pressure Point	X Coordinate	Y Coordinate	Z Coordinate	Pressure (ksf)
A	0.00	0.00	0.00	9.22
AB	13.99	0.00	0.00	0.00
CD	18.62	36.00	0.00	0.00
D	3.45	36.00	0.00	10.00
E	3.45	17.00	0.00	8.39
F	0.00	14.00	0.00	10.41



*Axis rotated to coincide with sliding plane.
**Values are after iteration releasing tension at base-foundation interface and applying full uplift under noncompressive area of base.

SUBJECT: Monolith L-3, Troy Lock and Dam - Relocation of Center of Moments	COMPUTED BY:	DATE:	FILE NO.
	CHECKED BY:	DATE:	SHEET NO.

Load Case	F_x (kips)	M_{yy} (ft-k)	$M_{yy}=M_{yy}-0.48F_x$ (ft-k)
Normal Operation (most critical condition of upper pool in lock chamber and no gate thrust)	768.23	21,290.77	20,922.02
Normal Operation with Earthquake	1127.24	14,415.46	13,874.38
Flood Condition	613.48	18,522.54	18,228.07
*Dewatered Condition	1178.14	29,717.59	29,152.08
*Dewatered Condition Plus Surcharge	1282.54	27,939.66	27,324.04

* Uplift not included.

WES FORM NO. 1253
REV OCT 1966

SUBJECT:

Monolith L-3, Troy Lock and Dam - Normal and Tangent Forces and Moments on Inclined Base Plane (Uplift Included)

COMPUTED BY:

DATE:

CHECKED BY:

DATE:

Load Case	F_x (kips)	F_z (kips)	O (Angle Inclined Base Plane Makes w/Horz) (Degrees)	F_{xi}** = - [F_z * sin O + F_x * cos O] (kips)	F_{zi} = - [F_z * cos O - F_x * sin O] (kips)	Arm_{xx} (ft)	Arm_{zz} (ft)	M_{xi} = F_x * sin O * Arm_{zz} - F_z * cos O * Arm_{xx} (ft-k)	M_{yi} = M_{yy} (ft-k)	M_{zi} F_x * cos O * Arm_{zz} + F_z * sin O * Arm_{xx} (ft-k)
Normal Operation (Most critical condition of upper pool in lock chamber and no gate thrust.)	768.23	2439.62	7.914	-1096.82	-2310.66	17.70	18.00	-40,866.06	20,922.02	19,641.92
Normal Operation with Earthquake	1127.24	2439.62	7.914	-1452.41	-2261.18	17.70	18.00	-39,976.30	13,874.38	26,042.55
Flood Condition	613.48	1988.01	7.914	-881.36	-1884.61	17.88	18.00	-33,686.65	18,228.01	15,831.62
Dewatered Condition*	1178.14	3357.96	7.914	-1629.27	-3163.76	17.67	18.00	-55,850.18	29,152.08	29,174.20
Dewatered Condition with Surcharge Loads Behind Monolith*	1282.54	3357.96	7.914	-1732.67	-3148.44	17.67	18.00	55,591.44	27,324.04	31,035.50

*Uplift not included.

**Subscript "i" denotes values for inclined plane.

WES FORM NO. 1253A

PAGE OF

SUBJECT:

Monolith L-3, Troy Lock and Dam –
Normal Operation (Upper Pool in Chamber)

COMPUTED BY: DATE:

CHECKED BY: DATE:

Item	Factors	F_x	F_y	F_z	Arm_{xx}	Arm_{yy}	M_{xx}	M_{yy}
W_{conc}	(.15)(21.58)(8-5)(36)(1/2)			174.80	18.00	10.61	3,146.40	1,854.63
	(.15)(36)(18.08)(24+5)			2831.33	18.00	12.46	50,963.44	35,278.37
	(.15)(36)(3.5)(1+5)			113.40	18.00	23.25	2,041.20	2,635.55
	(.15)(14)(3.42)(24+8+(0.48/2))			231.55	7.00	1.71	1,620.85	395.95
	(.15)(3.42)(3)(24+8)(1/2)			24.62	15.00	2.28	369.30	56.13
	-(.15)(9.5)(3)(24+2.29)+(0.0625)(9.5)(3)(14.33+2.29)			-82.79	5.00	11.92	-413.95	-986.86
	$-(.15-0.0625)\pi(11)^2(10)/4$			-83.15	25.17	9.09	-2,092.89	-755.83
	-(.15-0.0625)(4)(7+4)(10)			-38.50	18.50	9.92	-712.25	-381.92
	$(.15-0.0625)\pi(4)^2(10)/4$			11.00	18.20	6.12	200.20	67.32
	-(.15-0.0625)(1/2)(7)(1)(10)			-3.06	13.17	11.92	-40.30	-36.42
	-(.15-0.0625)(9)(10)(7)			-55.13	11.50	11.92	-634.00	-657.15
	-(.15-0.0625)(9)(35)(7)			-19.29	1.75	11.92	-33.76	-229.94
	-(.15-0.0625)(1)(11+13)(11)(1/2)			-11.55	26.00	3.92	-300.30	-45.28
				3093.23			54,114.44	37,195.49
P_{water} landside	$-(0.0625)(14.33+5.0)^2(1/2)(36)$	-420.36				9.44		-3,968.20
P_{water} lockside	$(0.0625)(14.33+8.0)^2(1/2)(36)$	460.96				7.44		4,173.54
P_{soil}	$-(0.5)[(.115)(24-14.33)^2(1/2)(36)]$	-96.78				25.55		-2,472.73
	-(0.5)[(.115)(24-14.33)(14.33+5.0)(36)]	-386.93				12.67		-4,902.40
	$-(0.5)[(.144-0.0625)(14.33+5.0)^2(1/2)(36)]$	-274.07				9.44		-2,587.22
		-757.78						-9,962.35
W_{soil}	[(.115)(24-14.33)+(.144)(14.33-1.0)](3.5)(36)			381.98	18.00	23.25	6,875.64	8,881.04
W_{gate}	[(55/0.49)][(9.67/26)(0.49)+(16.33/26)(0.49-0.0625)]			50.59	19.35	-11.25	978.92	-569.14
Subtotal		-617.18		3525.80			61,969.00	35,750.38
Uplift	-(0.0625)(14.33+5.0)(14)(25)			-422.84	7.00	12.50	-2,959.88	-5,285.50
	-(0.0625)(14.33+5.0)(14)(3.48)	-58.86				1.26		-74.16
	-(0.0625)(8.48-5)(14)(25)(1/2)			-38.06	7.00	8.33	-266.42	-317.04
	-(0.0625)(8.48-5)(14)(3.48)(1/2)	-5.30				0.68		-3.60
	-(0.0625)(14.33+5.0)(3)(25+21.58)(1/2)			-84.41	15.50	13.36	-1,308.36	-1,127.72
	-(0.0625)(14.33+5.0)(3)(3+3.48)(1/2)	-11.74				1.38		-16.20
	-(0.0625)(8.24-5.0)(3)(25+21.58)(1/4)			-7.07	15.50	11.18	-109.59	-79.04
	-(0.0625)(8.24-5.0)(3)(3+3.24)(1/4)	-0.95				0.84		-0.30
	-(0.0625)(14.33+5.0)(19)(21.58)			-495.36	26.50	14.21	-13,127.04	-7,039.07
	-(0.0625)(14.33+5.0)(19)(3)	-68.86				1.50		-103.29
	-(0.0625)(8-5)(19)(21.58)(1/2)			-38.44	26.50	10.61	-1,018.66	-407.85
	-(0.0625)(8-5)(19)(3)(1/2)	-5.34				1.00		-5.39
Subtotal		-151.05		-1086.18			-18,789.45	-14,459.61
Total		-768.23		2439.62			43.179.05	21,290.77

WES FORM NO. 1253A DECEMBER 1964

PAGE OF

SUBJECT: Monolith L-3, Troy Lock and Dam - Normal Operation with Earthquake

COMPUTED BY: DATE:

CHECKED BY: DATE:

Item	Factors	F_x	F_y	F_z	Arm_{xx}	Arm_{yy}	M_{xx}	M_{yy}
Normal Operation Loads	(Values are after releasing tension at base-foundation interface.)	-768.23		2,439.62			43,179.05	21,290.77
Earthquake Str	$Pe_1 = \alpha W = (0.05)(3093.23+381.98+50.59)$	-176.29				16.83		-2,966.96
Earthquake water	$0.7Pe_2 = (.7)[(\frac{2}{3})(51)(.05)(14.33)\sqrt{(19.33)(19.33)}(36)$ (1/1000)	-16.01				11.60 11.21		-185.72
Earthquake soil	$P = K_{EAK}\frac{P_{soil}}{K_{o_{soil}}} = (.11)(757.78)/(0.5)$	-166.71				22.33		-3,722.63
Total		-1127.24		2,439.62			43,179.05	14,415.46

OPS FORM NO 1293A

PAGE OF

SUBJECT: Monolith L-3, Centroid Location, Troy Lock and Dam - Normal Operation with Earthquake

COMPUTED BY: | DATE:
CHECKED BY: | DATE:

LOCATION OF CENTROID IN Y-Z PLANE - CONCRETE

Volume			Arm	Volume-Moment
(21.58)(3)(36)(.5)	=	1,165.32	2.00	2,330.64
(36)(18.08)(29)	=	18,875.52	17.50	330,321.60
(36)(3.5)(6)	=	756.00	6.00	4,536.00
(14)(3.42)(32.24)	=	1,543.65	15.88	24,513.16
(3.42)(3)(32)(.5)	=	164.16	16.00	2,626.56
-(9.5)(3)(26.29)	=	- 749.27	18.86	- 14,131.23
$-\pi(11)^2(10)/4$	=	- 950.33	11.00	- 10,453.63
-(4)(11)(10)	=	- 440.00	11.00	- 4,840.00
$\pi(4)^2(10)/4$	=	125.66	11.00	1,382.26
-(0.5)(7)(1)(10)	=	- 35.00	15.33	- 536.55
-(9)(10)(7)	=	630.00	10.50	- 6,615.00
-(9)(3.5)(7)	=	- 220.50	10.50	- 2,315.25
-(1)(24)(11)(0.5)	=	- 132.00	11.00	- 1,452.00
		19,473.21		325,366.56

$$\bar{z} = \frac{325,366.56}{19,473.21} = 16.71 \text{ ft}$$

LOCATION OF CENTROID IN Y-Z PLANE - WATER

Volume			Arm	Volume-Moment
(9.5)(3)(14.33+2.29)	=	473.67	14.02	6,640.85
$\pi(11)^2(10)/4$	=	950.33	11.00	10,453.63
(4)(11)(10)	=	440.00	11.00	4,840.00
$\pi(4)^2(10)/4$	=	- 125.66	11.00	- 1,382.26
(0.5)(7)(1)(10)	=	35.00	15.33	536.55
(9)(10)(7)	=	630.00	10.50	6,615.00
(9)(3.5)(7)	=	220.50	10.50	2,315.25
(1)(24)(11)(0.5)	=	132.00	11.00	1,452.00
		2,755.84		31,471.02

$$\bar{z} = \frac{31,471.02}{2,755.84} = 11.42 \text{ ft}$$

(Continued)

WES FORM NO. 1293A

PAGE OF

SUBJECT: Monolith L-3, Centroid Location, Troy Lock and Dam - Normal Operation with Earthquake (Concluded)

COMPUTED BY: | DATE:
CHECKED BY: | DATE:

LOCATION OF CENTROID OF HORIZONTAL EARTHQUAKE FORCES ABOVE BASE OF STRUCTURE

Item	Force			Arm	Moment
Concrete	(.150)(19,473.21)	=	2920.98	16.71	48,809.58
Water (in structure)	(.0625)(2755.84)	=	172.24	11.42	1,966.98
Soil (above water table)	(.115)(3.5)(36)(24-14.33)	=	140.12	27.165	3,806.36
Soil (below water table)	(.144)(3.5)(36)(14.33-1)	=	241.86	15.665	3,788.74
Gate (above water)	(55)(24-14.33)/26	=	20.46	27.165	555.80
Gate (below water)	(55)(14.33+2)(.49-0.0625)/[(26)(.49)]	=	30.14	14.165	426.93
			3525.80		59,354.39

$$\bar{z} = \frac{57,354.39}{3,525.80} = 16.83 \text{ ft}$$

WES FORM NO. 1253A DECEMBER 1966

PAGE OF

SUBJECT: Monolith L-3, Troy Lock and Dam - Flood Condition	COMPUTED BY:	DATE:
	CHECKED BY:	DATE:

Item	Factors	F_x	F_y	F_z	Arm_{xx}	Arm_{yy}	M_{xx}	M_{yy}
W_{conc}	(.15)(21.58)(8-5)(36)(1/2)			174.80	18.00	10.61	3,146.40	1,854.63
	(.15)(36)(18.08)(24+5)			2831.33	18.00	12.46	50,963.94	35,278.37
	(.15)(36)(3.5)(1+5)			113.40	18.00	23.25	2,041.20	2,636.55
	(.15)(16)(3.42)(24+8+(0.48/2))			231.55	7.00	1.71	1,620.85	395.95
	(.15)(3.42)(3)(24+8)(1/2)			24.62	15.00	2.28	369.30	56.13
	$-(.15-0.0625)(9.5)(3)(24+2.29)$			-65.56	5.00	11.92	-327.80	-781.48
	$-(.15-0.0625)\pi(11)^2(10)/4$			-83.15	25.17	9.09	-2,092.89	-755.83
	$-(.15-0.0625)(4)(7+4)(10)$			-38.50	18.50	9.92	-712.25	-381.92
	$(.15-0.0625)\pi(4)^2(10)/4$			11.00	18.20	6.12	200.20	67.32
	-(.15-0.0625)(1/2)(7)(1)(10)			-3.06	13.17	11.92	-40.30	-36.48
	-(.15-0.0625)(9)(10)(7)			-55.13	11.50	11.92	-634.00	-657.15
	-(.15-0.0625)(9)(3.5)(7)			-19.29	1.75	11.92	-33.76	-229.94
	-(.15-0.0625)(1)(11+13)(11)(1/2)			-11.55	26.00	3.92	-300.30	-45.28
				3110.46			54,200.59	37,400.87
$\Delta\gamma_{water}$	$(0.0675)(8.0-5.0)^2(1/2)(36)$	10.13				1.00		10.13
	(0.0625)(29-1+8)(3)(36)	254.48				1.50		381.72
		264.61						391.85
P_{soil}	$(0.5)[(.144-0.0625)(24+5)^2(36)(1/2)]$	-616.87				12.67		-7,815.74
W_{soil}	(.144)(3.5)(36)(23)			417.31	18.00	23.50	7,511.58	9,806.79
W_{water}	(.0625)(25)(36)(29.7-24)			320.63	18.00	12.50	5,771.34	4,007.82
	-(.0625)(3.42)(3)(29.7-24)(1/2)			-1.83	15.00	1.14	-27.45	-2.09
	-(.0675)(3.42)(19)(29.7-24)			-23.15	26.50	1.71	-613.42	-39.59
				295.65			5,130.41	3,966.20
W_{gate}	(55)(.49-0.0625)/0.49			47.98	27.47	1.71	1,318.01	82.05
Subtotal		-352.26		3871.40			68,160.59	43,832.02
Uplift	-(0.0625)(29.7+5)(14)(25)			-759.06	7.00	12.50	-5,313.42	-9,488.25
	-(0.0625)(29.7+5)(14)(3.48)	-105.66				1.26		-133.13
	-(0.0625)(8.48-5)(14)(25)(1/2)			-38.06	7.00	8.33	-266.42	-317.04
	-(0.0625)(8.48-5)(14)(3)(1/2)	-4.57				0.68		3.11
	-(0.0625)(29.7+5)(3)(25+21.58)(1/2)			-151.53	15.50	13.36	-2,348.72	-2,024.44
	-(0.0625)(29.7+5)(3)(3+3.48)(1/2)	-21.08				1.38		-29.09
	-(0.0625)(8.24-5)(3)(25+21.58)(1/4)			-7.07	15.50	11.18	-109.59	-79.04
	-(0.0625)(8.24-5)(3)(3+3.24)(1/4)	-0.95				0.84		-0.80
	-(0.0625)(29.7+5)(19)(21.58)			-889.23	26.50	14.21	-23,564.60	-12,635.96
	-(0.0625)(29.7+5)(19)(3)	-123.62				1.50		-185.43
	-(0.0625)(8-5)(17)(21.58)(1/2)			-38.44	26.50	10.61	-1,018.66	-407.85
	-(0.0625)(8-5)(19)(3)(1/2)	-5.34				1.00		-5.34
Subtotal		-261.22		-1883.39			-32,621.41	-25,309.48
Total		-613.48		1988.01			35,539.18	18,522.54

SUBJECT: Monolith L-3, Troy Lock and Dam - Dewatered Condition

COMPUTED BY: DATE:

CHECKED BY: DATE:

Item	Factors	F_x	F_y	F_z	Arm_{xx}	Arm_{yy}	M_{xx}	M_{yy}
W_{conc}	(.15)(21.58)(8-5)(36)(1/2)			174.80	18.00	10.61	3,146.40	1,854.63
	(.15)(36)(18.08)(24+5)			2831.33	18.00	12.46	50,963.94	35,278.37
	(.15)(36)(3.5)(1+5)			113.40	18.00	23.25	2,041.20	2,636.55
	(.15)(14)(3.42)(24+8+(0.48/2))			231.55	7.00	1.71	1,620.85	395.95
	(.15)(3.42)(3)(24+8)(1/2)			24.62	15.00	2.28	369.30	56.13
	-(.15)(9.5)(3)(24+2.29)			-112.39	5.00	11.92	-561.95	-1,339.69
	-(.15)π(11)^2(10)/4			-142.55	25.17	9.09	-3,587.98	-1,295.78
	-(.15)(4)(7+4)(10)			-66.00	18.50	9.92	-1,221.00	-654.72
	(.15)π(4)^2(10)/4			18.85	18.20	6.12	343.07	115.36
	-(.15)(1/2)(7)(1)(10)			-5.25	13.17	11.92	-69.14	-62.58
	-(.15)(9)(10)(7)			-94.50	11.50	11.92	-1,086.75	-1,126.44
	-(.15)(9)(3.5)(7)			-33.08	1.75	11.92	-57.89	-394.31
	-(.15)(1)(11+13)(11)(1/2)			-19.80	26.00	3.92	-514.80	-77.62
				2920.98			51,385.25	35,385.25
P_{water} landside	(0.0625)(14.33+5.0)^2(0.5)(36)	-420.36				9.44		-3,968.30
P_{soil}	-(0.5)[(.115)(24-14.33)^2(0.5)(36)]	-96.78				25.55		-2,472.73
	-(0.5)[(.115)(24-14.33)(14.33+5.0)(36)]	-386.93				12.67		-4,902.40
	-(0.5)[(.144-0.0625)(14.33+5.0)^2(0.5)(36)]	-274.07				9.44		-2,587.22
		-757.78						-9,962.35
W_{soil}	[(.115)(24-14.33)+(.144)(14.33-1)](3.5)(36)			381.98	18.00	23.25	6,875.64	8,881.04
W_{gate}				55.00	19.35	-11.25	1,064.25	-618.75
Uplift	-(0.0625)(14.33+5.0)(1/2)(14)(25)			-211.42	7.00	16.67	-1,479.94	-3,524.37
	-(0.0625)(14.33+5.0)(1/2)(14)(3.48)	-29.43				1.84		-54.15
	-(0.0625)(14.33+5.0)(1/2)(3)(25+21.58)(1/2)			-42.21	15.50	17.23	-654.26	-727.28
	-(0.0625)(14.33+5.0)(1/2)(3)(3+3.48)(1/2)	-5.87				1.92		-11.27
	-(0.0625)(14.33+5.0)(1/2)(19)(21.58)			-247.68	26.50	17.81	-6,563.52	-4,411.18
	-(0.0625)(14.33+5.0)(1/2)(19)(3)	-34.43				2.00		68.86
		-69.73		-501.31			-8,697.72	-8,797.11
Total		-1247.87		2856.65			50,627.42	20,920.48

WES FORM NO. 1253A DECEMBER 1964

PAGE OF

SUBJECT:

Monolith L-3, Troy Lock and Dam -
Dewatered Condition with Surcharge Loads Behind Monolith

COMPUTED BY: DATE:

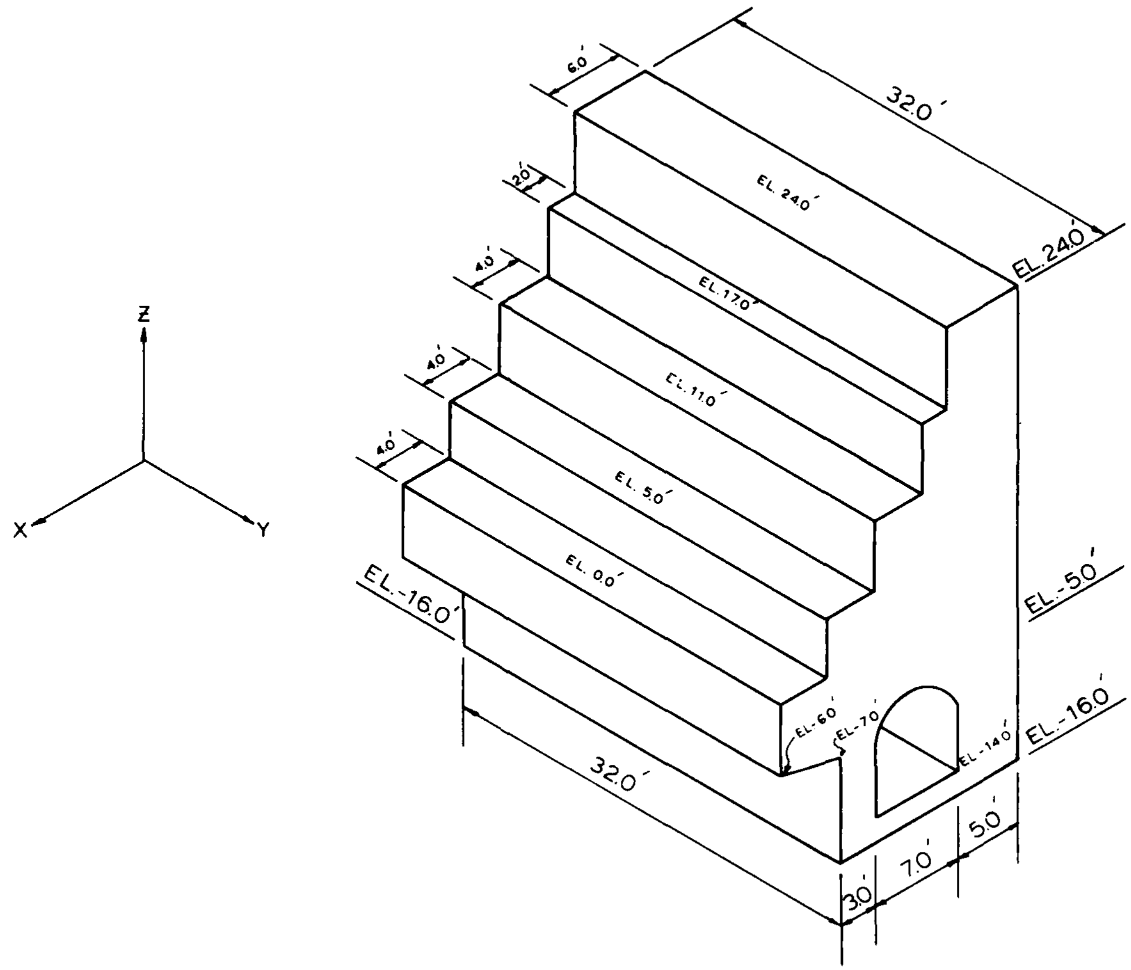
CHECKED BY: DATE:

Item	Factors	F_x	F_y	F_z	Arm_{xx}	Arm_{yy}	M_{xx}	M_{yy}
Dewatered Loads	Loads taken from dewatered condition.	-1,247.87	0.00	2,856.65			50,627.42	20,920.48
$P_{surcharge}$	Maximum crane surcharge loading of 110 kips on each of the front pads placed behind and symmetrically along the monolith were used. (Calculations made using the distributions as defined on pages 298-299 as presented in Reference 2.)	-104.40				17.03		-1,777.93
Total		-1,352.27	0.00	2,856.65			50,627.42	19,142.55

WES FORM NO. 1253A
DECEMBER 1964

PAGE OF

LOCK MONOLITH L-5



Stability analysis, monolith L-5, Troy Lock and Dam

SUBJECT: Monolith L-5, Troy Lock and Dam - Percent Effective Base (No Posttensioning)

COMPUTED BY: | DATE:

CHECKED BY: | DATE:

LOAD CASE	Sum of Vertical Forces F_V (kips)	Sum of Moments M (ft-kips)	Resultant Moment Arm $e = \frac{M}{F_V}$ (ft)	Percent Effective Base $\frac{3e}{b} * 100$ (%)	Full Uplift Under Non-Compressive Base Area: Sum of Vert. Forces F_V (kips)	Sum of Moments M (ft-kips)	Resultant Moment Arm $e = \frac{M}{F_V}$ (ft)	Percent Effective Base $\frac{3e}{b} * 100$ (%)	Base Width b (ft)
Normal Operation	77.82	126.18	1.62	32.4	75.42	110.67	1.47	29.4	15
Normal Operation with Hawser	77.82	99.81	1.28	25.6	75.20	83.82	1.11	22.2	15
Normal Operation with Earthquake	75.42	-158.71	0.	0.0	--	--	--	--	15
*Normal Operation with Impact	70.68	378.90	5.36	100.0	70.68	378.90	5.36	100.0	15
*Normal Operation with Ice	57.38	399.59	6.96	100.0	57.38	399.59	6.96	100.0	15
Dewatered Condition	79.72	- 65.59	0.0	0.0	-67.38	-128.28	0.0	0.0	15
Flood Condition	58.33	183.05	3.14	62.8	--	--	--	--	15
Dewatered Condition with Surcharge	79.72	-126.40	0.0	0.0	67.38	-189.09	0.0	0.0	15

*Includes vertical and horizontal reactions on stepped base.

WES FORM NO 1253A

PAGE OF

SUBJECT: Monolith L-5, Troy Lock and Dam - Factor of Safety Against Sliding (No Posttensioning)

COMPUTED BY: | DATE:

CHECKED BY: | DATE:

LOAD CASE	Sum of Vertical Forces F_V (kips)	Sum of Horizontal Forces F_H (kips)	Friction Angle ϕ (Degrees)	Cohesive Strength C (ksf)	Base Area A (sq ft)	Strut Resistance R_s (kips)	Shear Resistance $R_f = F_V \tan \phi$ (kips)	Cohesive Resistance R_c = CA (kips)	Total Sliding Resistance $R = R_s + R_f + R_c$ (kips)	Factor of Safety Against Sliding $F.S. = \frac{R}{F_H}$
Normal Operation	75.42	33.23	30.4	0.04	4.41	0	44.25	0.18	44.43	1.34
Normal Operation with Hawser	75.20	34.48	30.4	0.04	3.36	0	44.12	0.13	44.25	1.78
Normal Operation with Earthquake	77.82	43.83	30.4	0.04	0.00	0	45.66	0.00	45.66	1.04
Normal Operation with Impact	71.11*	11.23*	30.4	0.04	15.00	0	41.72	0.60	42.32	3.77
Normal Operation with Ice	71.11*	2.48*	30.4	0.04	15.00	0	41.72	0.60	42.32	17.06
Dewatered Condition	67.38	62.37	30.4	0.04	0.00	0	39.53	0.00	39.53	.63
Flood Condition	58.33	18.34	30.4	0.04	10.35	0	34.22	0.41	34.63	1.89
Dewatered Condition with Surcharge	67.38	64.96	30.4	0.04	0.0	0	39.53	0.0	39.53	.61

*Includes vertical and horizontal reactions on stepped base.

1243A

PAGE OF

SUBJECT: Monolith L-5, Troy Lock and Dam - Base Pressures (No Posttensioning)

COMPUTED BY: | DATE:

CHECKED BY: | DATE:

LOAD CASE	Sum of Vertical Forces F_V (kips)	Resultant Moment Arm e (ft)	Effective Base Width b (ft)	Axial Stress $f_a = \frac{F_V}{b}$ (ksf)	Bending Stress $f_b = \pm \frac{F_V\left(\frac{b}{2} - e\right)\frac{b}{2}}{b^3/12}$ (ksf)	Inter-granular Stress At Heel $f_h = f_a - f_b$ (ksf)	Inter-granular Stress At Toe $f_t = f_a + f_b$ (ksf)	Hydrostatic Pressure At Heel $f_{uh} = \gamma_w h_{wh}$ (ksf)	Hydrostatic Pressure At Toe $f_{ut} = \gamma_w h_{wt}$ (ksf)	Total Pressure At Heel $f_{th} = f_h + f_{uh}$ (ksf)	Total Pressure At Toe $f_{Tt} = f_t + f_{ut}$ (ksf)
Normal Operation	75.42	1.47	4.41	17.10	$\pm$17.10	0.	34.20	1.45	1.0	1.45	35.20
Normal Operation with Hawser	75.20	1.11	3.33	22.58	$\pm$22.58	0.	45.16	1.45	1.0	1.45	46.16
Normal Operation with Earthquake	77.82	0.	0.	∞	$\pm$ ∞	0.	∞	1.45	1.0	1.45	∞
†Normal Operation with Impact	70.68	5.36	15.0	4.71	$\pm$ 4.03	0.68	8.74	1.45	1.90	2.13	10.64
*Normal Operation with Ice	57.38	6.96	15.0	3.83	$\pm$ 0.83	3.00	4.66	1.45	1.90	4.45	6.56
Dewatered Condition	67.38	0.0	0.0	∞	∞	0	∞	1.67	0.00	1.67	∞
Flood Condition	58.33	3.45	10.35	5.64	$\pm$ 5.64	0.0	11.28	2.86	2.86	2.86	14.14
Dewatered Condition with Surcharge	67.38	0.0	0.0	∞	∞	0	∞	1.67	0.0	1.67	∞

†Includes vertical and horizontal reactions on stepped base.

WES FORM NO. 1253A

PAGE OF

SUBJECT: Monolith L-5, Troy Lock and Dam Percent Effective Base (After Posttensioning)	COMPUTED BY:	DATE:	FILE NO.
	CHECKED BY:	DATE:	SHEET NO.

Load Case	Sum of Vertical Force F_V (kips)	Sum of Moments M (ft-kips)	Resultant Moment Arm $e = \frac{M}{F_V}$ (ft)	Percent Effective Base $\frac{3e}{b} * 100$ (%)
Normal Operation	105.99	666.93	6.29	100.0
Normal Operation with Hawser	105.77	640.08	6.04	100.0
Normal Operation with Earthquake	105.99	397.55	3.75	75.0
*Normal Operation with Impact	101.25	935.16	9.19	100.0**
*Normal Operation with Ice	87.95	955.85	10.87	82.6**
Dewatered Condition	97.95	427.98	4.37	87.4
Flood Condition	88.90	739.31	7.55	100.0
Dewatered Condition with Surcharge	97.95	367.17	3.75	75.0

* Reactions on stepped base neglected (conservative approach).
** Percent effective base = (b-e)/b * 300.

WES FORM NO. 1253
REV OCT 1968

SUBJECT: Monolith L-5, Troy Lock and Dam - Factor of Safety Against Sliding (After Posttensioning)

COMPUTED BY: | DATE:
CHECKED BY: | DATE:

Load Case	Sum of Vertical Forces F_V (kips)	Sum of Horizontal Forces F_H (kips)	Friction Angle ϕ (Degrees)	Cohesive Strength C (ksf)	Base Area A (sq ft)	Horizontal Posttensioning Resistance R_s (kips)	Shear Resistance $R_f = F_V \tan \phi$ (kips)	Cohesive Resistance $R_c = CA$ (kips)	Total Sliding Resistance $R = R_s + R_f + R_c$ (kips)	Factor of Safety Against Sliding $F.S. = \frac{R}{F_H}$
Normal Operation	105.99	33.23	30.4	0.04	4.41	30.57	62.18	0.18	92.93	2.80
Normal Operation with Hawser	105.77	34.48	30.4	0.04	3.36	30.57	62.05	0.13	92.75	2.69
Normal Operation with Earthquake	105.99	43.83	30.4	0.04	0.00	30.57	62.18	0.00	92.75	2.12
Normal Operation with Impact	101.25	11.23	30.4	0.04	15.00	30.57	59.40	0.60	90.57	8.06
*Normal Operation with Ice	87.95	2.48	30.4	0.04	15.00	30.57	51.60	0.60	82.77	33.38
*Dewatered Condition	97.95	62.37	30.4	0.04	0.00	30.57	57.47	0.00	88.04	1.41
Flood Condition	88.90	18.34	30.4	0.04	10.35	30.57	52.16	0.41	83.14	4.53
Dewatered Condition with Surcharge	97.95	64.96	30.4	0.04	0.0	30.57	57.47	0.00	88.04	1.36

* Reactions on stepped base neglected (conservative approach).

WES FORM NO. 1253A DECEMBER 1964

SUBJECT: Monolith L-5, Troy Lock and Dam - Base Pressures (After Posttensioning)

COMPUTED BY: | DATE:

CHECKED BY: | DATE:

Load Case	Sum of Vertical Forces F_v (kips)	Resultant Moment Arm e (ft)	Effective Base Width b (ft)	Axial Stress $f_a = \frac{F_v}{b}$ (ksf)	Bending Stress $f_b = \pm \frac{F_v\left(\frac{b}{2}-e\right)\frac{b}{2}}{b^3/12}$ (ksf)	Intergranular Stress At Heel $f_y = f_a - f_b$ (ksf)	Intergranular Stress At Toe $f_t = f_a + f_b$ (ksf)	Hydrostatic Pressure At Heel $f_{uh} = \gamma_w h_{wh}$ (ksf)	Hydrostatic Pressure At Toe $f_{ut} = \gamma_w h_{wt}$ (ksf)	Total Pressure At Heel $f_{th} = f_h + f_{uh}$ (ksf)	Total Pressure At Toe $f_{Tt} = f_t + f_{ut}$ (ksf)
Normal Operation	105.99	6.29	15	7.07	1.22	5.85	8.29	1.45	1.0	7.30	9.29
Normal Operation with Hawser	105.77	6.04	15	7.05	1.27	5.78	8.32	1.45	1.0	7.23	9.32
Normal Operation with Earthquake	105.99	3.75	11.25	9.42	9.42	0	18.82	1.45	1.0	1.45	19.82
*Normal Operation with Impact	101.25	9.19	15	6.75	4.56	11.31	2.19	1.45	1.90	12.76	4.09
*Normal Operation with Ice	87.95	10.87	15	5.86	0	11.72	0	1.45	1.90	13.17	1.90
Dewatered Condition	97.95	4.37	13.11	7.47	7.47	0	14.94	1.67	0.00	1.67	14.94
Flood Condition	88.90	7.55	15	5.93	0.12	6.05	5.81	2.86	2.86	8.91	8.67
Dewatered Condition with Surcharge	97.95	3.75	11.25	8.71	8.71	0	17.42	1.67	0.0	1.67	17.42

* Reaction on stepped base neglected (conservative approach).

WES FORM NO. 1293A

PAGE OF

SUBJECT:

Monolith L-5, Troy Lock and Dam - Normal Operation

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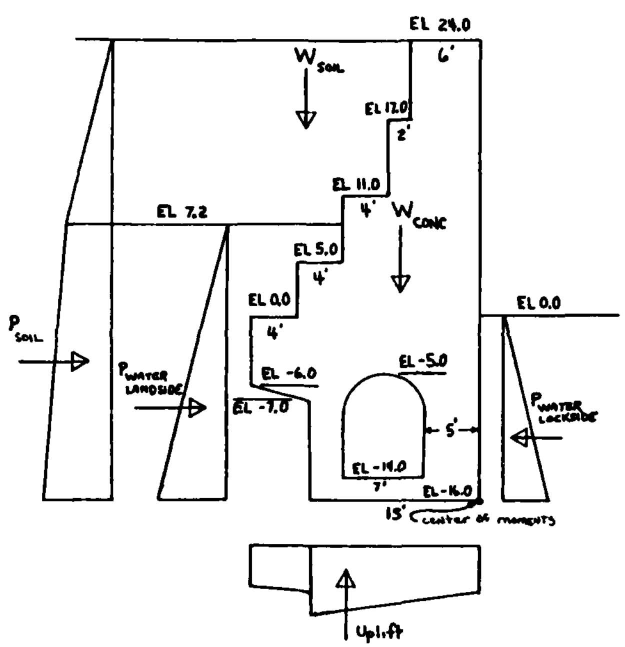
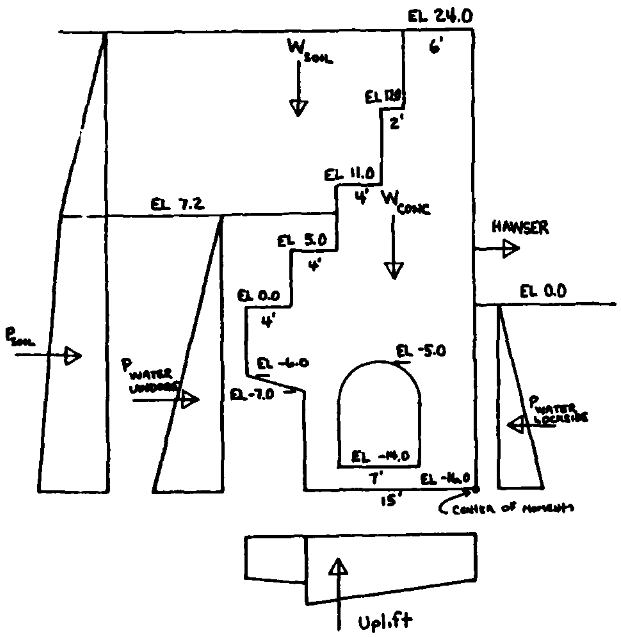


Item	Factors	F_V	F_H	Arm	Moment
W_{conc}	(0.15)(6)(24-17)	6.3		3	18.9
	(0.15)(8)(17-11)	7.2		4	28.8
	(0.15)(12)(11-5)	10.8		6	64.8
	(0.15)(16)(5-0)	12.0		8	96.0
	(0.15)(0.5)(1)(5)	0.38		16.67	6.33
	(0.15)(6)(5)	4.5		17.5	78.75
	-(0.15-0.0625)(π)(3.5) /2	- 1.68		8.5	- 14.28
	-(0.15-0.0625)(5.5)(7)	- 3.37		8.5	- 28.65
	-(0.15-0.0625)(2.33)(3)(5)/32	- 0.10		2.5	- 0.25
	(0.15)(16)(15)	36.0		7.5	270.0
		72.03			520.40
P_{water} landside	$-0.0625(7.2+16)^2(1/2)(1)$		-16.82	7.73	-130.02
P_{water} lockside	$0.0625(16)^2(1/2)(1)$		8.0	5.33	42.64
P_{soil}	$-(0.50)\{(0.115)(24-7.2)^2(1/2)(1)$		- 8.11	28.8	-233.57
	- 0.115 (24-7.2)(7.2+6)		-12.75	16.6	-211.65
	$-(0.144-0.0625)(7.2+6)^2(1/2)(1)\}$		- 3.55	14.4	- 51.12
			-24.41		-496.34
Uplift	-0.0625(7.2+6)(5)	- 4.13		17.5	- 72.28
	-0.0625(1)(5)(0.5)	- 0.16		16.7	- 2.67
	-0.0625(16)(15)	-15.0		7.5	-112.5
	-0.0625(7.2)(0.5)(15)	- 3.38		10.0	- 33.8
		-22.67			-221.25
W_{soil}	(0.115)(24-17)(14)	11.27		13.00	146.51
	(0.115)(17-11)(12)	8.28		14.0	115.92
	(0.115)(11-7.2)(8)	3.50		16.0	56.00
	(0.144)(7.2-5.0)(8)	2.53		16.0	40.48
	(0.144)(5.0-0)(4)	2.88		18.0	51.84
		28.46			410.75
Total		77.82	-33.23		126.18

WES FORM NO 1253A DECEMBER 1964

SUBJECT:	COMPUTED BY:	DATE:
Monolith L-5, Troy Lock and Dam - Normal Operation with Hawser	CHECKED BY:	DATE:



Item	Factors	F_V	F_H	Arm	Moment
W_{conc}	(0.15)(6)(24-17)	6.3		3	18.9
	(0.15)(8)(17-11)	7.2		4	28.8
	(0.15)(12)(11-5)	10.8		6	64.8
	(0.15)(16)(5-0)	12.0		8	96.0
	(0.15)(0.5)(1)(5)	0.38		16.67	6.33
	(0.15)(6)(5)	4.5		17.5	78.75
	$-(0.15-.0625)(\pi)(3.5)^2/2$	- 1.68		8.5	-14.28
	-(0.15-.0625)(5.5)(7)	- 3.37		8.5	-28.65
	(.15-.0625)(2.33)(5)(3)/32	- .10		2.5	- 0.25
	(0.15)(16)(15)	36.0		7.5	270.0
		72.03			520.42
P_{water} landside	$-0.0625(7.2+16)^2(1/2)(1)$		-16.82	7.73	-130.02
P_{water} lockside	$0.0625(16)^2(1/2)(1)$		8.0	5.33	42.64
P_{soil}	$(0.5)\{(0.115)(24-7.2)^2(1/2)(1)$ 0.115(24-7.2)(7.2+6) $(0.144-0.0625)(7.2+6)^2(1/2)(1)\}$		-24.42	20.33	-496.46
Uplift	-0.0625(7.2+6)(5)	- 4.13		17.5	- 72.28
	-0.0625(1)(5)(0.5)	- 0.16		16.7	- 2.67
	-0.0625(16)(15)	-15.0		7.5	-112.5
	-0.0625(7.2)(0.5)(15)	- 3.38		10.0	- 33.8
		-22.67			-221.25
W_{soil}	(0.115)(24-17)(14)	11.27		13.0	-146.51
	(0.115)(17-11)(12)	8.28		14.0	-115.92
	(0.115)(11-7.2)(8)	3.50		16.0	- 56.00
	(0.144)(7.2-5.0)(8)	2.53		16.0	- 40.48
	(0.144)(5.0-0)(4)	2.88		18.0	- 51.84
		28.46			410.75
Hawser	-40/32		- 1.25	21.0	- 26.25
Total		77.82	-34.48		99.81

WES FORM NO. 1253A DECEMBER 1964

PAGE OF

SUBJECT: Monolith L-5, Troy Lock and Dam - Normal Operation with Earthquake

COMPUTED BY: DATE:

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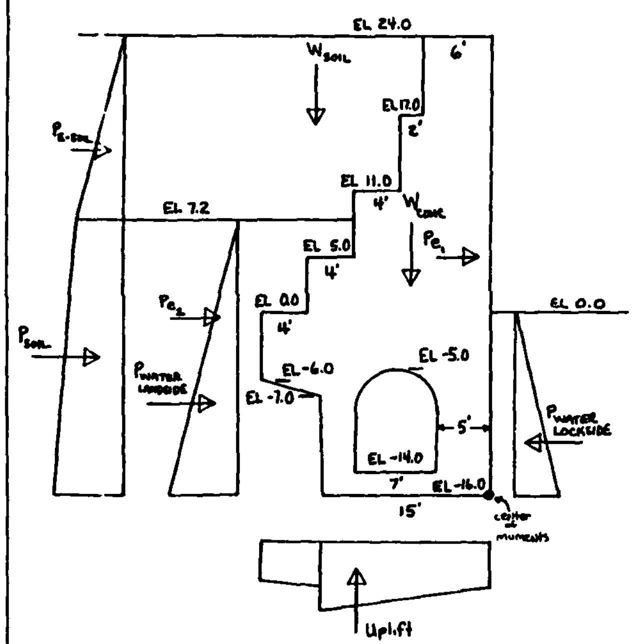

Item	Factors	F_V	F_H	Arm	Moment
Normal Operation Loads	(Full uplift under noncompressive area of base)	75.42	-33.23		110.67
Earthquake	$P_{e_1} = \alpha W = -[0.05][72.03 + 28.46]$		-5.02	20.93	-105.07
	$P_{e_2} = -(.7)[2/3(51)(.05)(13.2)^2](1/1000)$		-0.21	15.28	-3.21
	$P_{E\text{-soil}} = K_{EQK} \frac{P_{soil}}{K_{soil}} = (.11)\frac{(-24.41)}{(0.5)}$		-5.37	30.00	-161.10
TOTAL		75.42	-43.83		-158.71

ENG FORM NO 1253A

PAGE OF

SUBJECT:
Monolith L-5, Center of Gravity Location,
Troy Lock and Dam, Normal Operation with Earthquake

COMPUTED BY:	DATE:
CHECKED BY:	DATE:

LOCATION OF CENTER OF GRAVITY OF CONCRETE

Area		Arm	Area Moment
(24-17)6	= 42	$\left(\frac{24-17}{2}\right)+33$	1533
(17-11)(6+2)	= 48	$\left(\frac{17-11}{2}\right)+27$	1440
(11-5)(8+4)	= 72	$\left(\frac{11-5}{2}\right)+21$	1728
(5-0)(12+4)	= 80	$\left(\frac{5-0}{2}\right)+16$	1480
(0-(-6))(16+4)	= 120	$\left(\frac{0-(-6)}{2}\right)+10$	1560
(1/2)(-6-(-7))(5)	= 2.5	(1/3) + 9	23
(-6)-(-16)(15)	= 150	$\frac{10}{2}$	750
-(-8.5-(-14))(7)	= -38.5	$\left(\frac{14-8.5}{2}\right)+2$	-183
$-\pi(3.5)^2/2$	= -19.2	$\frac{4(3.5)}{3\pi}+7.5$	-173
-(2.33)(3)(5)/32	= -1.1	$\frac{2.33}{2}+1.5$	-3
	455.7		8157

$$\bar{y} = \frac{8157}{455.7} = 17.90 \text{ ft}$$

LOCATION OF CENTER OF GRAVITY OF WATER

Area		Arm	Area Moment
(-8.5-(-14))(7)	= 38.5	$\left(\frac{14-8.5}{2}\right)+2$	183
$\pi(3.5)^2/2$	= 19.2	$\frac{4}{3}\frac{3.5}{\pi}+7.5$	173
(2.33)(3)(5)/32	= 1.1	$\frac{2.33}{2}+1.5$	3
	58.8		359

$$\bar{y} = \frac{359}{58.8} = 6.11 \text{ ft}$$

LOCATION OF CENTER OF GRAVITY OF SOIL ABOVE TABLE

Area		Arm	Area Moment
(24-17)(20-6)	= 98	$\frac{7}{2}+33$	3577
(17-11)(20-8)	= 72	$\frac{6}{2}+27$	2160
(11-7.2)(20-12)	= 30.4	$\frac{11-7.2}{2}+7.2+16$	763
	200.4		6500

$$\bar{y} = \frac{6500}{200.4} = 32.44 \text{ ft}$$

LOCATION OF CENTER OF GRAVITY OF SOIL BELOW TABLE

Area		Arm	Area Moment
(7.2-5)(20-12)	= 17.6	$\left(\frac{7.2-5}{2}\right)+21$	389
(5-0)(20-16)	= 20.0	$\frac{5}{2}+16$	370
	37.6		759

$$\bar{y} = \frac{759}{37.6} = 20.19 \text{ ft}$$

WES FORM NO. 1273A
DECEMBER 1964

PAGE OF

SUBJECT	COMPUTED BY:	DATE:
Monolith L-5, Center of Gravity Location, Troy Lock and Dam, Normal Operation with Earthquake (Continued)	CHECKED BY:	DATE:

LOCATION OF CENTER OF GRAVITY OF EARTHQUAKE FORCES (HORIZONTAL)

Item	Force	Arm	Moment
Concrete	(455.7)(.150) = 68.36	17.90	1224
Soil (above water table)	(200.4)(.115) = 23.05	32.44	748
Soil (below water table)	37.6(.144) = 5.41	20.19	109
Water (in culvert)	58.8(.0625) = 3.68	6.11	22
	100.50		2103

$$\bar{y} = \frac{2103}{100.5} = 20.93$$

SUBJECT: Monolith L-5, Troy Lock and Dam - Normal Operation Plus Impact

COMPUTED BY: | DATE:

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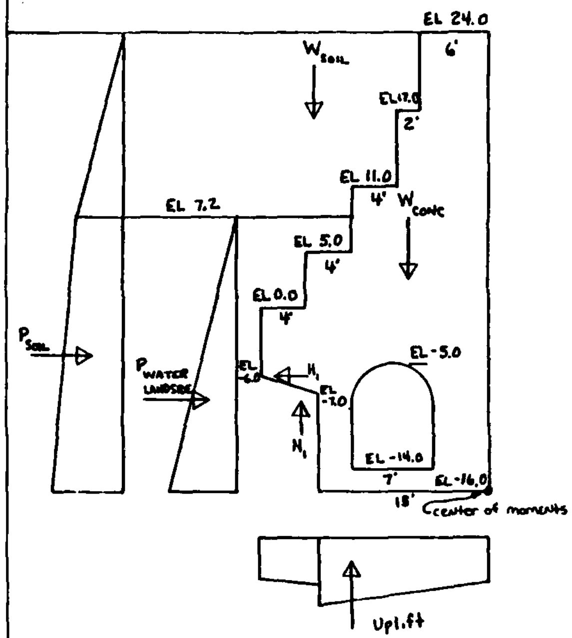

Item	Factors	F_V	F_H	Arm	Moment
W_{conc}	(.15)(6)(24-17)	6.3		3.	18.9
	(.15)(8)(17-11)	7.2		4.	28.8
	(.15)(12)(11-5)	10.8		6.	64.8
	(.15)(16)(5-0)	12.0		8.	96.0
	(.15)(.5)(1)(5)	0.38		16.67	6.33
	(.15)(6)(5)	4.5		17.5	78.75
	(.15)(16)(15)	36.0		7.5	270.0
	$-(.15-.0625)\pi(3.5)^2(1/2)$	- 1.68		8.5	- 14.28
	-(.15-.0625)(5.5)(7)	- 3.37		8.5	- 28.65
	-(.15-.0625)(2.33)(3)(5)/32	- 0.10		2.5	- 0.25
		72.03			520.40
P_{water} landside	$-(0.0625)\{7.2-(-16)\}^2(1/2)$		-16.82	7.73	-130.02
P_{water} lockside	$(.0625)\{14.33-(-16)\}^2(1/2)$		28.75	10.11	290.66
P_{soil}	$-(.5)\{(.115)(24-7.2)^2(1/2)\}$		- 8.11	28.8	-233.57
	-(.5){(.115)(24-7.2)(7.2-(-6)}		-12.75	16.6	-211.65
	$-(.5)\{\frac{.144-.0625}{2}(7.2-(-6))^2\}$		- 3.55	14.4	- 51.12
			-24.41		-496.34
Uplift	-(0.0625){7.2-(-6)}{5}{1}	- 4.13		17.5	- 72.28
	-(0.0625){1}{5}{1}{1/2}	- 0.16		16.67	- 2.67
	-(0.0625){ 7.2 -(-16)}{15}	-21.75		7.5	-163.13
	-(0.0625){14.33-7.2}{15}(1/2)	- 3.34		5.0	- 16.70
		-29.38			-254.78
W_{soil}	(.115)(14)(24-17)	11.27		13.0	146.51
	(.115)(12)(17-11)	8.28		14.0	115.92
	(.115)(8)(11-7.2)	3.50		16.0	56.00
	(.144)(8)(7.2-5)	2.53		16.0	40.48
	(.144)(4)(5-0)	2.88		18.0	51.84
		28.46			410.75
Impact			1.25	35.33	44.16
N_1		- 0.43		15.42	- 6.63
H_1			0.07	10	0.70
Total		70.68	-11.16		378.90

WES FORM NO. 1253A DECEMBER 1964

PAGE OF

SUBJECT: Monolith L-5, Troy Lock and Dam - Normal Operation Plus Ice

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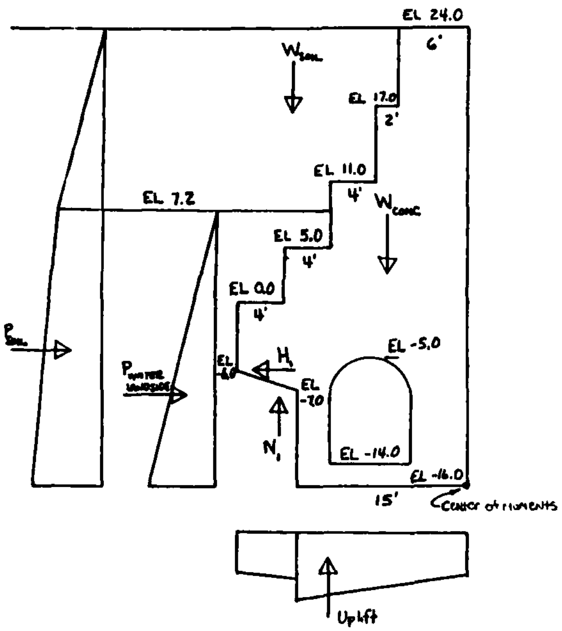

Item	Factors	F_V	F_H	Arm	Moment
W_{conc}	(.15)(6)(24-17)	6.3		3.	18.9
	(.15)(8)(17-11)	7.2		4.	28.8
	(.15)(12)(11-5)	10.8		6.	64.8
	(.15)(16)(5-0)	12.0		8.	96.0
	(.15)(.5)(1)(5)	0.38		16.67	6.33
	(.15)(6)(5)	4.5		17.5	78.75
	(.15)(16)(15)	36.0		7.5	270.0
	$-(.15-.0625)\pi(3.5)^2(1/2)$	- 1.68		8.5	- 14.28
	-(.15-.0625)(5.5)(7)	- 3.37		8.5	- 28.65
	-(.15-.0625)(2.33)(3)(5)/32	- 0.10		2.5	- 0.25
		72.03			520.40
$P_{water\ landside}$	$-(0.0625)\{7.2-(-16)\}^2(1/2)$		-16.82	7.73	-130.02
$P_{water\ lockside}$	$(.0625)\{14.33-(-16)\}^2(1/2)$		28.75	10.11	290.66
P_{soil}	$-(.5)\{(.115)(24-7.2)^2(1/2)\}$		- 8.11	28.8	-233.57
	-(.5){(.115)(24-7.2)(7.2-(-6)}		-12.75	16.6	-211.65
	$-(.5)\{(\frac{.144-.0625}{2})(7.2-(-6))^2\}$		- 3.55	14.4	- 51.12
			-24.41		-496.34
Uplift	-(0.0625){7.2-(-6)}{5}{1}	- 4.13		17.5	- 72.28
	-(0.0625){1}{5}{1}{1/2}	- 0.16		16.67	- 2.67
	-(0.0625){7.2-(-16) }{15}	-21.75		7.5	-163.13
	-(0.0625){14.33-7.2}{15}(1/2)	- 3.34		5.0	- 16.70
		-29.38			-254.78
W_{soil}	(.115)(14)(24-17)	11.27		13.0	146.51
	(.115)(12)(17-11)	8.28		14.0	115.92
	(.115)(8)(11-7.2)	3.50		16.0	56.00
	(.144)(8)(7.2-5)	2.53		16.0	40.48
	(.144)(4)(5-0)	2.88		18.0	51.84
		28.46			410.75
Ice	(5)(2)(1)		10.0	29.33	293.30
N_1		-13.73		17.42	-239.18
H_1			0.48	10.00	4.80
Total		57.38	- 2.00		399.59

WES FORM NO. 1253A DECEMBER 1964

PAGE OF

SUBJECT: Monolith L-5, Troy Lock and Dam, Chamber Dewatered

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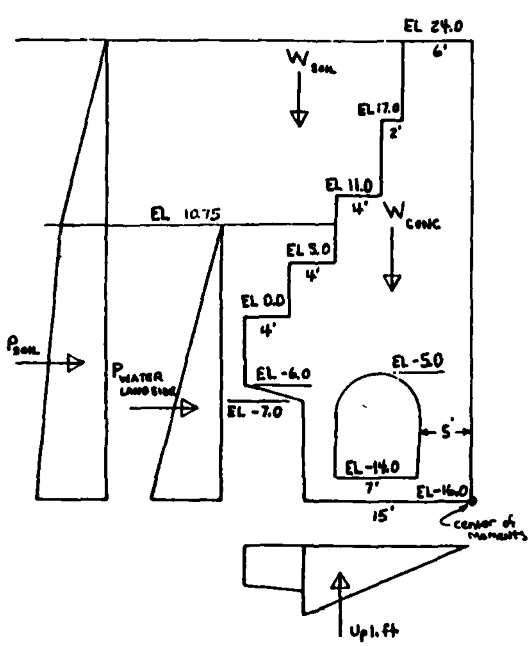

Item	Factors	F_V	F_H	Arm	Moment
W_{conc}	(0.15)(6)(24 - 17)	6.3		3	18.9
	(0.15)(8)(17 - 11)	7.2		4	28.8
	(0.15)(12)(11 - 5)	10.8		6	64.8
	(0.15)(16)(5 - 0)	12.0		8	96.0
	(0.15)(0.5)(1)(5)	0.38		16.67	6.33
	-(0.15)(6)(5)	4.5		17.5	78.75
	$-(0.15)(\pi)(3.5)^2/2$	-2.88		8.5	-24.48
	-(.15)(5.5)(7)	-5.78		8.5	-49.13
	-(.15)(2.33)(5)(3/32)	-.16		2.5	0.40
	(0.15)(16)(15)	36.0		7.5	270.0
		68.36			489.57
P_{soil}	$-(.5)(1/2)(.115)(24 - 10.75)^2$		-5.05	31.17	-157.41
	-(.5)(.115)(24 - 10.75)(10.75 + 16.00)		-20.38	13.38	-272.68
	$-(.5)(1/2)(.144 - .0625)(10.75 + 16.00)^2$		-14.58	8.92	-130.05
			-40.01		-560.14
Uplift	-(.0625)(10.75 + 6)(5)	-5.23		17.50	-91.53
	-(1/2)(.0625)(1)(5)	-0.16		16.67	-2.67
	-(1/2)(.0625)(10.75 + 16.00)(15)	-12.54		10.00	-125.40
		-17.93			-219.60
$P_{water\ land}$	$(1/2)(.0625)(10.75 + 16.00)^2$		-22.36	8.92	-199.45
W_{soil}	(.115)(24 - 17)(2)	1.61		7.00	11.27
	(.115)(24 - 11)(4)	5.98		10.00	59.80
	[(.115)(24 - 10.75) + (.144)(10.75 - 5)](4)	9.41		14.00	131.74
	[(.115)(24 - 10.75) + (.144)(10.75)] (4)	12.29		18.00	221.22
		29.29			424.03
TOTAL		79.92	-62.37		-65.59

WES FORM NO. 1253A DECEMBER 1964

PAGE OF

SUBJECT: Monolith L-5, Troy Lock and Dam - Flood Condition

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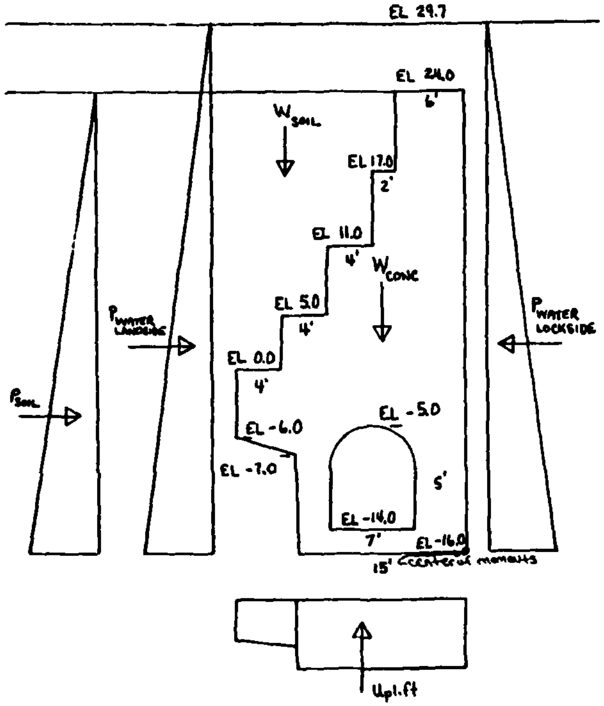

Item	Factors	F_V	F_H	Arm	Moment
W_{conc}	(0.15)(6)(24-17)	6.3		3	18.9
	(0.15)(8)(17-11)	7.2		4	28.8
	(0.15)(12)(11-5)	10.8		6	64.8
	(0.15)(16)(5-0)	12.0		8	96.0
	(0.15)(0.5)(1)(5)	0.38		16.67	6.33
	(0.15)(6)(5)	4.5		17.5	78.75
	$-(0.15-0.0625)(\pi)(3.5)^2/2$	- 1.68		8.5	- 14.28
	-(0.15-0.0625)(5.5)(7)	- 3.37		8.5	- 28.65
	-(0.15-0.0625)(0.5)(1)(5)(3/32)	- 0.02		3.33	- 0.07
	-(0.15-0.0625)(0.5)(1)(5)(3/32)	- 0.02		1.67	- 0.03
	-(0.15-0.0625)(1.33)(5)(3/32)	- 0.05		2.5	- 0.13
	(0.15)(16)(15)	36.0		7.5	270.0
		72.04			520.42
P_{water} landside	$-(0.0625)(29.70+16)^2(0.5)(1)$		-65.27	15.23	-994.06
P_{water} lockside	$(0.0625)(29.70+16)^2(0.5)(1)$		65.27	15.23	994.06
P_{soil}	$-(0.5)(0.144-0.0625)(24.0+6.0)^2(0.5)(1)$		-18.34	20.0	-366.80
Uplift	-(0.0625)(29.70+16)(15)	-42.84		7.5	-321.3
	-(0.0625)(29.70+6)(5)	-11.16		17.5	-195.3
	-(0.0625)(1)(5)(0.5)	- 0.16		16.67	- 2.67
		-54.16			-519.27
W_{soil}	(0.0625)(29.70-24.0)(20)	7.13		10.0	71.3
	(0.14)(24.0-17.0)(14)	13.72		13.0	178.36
	(0.14)(17.0-11.0)(12)	10.08		14.0	141.12
	(0.14)(11.0-5.0)(8)	6.72		16.0	107.52
	(0.14)(5.0-0.0)(4)	2.8		18.0	50.40
		40.45			548.70
Total		58.33	18.34		183.05

WES FORM NO 1253A

PAGE OF

SUBJECT: Monolith L-5, Troy Lock and Dam - Dewatered Condition with Surcharge Loads Behind Monolith

COMPUTED BY: | DATE:

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Item	Factor	F_V	F_H	Arm	Moment
Dewatered	Loads taken from dewatered condition	79.72	-62.37		-65.59
Surcharge			-2.59	23.48	-60.81
Total		79.72	-64.96		-126.40

NOTE: Maximum crane surcharge loading of 110 kips on each of the front pads placed behind and symmetrically along the monolith were used. (Calculations made using the distributions as defined on pages 298-299 as presented in Bowles (1968)*).

* The references cited in the Appendices of this report are listed with those cited in the main text.

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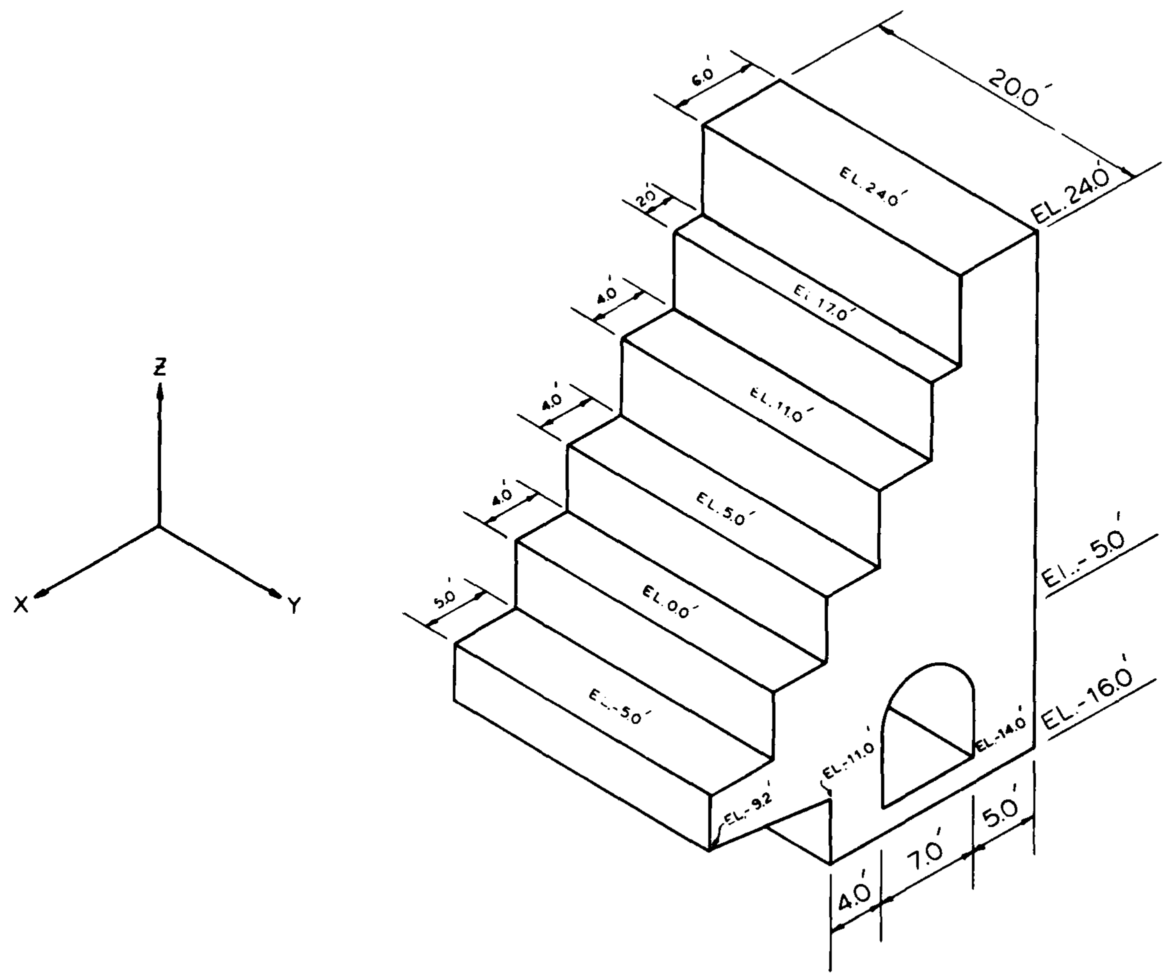
LOCK MONOLITH L-12



Stability analysis, monolith L-12, Troy Lock and Dam

SUBJECT: Monolith L-12, Troy Lock and Dam - Effective Base (No Posttensioning)

COMPUTED BY: DATE

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LOAD CASE	Base Width	Sum of Vertical Forces	Sum of Moments	Resultant Moment Arm	Percent Effective Base	Full Uplift Under Non-Compressive Base Area: Sum of Vertical Forces	Sum of Moments	Resultant Moment Arm	Percent Effective Base
	b (ft)	F_V (kips)	M (ft-kips)	$e = \frac{M}{F_V}$ (ft)	$\frac{3e}{b} * 100$ (%)	F_V (kips)	M (ft-kips)	$e = \frac{M}{F_V}$ (ft)	$\frac{3e}{b} * 100$ (%)
Normal Operation	16	96.96	500.54	5.16	96.75	96.84	499.29	5.16	96.75
Normal Operation with Hawser	16	96.96	458.54	4.73	88.69	96.54	454.30	4.71	88.31
Normal Operation with Earthquake	16	96.84	247.26	2.55	47.81	--	--	--	--
Flood Condition	16	75.36	512.82	6.80	100	--	--	--	--
Dewatered Condition	16	98.80	343.35	3.48	65.25	93.42	297.55	3.19	59.81
*Normal Operation with Ice	16	52.12	442.39	8.49	100**	--	--	---	--
Dewatered Condition with Surcharge	16	98.80	282.07	2.85	53.44	91.62	226.1	2.47	46.31

*Includes vertical and horizontal reactions on stepped base.
**Percent effective base = (b - e)/b * 300.

WES FORM NO. 1253A

PAGE OF

SUBJECT: Monolith L-12, Troy Lock and Dam - Factor of Safety Against Sliding (No Posttensioning)

COMPUTED BY: | DATE

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LOAD CASE	Sum of Vertical Forces F_V (kips)	Sum of Horizontal Forces F_H (kips)	Friction Angle ϕ (Degrees)	Cohesive Strength C (ksf)	Base Area A (sq ft)	Strut Resistance R_s (kips)	Shear Resistance $R_f = F_V \tan \phi$ (kips)	Cohesive Resistance $R_c = CA$ (kips)	Total Sliding Resistance $R = R_s + R_f + R_c$ (kips)	Factor of Safety Against Sliding $F.S. = \frac{R}{F_H}$
Normal Operation	96.84	38.25	30.4	0.04	15.48	0	56.82	0.62	57.44	1.50
Normal Operation with Hawser	96.54	40.25	30.4	0.04	14.13	0	56.64	0.57	57.21	1.42
Normal Operation with Earthquake	96.84	51.36	30.4	0.04	7.65	0	56.82	0.31	57.13	1.11
Flood Condition	75.36	22.46	30.4	0.04	16	0	44.21	0.64	44.85	2.00
Dewatered Condition	93.42	62.37	30.4	0.04	9.57	0	54.81	0.38	55.19	0.88
*Normal Operation with Ice	89.79	6.30	30.4	0.04	16	0	52.68	0.64	53.32	8.46
Dewatered Condition with Surcharge	91.62	64.98	30.4	0.04	7.41	0	53.75	0.30	54.05	0.83

*Includes vertical and horizontal reactions on stepped base.

WES FORM NO. 1253A

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SUBJECT

Monolith L-12, Troy Lock and Dam - Base Pressure (No Posttensioning)

COMPUTED BY

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Load Case	Sum of Vertical Forces F_v (kips)	Resultant Moment Arm e (ft)	Effective Base Width b (ft)	Axial Stress $f_a = \frac{F_v}{b}$ (ksf)	Bending Stress $f_b = \pm \frac{F_v\left(\frac{b}{2}-e\right)\frac{b}{2}}{b^3/12}$	Inter-granular Stress at Heel $f_h = f_a - f_b$ (ksf)	Inter-granular Stress at Toe $f_t = f_a + f_b$ (ksf)	Hydrostatic Pressure at Heel $f_{uh} = h_w w_h$ (ksf)	Hydrostatic Pressure at Toe $f_{ut} = h_w w_t$ (ksf)	Total Pressure at Heel $f_{Th} = f_h + f_{uh}$ (ksf)	Total Pressure at Toe $f_{Tt} = f_t + f_{ut}$ (ksf)
Normal Operation	96.84	5.16	15.48	6.26	6.26	0	12.52	1.45	1.00	1.45	13.52
Normal Operation with (Hawser)	96.54	4.71	14.13	6.83	6.83	0	13.66	1.45	1.00	1.45	14.66
Normal Operation with Earthquake	96.84	2.55	7.65	12.66	12.66	0	25.32	1.45	1.00	1.45	26.32
Flood Condition	75.36	6.81	16	4.71	2.12	2.59	6.83	2.86	2.86	5.45	9.69
Dewatered Condition	93.42	3.19	9.57	9.76	9.76	0.00	19.52	1.67	0.0	1.67	19.52
*Normal Operation plus (Ice)	52.12	8.49	16	3.26	0.60	2.66	3.86	1.45	1.90	4.11	5.76
Dewatered Condition with Surcharge	91.62	2.47	7.41	12.36	12.36	0.00	24.72	1.67	0.0	1.67	24.72

*Includes vertical and horizontal reactions on stepped base.

WES FORM NO. 1253A DECEMBER 1964

PAGE OF

SUBJECT: Monolith L-12, Troy Lock and Dam Effective Base (After Posttensioning)	COMPUTED BY:	DATE:	FILE NO.
	CHECKED BY:	DATE:	SHEET NO.

Load Case	Base Width b (ft)	Sum of Vertical Forces F_V (kips)	Sum of Moments M (ft-kips)	Resultant Moment Arm $e = \frac{M}{F_V}$ (ft)	Percent Effective Base $\frac{3e}{b} * 100$ (%)
Normal Operation	16	106.74	679.56	6.37	100.0
Normal Operation with Hawser	16	106.44	634.57	5.96	100.0
Normal Operation with Earthquake	16	106.74	427.53	4.01	75.1
*Flood Condition	16	85.26	693.09	8.13	100.0**
Dewatered Condition	16	103.52	477.82	4.62	86.7
*Normal Operation with Ice	16	62.02	622.66	10.04	100.0**
Dewatered Condition with Surcharge	16	101.52	406.37	4.00	75.0

* Reactions on stepped base neglected (conservative approach).

** Percent effective base = (b-e)/b * 300.

WES FORM NO. 1253
REV OCT 1968

SUBJECT: Monolith L-12, Troy Lock and Dam –
Factor of Safety Against Sliding (After Posttensioning)

COMPUTED BY: | DATE:
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Load Case	Sum of Vertical Forces F_V (kips)	Sum of Horizontal Forces F_H (kips)	Friction Angle ϕ (Degrees)	Cohesive Strength C (ksf)	Base Area A (sq ft)	Horizontal Posttensioning Resistance R_R (kips)	Shear Resistance $R_f = F_V \tan \phi$ (kips)	Cohesive Resistance $R_c = CA$ (kips)	Total Sliding Resistance $R = R_s + R_f + R_c$ (kips)	Factor of Safety Against Sliding $F.S. = \frac{R}{F_H}$
Normal Operation	106.74	38.25	30.4	0.04	15.48	9.90	62.62	0.62	73.14	1.91
Normal Operation with Hawser	106.44	40.25	30.4	0.04	14.13	9.90	62.45	0.57	72.92	1.81
Normal Operation with Earthquake	106.74	51.36	30.4	0.04	7.65	9.90	62.62	0.31	72.83	1.42
Flood Condition	85.26	22.46	30.4	0.04	16.00	9.90	50.02	0.64	60.56	2.70
Dewatered Condition	103.32	62.37	30.4	0.04	9.57	9.90	60.62	0.38	70.90	1.14
*Normal Operation Plus Ice	62.02	6.30	30.4	0.04	16.00	9.90	36.59	0.64	47.13	7.48
Dewatered Condition with Surcharge	101.52	64.98	30.4	0.04	7.41	9.90	59.56	0.30	69.76	1.07

* Reactions on stepped base neglected (conservative approach).

WES FORM NO. 1253A

PAGE OF

SUBJECT: Monolith L-12, Troy Lock and Dam - Maximum Base Pressure (After Posttensioning)

COMPUTED BY: | DATE:

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	Sum of Vertical Forces	Resultant Moment Arm	Effective Base Width	Axial Stress	Bending Stress	Intergranular Stress At Heel	Intergranular Stress At Toe	Hydrostatic Pressure At Heel	Hydrostatic Pressure At Toe	Total Pressure At Heel	Total Pressure At Toe
	F_v	e	b	$f_a = \frac{F_v}{b}$	$f_b = \pm\frac{F_v\left(\frac{b}{2}-e\right)\frac{b}{2}}{b^3/12}$	$f_y = f_h - f_b$	$f_t = f_h + f_b$	$f_{uh} = w_w h_{wh}$	$f_{ut} = w_w h_{wt}$	$f_{th} = f_h + f_{uh}$	$f_{Tt} = f_t + f_{ut}$
	(kips)	(ft)	(ft)	(ksf)	(ksf)	(ksf)	(ksf)	(ksf)	(ksf)	(ksf)	(ksf)
Normal Operation	106.74	6.37	16	6.67	4.08	2.59	10.75	1.45	1.00	4.04	11.75
Normal Operation with Hawser	106.44	5.96	16	6.65	5.09	1.56	11.74	1.45	1.00	3.01	12.74
Normal Operation with Earthquake	106.74	4.01	12.03	8.87	8.87	0.0	17.76	1.45	1.00	1.45	18.76
Flood Condition	85.26	8.13	16	5.33	0.26	5.07	5.59	2.86	2.86	7.93	8.45
Dewatered Condition	103.32	4.62	13.86	7.45	7.45	0.0	14.90	1.67	0.00	1.67	14.90
*Normal Operation plus Ice	62.02	10.04	16	3.88	2.97	6.85	0.91	1.45	1.9	8.30	2.81
Dewatered Condition with Surcharge	101.52	4.00	12	8.46	8.46	0.0	16.92	1.67	0.0	1.67	16.92

* Reactions on stepped base neglected (conservative approach).

WES FORM NO. 1253A

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SUBJECT: Monolith L-12, Troy Lock and Dam - Normal Operation

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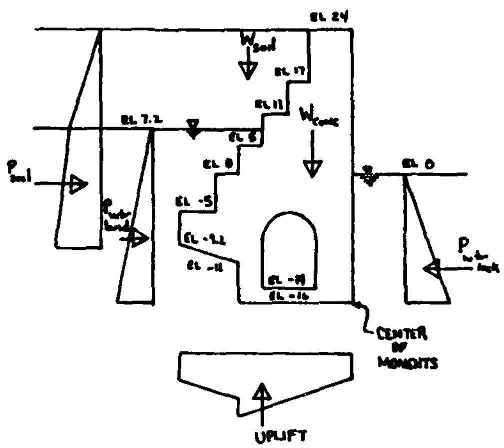

Item	Factor	F_V	F_H	Arm	Moment
W_{conc}	(0.15)(24-17)(6)(1)+	6.3		3	18.9
	(0.15)(17-11)(8)+	7.2		4	28.8
	(0.15)(11-5)(12)+	10.8		6	64.8
	(0.15)(5-0)(16)+	12.0		8	96.0
	(0.15)(0+5)(20)+	15.0		10	150.0
	(0.15)(4.2)(9)+	5.67		20.5	116.26
	(0.15)(0.5)(9)(1.8)+	1.22		19.0	23.18
	(0.15)(16)(11)-	26.4		8.0	211.2
	$(0.15-0.0625)(\pi)(3.5)^2/2-$	-1.68		8.5	-14.28
	(0.15-0.0625)(5.5)(7)-	-3.37		8.5	-28.65
	(0.15-0.0625)(5)(2.33)(3/20)	-0.15		2.5	-0.38
		79.39			665.81
$P_{wtr\ land}$	$(0.0625)(7.2+16)^2(1/2)(1)$		-16.82	7.73	-130.02
$P_{wtr\ lock}$	$(0.0625)(16)^2(1/2)(1)$		8.00	5.33	42.64
P_{soil}	$-[0.5][(.115)(24-7.2)^2(1/2)(1)]$		-8.11	28.80	-233.57
	$-[0.5][(.115)(24-7.2)(7.2+9.2)]$		-15.84	15.00	-237.60
	$-[0.5][(0.144-0.0625)(7.2+9.2)^2(1/2)$		-5.42	12.27	-67.24
			-29.43		-538.41
Uplift	-(0.625)(7.2+9.2)(7)	-9.23		20.5	-189.22
	-(1/2)(0.0625)(1.8)(9)	-0.51		19.0	-9.69
	-(.0625)(16)(16)	-16.0		8.0	-128.00
	-(1/2)(.0625)(7.2)(16)	-3.60		12.67	-32.41
		-29.34			-365.32
W_{soil}	(0.115)(24-17)(19)+	15.30		15.5	237.15
	(0.115)(17-11)(19)+	11.73		16.5	193.55
	(0.115)(11-7.2)(13)+	5.68		18.5	105.08
	(0.144)(7.2-5)(13)+	4.12		18.5	76.22
	(0.144)(5.0-0)(9)+	6.48		20.5	132.84
	(0.144)(0+5.0)(5)	3.60		22.5	81.00
		46.91			825.84
Total		96.96	-38.25		500.54

WES FORM NO. 1253A

PAGE OF

SUBJECT: Monolith L-12, Troy Lock and Dam - Normal Operation with Hawser

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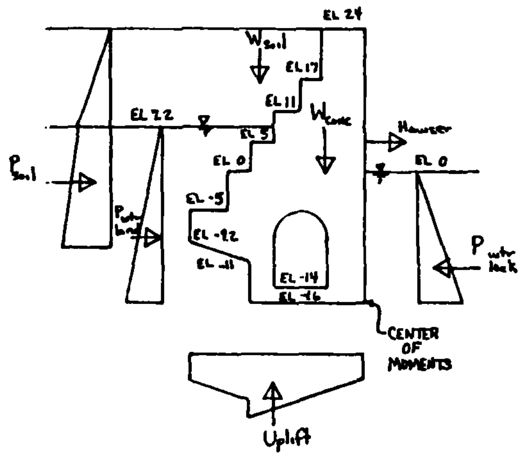

Item	Factor	F_V	F_H	Arm	Moment
W_{conc}	(0.15)(24-17)(6)(1)+	6.3		3	18.9
	(0.15)(17-11)(8)+	7.2		4	28.8
	(0.15)(11-5)(12)+	10.8		6	64.8
	(0.15)(5-0)(16)+	12.0		8	96.0
	(0.15)(0+5)(20)+	15.0		10	150.0
	(0.15)(4.2)(9)+	5.67		20.5	116.26
	(0.15)(0.5)(9)(1.8)+	1.22		19.0	23.18
	(0.15)(16)(11)-	26.4		8.0	211.2
	$(0.15-0.0625)(\pi)(3.5)^2/2-$	-1.68		8.5	-14.28
	(0.15-0.0625)(5.5)(7)-	-3.37		8.5	-28.65
	(0.15-0.0625)(5)(2.33)(3/20)	-0.15		2.5	-0.38
		79.39			665.81
$P_{wtr\ land}$	$(0.0625)(7.2+16)^2(1/2)(1)$		-16.82	7.73	-130.02
$P_{wtr\ lock}$	$(0.0625)(16)^2(1/2)(1)$		8.00	5.33	42.64
P_{soil}	$-[0.5][-(.115)(24-7.2)^2(1/2)(1)]$		-8.11	28.80	-233.57
	-[0.5][(.115)(24-7.2)(7.2+9.2)]		-15.84	15.00	-237.60
	$-[0.5][(0.144-0.0625)(7.2+9.2)^2(1/2)(1)]$		-5.42	12.27	-67.21
			27.43		-538.41
Uplift	-(.0625)(7.2+9.2)(9)	-9.23		20.5	-189.22
	-(1/2)(0.0625)(1.8)(9)	-0.51		19.0	-9.69
	-(.0625)(16)(16)	-16.0		8.0	-128.00
	-(1/2)(.0625)(7.2)(16)	-3.60		10.67	-32.41
		-29.34			-365.32
W_{soil}	(0.115)(24-17)(17)+	15.30		15.5	237.15
	(0.115)(17-11)(17)+	11.73		16.5	193.55
	(0.115)(11-7.2)(13)+	5.68		18.5	105.08
	(0.144)(7.2-5)(13)+	4.12		18.5	76.22
	(0.144)(5.0-0)(9)+	6.48		20.5	132.84
	(0.144)(0+5.0)(5)	3.60		22.5	81.00
		46.91			825.84
Hawser			-2.0	21.0	-42.00
Total		96.96	-40.25		458.54

WES FORM NO. 1253A

PAGE OF

SUBJECT: Monolith L-12, Troy Lock and Dam - Normal Operation with Earthquake

COMPUTED BY: | DATE:

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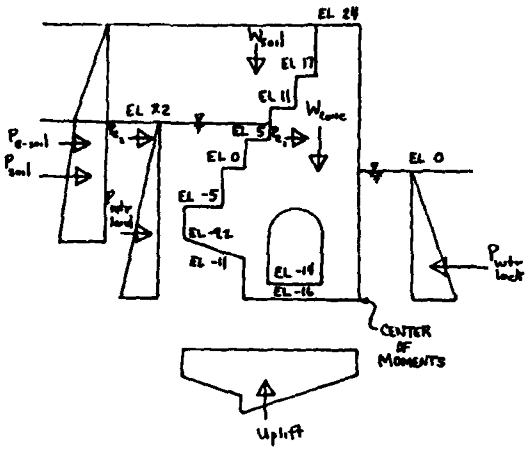
Item	Factor	F_V	P_H	Arm	Moment
Normal Operation Loads	(Full uplift under noncompressive area of base)	96.84	-38.25		499.29
Earthquake	$Pe_1 = aW = [0.05][79.39+46.91]$		-6.32	20.71	-130.89
	$Pe_2 = [0.7][\frac{2}{3}(51)(.05)(16.4)^2][\frac{1}{1000}]$		-0.32	20.08	-6.43
	$P_{E\text{-}Soil} = K_{soil}\frac{P_{soil}}{K_{soil}} = (.11)\frac{(29.43)}{(0.5)}$		-6.47	17.73	-114.71
Total		96.84	-51.36		247.26



WES FORM NO. 1253A DECEMBER 1966

PAGE OF

SUBJECT: Monolith L 12, Troy Lock and Dam, Location of Center of Gravity
Normal Operation with Earthquake

COMPUTED BY: | DATE:
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LOCATION OF CENTER OF GRAVITY OF CONCRETE

Area		Arm	Moment
(6)(7)	= 42.0	36.5	1533
(8)(6)	= 48.0	30.0	1440
(12)(6)	= 72.0	24.0	1728
(16)(5)	= 80.0	18.5	1480
(20)(5)	= 100.0	13.5	1350
(25)(4.2)	= 105.0	8.9	934
1/2(9)(1.8)	= 8.1	6.2	50
(16)(6.8)	= 108.8	3.4	370
-(5.5)(7)	= -38.5	4.75	-183
$-\pi(3.5)^2/2$	= -19.2	8.99	-173
$\frac{-2.33(3)(5)}{20}$	= -1.8	2.67	-5
	504.4		8524

$$\bar{y} = \frac{8524}{504.4} = 16.90$$

LOCATION OF CENTER OF GRAVITY OF WATER

Area		Arm	Moment
(5.5)(7)	= 38.5	4.75	183
$\pi(3.5)^2/2$	= 19.2	8.99	173
2.33(3)(5)/20	= 1.8	2.67	5
	59.5		361

$$\bar{y} = \frac{361}{59.5} = 6.07$$

LOCATION OF CENTER OF GRAVITY OF SOIL ABOVE TABLE

Area		Arm	Moment
19(7)	= 133	36.5	4855
17(6)	= 102	30.0	3060
13(3.8)	= 49.4	25.1	1240
	284.4		9155

$$\bar{y} = \frac{9155}{284.4} = 32.19'$$

LOCATION OF CENTER OF GRAVITY OF SOIL BELOW TABLE

Area		Arm	Moment
13(2.2)	= 28.6	22.1	632
9(5)	= 45.0	18.5	832
(5)(5)	= 25.0	13.5	338
	98.6		1802

$$\bar{y} = \frac{1802}{98.6} = 18.28'$$

WES FORM NO. 1253A DECEMBER 1984

PAGE OF

SUBJECT: Monolith L-12, Troy Lock and Dam, Location of Center of Gravity Normal Operation with Earthquake (Continued)	COMPUTED BY:	DATE:
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LOCATION CENTER OF GRAVITY OF HORIZONTAL EARTHQUAKE FORCES

Item	Force	Arm	Moment
Concrete	504.4(150) = 75.66	16.90	1279
Soil (above water table)	284.4(.115) = 32.71	32.19	1053
Soil (below water table)	98.6(.144) = 14.20	18.28	260
Water (in culvert)	59.5(.0625) = 3.72	6.07	23
	126.29		2615

$$\bar{y} = \frac{2615}{126.29} = 20.71$$

WES FORM NO. 1253A DECEMBER 1964

SUBJECT: Monolith L-12, Troy Lock and Dam - Flood Condition

COMPUTED BY: DATE:

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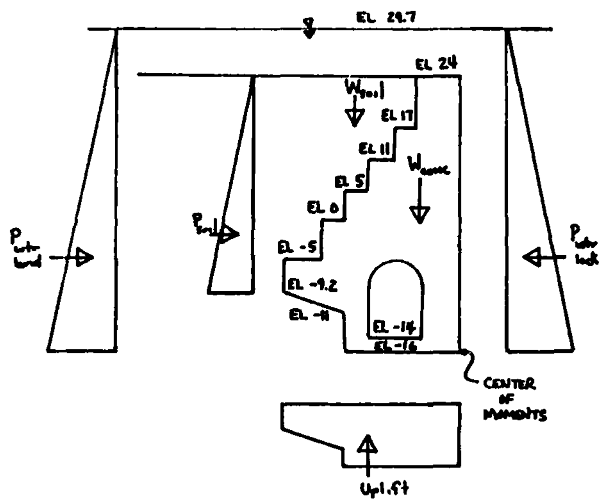

Item	Factor	F_V	F_H	Arm	Moment
W_{conc}	(0.15)24-17)(6)(1)+	6.3		3	18.9
	(0.15)(17-11)(8)+	7.2		4	28.2
	(0.15)(11-5)(12)+	10.8		6	64.8
	(0.15)(5-0)(16)+	12.0		8	96.0
	(0.15)(0+5)(20)+	15.0		10	150.0
	(0.15)(4.2)(9)+	5.67		20.5	116.26
	(0.15)(0.5)(9)(1.8)+	1.22		19.0	23.18
	(0.15)(16)(11)-	26.4		8.0	211.2
	$(0.15-0.0625)(\pi)(3.5)^2/2-$	-1.68		8.5	-14.28
	(0.15-0.0625)(5.5)(7)-	-3.37		8.5	-28.65
	(0.15-0.0625)(5)(2.33)(3/20)	-0.15		2.5	-0.38
		79.39(			665.81
P_{wtr} land	$(0.0625)(29.70+16)^2(1/2)(1)$		-65.27	15.23	-994.06
P_{wtr} lock	$(0.0625)(29.70+16)^2(1/2)(1)$		65.27	15.23	994.06
P_{soil}	$(0.5)(0.144-0.0625)(24+9.2)^2(0.5)(1)$		-22.46	17.87	-401.36
Uplift	-(0.0625)(29.70+9.2)(9)	-21.88		20.5	-448.54
	-(0.0625)(1.8)(9)(0.5)	-0.51		19.0	-9.67
	-(0.0625)(29.70+16)(16)	-45.7		8.0	-365.6
		-68.09			-823.83
W_{soil}	(0.0625)(29.70-24.0)(25)	8.91		12.5	111.38
	(0.144)(7.0)(19)	19.15		15.5	296.83
	(0.144)(6.0)(17)	14.69		16.5	242.39
	(0.144)(6.0)(13)	11.23		18.5	207.76
	(0.144)(5.0)(9.0)	6.48		20.5	132.84
	(0.144)(5.0)(5.0)	3.60		22.5	81.00
		64.06			1072.26
Total		75.35	-22.46		512.82

WES FORM NO 1253A DECEMBER 1966

PAGE OF

SUBJECT: Monolith L-12, Troy Lock and Dam - Dewatered Condition

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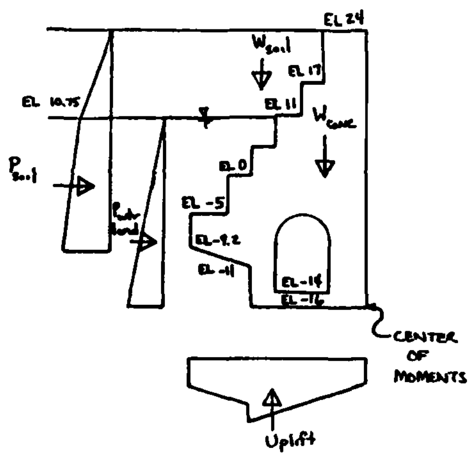

Item	Factor	F_V	F_H	Arm	Moment
W_{conc}	(0.15)(24-17)(6)(1)+	6.3		3	18.9
	(0.15)(17-11)(8)+	7.2		4	28.2
	(0.15)(11-5)(12)+	10.8		6	64.8
	(0.15)(5-0)(16)+	12.0		8	96.0
	(0.15)(0+5)(20)+	15.0		10	150.0
	(0.15)(4.2)(9)+	5.67		20.5	116.26
	(0.15)(0.5)(9)(1.8)+	1.22		19.0	23.18
	(0.15)(16)(11)-	26.4		8.0	211.2
	$(0.15)(\pi)(3.5)^2/2$-	-2.89		8.5	-24.57
	(0.15)(5.5)(7)-	-5.78		8.5	-49.13
	(0.15)(5)(2.33)(3/20)	-0.26		2.5	-0.65
		75.66			634.77
P_{soil}	$(.5)(1/2)(.115)(24-10.75)^2$		-5.05	31.17	-157.41
	(.5)(.115)(24-10.75)(10.75+16.00)		-20.38	13.38	-272.68
	$(.5)(1/2)(.144-.0625)(10.75+16.00)^2$		-14.58	8.92	-130.05
			-40.01		-560.14
Uplift	(.0625)(10.75+9.2)(9)	-11.22		20.50	-230.01
	(1/2)(.0625)(1.8)(9)	-0.51		19.00	-9.69
	(1/2)(.0625)(10.75+16)(16)	-13.38		10.67	-142.76
		-25.11			-382.46
P_{water} landside	$(1/2)(.0625)(10.75+16)^2$		-22.36	8.92	-199.45
W_{soil}	(.115)(24-17)(2)	1.61		7.00	11.27
	(.115)(24-11)(4)	5.98		10.00	59.80
	[(.115)(24-10.75)+(.144)(10.75-5)](4)	9.41		14.00	131.74
	[(.115)(24-10.75)+(.144)(10.75-0)](4)	12.29		18.00	221.22
	[(.115)(24-10.75)+(.144)(10.75+5)](5)	18.96		22.50	426.60
		48.25			850.35
Total		98.80	-62.37		343.35

WES FORM NO. 1253A

PAGE OF

SUBJECT: Monolith L-12, Troy Lock and Dam - Normal Operation with Ice

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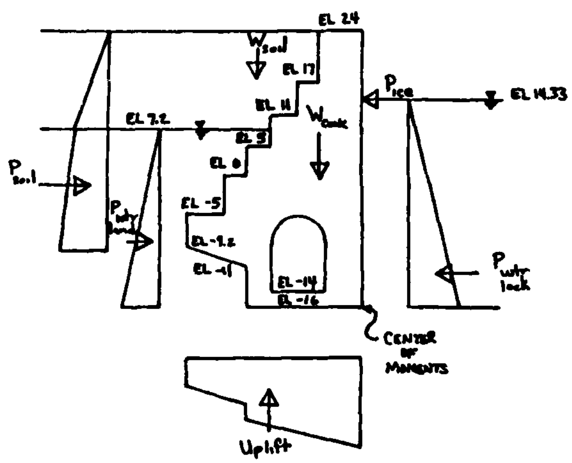

Item	Factor	F_V	F_H	Arm	Moment
W_{conc}	(0.15)(24-17)(6)(1)+	6.3		3	10.7
	(0.15)(17-11)(8)+	7.2		4	28.8
	(0.15)(11-5)(12)+	10.8		6	64.8
	(0.15)(5-0)(16)+	12.0		8	96.0
	(0.15)(0+5)(20)+	15.0		10	150.0
	(0.15)(4.2)(9)+	5.67		20.5	116.26
	(0.15)(0.5)(9)(1.8)+	1.22		19.0	23.18
	(0.15)(16)(11)-	26.4		8.0	211.2
	$(0.15-0.0625)(\pi)(3.5)^2/2-$	-1.68		8.5	-14.28
	(0.15-0.0625)(5.5)(7)-	-3.37		8.5	-28.65
	(0.15-0.0625)(5)(2.33)(3/20)	-0.15		2.5	-0.38
		79.39			665.81
P_{wtr} land	$(0.0625)(7.2+16)^2(1/2)(1)$		-16.82	7.73	-130.02
P_{wtr} lock	$(0.0625)(14.33+16)^2(1/2)(1)$		28.75	10.11	290.66
P_{soil}	$-[0.75][(0.125)(24-7.2)^2(1/2)(1)]$		-4.41	28.8	-127.01
	-[0.25][(0.125)(24-7.2)(7.2+9.2)]		-8.61	15.0	-129.15
	$-[0.25][(0.14-0.0625)(7.2+9.2)^2(1/2)(1)$		-2.61	12.3	-32.10
			-15.63		-288.26
Uplift	-(0.0625)(7.2+9.2)(9)	-9.23		2.05	-189.22
	-(0.0625)(1.8)(9)(10.5)	-0.51		19.00	-9.69
	-(0.0625)(7.2+16)(16)	-23.2		8.00	-185.6
	-(0.0625)(7.13)(16)(1/2)	-3.57		10.67	-38.09
		-36.51			-422.60
W_{soil}	(0.115)(24-17)(17)+	15.30		15.5	237.15
	(0.115)(17-11)(17)+	11.73		16.5	193.55
	(0.115)(11-7.2)(13)+	5.68		18.5	105.08
	(0.144)(7.2-5)(13)+	4.12		18.5	76.22
	(0.144)(5.0-0)(9)+	6.48		20.5	132.84
	(0.144)(0+5.0)(5)	3.60		22.5	81.00
		46.91			825.89
P_{ice}	(5)(2)(1)		10	24.33	293.30
Subtotal		89.79	7.30		1234.13
N_1		-37.67		20.62	-776.76
H_1			-2.64	5.9	-15.59
Total		52.12	-3.70		442.39

WES FORM NO. 1293A DECEMBER 1964

PAGE OF

SUBJECT:
Monolith L-12, Troy Lock and Dam -
Dewatered Condition with Surcharge Load Behind Monolith

COMPUTED BY: DATE:

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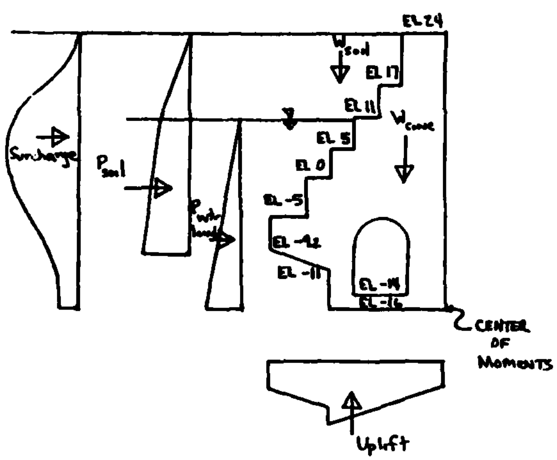
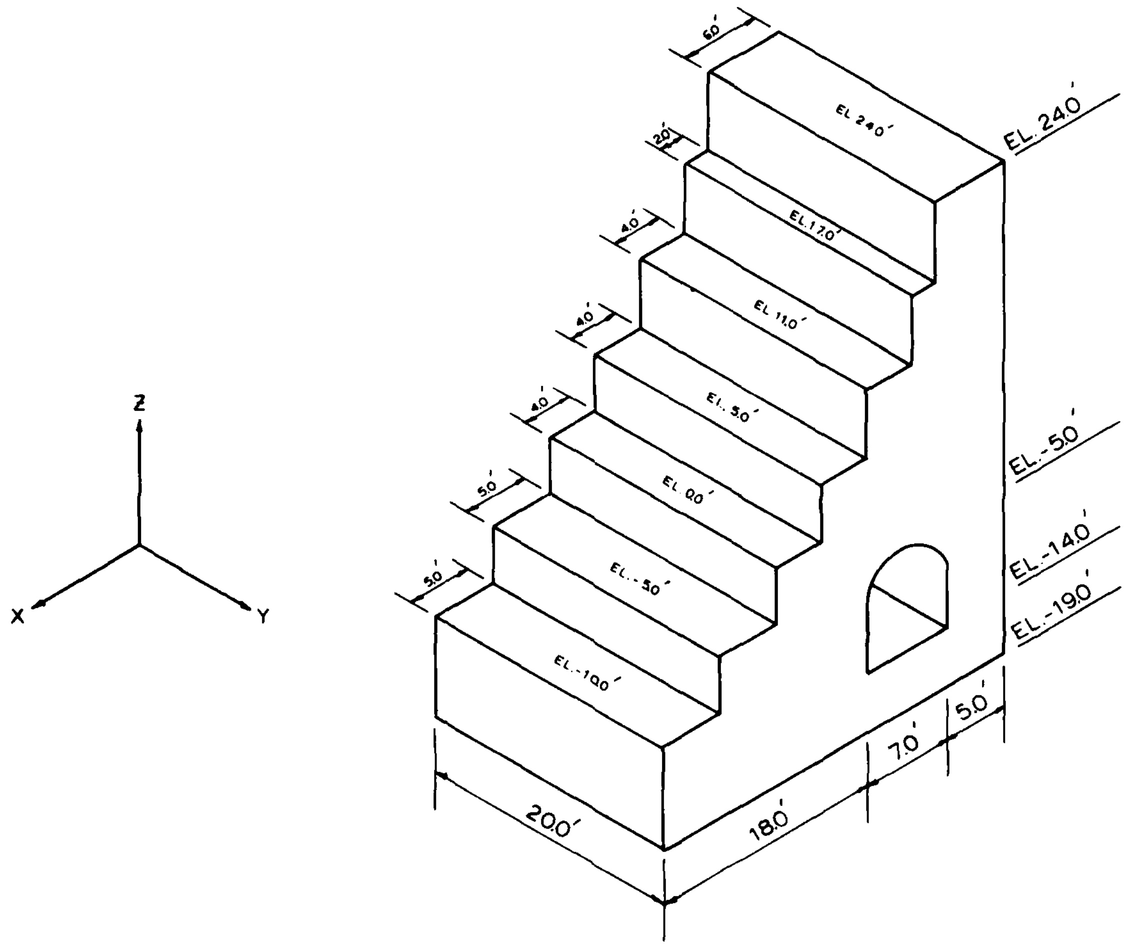
Item	Factor	F_V	F_H	Arm	Moment
Dewatered Load	Loads taken from dewatered condition	98.80	-62.37		343.35
Surcharge			-2.61	23.48	-61.28
Total		98.80	-64.98		282.07

NOTE: Maximum crane surcharge loading of 110 kips on each of the front pads placed behind and symmetrically along the monolith were used. (Calculations made using the distributions as defined on pages 298-299 as presented in Reference 2.)



WES FORM NO. 1293A

LOCK MONOLITH L-20



Stability analysis, monolith L-20, Troy Lock and Dam

SUBJECT: Monolith L-20, Troy Lock and Dam - Percent Effective Base (No Posttensioning)

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						Full Uplift Under Non-Compressive Base Area*			
LOAD CASE	Base Width b (ft)	Sum of Vertical Forces F_v (kips)	Sum of Moments M (ft-kips)	Resultant Moment Arm $e = \frac{M}{F_v}$ (ft)	Percent Effective Base $\frac{3e}{b} \times 100$ (%)	Sum of Vertical Forces F_v (kips)	Sum of Moments M (ft-kips)	Resultant Moment Arm $e = \frac{M}{F_v}$ (ft)	Percent Effective Base $\frac{3e}{b} \times 100$ (%)
Normal Operation	30	131.92	1072.16	8.06	80.6	130.70	1069.97	8.17	81.9
Normal Operation with Hawser	30	131.92	1044.16	7.70	77.0	130.44	1017.83	7.80	78.0
Normal Operation with Earthquake	30	130.70	632.17	4.84	48.4	--	--	--	--
Dewatered Condition	30	144.53	1075.93	7.44	74.4	135.70	927.23	6.83	68.3
Flood Condition	30	104.36	1041.96	9.98	99.8	--	--	--	--
Dewatered Condition with Surcharge	30	144.53	1012.12	7.00	10.0	134.17	843.41	6.29	62.90

* Trial and Error Solution.

WES FORM NO. 1253A

PAGE OF

SUBJECT: Monolith L-20, Troy Lock and Dam - Factor of Safety Against Sliding (No Posttensioning)

COMPUTED BY: | DATE:

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LOAD CASE	Sum of Vertical Forces F_V (kips)	Sum of Horizontal Forces F_H (kips)	Friction Angle ϕ (degrees)	Cohesive Strength C (ksf)	Base Area A (sq ft)	Strut Resistance R_s (kips)	Shear Resistance $R_f = F_V \tan \phi$ (kips)	Cohesive Resistance $R_c = CA$ (kips)	Total Sliding Resistance $R = R_s + R_f + R_c$ (kips)	Factor of Safety Against Sliding $F.S. = \frac{R}{F_H}$
Normal Operation	130.70	57.58	30.4	0.04	24.57	0	76.68	0.98	77.66	1.35
Normal Operation with Hawser	130.44	59.58	30.4	0.04	23.40	0	76.53	0.94	77.47	1.30
Normal Operation with Earthquake	130.7	75.71	30.4	0.04	14.52	0	76.68	0.58	77.26	1.02
Dewatered Condition	135.70	73.41	30.4	0.04	20.49	0	79.61	0.82	80.43	1.10
Flood Condition	104.36	37.67	30.4	0.04	29.94	0	61.23	1.20	62.43	1.66
Dewatered Condition with Surcharge	134.17	75.94	30.4	0.04	18.87	0	78.72	0.75	79.47	1.05

1253A

PAGE OF

SUBJECT: Monolith L-20, Troy Lock and Dam - Base Pressures (No Posttensioning)

COMPUTED BY: DATE:

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	Sum of Vertical Forces	Resultant Moment Arm	Effective Base Width	Axial Stress	Bending Stress	Intergranular Stress At Heel	Intergranular Stress At Toe	Hydrostatic Pressure At Heel	Hydrostatic Pressure At Toe	Total Pressure At Heel	Total Pressure At Toe
	F_v (kips)	e (ft)	b (ft)	$f_a = \frac{F_v}{b}$ (ksf)	$f_b = \pm\frac{F_v\left(\frac{b}{2}-e\right)\frac{b}{2}}{b^3/12}$ (ksf)	$f_h = f_a - f_b$ (ksf)	$f_t = f_a + f_b$ (ksf)	$f_{uh} = \gamma h_{uh}$ (ksf)	$f_{ut} = \gamma y_{ut}$ (ksf)	$f_{Th} = f_h + f_{uh}$ (ksf)	$f_{Tt} = f_t + f_{ut}$ (ksf)
Normal Operation	130.70	8.17	24.57	5.32	±5.32	0.0	10.64	1.64	1.19	1.64	11.83
Normal Operation with Hawser	130.44	7.80	23.40	5.57	±5.57	0.0	11.14	1.64	1.19	1.64	12.33
Normal Operation with Earthquake	130.70	4.84	14.52	9.00	±9.00	0.0	18.00	1.64	1.19	1.64	19.19
Dewatered Condition	135.70	6.83	20.49	6.62	±6.62	0.0	13.24	1.86	0.0	1.86	13.24
Flood Condition	104.36	9.98	29.94	3.49	±3.49	0.0	6.98	3.04	3.04	3.04	10.02
Dewatered Condition with Surcharge	134.17	6.29	18.87	7.11	±7.11	0.0	14.22	1.86	0.0	1.86	14.22

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PAGE OF

SUBJECT: Monolith L-20, Troy Lock and Dam Percent Effective Base (After Posttensioning)	COMPUTED BY:	DATE:	FILE NO.
	CHECKED BY:	DATE:	SHEET NO.

Load Case	Base Width b (ft)	Sum of Vertical Forces F_V (kips)	Sum of Moments M (ft-kips)	Resultant Moment Arm $e = \frac{M}{F_V}$ (ft)	Percent Effective Base $\frac{3e}{b} * 100$ (%)
Normal Operation	30	145.90	1346.81	9.23	92.3
Normal Operation with Hawser	30	145.64	1294.67	8.89	88.9
Normal Operation with Earthquake	30	145.90	909.01	6.23	62.3
Dewatered Condition	30	150.90	1204.07	7.98	79.8
Flood Condition	30	119.56	1318.80	11.03	100.0
Dewatered Condition with Surcharge	30	149.37	1120.25	7.50	75.0

WES FORM NO. 1253
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SUBJECT: Monolith L-20, Troy Lock and Dam - Factor of Safety Against Sliding (After Posttensioning)

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Load Case	Sum of Vertical Forces F_V (kips)	Sum of Horizontal Forces F_H (kips)	Friction Angle ϕ (Degrees)	Cohesive Strength C (ksf)	Base Area A (sq ft)	Horizontal Posttensioning Resistance R_s (kips)	Shear Resistance $R_f = F_V \tan \phi$ (kips)	Cohesive Resistance $R_c = CA$ (kips)	Total Sliding Resistance $R = R_s + R_f + R_c$ (kips)	Factor of Safety Against Sliding $F.S. = \frac{R}{F_H}$
Normal Operation	145.90	57.58	30.4	0.04	24.57	15.20	85.60	0.98	101.78	1.77
Normal Operation with Hawser	145.64	59.58	30.4	0.04	23.40	15.20	85.45	0.94	101.59	1.71
Normal Operation with Earthquake	145.90	75.74	30.4	0.04	14.52	15.20	85.60	0.58	101.38	1.34
Dewatered Condition	150.90	73.41	30.4	0.04	20.49	15.20	88.53	0.82	104.55	1.42
Flood Condition	119.56	37.67	30.4	0.04	29.94	15.20	70.15	1.20	86.55	2.30
Dewatered Condition with Surcharge	149.37	75.94	30.4	0.04	18.87	15.20	87.63	0.75	103.58	1.36

WES FORM NO. 1253A DECEMBER 1964 | PAGE OF

SUBJECT: Monolith L-20, Troy Lock and Dam - Base Pressures (After Posttensioning)

COMPUTED BY: | DATE:

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	Sum of Vertical Forces	Resultant Moment Arm	Effective Base Width	Axial Stress	Bending Stress	Intergranular Stress At Heel	Intergranular Stress At Toe	Hydrostatic Pressure At Heel	Hydrostatic Pressure At Toe	Total Pressure At Heel	Total Pressure At Toe
	F_v	e	b	$f_a = \frac{F_v}{b}$	$f_b = \pm \frac{F_v\left(\frac{b}{2}-e\right)\frac{b}{2}}{b^3/12}$	$f_y = f_h - f_b$	$f_t = f_h + f_b$	$f_{uh} = 8_v h_{uh}$	$f_{ut} = 8_v y_{uh}$	$f_{th} = f_h + f_{uh}$	$f_{Tt} = f_t + f_{ut}$
	(kips)	(ft)	(ft)	(ksf)	(ksf)	(ksf)	(ksf)	(ksf)	(ksf)	(ksf)	(ksf)
Normal Operation	145.90	9.23	27.69	5.27	5.27	0	10.54	1.64	1.19	1.64	11.73
Normal Operation with Hawser	145.64	8.89	26.67	5.46	5.46	0	10.92	1.64	1.19	1.64	12.11
Normal Operation with Earthquake	145.90	6.23	18.69	7.81	7.81	0	15.62	1.64	1.19	1.64	16.81
Dewatered Condition	150.90	7.98	23.94	6.30	6.30	0	12.60	1.86	0.0	1.86	12.60
Flood Condition	119.56	11.03	30.00	3.99	3.16	0.83	7.15	3.04	3.04	3.87	10.19
Dewatered Condition with Surcharge	149.37	7.50	22.50	6.64	6.64	0	13.28	1.86	0.0	1.86	13.28

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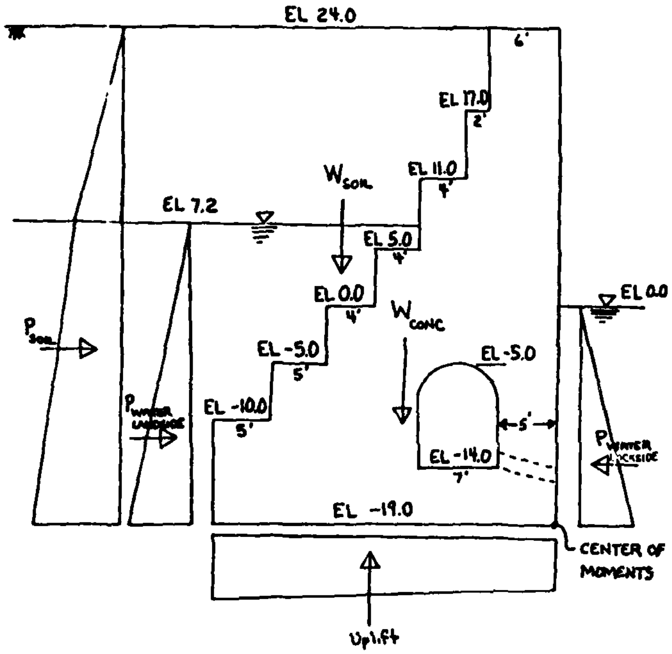
Monolith L-20, Troy Lock and Dam - Normal Operation



Item	Factors	F_V	F_H	Arm	Moment
W_{conc}	(.15) (6) (7)	6.30		3.00	18.90
	(.15) (8) (6)	7.20		4.00	28.80
	(.15) (12) (6)	10.80		6.00	64.80
	(.15) (16) (5)	12.00		8.00	96.00
	(.15) (20) (5)	15.00		10.00	150.00
	(.15) (25) (5)	18.75		12.50	234.38
	(.15) (30) (9)	40.50		15.00	607.50
	$-(.15-.0625)\ \pi(3.5)^2/2$	- 1.68		8.50	- 14.28
	-(.15-.0625) (7) (5.5)	- 3.37		8.50	- 28.65
	-(.15-.0625) (5) (2.33) (3/20)	- 0.15		2.50	- 0.38
		105.35			1157.07
W_{soil}	(.115) (24) (7)	19.32		18.00	347.76
	(.115) (22) (6)	15.18		19.00	288.42
	(.115) (18) (3.8)	7.87		21.00	165.27
	(.144) (18) (2.2)	5.70		21.00	119.70
	(.144) (14) (5)	10.08		23.00	231.84
	(.144) (10) (5)	7.20		25.00	180.00
	(.144) (5) (5)	3.60		27.50	99.00
		68.95			1431.99
P_{water} landside	$-(.0625)\ (26.2)^2/2$		-21.45	8.73	- 187.26
P_{water} lockside	$(.0625)\ (19)^2/2$		8.00	6.33	71.40
P_{soil}	$-(.5)\ (.115)\ (16.8)^2/2$		- 8.11	31.80	- 257.90
	-(.5) (.115) (16.8) (26.2)		-25.31	13.10	- 331.56
	$-(.5)\ (.144-.0625)\ (26.2)^2/2$		-13.99	8.73	- 122.13
			-47.41		- 711.59
Uplift	-(.0625) (19) (30)	-35.63		15.00	- 534.45
	-(.0625) (7.2) (30) (1/2)	- 6.75		20.00	- 135.00
		-42.38			- 669.45
Total		131.92	-57.58		1092.16

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SUBJECT: Monolith L-20, Troy Lock and Dam - Normal Operation with Hawser

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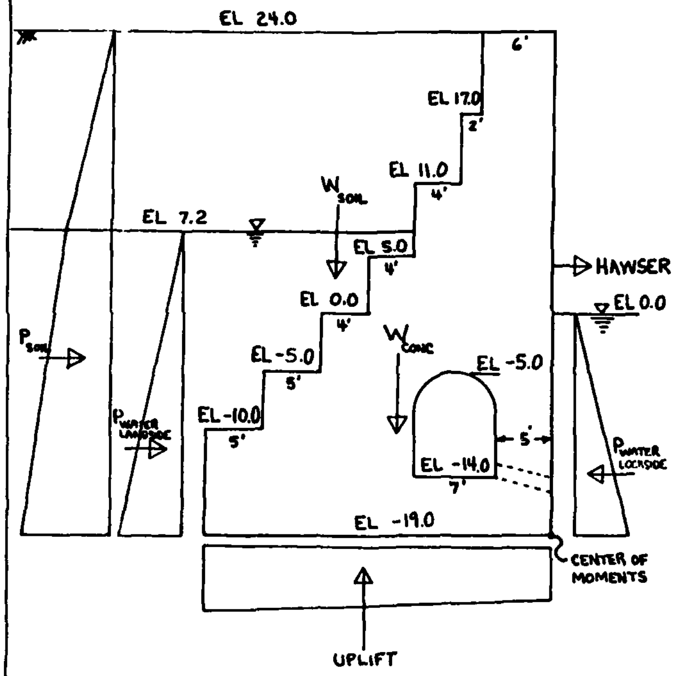

Item	Factors	F_V	F_H	Arm	Moment
W_{conc}	(.15) (6) (7)	6.30		3.00	18.90
	(.15) (8) (6)	7.20		4.00	28.80
	(.15) (12) (6)	10.80		6.00	64.80
	(.15) (16) (5)	12.00		8.00	96.00
	(.15) (20) (5)	15.00		10.00	150.00
	(.15) (25) (5)	18.75		12.50	234.38
	(.15) (30) (9)	40.50		15.00	607.50
	-(.15-.0625) $\pi(3.5)^2/2$	- 1.68		8.50	- 14.28
	-(.15-.0625) (7) (5.5)	- 3.37		8.50	- 28.65
	-(.15-.0625) (5) (2.33) (3/20)	- 0.15		2.50	- 0.38
		105.35			1157.07
W_{soil}	(.115) (24) (7)	19.32		18.00	347.76
	(.115) (22) (6)	15.18		19.00	288.42
	(.115) (18) (3.8)	7.87		21.00	165.27
	(.144) (18) (2.2)	5.70		21.00	119.70
	(.144) (14) (5)	10.08		23.00	231.84
	(.144) (10) (5)	7.20		25.00	180.00
	(.144) (5) (5)	3.60		27.50	99.00
		68.95			1431.99
P_{water} landside	- (.0625) $(26.2)^2/2$		- 21.45	8.73	- 187.26
P_{water} lockside	(.0625) $(19)^2/2$		11.28	6.33	71.40
P_{soil}	- (.5) (.115) $(16.8)^2/2$		- 8.11	31.80	- 257.90
	- (.5) (.115) (16.8) (26.2)		- 25.31	13.10	- 331.56
	- (.5) (.144-.0625) $(26.2)^2/2$		- 13.99	8.73	- 122.13
			- 47.41		- 711.59
Uplift	- (.0625) (19) (30)	-35.63		15.00	- 534.45
	- (.0625) (7.2) (30) (1/2)	- 6.75		20.00	- 135.00
		-42.38			- 669.45
Hawser	- 40/20		- 2.00	24.00	- 48.00
Total		131.92	- 59.58		1064.16

ENG FORM 1253A

PAGE OF

SUBJECT: Monolith L-20, Troy Lock and Dam - Normal Operation with Earthquake

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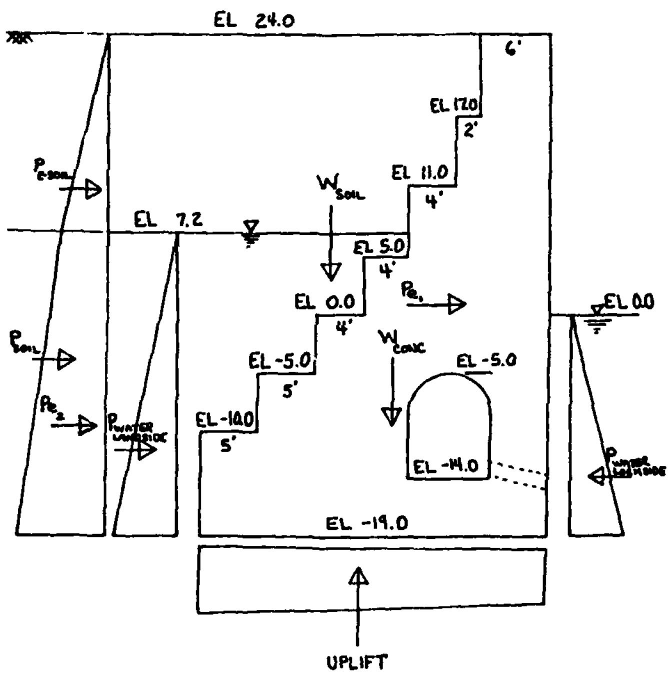

Item	Factors	F_v	F_h	Arm	Moment
Normal Operation Loads	(Full uplift under non-compressive area of base)	130.70	-57.58		1069.87
Earthquake	$Pe_1 = \alpha W = -[0.05][105.35 + 68.95]$		-8.72	20.88	-182.07
	$Pe_2 = -[2/3(51)(.05)(26.2)^2(0.7)](1/1000)$		-0.82	10.48	-8.59
	$P_{E\text{-}soil} = K_{EQK}\frac{P_{soil}}{K_{soil}} = (.11)\frac{-(39.17)}{(0.5)}$		-8.62	28.67	-247.14
		130.70	-75.74		632.17
TOTAL		130.70	-75.74		632.17

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SUBJECT: Monolith L-20, Troy Lock and Dam, Location of Center of Gravity - Normal Operation with Earthquake

COMPUTED BY: | DATE:
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LOCATION OF CENTER OF GRAVITY OF CONCRETE

Area	Arm	Moment
(6)(7) = 42.00	39.5	1,659
(8)(6) = 48.00	33.0	1,584
(12)(6) = 72.00	27.0	1,944
(16)(5) = 80.00	21.5	1,720
(20)(5) = 100.00	16.5	1,650
(25)(5) = 125.00	11.5	1,438
(30)(9) = 270.00	4.5	1,215
$-\pi(3.5)^2/2$ = -19.24	11.99	-231
-(7)(5.5) = -38.50	7.75	-298
-(5)(2.33)(3/20) = -1.75	5.67	-10
677.51		10,671

$$\bar{y} = \frac{10,671}{677.51} = 15.75'$$

LOCATION OF CENTER OF GRAVITY OF WATER

Area	Arm	Moment
$\pi(3.5)^2/2$ = 19.24	11.99	230.69
(7)(5.5) = 38.50	7.75	298.38
(5)(2.33)(3/20) = 1.75	5.67	9.92
59.49		538.99

$$\bar{y} = \frac{538.99}{59.49} = 9.06$$

LOCATION OF CENTER OF GRAVITY OF SOIL ABOVE TABLE

Area	Arm	Moment
(24)(7) = 168	39.5	6,636
(22)(6) = 132	33.0	4,356
(18)(3.8) = 68.4	28.1	1.922
368.4		12.914

$$\bar{y} = \frac{12,914}{368.4} = 35.05'$$

LOCATION OF CENTER OF GRAVITY OF SOIL BELOW TABLE

Area	Arm	Moment
(18)(2.2) = 39.6	25.1	994
(14)(5) = 70	21.5	1505
(10)(5) = 50	16.5	825
(5)(5) = 25	11.5	288
184.6		3612

$$\bar{y} = \frac{3612}{184.6} = 19.57'$$

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SUBJECT: Monolith L-20, Troy Lock and Dam, Location of Center of Gravity - Normal Operation with Earthquake (Continued)

COMPUTED BY: DATE:

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LOCATION OF CENTER OF GRAVITY OF EARTHQUAKE FORCES (Horizontal)

Item	Force	Arm	Moment
Concrete	677.51 (.15) = 101.63	15.75	1600.67
Soil (Above Water Table)	368.4 (.115) = 42.37	35.05	1485.07
Soil (Below Water Table)	184.6 (.144) = 26.58	19.57	520.17
Water	59.49 (.0625) = 3.72	9.06	33.70
	174.30		3639.61

$$\bar{y} = \frac{3639.61}{174.30} = 20.88'$$

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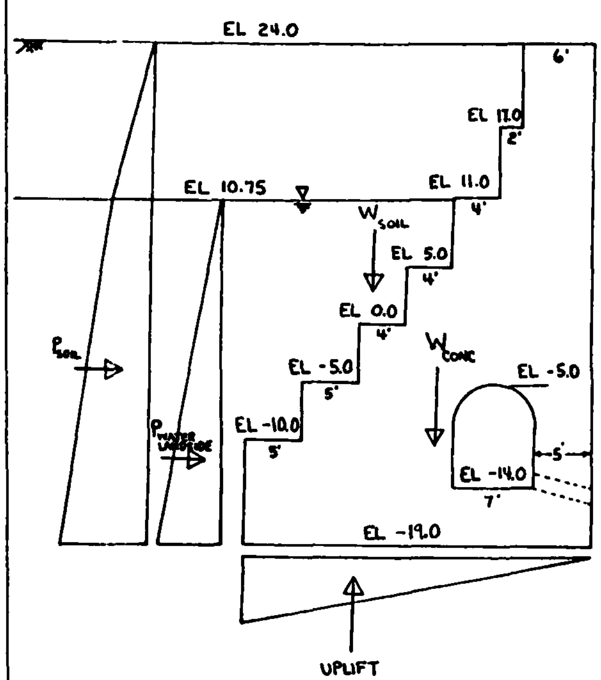
SUBJECT:	COMPUTED BY:	DATE:
Monolith L-20, Troy Lock and Dam - Dewatered	CHECKED BY:	DATE:



Item	Factor	F_v	F_h	Arm	Moment
W_{conc}	(.15)(6)(7)	6.30		3.00	18.90
	(.15)(8)(6)	7.20		4.00	28.80
	(.15)(12)(6)	10.80		6.00	64.80
	(.15)(16)(5)	12.00		8.00	96.00
	(.15)(20)(5)	15.00		10.00	150.00
	(.15)(25)(5)	18.75		12.50	234.38
	(.15)(30)(9)	40.50		15.00	607.50
	$-(.15)\ \pi(3.5)^2/2$	-2.89		8.50	-24.57
	-(.15)(7)(5.5)	-5.78		8.50	-49.13
	-(.15)(5)(2.33)(3/20)	-0.26		2.50	-0.65
		101.62			1126.03
W_{soil}	(.115)(24)(7)	19.32		18.00	347.76
	(.115)(22)(6)	15.18		19.00	288.42
	(.115)(18)(0.25)	0.52		21.00	10.92
	(.144)(18)(5.75)	14.90		21.00	312.90
	(.144)(14)(5)	10.08		23.00	231.84
	(.144)(10)(5)	7.20		25.00	180.00
	(.144)(5)(5)	3.60		27.50	99.00
		70.80			1470.84
P_{water} Landside	$-(.0625)(10.75 + 19)^2(1/2)$		-27.66	9.92	-274.39
P_{soil}	$-(.5)(.115)(24 - 10.75)^2(1/2)$		-5.05	34.17	-172.56
	-(.5) (.115)(24 - 10.75)(10.75 + 19)		-22.67	14.88	-337.33
	$-(.5)(.144 - .0625)(10.75 + 19)^2\ (1/2)$		-18.03	9.92	-178.86
			-45.75		-688.75
Uplift	-(.0625)(10.75 + 19)(30)(1/2)	-27.89		20.00	-557.80
TOTAL		144.53	-73.41		1075.93

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SUBJECT: Monolith L-20, Troy Lock and Dam - Flood Condition

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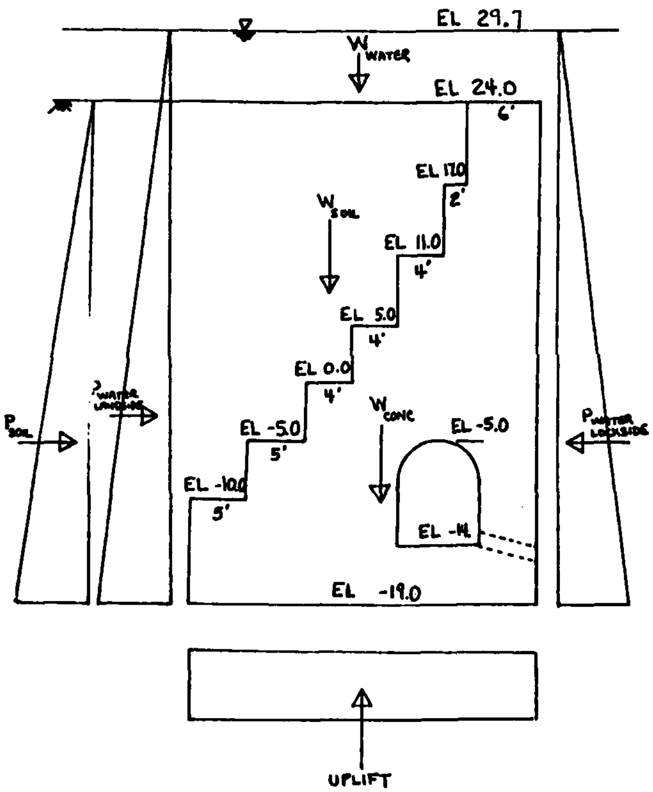

Item	Factors	F_V	F_H	Arm	Moment
W_{conc}	(.15)(6)(7)	6.30		3.00	18.90
	(.15)(8)(6)	7.20		4.00	28.80
	(.15)(12)(6)	10.80		6.00	64.80
	(.15)(16)(5)	12.00		8.00	96.00
	(.15)(20)(5)	15.00		10.00	150.00
	(.15)(25)(5)	18.75		12.50	234.38
	(.15)(30)(9)	40.50		15.00	607.50
	$-(.15 = .0625)\ \pi(3.5)^2/2$	-1.68		8.50	-14.28
	-(.15 - .0625)(7)(5.5)	-3.37		8.50	-28.65
	-(.15 - .0625)(5)(2.33)(3/20)	-0.15		2.50	-0.38
		105.35			1157.07
W_{soil}	(.144)(24)(7)	24.19		18.00	435.42
	(.144)(22)(6)	19.01		19.00	361.19
	(.144)(18)(6)	15.55		21.00	326.55
	(.144)(14)(5)	10.08		23.00	231.84
	(.144)(10)(5)	7.20		25.00	180.00
	(.144)(5)(5)	3.60		27.50	99.00
		79.63			1634.00
W_{water}	(.0625)(30)(5.7)	10.69		15.00	160.35
P_{soil}	$-(.5)(.144 - .0625)(43)^2/2$		-37.67	14.33	-539.81
Uplift	-(.0625)(48.7)(30)	-91.31		15.00	-1369.65
TOTAL		104.36	-37.67		1041.96

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SUBJECT: Monolith L-20, Troy Lock and Dam - Dewatered Condition with Surcharge Load Behind Monolith

COMPUTED BY: | DATE:

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Item	Factor	F_V	F_H	Arm	Moment
Dewatered Load	Loads taken from dewatered condition	144.53	-73.41		1075.73
Surcharge			-2.53	25.25	-63.81
Total		144.53	75.94		1012.12

NOTE: Maximum crane surcharge loading of 110 kips on each of the front pads placed behind and symmetrically along the monolith were used. (Calculations made using the distributions as defined on pages 298-299 as presented in Reference 2.)

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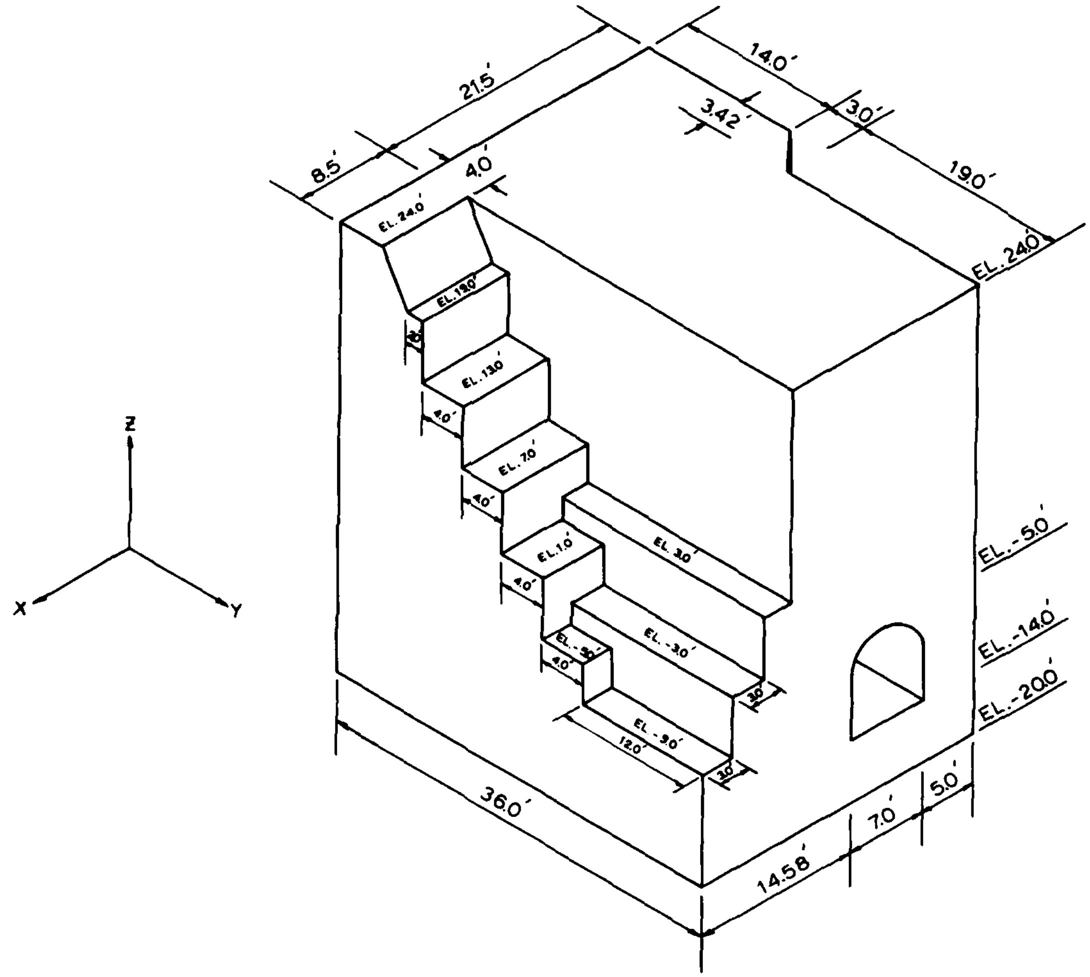
LOCK MONOLITH L-24



Stability analysis, monolith L-24, Troy Lock and Dam

SUBJECT: Monolith L-24, Troy Lock and Dam - Stability Summary - No Posttensioning

COMPUTED BY: DATE

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LOAD CASE	Effective Area of Base in Compression (%)	Factor of Safety Against Sliding	Maximum Base Pressure (ksf)
Normal Operation (Most Critical Condition of Lower Pool in Lock Chamber and No Gate Thrust)	72.3	1.33	15.60
Normal Operation with Earthquake	31.3	0.99	36.88
Flood Condition	94.1	1.65	11.45
Dewatered Condition	54.3	1.04	19.53
Dewatered Condition with Surcharge Behind Monolith	48.8	0.99	21.69

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SUBJECT: Monolith L-24, Troy Lock and Dam - Maximum Bearing Pressure (No Posttensioning)

COMPUTED BY: DATE:

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LOAD CASE	Height of Water Over Toe (ft)	Hydrostatic Pressure at Toe (ksf)	Maximum Intergranular Pressure at Toe (ksf)	Maximum Base Pressure (ksf)
Normal Operation (Most Critical Condition of Lower Pool in Lock Chamber and No Cate Thrust)	20.0	1.25	14.35	15.60
Normal Oneration with Earthquake	20.0	1.25	35.63	36.88
Flood Condition	49.7	3.11	8.34	11.45
Dewatered Condition	0.0	0.00	19.53	19.53
Dewatered Condition with Surcharge Behind Monolith	0.0	0.00	21.69	21.69

WES FORM NO. 1253A DECEMBER 1964

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SUBJECT: Monolith L-24, Troy Lock and Dam - Stability Summary - After Posttensioning

COMPUTED BY: DATE:

CHECKED BY: DATE:

LOAD CASE	Effective Area of Base in Compression (%)	Factor of Safety Against Sliding	Maximum Base Pressure (ksf)
Normal Operation (Most Critical Condition of Lower Pool in Lock Chamber and No Gate Thrust)	89.6	1.69	15.74
Normal Operation with Earthquake	61.8	1.25	22.71
Flood Condition	100.0	2.21	11.89
Dewatered Condition	80.1	1.31	16.32
Dewatered Condition with Surcharge Behind Monolith	75.9	1.26	17.12

WES FORM NO. 1253A

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SUBJECT: Monolith L-24, Troy Lock and Dam - Maximum Bearing Pressure - After Posttensioning

COMPUTED BY: DATE:

CHECKED BY: DATE:

LOAD CASE	Height of Water Over Toe (ft)	Hydrostatic Pressure at Toe (ksf)	Maximum Intergranular Pressure at Toe (ksf)	Maximum Base Pressure (ksf)
Normal Operation (Most Critical Condition of Lower Pool in Lock Chamber and No Gate Thrust)	20.0	1.25	14.49	15.74
Normal Operation with Earthquake	20.0	1.25	21.46	22.71
Flood Condition	49.7	3.11	8.78	11.89
Dewatered Condition	0.0	0.00	16.32	16.32
Dewatered Condition with Surcharge Behind Monolith	0.0	0.00	17.12	17.12

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AD-A094 683 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS F/G 13/13
ENGINEERING CONDITION SURVEY AND EVALUATION OF TROY LOCK AND DA--ETC(U)
JAN 81 C E PACE, R CAMPBELL, S WONG
UNCLASSIFIED WES-MP-C-78-6-2 NL

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AD
A094683

SUBJECT: Monolith L-24, Troy Lock and Dam - Normal Operation (Lower Pool in Chamber)

COMPUTED BY: | DATE:

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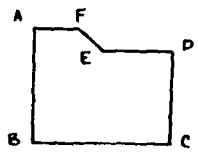
<u>Base Area Properties - Initial</u>

Area (ft^2)	Inertia About Principle X-Axis (ft^4)	Inertia About Principle Y-Axis (ft^4)	XBar (ft)	YBar (ft)	ZBar (ft)	Angle Principle X-Axis Makes with X-Axis (Degrees)
1009.89	111041	66241	15.93	17.46	0.0	-10.05

<u>Summary of Forces and Moments - Initial</u>

F_x (kips)	F_y (kips)	F_z (kips)	M_{xx} (ft-k)	M_{yy} (ft-k)	M_{zz} (ft-k)
2163.02	0.00	4922.33	-85,225.4	42,868.1	38934.4



<u>Base Pressures - Initial</u>

Pressure Point	X Coordinate	Y Coordinate	Z Coordinate	Pressure (ksf)
A	0.00	0.00	0.00	12.76
B	30.00	0.00	0.00	-3.10
C	30.00	36.00	0.00	-2.00
D	3.42	36.00	0.00	12.05
E	3.42	17.00	0.00	11.47
F	0.00	14.00	0.00	13.19

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SUBJECT: Monolith L-24, Troy Lock and Dam - Normal Operation (Lower Pool in Chamber)

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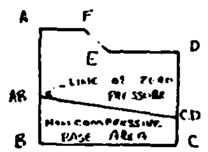
Base Area Properties - Final*

Area (ft^2)	Inertia About Principle X-Axis (ft^4)	Inertia About Principle Y-Axis (ft^4)	XBar (ft)	YBar (ft)	ZBar (ft)	Angle Principle X-Axis Makes with X-Axis (Degrees)
730.3	81041	24921	12.04	17.46	0.00	-8.93

Summary of Forces and Moments - Final*

F_x (kips)	F_y (kips)	F_z (kips)	M_{xx} (ft-k)	M_{yy} (ft-k)	M_{zz} (ft-k)
2163.02	0.00	4859.43	-84,163.6	41,739.5	38,934.4



Base Pressures - Final*

Pressure Point	X Coordinate	Y Coordinate	Z Coordinate	Pressure (ksf)
A	0.00	0.00	0.00	13.65
AB	20.86	0.00	0.00	0.00
CD	23.60	36.00	0.00	0.00
D	3.42	36.00	0.00	13.21
E	3.42	-17.00	0.00	12.26
F	0.00	-14.00	0.00	14.35

* Values are after iteration releasing tension at base-foundation interface and applying full uplift under noncompressive area of base.

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SUBJECT: Monolith L-24, Troy Lock and Dam - Normal Operation with Earthquake

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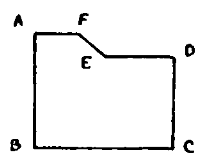
Base Area Properties - Initial

Area (ft^2)	Inertia About Principle X-Axis (ft^4)	Inertia About Principle Y-Axis (ft^4)	XBar (ft)	YBar (ft)	ZBar (ft)	Angle Principle X-Axis Makes with X-Axis (Degrees)
1009.89	111041	66241	15.93	17.46	0.0	-10.05

Summary of Forces and Moments - Initial

F_x (kips)	F_y (kips)	F_z (kips)	M_{xx} (ft-k)	M_{yy} (ft-k)	M_{zz} (ft-k)
-2906.72	0.00	4860.77	-84,163.6	22,833.3	91,255.4

Base Pressures - Initial



Pressure Point	X Coordinate	Y Coordinate	Z Coordinate	Pressure (ksf)
A	0.00	0.00	0.00	16.87
B	30.00	0.00	0.00	-7.51
C	30.00	36.00	0.00	-5.69
D	3.42	36.00	0.00	15.92
E	3.42	17.00	0.00	14.95
F	0.00	14.00	0.00	17.58

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SUBJECT: Monolith L-24, Troy Lock and Dam - Normal Operation with Earthquake

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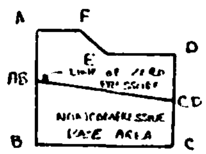
Base Area Properties - Final*

Area (ft^2)	Inertia About Principle X-Axis (ft^4)	Inertia About Principle Y-Axis (ft^4)	XBar (ft)	YBar (ft)	ZBar (ft)	Angle Principle X-Axis Makes with X-Axis (Degrees)
316.45	35630.6	2102.7	6.27	17.66	0.00	7.63

Summary of Forces and Moments - Final*

F_x (kips)	F_y (kips)	F_z (kips)	M_{xx} (ft-k)	M_{yy} (ft-k)	M_{zz} (ft-k)
-2906.72	0.00	-4859.43	-84,163.6	22,833.2	91,255.4

Base Pressures - Final*



Pressure Point	X Coordinate	Y Coordinate	Z Coordinate	Pressure (ksf)
A	0.00	0.00	0.00	30.20
AB	8.72	0.00	0.00	0.00
CD	12.76	36.00	0.00	0.00
D	3.42	36.00	0.00	32.33
E	3.42	17.00	0.00	24.95
F	0.00	14.00	0.00	35.63

* Values are after iteration releasing tension at base-foundation interface.

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SUBJECT: Monolith L-24, Troy Lock and Dam - Flood Condition

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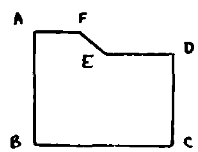
Base Area Properties - Initial

Area (ft^2)	Inertia About Principle X-Axis (ft^4)	Inertia About Principle Y-Axis (ft^4)	XBar (ft)	YBar (ft)	ZBar (ft)	Angle Principle X-Axis Makes with X-Axis (Degrees)
1009.89	11140.8	66241.2	15.93	17.46	0.00	-10.05

Summary of Forces and Moments - Initial

F_x (kips)	F_y (kips)	F_z (kips)	M_{xx} (ft-k)	M_{yy} (ft-k)	M_{zz} (ft-k)
-1356.24	0.00	-3742.13	-65,729.3	39,900.7	24,412.3

Base Pressures - Initial



Pressure Point	X Coordinate	Y Coordinate	Z Coordinate	Pressure (ksf)
A	0.00	0.00	0.00	7.96
B	30.00	0.00	0.00	-0.86
C	30.00	36.00	0.00	0.01
D	3.42	36.00	0.00	7.83
E	3.42	17.00	0.00	7.37
F	0.00	14.00	0.00	8.30

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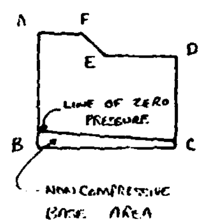

Base Area Properties - Final*

Area (ft^2)	Inertia About Principle X-Axis (ft^4)	Inertia About Principle Y-Axis (ft^4)	XBar (ft)	YBar (ft)	ZBar (ft)	Angle Principle X-Axis Makes with X-Axis (Degrees)
949.82	106214	54004	15.10	17.78	0.00	-13.34

Summary of Forces and Moments - Final*

F_x (kips)	F_y (kips)	F_z (kips)	M_{xx} (ft-k)	M_{yy} (ft-k)	M_{zz} (ft-k)
-1356.24	0.00	-3738.35	-65,729.3	39,900.7	24,412.3

Base Pressures - Final*

Pressure Point	X Coordinate	Y Coordinate	Z Coordinate	Pressure (ksf)
A	0.00	0.00	0.00	7.98
AB	26.77	0.00	0.00	0.00
CD	29.90	36.00	0.00	0.00
D	3.42	36.00	0.00	7.89
E	3.42	17.00	0.00	7.40
F	0.00	14.00	0.00	8.34

* Values are after iteration releasing tension at base-foundation interface.

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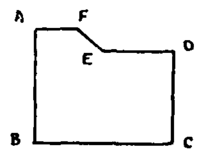

Base Area Properties - Initial

Area (ft^2)	Inertia About Principle X-Axis (ft^4)	Inertia About Principle Y-Axis (ft^4)	XBar (ft)	YBar (ft)	ZBar (ft)	Angle Principle X-Axis Makes with X-Axis (Degrees)
1009.89	111041	66241	15.93	17.46	0.00	-10.05

Summary of Forces and Moments - Initial

F_x (kips)	F_y (kips)	F_z (kips)	M_{xx} (ft-k)	M_{yy} (ft-k)	M_{zz} (ft-k)
-2782.44	0.00	5313.68	92,241.4	40,783.7	50,083.9

Base Pressures - Initial

Pressure Point	X Coordinate	Y Coordinate	Z Coordinate	Pressure (ksf)
A	0.00	0.00	0.00	14.95
B	30.00	0.00	0.00	-4.64
C	30.00	36.00	0.00	-3.17
D	3.42	36.00	0.00	14.19
E	3.42	17.00	0.00	13.41
F	0.00	14.00	0.00	15.52

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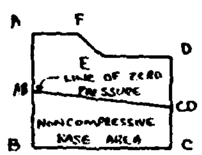
Base Area Properties - Final*

Area (ft^2)	Inertia About Principle X-Axis (ft^4)	Inertia About Principle Y-Axis (ft^4)	XBar (ft)	YBar (ft)	ZBar (ft)	Angle Principle X-Axis Makes with X-Axis (Degrees)
548.23	61068	10609	9.51	17.69	0.00	-8.14

Summary of Forces and Moments - Final*

F_x (kips)	F_y (kips)	F_z (kips)	M_{xx} (ft-k)	M_{yy} (ft-k)	M_{zz} (ft-k)
-2782.44	0.00	-4871.42	84,640.3	33,574.8	50,083.9

Base Pressures - Final*



Pressure Point	X Coordinate	Y Coordinate	Z Coordinate	Pressure (ksf)
A	0.00	0.00	0.00	17.97
AB	15.45	0.00	0.00	0.00
CD	18.90	36.00	0.00	0.00
D	3.42	36.00	0.00	18.00
E	3.42	17.00	0.00	15.89
F	0.00	14.00	0.00	19.53

* Values are after iteration releasing tension at base-foundation interface and applying full uplift under noncompressive area of base.

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SUBJECT: Monolith L-24, Troy Lock and Dam - Dewatered Condition with Surcharge Behind Monolith

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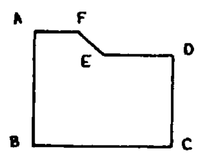
Base Area Properties - Initial

Area (ft^2)	Inertia About Principle X-Axis (ft^4)	Inertia About Principle Y-Axis (ft^4)	XBar (ft)	YBar (ft)	ZBar (ft)	Angle Principle X-Axis Makes with X-Axis (Degrees)
1009.89	111041	66241	15.93	17.46	0.0	-10.05

Summary of Forces and Moments - Initial

F_x (kips)	F_y (kips)	F_z (kips)	M_{xx} (ft-k)	M_{yy} (ft-k)	M_{zz} (ft-k)
2870.40	0.0	5313.68	92,241.4	38,511.7	516,667.2

Base Pressures - Initial



Pressure Point	X Coordinate (ft)	Y Coordinate (ft)	Z Coordinate (ft)	Pressure (ksf)
A	0.00	0.00	0.00	15.45
B	30.00	0.00	0.00	-5.16
C	30.00	36.00	0.00	-3.60
D	3.42	36.00	0.00	14.65
E	3.42	17.00	0.00	13.83
F	0.00	14.00	0.00	16.05

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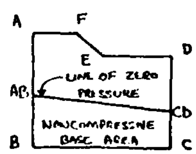
Base Area Properties - Final*

Area (ft^2)	Inertia About Principle X-Axis (ft^4)	Inertia About Principle Y-Axis (ft^4)	XBar (ft)	YBar (ft)	ZBar (ft)	Angle Principle X-Axis Makes with X-Axis (Degrees)
492.41	54938	7716	8.73	17.69	0.00	-7.96

Summary of Forces and Moments - Final*

F_x (kips)	F_y (kips)	F_z (kips)	M_{xx} (ft-k)	M_{yy} (ft-k)	M_{zz} (ft-k)
-2870.4	0.0	-4817.83	-83,691.5	30,683.9	51,667.2

Base Pressures - Final*



Pressure Point	X Coordinate (ft)	Y Coordinate (ft)	Z Coordinate (ft)	Pressure (ksf)
A	0.00	0.00	0.00	19.70
AB	13.82	0.00	0.00	0.00
CD	17.43	36.00	0.00	0.00
D	3.42	36.00	0.00	19.96
E	3.42	17.00	0.00	17.25
F	0.00	14.00	0.00	21.69

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SUBJECT: Monolith L-24, Troy Lock and Dam - Normal Operation (Lower Pool in Chamber)

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Item	Factors	F_x	F_y	F_z	Arm_{xx}	Arm_{yy}	M_{xx}	M_{yy}
W_{conc}	(.15)(8.5)(4)(33)			168.30	2.00	25.75	336.60	4,333.73
	(.15)(8.5)(2)(5)(1/2)			6.38	4.67	25.75	29.79	164.29
	(.15)(8.5)(4)(28)			142.80	6.00	25.75	856.80	3,677.10
	(.15)(8.5)(4)(22)			112.20	10.00	25.75	1,122.00	2,881.15
	(.15)(8.5)(4)(16)			81.60	14.00	25.75	1,142.40	2,101.20
	(.15)(6.0)(4)(10)			36.00	18.00	27.00	648.00	972.00
	(.15)(3.0)(4)(4)			7.20	22.00	28.5	158.40	205.20
	(.15)(8.5)(36)(11)			504.90	18.00	25.75	9,088.20	13,001.18
	(.15)(3)(16)(6)			43.20	28.00	25.50	1,209.60	1,101.60
	(.15)(2.5)(20)(12)			90.00	26.00	22.75	2,340.00	2,047.50
	(.15)(18.08)(36)(44)			4295.81	18.00	12.46	77,324.58	53,526.79
	(.15)(3.42)(14)(44)			316.01	7.00	1.71	2,212.07	540.88
	(.15)(3.42)(3)(44)(1/2)			33.86	15.00	2.28	507.90	77.20
	-(.15 - .0625)(7)(18.58)(5.5)			-62.59	26.71	11.92	-1,671.78	-746.07
	-(.15 - .0625)(π)(3.5)^2)(18.58)(1/2)			-31.28	26.71	11.92	-835.49	-372.86
	-(.15 - .0625)(π/4)[14.92^2 - 7.92^2](5.5)			-60.43	9.92	8.00	-599.47	-483.44
	-(.15 - .0625)[π(3.5)^2(1/2)][(2)(π)(11.42)(1/4)]			-30.20	9.92	8.00	-299.58	-241.65
	-(.15 - .0625)(.5)(7)(5.5)$_2$			-1.62	6.00	0.25	-10.08	-0.42
	-(.15 - .0625)(.5)(π)(3.5)^2(1/2)			-0.84	6.00	0.25	-5.04	-0.21
				5651.24			93,554.90	82,791.72
W_{soil}	(.115)(8.5)(2)(5)1/2			4.89	5.33	25.75	26.06	125.92
	(.115)(8.5)(2)(5)			9.78	7.00	25.75	68.46	251.84
	(.115)(8.5)(4)(11)			43.01	10.00	25.75	430.10	1,107.51
	[(.115)(16.8) + (.144)(0.2)](8.5)(4)			66.67	14.00	25.75	933.38	1,716.75
	[(.115)(16.8) + (.144)(6.2)](6.0)(4)			67.80	18.00	27.00	1,220.40	1,830.60
	[(.115)(16.8) + (.144)(12.2)](3.0)(4)			44.27	22.00	28.50	973.94	1,261.70
	[(.115)(16.8) + (.144)(4.2)](20)(2.5)			126.84	26.00	22.75	3,297.84	2,888.61
	[(.115)(16.8) + (.144)(10.2)](16)(3)			163.24	28.00	25.50	4,570.72	4,162.62
	[(.115)(16.8) + (.144)(16.2)](12)(3)			153.53	30.00	28.50	4,605.90	4,375.61
				680.03			16,126.80	17,718.16
P_{soil}	(.5)[(1/2)(.115)(16.8)^2](36)	-292.12				32.80		-9,581.54
	(.5)[(.115)(16.8)(27.2)](36)	-945.91				13.60		-12,864.38
	(.5)[(1/2)(.144 - .0625)(27.2)^2](36)	-542.67				9.09		-4,932.87
		-1780.70						-27,378.79
P_{water} landside	(1/2)(.0625)(27.2)^2(36)	-832.32				9.09		-7,565.79
Sub-Total		-2613.02		6331.27			109,681.70	65,565.30

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Monolith L-24, Troy Lock and Dam - Normal Operation (Continued)

Item	Factors	F_x	F_y	F_z	Arm_{xx}	Arm_{yy}	M_{xx}	M_{yy}
P_{water} lockside	$(1/2)(.0625)(20)^2(36)$	450.00				6.67		3,001.50
Uplift	-(.0625)(20)(30)(14)			-525.00	7.00	15.00	-3,675.00	-7,875.00
	-(.0625)(7.2)(30)(14)(1/2)			-94.50	7.00	20.00	-661.50	-1,890.00
	-(.0625)(20)(28.29)(3)			-106.07	15.50	15.86	-1,644.40	-1,682.59
	-(.0625)(7.2)(28.29)(3)(1/2)			-19.10	15.50	20.57	-296.05	-392.81
	-(.0625)(20)(26.58)(19)			-631.28	26.50	16.71	-16,728.92	-10,548.69
	-(.0625)(7.2)(26.58)(19)(1/2)			-113.63	26.50	21.14	-3,011.20	-2,402.14
				-1489.60			-26,017.07	-24,791.31
W_{gate}	(85/0.49)[24/40(.49) + 16/40(.49 - .0625)]			80.66	19.35	-11.25	1,560.77	-907.43
Total		-2163.02		4922.33			85,225.40	42,868.06

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SUBJECT: Monolith L-24, Troy Lock and Dam - Normal Operation with Earthquake

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Item	Factors	F_x	F_y	F_z	Arm_{xx}	Arm_{yy}	M_{xx}	M_{yy}
Normal Operation Loads	(Values are after releasing tension at base-foundation interface and applying full uplift under non-compressive area of base)	-2163.02		4859.43			84,163.60	41,739.50
Earthquake	$P_{e_1} = \alpha W = [0.05][5651.24 + 680.03 + 74.02]$	-320.26				22.08		-7,071.34
	$P_{e_2} = (.7)[2/3(51)(.05)(27.2)^2](36)(1/1000)$	-31.69				10.88		-344.79
	$P_{e\text{-soil}} = K_{EQK}\, P_{soil}/K_{soil} = (.11)(1780.70)/(0.50)$	-391.75				29.33		-11,490.03
Total		-2906.72		4859.43			84,163.60	22,833.34

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Monolith L-24, Troy Lock and Dam, Centroid Location - Normal Operation with Earthquake	CHECKED BY:	DATE:

Location of Centroid in Y-Z Plane - Concrete

Volume		Arm	Volume-Moment
$(8.5)(4)(33) =$	1,122.00	27.50	30,855.00
$(1/2)(8.5)(2)(5) =$	42.50	40.67	1,728.48
$(8.5)(4)(28) =$	958.00	25.00	23,800.00
$(8.5)(4)(22) =$	748.00	22.00	16,456.00
$(8.5)(4)(16) =$	544.00	19.00	10,336.00
$(6)(4)(10) =$	240.00	16.00	3,840.00
$(3)(4)(4) =$	98.00	13.00	624.00
$(8.5)(36)(11) =$	3,366.00	5.50	18,513.00
$(3.0)(16)(6) =$	288.00	14.00	4,032.00
$(8.5)(20)(12) =$	600.00	17.00	10,200.00
$(18.08)(36)(44) =$	28,688.72	22.00	630,051.84
$(3.42)(14)(44) =$	2,106.72	22.00	46,347.84
$(1/2)(3.42)(3)(44) =$	225.72	22.00	4,965.84
$-(7)(18.58)(5.5) =$	-715.33	8.75	-6,259.14
$-(1/2)\pi(3.5)^2(18.58) =$	-357.52	12.99	-4,644.19
$-(\pi/4)[(14.92)^2 - (7.92)^2](5.5) =$	-690.63	8.75	-6,043.01
$-[\pi(3.5)^2(1/2)][2\pi(11.42)(1/4)] =$	-345.18	12.99	-4,483.89
$-(.5)(7)(5.5) =$	-19.25	8.75	-168.44
$-(.5)(\pi)(3.5)^2(1/2) =$	-9.62	12.99	-124.96
	36,784.13		780,026.37

$$\bar{Z} = \frac{780,026.37}{36,784.13} = 21.21 \text{ ft}$$

Location of Centroid in Y-Z Plane - Water (in Structure)

Volume		Arm	Volume-Moment
$(7)(18.58)(5.5) =$	715.33	8.75	6,259.14
$(1/2)(\pi)(3.5)^2(18.58) =$	357.52	12.99	4,644.19
$(\pi/4)[(14.92)^2 - (7.92)^2](5.5) =$	690.63	8.75	6,043.01
$[\pi(3.5)^2(1/2)][2\pi(11.42)(1/4)] =$	345.18	12.79	4,483.89
$(.5)(7)(5.5) =$	19.25	8.75	168.44
$(.5)(\pi)(3.5)^2(1/2) =$	9.62	12.79	124.96
	2,137.53		21,723.63

$$\bar{Z} = \frac{21,723.63}{2,137.53} = 10.16 \text{ ft}$$

WES FORM NO. 1253A

SUBJECT	COMPUTED BY:	DATE
Monolith L-24, Troy Lock and Dam, Centroid Location - Normal Operation with Earthquake (Continued)	CHECKED BY:	DATE:

Location of Centroid in Y-Z Plane - Soil (Above Water Table)

Volume		Arm	Volume-Moment
(1/2)(8.5)(2)(5) =	42.50	42.33	1,799.03
(8.5)(2)(5) =	85.00	41.50	3,527.50
(8.5)(4)(11) =	374.00	38.50	14,399.00
(8.5)(24)(16.8) =	3,427.20	35.60	122,008.32
	3,928.70		141,733.85

$$\bar{Z} = \frac{141,733.85}{3,928.70} = 36.08 \text{ ft}$$

Location of Centroid in Y-Z Plane - Soil (Below Water Table)

Volume		Arm	Volume-Moment
(8.5)(4)(0.2) =	6.80	27.10	184.28
(6)(4)(6.2) =	148.80	24.10	3,586.08
(3)(4)(12.2) =	146.40	21.10	3,089.04
(2.5)(20)(4.2) =	210.00	25.10	5,271.00
(3)(16)(10.2) =	489.60	22.10	10,820.16
(3)(12)(16.2) =	583.20	19.10	11,139.12
	1,584.80		34,089.68

$$\bar{Z} = \frac{34,089.68}{1,584.80} = 21.51 \text{ ft}$$

WES FORM NO. 1253A
DECEMBER 1964

PAGE OF

SUBJECT: Monolith L-24, Troy Lock and Dam, Centroid Location - Normal Operation with Earthquake (Continued)

COMPUTED BY: DATE:

CHECKED BY: DATE:

Location of Centroid of Horizontal Earthquake Forces Above Base of Structure

Item	Force		Arm	Moment
Concrete	(36,784.13)(.15) =	5,517.62	21.21	117,028.71
Water (in Structure)	(2,137.53)(.0625) =	133.60	10.16	1,357.38
Soil (Above Water Table)	(3,928.70)(.115) =	451.80	36.08	16,300.94
Soil (Below Water Table)	(1,584.80)(.144) =	228.21	21.51	4,908.80
Gate (Above Water)	(85)(24/40) =	51.00	32.00	1,632.00
Gate (Below Water)	(85)(16/40)(.49 - 0.0625)/(.49) =	29.66	12.00	355.92
		6,411.89		141,583.75

$$\overline{Y} = \frac{141,583.75}{6,411.89} = 22.08$$

WES FORM NO. 1253A

PAGE OF

SUBJECT: Monolith L-24, Troy Lock and Dam - Flood Condition

COMPUTED BY: DATE:

CHECKED BY: DATE:

Item	Factors	F_x	F_y	F_z	Arm_{xx}	Arm_{yy}	M_{xx}	M_{yy}
W_{conc}	(.15)(8.5)(4)(33)			168.30	2.00	25.75	336.60	4,333.73
	(.15)(8.5)(2)(5)(1/2)			6.38	4.67	25.75	29.79	164.29
	(.15)(8.5)(4)(28)			142.80	6.00	25.75	856.80	3,677.10
	(.15)(8.5)(4)(22)			112.20	10.00	25.75	1,122.00	2,889.15
	(.15)(8.5)(4)(16)			81.60	14.00	25.75	1,142.40	2,101.20
	(.15)(6.0)(4)(10)			36.00	18.00	27.00	648.00	972.00
	(.15)(3.0)(4)(4)			7.20	22.00	28.50	158.40	205.20
	(.15)(8.5)(36)(11)			504.90	18.00	25.75	9,088.20	13,001.18
	(.15)(3)(16)(6)			43.20	28.00	25.5	1,209.60	1,101.60
	(.15)(2.5)(20)(12)			90.00	26.00	22.75	2,340.00	2,047.50
	(.15)(18.08)(36)(44)			4295.81	18.00	12.46	77,324.58	53,525.79
	(.15)(3.42)(14)(44)			316.01	7.00	1.71	2,212.07	540.38
	(.15)(3.42)(3)(44)(1/2)			33.86	15.00	2.28	507.90	77.20
	-(.15 - .0625)(7)(18.58)(5.5)			-62.59	26.71	11.92	-1,671.78	-746.07
	-(.15 - .0625)(π)(3.5)^2(18.58)(1/2)			-31.28	26.71	11.92	-835.49	-372.86
	-(.15 - .0625)(π/4)[(14.92)^2 - (7.92)^2](5.5)			-60.43	9.92	8.00	-599.47	-483.44
	-(.15 - .0625)[(π)(3.5)^2(1/2)][(2π)(11.42)(1/4)]			-30.20	9.92	8.00	-299.58	-241.60
	-(.15 - .0625)(.5)(7)(5.5)			-1.68	6.00	0.25	-10.08	-0.42
	-(.15 - .0625)(.5)(π)(3.5)^2(1/2)			-0.84	6.00	0.25	-5.04	-0.21
				5651.24			93,554.90	82,791.72
W_{soil}	(.144)(8.5)(2)(5)(1/2)			6.12	5.33	25.75	32.62	157.59
	(.144)(8.5)(2)(5)			12.24	7.00	25.75	85.68	315.18
	(.144)(8.5)(4)(11)			53.86	10.00	25.75	538.60	1,386.90
	(.144)(8.5)(4)(17)			83.23	14.00	25.75	1,165.22	2,143.17
	(.144)(6)(4)(23)			79.49	18.00	27.00	1,430.82	2,146.23
	(.144)(3)(4)(29)			50.11	22.00	28.50	1,102.42	1,428.14
	(.144)(20)(2.5)(21)			151.20	26.00	22.75	3,931.20	3,439.80
	(.144)(16)(3)(27)			186.62	28.00	25.50	5,225.36	4,758.81
	(.144)(12)(3)(33)			171.07	30.00	28.50	5,132.10	4,875.50
				793.94			18,644.02	20,651.32
W_{water}	(.0625)(30)(36)(5.7)			384.75	18.00	15.00	6,925.50	5,771.25
	-(.0625)(3.42)(19)(5.7)			-23.15	26.50	1.71	-613.48	-39.59
	-(.0626)(3.42)(3)(5.7)(1/2)			-1.83	16.00	1.14	-29.28	-2.09
				359.77			6,282.74	5,729.59
P_{soil}	(.5)(.144 - .0625)(43)^2(1/2)(36)	-1356.24				14.33		-19,434.92
Sub-Total		-1356.24		6804.95			118,481.66	89,737.69

WES FORM NO. 1253A DECEMBER 1964

PAGE OF

SUBJECT: Monolith L-24, Troy Lock and Dam - Flood Condition (Continued)

COMPUTED BY: DATE:

CHECKED BY: DATE:

Item	Factors	F_x	F_y	F_z	Arm_{xx}	Arm_{yy}	M_{xx}	M_{yy}
Uplift	(.0625)(49.70)(30)(4)			-1304.63	7.00	15.00	-9,132.41	-19,569.45
	(.0625)(49.70)(28.29)(3)			-263.63	15.50	15.86	-4,086.27	-4,181.17
	(.0625)(49.70)(26.58)(19)			-1568.72	26.50	16.71	-41,570.82	-26,213.14
				-3136.98			-54,789.50	-49,963.76
W_{gate}	(85)(.490 - .0625)/(.490)			74.16	27.47	1.71	2,037.18	126.81
Total		-1356.24		3742.13			65,729.34	39,900.74

WES FORM NO. 1253A

PAGE OF

SUBJECT

Monolith L-24, Troy Lock and Dam - Dewatered Condition

COMPUTED BY:

DATE:

CHECKED BY:

DATE:

Item	Factors	F_x	F_y	F_z	Arm_{xx}	Arm_{yy}	M_{xx}	M_{yy}
W_{conc}	(.15)(8.5)(4)(33)			168.30	2.00	25.75	336.60	4,333.73
	(.15)(8.5)(2)(5)(1/2)			6.38	4.67	25.75	29.79	164.29
	(.15)(8.5)(4)(28)			142.80	6.00	25.75	856.80	3,677.10
	(.15)(8.5)(4)(22)			112.20	10.00	25.75	1,122.00	2,889.15
	(.15)(8.5)(4)(16)			81.60	14.00	25.75	1,142.40	2,101.20
	(.15)(6.0)(4)(10)			36.00	18.00	27.00	648.00	972.00
	(.15)(3.0)(4)(4)			7.20	22.00	28.50	158.40	205.20
	(.15)(8.5)(36)(11)			504.90	18.00	25.75	9,088.20	13,001.18
	(.15)(3)(16)(6)			43.20	28.00	25.5	1,209.60	1,101.60
	(.15)(2.5)(20)(12)			90.00	26.00	22.75	2,340.00	2,047.50
	(.15)(18.08)(36)(44)			4295.81	18.00	12.46	77,324.58	53,525.79
	(.15)(3.42)(14)(44)			316.01	7.00	1.71	2,212.07	540.38
	(.15)(3.42)(3)(44)(1/2)			33.86	15.00	2.28	507.90	77.20
	-(.15)(7)(18.58)(5.5)			-107.30	26.71	11.92	-2,865.98	-1,279.02
	$-(.15)(\pi)(3.5)^2(18.58)(1/2)$			-53.63	26.71	11.92	-1,432.46	-639.27
	$-(.15)(\pi/4)[(14.92)^2 - (7.92)^2](5.5)$			-103.59	9.92	8.00	-1,027.61	-828.72
	$-(.15)[(\pi)(3.5)^2(1/2)][(2\pi)(11.42)(1/4)]$			-51.78	9.92	8.00	-513.66	-414.24
	-(.15)(7)(5.5)(.5)			-2.89	6.00	0.25	-17.34	-0.72
	$-(.15)(\pi)(3.5)^2(1/2)(.5)$			-1.44	6.00	0.25	-8.64	-0.36
				5517.63			91,110.65	81,473.99
W_{soil}	(.115)(8.5)(2)(5)(1/2)			4.89	5.33	25.75	26.06	125.92
	(.115)(8.5)(2)(5)			9.78	7.00	25.75	68.46	251.89
	(.115)(6.0)(8.5)(4)			23.46	10.00	25.75	234.60	604.10
	[(.115)(13.25) + (.144)(3.75)](8.5)(4)			70.17	14.00	25.75	982.38	1,806.88
	[(.115)(13.25) + (.144)(9.75)](6.0)(4)			70.27	18.00	27.00	1,264.86	1,897.29
	[(.115)(13.25) + (.144)(15.75)](3.0)(4)			45.50	22.00	28.50	1,001.00	1,296.75
	[(.115)(13.25) + (.144)(7.75)](20)(2.5)			131.99	26.00	22.75	3,431.74	3,002.77
	[(.115)(13.25) + (.144)(13.75)](16)(3)			168.18	28.00	25.50	4,709.04	4,288.59
	[(.115)(13.25) + (.144)(19.75)](12)(3)			157.24	30.00	28.50	4,717.20	4,481.34
				681.48			16,435.34	17,755.48
P_{soil}	$(.5)[(1/2)(.115)(13.25)^2](36)$	-181.71				35.17		-6,390.79
	(.5)[(.115)(13.25)(30.75)](36)	-843.40				15.38		-12,971.49
	$(.5)[(1/2)(.144 - .0625)(30.75)^2](36)$	-693.57				10.25		-7,109.09
		-1718.68						-26,471.32
P_{water} landside	$(1/2)(.0625)(30.75)^2(36)$	-1063.76				10.35		-11,009.92
Sub-Total		-2782.44		6199.11			107,545.99	61,748.23

WES FORM NO. 1253A

PAGE OF

SUBJECT: Monolith L-24, Troy Lock and Dam - Dewatered Condition (Continued)

COMPUTED BY: | DATE:

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Item	Factors	F_x	F_y	F_z	Arm_{xx}	Arm_{yy}	M_{xx}	M_{yy}
Uplift	-(1/2)(.0625)(30.75)(30)(14)			-403.59	7.00	20.00	-2,825.13	-8,071.80
	-(1/2)(.0625)(30.75)(28.29)(3)			-81.55	15.50	20.57	-1,264.03	-1,677.48
	-(1/2)(.0625)(30.75)(26.58)(19)			-485.29	26.50	21.14	-12,860.19	-10,859.03
				-970.43			-16,949.35	-20,008.31
W_{gate}				85.00	19.35	-11.25	1,644.75	-956.25
Total		-2782.44		5313.68			92,241.39	40,783.67

WES FORM NO. 1253A

PAGE OF

SUBJECT: Monolith L-24, Troy Lock and Dam - Dewatered Condition with Surcharge Load Behind Monolith

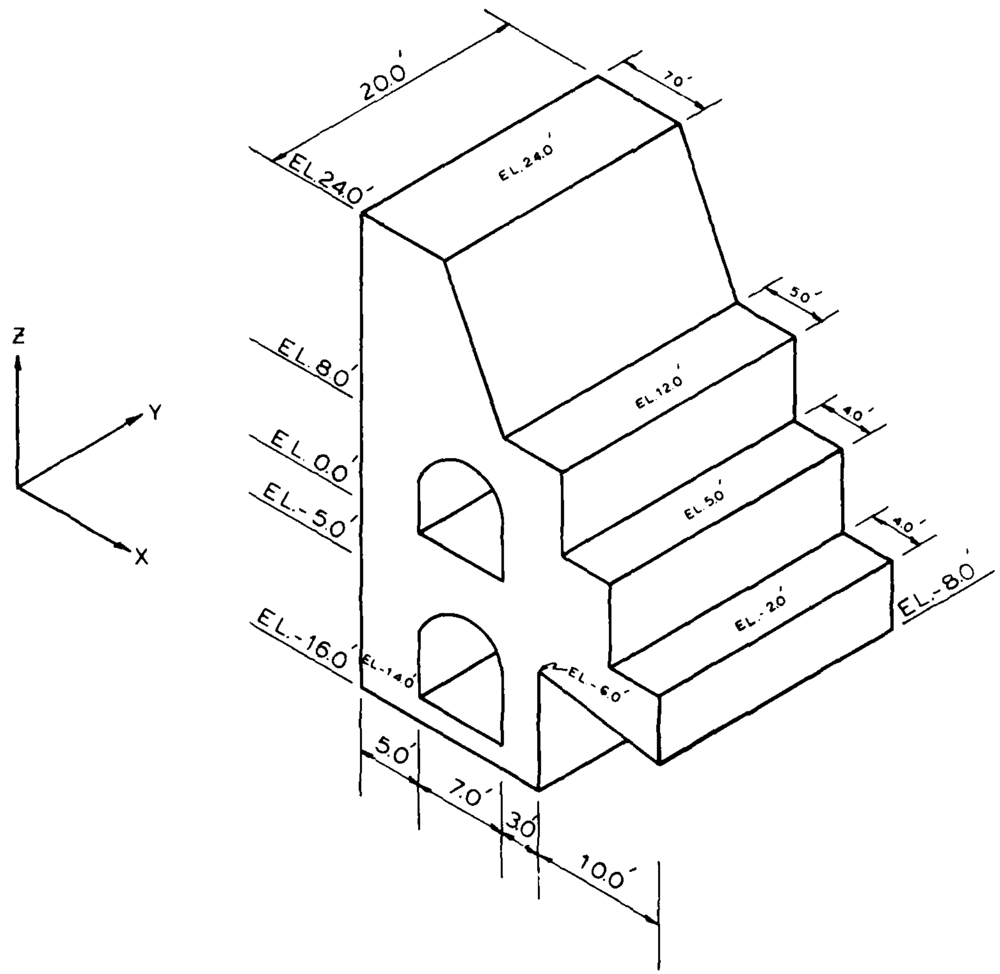
COMPUTED BY: DATE:

CHECKED BY: DATE:

Item	Factors	F_x	F_y	F_z	Arm_{xx}	Arm_{yy}	M_{xx}	M_{yy}
Dewatered Loads	Loads taken from dewatered condition	-2782.44		5313.68			92,241.39	40,783.67
Surcharge	Maximum crane surcharge loading of 110 kips each of the front pads placed behind and symmetrically along the monolith were used. (Calculations made using the distributions as defined on pages 298-299 as presented in Reference 2)	-87.96				25.83		-2,272.01
Total		-2870.40		5313.68			92,241.39	38,511.66

WES FORM NO. 1253A

LOCK MONOLITH R-36



Stability analysis, monolith R-36, Troy Lock and Dam

SUBJECT:

Monolith R-36, Troy Lock and Dam - Percent Effective Base (No Posttensioning)

COMPUTED BY: | DATE

CHECKED BY: | DATE

LOAD CASE	Base Width	Sum of Vertical Forces	Sum of Moments	Resultant Moment Arm	Percent Effective Base	Full Uplift Under Non-Compressive Base Area: Sum of Vertical Forces	Sum of Moments	Resultant Moment Arm	Percent Effective Base
	b (ft)	F_V (kips)	M (ft-kips)	$e = \frac{M}{F_V}$ (ft)	$\frac{3e}{b} * 100$ (%)	F_V (kips)	M (ft-kips)	$e = \frac{M}{F_V}$ (ft)	$\frac{3e}{b} * 100$ (%)
Normal Operation	15	58.51	228.18	3.90	78.0	56.84	213.83	3.76	75.2
Normal Operation with Hawser	15	58.51	186.22	3.18	63.6	55.75	164.33	2.95	59.0
Normal Operation with Earthquake	15	56.84	108.08	1.90	38.00	--	--	--	--
Chamber Dewatered	15	62.24	191.34	3.07	61.40	55.19	138.48	2.51	50.2
*Flood Condition	15	37.08	243.21	6.55	100	--	--	--	--
*Normal Operation with Impact	15	39.04	262.71	6.73	100	--	--	--	--
*Normal Operation with Ice (Lockside)	15	27.74			100	--	--	--	--

* Includes vertical and horizontal reactions on stepped base.

WES FORM NO. 1253A DECEMBER 1964

SUBJECT:

Monolith R-36, Troy Lock and Dam - Factor of Safety Against Sliding (No Posttensioning)

COMPUTED BY: DATE:

CHECKED BY: DATE:

LOAD CASE	Sum of Vertical Forces	Sum of Horizontal Forces	Friction Angle	Cohesive Strength	Base Area	Strut Resistance	Shear Resistance	Cohesive Resistance	Total Sliding Resistance	Factor of Safety Against Sliding
	F_V (kips)	F_H (kips)	ϕ (Degrees)	C (ksf)	A = 3e (sq ft)	R_s (kips)	$R_f = F_V \tan \phi$ (kips)	$R_c = CA$ (kips)	$R = R_s + R_f + R_c$ (kips)	$F.S. = \frac{R}{F_H}$
Norm 1 Operation	56.84	20.75	30.4	0.04	11.28	0	33.35	0.45	33.80	1.63
Normal Operation with Hawser	55.75	22.75	30.4	0.04	8.85	0	32.71	0.35	33.06	1.45
Normal Operation Plus Earthquake	56.84	26.44	30.4	0.04	5.70	0	33.35	0.23	33.58	1.27
Chamber Dewatered	55.19	28.75	30.4	0.04	7.53	0	32.38	0.30	32.68	1.14
*Flood Condition	46.29	0	30.4	0.04	15	0	27.16	0.60	27.76	∞
*Normal Operation with Impact	51.77	2	30.4	0.04	15	0	30.37	0.60	30.97	15.49
*Normal Operation with Ice (Lockside)	51.77	10.00	30.4	0.04	15	0	30.37	0.60	30.97	3.10

* Includes vertical and horizontal reactions on stepped base.

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PAGE OF

SUBJECT: Monolith R-36, Troy Lock and Dam - Base Pressure (No Posttensioning)

COMPUTED BY: DATE:

CHECKED BY: DATE:

LOAD CASE	Sum of Vertical Forces F_V (kips)	Resultant Moment Arm e (ft)	Effective Base Width b (ft)	Axial Stress $f_a = \frac{F_V}{b}$ (ksf)	Bending Stress $f_b = \pm \frac{F_V\left(\frac{b}{2} - e\right)\frac{b}{2}}{b^3/12}$ (ksf)	Intergranular Stress At Heel $f_h = f_a - f_b$ (ksf)	Intergranular Stress At Toe $f_t = f_a + f_b$ (ksf)	Hydrostatic Pressure At Heel $f_{uh} = \gamma_w h_{wh}$ (ksf)	Hydrostatic Pressure At Toe $f_{ut} = \gamma_w h_{wt}$ (ksf)	Total Pressure At Heel $f_{th} = f_h + f_{uh}$ (ksf)	Total Pressure At Toe $f_{Tt} = f_t + f_{ut}$ (ksf)
Normal Operation	56.84	3.76	11.28	5.04	5.04	0	10.08	1.90	1.00	1.90	11.08
Normal Operation with Hawser	55.75	2.95	8.85	6.30	6.30	0	12.60	1.90	1.00	1.90	13.60
Normal Operation Plus Earthquake	56.84	1.90	5.70	9.97	9.97	0.00	19.84	1.90	1.00	1.90	20.84
Chamber Dewatered	55.19	2.51	7.53	7.33	7.33	0.00	14.66	1.90	0.0	1.90	14.66
*Flood Condition	37.08	6.55	15	2.47	0.94	1.53	3.41	2.86	2.86	4.39	6.27
*Normal Operation with Impact	39.04	6.73	15	2.60	0.80	1.80	3.40	1.90	1.90	3.70	5.30
*Normal Operation with Ice (Lockside)	27.74		15	1.85				1.90	1.90		

* Includes vertical and horizontal reactions on stepped base.

WES FORM NO 1253A DECEMBER 1964

PAGE OF

SUBJECT: Monolith R-36, Troy Lock and Dam - Percent Effective Base (After Posttensioning)

COMPUTED BY: DATE:

CHECKED BY: DATE:

LOAD CASE	Base Width b (ft)	Sum of Vertical Forces F_V (kips)	Sum of Moments M (ft-kips)	Resultant Moment Arm $c = \frac{M}{F_V}$ (ft)	Percent Effective Base $\frac{3c}{b} * 100$ (%)
Normal Operation	15	72.48	498.63	6.85	100.0
Normal Operation with Hawser	15	71.39	449.13	6.29	100.0
Normal Operation with Earthquake	15	72.48	392.88	5.42	100.0
Chamber Dewatered	15	70.83	423.28	5.98	100.0
*Flood Condition	15	37.08	243.21	6.55	100.0
*Normal Operation Impact	15	39.04	262.71	6.73	100.0
*Normal Operation Ice (Lockside)	15	27.74	219.49	7.91	100.0

* Note: 1) Posttensioning force is neglected due to direction of forces and moments causing posttensioning force to be less than or equal to initial force which is negligible.
2) Includes vertical and horizontal reactions on stepped base.

WES FORM NO. 1253A

PAGE OF

SUBJECT:

Monolith R-36, Troy Lock and Dam - Factor of Safety Against Sliding (After Posttensioning)

COMPUTED BY: | DATE:

CHECKED BY: | DATE:

LOAD CASE	Sum of Vertical Forces F_V (kips)	Sum of Horizontal Forces F_H (kips)	Friction Angle ϕ (Degrees)	Cohesive Strength C (ksf)	Base Area A = 3e (sq ft)	Horizontal Posttensioning Resistance R_s (kips)	Shear Resistance $R_f = F_V \tan \phi$ (kips)	Cohesive Resistance $R_c = CA$ (kips)	Total Sliding Resistance $R = R_s + R_f + R_c$ (kips)	Factor of Safety Against Sliding $F.S. = \frac{R}{F_H}$
Normal Operation	72.48	20.75	30.4	0.04	11.28	15.64	42.52	0.45	58.61	2.62
Normal Operation with Hawser	71.39	22.75	30.4	0.04	8.85	15.64	41.88	0.35	57.87	2.54
Normal Operation Plus Earthquake	72.48	26.44	30.4	0.04	5.70	15.64	42.52	0.23	58.39	2.21
Chamber Dewatered	70.83	28.75	30.4	0.04	7.53	15.64	41.56	0.30	57.50	2.00
*Flood Condition	46.29	0.00	30.4	0.04	15	0	27.16	0.60	27.76	∞
*Normal Operation Impact	51.77	2.00	30.4	0.04	15	0	30.37	0.60	30.97	15.49
*Normal Operation Ice (Lockside)	51.77	10.00	30.4	0.04	15	0	30.37	0.60	30.97	3.10

* Note: 1) Posttensioning force is neglected due to direction of forces and moments causing posttensioning force to be less than or equal to initial force which is negligible.
2) Includes vertical and horizontal reactions on stepped base.

WES FORM NO. 1253A DECEMBER 1966

PAGE OF

SUBJECT: Monolith R-36, Troy Lock and Dam - Base Pressure (After Posttensioning)

COMPUTED BY: DATE:

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LOAD CASE	Sum of Vertical Forces F_V (kips)	Resultant Moment Arm e (ft)	Effective Base Width b (ft)	Axial Stress $f_n = \frac{F_V}{b}$ (ksf)	Bending Stress $f_b = \pm \frac{F_V\left(\frac{b}{2} - e\right)\frac{b}{2}}{b^3/12}$ (ksf)	Inter-granular Stress At Heel $f_h = f_n - f_b$ (ksf)	Inter-granular Stress At Toe $f_t = f_a + f_b$ (ksf)	Hydrostatic Pressure At Heel $f_{uh} = \gamma_w h_{wh}$ (ksf)	Hydrostatic Pressure At Toe $f_{ut} = \gamma_w h_{wt}$ (ksf)	Total Pressure At Heel $f_{th} = f_h + f_{uh}$ (ksf)	Total Pressure At Toe $f_{Tt} = f_t + f_{ut}$ (ksf)
Normal Operation	72.48	6.85	15	4.83	1.26	3.57	6.09	1.90	1.00	5.47	7.09
Normal Operation with Hawser	71.39	6.29	15	4.76	2.30	2.46	7.06	1.90	1.00	4.36	8.06
Normal Operation Plus Earthquake	72.48	5.42	15	4.83	4.02	0.81	8.85	1.90	1.00	2.71	9.85
Chamber Dewatered	70.83	5.98	15	4.72	2.87	1.85	7.59	1.90	0.0	3.75	7.59
*Flood Condition	37.08	6.55	15	2.47	0.94	1.53	3.41	2.86	2.86	4.39	6.27
*Normal Operation Impact	39.04	6.73	15	2.60	0.80	1.80	3.40	1.90	1.90	3.70	5.30
*Normal Operation Ice (Lockside)	27.74	7.91	15	1.85	0.33	1.52	2.18	1.90	1.90	3.42	4.08

* Note: 1) Posttensioning force is neglected due to direction of forces and moments causing posttensioning.
2) Includes vertical and horizontal reactions on stepped base.

WES FORM NO. 1253A

PAGE OF

SUBJECT: Monolith R-36, Troy Lock and Dam - Normal Operation

COMPUTED BY: DATE:

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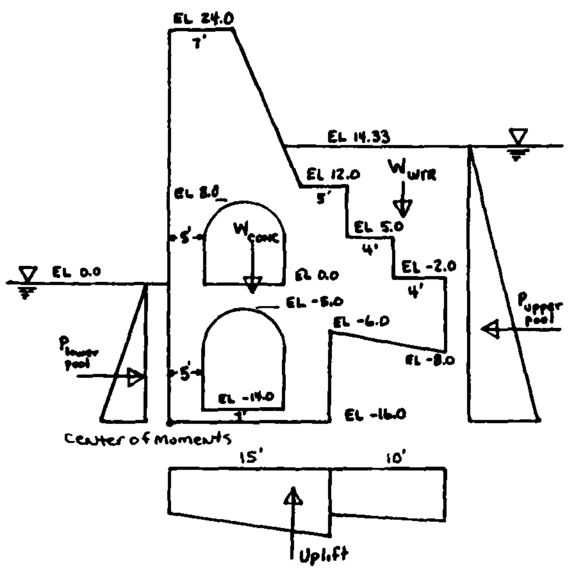

Item	Factors	F_V	F_H	Arm	Moment
W_{conc}	(0.15)(7)(24-12)	12.6		3.5	44.10
	(0.15)(0.5)(5)(24-12)	4.5		8.67	39.02
	(0.15)(17)(12-5)	17.85		8.50	151.73
	(0.15)(21)(5+2)	22.05		10.50	231.53
	(0.15)(15)(16-2)	31.50		7.50	236.25
	(0.15)(0.5)(10)(2)	1.50		21.67	32.51
	$-(0.15-0.0625)(\pi)(3.5)^2$	- 3.37		8.50	- 28.65
	-(0.15-0.0625)(4.5)(7)	- 2.76		8.50	- 23.46
	-(0.15-0.0625)(5.5)(7)	- 3.37		8.50	- 28.65
	$-(0.15-0.0625)(2.33)(5)\ (\frac{3}{20})$	- .15		2.50	- .38
	(0.15)(4)(10)	6.0		20.0	120.0
		86.35			774.00
$P_{upper\ pool}$	$(0.0625)(14.33+16)^2(0.5)(1)$		-28.75	10.11	-290.46
W_{WTR}	(.0625)(1/2)(.97)(2.33)	0.07		11.68	0.82
	(.0625)(13)(2.33)	1.89		18.50	34.97
	(.0625)(8)(7.00)	3.50		21.00	73.50
	(.0625)(4)(7.00)	1.75		23.00	40.25
		7.21			149.54
$P_{lower\ pool}$	$(0.0625)(0+16)^2(0.5)(1)$		8.0	5.33	42.64
Uplift	-(.0625)(16)(15)	-15.00		7.50	-112.50
	-(.0625)(1/2)(14.33)(15)	- 6.72		10.00	- 67.20
	-(.0625)(14.33+6)(10)	-12.71		20.00	-254.20
	-(.0625)(1/2)(2)(10)	- 0.62		21.67	13.44
		-35.05			-447.34
Total		58.51	-20.75		228.18

WES FORM NO. 1253A DECEMBER 1966

PAGE OF

SUBJECT: Monolitn R-36, Troy Lock and Dam - Normal Operation with Hawser

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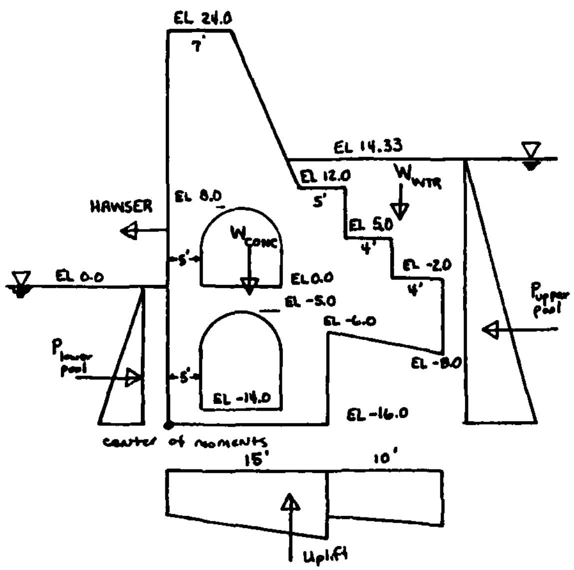

Item	Factors	F_V	F_H	Arm	Moment
W_{conc}	(0.15)(7)(24-12)	12.6		3.5	44.10
	(0.15)(0.5)(5)(24-12)	4.5		8.67	39.02
	(0.15)(17)(12-5)	17.85		8.50	151.73
	(0.15)(21)(5+2)	22.05		10.50	231.53
	(0.15)(15)(16-2)	31.50		7.50	236.25
	(0.15)(0.5)(10)(2)	1.50		21.67	32.51
	$-(0.15-0.0625)(\pi)(3.5)^2$	- 3.37		8.50	- 28.65
	-(0.15-0.0625)(4.5)(7)	- 2.76		8.50	- 23.46
	-(0.15-0.0625)(5.5)(7)	- 3.37		8.50	- 28.65
	-(0.15-0.0625)(2.33)(5)(3/20)	- 0.15		2.50	- 0.38
	(0.15)(4)(10)	6.0		20.0	120.0
		86.35			774.00
$P_{upper\ pool}$	$-(0.0625)(14.33+16)^2(0.5)(1)$		-28.75	10.11	290.66
W_{WTR}	(.0625)(1/2)(.97)(2.33)	0.07		11.68	0.82
	(.0625)(13)(2.33)	1.89		18.50	34.97
	(.0625)(8)(7.00)	3.50		21.00	73.50
	(.0625)(4)(7.00)	1.75		23.00	40.25
		7.21			149.54
$P_{lower\ pool}$	$(0.0625)(0+16)^2(0.5)(1)$		8.0	5.33	42.64
Uplift	-(.0625)(16)(15)	-15.00		7.50	-112.50
	-(.0625)(1/2)(14.33)(15)	- 6.72		10.00	- 67.20
	-(.0625)(14.33+6)(10)	-12.71		20.00	-254.20
	-(.0625)(1/2)(2)(10)	- 0.62		21.67	- 13.44
		-35.05			-447.30
Hawser	-40/20		- 2.0	21.00	- 42.00
Total		58.51	-22.75	3.18	186.22

WES FORM NO. 1253A

PAGE OF

SUBJECT: Monolith R-36, Troy Lock and Dam - Normal Operation with Earthquake

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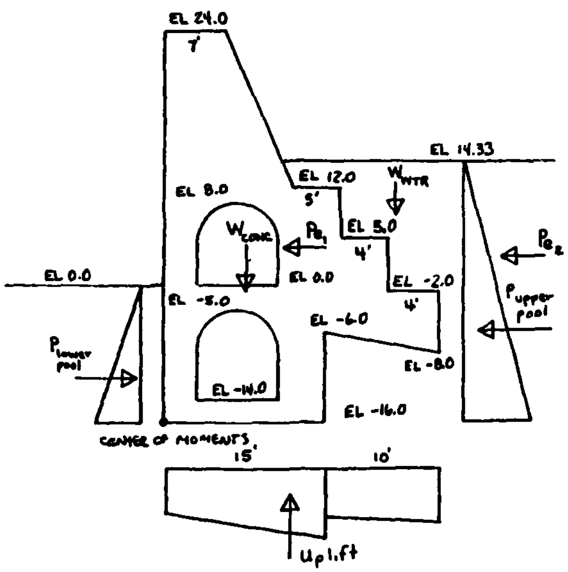

Item	Factors	F_V	F_H	Arm	Moment
Normal Operation Loads	(Full uplift under non-compressive area of base)	56.84	-20.75		213.83
Earthquake	$Pe_1 = \alpha W = -(0.05)(86.35+7.21)$		- 4.68	18.77	- 87.84
	$Pe_2 = -(2/3\ (51)(.05)(24.33)^2)(1/1000)$		- 1.01	17.73	- 17.91
Total		56.84	-26.44		108.08

WES FORM NO. 1253A DECEMBER 1964

PAGE OF

SUBJECT: Monolith R-36, Troy Lock and Dam, Location of Center of Gravity - Normal Operation with Earthquake

COMPUTED BY: DATE:

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LOCATION OF CENTER OF GRAVITY WITH RESPECT TO MONOLITH BASE

CONCRETE

AREA		ARM		AREA-MOMENT
$(24-12)7$	$= 84$	$\frac{24-12}{2} + 12 + 16$	$= 34$	2856
$\frac{1}{2}(24-12)(5)$	$= 30$	$\frac{24-12}{3} + 12 + 16$	$= 32$	960
$(12-5)17$	$= 119$	$\frac{12-5}{2} + 5 + 16$	$= 24.5$	2916
$(5+2)21$	$= 147$	$\frac{5+2}{2} + 16 - 2$	$= 17.5$	2573
$(16-2)15$	$= 210$	$\frac{16-2}{2}$	$= 7.0$	1470
$(6-2)10$	$= 40$	$\frac{6-2}{2} + 16 - 6$	$= 12.0$	480
$\frac{1}{2}(8-6)10$	$= 10$	$\frac{8-6}{2} + 16 - 8$	$= 9.0$	90
$\frac{-\pi(3.5)^2}{2}$	$= -19.24$	$\frac{4}{3\pi}(3.5) + 4.5 + 16$	$= 21.99$	-423
$-(4.5)7$	$= -31.50$	$\frac{4.5}{2} + 16$	$= 18.25$	-575
$\frac{-\pi(3.5)^2}{2}$	$= -19.24$	$\frac{4}{3\pi}(3.5) + 5.5 + 2$	$= 8.99$	-173
$-(5.5)7$	$= -38.5$	$\frac{5.5}{2} + 2$	$= 4.75$	-183
$-(2.33)(3)(5)/20$	$= -1.75$	$\frac{2.33}{2} + 1.5$	$= 2.67$	-5
	529.77			9986

$$\bar{y} = \frac{9886}{529.77} = 18.85'$$

WES FORM NO. 1293A

PAGE OF

SUBJECT	COMPUTED BY:	DATE:
Monolith R-36, Troy Lock and Dam, Location of Center of Gravity - Normal Operation with Earthquake (Continued)	CHECKED BY:	DATE:

LOCATION OF CENTER OF GRAVITY WITH RESPECT TO MONOLITH BASE (Continued)

WATER

AREA		ARM		AREA-MOMENT
$\frac{\pi(3.5)^2}{2}$	= 19.24	$\frac{4}{3\pi}(3.5) + 4.5 + 16$	= 21.99	423
(4.5)(7)	= 31.50	$\frac{4.5}{2} + 16$	= 18.25	575
$\frac{\pi(3.5)^2}{2}$	= 19.24	$\frac{4}{3\pi}(3.5) + 5.5 + 2$	= 8.99	173
(5.5)7	= 38.50	$\frac{5.5}{2} + 2$	= 4.75	183
$\frac{2.33(3)(5)}{20}$	= 1.75	$\frac{2.33}{2} + 1$	= 2.17	4
$\frac{1}{2}(0.97)(2.33)$	= 1.13	$\frac{(2)2.33}{3} + 16 + 12$	= 29.55	33
13(2.33)	= 30.29	$\frac{2.33}{2} + 16 + 12$	= 29.17	884
8(7)	= 56.00	$\frac{7}{2} + 5 + 16$	= 24.5	1372
4(7)	= 28.00	$\frac{7}{2} + 16 - 2$	= 17.5	490
	225.65			4137

$$\bar{y} = \frac{4137}{225.65} = 18.33$$

LOCATION OF CENTER OF GRAVITY EARTHQUAKE FORCE WITH RESPECT TO MONOLITH BASE

$$\bar{y} = \frac{(.15)(529.77)(18.85) + (.0625)(225.65)(18.33)}{(.15)(529.77) + (.0625)(225.65)} = 18.77$$

WES FORM NO. 1253A

SUBJECT: Monolith R-36, Troy Lock and Dam - Chamber Dewatered

COMPUTED BY: DATE:

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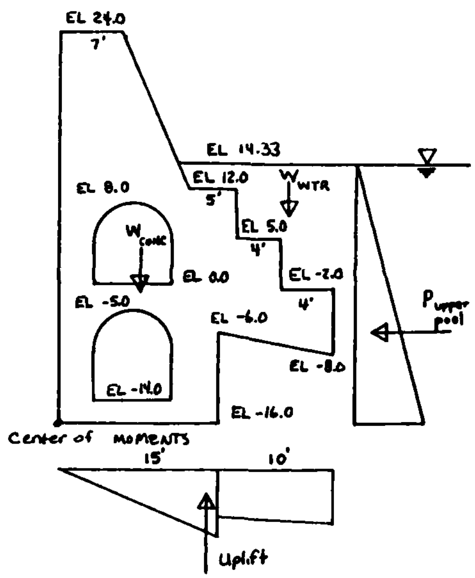

Item	Factors	F_V	F_H	Arm	Moment
W_{conc}	(0.15)(7)(24-12)	12.6		3.5	44.10
	(0.15)(0.5)(5)(24-12)	4.5		8.67	39.02
	(0.15)(17)(12-5)	17.85		8.50	151.73
	(0.15)(21)(5+2)	22.05		10.50	231.53
	(0.15)(15)(16-2)	31.50		7.50	236.25
	(0.15)(0.5)(10)(2)	1.50		21.67	32.51
	$-(2)(0.15-.0625)\pi(3.5)^2/2$	- 4.57		8.50	- 38.85
	-(.15-0.0625)(4.5)(7)	- 2.76		8.50	- 23.46
	-(.15)(5.5)(7)	- 5.78		8.50	- 49.13
	-(0.15)(2.33)(5)(3/20)	- 0.26		2.50	- 0.65
	(0.15)(4)(10)	6.0		20.0	120.0
		82.63			743.05
W_{WTR}	(.0625)(1/2)(.97)(2.33)	0.07		11.68	0.82
	(.0625)(13)(2.33)	1.89		18.50	34.97
	(.0625)(8)(7.00)	3.50		21.00	73.50
	(.0625)(4)(7.00)	1.75		23.00	40.25
		7.21			149.54
	$-(.0625)(14.33+16)^2(.5)$		-28.75	10.11	-290.66
Uplift	-(0.5)(15.0)(1.90)	-14.25		10.0	-142.50
	-(0.5)(10.0)(1.27)	- 6.35		18.33	-116.40
	-(0.5)(10.0)(1.40)	- 7.00		21.67	-151.69
		-27.60			-410.59
		62.24	-28.75		191.34

1253A

PAGE OF

SUBJECT: Monolith R-36, Troy Lock and Dam - Flood Condition

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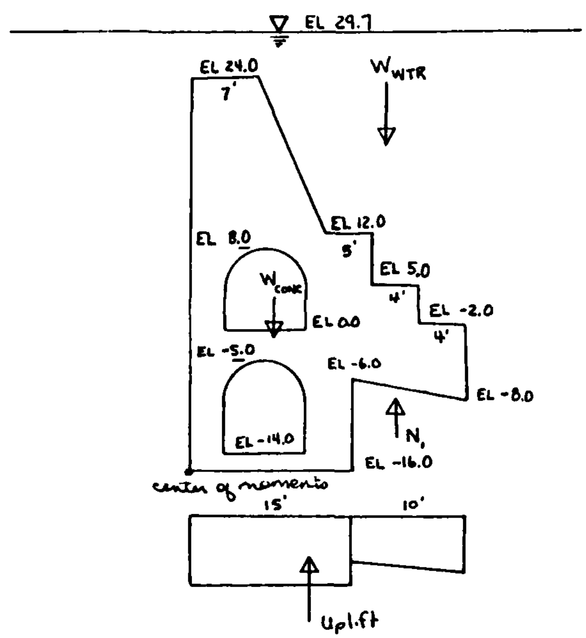

Item	Factors	F_V	F_H	Arm	Moment
W_{conc}	(0.15)(7)(24-12)	12.6		3.5	44.10
	(0.15)(0.5)(5)(24-12)	4.5		8.67	39.02
	(0.15)(17)(12-5)	17.85		8.50	151.73
	(0.15)(21)(5+2)	22.05		10.50	231.53
	(0.15)(15)(16-2)	31.50		7.50	236.25
	(0.15)(0.5)(10)(2)	1.50		21.67	32.51
	$-(0.15-0.0625)(\pi)(3.5)^2$	- 3.37		8.50	- 28.65
	-(0.15-0.0625)(4.5)(7)	- 2.76		8.50	- 23.46
	-(0.15-0.0625)(5.5)(7)	- 3.37		8.50	- 28.65
	-(0.15-0.0625)(2.33)(15)(3/20)	0.15		2.50	- 0.38
	(0.15)(4)(10)	6.0		20.0	120.00
		86.35			774.00
W_{WTR}	(0.0625)(29.70-24.0)(25.0)(1)	8.91		12.5	111.38
	(0.0625)(24.0-12.0)(5.0)(0.5)(1)	1.88		10.33	19.42
	(0.0625)(24.0-12.0)(13.0)(1)	9.75		18.50	180.38
	(0.0625)(12.0-5.0)(8.0)(1)	3.50		21.0	73.50
	(0.0625)(5.0+2.0)(4.0)(1)	1.75		23.0	40.25
		25.79			424.93
Uplift	-(2.86)(15)	-42.90		7.5	-321.75
	-(2.23)(10)(0.5)	-11.15		18.33	-204.38
	-(2.36)(10)(0.5)	-11.80		21.67	-255.71
		-65.85			-781.84
N_1	Vertical Reaction on stepped base	- 9.21		18.88	-173.88
H_1	Shear friction force on stepped base		0.0		0.00
Total		37.08	0.0		243.21

WES FORM NO. 1253A

PAGE OF

SUBJECT: Monolith R-36, Troy Lock and Dam - Normal Operation with Impact

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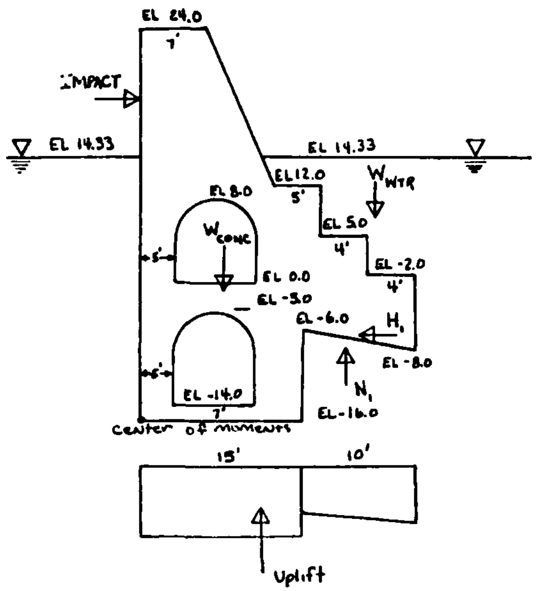

Item	Factors	F_V	F_H	Arm	Moment
W_{conc}	(0.15)(7)(24-12)	12.6		3.5	44.10
	(0.15)(0.5)(5)(24-12)	4.5		8.67	39.02
	(0.15)(17)(12-5)	17.85		8.50	151.73
	(0.15)(21)(5+2)	22.05		10.50	231.53
	(0.15)(15)(16-2)	31.50		7.50	236.25
	(0.15)(0.5)(10)(2)	1.50		21.67	32.51
	$-(0.15-0.0625)(\pi)(3.5)^2$	- 3.37		8.50	- 28.65
	-(0.15-0.0625)(4.5)(7)	- 2.76		8.50	- 23.46
	-(0.15-0.0625)(5.5)(7)	- 3.37		8.50	- 28.65
	-(0.15-.0625)(2.33)(5)(3/20)	- 0.15		2.50	- 0.38
	(0.15)(4)(10)	6.0		20.0	120.0
		86.35			774.00
W_{WTR}	(.0625)(1/2)(.97)(2.33)	0.07		11.68	0.82
	(.0625)(13)(2.33)	1.89		18.50	34.97
	(.0625)(8)(7.00)	3.50		21.00	73.50
	(.0625)(4)(7.00)	1.75		23.00	40.25
		7.21			149.54
Uplift	-(1.896)(15)	-28.44		7.5	-213.30
	-(1.27)(10)(0.5)	- 6.35		18.33	-116.40
	-(1.40)(10)(0.5)	- 7.00		21.67	-151.69
		-41.79		8.99	-481.39
Impact	40/20		2.0	35.33	70.66
N_1	Vertical Reaction on stepped base	-12.73		19.30	-245.69
H_1	Shear friction force on stepped base		-0.49	9.00	- 4.41
Total		39.04	1.51		262.71

WES FORM NO. 1253A DECEMBER 1966

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SUBJECT: Monolith R-36, Troy Lock and Dam - Normal Operation with Ice (Lockside Only)

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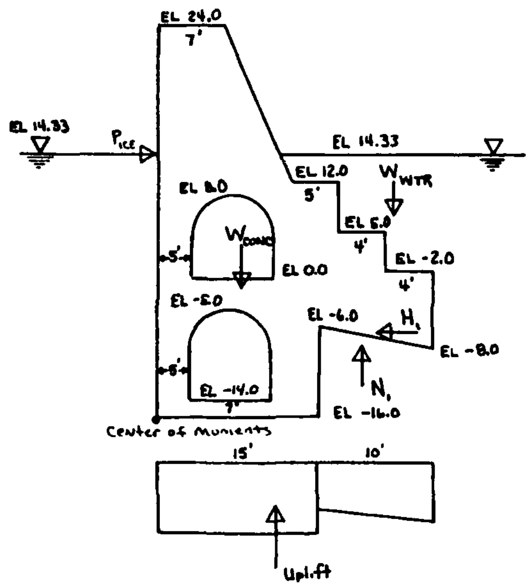
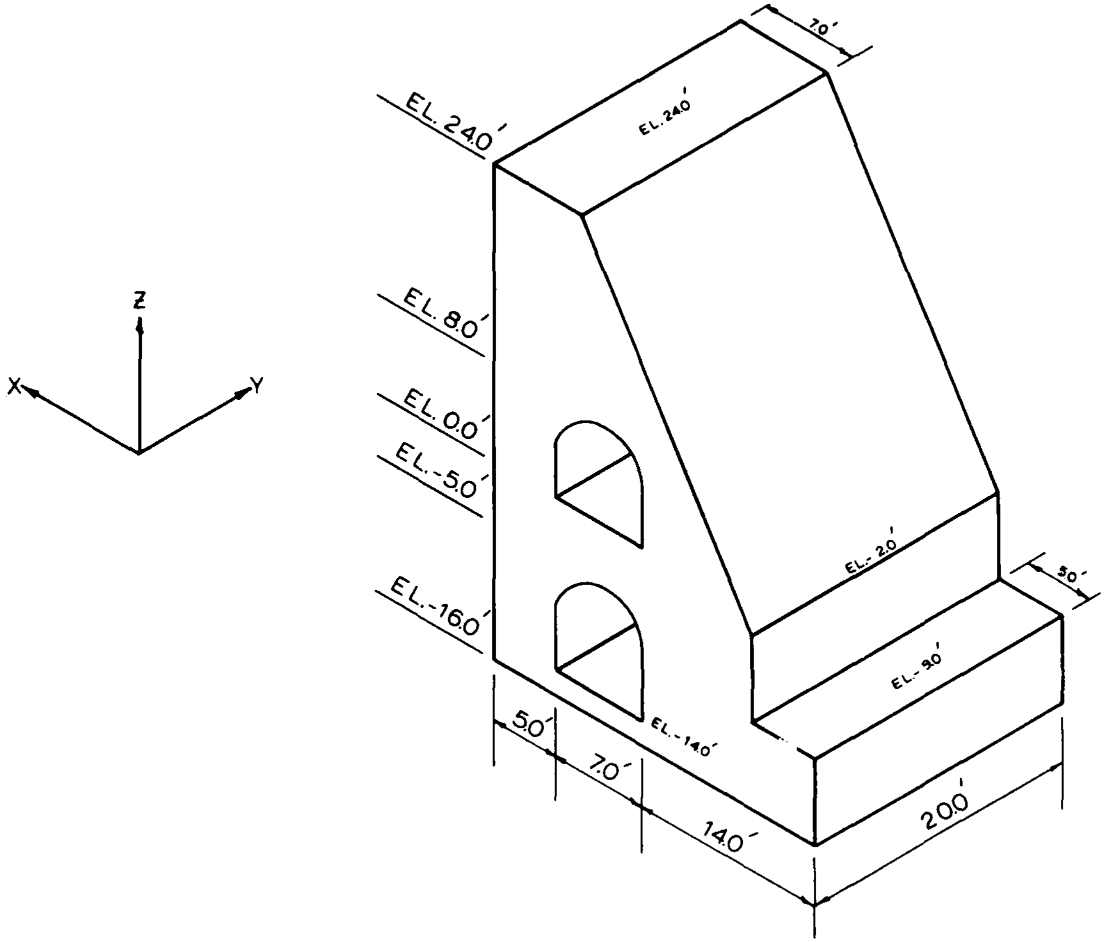


Item	Factors	F_V	F_H	Arm	Moment
W_{conc}	(0.15)(7)(24-12)	12.6		3.5	44.10
	(0.15)(0.5)(5)(24-12)	4.5		8.67	39.02
	(0.15)(17)(12-5)	17.85		8.50	151.73
	(0.15)(21)(5+2)	22.05		10.50	231.53
	(0.15)(15)(16-2)	31.50		7.50	236.25
	(0.15)(0.5)(10)(2)	1.50		21.67	32.51
	$-(0.15-0.0625)(\pi)(3.5)^2$	- 3.37		8.50	- 28.65
	-(0.15-0.0625)(4.5)(7)	- 2.76		8.50	- 23.46
	-(0.15-0.0625)(5.5)(7)	- 3.37		8.50	- 28.65
	-(0.15-0.0625)(2.33)(5)(3/20)	- 0.15		2.50	- 0.38
	(0.15)(4)(10)	6.0		20.0	120.0
		86.35			774.00
W_{WTR}	(.0625)(1/2)(.97)(2.33)	0.07		11.68	0.82
	(.0625)(13)(2.33)	1.89		18.50	34.97
	(.0625)(8)(7.00)	3.50		21.00	73.50
	(.0625)(4)(7.00)	1.75		23.00	40.25
		7.21			149.54
Uplift	-(1.896)(15)	-28.44		7.5	-213.30
	-(10)(0.5)	- 6.35		18.33	-116.40
	-(0.5)(10)(0.5)	- 7.00		21.67	-151.69
		-41.79		8.99	-481.39
P_{ice}	(5) (2)		10.0	29.33	293.30
N_1	Vertical reaction on stepped base	-23.46		20.13	472.20
H_1	Shear friction force on stepped base		- 4.53	9.00	- 40.77
Total		28.31	5.47		222.43

WES FORM NO 1253A

PAGE OF

LOCK MONOLITH R-44



Stability analysis, Monolith R-44, Troy Lock and Dam

SUBJECT: Monolith R-44, Troy Lock and Dam - Percent Effective Base

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LOAD CASE	Base Width	Sum of Vertical Forces	Sum of Moments	Resultant Moment Arm	Percent Effective Base	Full Uplift Under Non-Compressive Base Area: Sum of Vertical Forces	Full Uplift Under Non-Compressive Base Area: Sum of Moments	Full Uplift Under Non-Compressive Base Area: Resultant Moment Arm	Full Uplift Under Non-Compressive Base Area: Percent Effective Base
	b (ft)	F_V (kips)	M (ft-kips)	$e = \frac{M}{F_V}$ (ft)	$\frac{3e}{b} * 100$ (%)	F_V (kips)	M (ft-kips)	$e = \frac{M}{F_V}$ (ft)	$\frac{3e}{b} * 100$ (%)
Normal Operation	26	59.55	752.19	12.63	100.00	--	--	--	--
Normal Operation with Ice (Lockside)	26	59.55	448.89	7.54	87.0	57.66	418.70	7.26	83.77
Normal Operation with Earthquake (Lockside)	26	59.55	653.37	10.97	100.0	--	--	--	--
Normal Operation with Earthquake (Riverside)	26	71.19	1284.65	18.05	91.7*	--	--	--	--
Normal Operation with Impact	26	59.55	681.53	11.44	100.0	--	--	--	--

* Note: Percent effect base = $\frac{3 * (b - e)}{b} * 100.$

WES FORM NO. 1253A

PAGE OF

SUBJECT: Monolith R-44, Troy Lock and Dam - Percent Effective Base (Continued)

COMPUTED BY: | DATE:

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LOAD CASE	Base Width	Sum of Vertical Forces	Sum of Moments	Resultant Moment Arm	Percent Effective Base	Full Uplift Under Non-Compressive Base Area: Sum of Vertical Forces	Sum of Moments	Resultant Moment Arm	Percent Effective Base
	b (ft)	F_V (kips)	M (ft-kips)	$e = \frac{M}{F_V}$ (ft)	$\frac{3e}{b} * 100$ (%)	F_V (kips)	M (ft-kips)	$e = \frac{M}{F_V}$ (ft)	$\frac{3e}{b} * 100$ (%)
Normal Operation with Hawser	26	71.19	1243.93	17.47	98.4*	--	--	--	--
Flood Condition	26	51.00	823.34	16.14	100.0*	--	--	--	--
Dewatered Condition	26	77.30	1348.63	17.45	98.7*	77.10	1346.85	17.47	98.4

* Note: Percent effect base = $\frac{3 * (b - e)}{b} * 100$.

WES FORM NO. 1253A

PAGE OF

SUBJECT: Monolith R-44, Troy Lock and Dam - Factor of Safety Against Sliding

COMPUTED BY: DATE:

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LOAD CASE	Sum of Vertical Forces F_V (kips)	Sum of Horizontal Forces F_H (kips)	Friction Angle ϕ (Degrees)	Cohesive Strength C (ksf)	Base Area A (sq ft)	Strut Resistance R_s (kips)	Shear Resistance $R_f = F_V \tan \phi$ (kips)	Cohesive Resistance $R_c = CA$ (kips)	Total Sliding Resistance $R = R_s + R_f + R_c$ (kips)	Factor of Safety Against Sliding $F.S. = \frac{R}{F_H}$
Normal Operation	59.55	20.75	30.4	0.0	26.00	0.0	34.94	0.0	34.94	1.68
Normal Operation with Ice (Lockside)	57.94	30.75	30.4	0.0	22.62	0.0	33.99	0.0	33.99	1.11
Normal Operation with Earthquake (Lockside)	59.55	27.17	30.4	0.0	26.00	0.0	34.94	0.0	34.94	1.29
Normal Operation with Earthquake (Riverside)	71.19	5.30	30.4	0.0	23.85	0.0	41.77	0.0	41.77	7.88
Normal Operation with Impact	59.55	22.75	30.4	0.0	26.00	0.0	34.94	0.0	34.94	1.54

WES FORM 1253A

PAGE OF

SUBJECT: Monolith R-44, Troy Lock and Dam - Factor of Safety Against Sliding (Continued)

COMPUTED BY: DATE:

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LOAD CASE	Sum of Vertical Forces F_V (kips)	Sum of Horizontal Forces F_H (kips)	Friction Angle ϕ (Degrees)	Cohesive Strength C (KSF)	Base Area A (sq ft)	Strut Resistance R_s (kips)	Shear Resistance $R_f = F_v \tan \phi$ (kips)	Cohesive Resistance $R_c = CA$ (kips)	Total Sliding Resistance $R = R_s + R_f + R_c$ (kips)	Factor of Safety Against Sliding $F.S. = \frac{R}{F_H}$
Normal Operation with Hawser	71.19	2.00	30.4	0.0	25.59	0.0	41.77	0.0	41.77	20.89
Flood Control	51.00	0.00	30.4	0.0	26	0.0	29.92	0.0	29.92	∞
Dewatered Condition	77.30	8.00	30.4	0.0	25.59	0.0	45.35	0.0	45.35	5.67

WES FORM NO 1253A

PAGE OF

SUBJECT: Monolith R-44, Troy Lock and Dam - Base Pressures

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LOAD CASE	Sum of Vertical Forces F_V (kips)	Resultant Moment Arm e (ft)	Effective Base Width b (ft)	Axial Stress $f_a = \frac{F_V}{b}$ (ksf)	Bending Stress $f_b = \pm \frac{F_V\left(\frac{b}{2} - e\right)\frac{b}{2}}{b^3/12}$ (ksf)	Inter-granular Stress At Heel $f_h=f_a-f_b$ (ksf)	Inter-granular Stress At Toe $f_t=f_a+f_b$ (ksf)	Hydrostatic Pressure At Heel $f_{uh}=\gamma_w h_{wh}$ (ksf)	Hydrostatic Pressure At Toe $f_{ut}=\gamma_w h_{wt}$ (ksf)	Total Pressure At Heel $f_{Th}=f_h+f_{uh}$ (ksf)	Total Pressure At Toe $f_{Tt}=f_t+f_{uh}$ (ksf)
Normal Operation	59.55	12.63	26.00	2.29	0.20	2.09	2.49	1.90	1.00	3.99	3.49
Normal Operation with Ice (lockside)	57.94	7.47	22.41	2.59	2.59	0.0	5.18	1.90	1.00	1.90	6.18
Normal Operation with Earthquake (lockside)	59.55	10.97	26.00	2.29	1.07	1.22	3.36	1.90	1.00	3.12	4.36
Normal Operation with Earthquake (Riverside)	71.19	18.05	23.85	2.98	2.98*	5.96	0.00	1.00	1.00	6.96	1.00
Normal Operation with Impact	59.55	11.44	26.00	2.29	0.82	1.47	3.11	1.90	1.00	3.37	4.11

* Note: e = 26 - e .

WES FORM NO 1253A DECEMBER 1964

PAGE OF

SUBJECT: Monolith R-44, Troy Lock and Dam - Base Pressures (Continued)

COMPUTED BY: | DATE:

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LOAD CASE	Sum of Vertical Forces F_V (kips)	Resultant Moment Arm e (ft)	Effective Base Width b (ft)	Axial Stress $f_a = \frac{F_V}{b}$ (ksf)	Bending Stress $f_b = \pm \frac{F_V \frac{b}{2} - e \frac{b}{2}}{b^3/12}$ (ksf)	Inter-granular Stress At Heel $f_h = f_a - f_b$ (ksf)	Inter-granular Stress At Toe $f_t = f_a + f_b$ (ksf)	Hydrostatic Pressure At Heel $f_{uh} = \gamma_w h_{wh}$ (ksf)	Hydrostatic Pressure At Toe $f_{ut} = \gamma_w h_{wt}$ (ksf)	Total Pressure At Heel $f_{Th} = f_h + f_{uh}$ (ksf)	Total Pressure At Toe $f_{Tt} = f_t + f_{uh}$ (ksf)
Normal Operation with Hawser	71.19	17.47	25.59	2.78	2.78*	5.56	0.0	1.00	1.00	6.56	1.00
Flood Condition	51.00	16.14	26.00	1.96	1.42	3.38	0.54	2.86	2.86	6.24	3.40
Dewatered Condition	77.30	17.47	25.59	3.02	3.02*	6.04	0.0	0.00	1.00	6.04	1.00

* Note: e = 26 - e .

WES FORM NO. 1253A

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SUBJECT: Monolith R-44, Troy Lock and Dam - Normal Operation

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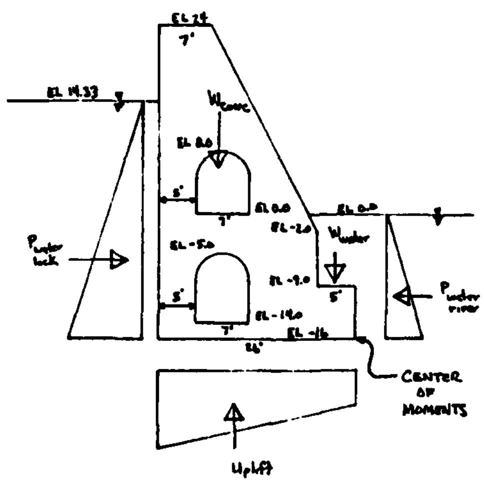

Item	Factor	F_V	F_H	Arm	Moment
W_{conc}	(.15)(26)(24 + 16)	156.00		13.00	2,028.00
	-(.15)(1/2)(14)(24 + 2)	-27.30		9.67	-263.99
	-(.15)(5)(24 + 9)	-24.75		2.50	-61.88
	-(.15 - 0.0625)[(π)(3.5)^2 + 7(4.5 + 5.5)]	-9.49		17.50	-166.08
	-(.15 - 0.0625)[(5)(2.33)(3/20)]	-0.15		23.50	-3.53
		94.31			1,532.52
W_{water}	(.0625)(1/2)(2)(14/26)(2)	0.07		5.36	0.38
	(.0625)(5)(9)	2.81		2.50	7.03
		2.88			7.41
P_{water} river	(.0625)(1/2)(16)^2		8.00	5.33	42.64
P_{water} lock	-(.0625)(1/2)(14.33 + 16)^2		-28.75	10.11	-290.66
Uplift	-(.0625)(16)(26)	-26.00		13.00	-338.00
	-(.0625)(1/2)(14.33)(26)	-11.64		17.33	-201.72
		-37.64			-539.72
Total		59.55	-20.75		752.19

SUBJECT: Monolith R-44, Troy Lock and Dam - Normal Operation with Ice (Lockside)

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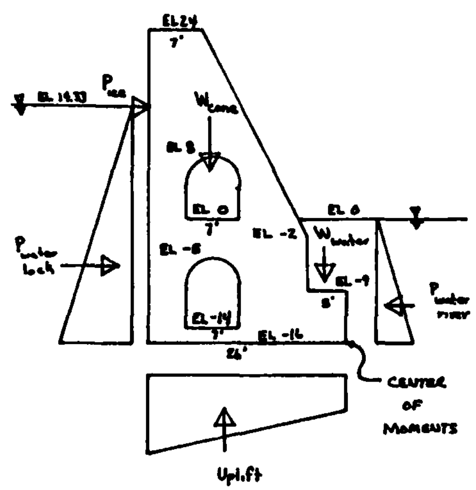

Item	Factor	F_V	F_H	Arm	Moment
W_{conc}	(.15)(26)(24 + 16)	156.00		13.00	2,028.00
	-(.15)(1/2)(14)(24 + 2)	-27.30		9.67	-263.99
	-(.15)(5)(24 + 9)	-24.75		2.50	-61.88
	$-(.15 - 0.0625)[(\pi)(3.5)^2 + 7(4.5 + 5.5)]$	-9.49		17.50	-166.08
	-(.15 - 0.0625)[(5)(2.33)(3/20)]	-0.15		23.50	-3.53
		94.31			1,532.52
W_{water}	(.0625)(1/2)(2)(14/26)(2)	0.07		5.36	0.38
	(.0625)(5)(9)	2.81		2.50	7.03
		2.88			7.41
$P_{water\ river}$	$(.0625)(1/2)(16)^2$		8.00	5.33	42.64
$P_{water\ lock}$	$-(.0625)(1/2)(14.33 + 16)^2$		-28.75	10.11	-290.66
Uplift	-(.0625)(16)(26)	-26.00		13.00	-338.00
	-(.0625)(1/2)(14.33)(26)	-11.64		17.33	-201.72
		-37.64			-539.72
P_{ice}	(5)(2)		-10.00	29.33	-293.3
Total		59.55	-30.75		458.89

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SUBJECT: Monolith R-44, Troy Lock and Dam - Normal Operation with Earthquake (Lockside)

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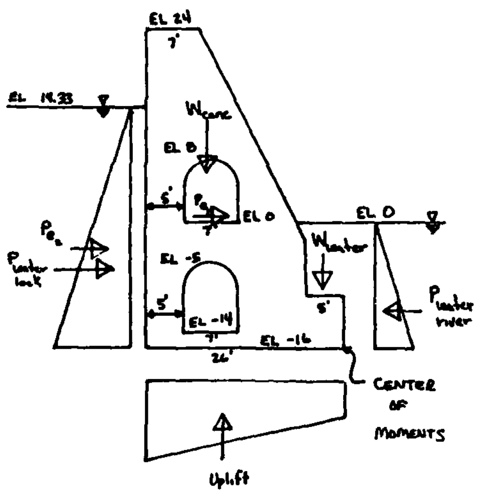

Item	Factor	F_V	F_H	Arm	Moment
W_{conc}	$(.15)(26)(24 + 16)$	156.00		13.00	2,028.00
	$-(.15)(1/2)(14)(24 + 2)$	-27.30		9.67	-263.99
	$-(.15)(5)(24 + 9)$	-24.75		2.50	-61.88
	$-(.15 - 0.0625)[(\pi)(3.5)^2 + 7(4.5 + 5.5)]$	-9.49		17.50	-166.08
	$-(.15 - 0.0625)[(5)(2.33)(3/20)]$	-0.15		23.50	-3.53
		94.31			1,532.52
W_{water}	$(.0625)(1/2)(2)(14/26)(2)$	0.07		5.36	0.38
	$(.0625)(5)(9)$	2.81		2.50	7.03
		2.88			7.41
P_{water} river	$(.0625)(1/2)(16)^2$		8.00	5.33	42.64
P_{water} lock	$-(.0625)(1/2)(14.33 + 16)^2$		-28.75	10.11	-290.66
Uplift	$-(.0625)(16)(26)$	-26.00		13.00	-338.00
	$-(.0625)(1/2)(14.33)(26)$	-11.64		17.33	-201.72
		-37.64			-539.72
Earth-quake	$P_{e_1} = \alpha W = (0.05)(94.31 + 2.88)$		-4.86	16.44	-79.90
	$P_{e_2} = [(2/3)(51)(.05)(30.33)^2][1/1000]$		-1.56	12.13	-18.92
			-6.42		-98.82
Total		59.55	-27.17		653.37

WES FORM NO. 1253A DECEMBER 1966

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SUBJECT: Monolith R-44, Troy Lock and Dam, Location of Center of Gravity - Normal Operation with Earthquake	COMPUTED BY:	DATE:
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Location of Center of Gravity with Respect to Monolith Base

Concrete

Area (ft^2)	Arm (ft)	Area-Moment (ft^3)
(26)(24 + 16) = 1,040.00	20.00	20,800.00
-(1/2)(14)(24 + 2) = -182.00	31.33	-5,702.06
-(5)(24 + 9) = -165.00	23.50	-3,877.50
$-\pi(3.5)^2(1/2)$ = -19.24	21.99	-423.09
-(7)(4.5) = -31.50	18.25	-574.88
$-\pi(3.5)^2(1/2)$ = -19.24	8.99	-172.97
-(7)(5.5) = -38.50	4.75	-182.88
-(5)(2.33)(3/20) = -1.75	2.67	-4.67
582.77		9,861.95

$$\bar{Z} = \frac{9,861.95}{582.77} = 16.92 \text{ ft}$$

Water

Area (ft^2)	Arm (ft)	Area-Moment (ft^3)
1/2(2)(14/26)(2) = 1.08	15.33	16.56
(5)(9) = 45.00	11.50	517.50
$\pi(3.5)^2(1/2)$ = 19.24	21.99	423.09
(7)(4.5) = 31.50	18.25	574.88
$\pi(3.5)^2(1/2)$ = 19.24	8.99	172.97
(7)(5.5) = 38.50	4.75	182.88
(5)(2.33)(3/20) = 1.75	2.67	4.67
156.31		1,892.55

$$\bar{Z} = \frac{1,892.55}{156.31} = 12.11 \text{ ft}$$

Location of Center of Gravity of Earthquake Forces (Horizontal)

Item	Force (kips)	Arm (ft)	Moment (ft-kips)
Concrete	(.15)(582.77) = 87.42	16.92	1,479.15
Water	(.0625)(156.31) = 9.77	12.11	118.31
	97.19		1,597.46

$$\bar{Z} = \frac{1,597.46}{97.19} = 16.44 \text{ ft}$$

WES FORM NO. 1253A

PAGE OF

SUBJECT: Monolith R-44, Troy Lock and Dam - Normal Operation with Earthquake (Riverside)

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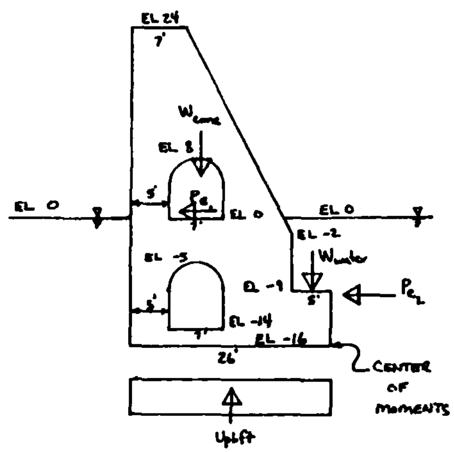

Item	Factor	F_V	F_H	Arm	Moment
W_{conc}	(.15)(26)(24 + 16)	156.00		13.00	2,028.00
	-(.15)(1/2)(14)(24 + 2)	-27.30		9.67	-263.99
	-(.15)(5)(24 + 9)	-24.75		2.50	-61.88
	$-(.15 - 0.0625)[\pi(3.5)^2 + 7(4.5 + 5.5)]$	-9.49		17.50	-166.08
	-(.15 - 0.0625)[(5)(2.33)(3/20)]	-0.15		23.50	-3.53
		94.31			1,532.52
W_{water}	(.0625)(1/2)(2)(14/26)(2)	0.07		5.36	0.38
	(.0625)(5)(9)	2.81		2.50	7.03
		2.88			7.41
Uplift	-(.0625)(16)(26)	-26.00		13.00	-338.00
Earth-quake	$P_{e_1} = \alpha W = (0.05)(94.31 + 2.88)$		-4.86	16.44	-79.90
	$P_{e_2} = [(2/3)(51)(.05)(16)^2](1/1000)$		0.44	6.40	2.82
			5.30		82.72
Total		71.19	5.30		1,284.65

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SUBJECT: Monolith R-44, Troy Lock and Dam - Normal Operation with Impact

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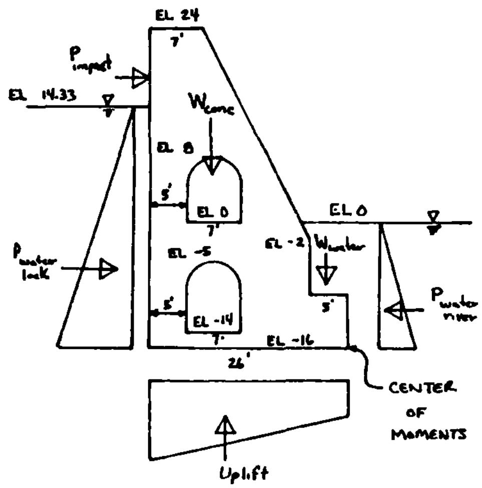

Item	Factor	F_V	F_H	Arm	Moment
W_{conc}	(.15)(26)(24 + 16)	156.00		13.00	2,028.00
	-(.15)(1/2)(14)(24 + 2)	-27.30		9.67	-263.99
	-(.15)(5)(24 + 9)	-24.75		2.50	-61.88
	$-(.15 - 0.0625)[(\pi)(3.5)^2 + 7(4.5 + 5.5)]$	-9.49		17.50	-166.08
	-(.15 - 0.0625)[(5)(2.33)(3/20)]	-0.15		23.50	-3.53
		94.31			1,532.52
W_{water}	(.0625)(1/2)(2)(14/26)(2)	0.07		5.36	0.38
	(.0625)(5)(9)	2.81		2.50	7.03
		2.88			7.41
$P_{water\ river}$	$(.0625)(1/2)(16)^2$		8.00	5.33	42.64
$P_{water\ lock}$	$-(.0625)(1/2)(14.33 + 16)^2$		-28.75	10.11	-290.66
Uplift	-(.0625)(16)(26)	-26.00		13.00	-338.00
	-(.0625)(1/2)(14.33)(26)	-11.64		17.33	-201.72
		-37.64			-539.72
P_{impact}	-40/20		-2.00	35.33	-70.66
Total		59.55	-22.75		681.53

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SUBJECT: Monolith R-44, Troy Lock and Dam - Normal Operation with Hawser

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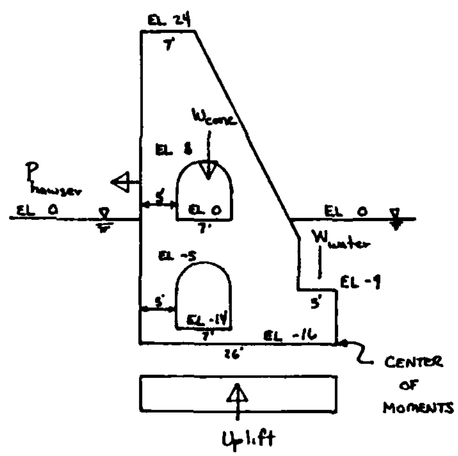

Item	Factor	F_V	F_H	Arm	Moment
W_{conc}	(.15)(26)(24 + 16)	156.00		13.00	2,028.00
	-(.15)(1/2)(14)(24 + 2)	-27.30		9.67	-263.99
	-(.15)(5)(24 + 9)	-24.75		2.50	-61.88
	$-(.15 - 0.0625)[\pi(3.5)^2 + 7(4.5 + 5.5)]$	-9.49		17.50	-166.08
	-(.15 - 0.0625)[(5)(2.33)(3/20)]	-0.15		23.50	-3.53
		94.31			1,532.52
W_{water}	(.0625)(1/2)(2)(14/26)(2)	0.07		5.36	0.38
	(.0625)(5)(9)	2.81		2.50	7.03
		2.88			7.41
Uplift	-(.0625)(16)(26)	-26.00		13.00	-338.00
P_{hawser}	(40/20)		2.00	21.00	42.00
Total		71.19	2.00		1,243.93

SUBJECT: Monolith R-44, Troy Lock and Dam - Flood Condition

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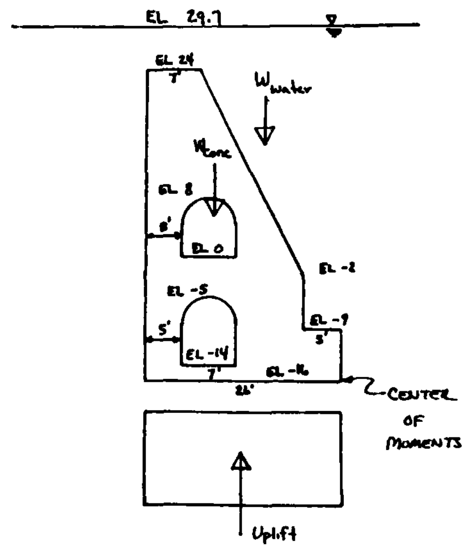

Item	Factor	F_V	F_H	Arm	Moment
W_{conc}	(.15)(26)(24 + 16)	156.00		13.00	2,028.00
	-(.15)(1/2)(14)(24 + 2)	-27.30		9.67	-263.99
	-(.15)(5)(24 + 9)	-24.75		2.50	-61.88
	$-(.15 - 0.0625)[(\pi)(3.5)^2 + 7(4.5 + 5.5)]$	-9.49		17.50	-166.08
	-(.15 - 0.0625)[(5)(2.33)(3/20)]	-0.15		23.50	-3.53
		94.31			1,532.52
W_{water}	(.0625)(5)(24 + 9)	10.31		2.50	25.78
	(.0625)(1/2)(14)(24 + 2)	11.38		9.67	110.04
	(.0625)(26)(29.7 - 24)	9.26		13.00	120.38
		30.95			256.20
Uplift	-(.0625)(29.7 +16)(26)	-74.26		13.00	-965.38
Total		51.00	0.00		823.34

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SUBJECT: Monolith R-44, Troy Lock and Dam - Dewatered Condition

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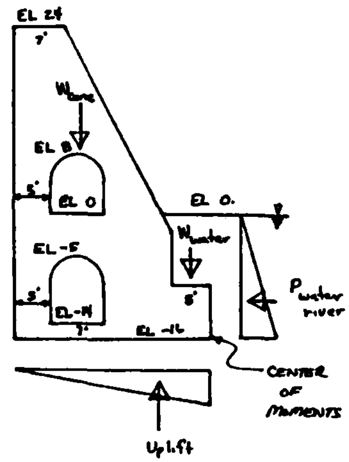

Item	Factor	F_V	F_H	Arm	Moment
W_{conc}	(.15)(26)(24 + 16)	156.00		13.00	2,028.00
	-(.15)(1/2)(14)(24 + 2)	-27.30		9.67	-263.99
	-(.15)(5)(24 + 9)	-24.75		2.50	-61.88
	-(.15)[π(3.5)2 + 7(4.5 + 5.5)]	-16.27		17.50	-284.73
	-(.15)[(5)(2.33)(3/20)]	-0.26		23.50	-6.11
		87.42			1,411.29
W_{water}	(.0625)(1/2)(2)(14/26)(2)	0.07		5.36	0.38
	(.0625)(5)(9)	2.81		2.50	7.03
		2.88			7.41
P_{water} river	$(.0625)(1/2)(16)^2$		8.00	5.33	42.64
Uplift	-(.0625)(1/2)(16)(26)	-13.00		8.67	-112.71
Total		77.30	8.00		1,348.63

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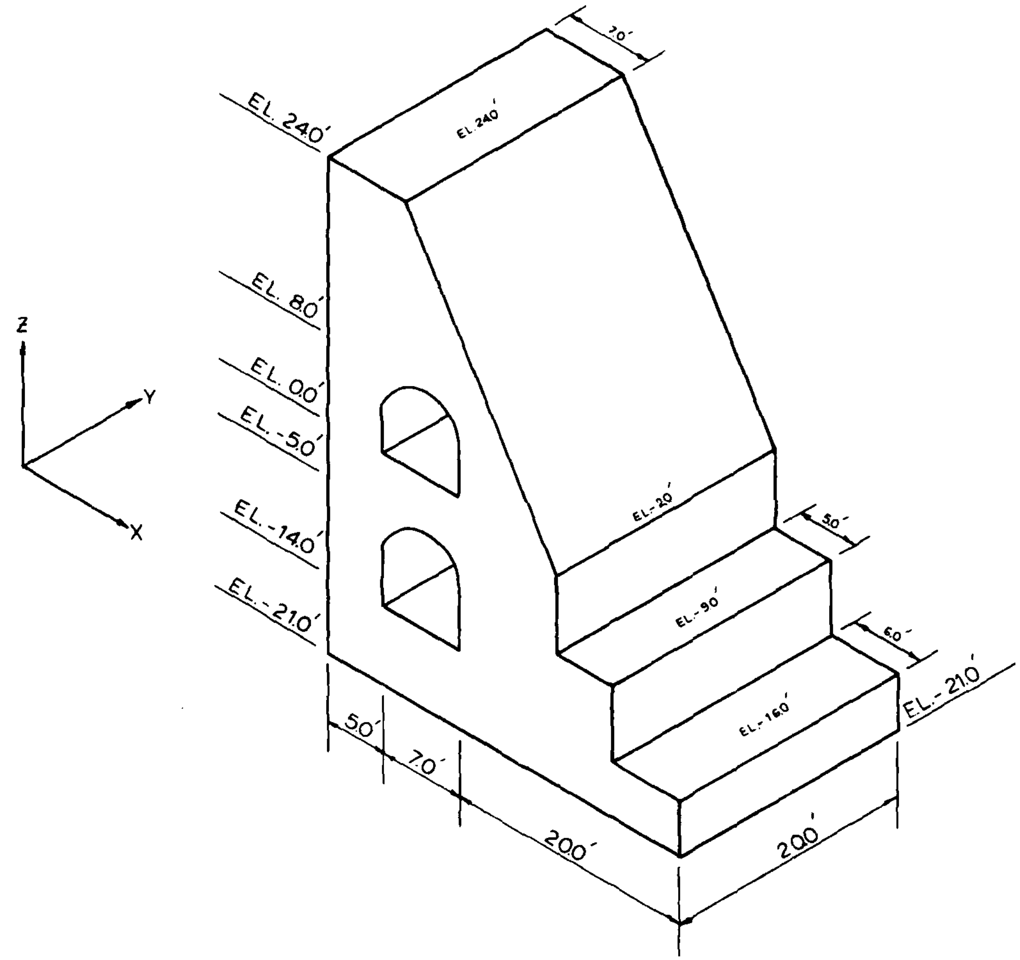
LOCK MONOLITH R-50



Stability analysis, monolith R-50, Troy Lock and Dam

SUBJECT: Monolith R-50, Troy Lock and Dam - Percent Effective Base

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LOAD CASE	Base Width	Sum of Vertical Forces	Sum of Moments	Resultant Moment Arm	Percent Effective Base	Full Uplift Under Non-Compressive Base Area*			
						Sum of Vertical Forces	Sum of Moments	Resultant Moment Arm	Percent Effective Base
	b (ft)	F_V (kips)	M (ft-kips)	$e = \frac{M}{F_V}$ (ft)	$\frac{3e}{b} * 100$ (%)	F_V (kips)	M (ft-kips)	$e = \frac{M}{F_V}$ (ft)	$\frac{3e}{b} * 100$ (%)
Normal Operation (Upper Pool in Chamber)	32	70.86	1083.18	15.29	100.0	--	--	--	--
Normal Operation with Ice-Lockside (Upper Pool)	32	70.86	1426.48	20.13	100.0**	--	--	--	--
Normal Operation with Earthquake-Lockside (Upper Pool)	32	70.86	1224.25	17.28	100.0**	--	--	--	--
Normal Operation with Impact (Upper Pool)	32	70.86	1163.84	16.42	100.0**	--	--	--	--

* Trial and error solution.

** Note: e = 32 - e .

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SUBJECT: Monolith R-50, Troy Lock and Dam - Percent Effective Base (Continued)

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LOAD CASE	Base Width	Sum of Vertical Forces	Sum of Moments	Resultant Moment Arm	Percent Effective Base	Full Uplift Under Non-Compressive Base Area: Sum of Vertical Forces	Full Uplift: Sum of Moments	Full Uplift: Resultant Moment Arm	Full Uplift: Percent Effective Base
	b (ft)	F_V (kips)	M (ft-kips)	$e = \frac{M}{F_V}$ (ft)	$\frac{3e}{b} * 100$ (%)	F_V (kips)	M (ft-kips)	$e = \frac{M}{F_V}$ (ft)	$\frac{3e}{b} * 100$ (%)
Normal Operation (Lower Pool In Chamber)	32	85.19	873.00	10.25	96.09	85.19	873.00	10.25	96.09
Normal Operation with Earthquake-Riverside (Lower Pool)	32	85.19	775.59	9.10	85.31	85.19	775.59	9.10	85.31
Normal Operation with Hawser (Lower Pool)	32	85.19	821.00	9.64	90.38	85.19	821.00	9.64	90.38
Flood Condition	32	65.01	726.92	11.18	100.0	--	--	--	--
Dewatered Condition	32	99.30	942.71	9.49	88.97	96.39	884.45	9.18	86.06

SUBJECT: Monolith R-50, Troy Lock and Dam - Factor of Safety Against Sliding

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LOAD CASE	Sum of Vertical Forces	Sum of Horizontal Forces	Friction Angle	Cohesive Strength	Base Area	Strut Resistance	Shear Resistance	Cohesive Resistance	Total Sliding Resistance	Factor of Safety Against Sliding
	F_V (kips)	F_H (kips)	ϕ (Degrees)	C (ksf)	A (sq ft)	R_s (kips)	$R_f = F_V \tan \phi$ (kips)	$R_c = CA$ (kips)	$R = R_s + R_f + R_c$ (kips)	$F.S. = \frac{R}{F_H}$
Normal Operation (Upper Pool in Chamber)	70.86	25.23	30.4	0.0	32.00	0.0	41.57	1.28	41.57	1.65
Normal Operation with Ice-Lockside (Upper Pool)	70.86	35.23	30.4	0.0	32.00	0.0	41.57	1.28	41.57	1.18
Normal Operation with Earthquake-Lockside (Upper Pool)	70.86	33.71	30.4	0.0	32.00	0.0	41.57	1.28	41.57	1.23
Normal Operation with Impact-Lockside (Upper Pool)	70.86	27.23	30.4	0.0	32.00	0.0	41.57	1.28	41.57	1.53

WES FORM NO. 1253A DECEMBER 1964

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SUBJECT: Monolith R-50, Troy Lock and Dam - Factor of Safety Against Sliding (Continued)

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LOAD CASE	Sum of Vertical Forces F_V (kips)	Sum of Horizontal Forces F_H (kips)	Friction Angle ϕ (Degrees)	Cohesive Strength C (KSF)	Base Area A (sq ft)	Strut Resistance R_s (kips)	Shear Resistance $R_f = F_v \tan \phi$ (kips)	Cohesive Resistance $R_c = CA$ (kips)	Total Sliding Resistance $R = R_s + R_f + R_c$ (kips)	Factor of Safety Against Sliding $F.S. = \frac{R}{F_H}$
Normal Operation (Lower Pool in Chamber)	85.19	0.00	30.4	0.0	30.75	0.0	49.98	0.0	49.98	∞
Normal Operation with Earthquake-Riverside (Lower Pool)	85.19	7.11	30.4	0.0	27.30	0.0	49.98	0.0	49.98	7.03
Normal Operation with Hawser (Lower Pool)	85.19	2.00	30.4	0.0	28.92	0.0	49.98	0.0	49.98	24.99
Flood Condition	65.01	0.00	30.4	0.0	32.00	0.0	38.14	0.0	38.14	∞
Dewatered Condition	96.39	13.78	30.4	0.0	27.54	0.0	56.55	0.0	56.55	4.10

WES FORM NO. 1253A

SUBJECT: Monolith R-50, Troy Lock and Dam - Base Pressures

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LOAD CASE	Sum of Vertical Forces F_V (kips)	Resultant Moment Arm e (ft)	Effective Base Width b (ft)	Axial Stress $f_a = \frac{F_V}{b}$ (ksf)	Bending Stress $f_b = \pm \frac{F_V\left(\frac{b}{2} - e\right)\frac{b}{2}}{b^3/12}$ (ksf)	Inter-granular Stress At Heel $f_h = f_a - f_b$ (ksf)	Inter-granular Stress At Toe $f_t = f_a + f_b$ (ksf)	Hydrostatic Pressure At Heel $f_{uh} = \gamma_w h_{uh}$ (ksf)	Hydrostatic Pressure At Toe $f_{ut} = \gamma_w h_{ut}$ (ksf)	Total Pressure At Heel $f_{Th} = f_h + f_{uh}$ (ksf)	Total Pressure At Toe $f_{Tt} = f_t + f_{uh}$ (ksf)
Normal Operation (Upper Pool in Chamber)	70.86	15.29	32.00	2.21	0.29	1.92	2.50	1.31	2.21	3.23	4.71
Normal Operation with Ice-Lockside (Upper Pool)	70.86	20.13	32.00	2.21	1.71	0.50	3.92	1.31	2.21	1.81	6.13
Normal Operation with Earthquake-Lockside (Upper Pool)	70.86	17.28	32.00	2.21	0.53	1.68	2.74	1.31	2.21	2.99	4.95
Normal Operation with Impact-Lockside (Upper Pool)	70.86	16.42	32.00	2.21	0.17	2.04	2.38	1.31	2.21	3.35	4.59

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SUBJECT: Monolith R-50, Troy Lock and Dam - Base Pressures (Continued)

COMPUTED BY: | DATE:
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LOAD CASE	Sum of Vertical Forces F_V (kips)	Resultant Moment Arm e (ft)	Effective Base Width b (ft)	Axial Stress $f_a = \frac{F_V}{b}$ (ksf)	Bending Stress $f_b = \pm \frac{F_V\left(\frac{b}{2} - e\right)\frac{b}{2}}{b^3/12}$ (ksf)	Inter-granular Stress At Heel $f_h = f_a - f_b$ (ksf)	Inter-granular Stress At Toe $f_t = f_a + f_b$ (ksf)	Hydrostatic Pressure At Heel $f_{uh} = \gamma_w h_{uh}$ (ksf)	Hydrostatic Pressure At Toe $f_{ut} = \gamma_w h_{ut}$ (ksf)	Total Pressure At Heel $f_{Th} = f_h + f_{uh}$ (ksf)	Total Pressure At Toe $f_{Tt} = f_t + f_{uh}$ (ksf)
Normal Operation (Lower Pool in Chamber)	85.19	10.25	30.75	2.77	2.77	0.00	5.54	1.31	1.31	1.31	6.85
Normal Operation with Earthquake-Riverside (Lower Pool)	85.19	9.10	27.30	3.12	3.12	0.00	6.24	1.31	1.31	1.31	7.55
Normal Operation with Hawser (Lower Pool)	85.19	9.64	28.92	2.95	2.95	0.00	5.90	1.31	1.31	1.31	7.21
Flood Condition	65.01	11.18	32.00	2.03	1.84	0.19	3.87	3.17	3.17	3.36	7.04
Dewatered Condition	99.30	9.49	28.47	3.49	3.49	0.00	6.98	1.31	0.00	1.31	6.98

WES FORM NO. 1253A DECEMBER 1966

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SUBJECT: Monolith R-50, Troy Lock and Dam - Normal Operation (Upper Pool in Chamber)

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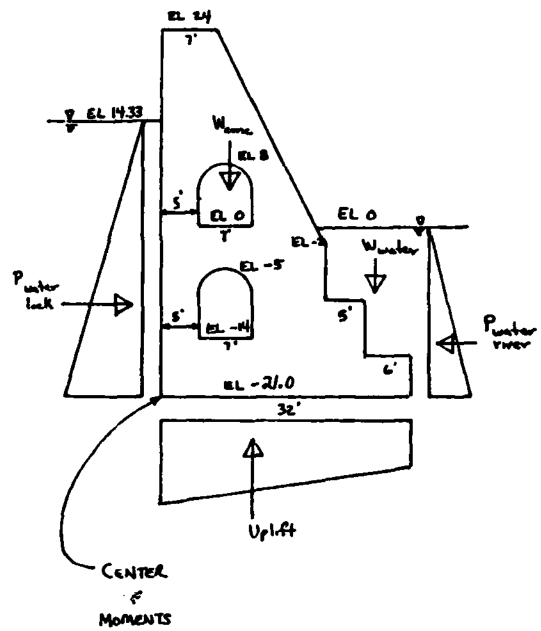

Item	Factors	F_Y	F_H	Arm	Moment
W_{conc}	(.15)(7)(26)	27.30		3.5	95.55
	(.15)(14)(26)(1/2)	27.30		11.67	318.59
	(.15)(21)(7)	22.05		10.50	231.53
	(.15)(26)(7)	27.30		13.00	354.90
	(.15)(32)(5)	24.00		16.00	384.00
	$-(.15 - .0625)[\pi(3.5)^2 + (7)(4.5 + 5.5)]$	-9.49		8.50	-80.67
	$-(.15 - .0625)[(5)(2.33)(3/20)]$	-0.15		2.50	-0.38
		118.31			1303.52
W_{water}	(.0625)(2)(14/26)(2)(1/2)	0.07		20.64	1.44
	(.0625)(5)(9)	2.81		23.50	66.04
	(.0625)(6)(16)	6.00		29.00	174.00
		8.88			241.48
P_{water} river	$-(.0625)(21)^2(1/2)$		-13.78	7.00	-96.46
P_{water} lock	$(.0625)(21 + 14.33)^2(1/2)$		39.01	11.78	459.54
Uplift	-(.0625)(21)(32)	-42.00		16.00	-672.00
	-(.0625)(14.33)(32)(1/2)	-14.33		10.67	-152.90
		-56.33			-824.90
Total		70.86	25.23		1083.18

WES FORM NO. 1253A DECEMBER 1966

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SUBJECT: Monolith R-50, Troy Lock and Dam - Normal Operation with Impact (Up)

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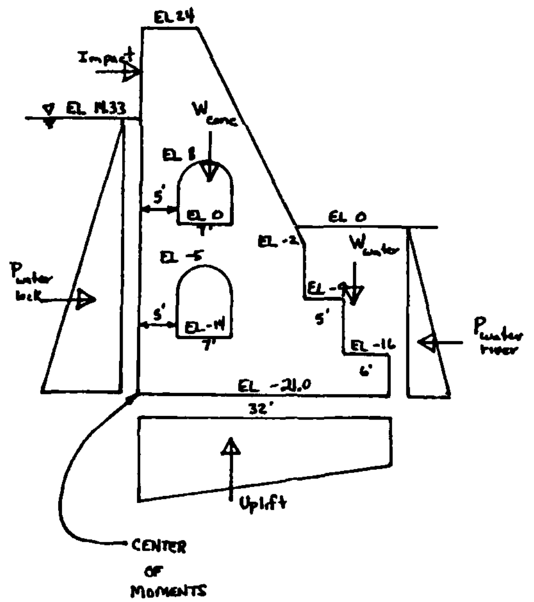

Item	Factors	F_Y	F_H	Arm	Moment
W_{conc}	(.15)(7)(26)	27.30		3.5	95.55
	(.15)(14)(26)(1/2)	27.30		11.67	318.59
	(.15)(21)(7)	22.05		10.50	231.53
	(.15)(26)(7)	27.30		13.00	354.90
	(.15)(32)(5)	24.00		16.00	384.00
	$-(.15 - .0625)[\pi(3.5)^2 + (7)(4.5 + 5.5)]$	-9.49		8.50	-50.67
	$-(.15 - .0625)[(5)(2.33)(3/20)]$	-0.15		2.50	-0.38
		118.31			1303.52
W_{water}	(.0625)(2)(14/26)(2)(1/2)	0.07		20.64	1.44
	(.0625)(5)(9)	2.81		23.50	66.04
	(.0625)(6)(16)	6.00		29.00	174.00
		8.88			241.48
P_{water} river	$-(.0625)(21)^2(1/2)$		-13.78	7.00	-96.46
P_{water} lock	$(.0625)(21 + 14.33)^2(1/2)$		39.01	11.78	459.54
Uplift	-(.0625)(21)(32)	-42.00		16.00	-672.00
	-(.0625)(14.33)(32)(1/2)	-14.33		10.67	-152.90
		-56.33			-824.90
Impact	40/20		2.00	40.33	80.66
Total		70.86	27.23		1163.84

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SUBJECT: Monolith R-50, Troy Lock and Dam - Normal Operation with Ice (Lockside) (Up)

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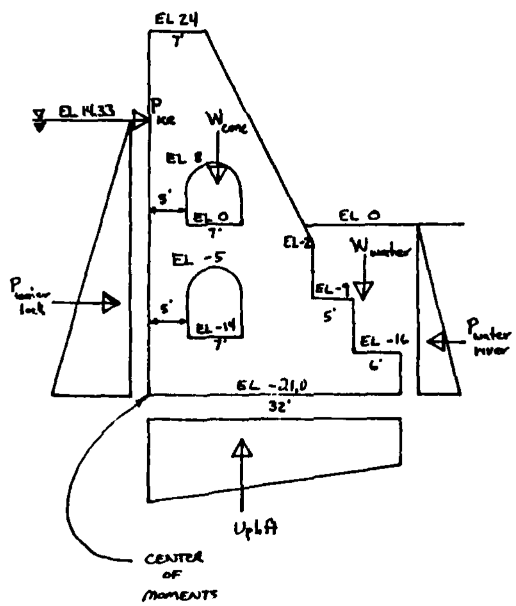

Item	Factors	F_Y	F_H	Arm	Moment
W_{conc}	(.15)(7)(26)	27.30		3.5	95.55
	(.15)(14)(26)(1/2)	27.30		11.67	318.59
	(.15)(21)(7)	22.05		10.50	231.53
	(.15)(26)(7)	27.30		13.00	354.90
	(.15)(32)(5)	24.00		16.00	384.00
	$-(.15 - .0625)[\pi(3.5)^2 + (7)(4.5 + 5.5)]$	-9.49		8.50	-80.67
	$-(.15 - .0625)[(5)(2.33)(3/20)]$	-0.15		2.50	-0.38
		118.31			1303.52
W_{water}	(.0625)(2)(14/26)(2)(1/2)	0.07		20.64	1.44
	(.0625)(5)(9)	2.81		23.50	66.04
	(.0625)(6)(16)	6.00		29.00	174.00
		8.88			241.48
P_{water} river	$-(.0625)(21)^2(1/2)$		-13.78	7.00	-96.46
P_{water} lock	$(.0625)(21 + 14.33)^2(1/2)$		39.01	11.78	459.54
Uplift	-(.0625)(21)(32)	-42.00		16.00	-672.00
	-(.0625)(14.33)(32)(1/2)	-14.33		10.67	-152.90
		-56.33			-824.90
P_{ice}	(5)(2)		10.00	34.33	343.30
Total		70.86	35.23		1426.48

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SUBJECT:

Monolith R-50, Troy Lock and Dam - Normal Operation with Earthquake (Lockside) (Up)

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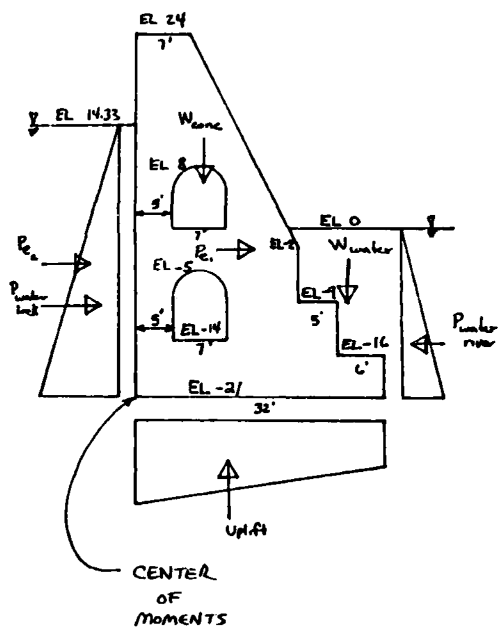

Item	Factors	F_Y	F_H	Arm	Moment
W_{conc}	(.15)(7)(26)	27.30		3.5	95.55
	(.15)(14)(26)(1/2)	27.30		11.67	318.59
	(.15)(21)(7)	22.05		10.50	231.53
	(.15)(26)(7)	27.30		13.00	354.90
	(.15)(32)(5)	24.00		16.00	384.00
	$-(.15 - .0625)[\pi(3.5)^2 + (7)(4.5 + 5.5)]$	-9.49		8.50	-80.67
	$-(.15 - .0625)[(5)(2.33)(3/20)]$	-0.15		2.50	-0.38
		118.31			1303.52
W_{water}	(.0625)(2)(14/26)(2)(1/2)	0.07		20.64	1.44
	(.0625)(5)(9)	2.81		23.50	66.04
	(.0625)(6)(16)	6.00		29.00	174.00
		8.88			241.48
P_{water} river	$-(.0625)(21)^2(1/2)$		-13.78	7.00	-96.46
P_{water} lock	$(.0625)(21 + 14.33)^2(1/2)$		39.01	11.78	459.54
Uplift	-(.0625)(21)(32)	-42.00		16.00	-672.00
	-(.0625)(14.33)(32)(1/2)	-14.33		10.67	-152.90
		-56.33			-824.90
Earth-quake	$P_{e_1} = \alpha W = (.05)[118.31 + 8.88]$		6.36	17.47	111.11
	$P_{e_2} = 2/3(51)(.05)(35.33)^2(1/1000)$		2.12	14.13	29.96
			8.48		141.07
Total		70.86	33.71		1224.25

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SUBJECT: Monolith R-50, Troy Lock and Dam, Location of Center of Gravity - Normal Operation with Earthquake	COMPUTED BY:	DATE:
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Location of Center of Gravity with Respect to Monolith Base

Concrete

Area (ft^2)	Arm (ft)	Area-Moment (ft^3)
(7)(26) = 182.00	32.00	5,824.00
1/2(14)(26) = 182.00	27.67	5,035.94
(21)(7) = 147.00	15.50	2,278.50
(26)(7) = 182.00	8.50	1,547.00
(32)(5) = 160.00	2.50	400.00
$-\pi(3.5)^2(1/2)$ = -19.24	26.99	-519.29
-(7)(4.5) = -31.50	23.25	-732.38
$-\pi(3.5)^2(1/2)$ = -19.24	13.99	-269.17
-(7)(5.5) = -38.50	9.75	-375.38
-(5)(2.33)(3/20) = -1.75	7.67	-13.42
742.77		13,175.80

$$\bar{Z} = \frac{13,175.80}{742.77} = 17.74 \text{ ft}$$

Water

Area $(ft)^2$	Arm (ft)	Area-Moment (ft^3)
$\pi(3.5)^2(1/2)$ = 19.24	26.29	519.29
7(4.5) = 31.50	23.25	732.38
$\pi(3.5)^2(1/2)$ = 19.24	13.99	269.17
7(5.5) = 38.50	9.75	375.38
(5)(2.33)(3/20) = 1.75	7.67	13.42
1/2(2)(14/26)(2) = 1.08	20.33	21.96
(5)(9) = 45.00	16.50	742.50
(6)(16) = 96.00	13.00	1,248.00
252.31		3,922.10

$$\bar{Z} = \frac{3,922.10}{252.31} = 15.54 \text{ ft}$$

Location of Center of Gravity of Earthquake Forces (Horizontal)

Item	Force (kips)	Arm (ft)	Moment (ft-kips)
Concrete	(.15)(742.77) = 111.42	17.74	1,976.59
Water	(.0625)(252.31) = 15.77	15.54	245.07
	127.19		2,221.66

$$Z = \frac{2,221.66}{127.19} = 17.47 \text{ ft}$$

SUBJECT: Monolith R-50, Troy Lock and Dam - Normal Operation (Lower Pool in Chamber)

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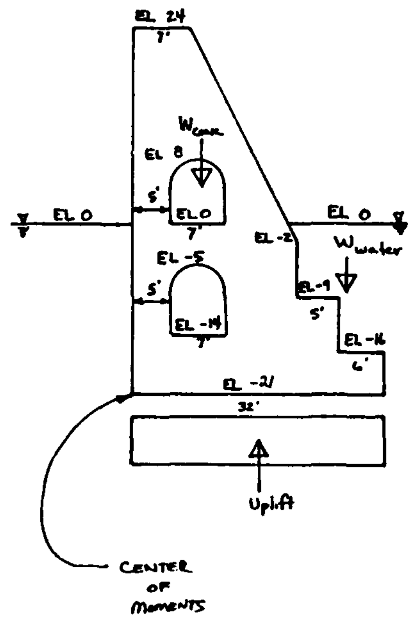

Item	Factors	F_Y	F_H	Arm	Moment
W_{conc}	(.15)(7)(26)	27.30		3.5	95.55
	(.15)(14)(26)(1/2)	27.30		11.67	318.59
	(.15)(21)(7)	22.05		10.50	231.53
	(.15)(26)(7)	27.30		13.00	354.90
	(.15)(32)(5)	24.00		16.00	384.00
	$-(.15 - .0625)[\pi(3.5)^2 + (7)(4.5 + 5.5)]$	-9.49		8.50	-80.67
	$-(.15 - .0625)[(5)(2.33)(3/20)]$	-0.15		2.50	-0.38
		118.31			1303.52
W_{water}	(.0625)(2)(14/26)(2)(1/2)	0.07		20.64	1.44
	(.0625)(5)(9)	2.81		23.50	66.04
	(.0625)(6)(16)	6.00		29.00	174.00
		8.88			241.48
Uplift	-(.0625)(21)(32)	-42.00		16.00	-672.00
Total		85.19	0.00		873.00

SUBJECT: Monolith R-50, Troy Lock and Dam - Normal Operation with Earthquake (Riverside)

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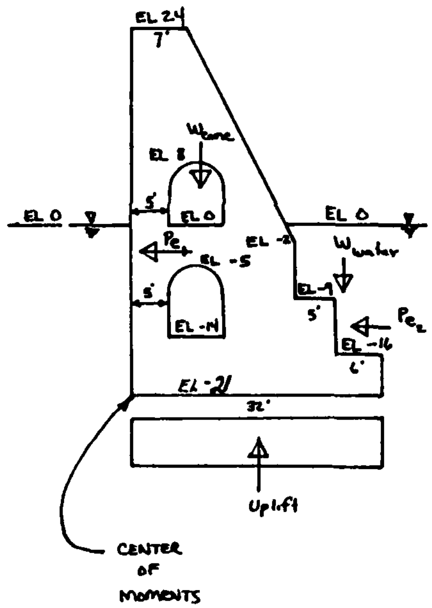

Item	Factors	F_Y	F_H	Arm	Moment
W_{conc}	(.15)(7)(26)	27.30		3.5	95.55
	(.15)(14)(26)(1/2)	27.30		11.67	318.59
	(.15)(21)(7)	22.05		10.50	231.53
	(.15)(26)(7)	27.30		13.00	354.90
	(.15)(32)(5)	24.00		16.00	384.00
	$-(.15 - .0625)[\pi(3.5)^2 + (7)(4.5 + 5.5)]$	-9.49		8.50	-80.67
	$-(.15 - .0625)[(5)(2.33)(3/20)]$	-0.15		2.50	-0.38
		118.31			1303.52
W_{water}	(.0625)(2)(14/26)(2)(1/2)	0.07		20.64	1.44
	(.0625)(5)(9)	2.81		23.50	66.04
	(.0625)(6)(16)	6.00		29.00	174.00
		8.88			241.48
Uplift	-(.0625)(21)(32)	-42.00		16.00	-672.00
Earth-quake	$P_{e_1} = \alpha W - [0.05][118.31 + 8.88]$		-6.36	17.47	-111.11
	$P_{e_2} = -2/3(51)(.05)(21)^2(1/1000)$		-0.75	8.40	-6.30
			-7.11		-117.41
Total		85.19	-7.11		775.59

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SUBJECT: Monolith R-50, Troy Lock and Dam - Normal Operation with Hawser (Lp)

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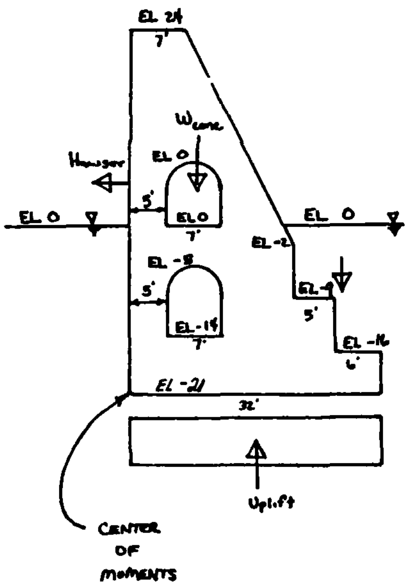

Item	Factors	F_Y	F_H	Arm	Moment
W_{conc}	(.15)(7)(26)	27.30		3.5	95.55
	(.15)(14)(26)(1/2)	27.30		11.67	318.59
	(.15)(21)(7)	22.05		10.50	231.53
	(.15)(26)(7)	27.30		13.00	354.90
	(.15)(32)(5)	24.00		16.00	384.00
	$-(.15 - .0625)[\pi(3.5)^2 + (7)(4.5 + 5.5)]$	-9.49		8.50	-80.67
	$-(.15 - .0625)[(5)(2.33)(3/20)]$	-0.15		2.50	-0.38
		118.31			1303.52
W_{water}	(.0625)(2)(14/26)(2)(1/2)	0.07		20.64	1.44
	(.0625)(5)(9)	2.81		23.50	66.04
	(.0625)(6)(16)	6.00		29.00	174.00
		8.88			241.48
Uplift	-(.0625)(21)(32)	-42.00		16.00	-672.00
Hawser	-40/20		-2.0	26.00	-52.00
Total		85.19	-2.0		821.00

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SUBJECT: Monolith R-50, Troy Lock and Dam - Flood Condition

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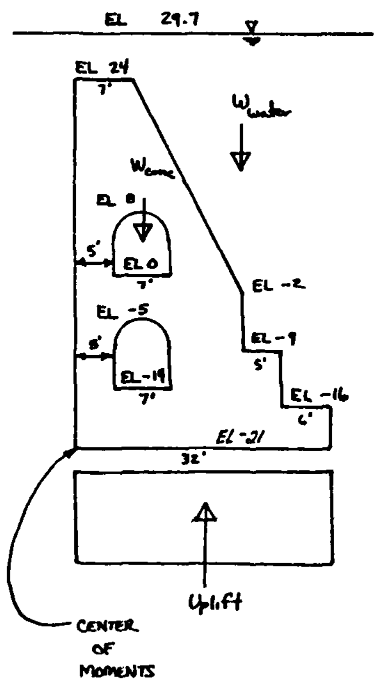

Item	Factors	F_Y	F_H	Arm	Moment
W_{conc}	(.15)(7)(26)	27.30		3.5	95.55
	(.15)(14)(26)(1/2)	27.30		11.67	318.59
	(.15)(21)(7)	22.05		10.50	231.53
	(.15)(26)(7)	27.30		13.00	354.90
	(.15)(32)(5)	24.00		16.00	384.00
	$-(.15 - .0625)[\pi(3.5)^2 + (7)(4.5 + 5.5)]$	-9.49		8.50	-80.67
	$-(.15 - .0625)[(5)(2.33)(3/20)]$	-0.15		2.50	-0.38
		118.31			1303.52
W_{water}	(.0625)(29.70 - 24)(32)	11.40		16.00	182.40
	(.0625)(24 + 2)(14)(1/2)	11.38		16.33	185.84
	(0.0625)(24 + 9)(11)	22.69		26.50	601.29
	(0.0625)(16 - 9)(6)	2.63		29.00	76.27
		48.10			1045.80
Uplift	-(.0625)(29.7 + 21)(32)	-101.40		16.00	-1622.40
Total		65.01	0.00		726.92

WES FORM NO. 1253A

PAGE OF

SUBJECT: Monolith R-50, Troy Lock and Dam - Dewatered Condition

COMPUTED BY: | DATE:

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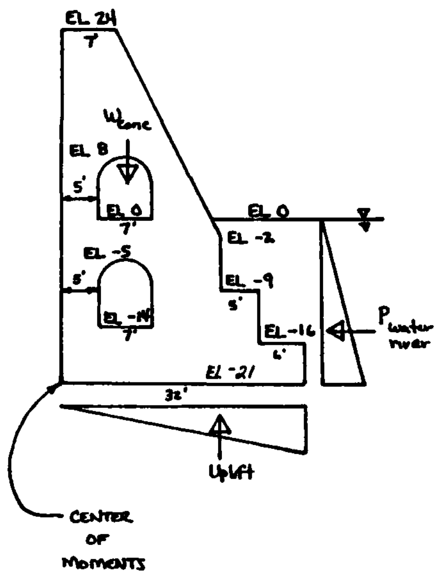
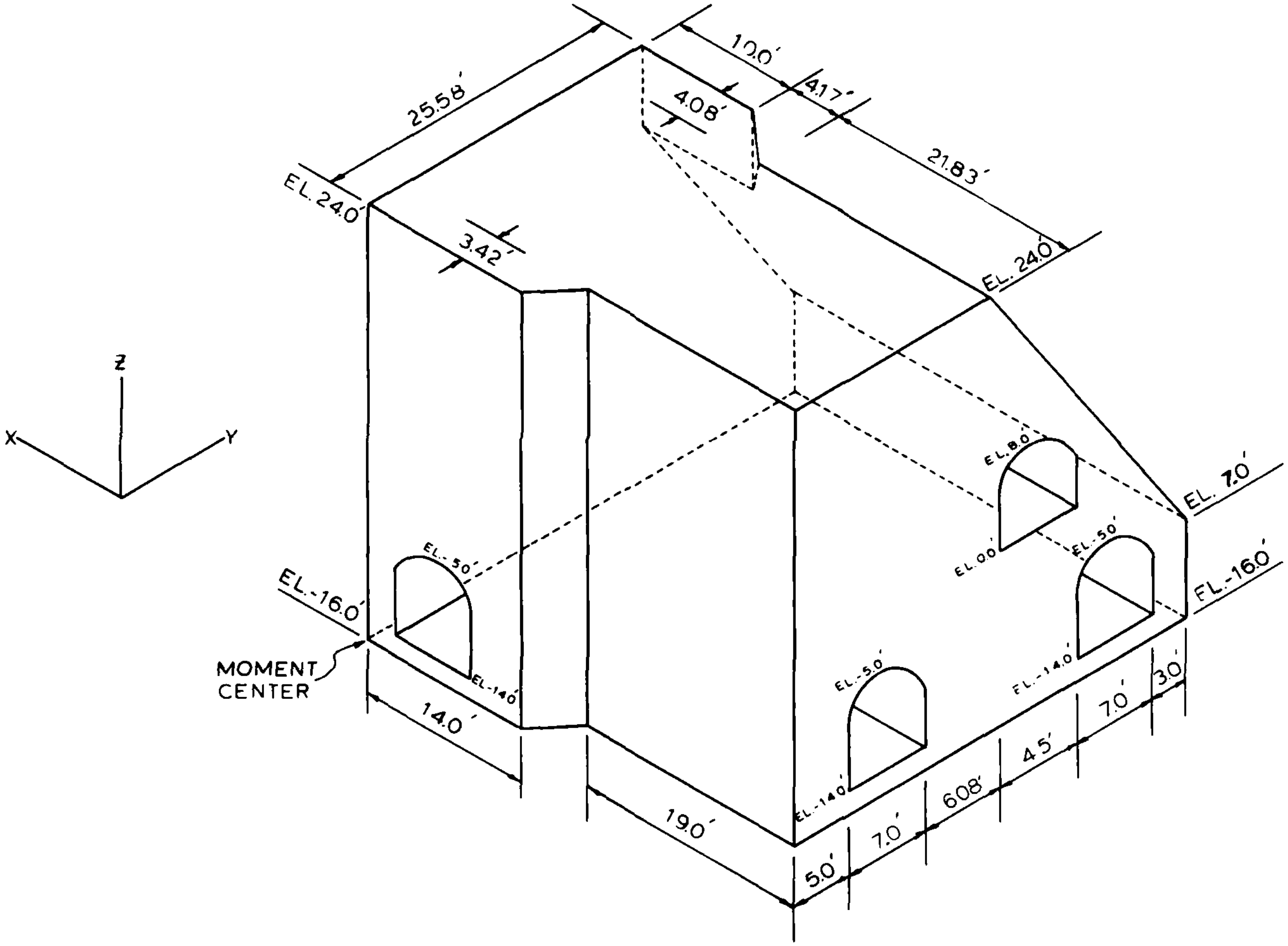


Item	Factors	F_Y	F_H	Arm	Moment
W_{conc}	(.15)(7)(26)	27.30		3.5	95.55
	(.15)(14)(26)(1/2)	27.30		11.67	318.59
	(.15)(21)(7)	22.05		10.50	231.53
	(.15)(26)(7)	27.30		13.00	354.90
	(.15)(32)(5)	24.00		16.00	384.00
	$-(.15)[\pi(3.5)^2 + (7)(4.5 + 5.5)]$	-16.27		8.50	-138.30
	-(.15)[(5)(2.33)(3/20)]	-0.26		2.50	-0.65
		111.42			1245.62
W_{water}	(.0625)(2)(14/26)(2)(1/2)	0.07		20.64	1.44
	(.0625)(5)(9)	2.81		23.50	66.04
	(.0625)(6)(16)	6.00		29.00	174.00
		8.88			241.48
P_{water} river	$-(.0625)(21)^2(1/2)$		-13.78	7.00	-96.46
Uplift	-(.0625)(21)(32)(1/2)	-21.00		21.33	-447.93
Total		99.30	-13.78		942.71

LOCK MONOLITH R-55



Stability analysis monolith R-55, Troy Lock and Dam

SUBJECT:

Monolith R-55, Troy Lock and Dam - Stability Summary

COMPUTED BY:

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LOAD CASE	Effective Area of Base in Compression (%)	Factor of Safety Against Sliding	Maximum Base Pressure (ksf)
Normal Operation (Most Critical Condition of Upper Pool in Lock Chamber and Gate Thrust)	100.0	2.53	5.70
Normal Operation with Earthquake	100.0	1.89	6.53
Flood Condition	100.0	∞	6.90
Dewatered Condition	100.0	9.70	6.91

WES FORM 1253A

PAGE OF

SUBJECT: Monolith R-55, Troy Lock and Dam - Maximum Bearing Pressure

COMPUTED BY:

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LOAD CASE	Height of Water Over Toe (ft)	Hydrostatic Pressure at Toe (ksf)	Maximum Intergranular Pressure at Toe (ksf)	Maximum Base Pressure (ksf)
Normal Operation (Most Critical Condition of Upper Pool in Lock Chamber and Gate Thrust)	16	1.00	4.70	5.70
Normal Operation with Earthquake	16	1.00	5.53	6.53
Flood Condition	45.7	2.86	4.04	6.90
Dewatered Condition	0.0	0.00	6.91	6.91

WES FORM NO. 1253A
DECEMBER 1964

SUBJECT: Monolith R-55, Troy Lock and Dam - Normal Operation

COMPUTED BY: | DATE:

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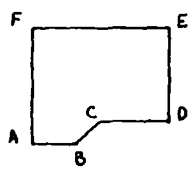
Base Area Properties - Initial

Area (ft^2)	Inertia About Principle X-Axis (ft^4)	Inertia About Principle Y-Axis (ft^4)	XBar (ft)	YBar (ft)	ZBar (ft)	Angle Principle X-Axis Makes with X-Axis (Degrees)
1225.89	115244	137942	-18.93	.7.56	0.00	20.16

Summary of Forces and Moments - Initial

F_x (kips)	F_y (kips)	F_z (kips)	M_{xx} (ft-k)	M_{yy} (ft-k)	M_{zz} (ft-k)
-1012.75	-466.80	4173.37	64,214.4	77,795.1	18,229.5

Base Pressures - Initial



Pressure Point	X Coordinate	Y Coordinate	Z Coordinate	Pressure (ksf)
A	0.00	0.00	0.00	4.70
B	0.00	14.00	0.00	3.80
C	-3.42	17.00	0.00	3.59
D	-3.42	36.00	0.00	2.36
E	-36.00	36.00	0.00	2.24
F	-36.00	0.00	0.00	4.56

WES FORM NO. 1253A

SUBJECT: Monolith R-55, Troy Lock and Dam - Normal Operation

COMPUTED BY: DATE:

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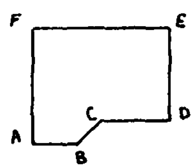
Base Area Properties - Final*

Area (ft^2)	Inertia About Principle X-Axis (ft^4)	Inertia About Principle Y-Axis (ft^4)	XBar (ft)	YBar (ft)	ZBar (ft)	Angle Principle X-Axis Makes with X-Axis (Degrees)
1225.89	115244	137942	-18.93	17.56	0.00	20.16

Summary of Forces and Moments - Final*

F_x (kips)	F_y (kips)	F_z (kips)	M_{xx} (ft-k)	M_{yy} (ft-k)	M_{zz} (ft-k)
-1012.75	-466.80	4173.37	64,214.4	77,795.1	18,229.5

Base Pressures - Final*



Pressure Point	X Coordinate	Y Coordinate	Z Coordinate	Pressure (ksf)
A	0.00	0.00	0.00	4.70
B	0.00	14.00	0.00	3.80
C	-3.42	17.00	0.00	3.59
D	-3.42	36.00	0.00	2.36
E	-36.00	36.00	0.00	2.24
F	-36.00	0.00	0.00	4.56

* Values are after iteration releasing tension at base-foundation interface and applying full uplift under noncompressive area of base.

WES FORM NO. 1253A

PAGE OF

SUBJECT: Monolith R-55, Troy Lock and Dam - Normal Operation with Earthquake

COMPUTED BY: DATE

CHECKED BY: DATE

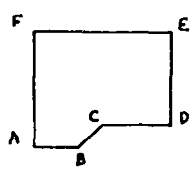
Base Area Properties - Initial

Area (ft^2)	Inertia About Principle X-Axis (ft^4)	Inertia About Principle Y-Axis (ft^4)	XBar (ft)	YBar (ft)	ZBar (ft)	Angle Principle X-Axis Makes with X-Axis (Degrees)
1225.89	115244	137942	-18.93	17.56	0.00	20.16

Summary of Forces and Moments - Initial

F_x (kips)	F_y (kips)	F_z (kips)	M_{xx} (ft-k)	M_{yy} (ft-k)	M_{zz} (ft-k)
-1324.88	466.80	4173.37	64,214.4	72,132.2	23,847.8

Base Pressures - Initial



Pressure Point	X Coordinate	Y Coordinate	Z Coordinate	Pressure (ksf)
A	0.00	0.00	0.00	5.53
B	0.00	14.00	0.00	4.62
C	-3.42	17.00	0.00	4.25
D	-3.42	36.00	0.00	3.03
E	36.00	36.00	0.00	1.32
F	36.00	0.00	0.00	3.64

WES FORM NO 1253A

SUBJECT: Monolith R-55, Troy Lock and Dam - Normal Operation with Earthquake

COMPUTED BY: DATE:

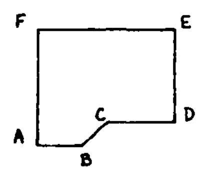
CHECKED BY: DATE:

Base Area Properties - Final*

Area (ft^2)	Inertia About Principle X-Axis (ft^4)	Inertia About Principle Y-Axis (ft^4)	XBar (ft)	YBar (ft)	ZBar (ft)	Angle Principle X-Axis Makes with X-Axis (Degrees)
1225.89	115244	137942	-18.93	17.56	0.00	20.16

Summary of Forces and Moments - Final*

F_x (kips)	F_y (kips)	F_z (kips)	M_{xx} (ft-k)	M_{yy} (ft-k)	M_{zz} (ft-k)
-1324.88	466.80	4173.37	64,214.4	72,132.2	23,847.8



Base Pressures - Final*

Pressure Point	X Coordinate	Y Coordinate	Z Coordinate	Pressure (ksf)
A	0.00	0.00	0.00	5.53
B	0.00	14.00	0.00	4.62
C	-3.42	17.00	0.00	4.25
D	-3.42	36.00	0.00	3.03
E	-36.00	36.00	0.00	1.32
F	-36.00	0.00	0.00	3.64

* Values are after iteration releasing tension at base-foundation interface.

SUBJECT: Monolith R-55, Troy Lock and Dam - Flood Condition

COMPUTED BY: DATE:

CHECKED BY: DATE:

Base Area Properties - Initial

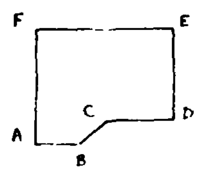
Area (ft^2)	Inertia About Principle X-Axis (ft^4)	Inertia About Principle Y-Axis (ft^4)	XBar (ft)	YBar (ft)	ZBar (ft)	Angle Principle X-Axis Makes with X-Axis (Degrees)
1225.89	115244	137942	-18.93	17.56	0.00	20.16

Summary of Forces and Moments - Initial

F_x (kips)	F_y (kips)	F_z (kips)	M_{xx} (ft-k)	M_{yy} (ft-k)	M_{zz} (ft-k)
0.00	0.00	-3096.78	-54,258.6	-48,942.3	0.0

Base Pressures - Initial

Pressure Point	X Coordinate	Y Coordinate	Z Coordinate	Pressure (ksf)
A	0.00	0.00	0.00	3.97
B	0.00	14.00	0.00	4.04
C	-3.42	17.00	0.00	3.78
D	-3.42	36.00	0.00	3.87
E	-36.00	36.00	0.00	1.23
F	-36.00	0.00	0.00	1.05



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Monolith R-55, Troy Lock and Dam - Flood Condition

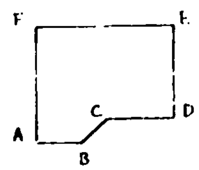
Base Area Properties - Final*

Area (ft^2)	Inertia About Principle X-Axis (ft^4)	Inertia About Principle Y-Axis (ft^4)	XBar (ft)	YBar (ft)	ZBar (ft)	Angle Principle X-Axis Makes with X-Axis (Degrees)
1225.89	115244	137942	-18.93	17.56	0.00	20.16

Summary of Forces and Moments - Final*

F_x (kips)	F_y (kips)	F_z (kips)	M_{xx} (ft-k)	M_{yy} (ft-k)	M_{zz} (ft-k)
0.0	0.0	3096.78	54,258.6	48,942.3	0.0

Base Pressures - Final*



Pressure Point	X Coordinate	Y Coordinate	Z Coordinate	Pressure (ksf)
A	0.00	0.00	0.00	3.97
B	0.00	14.00	0.00	4.04
C	-3.42	17.00	0.00	3.78
D	-3.42	36.00	0.00	3.87
E	-36.00	36.00	0.00	1.23
F	-36.00	0.00	0.00	1.05

* Values are after iteration releasing tension at base-foundation interface.

PAGE OF

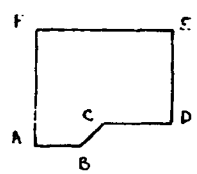
SUBJECT: Monolith R-55, Troy Lock and Dam - Dewatered Condition	COMPUTED BY:	DATE:
	CHECKED BY:	DATE:

Base Area Properties - Initial

Area (ft^2)	Inertia About Principle X-Axis (ft^4)	Inertia About Principle Y-Axis (ft^4)	XBar (ft)	YBar (ft)	ZBar (ft)	Angle Principle X-Axis Makes with X-Axis (Degrees)
1225.89	115244	137942	-18.93	17.56	0.00	20.16

Summary of Forces and Moments - Initial

F_x (kips)	F_y (kips)	F_z (kips)	M_{xx} (ft-k)	M_{yy} (ft-k)	M_z (ft-k)
288.00	0.00	4679.83	80,879.8	68,951.2	5184.0



Base Pressures - Initial

Pressure Point	X Coordinate	Y Coordinate	Z Coordinate	Pressure (ksf)
A	0.00	0.00	0.00	6.89
B	0.00	14.00	0.00	6.91
C	-3.42	17.00	0.00	6.36
D	-3.42	36.00	0.00	6.39
E	-36.00	36.00	0.00	1.06
F	-36.00	0.00	0.00	0.99

SUBJECT: Monolith R-55, Troy Lock and Dam - Dewatered Condition

COMPUTED BY: DATE:

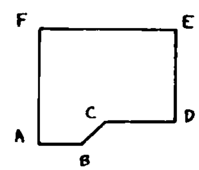
CHECKED BY: DATE:

Base Area Properties - Final*

Area (ft^2)	Inertia About Principle X-Axis (ft^4)	Inertia About Principle Y-Axis (ft^4)	XBar (ft)	YBar (ft)	ZBar (ft)	Angle Principle X-Axis Makes with X-Axis (Degrees)
1225.89	115244	137942	-18.93	17.56	0.00	20.16

Summary of Forces and Moments - Final*

F_x (kips)	F_y (kips)	F_z (kips)	M_{xx} (ft-k)	M_{yy} (ft-k)	M_{zz} (ft-k)
288.00	0.00	4679.83	80,879.8	68.951.2	5184.0



Base Pressures - Final*

Pressure Point	X Coordinate	Y Coordinate	Z Coordinate	Pressure (ksf)
A	0.00	0.00	0.00	6.89
B	0.00	14.00	0.00	6.91
C	-3.42	17.00	0.00	6.36
D	-3.42	36.00	0.00	6.39
E	-36.00	36.00	0.00	1.06
F	-36.00	0.00	0.00	0.99

* Values are after iteration releasing tension at base-foundation interface and applying full uplift under noncompressive area of base.

SUBJECT: Monolith R-55, Troy Lock and Dam - Normal Operation

COMPUTED BY:

DATE:

CHECKED BY:

DATE:

Item	Factors	F_x	F_y	F_z	Arm_{xx}	Arm_{yy}	M_{xx}	M_{yy}
W_{conc}	-(.15)(36)(36)(40)			7776.00	18.00	18.00	139,968.00	139,968.00
	(.15)(1/2)(3.42)(3)(40)			-30.78	16.00	2.28	-492.48	-70.18
	(.15)(3.42)(19)(40)			-389.88	26.50	1.71	-10,331.82	-666.69
	(.15)(1/2)(14.50)(36)(24 - (-7))			-1213.65	18.00	31.17	-21,845.70	-37,829.47
	-(.15)(1/2)(4.08)(10)(8.72)			26.68	5.00	24.22	133.40	646.19
	(.15)(π/4)[(14.92)^2 - (7.92)^2](5.5)			-103.59	9.92	8.00	-1,027.61	-828.72
	(.15)[(π)/2(3.5)^2][(2)(π/4)(11.42)]			-51.78	9.92	8.00	-513.66	-414.24
	(.15)(7)(18.58)(5.5)			-107.30	26.71	11.92	-2,865.98	-1,279.02
	(.15)(π/2)(3.5)^2(18.58)			-53.63	26.71	11.92	-1,432.46	-639.27
	(.15)(7)(.5)(5.5)			-2.89	6.00	0.25	-17.34	-0.72
	(.15)(π/2)(3.5)^2(.5)			-1.44	6.00	0.25	-8.64	-0.36
	(.15)π/4[(14.92)^2 - (7.92)^2](5.5)			-103.59	9.92	28.00	-1,027.61	-2,900.52
	(.15)[(π/2)(3.5)^2][(2)(π/4)(11.42)			-51.78	9.92	28.00	-513.66	-1,449.84
	(.15)(7)(18.58)(5.5)			-107.30	26.71	24.08	-2,865.98	-2,583.78
	(.15)(π/2)(3.5)^2(18.58)			-53.63	26.71	24.08	-1,432.46	-1,291.41
	(.15)(7)(.5)(5.5)			-2.89	6.00	35.75	-17.34	-103.32
	(.15)(π/2)(3.5)^2(.5)			-1.44	6.00	35.75	-8.64	-51.48
	(.15)(7)(17.4)(4.5)			-82.22	27.50	22.50	-2,261.05	-1,849.95
	(.15)(π/2)(3.5)^2(17.4)			-50.22	27.50	22.50	-1,381.05	-1,129.95
	(.15)($\sqrt{(8.3)^2 + 18.4)^2 + (6.8)^2}$)(7)(7.7)			-172.21	13.20	18.35	-2,273.17	-3,160.05
	(.15)(3)(7)(7.7)			-24.26	1.50	14.20	-36.39	-344.49
	(.15)(2)(7)(7.7)			-16.17	13.20	18.35	-213.44	-296.72
				5182.03			89,534.92	83,724.01
$Thrust_{gate}$	Fx = T cos 2α = 726.21 cos (2 * 20)	556.31				11.95		6,647.90
	Fy = T sin 2α = 726.61 sin (2 * 20)		-466.80		11.95		5,578.26	
		556.31	-466.80				5,578.26	6,647.90
Sub-Total		556.31	-466.80	5182.03			83,956.66	90,371.91

WES FORM NO 1253A DECEMBER 1964

PAGE OF

SUBJECT: Mono ith R-55, Troy Lock and Dam - Normal Operation (Continued)

COMPUTED BY:

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Item	Factors	F_x	F_y	F_z	Arm_{xx}	Arm_{yy}	M_{xx}	M_{yy}
W_{tunnel}	$(.0625)(\pi/4)[(14.92)^2 - (7.92)^2](5.5)$			43.16	9.92	8.00	428.15	345.28
	$(.0625)[(\pi/2)(3.5)^2][2(\pi/4)(11.42)]$			21.57	9.92	8.00	213.97	172.56
	$(.0625)(7)(18.58)(5.5)$			44.71	26.71	11.92	1,194.20	532.94
	$(.0625)(\pi/2)(3.5)^2(18.58)$			22.35	26.71	11.92	596.97	266.41
	$(.0625)(7)(0.5)(5.5)$			1.20	6.00	.25	7.20	0.30
	$(.0625)(\pi/2)(3.5)^2(0.5)$			0.60	6.00	.25	3.60	0.15
	$(.0625)(\pi/4)[(14.92)^2 - (7.92)^2][5.5]$			43.16	9.92	28.00	428.15	1,208.48
	$(.0625)[(\pi/2)(3.5)^2][(2)(\pi/4)(11.42)]$			21.57	9.92	28.00	213.97	603.96
	$(.0625)(7)(18.58)(5.5)$			44.71	26.71	24.08	1,194.20	1,076.62
	$(.0625)(\pi/2)(3.5)^2(18.58)$			22.35	26.71	24.08	596.97	538.19
	$(.0625)(7)(0.5)(5.5)$			1.20	6.00	35.75	7.20	42.90
	$(.0625)(\pi/2)(3.5)^2(0.5)$			0.60	6.00	35.75	3.60	21.45
	$(.0625)(7)(17.4)(4.5)$			34.26	27.50	22.50	942.15	770.85
	$(.0625)(\pi/2)(3.5)^2(17.4)$			20.93	27.50	22.50	575.58	470.93
	$(.0625)(\sqrt{(8.3)^2 + (18.4)^2 + (6.8)^2})(7)(7.7)$			71.75	13.20	18.35	947.10	1,316.61
	$(.0625)(3)(7)(7.53)$			9.88	1.50	14.20	14.82	140.30
	$(.0625)(2)(7)(7.7)$			6.74	13.20	18.35	88.97	123.68
				410.74			7,456.80	7,631.61
W_{water}	$-(.0625)(1/2)(3.27)(36)(7)$			25.75	18.00	34.91	463.50	898.93
W_{gate}	$-85[1 - (16 + 14.33)/(24 - (-16)) * (0.0625)]$			80.97	19.35	11.25	1,566.77	910.91
P_{water}	$(.0625)(1/2)(14.33)^2(22)$	141.18				20.78		2,933.72
	$(.0625)(14.33)(16)(22)$	315.26				8.00		2,522.08
		456.44						5,455.80
Sub-Total		1012.75	-466.80	5699.49			93,443.73	105,269.16

WES FORM NO. 1253A DECEMBER 1964

PAGE OF

SUBJECT: Monolith R-55, Troy Lock and Dam - Normal Operation (Continued)

COMPUTED BY: DATE:

CHECKED BY: DATE:

Item	Factors	F_x	F_y	F_z	Arm_{xx}	Arm_{yy}	M_{xx}	M_{yy}
Uplift	(.0625)(16)(36)(14)			-504.00	7.00	18.00	-3,528.00	-9,072.00
	(.0625)(16)(34.29)(3)			-102.87	15.50	18.86	-1,594.49	-1,940.13
	(.0625)(30.33 - 16)(1/2)(34.29)(3)(1/2)			-23.03	15.50	13.14	-356.97	-302.61
	(.0625)(16)(32.58)(19)			-619.02	26.50	19.71	-16,404.03	-12,200.88
	(.0625)(30.33 - 16)(1/2)(32.58)(19)			-277.20	26.50	14.28	-7,345.80	-3,958.42
				-1526.12			-29,229.29	-27,474.04
Total		1012.75	-466.80	4173.37			64,214.44	77,795.12

WES FORM NO. 1253A

PAGE OF

SUBJECT: Monolith R-55, Troy Lock and Dam - Normal Operation with Earthquake

COMPUTED BY: DATE:

CHECKED BY: DATE:

Item	Factors	F_x	F_y	F_z	Arm_{xx}	Arm_{yy}	M_{xx}	M_{yy}
Normal Operation Loads	(Values are after releasing tension at base-foundation interface and applying full uplift under noncompressive area of base)	1012.75	466.80	4173.37			64,214.44	77,795.12
Earthquake								
P_{e_1}	$(.05)(5182.03 + 410.74 + 82.88)$	283.78				18.83		-5,343.58
P_{e_2}	$(.7)(2/3)(51)(.05)[(30.33)^2(22) + (16)^2(14)(1/1000)]$	28.35				11.27		-319.34
		312.13						-5,662.92
Total		1324.88	466.80	4173.37			64,214.44	72,132.20

WES FORM NO. 1253A DECEMBER 1964

PAGE OF

SUBJECT:	COMPUTED BY:	DATE:
Monolith R-55, Troy Lock and Dam - Flood Condition	CHECKED BY:	DATE:

Item	Factors	F_x	F_y	F_z	Arm_{xx}	Arm_{yy}	M_{xx}	M_{yy}
W_{conc}	(.15)(36)(36)(40)			7776.00	18.00	18.00	139,968.00	139,968.00
	(.15)(1/2)(3.42)(3)(40)			-30.78	16.00	2.28	-492.48	-70.18
	(.15)(3.42)(19)(40)			-389.88	26.50	1.71	-10,331.82	-666.69
	(.15)(1/2)(14.50)(36)(24 - (-7))			-1213.65	18.00	31.17	-21,845.70	-37,829.47
	(.15)(1/2)(4.08)(10)(8.72)			26.68	5.00	24.22	133.40	646.19
	$(.15)(\pi/4)[(14.92)^2 - (7.92)^2](5.5)$			-103.59	9.92	8.00	-1,027.61	-828.72
	$(.15)[\pi/2](3.5)^2(2)(\pi/4)(11.42)$			-51.78	9.92	8.00	-513.66	-414.24
	(.15)(7)(18.58)(5.5)			-107.30	26.71	11.92	-2,865.98	-1,279.02
	$(.15)(\pi/2)(3.5)^2(18.58)$			-53.63	26.71	11.92	-1,432.46	-639.27
	(.15)(7)(0.5)(5.5)			-2.89	6.00	.25	-17.34	-0.72
	$(.15)(\pi/2)(3.5)^2(.5)$			-1.44	6.00	.25	-8.64	-0.36
	$(.15)(\pi/4)[(14.92)^2 - (7.92)^2](5.5)$			-103.59	9.92	28.00	-1,027.61	-2,900.52
	$(.15)(\pi/2)(3.5)^2(2)(\pi/4)(11.42)$			-51.78	9.92	28.00	-513.66	-1,449.84
	(.15)(7)(18.58)(5.5)			-107.30	26.71	24.08	-2,865.98	-2,583.78
	$(.15)(\pi/2)(3.5)^2(18.58)$			-53.63	26.71	24.08	-1,432.46	-1,291.41
	(.15)(7)(.5)(5.5)			-2.89	6.00	35.75	-17.34	-103.32
	$(.15)(\pi/2)(3.5)^2(.5)$			-1.44	6.00	35.75	-8.64	-51.48
	(.15)(7)(17.4)(4.5)			-82.22	27.50	22.50	-2,261.05	-1,849.95
	$(.15)(\pi/2)(3.5)^2(17.4)$			-50.22	27.50	22.50	-1,381.05	-1,129.95
	$(.15)(\sqrt{(8.3)^2 + 18.4)^2 + (6.8)^2})(7)(7.7)$			-172.21	13.20	18.35	-2,273.17	-3,160.05
	(.15)(3)(7)(7.7)			-24.26	1.50	14.20	-36.39	-344.49
	(.15)(2)(7)(7.7)			-16.17	13.20	18.35	-213.44	-296.72
				5182.03			89,534.92	83,724.01
W_{water}	(.0625)(1/2)(14.5)(36)(31)			505.69	18.00	31.17	9,102.42	15,762.36
	(.0625)(1/2)(4.08)(10)(8.72)			-11.12	5.00	24.22	-55.60	-269.33
	(.0625)(36)(14)(29.7 - 24)			179.55	7.00	18.00	1,256.85	3,231.90
	(.0625)(32.58)(22)(29.7 - 24)			255.35	25.00	19.71	6,383.75	5,032.95
	(.0625)(1/2)(3.42)(3)(29.7 - 24)			1.83	15.00	2.28	27.45	4.17
				931.30			16,714.87	23,762.05
Sub-Total		0.00	0.00	6113.33			106,249.79	107,486.06

SUBJECT: Monolith R-55, Troy Lock and Dam - Flood Condition (Continued)

COMPUTED BY: | DATE:
CHECKED BY: | DATE:

Item	Factors	F_x	F_y	F_z	Arm_{xx}	Arm_{yy}	M_{xx}	M_{yy}
W_{tunnel}	$(.0625)(\pi/4)[(14.92)^2 - (7.92)^2](5.5)$			43.16	9.92	8.00	428.15	345.28
	$(.0625)(\pi/2)(3.5)^2(2)(\pi/4)(11.42)$			21.57	9.92	8.00	213.97	172.56
	$(.0625)(7)(18.58)(5.5)$			44.71	26.71	11.92	1,194.20	532.94
	$(.0625)(\pi/2)(3.5)^2(18.58)$			22.35	26.71	11.92	596.97	266.41
	$(.0625)(7)(0.5)(5.5)$			1.20	6.00	0.25	7.20	0.30
	$(.0625)(\pi/2)(3.5)^2(0.5)$			0.60	6.00	0.25	3.60	0.15
	$(.0625)(\pi/4)[(14.92)^2 - (7.92)^2](5.5)$			43.16	9.92	28.00	428.15	1,208.48
	$(.0625)(\pi/2)(3.5)^2(2)(\pi/4)(11.42)$			21.57	9.92	28.00	213.97	603.96
	$(.0625)(7)(18.58)(5.5)$			44.71	26.71	24.08	1,194.20	1,076.62
	$(.0625)(\pi/2)(3.5)^2(18.58)$			22.35	26.71	24.08	596.97	538.19
	$(.0625)(7)(0.5)(5.5)$			1.20	6.00	35.75	7.20	42.90
	$(.0625)(\pi/2)(3.5)^2(0.5)$			0.60	6.00	35.75	3.60	21.45
	$(.0625)(7)(17.4)(4.5)$			34.26	27.50	22.50	942.15	770.85
	$(.0625)(\pi/2)(3.5)^2(17.4)$			20.93	27.50	22.50	575.58	470.93
	$(.0625)(\sqrt{(8.3)^2 + (18.4)^2 + (6.8)^2})(7)(7.7)$			71.75	13.20	18.35	947.10	1,316.61
	$(.0625)(3)(7)(7.53)$			9.88	1.50	14.20	14.82	140.30
	$(.0625)(2)(7)(7.7)$			6.74	13.20	18.35	88.97	123.68
				410.74			7,456.80	7,631.61
W_{gate}	$(85)(.490 - .0625)(1/.49)$			74.16	27.47	1.71	2,037.18	126.81
Sub-Total		0.00	0.00	6598.23			115,743.77	115,244.48

WES FORM No. 1253A

PAGE OF

SUBJECT: Monolith R-55, Troy Lock and Dam - Flood Condition (Continued)

COMPUTED BY:

CHECKED BY:

DATE:

DATE:

Item	Factors	F_x	F_y	F_z	Arm_{xx}	Arm_{yy}	M_{xx}	M_{yy}
Uplift	(.0625)(29.7 + 16)(36)(14)			-1,439.55	7.00	18.00	-10,076.85	-25,911.90
	(.0625)(29.7 + 16)(34.29)(3)			-293.82	15.00	18.86	-4,554.21	-5,541.45
	(.0625)(29.7 + 16)(32.58)(19)			-1,768.08	26.50	19.71	-46.854.12	-34,848.86
				-3,501.45			-61,485.18	-66,302.21
Total		0.00	0.00	3,096.78			54,258.59	48,942.27

WES FORM NO. 1253A DECEMBER 1966

PAGE OF

SUBJECT: Monolith R-55, Troy Lock and Dam - Dewatered Condition

COMPUTED BY:

DATE:

CHECKED BY:

DATE:

Item	Factors	F_x	F_y	F_z	Arm_{xx}	Arm_{yy}	M_{xx}	M_{yy}
W_{conc}	$(.15)(36)(36)(40)$			7776.00	18.00	18.00	139,968.00	139,968.00
	$(.15)(1/2)(3.42)(3)(40)$			-30.78	16.00	2.28	-492.48	-70.18
	$(.15)(3.42)(19)(40)$			-389.88	26.50	1.71	-10,331.82	-666.69
	$(.15)(1/2)(14.50)(36)(24 - (-7))$			-1213.65	18.00	31.17	-21,845.70	-37,829.47
	$(.15)(1/2)(4.08)(10)(8.72)$			26.68	5.00	24.22	133.40	646.19
	$(.15)(\pi/4)[(14.92)^2 - (7.92)^2](5.5)$			-103.59	9.92	8.00	-1,027.61	-828.72
	$(.15)[\pi/2](3.5)^2(2)(\pi/4)(11.42)$			-51.78	9.92	8.00	-513.66	-414.24
	$(.15)(7)(18.58)(5.5)$			-107.30	26.71	11.92	-2,865.98	-1,279.02
	$(.15)(\pi/2)(3.5)^2(18.58)$			-53.63	26.71	11.92	-1,432.46	-639.27
	$(.15)(7)(0.5)(5.5)$			-2.89	6.00	.25	-17.34	-0.72
	$(.15)(\pi/2)(3.5)^2(.5)$			-1.44	6.00	.25	-8.64	-0.36
	$(.15)(\pi/4)[(14.92)^2 - (7.92)^2](5.5)$			-103.59	9.92	28.00	-1,027.61	-2,900.52
	$(.15)(\pi/2)(3.5)^2(2)(\pi/4)(11.42)$			-51.78	9.92	28.00	-513.66	-1,449.84
	$(.15)(7)(18.58)(5.5)$			-107.30	26.71	24.08	-2,865.98	-2,583.78
	$(.15)(\pi/2)(3.5)^2(18.58)$			-53.63	26.71	24.08	-1,432.46	-1,291.41
	$(.15)(7)(.5)(5.5)$			-2.89	6.00	35.75	-17.34	-103.32
	$(.15)(\pi/2)(3.5)^2(.5)$			-1.44	6.00	35.75	-8.64	-51.48
	$(.15)(7)(17.4)(4.5)$			-82.22	27.50	22.50	-2,261.05	-1,849.95
	$(.15)(\pi/2)(3.5)^2(17.4)$			-50.22	27.50	22.50	-1,381.05	-1,129.95
	$(.15)(\sqrt{(8.3)^2 + 18.4)^2 + (6.8)^2})(7)(7.7)$			-172.21	13.20	18.35	-2,273.17	-3,160.05
	$(.15)(3)(7)(7.7)$			-24.26	1.50	14.20	-36.39	-344.49
	$(.15)(2)(7)(7.7)$			-16.17	13.20	18.35	-213.44	-296.72
				5182.03			89,534.92	83,724.01
W_{water}	$(.0625)(1/2)(3.27)(36)(7)$			25.75	18.00	34.91	463.50	898.93
W_{gate}	$(85)(1)$			85.00	19.35	11.25	1,644.75	956.25
P_{water}	$(.0625)(1/2)(16)^2(36)$	-288.00				5.33		-1,535.04
Sub-Total		-288.00		5292.78			91,643.17	84,044.15

1253A

PAGE OF

SUBJECT: Monolith R-55, Troy Lock and Dam - Dewatered Condition (Continued)

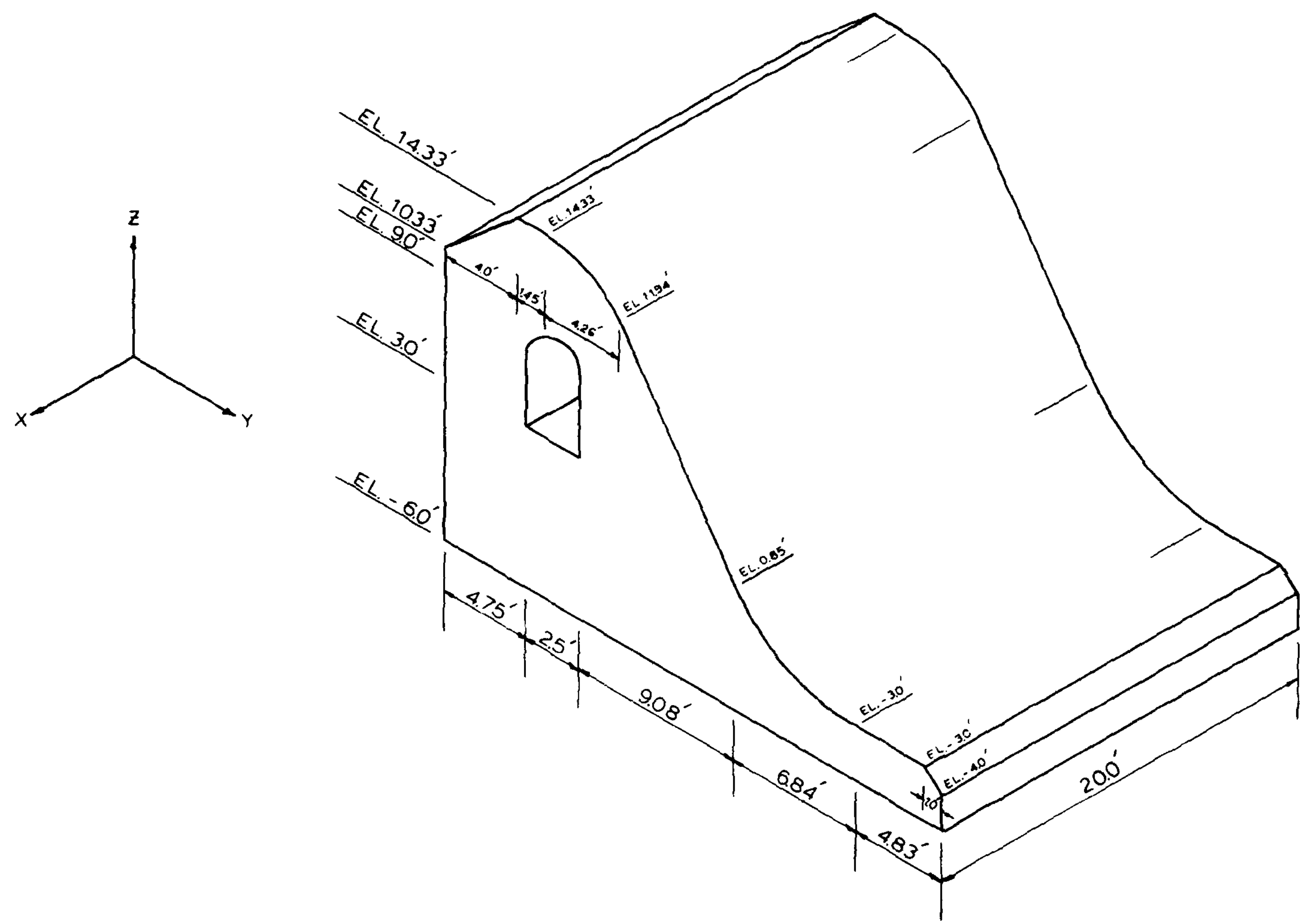
COMPUTED BY: DATE:

CHECKED BY: DATE:

Item	Factors	F_x	F_y	F_z	Arm_{xx}	Arm_{yy}	M_{xx}	M_{yy}
Uplift	(.0625)(1/2)(16)(36)(14)			-252.00	7.00	24.00	-1,764.00	-6,048.00
	(.0625)(1/2)(16)(34.29)(3)			-51.44	15.50	24.57	-797.32	-1,263.88
	(.0625)(1/2)(16)(32.58)(19)			-309.51	26.50	25.14	-8,202.02	-7,781.08
				-612.95			-10,763.34	-15,092.96
Total		288.00		4679.83			80,879.83	68,951.19

WES FORM NO. 1253A DECEMBER 1966

DAM STABILITY



Stability analysis, dam spillway, Troy Lock and Dam

AD-A094 683 ARMY ENGINEER WATERWAYS EXPERIMENT STATION VICKSBURG MS F/G 13/13
ENGINEERING CONDITION SURVEY AND EVALUATION OF TROY LOCK AND DA--ETC(U)
JAN 81 C E PACE, R CAMPBELL, S WONG
UNCLASSIFIED WES-MP-C-78-6-2 NL

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Dam Spillway Monoliths D1-D33, Troy L&D - Percent Effective Base

(No Posttensioning)

LOAD CASE	Base Width b ft	Sum of Vertical Forces F_V kips	Sum of Moments M ft-kips	Resultant Moment Arm $e = \frac{M}{F_V}$ ft	Percent Effective Base $\frac{3e}{b}*100$ %
NORMAL OPERATION With Impact or Ice, Upper Pool at EL 16.33 and Lower Pool at EL -2.0	28.00	22.01	248.60	11.29	100.0

Dam Spillway Monoliths D1-D33, Troy L&D - Factor of Safety Against Sliding (No Posttensioning)

LOAD CASE	Sum of Vertical Forces F_V kips	Sum of Horizontal Forces F_H kips	Friction Angle ϕ degrees	Cohesive Strength C ksf	Base Area A sq ft	Resistance Due to Rock Anchors R_s kips	Shear Resistance $R_f = F_v \tan \phi$ kips	Cohesive Resistance $R_c = CA$ kips	Total Sliding Resistance $R = R_s + R_f + R_c$ kips	Factor of Safety Against Sliding $FS = \frac{R}{F_H}$
NORMAL OPERATION WITH IMPACT OR ICE, UPPER POOL AT EL 16.33 AND LOWER POOL AT EL -2.0	22.01	19.73	30.4	0.04	28.00	19.09	12.91	1.12	33.12	1.68

Dam Spillway Monoliths D1-D33, Troy L&D - Base Pressures (No Posttensioning)

LOAD CASE	Sum of Vertical Forces	Resultant Moment Arm	Effective Base Width	Axial Stress	Bending Stress	Intergranular Stress At Heel	Intergranular Stress At Toe	Hydrostatic Pressure At Heel	Hydrostatic Pressure At Toe	Total Pressure At Heel	Total Pressure At Toe
	F_V	c	b	$f_a = \frac{F_V}{b}$	$f_b = \pm \frac{F_V(\frac{b}{2} - c)\frac{b}{2}}{b^3/12}$	$f_h = f_a - f_b$	$f_c = f_a + f_b$	$f_{uh} = \gamma_w h_{uh}$	$f_{ut} = \gamma_w h_{ut}$	$f_{Th} = f_h + f_{uh}$	$f_{Th} = f_t + f_{ut}$
	kips	ft	ft	ksf	ksf	ksf	ksf	ksf	ksf	ksf	ksf
NORMAL OPERATION WITH IMPACT OR ICE, UPPER POOL AT EL 16.33 AND LOWER POOL AT EL 2.0	22.01	11.29	28.00	0.79	0.46	0.33	1.25	1.40	0.38	1.73	1.63

Dam Spillway Monoliths D1-D33, Troy L&D - Percent Effective Base
(After Posttensioning)

LOAD CASE	Base Width b ft	Sum of Vertical Forces F_V kips	Sum of Moments M ft-kips	Resultant Moment Arm $e = \frac{M}{F_V}$ ft	Percent Effective Base $\frac{e}{b}*300$ %
NORMAL OPERATION With Impact or Ice, Upper Pool at EL 16.33 and Lower Pool at EL -2.0	28.00	24.75	320.22	12.94	100.0

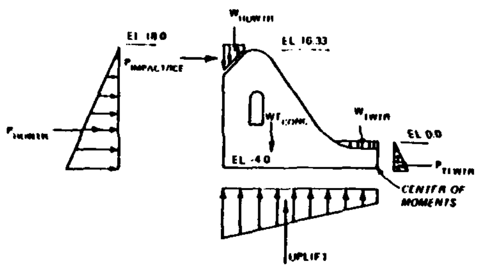
Dam Spillway Monoliths D1-D33, Troy L&D - Factor of Safety Against Sliding (After Posttensioning)

LOAD CASE	Sum of Vertical Forces F_V kips	Sum of Horizontal Forces F_H kips	Friction Angle ϕ degrees	Cohesive Strength C ksf	Base Area A sq ft	Resistance Due to Rock Anchors R_a kips	Horizontal Posttensioning Resistance R_p kips	Shear Resistance $R_f = F_v \tan \phi$ kips	Cohesive Resistance $R_c = CA$ kips	Total Sliding Resistance $R = R_a + R_p + R_f + R_c$ kips	Factor of Safety Against Sliding $FS = \frac{R}{F_H}$
NORMAL OPERATION WITH IMPACT OR ICE, UPPER POOL AT EL 16.33 AND LOWER POOL AT EL -2.0	24.75	19.73	30.4	0.04	28.00	19.09	4.74	14.52	1.12	39.47	2.00

Dam Spillway Monoliths D1-D33, Troy L&D - Base Pressures (After Posttensioning)

LOAD CASE	Sum of Vertical Forces	Resultant Moment Arm	Effective Base Width	Axial Stress	Bending Stress	Intergranular Stress At Heel	Intergranular Stress At Toe	Hydrostatic Pressure At Heel	Hydrostatic Pressure At Toe	Total Pressure At Heel	Total Pressure At Toe
	F_V	c	b	$f_a = \frac{F_V}{b}$	$f_b = \pm \frac{F_V(\frac{b}{2} - c)\frac{b}{2}}{b^3/12}$	$f_h = f_a - f_b$	$f_c = f_a + f_b$	$f_{uh} = \gamma_w h_{uh}$	$f_{ut} = \gamma_w h_{ut}$	$f_{Th} = f_h + f_{uh}$	$f_{Th} = f_t + f_{ut}$
	kips	ft	ft	ksf	ksf	ksf	ksf	ksf	ksf	ksf	ksf
NORMAL OPERATION WITH IMPACT OR ICE, UPPER POOL AT EL 16.3 AND LOWER POOL AT EL 2.0	24.75	12.94	28.00	0.88	0.20	0.68	1.08	1.40	0.38	2.08	1.46

Dam Spillway, Monoliths D1-D33, Troy L&D - Normal Operation With Impact or Ice, Upper Pool at Elevation 16.33 and Lower Pool at Elevation 0.0

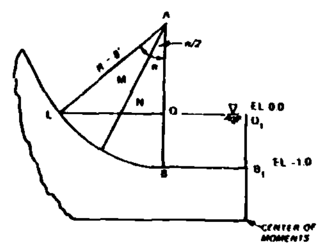


Item	Factors	F_V	F_H	Arm	Moment
W_{CONC}		43.59	--		831.84
W_{TLWTR}		0.46	--		1.74
W_{HDWTR}	(.0625)(1/2)(4)(4)	0.50	--	25.33	12.67
	(.0625)(2)(18 - 16.33)	0.21		26.00	5.46
		0.71			18.13
P_{TLWTR}	$(.0625)(1/2)(4)^2(.6)$	--	0.3	2.67	0.80
P_{HDWTR}	$(.0625)(1/2)(18 + 4)^2$	--	-15.12	7.33	-110.83
	$(.0625)(1/2)(18 - 16.33)^2$	--	.09	20.89	1.88
			-15.03		-108.95
UPLIFT	(.0625)(4)(28)	-7.00	--	14.00	-98.00
	(.0625)(1/2)(18)	-15.75	--	18.67	-295.31
		-22.75			-393.31
$P_{IMPACT/ICE}$			-5.00	20.33	-101.65
TOTAL		22.01	-19.73		248.60

Dam Spillway, Monoliths D1-D33, Troy L&D - Weight of Water on Structure During Normal Operation With Impact or Ice, Lower Pool at Elevation 0.0

Location	X Coordinate	Y Coordinate	
A	23.17	7.00	
B	23.17	-1.00	
L	18.30	2.00	
Q	23.17	2.00	
M	21.88	2.33	(Centroid of Triangle AQL)
N	21.85	1.89	(Centroid of Area A L)

$X(L) = 23.17 - \left[\sqrt{8^2 - 7^2}\right] = 19.30'$



$X(M) = 23.17 - 1/3(23.17 - 19.30) = 21.88$

$Y(M) = 7.00 - 2/3(5 + 2) = 2.33$

$<LAB = \alpha = ARC \cos 7/8 = 28.96°$

r = radius of circle = 8.00'

R = Dist from PT A to N (Centroid of Section ABL)

$R = \frac{4r}{3\alpha} \sin\left(\frac{\alpha}{2}\right) = \frac{4(8)}{3(28.96)} \left(\frac{180°}{\pi}\right) \sin\left(\frac{28.96}{2}\right) = 5.28'$

Section	Factors	F_V	Arm	Moment
ARC ABL	$\left(\frac{28.96}{360}\right)(\pi)(8.00)^2(.0625)$	1.01	6.15	6.21
Triangle AQL	1/2(3.87)(7.00)(.0625)	-0.85	6.12	-5.20
Rectangle Q, Q, B, B	(4.83)(1.0)(.0625)	0.30	2.42	0.73
TOTAL		0.46	3.78	1.74

$X(N) = 23.17 - 5.28 \sin\left(\frac{28.96}{2}\right) = 21.85'$

$Y(N) = 7.00 - 5.28 \cos\left(\frac{28.96}{2}\right) = 1.89$

Distance LQ = 23.17 - 19.30 = 3.87'

Distance AQ = 5.00 + 2.00 = 7.00'

Dam Spillway Monoliths D1-D33, Troy Lock and Dam - Posttensioning

Required Posttensioning Force for Sliding Stability

$$FSR = \frac{R}{F_H} = \text{factor of safety against sliding required to meet stability criteria}$$

$$FSR = \frac{(F_v + PS * \cos\theta) * \tan\phi + C * A + PS * \sin\theta - \text{resistance due to rock anchors}}{F_H}$$

$$PS = \frac{FSR * F_H - F_v * \tan\phi - C * A - \text{resistance due to rock anchors}}{\cos\theta * \tan\phi + \sin\theta}$$

$$PS = \frac{2 * 19.73 - 22.01 * \tan 30.4° - 0.04 * 28 - 19.09}{\cos 60° * \tan 30.4° + \sin 60°}$$

PS = 5.47 kips/ft of monolith

PS = 5.47 * 20 = 109.4 kips/monolith

Dam Spillway Monoliths D34-D62, Troy L&D - Percent Effective Base

(No Posttensioning)

LOAD CASE	Base Width b ft	Sum of Vertical Forces F_V kips	Sum of Moments M ft-kips	Resultant Moment Arm $e = \frac{M}{F_V}$ ft	Percent Effective Base $\frac{3e}{b}*100$ %
NORMAL OPERATION (Most Critical Condition With Upper Pool at EL 18.0 and Lower Pool at EL 0.0)	28.00	21.48	301.86	14.05	100.0
NORMAL OPERATION WITH EARTHQUAKE	28.00	21.48	274.77	12.79	100.0
NORMAL OPERATION WITH IMPACT	28.00	21.48	200.21	9.32	99.9
FLOOD CONDITION	28.00	18.90	213.65	11.30	100.0

Dam Spillway Monoliths D34-D62, Troy L&D - Factor of Safety Against Sliding (No Posttensioning)

LOAD CASE	Sum of Vertical Forces F_V kips	Sum of Horizontal Forces F_H kips	Friction Angle ϕ degrees	Cohesive Strength C ksf	Base Area A sq ft	Resistance Due to Rock Anchors R_s kips	Shear Resistance $R_f = F_v \tan \phi$ kips	Cohesive Resistance $R_c = CA$ kips	Total Sliding Resistance $R = R_s + R_f + R_c$ kips	Factor of Safety Against Sliding $FS = \frac{R}{F_H}$
NORMAL OPERATION (Most Critical Condition With Upper Pool at EL 18.0 and Lower Pool at EL 0.0)	21.48	16.90	30.4	0.04	28.00	15.27	12.60	1.12	28.99	1.72
NORMAL OPERATION WITH EARTHQUAKE	21.48	20.13	30.4	0.04	28.00	15.27	12.60	1.12	28.99	1.44
NORMAL OPERATION WITH IMPACT	21.48	21.90	30.4	0.04	27.96	15.27	12.60	1.12	28.99	1.32
FLOOD CONDITION	18.90	13.74	30.4	0.04	28.00	15.27	11.09	1.12	27.48	2.00

Dam Spillway Monoliths D34-D62, Troy L&D - Base Pressures (No Posttensioning)

LOAD CASE	Sum of Vertical Forces	Resultant Moment Arm	Effective Base Width	Axial Stress	Bending Stress	Intergranular Stress At Heel	Intergranular Stress At Toe	Hydrostatic Pressure At Heel	Hydrostatic Pressure At Toe	Total Pressure At Heel	Total Pressure At Toe
	F_V	e	b	$f_a = \frac{F_V}{b}$	$f_b = \pm \frac{F_V(\frac{b}{2} - e)\frac{b}{2}}{b^3/12}$	$f_h = f_a - f_b$	$f_c = f_a + f_b$	$f_{uh} = \gamma_w h_{uh}$	$f_{ut} = \gamma_w h_{ut}$	$f_{Th} = f_h + f_{uh}$	$f_{Th} = f_t + f_{ut}$
	kips	ft	ft	ksf	ksf	ksf	ksf	ksf	ksf	ksf	ksf
NORMAL OPERATION (Most Critical Condition With Upper Pool at El. 18.0 and Lower Pool at El. 0.0)	21.48	14.05	28.00	0.77	0.01	0.78	0.76	1.50	0.38	2.28	1.14
NORMAL OPERATION WITH EARTHQUAKE	21.48	12.79	28.00	0.77	0.20	0.57	0.97	1.50	0.38	2.07	1.35
NORMAL OPERATION WITH IMPACT	21.48	9.32	27.96	0.77	0.77	0.00	1.54	1.50	0.38	1.50	1.92
FLOOD CONDITION	18.90	11.30	28.00	0.68	0.39	0.29	1.07	2.23	2.17	2.52	3.24

Dam Spillway Monoliths D34-D62, Troy L&D - Percent Effective Base
(After Posttensioning)

LOAD CASE	Base Width b ft	Sum of Vertical Forces F_V kips	Sum of Moments M ft-kips	Resultant Moment Arm $e = \frac{M}{F_V}$ ft	Percent Effective Base $\frac{b-e}{b}*300$ %
NORMAL OPERATION (Most Critical Condition With Upper Pool at EL 18.0 and Lower Pool at EL 0.0)	28.00	27.86	469.06	16.84	100.0
NORMAL OPERATION WITH EARTHQUAKE	28.00	27.86	441.97	15.86	100.0
NORMAL OPERATION WITH IMPACT	28.00	27.86	367.41	13.19*	100.0
FLOOD CONDITION	28.00	25.28	380.85	15.07	100.0

* Percent effective base = $\frac{e}{b}*300$

Dam Spillway Monoliths D34-D62, Troy L&D - Factor of Safety Against Sliding (After Posttensioning)

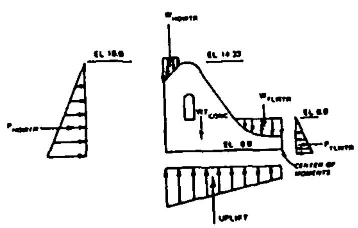
LOAD CASE	Sum of Vertical Forces F_V kips	Sum of Horizontal Forces F_H kips	Friction Angle ϕ degrees	Cohesive Strength C ksf	Base Area A sq ft	Resistance Due to Rock Anchors R_a kips	Horizontal Posttensioning Resistance R_p kips	Shear Resistance $R_f = F_v \tan \phi$ kips	Cohesive Resistance $R_c = CA$ kips	Total Sliding Resistance $R = R_a + R_p + R_f + R_c$ kips	Factor of Safety Against Sliding $FS = \frac{R}{F_H}$
NORMAL OPERATION (Most Critical Condition with Upper Pool at EL 18.0 and Lower Pool at EL 0.0)	27.86	16.90	30.4	0.04	28.00	15.27	11.06	16.35	1.12	43.80	2.59
NORMAL OPERATION WITH EARTHQUAKE	27.86	20.13	30.4	0.04	28.00	15.27	11.06	16.35	1.12	43.80	2.18
NORMAL OPERATION WITH IMPACT	27.86	21.90	30.4	0.04	27.96	15.27	11.06	16.35	1.12	43.80	2.00
FLOOD CONDITION	25.28	13.74	30.4	0.04	28.00	15.27	11.06	14.83	1.12	42.28	3.08

Dam Spillway Monoliths D34-D62, Troy L&D - Base Pressures (After Posttensioning)

LOAD CASE	Sum of Vertical Forces F_V kips	Resultant Moment Arm e ft	Effective Base Width b ft	Axial Stress $f_a = \frac{F_V}{b}$ ksf	Bending Stress $f_b = \pm \frac{F_V(e - \frac{b}{2})\frac{b}{2}}{b^3/12}$ ksf	Intergranular Stress At Heel $f_h = f_a - f_b$ ksf	Intergranular Stress At Toe $f_c = f_a + f_b$ ksf	Hydrostatic Pressure At Heel $f_{uh} = \gamma_w h_{uh}$ ksf	Hydrostatic Pressure At Toe $f_{ut} = \gamma_w h_{ut}$ ksf	Total Pressure At Heel $f_{Th} = f_h + f_{uh}$ ksf	Total Pressure At Toe $f_{Th} = f_t + f_{ut}$ ksf
NORMAL OPERATION (Most Critical Condition With Upper Pool at EL 18.0 and Lower Pool at El 0.0)	27.86	16.84	28.00	1.00	0.61	1.61	0.39	1.50	0.38	3.11	0.77
NORMAL OPERATION WITH EARTHQUAKE	27.86	15.86	28.00	1.00	0.40	1.40	0.60	1.50	0.38	2.90	0.98
NORMAL OPERATION WITH IMPACT	27.86	13.19	28.00	1.00	0.17	0.83	1.17	1.50	0.38	2.33	1.45
FLOOD CONDITION	25.28	15.07	28.00	0.90	0.21	1.11	0.69	2.23	2.17	3.34	2.86

Data Spillway, Monoliths D34 - D62

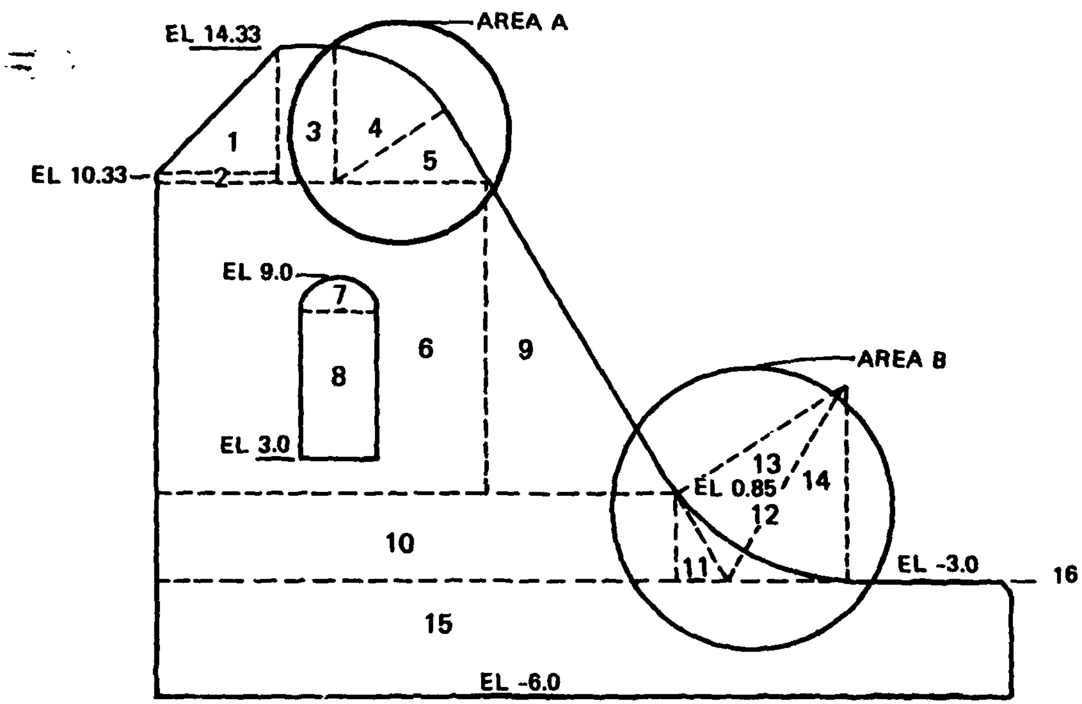
Troy Lock and Dam - Normal Operation with Upper Pool at Elevation 18.0 and Lower Pool at Elevation 0.0



Item	Factors	F_V	F_H	Arm	Moment
W_{conc}		43.59	--		831.84
W_{tlwtr}		1.72	--		8.07
W_{hdwtr}	(0.0625)(1.2)(4)(4)	0.50	--	25.33	12.67
	(0.0625)(3.67)(4)	0.92	--	26.00	23.92
		1.42			36.59
P_{tlwtr}	$(0.6)(0.0625)(1/2)(6)^2$	--	0.68	2.00	1.36
P_{hdwtr}	$(0.0625)(1/2)(18 + 6)^2$		-18.00	8.00	-144.00
	$(0.0625)(1/2)(3.67)^2$		0.42	21.55	9.05
			-17.58		-134.95
Uplift	(0.0625)(6)(28)	-10.50	--	14.00	-147.00
	(0.0625)(1.2)(18)(28)	-15.75	--	18.67	-294.05
		-25.25			441.05
Total		21.48	-16.40		301.86

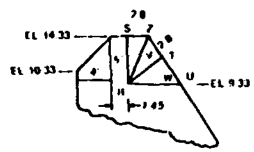
Dam Spillway, Monoliths D34 - D62

Troy Lock and Dam - Weight of Structure



Dam Spillway, Monoliths D34-D62, Troy L&D - Weight of Structure (Continued)

Sections 4 & 5 - Geometry



Location	X Coordinate	Y Coordinate
Z	8.16	14.33
R	5.45	9.33
S	5.45	14.33
T	9.71	11.94
U	11.31	9.33
V(Centroid of Area RST)	7.01	12.11
W(Centroid of Area RTU)	7.79	10.20
		9.33

$<SRT = \alpha = 2\left[\text{ARC tan}\left(\frac{2.80}{5.00}\right)\right] = 58.50'$

$<TRU = 90 - \alpha = 90 - 58.5 = 31.50'$

$X(R) = 4 = 1.45 = 5.45'$

$Y(R) = 14.33 - 5 = 9.33'$

$X(T) = 5.45 + 5 \cos 31.50° = 9.71$

$Y(T) = 9.33 + 5 \sin 31.50° = 11.94$

$X(U) = 5.45 + 5/\cos 31.50° = 11.31$

$Y(U) = Y(R) = 9.33$

$\bar{R}$ = Distance from point R along line ZZ to Centroid of Area RST

r = Radius of ARC = 5.0'

$\bar{R} = \frac{4r}{3\alpha} \sin\left(\frac{\alpha}{2}\right)$

$\bar{R} = \frac{4(5)}{3\,(58.5)(\pi/180)} \sin\left(\frac{58.50}{2}\right)$

$\bar{R} = 3.19$

$X(U) = 5.45 + 3.19 \sin\left(\frac{58.50}{2}\right) = 7.01$

$Y(V) = 9.33 + 3.19 \cos\left(\frac{58.50}{2}\right) = 12.11$

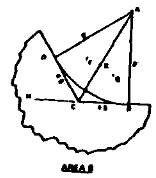
$X(W) = 5.45 + \left\{\left[(2)(4.26)^2/3\right] + [4.26 + (1.6/3)](1.6)\right\}/(5.86) = 8.82$

$Y(W) = 9.33 + 1/3(11.94 - 9.33) = 10.20$

Dam Spillway, Monoliths D34-D62, Troy L&D - Weight of Structure (Continued)

Sections 12, 13 & 14 - Geometry

Location	X Coordinate	Y Coordinate	
A	23.17	5.00	
B	23.17	-3.00	
C	18.67	-3.00	
D	16.33	0.85	
E	18.61	2.23	
F	19.39	0.95	(Centroid of Triangle ACD)
G	21.67	-0.33	(Centroid of Triangle ABC)
K	20.67	0.56	(Centroid of Area ABD)



$X(K)_{COORD} = 23.17 - 5.10 \sin\left(\frac{58.72}{2}\right) = 20.67$

$Y(K)_{COORD} = 5.00 - 5.10 \cos\left(\frac{58.72}{2}\right) = 0.56$

$<DAB = \alpha = 2 \text{ ARC tan}\left(\frac{4.5}{8}\right) = 58.72°$

$<DCH = \alpha = 58.72°$

$X(D)_{COORD} = 18.67 - 4.5 \cos 58.72° = 16.33°$

$Y(D)_{COORD} = 4.5 \sin 58.72 - 3.00 = 0.85°$

$<iDE = 90° - \alpha = 31.28°$

$X(E)_{COORD} = 16.33 + \frac{8}{3} \cos 31.28° = 18.61$

$Y(E)_{COORD} = 0.85 + \frac{8}{3} \sin 31.28° = 2.23$

$<FEj = \alpha = 58.72°$

$X(F)_{COORD} = 18.61 + \frac{4.5}{3} \cos 58.72° = 19.39$

$Y(F)_{COORD} = 2.23 - \frac{4.5}{3} \sin 58.72° = 0.95°$

$X(G)_{COORD} = 23.17 - \frac{4.5}{3} = 21.67$

$Y(G)_{COORD} = \frac{8}{3} - 3.00 = -0.33$

$<CAB = \frac{\alpha}{2}$

R = Distance from PT A along line AC to Centroid of Area ABD

r = radius of circle = 8.00'

$R = \frac{4r}{3\alpha} \sin\left(\frac{\alpha}{2}\right) = \frac{4(8)}{3(58.72)\left(\frac{\pi}{180}\right)} \sin\left(\frac{58.72}{2}\right) = 5.10'$

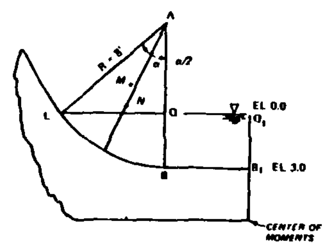
Dam Spillway, Monoliths D34-D62, Troy L&D - Weight of Structure (Continued)

Section	Factors	F_V	Arm	Moment
1	1/2 (4)(4)(1)(.15)	1.20	25.33	30.40
2	(1)(4)(1)(.15)	0.60	26.00	15.60
3	(5)(1.45)(1)(.15)	1.09	23.28	23.38
4	$\frac{58.50}{360} \pi (5)^2 (.15)$	1.91	20.99	40.09
5	(1/2)(2.61)(5.86)(.15)	1.15	17.18	22.06
6	(8.48)(11.31)(.15)	14.39	22.34	321.47
7	$-1/2 \pi \left(\frac{2.5}{2}\right)^2 (.15)$	-0.37	22.0	-8.14
8	-(4.75)(2.5)(.15)	-1.78	22.0	-39.16
9	(1/2)(8.48)(5.02)(.15)	3.19	15.02	47.91
10	(3.85)(16.33)(.15)	9.43	19.84	187.09
11	1/2 (3.85)(2.34)(.15)	0.68	10.89	7.41
12	$\frac{58.72}{360} \pi (8)^2 (.15)$	4.92	8.58	42.21
13	-(1/2)(8)(4.5)(.15)	-2.70	7.33	-19.79
14	-(1/2)(8)(4.5)(.15)	-2.70	6.33	-17.09
15	(3)(28)(.15)	12.60	14.00	176.40
16	-(1/2)(.5)(.5)(.15)	-0.02	0.17	-0.00
TOTAL		43.59		831.84

Dam Spillway, Monoliths D34-D62, Troy L&D - Weight of Water on Structure During Normal Operation With Lower Pool at Elevation 0.0

Location	X Coordinate	Y Coordinate	
A	23.17	5.00	
B	23.17	-3.00	
L	16.73	0.00	
Q	23.17	0.00	
M	21.09	1.67	(Centroid of Triangle AQL)
N	20.94	0.35	(Centroid of Area ABL)

$X(L) = 23.17 - \left[\sqrt{8^2 - 5^2}\right] = 16.93'$



$X(M) = 23.17 - 1/3(23.17 - 16.93) = 21.09'$

$Y(M) = 5.00 - 2/3(5.00 - 0) = 1.67'$

$<LAB = \alpha = \text{ARC} \cos 5/8 = 51.32°$

r = radius of circle = 8.00'

R = Dist from PT A to N (Centroid of Section ABL)

$R = \frac{4r}{3\alpha} \sin\left(\frac{\alpha}{2}\right) = \frac{4(8)}{3(51.32)} \left(\frac{180°}{\pi}\right) \sin\left(\frac{51.32}{2}\right) = 5.16$

$X(N) = 23.17 - 5.16 \sin\left(\frac{51.32}{2}\right) = 20.94$

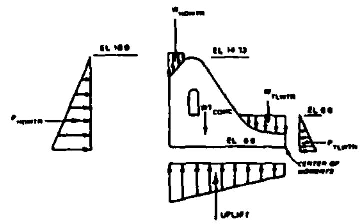
$Y(N) = 5.00 - 5.16 \cos\left(\frac{51.32}{2}\right) = 0.35$

Distance LQ = 23.17 - 16.93 = 6.24'

Distance AQ = 5.00 - 0.00 = 5.00

Section	Factors	F_V	Arm	Moment
ARC ABL	$\left(\frac{51.32}{360}\right)(\pi)(8.00)^2(.0625)$	1.79	7.06	12.64
Triangle AQL	1/2(6.24)(5.00)(.0625)	-0.98	6.91	-6.77
Rectangle Q, Q, B, B	(4.83)(3.0)(.0625)	0.91	2.42	2.20
TOTAL		1.72	4.66	8.07

Dam Spillway, Monoliths D34-D62, Troy L&D - Normal Operation With Earthquake, Upper Pool at Elevation 18.0 and Lower Pool at Elevation 0.0



Item	Factors	F_V	F_H	Arm	Moment
W_{CONC}		43.59	--		831.84
W_{TLWTR}		1.72	--		8.07
W_{HDWTR}	(.0625)(1/2)(4)(4)	0.50	--	25.33	12.67
	(.0625)(3.67)(4)	0.92		26.00	23.92
		1.42			36.59
P_{TLWTR}	$(.06)(.0625)(1/2)(6)^2$	--	0.68	2.00	1.36
P_{HDWTR}	$(.0625)(1/2)(18 + 6)^2$	--	-18.00	8.00	-144.00
	$(.0625)(1/2)(3.67)^2$	--	0.42	21.55	9.05
			-17.58		-134.95
UPLIFT	(.0625)(6)(28)	-10.50	--	14.00	-147.00
	(.0625)(1/2)(18)(28)	-15.75	--	18.67	-294.05
		-25.25			-441.05
EARTHQUAKE					
Pe_1	(0.05)(43.59 + 1.72)	--	-2.27	7.98	-18.11
Pe_2	$(2/3)(51)(.05)(18 + 6)^2(1/1000)$	--	-0.98	9.60	-9.41
	$(2/3)(51)(.05)(18 - 14.33)^2(1/1000)$	--	0.02	21.55	0.43
			-3.23		-27.09
TOTAL		21.48	-20.13		274.77

Dam Spillway, Monoliths D34-D62, Troy Lock and Dam, Location of Center of Gravity-Normal Operation with Earthquake

Section	Area			Arm	Moment
	Location of Center of Gravity of Concrete				
1	(1/2)(4)(4) =	8.00	17.66	141.28	$Z = \frac{2355.28}{290.57} = 8.11$ ft
2	(1)(4) =	4.00	15.83	63.32	
3	(5)(1.45) =	7.25	17.83	129.27	
4	$(58.50/360)(\pi)(5)^2$ =	12.76	18.11	231.08	
5	(1/2)(2.61)(5.86) =	7.65	16.20	123.93	
6	(8.48)(11.31) =	95.91	11.09	1063.64	
7	$-(1/2)(\pi)(1.25)^2$ =	2.45	14.28	-34.99	
8	-(4.75)(2.5) =	11.88	11.38	-135.19	
9	(1/2)(8.48)(5.02) =	21.28	9.68	205.99	
10	(3.85)(16.33) =	62.87	4.92	309.32	
11	(1/2)(3.85)(2.34) =	4.50	4.05	18.23	
12	$(58.72/360)(\pi)(8)^2$ =	32.80	6.56	215.17	
13	-(1/2)(8)(4.5) =	18.00	6.95	-125.10	
14	-(1/2)(8)(4.5) =	18.00	5.67	-102.06	
15	(3)(28) =	84.00	3.00	252.00	
16	-(1/2)(0.5)(0.5) =	0.12	5.67	0.68	
		290.57		2355.28	

(Continued)

Dam Spillway, Monoliths D34-D62, Troy Lock and Dam, Location of Center of Gravity-Normal Operation with Earthquake (Concluded)

Section	Area			Arm	Moment
	Location of Center of Gravity of Water				
ARC ABL	$(51.30/360)(\pi)(8)^2$	=	28.65	6.35	181.93
Triangle AQL	$-(1/2)(6.24)(5)$	=	-15.60	7.67	-119.65
Rectangle QQ_1 BB_1	$(4.83)(3)$	=	14.47	4.50	65.20
			27.54		127.48

$$Z = \frac{127.48}{27.54} = 4.63 \text{ ft}$$

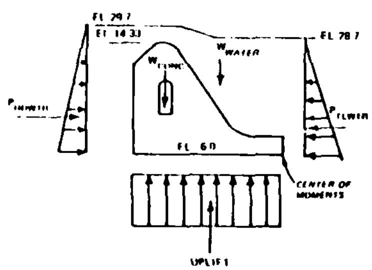
Location of Center of Gravity of Earthquake Forces (Horizontal)

$$\overline{Z} = \frac{(0.15)(290.57)(8.11) + (0.0625)(27.54)(4.63)}{(0.15)(290.57) + (0.0625)(27.54)} = 7.98 \text{ ft}$$

Dam Spillway, Monoliths D34-D62, Troy L&D - Normal Operation with Boat Impact, Upper Pool at Elevation 18.0 and Lower Pool at Elevation 0.0

Item	Factors	F_V	F_H	Arm	Moment
W_{CONC}		43.59	--		831.84
W_{TLWTR}		1.72	--		8.07
W_{HDWTR}	(.0625)(1/2)(4)(4)	0.50	--	25.33	12.67
	(.0625)(3.67)(4)	0.92		26.00	23.92
		1.42			36.59
P_{TLWTR}	$(.06)(.0625)(1/2)(6)^2$	--	0.68	2.00	1.36
P_{HDWTR}	$(.0625)(1/2)(18 + 6)^2$	--	-18.00	8.00	-144.00
	$(.0625)(1/2)(3.67)^2$	--	0.42	21.55	9.05
			-17.58		-134.95
UPLIFT	(.0625)(6)(28)	-10.50	--	14.00	-147.00
	(.0625)(1/2)(18)(28)	-15.75	--	18.67	-294.05
		-25.25			-441.05
IMPACT			-5.00	20.33	-101.65
TOTAL		21.48	-20.90		200.21

Dam Spillway, Monoliths D34-D62, Troy L&D - Flood Condition

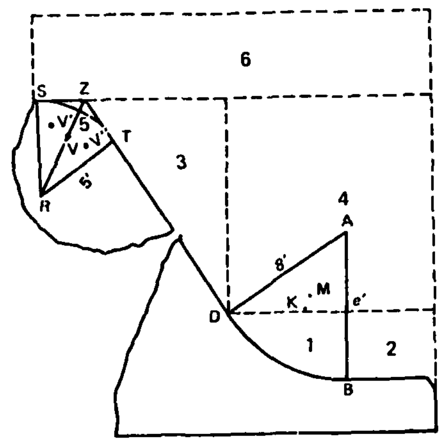


Item	Factors	F_V	F_H	Arm	Moment
W_{CONC}		43.59	--		831.84
W_{WATER}		36.91	--		370.44
UPLIFT	$(.0625)(29.7 + 6)(28)$	-62.48	--	14.00	-874.72
	$(.0625)(1/2)(1)(28)$	.88	--	9.33	8.21
		-61.60			-866.51
P_{TLWTR}	$(.0625)(1/2)(28.7 + 6)^2(.6)$	--	22.58	11.57	261.25
	$(.0625)(1/2)(28.7 - 14.33)^2(.6)$	--	-3.87	25.12	-97.21
			18.71		164.04
P_{HDWTR}	$(.0625)(1/2)(29 + 6)^2$	--	-39.83	11.90	-473.98
	$(.0625)(1/2)(29.7 - 14.33)^2$	--	7.38	25.45	187.82
			-32.45		-286.16
TOTAL		18.90	-13.74		213.65

Dam Spillway, Monoliths D34-D62, Troy L&D - Weight of Water on Structure During Flood Condition

Section	Factor	F_V	Arm	Moment
1	$\left(\frac{58.72}{360}\right) \pi (8)^2(.0625)$	2.05	27.33	15.03
	1/2(23.17 - 16.33)(5.00 - 0.85)(0.0625)	-0.89	7.11	-6.33
2	(4.83)(3 + 0.85)(.0625)	1.16	2.42	2.81
	1/2 (.5)(.5)(.0625)	0.01	0.17	0.00
3	1/2(16.33 - 8.16)(14.33 - 0.85)(.0625)	3.44	14.39	49.50
4	(28 - 16.33)(14.33 - .85)(0.0625)	9.83	5.84	57.41
5	1/2(2.8)(5)(.0625)	0.44	21.71	7.55
	1/2(2.8)(5)(.0625)	0.44	20.56	9.05
	$\left(\frac{58.32}{360}\right)\pi (5)^2(.0625)$	-0.80	21.09	-16.87
6	(28 - 5.36)(28.7 - 14.33)(.0625)	20.33	11.32	230.14
Gallery	$\left[(1/2) \pi (1.25)^2 + (4.75)(2.5)\right][.0625]$	0.90	22.00	19.80
TOTAL		36.91		370.44

Dam Spillway, Monoliths D34-D62, Troy Lock and Dam--Weight of Water on Structure During Flood Condition (Continued)



$$X(V')_{coord} = 5.36 + \frac{1}{3}(8.16 - 5.36) = 6.29$$

$$Y(V')_{coord} = 14.33 - \frac{1}{3}(14.33 - 9.33) = 12.66$$

$\tan \phi$ = slope of RT; $\tan \phi'$ = slope of ZT

$$\phi = \arctan \frac{11.94 - 9.33}{9.62 - 5.36} = 31.49°$$

$$\phi' = \arctan \frac{14.33 - 11.94}{9.62 - 6.29} = 35.67°$$

$$X(V'')_{coord} = 9.62 - \frac{2.8}{3}\cos 35.67° - \frac{5}{3}\cos 31.49° = 7.44'$$

$$Y(V'')_{coord} = 11.94 + \frac{2.8}{3}\sin 35.67° - \frac{5}{3}\sin 31.49° = 11.61$$

$$X(M')_{coord} = 23.17 - \frac{1}{3}(23.17 - 16.33) = 20.89$$

$$Y(M')_{coord} = 0.85 + \frac{1}{3}(5.00 - 8.5) = 2.23$$

Location	X Coordinate	Y Coordinate	
A	23.17	5.00	
B	23.17	-3.00	
D	16.33	0.85	
Q'	23.17	0.85	
R	5.36	9.33	
S	5.36	14.33	
T	9.62	11.94	
V	6.91	12.11	(Centroid of area RST)
Z	8.16	14.33	
V'	6.29	12.66	(Centroid of triangle RSZ)
V"	7.44	11.61	(Centroid of triangle RTZ)
M'	20.89	2.23	(Centroid of triangle AQD)
K	20.67	0.56	(Centroid of area ABD)

Dam Spillway Monoliths D34-D62, Troy Lock and Dam

Required Posttensioning Force for Sliding Stability

$$FSR = \frac{R}{F_H} = \text{factor of safety against sliding required to meet stability criteria}$$

$$FSR = \frac{(F_v + PS * \cos\theta) * \tan\phi + C * A + PS * \sin\theta + \text{resistance due to rock anchors}}{F_H}$$

$$PS = \frac{FSR * F_H - F_V \tan\phi - C * A - \text{resistance due to rock anchors}}{\cos\theta * \tan\phi + \sin\theta}$$

$$PS = \frac{2 * 21.9 - 21.48 * \tan 30.4° - (0.04) * (28) - 15.27}{\cos 60° * \tan 30.4° + \sin 60°}$$

PS = 12.77 kips/ft of monolith

PS = 12.77 * 20 = 255.4 kips/monolith

Posttensioning applied at elevation 2.0

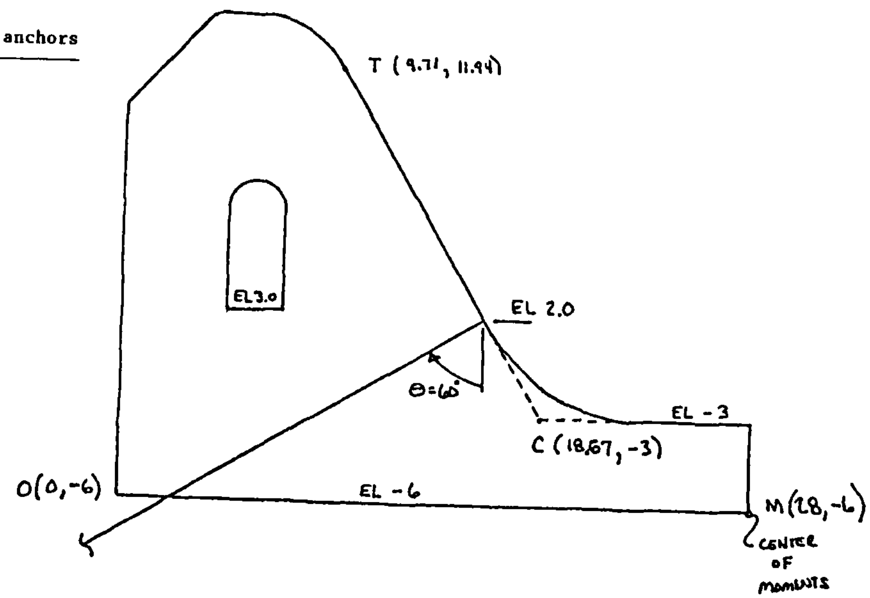
Y = 2.0 ft

$$X = 18.67 - [2 - (-3)] * \left[\frac{18.67 - 9.71}{11.94 - (-3)}\right] = 15.67 \text{ ft}$$

Location of posttensioning at dam-foundation interface

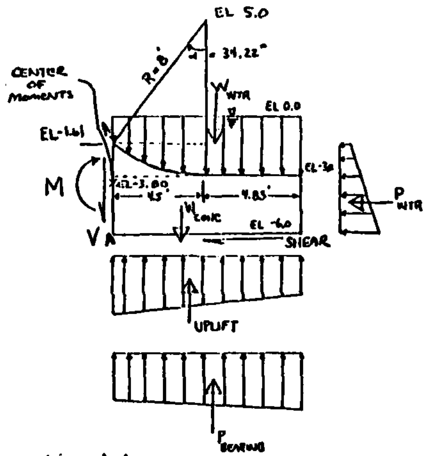
Y = -6.0 ft

X = 15.67 - [2 - (-6)[* tan 60° = 1.81 ft



Dam Spillway Monoliths D34-D62, Troy Lock and Dam

Normal Operation with Impact (no posttensioning)



Stress on section A-A
b = 6 - 1.61 = 4.39 ft

$$f = \frac{F_H}{b} \pm \frac{MC}{I} = \frac{11.16}{4.39} \pm \frac{(31.16)(4.39)(1/2)}{(4.39)^3/12} = 2.54 \pm 9.70$$

f_{max} = 12.24 ksf = 85.00 psi (compression)

f_{min} = -7.16 ksf = -49.72 psi (tension)

Item		F_V kips	F_H kips	Arm ft	Moment ft-k
W_{conc}	(0.15)(3 - 1.61)(4.5)	0.93		2.25	2.09
	(0.15)(1.19 - 0.93)/0.0625	-0.62		2.88	-1.79
	(0.15)(9.33)(3)	4.20		4.66	19.57
		4.51			19.87
W_{wtr}	$(0.0625)(34.22°/360°)(\pi)(8^2)$	1.19		2.88	3.43
	(0.0625)(1/2)(4.5)[5 - (-1.61)]	-0.93		3.00	-2.79
	(0.0625)(4.5)(1.61)	0.45		2.25	1.01
	(0.0625)(9.33 - 4.5)(3)	0.91		6.91	6.29
		1.62			7.94
Uplift	(0.0625)(9.33)(6)	-3.50		4.66	-16.31
	(0.0625)(9.33)(18/28)(9.33)(1/2)	-1.75		3.11	-5.44
		-5.25			-21.75
P_{wtr}	$(0.0625)(1/2)(6)^2$		1.12	0.20	0.24
	$(0.0625)(1/2)(1.61)^2$		-0.08	-2.73	-0.22
			1.04		0.02
$P_{bearing}$	(1.54)(9.33)	-14.37		4.66	-66.96
	$(1/2)(1/3)(1.54)(9.33)^2/9.32$	2.40		3.11	7.46
		-11.97			-59.50
Shear	N tan ϕ = 11.97 tan 30.4		7.02	2.20	15.44
	CA = (0.04)(9.33)		0.37	2.20	0.81
	R_{rod} = (21.9 - 12.6 - 1.12)(9.33)/28		2.73	2.20	6.01
			10.12		22.26
		-11.09	11.16		-31.16

Dam Spillway Monoliths D34-D62, Troy Lock and Dam

Forces and moments after posttensioning
(for normal operation with impact condition)

$F'_V = F_V + PS * \cos\theta$

$F'_V = 21.48 + 12.77 * \cos 60°$

$F'_V = 27.86$ kips

$F'_H = F_H + PS * \sin\theta$

$F'_H = -21.90 + 12.77 * \sin 60°$

$F'_H = -10.84$ kips

$M = M + PS* \cos\theta * ARM_V + PS * \sin\theta * ARM_H$

$M = 200.21 + 12.77 * \cos 60° * (28 - 15.67) + 12.77 * \sin 60° * [2 - (-6)]$

$M = 367.41$ ft-kips

$$e = \frac{M'}{F'_V} = \frac{367.41}{27.86} = 13.19 \text{ ft}$$

Base pressures after posttensioning

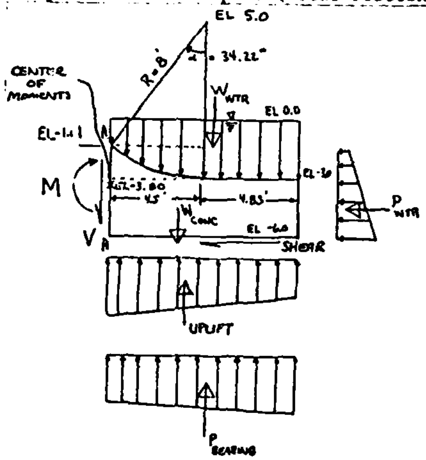
$$f = \frac{F_v}{A} \pm \frac{F_v\left(\frac{b}{2} - e\right)\frac{b}{2}}{b^3/12} = \frac{27.86}{28} \pm \frac{(27.86)\left(\frac{28}{2}\right) - 13.19\ \frac{28}{2}}{(28)^3/12} = 1.00 \pm 0.17$$

$f_{heel} = 0.83$ ksf

$f_{toe} = 1.17$ ksf

Dam Spillway Monoliths D34-D62, Troy Lock and Dam

Normal Operation with Impact (after Posttensioning)



Stress on section A-A
$b = 6 - 1.61 - 4.39$ ft

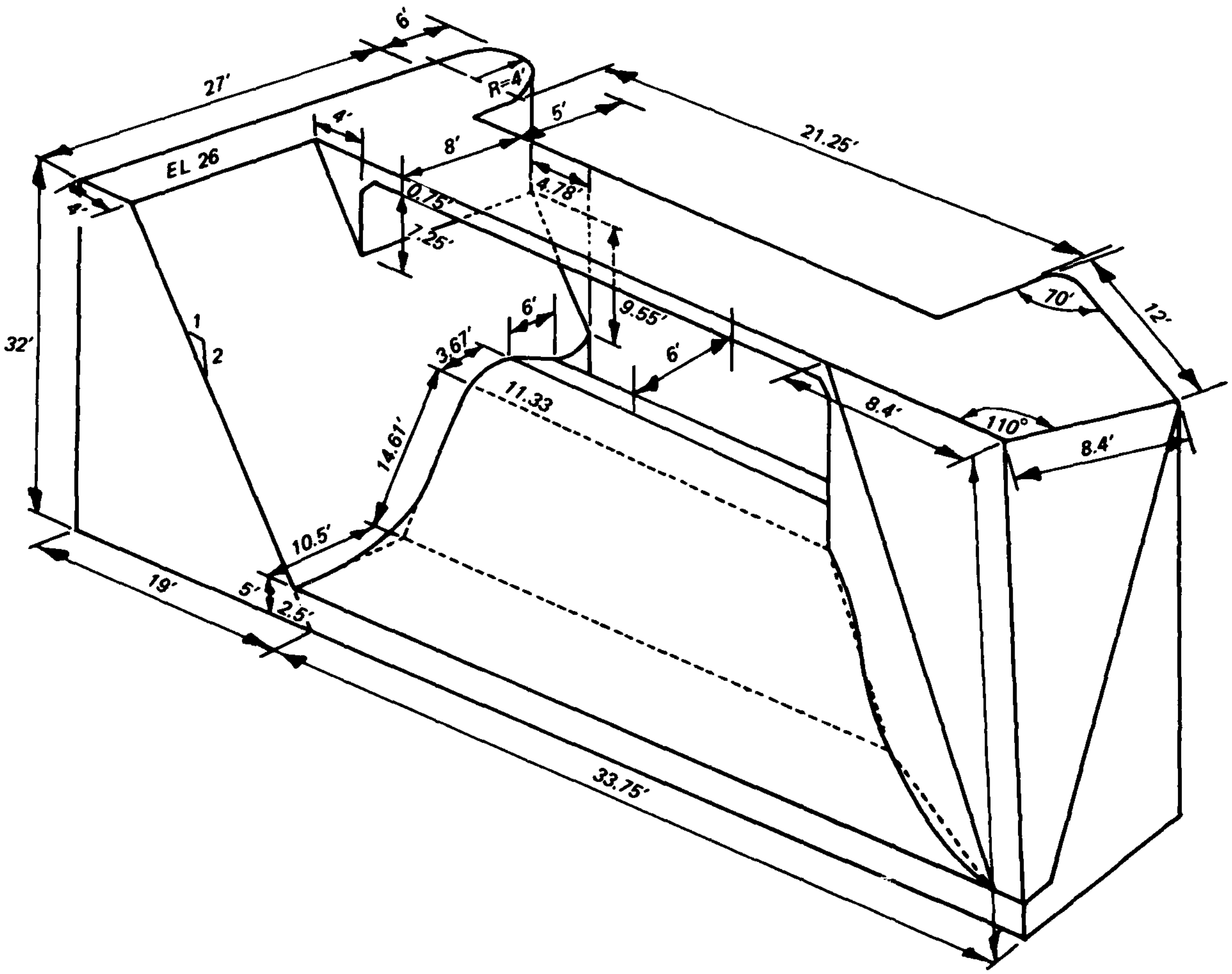
$$f = \frac{F_H}{b} \pm \frac{MC}{I} = \frac{8.99}{4.39} \pm \frac{(25.68)(4.39)(1/2)}{(4.39)^3/12} = 2.05 \pm 7.99$$

f_{max} = 10.04 ksf = 69.72 psi (compression)

f_{min} = -5.94 ksf = 41.25 psi (tension)

Item		F_v kips	F_H kips	Arm ft	Moment ft-k
W_{conc}	(0.15)(3 - 1.61)(4.5)	0.93		2.25	2.09
	(0.15)(1.19 - 0.93)/0.0625	-0.62		2.88	-1.79
	(0.15)(9.33)(3)	4.20		4.66	19.57
		4.51			19.87
W_{wtr}	$(0.0625)(34.22°/360°)(\pi)(8)^2$	1.19		2.88	3.43
	(0.0625)(1/2)(4.5)[5 - (-1.61)]	-0.93		3.00	-2.79
	(0.0625)(4.5)(1.61)	0.45		2.25	1.01
	(0.0625)(9.33 - 4.5)(3)	0.91		6.91	6.29
		1.62			7.94
Uplift	(0.0625)(9.33)(6)	-3.50		4.66	-16.31
	(0.0625)(9.33)(18/28)(9.33)(1/2)	-1.75		3.11	-5.44
		-5.25			-21.75
P_{wtr}	$(0.0625)(1.2)(6)^2$		1.12	0.20	0.24
	$(0.0625)(1/2)(1.61)^2$		-0.08	-2.73	-0.22
			1.04		0.02
$P_{bearing}$	(1.17)(9.33)	-10.92		4.66	-50.89
	$(1/2)(1.17 - 0.83)(9.33)^2/28$	0.53		3.11	1.64
		-10.39			-49.25
Shear	N tan ϕ = 10.39 tan 30.4		6.10	2.20	13.42
	CA = (0.04)(9.33)		0.37	2.20	0.81
	R_{rod} = (21.9 - 16.35 - 1.12) (9.33)/28		1.48	2.20	3.26
			7.95		17.49
		-9.51	8.99		-25.68

HEADGATE STABILITY



Stability analysis, headgate monolith, Troy Lock and Dam

SUBJECT: HEAD GATE MONOLITH TROY LOCK AND DAM	COMPUTED BY:	DATE:	FILE NO.
	CHECKED BY:	DATE:	SHEET NO.

STABILITY SUMMARY

LOAD CASE	EFFECTIVE AREA OF BASE IN COMPRESSION (%)	FACTOR OF SAFETY AGAINST SLIDING	MAXIMUM BASE PRESSURE (KSF)
NORMAL OPERATION (MOST CRITICAL CONDITION OF UPPER POOL = EL 18' AND LOWER POOL = EL. 0')	100	3.66	2.645
NORMAL OPERATION WITH EARTHQUAKE	100	2.71	2.424
NORMAL OPERATION WITH ICE	100	2.26	3.110
FLOOD CONDITION	100	2.27	1.971

WES FORM NO. 1253

SUBJECT: HEAD GATE MONOLITH TROY LOCK AND DAM	COMPUTED BY:	DATE:	FILE NO.
	CHECKED BY:	DATE:	SHEET NO.

MAXIMUM BEARING PRESSURES

LOAD CASE	HEIGHT OF WATER OVER TOE (FT)	HYDROSTATIC PRESSURE AT TOE (KSF)	MAXIMUM INTERGRANULAR PRESSURE AT TOE (KSF)	TOTAL PRESSURE AT TOE MAX. BASE PRESSURE (KSF)
NORMAL OPERATION (MOST CRITICAL CONDITION OF UPPER POOL EL= 18' LOWER POOL EL= 0')	—	0.375	2.645	3.020
NORMAL OPER. WITH EARTHQUAKE	—	0.375	2.424	2.799
NORMAL OPER. WITH ICE	—	0.375	3.110	3.485
FLOOD CONDITION	29.7	2.17	1.971	4.141

WES FORM NO. 1253

HEAD GATE MONOLITH TROY LOCK AND DAM
NORMAL OPERATION

BASE AREA PROPERTIES — INITIAL

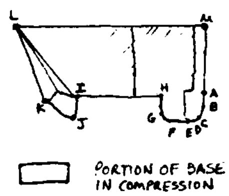
AREA (FT^2)	INERTIA ABOUT PRINCIPLE X-AXIS (FT^4)	INERTIA ABOUT PRINCIPLE Y-AXIS (FT^4)	XBAR (FT)	YBAR (FT)	ZBAR (FT)	ANGLE PRINCIPLE X-AXIS MAKES WITH X-AXIS (DEGREES)
1335.42	252891.4	89925.4	17.16	22.98	0	-8.95

SUMMARY OF FORCES AND MOMENTS — INITIAL

F_x (KIPS)	F_y (KIPS)	F_z (KIPS)	M_{xx} (FT-K)	M_{yy} (FT-K)	M_{zz} (FT-K)
561.84	-36.11	-2597.95	-63943.0	42537.0	0

BASE PRESSURES — INITIAL

PRESSURE POINT	X COORDINATE (FT)	Y COORDINATE (FT)	Z COORDINATE (FT)	PRESSURE (KSF)
A	13.00	0.00	0	1.604
B	4.00	0.00	0	1.847
C	2.00	0.50	0	1.911
D	0.50	2.00	0	1.981
E	0.00	4.00	0	2.034
F	0.00	8.78	0	2.129
G	1.50	10.78	0	2.128
H	3.00	12.78	0	2.127
I	3.00	29.25	0	2.452
J	0.00	29.25	0	2.533
K	4.10	40.53	0	2.645
L	31.00	52.53	0	2.155
M	31.00	0.00	0	1.117



HEAD GATE MONOLITH TROY LOCK AND DAM

NORMAL OPERATION

BASE AREA PROPERTIES — FINAL

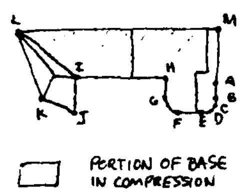
AREA (FT^2)	INERTIA ABOUT PRINCIPLE X-AXIS (FT^4)	INERTIA ABOUT PRINCIPLE Y-AXIS (FT^4)	XBAR (FT)	YBAR (FT)	ZBAR (FT)	ANGLE PRINCIPLE X-AXIS MAKES WITH X-AXIS (DEGREES)
1335.42	252891.4	89925.4	17.16	22.98	0	-8.95

SUMMARY OF FORCES AND MOMENTS — FINAL

F_x (KIPS)	F_y (KIPS)	F_z (KIPS)	M_{xx} (FT-K)	M_{yy} (FT-K)	M_{zz} (FT-K)
561.84	-36.11	-2597.95	-63943.0	42537.0	0

BASE PRESSURES — FINAL

PRESSURE POINT	X COORDINATE (FT)	Y COORDINATE (FT)	Z COORDINATE (FT)	PRESSURE (KSF)
A	13.00	0.00	0	1.604
B	4.00	0.00	0	1.847
C	2.00	0.50	0	1.911
D	0.50	2.00	0	1.981
E	0.00	4.00	0	2.034
F	0.00	8.78	0	2.129
G	1.50	10.78	0	2.128
H	3.00	12.78	0	2.127
I	3.00	29.25	0	2.452
J	0.00	29.25	0	2.533
K	4.10	40.53	0	2.645
L	31.00	52.53	0	2.155
M	31.00	0.00	0	1.117



HEAD GATE MONOLITH TROY LOCK AND DAM
NORMAL OPERATION PLUS EARTHQUAKE

BASE AREA PROPERTIES — INITIAL

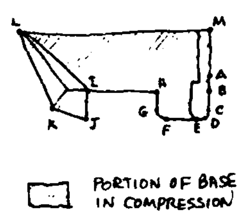
AREA (FT²)	INERTIA ABOUT PRINCIPLE X-AXIS (FT^4)	INERTIA ABOUT PRINCIPLE Y-AXIS (FT^4)	XBAR (FT)	YBAR (FT)	ZBAR (FT)	ANGLE PRINCIPLE X-AXIS MAKES WITH X-AXIS (DEGREES)
1335.42	252891.4	89925.4	17.16	22.98	0	−8.950

SUMMARY OF FORCES AND MOMENTS — INITIAL

F_x (KIPS)	F_y (KIPS)	F_z (KIPS)	M_{xx} (FT-K)	M_{yy} (FT-K)	M_{zz} (FT-K)
759.79	-36.11	-2597.95	-63943.0	44795.3	0

BASE PRESSURES — INITIAL

PRESSURE POINT	X COORDINATE (FT)	Y COORDINATE (FT)	Z COORDINATE (FT)	PRESSURE (KSF)
A	13.00	0.00	0	1.558
B	4.00	0.00	0	1.579
C	2.00	0.50	0	1.592
D	0.50	2.00	0	1.622
E	0.00	4.00	0	1.657
F	0.00	8.78	0	1.740
G	1.50	10.78	0	1.771
H	3.00	12.78	0	1.802
I	3.00	29.25	0	2.087
J	0.00	29.25	0	2.093
K	4.10	40.53	0	2.279
L	31.00	52.53	0	2.424
M	31.00	0.00	0	1.516



HEAD GATE MONOLITH TROY LOCK AND DAM
NORMAL OPERATION PLUS EARTHQUAKE

BASE AREA PROPERTIES — FINAL

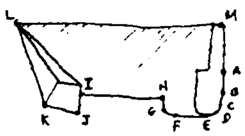
AREA (FT^2)	INERTIA ABOUT PRINCIPLE X-AXIS (FT^4)	INERTIA ABOUT PRINCIPLE Y-AXIS (FT^4)	XBAR (FT)	YBAR (FT)	ZBAR (FT)	ANGLE PRINCIPLE X-AXIS MAKES WITH X-AXIS (DEGREES)
1335.42	252891.4	89925.4	17.16	22.98	0	-8.950

SUMMARY OF FORCES AND MOMENTS — FINAL

F_x (KIPS)	F_y (KIPS)	F_z (KIPS)	M_{xx} (FT-K)	M_{yy} (FT-K)	M_{zz} (FT-K)
759.79	-36.11	-2597.95	-63943.0	44795.3	0

BASE PRESSURES ~ FINAL

PRESSURE POINT	X COORDINATE (FT)	Y COORDINATE (FT)	Z COORDINATE (FT)	PRESSURE (KSF)
A	13.00	0.00	0	1.558
B	4.00	0.00	0	1.579
C	2.00	0.50	0	1.592
D	0.50	2.00	0	1.622
E	0.00	4.00	0	1.657
F	0.00	8.78	0	1.740
G	1.50	10.78	0	1.771
H	3.00	12.78	0	1.802
I	3.00	29.25	0	2.087
J	0.00	29.25	0	2.093
K	4.10	40.53	0	2.219
L	31.00	52.53	0	2.424
M	31.00	0.00	0	1.516



PORTION OF BASE IN COMPRESSION

HEAD GATE MONOLITH TROY LOCK AND DAM
NORMAL OPERATION PLUS ICE

BASE AREA PROPERTIES — INITIAL

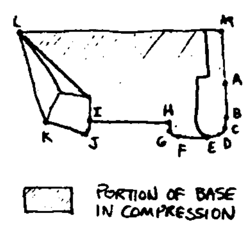
AREA (FT^2)	INERTIA ABOUT PRINCIPLE X-AXIS (FT^4)	INERTIA ABOUT PRINCIPLE Y-AXIS (FT^4)	XBAR (FT)	YBAR (FT)	ZBAR (FT)	ANGLE PRINCIPLE X-AXIS MAKES WITH X-AXIS (DEGREES)
1335.42	252891.4	89925.4	17.16	22.98	0	−8.95

SUMMARY OF FORCES AND MOMENTS — INITIAL

F_x (KIPS)	F_y (KIPS)	F_z (KIPS)	M_{xx} (FT-K)	M_{yy} (FT-K)	M_{zz} (FT-K)
910.72	-36.11	-2597.95	-63943.0	50561.3	0

BASE PRESSURES — INITIAL

PRESSURE POINT	X COORDINATE (FT)	Y COORDINATE (FT)	Z COORDINATE (FT)	PRESSURE (KSF)
A	13.00	0.00	0	1.441
B	4.00	0.00	0	0.894
C	2.00	0.50	0	0.778
D	0.50	2.00	0	0.703
E	0.00	4.00	0	0.695
F	0.00	8.78	0	0.747
G	1.50	10.78	0	0.860
H	3.00	12.78	0	0.973
I	3.00	29.25	0	1.153
J	0.00	29.25	0	0.971
K	4.10	40.53	0	1.343
L	31.00	52.53	0	3.110
M	31.00	0.00	0	2.536



HEADGATE MONOLITH TROY LOCK AND DAM
NORMAL OPERATION PLUS ICE

BASE AREA PROPERTIES — FINAL

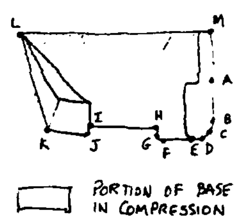
AREA (FT^2)	INERTIA ABOUT PRINCIPLE X-AXIS (FT^4)	INERTIA ABOUT PRINCIPLE Y-AXIS (FT^4)	XBAR (FT)	YBAR (FT)	ZBAR (FT)	ANGLE PRINCIPLE X-AXIS MAKES WITH X-AXIS (DEGREES)
1335.42	252891.4	89925.4	17.16	22.98	0	-8.95

SUMMARY OF FORCES AND MOMENTS — FINAL

F_x (KIPS)	F_y (KIPS)	F_z (KIPS)	M_{xx} (FT-K)	M_{yy} (FT-K)	M_{zz} (FT-K)
910.72	-36.11	-2597.95	-63943.0	50561.3	0

BASE PRESSURES — FINAL

PRESSURE POINT	X COORDINATE (FT)	Y COORDINATE (FT)	Z COORDINATE (FT)	PRESSURE (KSF)
A	13.00	0.00	0	1.441
B	4.00	0.00	0	0.894
C	2.00	0.50	0	0.778
D	0.50	2.00	0	0.703
E	0.00	4.00	0	0.695
F	0.00	8.78	0	0.747
G	1.50	10.78	0	0.860
H	3.00	12.78	0	0.973
I	3.00	29.25	0	1.153
J	0.00	29.25	0	0.971
K	4.10	40.53	0	1.343
L	31.00	52.53	0	3.110
M	31.00	0.00	0	2.536



HEAD GATE MONOLITH TROY LOCK AND/DAM
FLOOD CONDITION

BASE AREA PROPERTIES — INITIAL

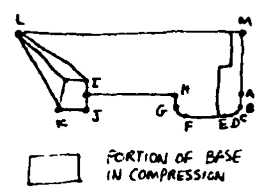
AREA (FT^2)	INERTIA ABOUT PRINCIPLE X-AXIS (FT^4)	INERTIA ABOUT PRINCIPLE Y-AXIS (FT^4)	XBAR (FT)	YBAR (FT)	ZBAR (FT)	ANGLE PRINCIPLE X-AXIS MAKES WITH X-AXIS (DEGREES)
1335.42	252891.4	89925.4	17.16	22.98	0	-8.95

SUMMARY OF FORCES AND MOMENTS — INITIAL

F_X (KIPS)	F_Y (KIPS)	F_Z (KIPS)	M_{XX} (FT-K)	M_{YY} (FT-K)	M_{ZZ} (FT-K)
733.53	0	-1928.40	-45781.6	36202.2	0

BASE PRESSURES — INITIAL

PRESSURE POINT	X COORDINATE (FT)	Y COORDINATE (FT)	Z COORDINATE (FT)	PRESSURE (KSF)
A	13.00	0.00	0	1.249
B	4.00	0.00	0	0.957
C	2.00	0.50	0	0.893
D	0.50	2.00	0	0.848
E	0.00	4.00	0	0.837
F	0.00	8.78	0	0.850
G	1.50	10.78	0	0.904
H	3.00	12.78	0	0.958
I	3.00	29.25	0	1.001
J	0.00	29.25	0	0.904
K	4.1	40.53	0	1.066
L	31.00	52.53	0	1.971
M	31.00	0.00	0	1.833



HEAD GATE MONOLITH TROY LOCK AND DAM
FLOOD CONDITION

BASE AREA PROPERTIES — FINAL

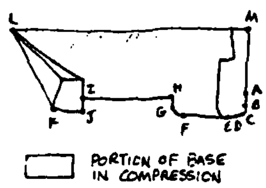
AREA (FT^2)	INERTIA ABOUT PRINCIPLE X-AXIS (FT^4)	INERTIA ABOUT PRINCIPLE Y-AXIS (FT^4)	XBAR (FT)	YBAR (FT)	ZBAR (FT)	ANGLE PRINCIPLE X-AXIS MAKES WITH X-AXIS (DEGREES)
1335.42	252891.4	89925.4	17.16	22.98	0	-8.95

SUMMARY OF FORCES AND MOMENTS — FINAL

F_x (KIPS)	F_y (KIPS)	F_z (KIPS)	M_{xx} (FT-K)	M_{yy} (FT-K)	M_{zz} (FT-K)
733.53	0	-1928.40	-45781.6	36202.2	0

BASE PRESSURES — FINAL

PRESSURE POINT	X COORDINATE (FT)	Y COORDINATE (FT)	Z COORDINATE (FT)	PRESSURE (KSF)
A	13.00	0.00	0	1.249
B	4.00	0.00	0	0.957
C	2.00	0.50	0	0.893
D	0.50	2.00	0	0.848
E	0.00	4.00	0	0.837
F	0.00	8.78	0	0.850
G	1.50	10.78	0	0.904
H	3.00	12.78	0	0.958
I	3.00	29.25	0	1.001
J	0.00	29.25	0	0.904
K	4.10	40.53	0	1.066
L	31.00	52.53	0	1.971
M	31.00	0.00	0	1.633



SUBJECT STABILITY ANALYSIS
HEAD GATE MONOLITH - TROY LOCK AND DAM
NORMAL OPERATION

COMPUTED BY: EFO DATE 3-24-80
CHECKED BY: DATE:

ITEM	FACTORS		F_x	F_y	F_z	ARM_{xx}	ARM_{yy}	MOMENT xx	MOMENT yy
$W_{concrete}$	(.15)(27)(4)(32)	(WEST PIER)			-518.40	2.00	-17.50	-1036.80	9072.00
	(.15)(1/2)(27)(15)(32)				-972.00	9.00	-17.50	-8748.00	17010.00
	(.15)(π)(4)²(32)(1/2)				-120.64	4.00	-2.30	-482.55	277.47
	(.15)(1/2)(4.78)(4)(9.55)				-13.69	9.59	-2.00	-131.33	27.39
	(.15)(4.78)(4)(14.45)				-41.44	10.39	-2.00	-430.59	82.89
	(.15)(21.25)(8)(.75)				-19.13	18.63	-9.00	-356.30	172.13
	(.15)(28)(9.25)(5)	(SPILLWAY)			-194.25	23.63	-17.00	-4590.13	3302.25
	(.15)(1/2)(28)(2.5)(5)				-26.25	18.17	-17.00	-476.96	446.25
	(.15)(1/2)(18.33)(22.75)(5)				-156.38	35.83	-24.89	-5603.02	3892.24
	(.15)(1/2)(7.83)(11.75)(12.33)				-85.08	22.38	-15.28	-1904.08	1300.01
	(.15)(6.67)(11.75)(12.33)				-144.95	22.38	-9.34	-3243.98	1353.83
	(.15)(1/2)(3)(11.75)(2.88)				-7.61	22.38	-5.00	-170.40	38.07
	(.15)(3)(11.75)(9.46)				-50.02	22.38	-4.50	-1119.44	225.09
	(.15)(1/6)(7.83)(9.72)(12.33)				-23.47	30.41	-16.15	-713.60	378.97
	(.15)(1/6)(7.83)(6.17)(12.33)				-14.89	14.44	-15.28	-215.04	227.55
	(.15)(1/2)(6.67)(6.17)(12.33)				-38.06	14.44	-9.34	-549.54	355.45
	(.15)(1/2)(3)(4.73)(2.88)				-3.07	14.14	-5.00	-43.34	15.33
	(.15)(1/2)(3)(4.73)(9.46)				-10.07	14.92	-4.50	-150.21	45.31
	(.15)(1/2)(12)(8.4)(32)	(EAST PIER)			-241.92	49.80	-8.00	-12047.62	1935.36
	(.15)(1/2)(12)(8.4)(32)				-241.92	53.56	-5.37	-12957.24	1299.11
	(.15)(16/6)[(8.4)(32)+(4)(4.2)(16)+0]				-215.04	55.03	-16.00	-11833.65	3440.64
	(.15)(16/6)[(8.4)(32)+(4)(4.2)(16)+0]				-215.04	59.25	-13.15	-12741.12	2827.78
	(.15)(1/2)(4)(9)(8)				-21.60	6.67	-8.50	-144.07	183.60
	(.15)(3)(4)(23)	(VOIDS IN MONO'S)			41.40	4.00	-9.00	165.60	-372.60
	(.15)(2.5)(4.75)(37)				65.91	24.50	-9.00	1614.80	-593.19
	(.15)(π)(1.25)²(1/2)(37)				13.62	24.50	-9.00	333.69	-122.58
W_{water}	(.0625)(4)(1/2)(4.78)(9.55)				-5.71	11.19	-2.00	-63.85	11.41
	(.0625)(1/2)(.5)(1)(10.5)				-0.16	16.33	-25.75	-2.70	4.29
	(.0625)[(21.47+34.5)/2](10.5)(1)				-18.37	30.38	-26.16	-557.93	480.43

WES FORM NO. 1253A

SUBJECT STABILITY ANALYSIS
HEAD GATE MONOLITH TROY LOCK AND DAM
NORMAL OPERATION

COMPUTED BY: EFO DATE 3-24-80
CHECKED BY: DATE

ITEM	FACTORS	F_x	F_y	F_z	ARM_{XX}	ARM_{YY}	$MOMENT_{XX}$	$MOMENT_{YY}$
$P_{WATER\ UPSTR}$	(.0625)(24)(24/2)(8)	144.00				8.00		1152.00
	(.0625)(24)(24/2)(5 Cos 20°)	84.57				8.00		676.58
	(.0625)(6.67)(17.33)(21.25)	153.52				8.67		1331.02
	(.0625)(17.33)(17.33/2)(21.25)	199.44				6.78		1152.76
	(.0625)(6.67)(3.33)(6.67/3)	3.09				21.77		67.21
	(.0625)(24)(24/2)(5 Sin 20°)		-30.78		-8.00		264.25	
$P_{WATER\ DNSTR}$	(.0625)(.6)(6)(6/2)(33.75)	-22.78				2.00		-45.56
	(.0625)(.6)(6)(6/2)(8.4 Cos 20°)		-5.33		-2.00		10.67	
UPLIFT	SEE CALCULATIONS ON SHEET			680.28	20.46	-13.40	13981.46	-9113.47
		561.84	-36.11	-2597.95			-63943.02	42537.02
TOTAL		561.84	-36.11	-2597.95			-63943.02	42537.02

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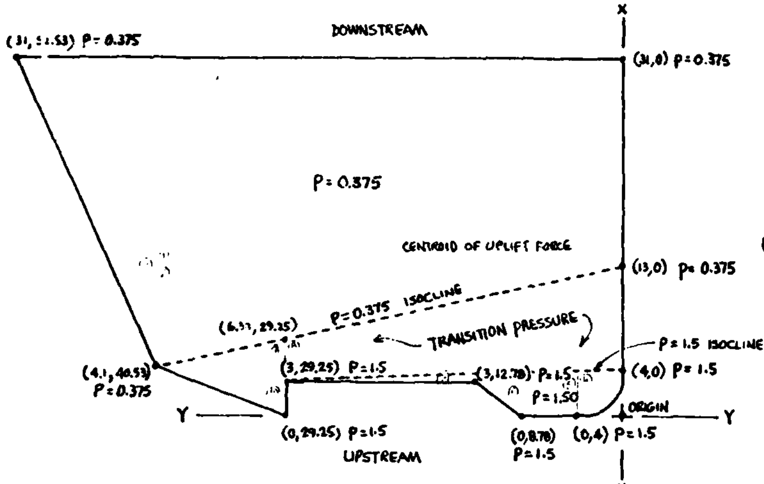
PAGE OF

SUBJECT STABILITY ANALYSIS
HEAD GATE MONOLITH TROY LOCK AND DAM
UPLIFT CALCULATIONS FOR NORMAL OPERATIONS

COMPUTED BY: EFO DATE 3-24-80

CHECKED BY: DATE



UPLIFT ASSUMPTIONS:

UPLIFT PRESSURE UPSTREAM OF P=1.5 ISOCLINE IS UNIFORM AT 1.5 KSF
" " DOWNSTREAM " P=0.375 " " " " 0.375 KSF
" " BETWEEN THESE ISOCLINES VARIES LINEARLY FROM .375 TO 1.5 KSF

ITEM		ARM_{xx}	ARM_{yy}	$MOMENT_{xx}$	$MOMENT_{yy}$
① (18)(40.53)(.375)	= 273.58	20.27	22.00	5545.42	6018.71
② (8.9)(40.53)(.375)(1/2)	= 67.63	27.02	7.07	1827.48	477.95
③ (26.9)(12)(.375)(1/2)	= 60.53	44.53	22.03	2695.18	1333.57
④ (π)(4)²(1/4)(1.5)	= 18.85	2.50	2.50	47.12	47.12
⑤ (4)(4.78)(1.5)	= 28.68	6.39	2.00	183.27	57.36
⑥ (4)(3)(1.5)(1/2)	= 9.00	10.11	2.00	91.02	18.00
⑦ (20.47)(1)(1.5)(1/2)	= 15.35	15.60	3.33	239.55	51.17
⑧$_1$ $\left(\frac{9.80+3.58}{2}\right)$(29.25)(.375)	= 68.99	12.53	6.91	864.49	476.89
⑨⑩$_1$ (1/2)(6.58)(40.53−29.25)(.375)	= 13.92	33.01	3.56	459.39	49.54
⑧$_2$ $\left(\frac{9.80+3.58}{2}\right)$(29.25)(1.125)(1/2)	= 103.49	12.53	5.04	1296.73	521.59
⑨$_2$ (1/3)(1.125)(3.58)(1/2)(11.28)	= 7.57	33.01	4.16	249.92	31.49
⑩$_2$ (1/3)(1.125)(3)(11.28)	= 12.69	33.01	2.37	418.90	30.08
Σ	680.28			13981.46	9113.47

UPLIFT FORCE = 680.28 KIPS
RESULTANT X ARM = 13981.46 ÷ 680.28 = 20.46′
RESULTANT Y ARM = 9113.47 ÷ 680.28 = 13.40′

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PAGE OF

SUBJECT: STABILITY ANALYSIS
HEAD GATE MONOLITH TROY LOCK AND DAM
NORMAL OPERATION PLUS EARTHQUAKE

COMPUTED BY: EFO DATE: 3-24-80
CHECKED BY: DATE:

ITEM	FACTORS	F_X	F_Y	F_Z	ARM_{XX}	ARM_{YY}	$MOMENT_{XX}$	$MOMENT_{YY}$
$W_{CONCRETE}$	SEE CALCULATIONS UNDER NORMAL OPERATION CONDITION			-3253.99	23.84	-14.39	-77574.92	46820.35
W_{WATER}	SEE CALCULATIONS UNDER NORMAL OPERATION CONDITION			-24.24	25.76	-20.47	-624.48	496.13
$P_{WATER\ UPSTR}$	SEE CALCULATIONS UNDER NORMAL OPERATION CONDITION	584.62	-30.78		-8.00	7.49	264.25	4379.57
$P_{WATER\ DNSTR}$	SEE CALCULATIONS UNDER NORMAL OPERATION CONDITION	-22.78	-5.33		-2.00	2.00	10.67	-45.56
$P_{STRUCTURE_{EQ}}$	$P_{e_1} = \alpha W = 0.05(3253.99)$	162.70				11.80		1919.85
$P_{WATER_{EQ}}$	$P_{e_2} = \frac{2}{3} C_e \alpha \gamma \sqrt{h y}\, l = (\frac{2}{3})(51)(0.05)(24)\sqrt{(24)(24)}(36)(.001)$	35.25				9.60		338.41
UPLIFT	SEE CALCULATIONS ON SHEET			680.28	20.46	-13.40	13981.46	-9113.47
		759.79	-36.11	-2597.95			-63943.02	44795.28
TOTAL		759.79	-36.11	-2597.95			-63943.02	44795.28

WES FORM NO. 1253A

PAGE OF

SUBJECT	STABILITY ANALYSIS HEAD GATE MONOLITH TROY LOCK AND DAM NORMAL OPERATION PLUS EARTHQUAKE
COMPUTED BY:	DATE:
CHECKED BY:	DATE:

LOCATION OF CENTROID IN Y-Z PLANE FOR MONOLITH

	VOLUME	x ARM	= VOLUME-MOMENT
1	(27)(4)(32)	= 3456.00 · 16.00	55296.00
2	(1/2)(27)(15)(32)	= 6480.00 · 10.67	69120.00
3	$(\pi)(4)^2(32)(1/2)$	= 804.27 · 16.00	12868.27
4	(1/2)(4)(9)(8)	= 144.00 · 29.33	4224.00
5	(1/2)(-.78)(4)(9.55)	= 91.27 · 17.63	1609.39
6	(4.78)(4)(14.45)	= 276.27 · 7.22	1996.03
7	(21.25)(8)(.75)	= 127.53 · 31.62	4033.24
8	(20)(1.25)(5)	= 1296.00 · 2.50	3237.50
9	(1/2)(28)(2.5)(5)	= 175.00 · 3.33	583.33
10	(1/2)(18.33)(21.75)(5)	= 1042.53 · 2.50	2606.33
11	(1/2)(7.83)(11.75)(12.33)	= 567.20 · 9.11	5167.19
12	(6.67)(11.75)(12.33)	= 966.33 · 11.16	10789.11
13	(1/2)(3)(11.75)(2.88)	= 50.73 · 15.41	781.75
14	(3)(11.75)(9.46)	= 333.47 · 9.73	3244.63
15	(1/6)(7.83)(4.72)(12.33)	= 156.47 · 8.08	1264.64
16	(1/6)(7.83)(6.17)(12.33)	= 99.27 · 8.08	802.07
17	(1/2)(6.67)(6.17)(12.33)	= 253.73 · 13.22	3354.35
18	(1/2)(3)(4.73)(2.88)	= 20.47 · 15.41	315.39
19	(1/2)(3)(4.73)(9.46)	= 57.13 · 11.31	759.05
20	(1/2)(12)(8.4)(32)	= 1612.80 · 16.00	25804.80
21	(1/2)(12)(8.4)(32)	= 1612.80 · 16.00	25804.80
22	(4/6)[(8.4)(32)+(4)(4.2)(16)]	= 1433.60 · 12.00	17203.20
23	(4/6)[(8.4)(32)+(4)(4.2)(16)]	= 1433.60 · 12.00	17203.20
	− (1/2)(4)(3)(23)	= −276.00 · 20.50	− 5658.00
	− (2.5)(4.75)(37)	= −439.40 · 12.00	− 5272.80
	$-(\pi)(1.25)^2(1/2)(37)$	= −90.80 · 14.00	− 1271.00
		21683.27	255866.47

$$\bar{Z} = \frac{255866.47}{21683.27} = 11.80' \quad (\text{El. } 5.80)$$

PAGE OF

SUBJECT: STABILITY ANALYSIS
HEAD GATE MONOLITH TROY LOCK AND DAM
NORMAL OPERATION PLUS ICE

COMPUTED BY: EFO DATE: 3-24-80
CHECKED BY: DATE:

ITEM	FACTORS	F_x	F_y	F_z	ARM_{xx}	ARM_{yy}	$MOMENT_{xx}$	$MOMENT_{yy}$
$W_{CONCRETE}$	SEE CALCULATIONS UNDER NORMAL OPERATION CONDITION			-3253.99	23.84	-14.39	-77574.92	46820.35
W_{WATER}	SEE CALCULATIONS UNDER NORMAL OPERATION CONDITION			-24.14	25.76	-20.47	-624.48	496.13
$P_{WATER\ UPSTR}$	SEE CALCULATIONS UNDER NORMAL OPERATION CONDITION	584.62	-30.78		-8.00	7.49	264.25	4379.57
$P_{WATER\ DNSTR}$	SEE CALCULATIONS UNDER NORMAL OPERATION CONDITION	-22.78	-5.33		-2.00	2.00	10.67	-45.56
$P_{ICE\ UPSTR}$	(34.89)(2)(5)	348.88				23.00		8024.28
UPLIFT	SEE CALCULATIONS ON SHEET			680.28			13981.46	-9113.47
		910.72	-36.11	-2597.95			-63943.02	50561.30
TOTAL		910.72	-36.11	-2597.95			-63943.02	50561.30

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PAGE OF

SUBJECT STABILITY ANALYSIS HEAD GATE MONOLITH TROY LOCK AND DAM FLOOD CONDITION	COMPUTED BY: EPO	DATE: 3-24-80
	CHECKED BY:	DATE:

ITEM	FACTORS	F_X	F_Y	F_Z	ARM_{XX}	ARM_{YY}	$MOMENT_{XX}$	$MOMENT_{YY}$
$W_{CONCRETE}$	SEE CALCULATIONS UNDER NORMAL OPERATIONS CONDITION			-3253.99	23.84	-14.39	- 77574.92	46820.35
W_{WATER}	CALCULATE WATER WEIGHT CONSIDERING WATER AND STRUCTURE AS WATER, THEN SUBTRACT WEIGHT OF WATER EQUAL TO VOLUME OF CONCRETE ACTING AT (23.84, -14.39)							
	(.0625)(π)(4)^2(1/4)(35.7)			- 28.04	2.30	- 2.30	- 64.49	64.49
	(.0625)(4)(4.78)(35.7)			- 42.66	6.39	- 2.00	- 272.61	85.32
	(.0625)(π)(4)^2(1/4)(35.7)			- 28.04	10.40	- 2.30	- 291.60	64.49
	(.0625)(8.67)(12.78)(35.7)			- 247.23	6.39	- 8.34	- 1579.79	2061.88
	(.0625)(16.47)(9.67)(35.7)			- 355.36	20.01	- 7.84	- 7110.75	2786.02
	(.0625)(4.10)(11.28)(1/2)(35.7)			- 51.60	33.01	- 2.73	- 1703.16	140.86
	(.0625)(11.28)(8.57)(35.7)			- 215.69	34.89	- 8.39	- 7525.57	1809.67
	(.0625)(8.57)(3.89)(1/2)(35.7)			- 37.19	41.83	- 9.81	- 1555.74	364.86
	(.0625)(7.83)(44.42)(1/2)(1)			- 10.87	22.21	- 15.28	- 241.40	166.08
	(.0625)(1/6)(3.56)(7.83)(1)			- 0.29	45.61	- 16.59	- 13.24	4.82
	(.0625)[(44.42 + 47.98)/2](7.83)(34.7)			- 784.54	23.11	- 16.63	- 18131.43	13046.90
	(.0625)[(47.98 + 52.75)/2](10.5)(34.7)			- 1146.91	25.20	- 25.83	- 28903.51	29624.68
	Vol. concrete = -3253.99/.15 = 21693.27 ft^3 weight of water for that volume = 21693.27 (.0625) = 1355.83 kips			+1355.83	23.84	- 14.39	+ 32322.97	- 19510.38
$P_{WATER\ UPSTR}$	(.0625)(3.1)(32)(8)	59.20				16.00		947.20
	(.0625)(32)^2(8)(1/2)	256.00				10.67		2731.52
	(.0625)(11.7)(6.67)(4.78)(1/2)	11.66				19.55		227.90
	(.0625)(6.67)^2(4.78)(1/3)	4.43				18.99		84.12
	(.0625)(18.37)(17.33)(21.25)	422.81				8.67		3665.77
	(.0625)(17.33)^2(21.25)(1/2)	199.44				5.78		1152.75
	(.0625)(3.7)(32)(11.28)	83.47				16.00		1335.55
	(.0625)(32.09)^2(11.28)(1/2)	360.96				10.67		3851.44
	(.0625)(2.7)(32)(12.22)(1/2)	32.99				10.67		352.05
	(.0625)(32)^2(12.22)(1/3)	260.67				8.00		2085.34
	(.0625)(.75)(21.25)[(3.7) + (.75)(1/2)]	4.06				31.59		128.23
$P_{WATER\ DWSTR}$	(.0625)(2.7)(32)(12.22)(1/2)(.6)	- 19.79				10.67		- 211.09
	(.0625)(32)^2(12.22)(1/3)(.6)	- 156.40				8.00		- 1251.20
	(.0625)(2.7)(32)(11.28)(.6)	- 36.55				16.00		- 584.74
	(.0625)(32)^2(11.28)(1/2)(.6)	- 216.58				10.67		- 2310.15

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PAGE OF

SUBJECT: STABILITY ANALYSIS
HEAD GATE MONOLITH TROY LOCK AND DAM
FLOOD CONDITION

COMPUTED BY: EFO DATE: 3-24-80
CHECKED BY: DATE:

ITEM	FACTORS	F_X	F_Y	F_Z	ARM_{XX}	ARM_{YY}	MOMENT XX	MOMENT YY
$P_{WATER\ DISTR}$ (CONT)	(.0625)(17.37)(17.33)(9.25)(.6)	-104.42				8.67		-904.96
	(.0625)(17.33)^2(9.25)(½)(.6)	-52.09				5.78		-301.06
	(.0625)(17.37)(17.33)(8.67)(½)(.6)	-48.94				11.55		-565.21
	(.0625)(17.33)^2(8.67)(1/6)(.6)	-16.27				8.67		-141.88
	(.0625)(2.7)(.75)(21.25)(.6)	-1.62				31.63		-51.24
	(.0625)(.75)^2(21.25)(½)(.6)	-.22				31.50		-6.99
	(.0625)(2.7)(4)(8)(½)(.6)	-1.62				29.33		-47.51
	(.0625)(8)^2(4)(1/6)(.6)	-1.60				28.00		-44.86
	(.0625)(2.7)(4)(32)(.6)	-12.96				16.00		-207.36
	(.0625)(32)^2(4)(½)(.6)	-76.80				10.67		-819.20
	(.0625)(2.7)(32)(15)(½)(.6)	-24.30				10.67		-259.20
	(.0625)(32)(15)(32)(1/3)(.6)	-192.00				8.00		-1536.00
UPLIFT	SEE CALCULATIONS ON SHEET			2918.18	22.91	-16.67	66863.61	-48646.76
		733.53	0	-1928.40			-45781.63	36202.20
TOTALS		733.53	0	-1928.40			-45781.63	36202.20

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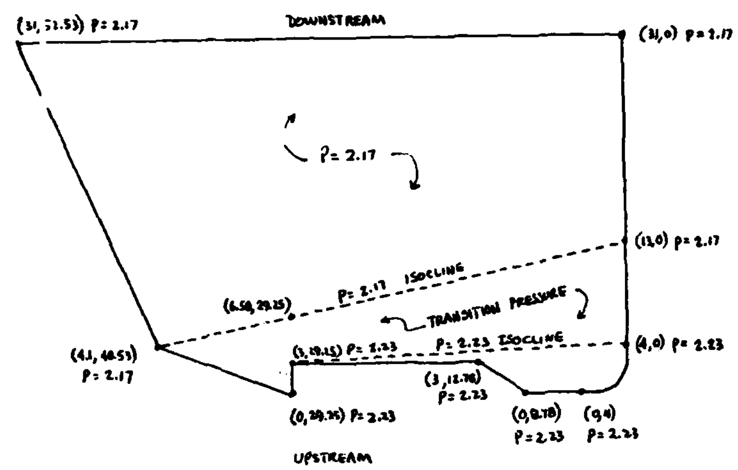
SUBJECT STABILITY ANALYSIS
HEAD GATE MONOLITH TROY LOCK AND DAM
UPLIFT CALCULATIONS FOR FLOOD CONDITION

COMPUTED BY: EFO DATE 3-24-80
CHECKED BY: DATE



ITEM		ARM$_{XX}$	ARM$_{YY}$	MOMENT$_{XX}$	MOMENT$_{YY}$
① (18)(40.53)(2.17)	= 1583.10	20.27	22.00	32089.47	34828.24
② (8.9)(40.53)(2.17)(1/2)	= 391.38	27.02	7.07	10575.03	2767.04
③ (26.9)(12)(2.17)(1/2)	= 350.24	44.53	22.03	15596.10	7715.74
④ (π)(4)²(1/4)(2.23)	= 28.02	2.50	2.50	70.06	70.06
⑤ (4)(4.78)(2.23)	= 42.64	6.39	2.00	272.45	85.28
⑥ (4)(3)(2.23)(1/2)	= 13.38	10.11	2.00	135.27	26.76
⑦ (20.47)(1)(2.23)(1/2)	= 22.82	15.60	3.33	356.06	76.08
⑧$_1$ $\left(\frac{9.00+3.58}{2}\right)$(29.25)(2.17)	= 399.24	12.53	6.91	5002.50	2758.76
⑨⑩$_1$ (1/2)(6.50)(11.28)(2.17)	= 80.53	33.01	3.56	2658.34	286.67
⑧$_2$ $\left(\frac{9.00+3.58}{2}\right)$(29.25)(0.062)(1/2)	= 5.70	12.53	5.04	71.46	28.75
⑨$_2$ (1/3)(0.062)(3.58)(1/2)(11.28)	= 0.42	33.01	4.16	13.77	1.74
⑩$_2$ (1/3)(0.062)(3)(11.28)	= 0.70	33.01	2.37	23.09	1.63
Σ	2918.18			66863.61	48646.76

UPLIFT FORCE = 2918.18 kips
RESULTANT X ARM = 66863.61 ÷ 2918.18 = 22.91
RESULTANT Y ARM = 46846.76 ÷ 2918.18 = 16.67

WES FORM NO 1253A

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In accordance with letter from DAEN-RDC, DAEN-ASI dated 22 July 1977, Subject: Facsimile Catalog Cards for Laboratory Technical Publications, a facsimile catalog card in Library of Congress MARC format is reproduced below.

Pace, Carl E

Engineering condition survey and evaluation of Troy Lock and Dam, Hudson River, New York; Report 2: Evaluation and rehabilitation / by Carl E. Pace ... [et al]. Viçksburg, Miss. : U. S. Waterways Experiment Station ; Springfield, Va. : available from National Technical Information Service, 1981.

64, [118], 270 p. : ill. ; 27 cm. (Miscellaneous paper - U. S. Army Engineer Waterways Experiment Station ; C-78-6, Report 2)

Prepared for U. S. Army Engineer District, New York, New York, N. Y., under Intra-Army Order No. NYD-78-52(c).

References: p. 64.

1. Concrete cores. 2. Concrete dams. 3. Concrete deterioration. 4. Engineering condition survey. 5. Locks (Waterways). 6. Stability analysis. 7. Troy Lock and Dam. I. United States. Army. Corps of Engineers. New York District. II. Series: United States. Waterways Experiment Station, Vicksburg, Miss. Miscellaneous Paper; C-78-6, Report 2.

TA7.W34 no.C-78-6 Report 2

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