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Structural Model Investigations for Ross High Dam - Model 3, Staged Construction

Author

Raphael, Jerome

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STRUCTURAL MODEL INVESTIGATIONS FOR ROSS HIGH DAM

MODEL 3 – STAGED CONSTRUCTION

BY

JEROME M. RAPHAEL

REPORT TO
INTERNATIONAL ENGINEERING COMPANY, INC.
SAN FRANCISCO, CALIFORNIA

AUGUST 1972

STRUCTURAL ENGINEERING LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY CALIFORNIA

STRUCTURAL MODEL INVESTIGATIONS

FOR

ROSS HIGH DAM

MODEL 3 - STAGED CONSTRUCTION

Report No.

UC SESM 72-11

INTERNATIONAL ENGINEERING COMPANY, INC.

San Francisco, California

JEROME M. RAPHAEL

Professor of Civil Engineering

UNIVERSITY OF CALIFORNIA

Berkeley, California

August, 1972

TABLE OF CONTENTS

	Page
INTRODUCTION	1
ACKNOWLEDGMENTS	3
MODEL	4
MATERIALS	5
SCOPE OF TESTS	6
LOADING	7
INSTRUMENTATION	8
RECORDING	8
STRESSES	8
STRESS SUMMARY	13
DEFLECTIONS	14
DISCUSSION	14
CONCLUSIONS	16
APPENDIX A - ILLUSTRATIONS	17
APPENDIX B - TABLES	44

LIST OF ILLUSTRATIONS

Figure No.		Page
1.	General Arrangement	18
2.	Geometric Data and Sections	19
3.	Test Phases	20
4.	Strain Gage Locations - Downstream Face	21
5.	Strain Gage Locations - Upstream Face	22
6.	Orthogonal Stresses - Phase 1 - Downstream Face	23
7.	Orthogonal Stresses - Phase 1 - Upstream Face	24
8.	Orthogonal Stresses - Phase 2 - Downstream Face	25
9.	Orthogonal Stresses - Phase 2 - Upstream Face	26
10.	Orthogonal Stresses - Phase 4 - Downstream Face	27
11.	Orthogonal Stresses - Phase 4 - Upstream Face	28
12.	Orthogonal Stresses - Phase 5 - Downstream Face	29
13.	Orthogonal Stresses - Phase 5 - Upstream Face	30
14.	Orthogonal Stresses - Phase 6 - Downstream Face	31
15.	Orthogonal Stresses - Phase 6 - Upstream Face	32
16.	Orthogonal Stresses - Phase 7 - Downstream Face	33
17.	Orthogonal Stresses - Phase 7 - Upstream Face	34
18.	Orthogonal Stresses - Phase 8 - Downstream Face	35
19.	Orthogonal Stresses - Phase 8 - Upstream Face	36
20.	Orthogonal Stresses - Phase 9 - Downstream Face	37
21.	Orthogonal Stresses - Phase 9 - Upstream Face	38
22.	Principal Stresses - Phase 2 - Downstream Face	39
23.	Principal Stresses - Phase 2 - Upstream Face	40
24.	Principal Stresses at Abutments - Phase 9 - Downstream Face	41
25.	Principal Stresses at Abutments - Phase 9 - Upstream Face	42
26.	Radial Deflections	43

LIST OF TABLES

Table No.		Page
A.	Mix Proportions for Model 3	5
1.	Arch Stresses - Downstream Face	45
2.	Arch Stresses - Upstream Face	46
3.	Cantilever Stresses - Downstream Face	47
4.	Cantilever Stresses - Upstream Face	48

STRUCTURAL MODEL INVESTIGATIONS FOR ROSS HIGH DAM

MODEL 3 - STAGED CONSTRUCTION

INTRODUCTION

Ross Dam, a 661-ft. high by 1500-ft. long arch dam, which is the major storage structure of the City of Seattle, Department of Lighting's hydroelectric power project on the Skagit River, Washington, was designed to be constructed in four stages. In the original plan, the first three stages had been constructed essentially as a thin arch dam, and the fourth stage of construction necessitated the addition of a large volume of concrete downstream of this thin arch dam in addition to raising the height. A revised scheme for the fourth stage, based on raising the dam essentially as a thin arch dam with a minimal addition of concrete and thickening only the upper 150 feet of the present dam, was the subject of a model investigation at the University of California, which had the objective of determining the structural stresses in the dam under the proposed plan of development.

Figure 1 shows in plan the general arrangement at the dam site, and Figure 2 shows a cross section of the maximum cantilever of the dam. The section shows Ross Dam as presently constructed, together with the contemplated additional mass of concrete as laid out by International Engineering Company, Inc. (IECO).

In the course of the investigations reported here, a reinforced concrete test facility was constructed in the Models Laboratory at the University of California, a foundation and three model dams were constructed of mixtures of plaster and celite, and the models were tested over a period of two years using resistance strain gages bonded to the surface of the models to determine the stresses.

This report is the third of a series of three reports covering the structural model investigations for Ross High Dam. The first report, entitled Model 1 - Ross High Dam, covers the model analysis of a homogeneous dam model of Ross Dam raised to its ultimate stage of construction with crest at elevation 1736. That first report gave details of the construction of the test facilities and foundation of the model. The second report, entitled Model 2 - Step 3 As Constructed, discusses tests of a model of the present stage of Ross Dam, constructed to elevation 1615. The report that follows discusses the construction and testing of a two-stage model constructed much as the dam itself will be constructed. This consists of a low dam representing the present stage of construction of Ross Dam to elevation 1615, with additional material cast on top of it representing the planned fourth stage of construction for Ross High Dam to its ultimate height of elevation 1736.

Since the additional concrete will be 25 years younger than the concrete presently in the dam, it is possibly more deformable due to creep, and hence the second portion of the model has been made of a more deformable plaster than the lower portion. Assuming that creep strain is equal to elastic strain in the old concrete and that for an extreme case the creep in the new concrete is twice as great as the creep in the old concrete, the material in the cap has been designed with an elastic modulus two-thirds that of the material in the low dam.

Additional studies needed to cast the plaster cap on top of the already-cast low dam without structural discontinuities due to plastic shrinkage were needed, and are described.

Finally, a series of structural discontinuities representing extremely remote possibilities such as cracks or loss of bonding were introduced to study their effects on stability and redistribution and magnitude of stresses in the dam.

ACKOWLEDGMENTS

Overall supervision of the Ross High Dam Project is by the owner, the City of Seattle, Department of Lighting, under the direction of Chief Engineer R. L. Skone, Chief Civil Engineer C. R. Hoidal, and Engineer E. J. Drobnack.

Engineering studies and layouts for the fourth stage of Ross Dam were carried out by International Engineering Company, Inc., under the direction of Chief Engineer G. S. Sarkaria and Project Manager E. B. Kollgaard, assisted by Engineers R. P. Sharma and H. E. Jackson.

Construction and testing of the models were carried out under the direction of Professor Jerome M. Raphael of the University of California, Department of Civil Engineering. The testing organization was led by Engineer Charles Mercer, assisted by Research Assistant Otto Fajardo and a staff varying from about four to ten technicians from an international organization of 42 undergraduate and graduate students.

MODEL

The model was constructed at a scale of 1:240, or twenty feet to the inch, which resulted in a model dam with a gross length of six feet and a height of thirty inches. After including sufficient foundation material to correctly model dam-foundation interaction and an 18-inch thick channel-shaped reinforced concrete test pit, the gross dimensions of the project were 6 x 12.5 x 6.5-ft.

Study of the cross section of the dam, shown in Fig. 2, gives an indication of the problem faced in producing a two-stage model. The test pit and foundation had already been constructed for Models 1 and 2, and molds were available for the low dam and for the high dam. The only new problem to be faced was casting the cap with its very thin overlays over the old dam without excessive moisture loss which would lead to shrinkage, cracking and structural discontinuities.

In an auxiliary study, conducted principally by Mr. Otto Fajardo, various combinations of casting over wet or dry plaster, with and without surface coatings, were tried. The method used successfully was to cast the low dam, trim it and dry it out completely. The surfaces of contact between the low dam and the overlay were then given two coats of cut-back shellac. The molds for the high dam were then assembled around the low dam, using a thin bead of modelling clay to prevent leakage, and the low-elasticity cap was then poured. Despite a small amount of leakage, the cap proved to be perfectly sound when the forms were removed, and the entire model was then dried out, trimmed and shellaced for attachment of gages. Later, when parts of the overlay were removed as needed at various stages of the test, the bond between old and new plaster proved to be very strong.

MATERIALS

The modulus of elasticity of the low dam model was the same as that used in the previous models, 250,000 psi. For the cap, the modulus of elasticity was two-thirds that of the material in the low dam, or 167,000 psi. U.S. Gypsum Red Top #1 White Industrial Molding Plaster, Johns-Manville Superfloss Celite, and water were combined to produce two plasters of the strengths shown in Table A.

Table A

Mix Proportions for Model 3

Modulus of Elasticity, psi	Plaster	Water	Celite
250,000	1.00	1.82	0.28
167,000	1.00	2.27	0.42

Both these mixtures had an initial 5.5" consistency and were poured at about 4.3" consistency after about 18 minutes mixing. Both set about 5 minutes after the beginning of pour with no evidence of bleeding or shrinkage.

SCOPE OF TESTS

The tests for Model 3 were conducted in 9 phases, as shown in Fig. 3. Phase 1 represented the complete dam cast in two stages, new concrete on top of old concrete, with water to elevation 1725, the maximum reservoir level.

For Phase 2 a vertical slot was cut in the left abutment at station 3+00 from the top of the dam downward to elevation 1660 to remove arch load from the right abutment. The dam was then loaded with water to elevation 1725.

Phases 3 and 4 were designed to test the effect of horizontal cracking in the tension zone on the downstream face at elevation 1520.

For Phase 3, a 7.5-foot deep discontinuous slit was cut from station 8 + 00 to station 12 + 00, leaving some material undisturbed at the centerline of the dam to avoid interference with a nearby strain gage rosette. This phase is not discussed in this report. In Phase 4 the 7.5-ft. deep crack was made continuous and extended at the ends so that it reached from station 7 + 50 to station 12 + 50.

Phase 5 was intended to explore the formation of a shrinkage crack on the downstream face at elevation 1615 extending from the top of the old concrete outward and cutting completely through the overlay.

In Phase 6 all the overlay concrete on the downstream face was removed as though the overlay concrete had no structural action, and the strain gage rosettes were moved radially to corresponding positions on the old concrete.

For Phase 7 a continuous horizontal slit was made at the top of the old dam completely through the upstream overlay to show the effect of a shrinkage crack at this location.

For Phase 8 the upstream overlay below the horizontal slit was completely removed and the strain gages moved to the old concrete.

For Phase 9 a continuous horizontal slit was cut through the model at the top of the old concrete so that the cap and the old dam were completely discontinuous and acted as independent arch units.

All phases were loaded with water to elevation 1725, the maximum reservoir water elevation.

LOADING

Loads to simulate live loads such as water load and earthquake load were applied to the upstream face of the model by means of a series of horizontal air bags, the incremental pressures of which were controlled by a tilting frame holding a series of water columns. Using the Westergaard equivalent, horizontal earthquake load of dam and reservoir was made a multiple of the water load. Dead load was applied to a number of horizontal sections on the model by lead bricks. Both methods are described fully in Report No. UC SESM 71-11 on the testing of Model 1.

INSTRUMENTATION

The layout of strain gage rosettes for the downstream and upstream faces of Model 3 is shown in Figures 4 and 5. Where the overlaid parts of the model were removed for Phases 6 and 8, the affected strain gage rosettes were moved radially from the surface of the overlay back to the original surface of the dam, maintaining the same coordinates. The few rosettes attached to the concrete filling the old spillway crest were simply taken out of action, as it is difficult to attach any physical meaning from indications in these locations. Finally, four rosettes, numbered 5A, 9A, 37A and 44A, were added in regions of concentrated stress for Phase 9.

RECORDING

Indications from the strain gages and from control gages and pressure transducers were recorded automatically at the rate of four per second by a computer-controlled low speed scanner. Each stress reported here represents data from 105 separate recordings.

STRESSES

In the preliminary report of stresses in Model 3, dated July 1971, there was mention that the surface of the model had been hardened by the shellac coating to the extent that the apparent stresses were reduced by some unknown factor, estimated to average about ten percent. The determination of the effect of this surface coating was the subject of two experimental investigations, one involving the bending of beams of varying depth, and the other involving compression of cylinders, both with and without shellac coatings. This surface hardening effect was not found on Model 1, and the results contained in Report No. UC SESM 71-11, "Model 1 - Ross High Dam," July 1971, are valid as they stand. Post-mortem examination of the three models showed that the shellac coating remained on the surface of Model 1, but penetrated the plaster to an average depth of 0.35-in. in Models 2 and 3. Why this happened only to Models 2 and 3 may be due to slight changes in placement technique, but it did happen. The effect of this surface hardening has been evaluated, and the stresses given in Tables 1 through 4 reflect values that can be compared with like conditions in Model 1, and that are consistent among themselves.

Dead load stresses used in this analysis were taken directly from those determined for Model 1. These stresses changed to some degree as material was removed from the dam in the various stages of the test. Above elevation 1615, there should be no change in dead load stress. Between elevations 1615 and 1500, both mass and weight are removed, the effects of which roughly balance each other, leading to very little change in dead load stress. Below elevation 1500, dead load stress should decrease due to removal of weight above. Since there was no experimental procedure for redetermining dead load stresses, no change was made in these values as the tests progressed through the nine phases. The combination of dead load plus water load was used to compare stresses in the dam under various cumulative structural modifications, resulting in a slight discrepancy in the results from the true stresses. However, it is considered that this will not affect the interpretation of structural action of the dam under the various conditions of load and configuration.

The computed prototype surface stresses are shown in two ways. The orthogonal arch, cantilever, and shear stresses are shown on tables for each rosette location, for five cases of loadings: water load, dead load, water + dead load, water + earthquake load, and water + earthquake + dead loads. These results are given in Figs. 6 through 21 for Phases 1 through 9, with the exception of Phase 3, which is omitted as it is a partial case of Phase 4. Principal stresses have been displayed as vectors showing their sense, magnitude, and direction on Figs. 22 and 23 for dead + water load for Phase 2 only, since this is the case that reflects the normal service behavior of the dam. In addition Figs. 24 and 25 show in detail the principal stresses at the two abutments of dam when the concrete above elevation 1615 was completely separated from the concrete below that elevation in Phase 9.

Phases 1 and 2 nearly duplicate the tests for Model 1, with the exception that the Stage 4 concrete has been made weaker. Phase 1 of Model 3 corresponds to the test of Model 1 before cutting the slot in the right abutment. The stresses in Model 3 at the top of the dam are considerably less than in Model 1, reflecting the assumed weaker concrete. The maximum arch stress in the upper portion of the dam in Model 1 was 870 psi at the centerline at elevation 1540. This decreased to 758 psi in Model 3. The maximum arch stress in the lower part of Model 1 was 915 psi on the upstream face at elevation 1400. This increased to 965 psi in Model 3. The maximum cantilever stress of 840 psi for Model 1, at elevation 1300 right abutment, increased to 876 psi in Model 3.

Phase 2 explores the effect of cutting the right abutment slot, which primarily affects stresses in the immediate vicinity of the slot. On the downstream face, arch stress above the slot decreases from 399 to 229 psi compression, and the corresponding stress on the upstream face changes from 290 to 138 psi compression. This is picked up just below the slot, where the arch stresses increase from 260 to 371 psi on the upstream face, and from 355 to 518 psi compression on the downstream face. As can be seen from Tables 1 and 2, stress changes elsewhere are nominal, probably reflecting only two different test series.

Moving now to Phase 4, a horizontal slot was cut through the vertical tension region on the downstream face at elevation 1520, to explore stress readjustment if the concrete cracked. As might be expected, the principal stress changes were in the cantilever stresses on the downstream face. Twenty feet above the crack at the centerline, tensile stresses decreased from 115 to 42 psi, and twenty feet below the crack, the maximum tensile stresses decreased from 158 to 68 psi. In the immediate vicinity of the crack, arch stresses increased slightly by a magnitude of about 20 psi, but this is not considered significant. Both arch and cantilever stresses appeared relatively unchanged elsewhere.

For Phase 5, a deeper crack was cut on the downstream face, at elevation 1615, all the way back to the old concrete. This might represent a shrinkage crack at the former crest elevation of the dam. Fifteen feet below this crack, the former tensile stress region completely disappeared, and all vertical stress is compression. The greatest change was at the maximum cantilever where stress changed from 125 psi tension to 8 psi compression. Stresses elsewhere in the dam were practically unaffected by this manufactured crack.

In Phase 6, all concrete applied to the downstream face of the old dam below the present crest elevation of 1615 was removed, and the strain gages were relocated in corresponding positions on the downstream face of the old concrete. Thus, each gage was attached to concrete having a fifty percent higher elastic modulus, which in itself, if there were no change in surface strain, would give a fifty percent higher stress value. The heavy line on Tables 1 and 3 shows the gages that were relocated between Phases 5 and 6. Arch stresses increased an average of 150 psi compression, the maximum increase being 248 psi on the downstream face. Arch stresses also increased in this vicinity on the upstream face, but by a much smaller average of 50 psi. The greatest effect was on the cantilever stresses on the downstream face. Here tensile stresses were reestablished everywhere except at the abutments. At the centerline, the change was almost 250 psi, the maximum tensile stress being 272 psi at elevation 1540. This tension, while high as influenced both by the change in modulus and the reduction in section, is more than compensated by increases in compression at corresponding locations at the upstream face, and the stability of the dam is not diminished.

For Phase 7, a continuous crack was introduced at the upstream face at elevation 1615 completely through the new concrete back to the old concrete crest, simulating a volume change crack at that face. Compressive cantilever stresses on the upstream face at elevation 1600, just fifteen feet below this crack, were greatly reduced, by an average of 200 psi. On the downstream face, tensile cantilever stresses increased, to a maximum of 304 psi at the centerline. Both of these changes taken together illustrate the large vertical moment induced by the abrupt change in arch stiffness induced by the combination of material removed from the downstream face, and the deep and wide upstream slot, which was incapable of transmitting compression. This effect will be illustrated further in the discussion of deflection, later in this report.

Arch stresses on both faces generally decreased above the crack and increased below the crack, but there was practically no change in the average arch stresses after formation of the crack.

For Phase 8, all added concrete on the upstream face below old crest elevation 1615 was removed, and the strain gages were relocated on the old, stronger concrete. Gages thus affected are shown on Tables 2 and 4 by the double line between Phases 7 and 8. All stresses in the region of the removed concrete increased about fifty percent, as expected, due to the increase in elastic modulus. Moreover, as the dam readjusted to the new decreased total stiffness, all other parts of the dam show slightly higher stress. Taking both effects together, all stress increased an average of twenty percent. At the end of this phase, the highest compression was the arch stress of 1169 psi compression at elevation 1540 on the upstream face at the centerline. The highest tensile cantilever stress of 395 psi was found on the downstream face at the same locations. This tension was more than balanced by a compressive cantilever stress of 611 psi on the upstream face, indicating net compression across the section.

For Phase 9, a horizontal slot was cut completely through the dam at elevation 1615, separating the original dam from the added concrete above the crest of the old dam. This was of course a severe structural discontinuity so that the thick stiff upper arch acted completely independently of the old dam. Putting it another way, it was as though the dam as it now stands was subjected to an added surcharge head of 125 feet, while the added portion was relieved of the duty of supporting interacting arch loads from below. In testing this phase, the slot was gradually widened from the center to the abutments by three stages in case this deliberate weakening caused failure of the model. The model behaved well at all stages, and only the complete cut is reported here as Phase 9.

An immediate effect of the continuous crack at elevation 1615 was the relief of cantilever tension on the downstream face below that location. The stress relief averaged 350 psi at elevation 1600 and 380 psi at elevation 1540. On the upstream face, the heavy cantilever compressive stresses diminished an average of 350 psi at elevation 1600, and 300 psi at elevation 1540. In general, since the stiff upper portion was relieved of carrying part of the load of the old dam below elevation 1615, stress readjustment was manifested by generally smaller stresses in the upper portion, and increased stresses in the low portion of the dam. This can easily be seen by comparing Figs. 22 and 23 with Figs. 24 and 25. Except in the immediate vicinity below the slot and above the horizontal crack, principal stresses in Phase 9 averaged 70 percent of those in Phase 2. However, on the downstream face in the remaining concrete between the vertical slot and the horizontal crack, compressive stress increased from 570 to 640 psi at a location where there was direct comparison and was measured at 734 psi at one gage in this location.

STRESS SUMMARY

The state of stress after each phase of the testing is complete is shown on the individual drawings and tables cited above, but comparison among the phases is difficult. On this account, four summary tables have been prepared so that the stresses measured at each strain gage location can be followed easily throughout the progress of the test phases.

Tables 1 through 4 show the cumulative effect on arch and cantilever stresses of the successive phases tested. All stresses shown are for the combined effect of dead load and water load to elevation 1725. The listing is as follows:

Table 1 - Arch Stresses - Downstream Face

Table 2 - Arch Stresses - Upstream Face

Table 3 - Cantilever Stresses - Downstream Face

Table 4 - Cantilever Stresses - Upstream Face

Each table lists the strain gage rosettes on one face, together with their elevation and station, and then lists successively the dead plus water load stresses found for each phase tested. A double line shows when the gage was moved from the surface of the cap back to the surface of the old dam. By tracing along any line, changes in stress at a particular location, as the dam was successively modified through the nine stages, can easily be followed.

DEFLECTIONS

Deflections were measured at a number of stages, but only four stages have been illustrated on Figure 3. This compares the radial deflection of the crown cantilever from Stages 1, 2, 8, and 9. For Phase 2, corresponding to the most probable configuration of dam and load, the maximum deflection is about 2 1/2 inches. When the overlay concrete is removed from both faces, as in Phase 8, the maximum deflection increases to about 3-in. When the horizontal joint at elevation 1615 is opened the loss of shear transfer is shown by the discontinuous deflection, with the maximum deflection in the lightly-loaded stiff upper portion reducing to 1 1/2 inches, and the deflection for the heavily-loaded but more limber lower portion increasing to about four inches. Increased flexibility where the face concrete is removed is shown in the Stage 8 deflection, and the loss of the effect of shear transfer by opening a horizontal joint at elevation 1615 is shown by the Stage 9 deflection.

DISCUSSION

Before attaching undue significance to the magnitude of the stresses discussed here, it is well to review the actual conditions of the tests and compare them with reality. In each phase described here, stresses have been found due to the water load increasing from empty reservoir to full reservoir. The stress changes shown will occur when the reservoir is raised by the full height of the reservoir, from elevation 1075 to 1725. In constructing the actual dam, the reservoir will be partially drawn down for construction purposes from elevation 1600 to elevation 1475, and raised from elevation 1475 to 1725 after construction. The load of the reservoir when drawn down to elevation 1475 will be carried entirely by the old dam, and the additional load when the reservoir is raised to elevation 1725 will be divided between the old and new concrete. Hence the old concrete will be stressed slightly higher, and the new concrete will be stressed slightly lower than the stresses shown in this report for adding the full reservoir load.

New concrete will be placed over old concrete that is already stressed and deflected. It was impossible to duplicate this condition of construction in the model due to physical limitations. The effective modulus of elasticity of the concrete used in the fourth stage has a minor effect on stress distribution in the dam. The more the concrete in the fourth stage matches that in the present dam, the more load that will be carried in that stage. However, even with a fair degree of mismatch, stresses everywhere are well within the allowable.

As for the various phases considered, each represents an extreme case. When a crack was introduced, it extended across the entire dam. If concrete was removed, it was removed from the complete width of the face of the dam. It is very difficult to conceive of a natural circumstance that would cause a structural discontinuity of this extent. Thus, it has been shown that any conceivable finite crack or discontinuity will cause only a minor readjustment of stress as the dam accomodates itself to the changed structural configuration.

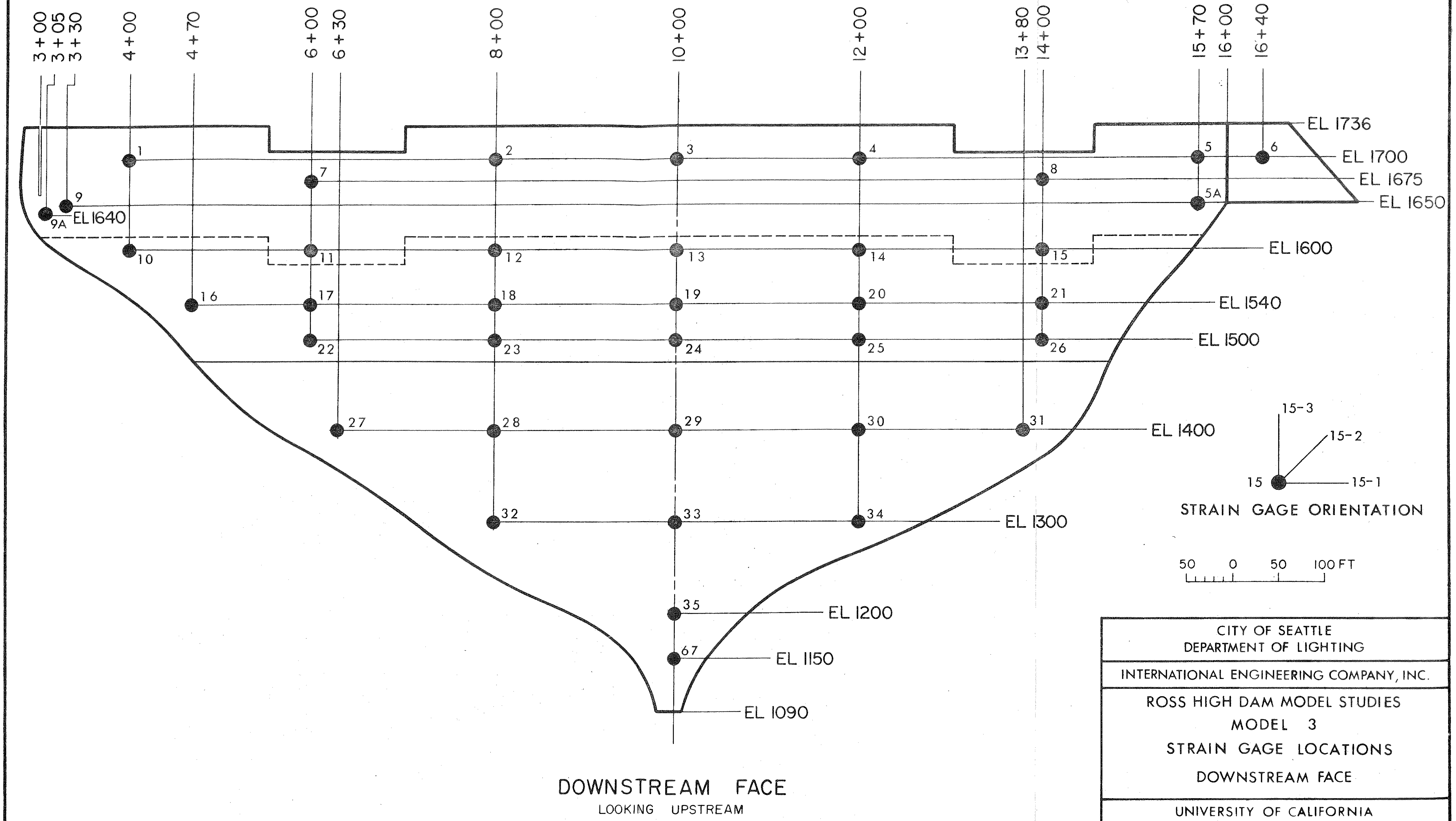
In any case, under the extreme conditions of loading and structural discontinuities tested, the dam showed consistently stable behavior and moderate stresses. The actual model, which did not have the stabilizing effect of dead load to help it, redistributed stresses away from each successively weakened section, and readjusted itself to handle the live load. In no case did the compressive stress exceed the allowable compressive stress, and the maximum tensile stresses for these extreme conditions were within the tensile strength of the concrete. Any cracks introduced in the tensile stress region caused favorable reduction of tensile stress and redistribution of load. And in the final phase, the present dam took a 125 foot overload with no apparent distress.

CONCLUSIONS

It is concluded that stresses and displacements will not be critically dependent on close matching of the elastic properties of the new fourth stage concrete with that of the present Ross Dam.

Surface cracking in regions of tensile stress does not result in instability, but reduces tension in that vicinity and redistributes compression to other regions.

A structural discontinuity such as loss of bond of the overlaid concrete can be absorbed by redistribution of stresses throughout the dam, with no adverse effect on its stability.



CITY OF SEATTLE
DEPARTMENT OF LIGHTING

INTERNATIONAL ENGINEERING COMPANY, INC.

ROSS HIGH DAM MODEL STUDIES
MODEL 3
STRAIN GAGE LOCATIONS
DOWNSTREAM FACE

UNIVERSITY OF CALIFORNIA
JEROME M. RAPHAEL, FACULTY INVESTIGATOR

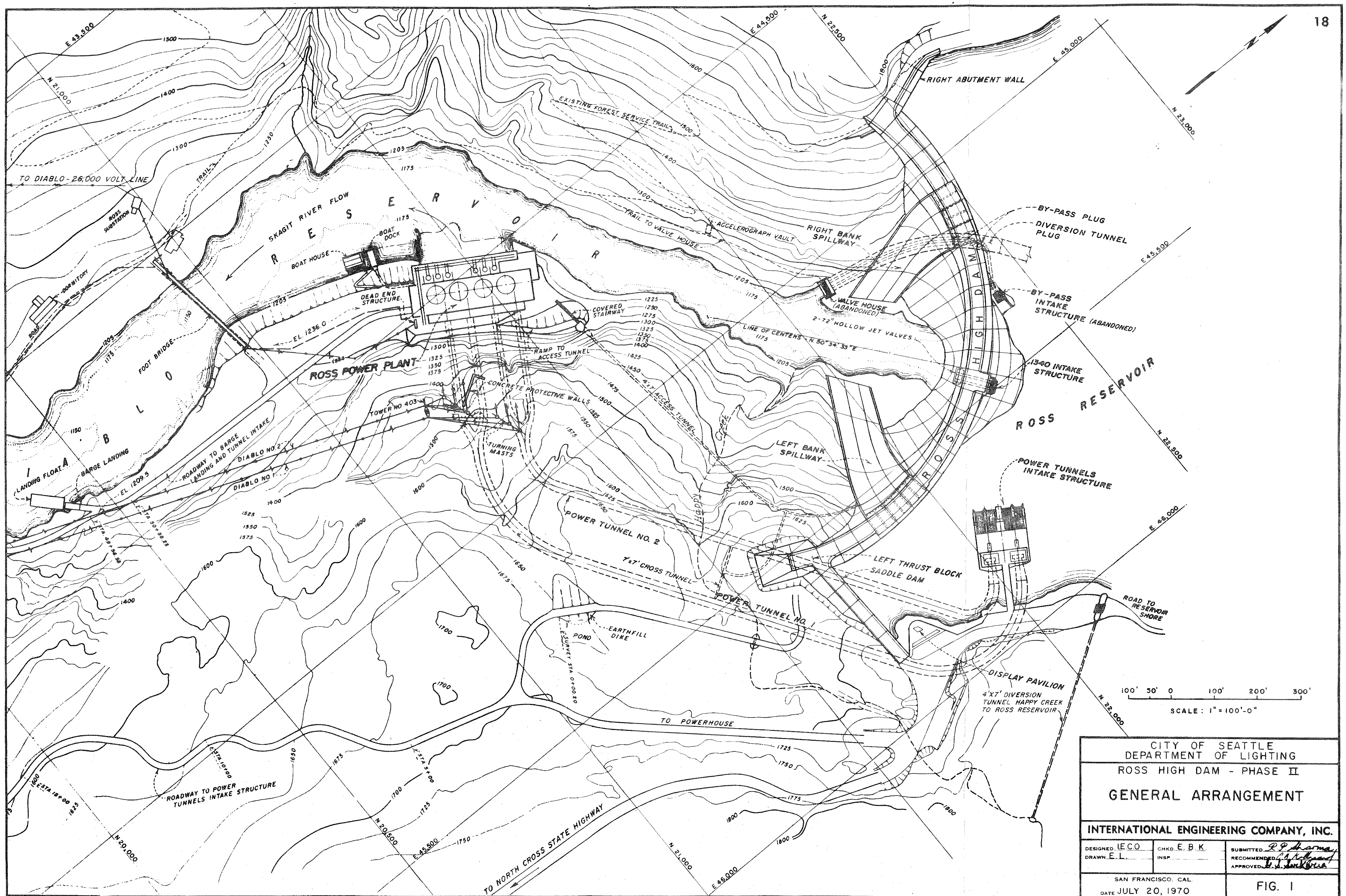
DRAWN: BL | CHKD: CM | APPROVED: [signature]

BERKELEY, CALIFORNIA
DATE: APRIL 1, 1972

FIG. 4

APPENDIX A

ILLUSTRATIONS

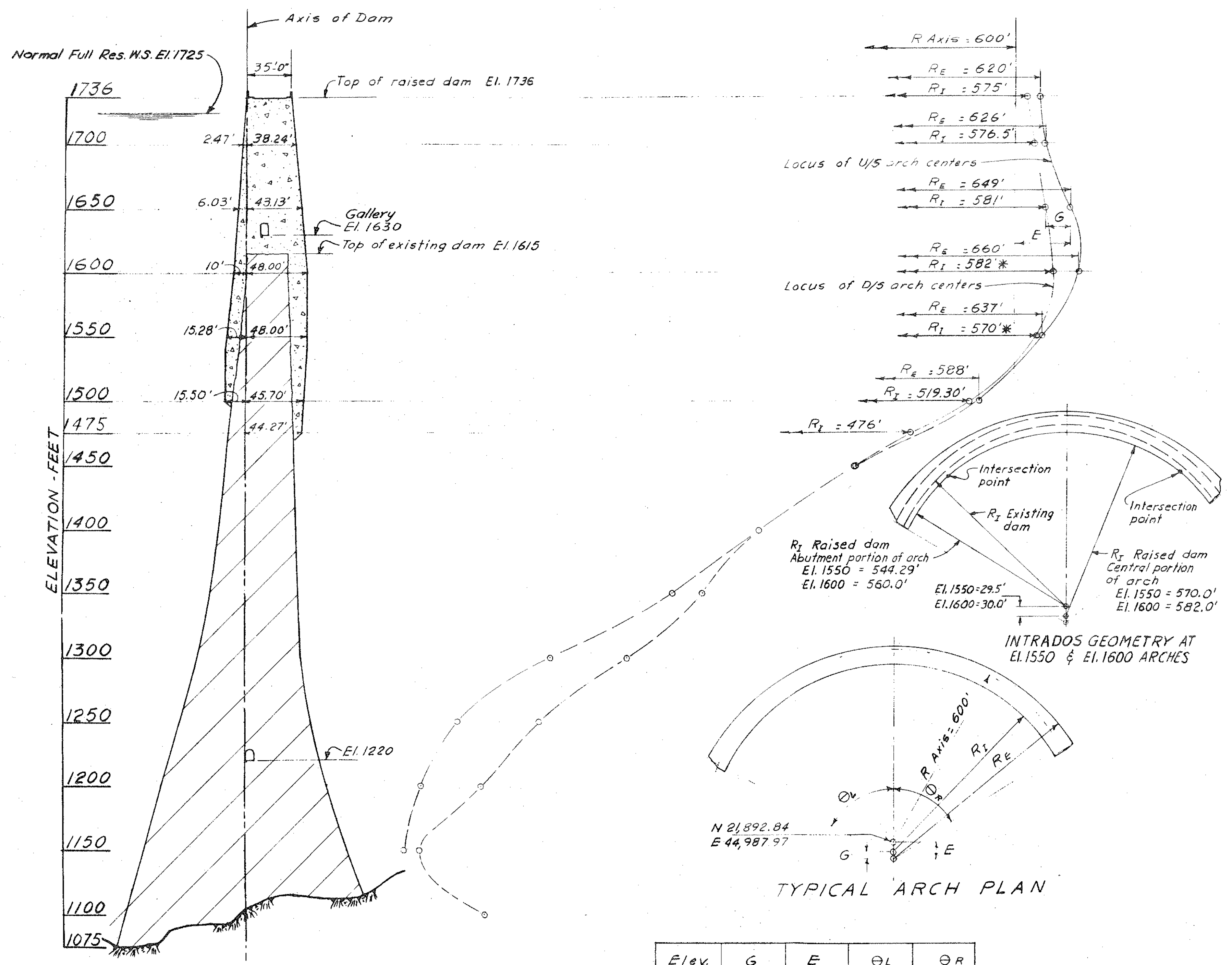


CITY OF SEATTLE
DEPARTMENT OF LIGHTING
ROSS HIGH DAM - PHASE II
GENERAL ARRANGEMENT
INTERNATIONAL ENGINEERING COMPANY, INC.

DESIGNED IECO — CHKD. E.B.K. — SUBMITTED R.P. Sharma
DRAWN E.L. — INSP. — RECOMMENDED — APPROVED

SAN FRANCISCO, CAL.
DATE JULY 20, 1970

FIG. 1



SECTION ALONG PLANE OF ARCH CENTERS

Scale: 1" = 50'

20 0 40 80 120 160 Feet

Elev.	G	E	Θ_L	Θ_R
1736	10.0'	-20.00'	65.8°	56.5°
1700	8.79'	-23.53'	65.5°	56.5°
1650	18.84'	-42.97'	63.8°	55.0°
1600	20.00'	-50.00'	59.8°	50.3°
1550	3.72'	-21.72'	56.5°	48.0°
1500	7.50	27.50'	55.2°	48.0°
1475	—**	—**	55.0°	49.0°

* Radii for central portion of arch only (See sketch)
** No new upstream concrete below El. 1500

LEGEND:

- Existing concrete
- New concrete

Scale as shown

CITY OF SEATTLE
DEPARTMENT OF LIGHTING

ROSS HIGH DAM - PHASE II

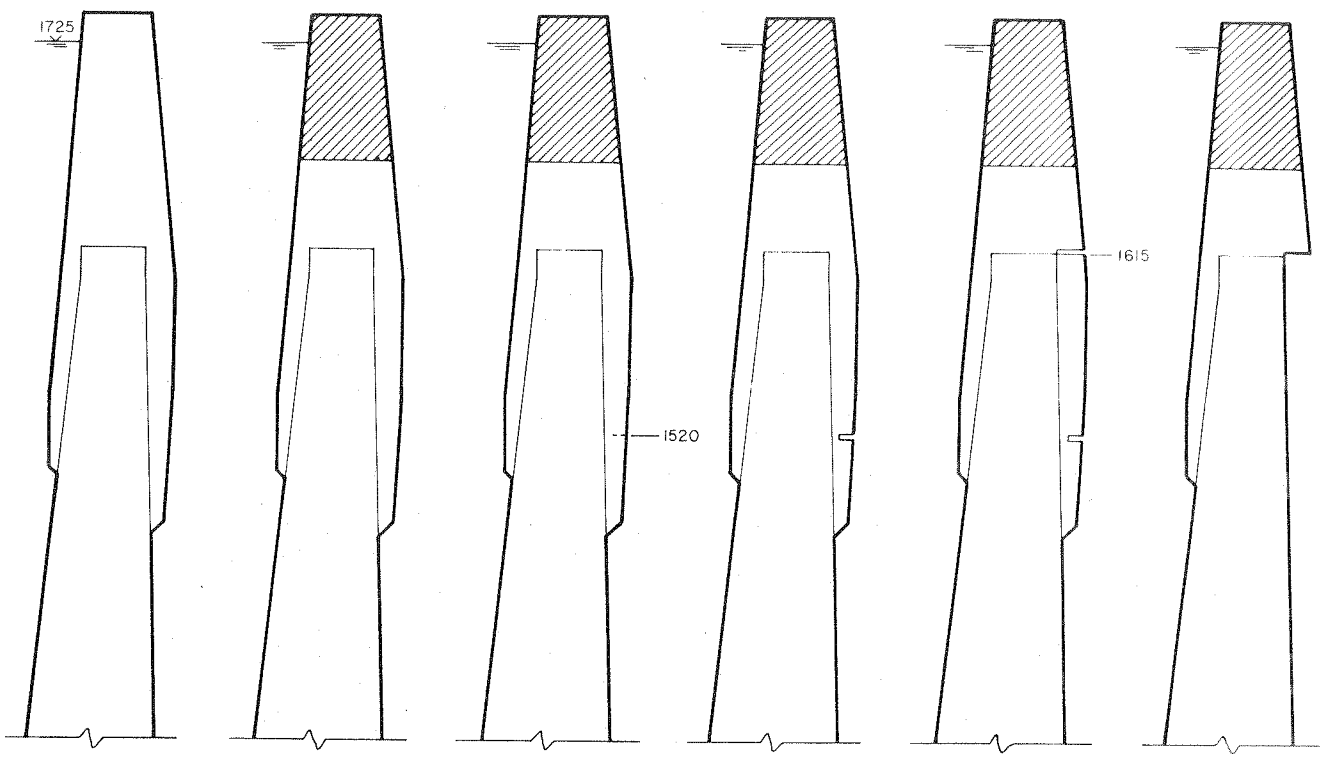
GEOMETRIC DATA AND SECTIONS

INTERNATIONAL ENGINEERING COMPANY, INC.

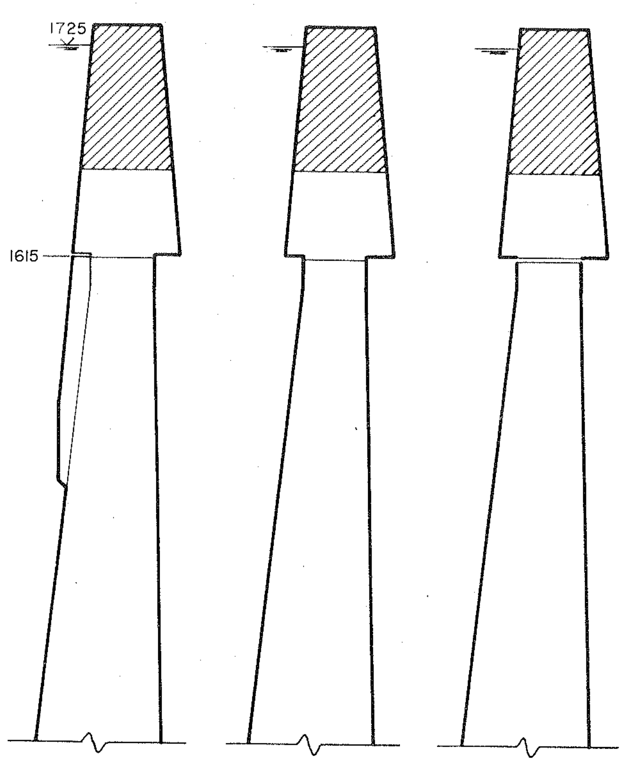
DESIGNED H.E.J. CHKD. R.P. Sharma SUBMITTED R.P. Sharma
DRAWN H.E.J./E.L. INSP. RECOMMENDED [illegible] APPROVED [illegible]

SAN FRANCISCO, CAL.
DATE JULY 20, 1970

FIG. 2



PHASE 1 PHASE 2 PHASE 3 PHASE 4 PHASE 5 PHASE 6



PHASE 7 PHASE 8 PHASE 9

NOTES:

PHASE 1 – NO SLOT.
PHASE 2 – VERTICAL SLOT AT STATION 3+00.
PHASE 3 – INTERMITTENT DOWNSTREAM HORIZONTAL SLIT, ELEV. 1520.
PHASE 4 – CONTINUOUS DOWNSTREAM HORIZONTAL SLIT, ELEV. 1520.
PHASE 5 – CONTINUOUS DOWNSTREAM HORIZONTAL SLIT, ELEV. 1615. PENETRATION TO EXISTING DAM DOWNSTREAM FACE.
PHASE 6 – DOWNSTREAM SECTION OF CAP BELOW ELEV. 1615 REMOVED.
PHASE 7 – CONTINUOUS UPSTREAM HORIZONTAL SLIT, ELEV. 1615. PENETRATION TO EXISTING DAM UPSTREAM FACE.
PHASE 8 – UPSTREAM SECTION OF CAP BELOW ELEV. 1615 REMOVED.
PHASE 9 – CONTINUOUS HORIZONTAL SLIT ENTIRELY THROUGH DAM.

CITY OF SEATTLE
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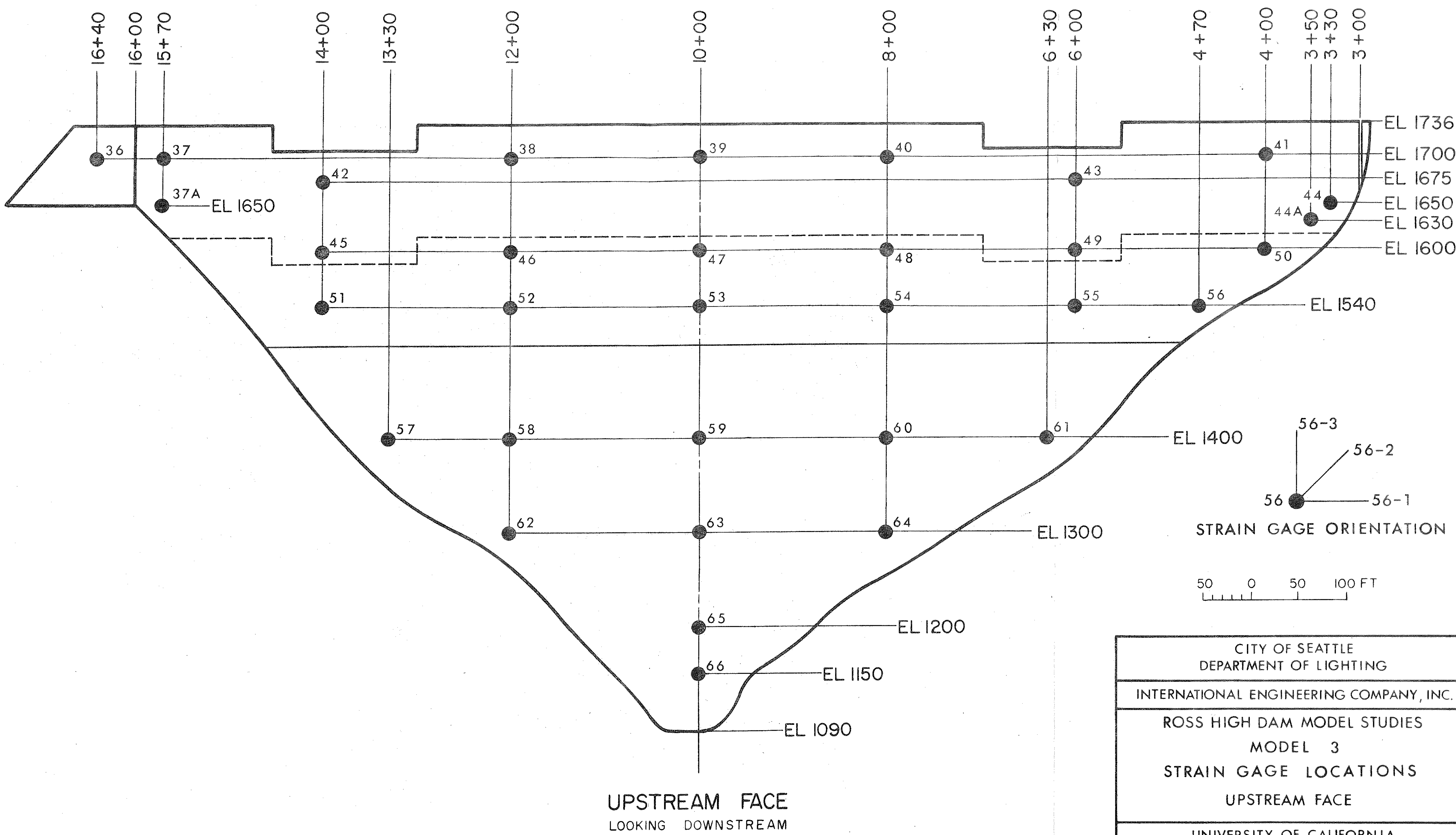
ROSS HIGH DAM MODEL STUDIES

MODEL 3

TEST PHASES

UNIVERSITY OF CALIFORNIA
JEROME M. RAPHAEL, FACULTY INVESTIGATOR

DRAWN: BL	CHKD: CM	APPROVED: [signature]
BERKELEY, CALIFORNIA DATE: APRIL 1, 1972		FIG. 3



CITY OF SEATTLE
DEPARTMENT OF LIGHTING

INTERNATIONAL ENGINEERING COMPANY, INC.

ROSS HIGH DAM MODEL STUDIES
MODEL 3
STRAIN GAGE LOCATIONS
UPSTREAM FACE

UNIVERSITY OF CALIFORNIA
JEROME M. RAPHAEL, FACULTY INVESTIGATOR

DRAWN: BL	CHKD: CM	APPROVED: J M Raphael
BERKELEY, CALIFORNIA DATE: APRIL 1, 1972		FIG. 5

HORIZONTAL, VERTICAL & SHEAR STRESSES
DOWNSTREAM FACE

GAGE #	ELEV.	STA.	WATER LOAD			WATER + EQKE LOADS			DEAD LOAD			WATER + DEAD LOAD			WATER+EQKE + DEAD LOAD		
			σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}
1	1700	4+00	-399	+21	+31	-477	+25	+37	0	-40	+2	-399	-19	+33	-477	-15	+39
2	1700	8+00	-185	+36	+9	-221	+44	+10	-9	-41	+1	-194	-5	+10	-230	+3	+11
3	1700	10+00	-249	+49	+1	-297	+58	+1	-3	-32	+1	-252	+17	+2	-300	+26	+2
4	1700	12+00	-160	+41	-2	-192	+49	-3	-4	-30	-1	-164	+11	-3	-196	+19	-4
5	1700	15+70	-427	-2	+45	-510	-3	+54	-1	-31	0	-428	-33	+45	-511	-34	+54
6	1700	16+40	-82	0	+41	-98	0	+49	-2	-43	+6	-84	-43	+47	-100	-43	+55
7	1675	6+00	-477	+3	+38	-570	+3	+45	-7	-36	0	-484	-33	+38	-577	-33	+45
8	1675	14+00	-436	+19	-7	-521	+23	-9	-3	-26	-1	-439	-7	-8	-524	-3	-10
9	1650	3+30	-359	+45	-50	-429	+54	-60	+4	-96	+6	-355	-51	-44	-425	-42	-54
10	1600	4+00	-353	+53	-25	-422	+63	-30	+58	-97	+42	-295	-44	+17	-364	-34	+12
11	1600	6+00	-446	+109	+11	-532	+130	+13	-21	-87	-7	-467	+22	+4	-553	+43	+6
12	1600	8+00	-282	+153	-8	-337	+183	-10	-22	-124	-8	-304	+29	-16	-359	+59	-18
13	1600	10+00	-201	+227	0	-240	+271	0	+24	-81	-1	-177	+146	-1	-216	+190	-1
14	1600	12+00	-333	+143	-27	-398	+171	-32	-5	-84	0	-338	+59	-27	-403	+87	-32
15	1600	14+00	-622	+49	-40	-743	+58	-47	+1	-107	+3	-621	-58	-37	-742	-49	-44
16	1540	4+70	-435	-11	-122	-519	-14	-145	+120	-82	+38	-315	-93	-84	-399	-96	-107
17	1540	6+00	-480	+128	-21	-574	+153	-26	-8	-251	+16	-488	-123	-5	-582	-98	-10
18	1540	8+00	-370	+222	-19	-442	+266	-23	-38	-258	-51	-408	-36	-70	-480	+8	-74
19	1540	10+00	-195	+275	-2	-233	+329	-3	+35	-152	-34	-160	+123	-36	-198	+177	-37
20	1540	12+00	-323	+234	-1	-386	+280	-2	-29	-166	+41	-352	+68	+40	-415	+114	+39
21	1540	14+00	-498	+32	+69	-595	+39	+83	+19	-244	+17	-479	-212	+86	-576	-205	+100
22	1500	6+00	-440	-13	-177	-526	-15	-212	+13	-170	-9	-427	-183	-186	-513	-185	-221
23	1500	8+00	-392	+257	-68	-468	+307	-81	-52	-200	-29	-444	+57	-97	-520	+107	-110
24	1500	10+00	-202	+336	+7	-242	+402	+8	+22	-169	-5	-180	+167	+2	-220	+233	+3
25	1500	12+00	-379	+241	+36	-452	+288	+43	-42	-229	+51	-421	+12	+87	-494	+59	+94
26	1500	14+00	-453	-60	+178	-541	-72	+212	+64	-181	+6	-389	-241	+184	-477	-253	+218
27	1400	6+30	-675	-292	-280	-807	-349	-335	+95	-112	-26	-580	-404	-306	-712	-461	-361
28	1400	8+00	-458	+17	-206	-548	+20	-246	-68	-266	-3	-526	-249	-209	-616	-246	-249
29	1400	10+00	-334	+306	+50	-399	+365	+60	-37	-278	+25	-371	+28	+75	-436	+87	+85
30	1400	12+00	-626	-67	+275	-748	-80	+329	-18	-208	+53	-644	-275	+328	-766	-288	+382
31	1400	13+80	-316	-104	+255	-439	-125	+305	-158	-109	+20	-474	-213	+275	-597	-234	+325
32	1300	8+00	-700	-534	-430	-837	-638	-514	-37	-342	+47	-737	-876	-383	-874	-980	-467
33	1300	10+00	-60	-83	+42	-72	-99	+50	-125	-308	+21	-185	-391	+63	-197	-407	+71
34	1300	12+00	-876	-274	+376	-1047	-327	+449	+75	-167	+41	-801	-441	+417	-972	-494	+490
35	1200	10+00	+321	-277	+23	+383	-331	+28	-174	-209	+49	+147	-486	+72	+209	-540	+77

NOTES

1. STATIONS ARE PROJECTED RADIALLY FROM DISTANCES MEASURED ON AXIS OF DAM
2. ALL STRESSES ARE SURFACE STRESS IN PSI
3. σ_X IS HORIZONTAL OR ARCH STRESS
4. σ_Y IS VERTICAL OR CANTILEVER STRESS
5. τ_{XY} IS SHEAR STRESS
6. SIGNS: + IS TENSION
   − IS COMPRESSION

CITY OF SEATTLE
DEPARTMENT OF LIGHTING

INTERNATIONAL ENGINEERING COMPANY, INC.

ROSS HIGH DAM MODEL STUDIES
MODEL 3 - PHASE 1

ORTHOGONAL STRESSES
DOWNSTREAM FACE

UNIVERSITY OF CALIFORNIA
JEROME M. RAPHAEL, FACULTY INVESTIGATOR

DRAWN: BL | CHKD: CM | APPROVED: [signature]

BERKELEY, CALIFORNIA
DATE: APRIL 1, 1972

FIG. 6

HORIZONTAL, VERTICAL & SHEAR STRESSES

UPSTREAM FACE

GAGE #	ELEV.	STA.	WATER LOAD			WATER + EQKE LOADS			DEAD LOAD			WATER + DEAD LOAD			WATER + EQKE + DEAD LOAD		
			σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}
41	1700	4+00	-202	-32	-4	-241	-39	-4	-7	-27	-1	-209	-59	-5	-248	-66	-5
40	1700	8+00	-366	-26	+33	-438	-31	+40	-3	-30	+2	-369	-56	+35	-441	-61	+42
39	1700	10+00	-469	-54	-23	-561	-64	-28	-4	-40	-1	-473	-94	-24	-565	-104	-29
38	1700	12+00	-344	-40	-78	-411	-48	-94	-2	-31	-2	-346	-71	-80	-413	-79	-96
37	1700	15+70	-100	+6	-29	-119	+7	-35	-6	-35	0	-106	-29	-29	-125	-28	-35
36	1700	16+40	-16	-21	-30	-19	-24	-36	0	-35	+7	-16	-56	-23	-19	-59	-29
43	1675	6+00	-373	-47	-10	-445	-56	-12	-1	-13	+1	-374	-60	-9	-446	-69	-11
42	1675	14+00	-397	-65	-15	-474	-77	-17	-2	-17	-1	-399	-82	-16	-476	-94	-18
44	1650	3+30	-255	-69	+25	-304	-82	+30	-5	-56	0	-260	-125	+25	-309	-138	+30
50	1600	4+00	-131	-54	-13	-156	-64	-16	-9	-74	+6	-140	-128	-7	-165	-138	-10
49	1600	6+00	-379	-181	+35	-453	-216	+42	+15	-61	+5	-364	-242	+40	-438	-277	+47
48	1600	8+00	-544	-176	+38	-650	-210	+45	+9	-120	-8	-535	-296	+30	-641	-330	+37
47	1600	10+00	-741	-169	-7	-886	-202	-9	-9	-145	+7	-750	-314	0	-895	-347	-2
46	1600	12+00	-534	-168	-54	-638	-201	-64	+19	-117	+2	-515	-285	-52	-619	-318	-62
45	1600	14+00	-289	-108	-3	-345	-129	-3	+12	-63	+4	-277	-171	+1	-333	-192	+1
56	1540	4+70	-131	-88	+2	-156	-106	+3	-60	-125	+69	-191	-213	+71	-216	-231	+72
55	1540	6+00	-284	-198	+17	-339	-237	+20	+73	-99	+23	-211	-297	+40	-266	-336	+43
54	1540	8+00	-541	-259	+79	-725	-309	+94	+33	-134	-33	-574	-393	+46	-692	-443	+61
53	1540	10+00	-734	-219	-15	-877	-262	-18	-24	-133	+1	-758	-352	-14	-901	-395	-17
52	1540	12+00	-535	-237	-71	-639	-283	-85	+40	-127	+18	-495	-364	-53	-599	-410	-67
51	1540	14+00	-210	-104	+8	-251	-124	+9	+47	-131	-13	-163	-235	-5	-204	-255	-4
61	1400	6+30	-111	+171	-122	-133	+204	-146	-49	-493	+120	-160	-322	-2	-182	-289	-26
60	1400	8+00	-561	-26	-76	-671	-31	-91	+5	-408	-57	-556	-434	-133	-666	-439	-148
59	1400	10+00	-924	-86	+18	-1104	-103	+21	-39	-278	-15	-963	-364	+3	-1143	-381	+6
58	1400	12+00	-518	0	+11	-619	0	+13	+22	-306	-27	-496	-306	-16	-597	-306	-14
57	1400	13+30	-184	+143	+185	-220	+171	+221	+26	-322	-102	-158	-179	+83	-194	-151	+119
64	1300	8+00	-219	+72	+2	-262	+86	+2	-49	-421	-57	-268	-349	-55	-311	-335	-55
63	1300	10+00	-719	+408	+14	-860	+488	+16	-48	-376	-9	-767	+32	+5	-908	+112	+7
62	1300	12+00	-186	+230	+85	-222	+275	+101	-137	-447	-154	-323	-217	-69	-359	-172	-53
65	1200	10+00	-457	+426	-2	-546	+509	-2	-100	-404	+7	-557	+22	+5	-646	+105	+5
66	1150	10+00	-360	+315	-19	-431	+377	-23	-123	-238	+27	-483	+77	+8	-554	+139	+4

NOTES

1. STATIONS ARE PROJECTED RADIALLY FROM DISTANCES MEASURED ON AXIS OF DAM
2. ALL STRESSES ARE SURFACE STRESS IN PSI
3. σ_X IS HORIZONTAL OR ARCH STRESS
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CITY OF SEATTLE
DEPARTMENT OF LIGHTING

INTERNATIONAL ENGINEERING COMPANY, INC.

ROSS HIGH DAM MODEL STUDIES
MODEL 3 - PHASE 1

ORTHOGONAL STRESSES
UPSTREAM FACE

UNIVERSITY OF CALIFORNIA
JEROME M. RAPHAEL, FACULTY INVESTIGATOR

DRAWN: BL | CHKD: CM | APPROVED: J M Raphael

BERKELEY, CALIFORNIA
DATE: APRIL 1, 1972

FIG. 7

HORIZONTAL, VERTICAL & SHEAR STRESSES
DOWNSTREAM FACE

GAGE #	ELEV.	STA.	WATER LOAD			WATER + EQKE LOADS			DEAD LOAD			WATER + DEAD LOAD			WATER+EQKE +DEAD LOAD		
			σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}
1	1700	4+00	-229	+21	-34	-274	+25	-40	0	-40	+2	-229	-19	-32	-274	-15	-38
2	1700	8+00	-189	+33	+7	-225	+39	+8	-9	-41	+1	-198	-8	+8	-234	-2	+9
3	1700	10+00	-234	+43	+2	-280	+52	+2	-3	-32	+1	-237	+11	+3	-283	+20	+3
4	1700	12+00	-161	+35	+15	-192	+42	+18	-4	-30	-1	-165	+5	+14	-196	+12	+17
5	1700	15+70	-401	-3	+34	-479	-3	+40	-1	-31	0	-402	-34	+34	-480	-34	+40
6	1700	16+40	-77	+3	+35	-92	+4	+42	-2	-43	+6	-79	-40	+41	-94	-39	+48
7	1675	6+00	-449	+1	+36	-536	+1	+44	-7	-36	0	-456	-35	+36	-543	-35	+44
8	1675	14+00	-443	+42	-18	-529	+2	-21	-3	-26	-1	-446	+16	-19	-532	+24	-22
9	1650	3+30	-522	-7	-163	-624	-9	-194	+4	-96	+6	-518	-103	-157	-620	-105	-188
10	1600	4+00	-380	+29	-54	-455	+35	-65	+58	-97	+42	-322	-68	-12	-397	-62	-23
11	1600	6+00	-430	+106	+2	-514	+127	+3	-21	-87	-7	-451	+19	-5	-535	+40	-4
12	1600	8+00	-273	+149	-9	-326	+178	-11	-22	-124	-8	-295	+25	-17	-348	+54	-19
13	1600	10+00	-192	+214	+9	-230	+256	+11	+24	-81	-1	-168	+133	+8	-206	+175	+10
14	1600	12+00	-331	+139	-12	-395	+166	-14	-5	-84	0	-336	+55	-12	-400	+82	-14
15	1600	14+00	-628	+58	-42	-750	+69	-50	+1	-107	+3	-627	-49	-39	-749	-38	-47
16	1540	4+70	-449	-39	-141	-537	-47	-169	+120	-82	+38	-329	-121	-103	-417	-129	-131
17	1540	6+00	-514	+113	-15	-615	+134	-18	-8	-251	+16	-522	-138	+1	-623	-117	-2
18	1540	8+00	-356	+215	-19	-425	+258	-23	-38	-258	-51	-394	-43	-70	-463	0	-74
19	1540	10+00	-179	+267	+2	-214	+320	+3	+35	-152	-34	-144	+115	-32	-179	+168	-31
20	1540	12+00	-319	+228	+9	-381	+273	+11	-29	-166	+41	-348	+62	+50	-410	+107	+52
21	1540	14+00	-496	+43	+64	-593	+52	+77	+19	-244	+17	-477	-201	+81	-574	-192	+94
22	1500	6+00	-441	-31	-186	-528	-37	-223	+13	-170	-9	-428	-201	-195	-515	-207	-232
23	1500	8+00	-378	+246	-67	-451	+294	-80	-52	-200	-29	-430	+46	-96	-503	+94	-109
24	1500	10+00	-187	+327	+10	-224	+390	+13	+22	-169	-5	-165	+158	+5	-202	+221	+8
25	1500	12+00	-377	+235	+44	-451	+281	+52	-42	-229	+51	-419	+6	+95	-493	+52	+103
26	1500	14+00	-448	-47	+171	-535	-56	+205	+64	-181	+6	-384	-228	+177	-471	-237	+211
27	1400	6+30	-681	-290	-279	-813	-347	-333	+95	-112	-26	-586	-402	-305	-718	-459	-359
28	1400	8+00	-450	+17	-208	-538	+20	-249	-68	-266	-3	-518	-249	-211	-606	-246	-252
29	1400	10+00	-315	+303	+46	-376	+362	+56	-37	-278	+25	-352	+25	+71	-413	+84	+81
30	1400	12+00	-620	-62	+274	-741	-74	+327	-18	-208	+53	-638	-270	+327	-759	-282	+380
31	1400	13+80	-314	-99	+251	-437	-118	+300	-158	-109	+20	-472	-208	+271	-595	-227	+320
32	1300	8+00	-697	-523	-432	-833	-625	-517	-37	-342	+47	-734	-865	-385	-870	-967	-470
33	1300	10+00	-48	-76	+37	-57	-91	+44	-125	-308	+21	-173	-384	+58	-182	-399	+65
34	1300	12+00	-865	-263	+370	-1034	-314	+442	+75	-167	+41	-790	-430	+411	-959	-481	+483
35	1200	10+00	+339	-279	+23	+406	-333	+27	-174	-209	+49	+165	-488	+72	+232	-542	+76

NOTES

1. STATIONS ARE PROJECTED RADIALLY FROM DISTANCES MEASURED ON AXIS OF DAM
2. ALL STRESSES ARE SURFACE STRESS IN PSI
3. σ_X IS HORIZONTAL OR ARCH STRESS
4. σ_Y IS VERTICAL OR CANTILEVER STRESS
5. τ_{XY} IS SHEAR STRESS
6. SIGNS: + IS TENSION
   − IS COMPRESSION

CITY OF SEATTLE
DEPARTMENT OF LIGHTING

INTERNATIONAL ENGINEERING COMPANY, INC.

ROSS HIGH DAM MODEL STUDIES
MODEL 3 – PHASE 2

ORTHOGONAL STRESSES
DOWNSTREAM FACE

UNIVERSITY OF CALIFORNIA
JEROME M. RAPHAEL, FACULTY INVESTIGATOR

DRAWN: BL | CHKD: CM | APPROVED: J M Raphael

BERKELEY, CALIFORNIA
DATE: APRIL 1, 1972

FIG. 8

HORIZONTAL, VERTICAL & SHEAR STRESSES
UPSTREAM FACE

GAGE #	ELEV.	STA.	WATER LOAD σ_X	WATER LOAD σ_Y	WATER LOAD τ_{XY}	WATER + EQKE LOADS σ_X	WATER + EQKE LOADS σ_Y	WATER + EQKE LOADS τ_{XY}	DEAD LOAD σ_X	DEAD LOAD σ_Y	DEAD LOAD τ_{XY}	WATER + DEAD LOAD σ_X	WATER + DEAD LOAD σ_Y	WATER + DEAD LOAD τ_{XY}	WATER+EQKE+DEAD LOAD σ_X	WATER+EQKE+DEAD LOAD σ_Y	WATER+EQKE+DEAD LOAD τ_{XY}
41	1700	4+00	-131	+2	+54	-157	+2	+65	-7	-27	-1	-138	-25	+53	-164	-25	+64
40	1700	8+00	-357	-22	+32	-427	-26	+38	-3	-30	+2	-360	-52	+34	-430	-56	+40
39	1700	10+00	-464	-50	-25	-555	-60	-30	-4	-40	-1	-468	-90	-26	-559	-100	-31
38	1700	12+00	-328	-37	-63	-392	-45	-76	-2	-31	-2	-330	-68	-65	-394	-76	-78
37	1700	15+70	-108	+3	-38	-128	+4	-45	-6	-35	0	-114	-32	-38	-134	-31	-45
36	1700	16+40	-24	-19	-33	-29	-22	-39	0	-35	+7	-24	-54	-26	-29	-57	-32
43	1675	6+00	-350	-36	+12	-418	-43	+14	-1	-13	+1	-351	-49	+13	-419	-56	+15
42	1675	14+00	-365	-85	-25	-436	-102	-30	-2	-17	-1	-367	-102	-26	-438	-119	-31
44	1650	3+30	-366	-45	+76	-437	-54	+91	-5	-56	0	-371	-101	+76	-442	-110	+91
50	1600	4+00	-165	-9	-14	-197	-10	-17	-9	-74	+6	-174	-83	-8	-206	-84	-11
49	1600	6+00	-373	-160	+62	-445	-192	+74	+15	-61	+5	-358	-221	+67	-430	-253	+79
48	1600	8+00	-533	-171	+42	-637	-205	+50	+9	-120	-8	-524	-291	+34	-628	-325	+42
47	1600	10+00	-733	-164	-5	-876	-196	-6	-9	-145	+7	-742	-309	+2	-885	-341	+1
46	1600	12+00	-518	-174	-43	-619	-208	-52	+19	-117	+2	-499	-291	-41	-600	-325	-50
45	1600	14+00	-274	-132	-9	-328	-158	-11	+12	-63	+4	-262	-195	-5	-316	-221	-7
56	1540	4+70	-165	-51	+13	-198	-61	+16	-60	-125	+69	-225	-176	+82	-258	-186	+85
55	1540	6+00	-280	-159	+31	-335	-190	+37	+73	-99	+23	-207	-258	+54	-262	-289	+60
54	1540	8+00	-593	-253	+86	-709	-302	+103	+33	-134	-33	-560	-387	+53	-676	-436	+70
53	1540	10+00	-728	-218	-10	-870	-260	-12	-24	-133	+1	-752	-351	-9	-894	-393	-11
52	1540	12+00	-523	-243	-62	-624	-290	-75	+40	-127	+18	-483	-370	-44	-584	-417	-57
51	1540	14+00	-201	-118	+3	-240	-140	+4	+47	-131	-13	-154	-249	-10	-193	-271	-9
61	1400	6+30	-111	+191	-116	-133	+228	-139	-49	-493	+120	-160	-302	+4	-182	-265	-19
60	1400	8+00	-546	-11	-67	-652	-14	-80	+5	-408	-57	-541	-419	-124	-647	-422	-137
59	1400	10+00	-918	-84	+22	-1097	-100	+26	-39	-278	-15	-957	-362	+7	-1136	-378	+11
58	1400	12+00	-513	-16	+13	-613	-19	+16	+22	-306	-27	-491	-322	-14	-591	-325	-11
57	1400	13+30	-178	+131	+199	-213	+157	+238	+26	-322	-102	-152	-191	+97	-187	-165	+136
64	1300	8+00	-206	+77	-9	-246	+92	-10	-49	-421	-57	-255	-344	-66	-295	-329	-67
63	1300	10+00	-720	+407	+19	-860	+487	+23	-48	-376	-9	-768	+31	+10	-908	+111	+14
62	1300	12+00	-200	+215	+80	-238	+257	+96	-137	-447	-154	-337	-232	-74	-375	-190	-58
65	1200	10+00	-453	+430	-1	-541	+514	-1	-100	-404	+7	-553	+26	+6	-641	+110	+6
66	1150	10+00	-355	+324	-14	-424	+387	-17	-123	-238	+27	-478	+86	+13	-547	+149	+10

NOTES

1. STATIONS ARE PROJECTED RADIALLY FROM DISTANCES MEASURED ON AXIS OF DAM
2. ALL STRESSES ARE SURFACE STRESS IN PSI
3. σ_X IS HORIZONTAL OR ARCH STRESS
4. σ_Y IS VERTICAL OR CANTILEVER STRESS
5. τ_{XY} IS SHEAR STRESS
6. SIGNS: + IS TENSION
   − IS COMPRESSION

CITY OF SEATTLE
DEPARTMENT OF LIGHTING

INTERNATIONAL ENGINEERING COMPANY, INC.

ROSS HIGH DAM MODEL STUDIES
MODEL 3 - PHASE 2

ORTHOGONAL STRESSES
UPSTREAM FACE

UNIVERSITY OF CALIFORNIA
JEROME M. RAPHAEL, FACULTY INVESTIGATOR

DRAWN: BL | CHKD: CM | APPROVED: [signature]

BERKELEY, CALIFORNIA
DATE: APRIL 1, 1972

FIG. 9

HORIZONTAL, VERTICAL & SHEAR STRESSES

DOWNSTREAM FACE

GAGE #	ELEV.	STA.	WATER LOAD			WATER + EQKE LOADS			DEAD LOAD			WATER + DEAD LOAD			WATER+EQKE + DEAD LOAD		
			σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}
1	1700	4+00	-236	+21	-36	-282	+25	-44	0	-40	+2	-236	-19	-34	-282	-15	-42
2	1700	8+00	-210	+32	-1	-251	+38	-1	-9	-41	+1	-219	-9	0	-260	-3	0
3	1700	10+00	-263	+41	-2	-314	+49	-3	-3	-32	+1	-266	+9	-1	-317	+17	-2
4	1700	12+00	-183	+33	+19	-219	+40	+23	-4	-30	-1	-187	+3	+18	-223	+10	+22
5	1700	15+70	-419	-3	+41	-501	-3	+49	-1	-31	0	-420	-34	+41	-502	-34	+49
6	1700	16+40	-83	-1	+41	-99	-1	+49	-2	-43	+6	-85	-44	+47	-101	-44	+55
7	1675	6+00	-472	-1	+39	-563	-1	+47	-7	-36	0	-479	-37	+39	-570	-37	+47
8	1675	14+00	-458	+32	-17	-547	+38	-20	-3	-26	-1	-461	+6	-18	-550	+12	-21
9	1650	3+30	-540	-11	-172	-645	-13	-206	+4	-96	+6	-536	-107	-166	-641	-109	-200
10	1600	4+00	-392	+30	-55	-469	+36	-65	+58	-97	+42	-334	-67	-13	-411	-61	-23
11	1600	6+00	-447	+107	+3	-535	+127	+4	-21	-87	-7	-468	+20	-4	-556	+40	-3
12	1600	8+00	-292	+142	-10	-349	+170	-12	-22	-124	-8	-314	+18	-18	-371	+46	-20
13	1600	10+00	-199	+206	+4	-238	+246	+5	+24	-81	-1	-175	+125	+3	-214	+165	+4
14	1600	12+00	-353	+132	-12	-422	+157	-14	-5	-84	0	-358	+48	-12	-427	+73	-14
15	1600	14+00	-653	+50	-41	-780	+60	-49	+1	-107	+3	-652	-57	-38	-779	-47	-46
16	1540	4+70	-462	-44	-145	-552	-52	-173	+120	-82	+38	-342	-126	-107	-432	-134	-135
17	1540	6+00	-490	+121	-30	-586	+144	-36	-8	-251	+16	-498	-130	-14	-594	-107	-20
18	1540	8+00	-383	+164	-12	-458	+196	-14	-38	-258	-51	-421	-94	-63	-496	-62	-65
19	1540	10+00	-205	+194	+5	-245	+232	+5	+35	-152	-34	-170	+42	-29	-210	+80	-29
20	1540	12+00	-348	+162	-2	-416	+193	-2	-29	-166	+41	-377	-4	+39	-445	+27	+39
21	1540	14+00	-515	+39	+67	-616	+47	+80	+19	-244	+17	-496	-205	+84	-597	-197	+97
22	1500	6+00	-457	-33	-191	-547	-40	-228	+13	-170	-9	-444	-203	-200	-534	-210	-237
23	1500	8+00	-407	+190	-81	-486	+227	-97	-52	-200	-29	-459	-10	-110	-538	+27	-126
24	1500	10+00	-222	+237	+7	-266	+284	+8	+22	-169	-5	-200	+68	+2	-244	+115	+3
25	1500	12+00	-405	+173	+58	-484	+207	+69	-42	-229	+51	-447	-56	+109	-526	-22	+120
26	1500	14+00	-460	-49	+175	-550	-59	+210	+64	-181	+6	-396	-230	+181	-486	-240	+216
27	1400	6+30	-700	-301	-284	-836	-360	-339	+95	-112	-26	-605	-413	-310	-741	-472	-365
28	1400	8+00	-460	+16	-212	-549	+20	-253	-68	-266	-3	-528	-250	-215	-617	-246	-256
29	1400	10+00	-333	+305	+48	-398	+364	+58	-37	-278	+25	-370	+27	+73	-435	+86	+83
30	1400	12+00	-638	-63	+281	-762	-75	+336	-18	-208	+53	-656	-271	+334	-780	-283	+389
31	1400	13+80	-331	-107	+262	-457	-127	+313	-158	-109	+20	-489	-216	+282	-615	-236	+333
32	1300	8+00	-712	-534	-445	-851	-638	-532	-37	-342	+47	-749	-876	-398	-888	-980	-485
33	1300	10+00	-58	-77	+38	-70	-92	+45	-125	-308	+21	-183	-385	+59	-195	-400	+66
34	1300	12+00	-889	-261	+375	-1062	-312	+448	+75	-167	+41	-814	-428	+416	-987	-479	+489
35	1200	10+00	+346	-286	+25	+413	-341	+30	-174	-209	+49	+172	-495	+74	+239	-550	+79

NOTES

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CITY OF SEATTLE
DEPARTMENT OF LIGHTING

INTERNATIONAL ENGINEERING COMPANY, INC.

ROSS HIGH DAM MODEL STUDIES
MODEL 3 - PHASE 4

ORTHOGONAL STRESSES
DOWNSTREAM FACE

UNIVERSITY OF CALIFORNIA
JEROME M. RAPHAEL, FACULTY INVESTIGATOR

DRAWN: BL | CHKD: CM | APPROVED: JM Raphael

BERKELEY, CALIFORNIA
DATE: APRIL 1, 1972

FIG. 10

HORIZONTAL, VERTICAL & SHEAR STRESSES
UPSTREAM FACE

GAGE #	ELEV.	STA.	WATER LOAD σ_X	WATER LOAD σ_Y	WATER LOAD τ_{XY}	WATER + EQKE LOADS σ_X	WATER + EQKE LOADS σ_Y	WATER + EQKE LOADS τ_{XY}	DEAD LOAD σ_X	DEAD LOAD σ_Y	DEAD LOAD τ_{XY}	WATER + DEAD LOAD σ_X	WATER + DEAD LOAD σ_Y	WATER + DEAD LOAD τ_{XY}	WATER + EQKE + DEAD LOAD σ_X	WATER + EQKE + DEAD LOAD σ_Y	WATER + EQKE + DEAD LOAD τ_{XY}
41	1700	4+00	-139	0	+56	-166	0	+67	-7	-27	-1	-146	-27	+55	-173	-27	+66
40	1700	8+00	-378	-12	+28	-452	-15	+33	-3	-30	+2	-381	-42	+30	-455	-45	+35
39	1700	10+00	-495	-48	-28	-592	-57	-34	-4	-40	-1	-499	-88	-29	-596	-97	-35
38	1700	12+00	-349	-35	-66	-417	-42	-79	-2	-31	-2	-351	-66	-68	-419	-73	-81
37	1700	15+70	-108	+1	-32	-128	+1	-38	-6	-35	0	-114	-34	-32	-134	-34	-38
36	1700	16+40	-18	-20	-31	-21	-24	-37	0	-35	+7	-18	-55	-24	-21	-59	-30
43	1675	6+00	-370	-36	+11	-442	-44	+13	-1	-13	+1	-371	-49	+12	-443	-57	+14
42	1675	14+00	-394	-73	-21	-470	-87	-25	-2	-17	-1	-396	-90	-22	-472	-104	-26
44	1650	3+30	-374	-49	+77	-447	-59	+92	-5	-56	0	-379	-105	+77	-452	-115	+92
50	1600	4+00	-171	-9	-17	-204	-11	-20	-9	-74	+6	-180	-83	-11	-213	-85	-14
49	1600	6+00	-388	-164	+64	-464	-195	+76	+15	-61	+5	-373	-225	+69	-449	-256	+81
48	1600	8+00	-553	-161	+40	-661	-194	+48	+9	-120	-8	-544	-282	+32	-652	-314	+40
47	1600	10+00	-760	-149	-7	-908	-178	-9	-9	-145	+7	-769	-294	0	-917	-323	-2
46	1600	12+00	-536	-160	-45	-640	-191	-53	+19	-117	+2	-517	-277	-43	-621	-308	-51
45	1600	14+00	-289	-120	-8	-345	-143	-10	+12	-63	+4	-277	-183	-4	-333	-206	-6
56	1540	4+70	-165	-51	+9	-197	-61	+11	-60	-125	+69	-225	-176	+78	-257	-186	+80
55	1540	6+00	-291	-160	+32	-348	-192	+39	+73	-99	+23	-218	-259	+55	-275	-291	+62
54	1540	8+00	-617	-254	+87	-737	-303	+104	+33	-134	-33	-584	-388	+54	-704	-437	+71
53	1540	10+00	-754	-221	-12	-901	-264	-15	-24	-133	+1	-778	-354	-11	-925	-397	-14
52	1540	12+00	-542	-243	-65	-648	-290	-77	+40	-127	+18	-502	-370	-47	-608	-417	-59
51	1540	14+00	-211	-111	+5	-252	-133	+6	+47	-131	-13	-164	-242	-8	-205	-264	-7
61	1400	6+30	-119	+195	-123	-142	+233	-147	-49	-493	+120	-168	-298	-3	-191	-260	-27
60	1400	8+00	-567	-9	-71	-677	-10	-85	+5	-408	-57	-562	-417	-128	-672	-418	-142
59	1400	10+00	-937	-71	+24	-1119	-84	+29	-39	-278	-15	-976	-349	+9	-1158	-362	+14
58	1400	12+00	-535	-11	+13	-639	-13	+16	+22	-306	-27	-513	-317	-14	-617	-319	-11
57	1400	13+30	-187	+138	+187	-224	+165	+224	+26	-322	-102	-161	-184	+85	-198	-157	+122
64	1300	8+00	-215	+65	-7	-256	+78	-9	-49	-421	-57	-264	-356	-64	-305	-343	-66
63	1300	10+00	-738	+418	+19	-881	+500	+23	-48	-376	-9	-786	+42	+10	-929	+124	+14
62	1300	12+00	-213	+215	+76	-254	+257	+90	-137	-447	-154	-350	-232	-78	-391	-190	-64
65	1200	10+00	-458	+448	0	-547	+535	+1	-100	-404	+7	-558	+44	+7	-647	+131	+8
66	1150	10+00	-353	+335	-15	-422	+400	-18	-123	-238	+27	-476	+97	+12	-545	+162	+9

NOTES

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CITY OF SEATTLE
DEPARTMENT OF LIGHTING

INTERNATIONAL ENGINEERING COMPANY, INC.

ROSS HIGH DAM MODEL STUDIES
MODEL 3 - PHASE 4

ORTHOGONAL STRESSES
UPSTREAM FACE

UNIVERSITY OF CALIFORNIA
JEROME M. RAPHAEL, FACULTY INVESTIGATOR

DRAWN: BL | CHKD: CM | APPROVED: [signature]

BERKELEY, CALIFORNIA
DATE: APRIL 1, 1972

FIG. 11

HORIZONTAL, VERTICAL & SHEAR STRESSES
DOWNSTREAM FACE

GAGE #	ELEV.	STA.	WATER LOAD			WATER + EQKE LOADS			DEAD LOAD			WATER + DEAD LOAD			WATER+EQKE + DEAD LOAD		
			σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}
1	1700	4+00	-232	+21	-34	-278	+25	-41	0	-40	+2	-232	-19	-32	-278	-15	-39
2	1700	8+00	-193	+29	+3	-231	+34	+4	-9	-41	+1	-202	-12	+4	-240	-7	+5
3	1700	10+00	-233	+35	+1	-279	+42	+1	-3	-32	+1	-236	+3	+2	-282	+10	+2
4	1700	12+00	-165	+31	+19	-197	+37	+23	-4	-30	-1	-169	+1	+18	-201	+7	+22
5	1700	15+70	-396	0	+34	-473	0	+40	-1	-31	0	-397	-31	+34	-474	-31	+40
6	1700	16+40	-78	+2	+37	-93	+2	+44	-2	-43	+6	-80	-41	+43	-95	-41	+50
7	1675	6+00	-462	-2	+43	-552	-3	+52	-7	-36	0	-469	-38	+43	-559	-39	+52
8	1675	14+00	-446	+52	-36	-533	+63	-43	-3	-26	-1	-449	+26	-37	-536	+37	-44
9	1650	3+30	-530	-3	-164	-634	-3	-197	+4	-96	+6	-526	-99	-158	-630	-99	-191
10	1600	4+00	-407	+6	-61	-487	+8	-73	+58	-97	+42	-349	-91	-19	-429	-89	-31
11	1600	6+00	-471	+64	+1	-563	+76	+1	-21	-87	-7	-492	-23	-6	-584	-11	-6
12	1600	8+00	-326	+57	-16	-389	+68	-19	-22	-124	-8	-348	-67	-24	-411	-56	-27
13	1600	10+00	-209	+73	+2	-249	+87	+2	+24	-81	-1	-185	-8	+1	-225	+6	+1
14	1600	12+00	-374	+61	+6	-447	+74	+7	-5	-84	0	-379	-23	+6	-452	-10	+7
15	1600	14+00	-659	+33	-21	-787	+40	-25	+1	-107	+3	-658	-74	-18	-786	-67	-22
16	1540	4+70	-455	-41	-142	-544	-49	-169	+120	-82	+38	-335	-123	-104	-424	-131	-131
17	1540	6+00	-487	+117	-34	-582	+140	-41	-8	-251	+16	-495	-134	-18	-590	-111	-25
18	1540	8+00	-377	+155	-16	-450	+185	-19	-38	-258	-51	-415	-103	-67	-488	-73	-70
19	1540	10+00	-195	+183	+5	-233	+219	+6	+35	-152	-34	-160	+31	-29	-198	+67	-28
20	1540	12+00	-343	+156	+4	-410	+187	+5	-29	-166	+41	-372	-10	+45	-439	+21	+46
21	1540	14+00	-507	+44	+63	-606	+53	+75	+19	-244	+17	-488	-200	+80	-587	-191	+92
22	1500	6+00	-452	-36	-192	-541	-43	-229	+13	-170	-9	-439	-206	-201	-528	-213	-238
23	1500	8+00	-402	+181	-82	-481	+216	-98	-52	-200	-29	-454	-19	-111	-533	+16	-127
24	1500	10+00	-213	+227	+9	-254	+272	+10	+22	-169	-5	-191	+58	+4	-232	+103	+5
25	1500	12+00	-398	+168	+62	-476	+201	+74	-42	-229	+51	-440	-61	+113	-518	-28	+125
26	1500	14+00	-454	-45	+172	-543	-54	+205	+64	-181	+6	-390	-226	+178	-479	-235	+211
27	1400	6+30	-687	-295	-281	-821	-352	-336	+95	-112	-26	-592	-407	-307	-726	-464	-362
28	1400	8+00	-455	+10	-212	-543	+12	-253	-68	-266	-3	-523	-256	-215	-611	-254	-256
29	1400	10+00	-321	+294	+49	-384	+351	+59	-37	-278	+25	-358	+16	+74	-421	+73	+84
30	1400	12+00	-628	-65	+279	-751	-77	+333	-18	-208	+53	-646	-273	+332	-769	-285	+386
31	1400	13+80	-321	-102	+256	-445	-122	+306	-158	-109	+20	-479	-211	+276	-603	-231	+326
32	1300	8+00	-702	-528	-439	-839	-630	-524	-37	-342	+47	-739	-870	-392	-876	-972	-477
33	1300	10+00	-49	-77	+36	-59	-92	+43	-125	-308	+21	-174	-385	+57	-184	-400	+64
34	1300	12+00	-867	-248	+367	-1036	-297	+438	+75	-167	+41	-792	-415	+408	-961	-464	+479
35	1200	10+00	+348	-282	+24	+416	-338	+29	-174	-209	+49	+174	-491	+73	+242	-547	+78

NOTES

1. STATIONS ARE PROJECTED RADIALLY FROM DISTANCES MEASURED ON AXIS OF DAM
2. ALL STRESSES ARE SURFACE STRESS IN PSI
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CITY OF SEATTLE
DEPARTMENT OF LIGHTING

INTERNATIONAL ENGINEERING COMPANY, INC.

ROSS HIGH DAM MODEL STUDIES
MODEL 3 - PHASE 5

ORTHOGONAL STRESSES
DOWNSTREAM FACE

UNIVERSITY OF CALIFORNIA
JEROME M. RAPHAEL, FACULTY INVESTIGATOR

DRAWN: BL | CHKD: CM | APPROVED: [signature]

BERKELEY, CALIFORNIA
DATE: APRIL 1, 1972

FIG. 12

HORIZONTAL, VERTICAL & SHEAR STRESSES
UPSTREAM FACE

GAGE #	ELEV.	STA.	WATER LOAD σ_X	WATER LOAD σ_Y	WATER LOAD τ_{XY}	WATER + EQKE LOADS σ_X	WATER + EQKE LOADS σ_Y	WATER + EQKE LOADS τ_{XY}	DEAD LOAD σ_X	DEAD LOAD σ_Y	DEAD LOAD τ_{XY}	WATER + DEAD LOAD σ_X	WATER + DEAD LOAD σ_Y	WATER + DEAD LOAD τ_{XY}	WATER + EQKE + DEAD LOAD σ_X	WATER + EQKE + DEAD LOAD σ_Y	WATER + EQKE + DEAD LOAD τ_{XY}
41	1700	4+00	-135	0	+58	-161	0	+69	-7	-27	-1	-142	-27	+57	-168	-27	+68
40	1700	8+00	-360	-18	+30	-430	-22	+36	-3	-30	+2	-363	-48	+32	-433	-52	+38
39	1700	10+00	-466	-43	-25	-557	-52	-30	-4	-40	-1	-470	-83	-26	-561	-92	-31
38	1700	12+00	-325	-34	-59	-389	-40	-71	-2	-31	-2	-327	-65	-61	-391	-71	-73
37	1700	15+70	-115	-1	-37	-137	-1	-44	-6	-35	0	-121	-36	-37	-143	-36	-44
36	1700	16+40	-23	-19	-31	-28	-23	-39	0	-35	+7	-23	-54	-26	-28	-58	-32
43	1675	6+00	-354	-35	+14	-423	-42	+17	-1	-13	+1	-355	-48	+15	-424	-55	+18
42	1675	14+00	-365	-83	-35	-436	-100	-42	-2	-17	-1	-367	-100	-36	-438	-117	-43
44	1650	3+30	-371	-50	+81	-444	-60	+96	-5	-56	0	-376	-106	+81	-449	-116	+96
50	1600	4+00	-170	-13	-13	-203	-15	-16	-9	-74	+6	-179	-87	-7	-212	-89	-10
49	1600	6+00	-379	-171	+63	-453	-204	+75	+15	-61	+5	-364	-232	+68	-438	-265	+80
48	1600	8+00	-551	-193	+38	-659	-230	+45	+9	-120	-8	-542	-313	+30	-650	-350	+37
47	1600	10+00	-766	-190	-5	-915	-227	-6	-9	-145	+7	-775	-335	+2	-924	-372	+1
46	1600	12+00	-530	-196	-39	-634	-235	-47	+19	-117	+2	-511	-313	-37	-615	-352	-45
45	1600	14+00	-277	-141	-13	-331	-168	-15	+12	-63	+4	-265	-204	-9	-319	-231	-11
56	1540	4+70	-164	-53	+12	-195	-64	+14	-60	-125	+69	-224	-178	+81	-255	-189	+83
55	1540	6+00	-284	-157	+31	-339	-187	+37	+73	-99	+23	-211	-256	+54	-266	-286	+60
54	1540	8+00	-604	-247	+82	-721	-295	+98	+33	-134	-33	-571	-381	+49	-688	-429	+65
53	1540	10+00	-745	-214	-11	-891	-256	-14	-24	-133	+1	-769	-347	-10	-915	-389	-13
52	1540	12+00	-528	-241	-60	-631	-288	-72	+40	-127	+18	-488	-368	-42	-591	-415	-54
51	1540	14+00	-202	-119	+3	-242	-142	+4	+47	-131	-13	-155	-250	-10	-195	-273	-9
61	1400	6+30	-117	+188	-113	-140	+224	-135	-49	-493	+120	-166	-305	+7	-189	-269	-15
60	1400	8+00	-552	-5	-69	-660	-6	-83	+5	-408	-57	-547	-413	-126	-655	-414	-140
59	1400	10+00	-921	-72	+23	-1101	-86	+27	-39	-278	-15	-960	-350	+8	-1140	-364	+12
58	1400	12+00	-524	-18	+13	-626	-21	+16	+22	-306	-27	-502	-324	-14	-604	-327	-11
57	1400	13+30	-182	+128	+184	-217	+153	+220	+26	-322	-102	-156	-194	+82	-191	-169	+118
64	1300	8+00	-209	+74	-14	-249	+89	-17	-49	-421	-57	-258	-347	-71	-298	-332	-74
63	1300	10+00	-725	+410	+19	-867	+490	+23	-48	-376	-9	-773	+34	+10	-915	+114	+14
62	1300	12+00	-203	+206	+74	-242	+246	+89	-137	-447	-154	-340	-241	-80	-379	-201	-65
65	1200	10+00	-451	+441	-1	-539	+527	-1	-100	-404	+7	-551	+37	+6	-639	+123	+6
66	1150	10+00	-354	+326	-12	-423	+390	-14	-123	-238	+27	-477	+88	+15	-546	+152	+13

NOTES

1. STATIONS ARE PROJECTED RADIALLY FROM DISTANCES MEASURED ON AXIS OF DAM
2. ALL STRESSES ARE SURFACE STRESS IN PSI
3. σ_X IS HORIZONTAL OR ARCH STRESS
4. σ_Y IS VERTICAL OR CANTILEVER STRESS
5. τ_{XY} IS SHEAR STRESS
6. SIGNS: + IS TENSION
   − IS COMPRESSION

CITY OF SEATTLE
DEPARTMENT OF LIGHTING

INTERNATIONAL ENGINEERING COMPANY, INC.

ROSS HIGH DAM MODEL STUDIES
MODEL 3 - PHASE 5

ORTHOGONAL STRESSES
UPSTREAM FACE

UNIVERSITY OF CALIFORNIA
JEROME M. RAPHAEL, FACULTY INVESTIGATOR

DRAWN: BL | CHKD: CM | APPROVED: [signature]

BERKELEY, CALIFORNIA
DATE: APRIL 1, 1972

FIG. 13

HORIZONTAL, VERTICAL & SHEAR STRESSES
DOWNSTREAM FACE

GAGE #	ELEV.	STA.	WATER LOAD			WATER + EQKE LOADS			DEAD LOAD			WATER + DEAD LOAD			WATER+EQKE +DEAD LOAD		
			σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}
1	1700	4+00	-249	+28	-33	-298	+34	-40	0	-40	+2	-249	-12	-31	-298	-6	-38
2	1700	8+00	-207	+28	+9	-247	+34	+11	-9	-41	+1	-216	-13	+10	-256	-7	+12
3	1700	10+00	-233	+34	-1	-279	+41	-1	-3	-32	+1	-236	+2	0	-282	+9	0
4	1700	12+00	-173	+30	+12	-207	+36	+14	-4	-30	-1	-177	0	+11	-211	+6	+13
5	1700	15+70	-450	-2	+39	-538	-3	+46	-1	-31	0	-451	-33	+39	-539	-34	+46
6	1700	16+40	-88	-1	+42	-105	-2	+51	-2	-43	+6	-90	-44	+48	-107	-45	+57
7	1675	6+00	-482	-9	+64	-575	-11	+77	-7	-36	0	-489	-45	+64	-582	-47	+77
8	1675	14+00	-456	+45	-45	-546	+54	-53	-3	-26	-1	-459	+19	-46	-549	+28	-54
9	1650	3+30	-636	+9	-204	-760	+11	-244	+4	-96	+6	-632	-87	-198	-756	-85	-238
10	1600	4+00	-479	+188	-22	-572	+225	-27	+58	-97	+42	-421	+91	+20	-514	+128	+15
11	1600	6+00							-21	-87	-7						
12	1600	8+00	-526	+269	-16	-629	+322	-19	-22	-124	-8	-548	+145	-24	-651	+198	-27
13	1600	10+00	-400	+322	+13	-478	+385	+16	+24	-81	-1	-376	+241	+12	-454	+304	+15
14	1600	12+00	-452	+281	+1	-540	+336	+2	-5	-84	0	-457	+197	+1	-545	+252	+2
15	1600	14+00							+1	-107	+3						
16	1540	4+70	-455	+38	-107	-544	+45	-127	+120	-82	+38	-335	-44	-69	-424	-37	-89
17	1540	6+00							-8	-251	+16						
18	1540	8+00	-625	+286	-13	-747	+342	-16	-38	-258	-51	-663	+28	-64	-785	+84	-67
19	1540	10+00	-351	+424	-1	-420	+507	-1	+35	-152	-34	-316	+272	-35	-385	+355	-35
20	1540	12+00	-521	+327	+35	-622	+391	+41	-29	-166	+41	-550	+161	+76	-651	+225	+82
21	1540	14+00							+19	-244	+17						
22	1500	6+00	-611	-81	-270	-730	-97	-323	+13	-170	-9	-598	-251	-279	-717	-267	-332
23	1500	8+00	-641	+350	-101	-766	+419	-121	-52	-200	-29	-693	+150	-130	-818	+219	-150
24	1500	10+00	-330	+528	+1	-394	+631	+2	+22	-169	-5	-308	+359	-4	-372	+462	-3
25	1500	12+00	-550	+313	+92	-658	+374	+110	-42	-229	+51	-592	+84	+143	-700	+145	+161
26	1500	14+00	-626	-104	+234	-748	-124	+280	+64	-181	+6	-562	-285	+240	-684	-305	+286
27	1400	6+30	-725	-342	-298	-866	-409	-356	+95	-112	-26	-630	-454	-324	-771	-521	-382
28	1400	8+00	-489	-54	-221	-584	-64	-264	-68	-266	-3	-557	-320	-224	-652	-330	-267
29	1400	10+00	-343	+248	+49	-410	+296	+59	-37	-278	+25	-380	-30	+74	-447	+18	+84
30	1400	12+00	-669	-114	+299	-799	-136	+357	-18	-208	+53	-687	-322	+352	-817	-344	+410
31	1400	13+80	-354	-125	+274	-484	-149	+327	-158	-109	+20	-512	-234	+294	-642	-258	+347
32	1300	8+00	-717	-548	-450	-857	-654	-538	-37	-342	+47	-754	-890	-403	-894	-996	-491
33	1300	10+00	-52	-95	+37	-62	-114	+44	-125	-308	+21	-177	-403	+58	-187	-422	+65
34	1300	12+00	-886	-246	+371	-1058	-294	+443	+75	-167	+41	-811	-413	+412	-983	-461	+484
35	1200	10+00	+358	-287	+26	+428	-343	+31	-174	-209	+49	+184	-496	+75	+254	-552	+80

NOTES

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CITY OF SEATTLE
DEPARTMENT OF LIGHTING

INTERNATIONAL ENGINEERING COMPANY, INC.

ROSS HIGH DAM MODEL STUDIES
MODEL 3 - PHASE 6

ORTHOGONAL STRESSES
DOWNSTREAM FACE

UNIVERSITY OF CALIFORNIA
JEROME M. RAPHAEL, FACULTY INVESTIGATOR

DRAWN: BL | CHKD: CM | APPROVED: [signature]

BERKELEY, CALIFORNIA
DATE: APRIL 1, 1972

FIG. 14

HORIZONTAL, VERTICAL & SHEAR STRESSES

UPSTREAM FACE

GAGE #	ELEV.	STA.	WATER LOAD			WATER + EQKE LOADS			DEAD LOAD			WATER + DEAD LOAD			WATER + EQKE + DEAD LOAD		
			σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}
41	1700	4+00	-167	-4	+70	-199	-4	+84	-7	-27	-1	-174	-31	+69	-206	-31	+83
40	1700	8+00	-364	-10	+30	-435	-12	+36	-3	-30	+2	-367	-40	+32	-438	-42	+38
39	1700	10+00	-478	-43	-28	-571	-51	-33	-4	-40	-1	-482	-83	-29	-575	-91	-34
38	1700	12+00	-329	-33	-65	-393	-40	-78	-2	-31	-2	-331	-64	-67	-395	-71	-80
37	1700	15+70	-107	0	-44	-128	0	-53	-6	-35	0	-113	-35	-44	-134	-35	-53
36	1700	16+40	-17	-20	-31	-21	-23	-37	0	-35	+7	-17	-55	-24	-21	-58	-30
43	1675	6+00	-391	-49	+22	-467	-59	+26	-1	-13	+1	-392	-62	+23	-468	-72	+27
42	1675	14+00	-405	-84	-39	-484	-100	-47	-2	-17	-1	-407	-101	-40	-486	-117	-48
44	1650	3+30	-374	-53	+78	-447	-63	+93	-5	-56	0	-379	-109	+78	-452	-119	+93
50	1600	4+00	-197	-44	+1	-236	-53	+1	-9	-74	+6	-206	-118	+7	-245	-127	+7
49	1600	6+00	-404	-215	+78	-482	-256	+93	+15	-61	+5	-389	-276	+83	-467	-317	+98
48	1600	8+00	-604	-258	+47	-722	-308	+56	+9	-120	-8	-595	-378	+39	-713	-428	+48
47	1600	10+00	-840	-250	-10	-1004	-299	-12	-9	-145	+7	-849	-395	-3	-1013	-444	-5
46	1600	12+00	-575	-244	-51	-687	-292	-61	+19	-117	+2	-556	-361	-49	-668	-409	-59
45	1600	14+00	-307	-182	-11	-366	-217	-13	+12	-63	+4	-295	-245	-7	-354	-280	-9
56	1540	4+70	-218	-89	+25	-261	-107	+30	-60	-125	+69	-278	-214	+94	-321	-232	+99
55	1540	6+00	-333	-205	+40	-397	-246	+48	+73	-99	+23	-260	-304	+63	-324	-345	+71
54	1540	8+00	-663	-312	+98	-792	-373	+117	+33	-134	-33	-630	-446	+65	-759	-507	+84
53	1540	10+00	-827	-290	-14	-988	-347	-17	-24	-133	+1	-851	-423	-13	-1012	-480	-16
52	1540	12+00	-577	-298	-67	-689	-356	-80	+40	-127	+18	-537	-425	-49	-649	-483	-62
51	1540	14+00	-239	-155	-5	-285	-185	-6	+47	-131	-13	-192	-286	-18	-238	-316	-19
61	1400	6+30	-128	+230	-124	-153	+274	-148	-49	-493	+120	-177	-263	-4	-202	-219	-28
60	1400	8+00	-567	+46	-75	-677	+55	-89	+5	-408	-57	-562	-362	-132	-672	-353	-146
59	1400	10+00	-935	-11	+26	-1117	-13	+31	-39	-278	-15	-974	-289	+11	-1156	-291	+16
58	1400	12+00	-533	+31	+17	-637	+37	+21	+22	-306	-27	-511	-275	-10	-615	-269	-6
57	1400	13+30	-195	+169	+195	-233	+202	+233	+26	-322	-102	-169	-153	+93	-207	-120	+131
64	1300	8+00	-214	+76	-15	-256	+91	-18	-49	-421	-57	-263	-345	-72	-305	-330	-75
63	1300	10+00	-732	+444	+21	-875	+530	+25	-48	-376	-9	-780	+68	+12	-923	+154	+16
62	1300	12+00	-213	+222	+77	-254	+266	+92	-137	-447	-154	-350	-225	-77	-391	-181	-62
65	1200	10+00	-455	+462	-2	-543	+257	-2	-100	-404	+7	-555	+58	+5	-643	+147	+5
66	1150	10+00	-349	+336	-14	-417	+401	-17	-123	-238	+27	-472	+98	+13	-540	+163	+10

NOTES

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CITY OF SEATTLE
DEPARTMENT OF LIGHTING

INTERNATIONAL ENGINEERING COMPANY, INC.

ROSS HIGH DAM MODEL STUDIES
MODEL 3 – PHASE 6

ORTHOGONAL STRESSES
UPSTREAM FACE

UNIVERSITY OF CALIFORNIA
JEROME M. RAPHAEL, FACULTY INVESTIGATOR

DRAWN: BL	CHKD: CM	APPROVED: J. M. Raphael
BERKELEY, CALIFORNIA DATE: APRIL 1, 1972		FIG. 15

HORIZONTAL, VERTICAL & SHEAR STRESSES

DOWNSTREAM FACE

GAGE #	ELEV.	STA.	WATER LOAD			WATER + EQKE LOADS			DEAD LOAD			WATER + DEAD LOAD			WATER+EQKE + DEAD LOAD		
			σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}
1	1700	4+00	- 247	+ 33	- 21	- 295	+ 40	- 25	0	- 40	+ 2	- 247	- 7	- 19	- 295	0	- 23
2	1700	8+00	- 160	+ 40	+ 44	- 191	+ 48	+ 52	- 9	- 41	+ 1	- 169	- 1	+ 45	- 200	+ 7	+ 53
3	1700	10+00	- 191	+ 44	- 15	- 228	+ 52	- 18	- 3	- 32	+ 1	- 194	+ 12	- 14	- 231	+ 20	- 17
4	1700	12+00	- 108	+ 40	+ 28	- 129	+ 47	+ 34	- 4	- 30	- 1	- 112	+ 10	+ 27	- 133	+ 17	+ 33
5	1700	15+70	- 356	+ 2	- 1	- 425	+ 3	- 1	- 1	- 31	0	- 357	- 29	- 1	- 426	- 28	- 1
6	1700	16+40	- 59	+ 3	+ 25	- 71	+ 4	+ 30	- 2	- 43	+ 6	- 61	- 40	+ 31	- 73	- 39	+ 36
7	1675	6+00	- 463	- 7	+ 95	- 554	- 9	+ 114	- 7	- 36	0	- 470	- 43	+ 95	- 561	- 45	+ 114
8	1675	14+00	- 434	+ 154	- 145	- 518	+ 184	- 174	- 3	- 26	- 1	- 437	+ 128	- 146	- 521	+ 158	- 175
9	1650	3+30	- 681	+ 27	- 215	- 814	+ 32	- 257	+ 4	- 96	+ 6	- 677	- 69	- 209	- 810	- 64	- 251
10	1600	4+00	- 507	+ 263	- 23	- 605	+ 314	- 28	+ 58	- 97	+ 42	- 449	+ 166	+ 19	- 547	+ 217	+ 14
11	1600	6+00							- 21	- 87	- 7						
12	1600	8+00	- 545	+ 404	+ 26	- 652	+ 483	+ 31	- 22	- 124	- 8	- 567	+ 280	+ 18	- 674	+ 359	+ 23
13	1600	10+00	- 427	+ 421	+ 18	- 511	+ 503	+ 21	+ 24	- 81	- 1	- 403	+ 340	+ 17	- 487	+ 422	+ 20
14	1600	12+00	- 463	+ 385	+ 17	- 553	+ 460	+ 20	- 5	- 84	0	- 468	+ 301	+ 17	- 558	+ 376	+ 20
15	1600	14+00							+ 1	- 107	+ 3						
16	1540	4+70	- 465	- 1	- 118	- 556	- 1	- 141	+ 120	- 82	+ 38	- 345	- 83	- 80	- 436	- 83	- 103
17	1540	6+00							- 8	- 251	+ 16						
18	1540	8+00	- 656	+ 313	+ 23	- 784	+ 374	+ 28	- 38	- 258	- 51	- 694	+ 55	- 28	- 822	+ 116	- 23
19	1540	10+00	- 392	+ 456	+ 7	- 469	+ 545	+ 9	+ 35	- 152	- 34	- 357	+ 304	- 27	- 434	+ 393	- 25
20	1540	12+00	- 556	+ 356	+ 38	- 664	+ 426	+ 45	- 29	- 166	+ 41	- 585	+ 190	+ 79	- 693	+ 260	+ 86
21	1540	14+00							+ 19	- 244	+ 17						
22	1500	6+00	- 633	- 153	- 280	- 757	- 182	- 335	+ 13	- 170	- 9	- 620	- 323	- 289	- 744	- 352	- 344
23	1500	8+00	- 664	+ 372	- 75	- 793	+ 444	- 89	- 52	- 200	- 29	- 716	+ 172	- 104	- 845	+ 244	- 118
24	1500	10+00	- 370	+ 569	+ 11	- 441	+ 680	+ 14	+ 22	- 169	- 5	- 348	+ 400	+ 6	- 419	+ 511	+ 9
25	1500	12+00	- 587	+ 342	+ 98	- 701	+ 409	+ 117	- 42	- 229	+ 51	- 629	+ 113	+ 149	- 743	+ 180	+ 168
26	1500	14+00	- 640	- 77	+ 227	- 765	- 92	+ 272	+ 64	- 181	+ 6	- 576	- 258	+ 233	- 701	- 273	+ 278
27	1400	6+30	- 750	- 372	- 311	- 896	- 445	+ 424	+ 95	- 112	- 26	- 655	- 484	- 337	- 801	- 557	- 398
28	1400	8+00	- 491	- 66	- 214	- 587	- 79	- 256	- 68	- 266	- 3	- 559	- 332	- 217	- 655	- 345	- 259
29	1400	10+00	- 389	+ 252	+ 62	465	+ 302	+ 75	- 37	- 278	+ 25	- 426	- 26	+ 87	- 502	+ 24	+ 100
30	1400	12+00	- 702	- 107	+ 310	- 839	- 128	+ 371	- 18	- 208	+ 53	- 720	- 315	+ 363	- 857	- 336	+ 424
31	1400	13+80	- 367	- 133	+ 282	- 501	- 159	+ 336	- 158	- 109	+ 20	- 525	- 242	+ 302	- 659	- 268	+ 356
32	1300	8+00	- 734	- 577	- 471	- 877	- 689	- 563	- 37	- 342	+ 47	- 771	- 919	- 424	- 914	- 1031	- 516
33	1300	10+00	- 70	- 101	+ 43	- 83	- 120	+ 51	- 125	- 308	+ 21	- 195	- 409	+ 64	- 208	- 428	+ 72
34	1300	12+00	- 898	- 225	+ 372	- 1073	- 269	+ 445	+ 75	- 167	+ 41	- 823	- 392	+ 413	- 998	- 436	+ 486
35	1200	10+00	+ 365	- 298	+ 29	+ 437	- 357	+ 35	- 174	- 209	+ 49	+ 191	- 507	+ 78	+ 263	- 566	+ 84

NOTES

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6. SIGNS: + IS TENSION
   − IS COMPRESSION

CITY OF SEATTLE
DEPARTMENT OF LIGHTING

INTERNATIONAL ENGINEERING COMPANY, INC.

ROSS HIGH DAM MODEL STUDIES
MODEL 3 - PHASE 7

ORTHOGONAL STRESSES
DOWNSTREAM FACE

UNIVERSITY OF CALIFORNIA
JEROME M. RAPHAEL, FACULTY INVESTIGATOR

DRAWN: BL | CHKD: CM | APPROVED: J.M. Raphael

BERKELEY, CALIFORNIA
DATE: APRIL 1, 1972

FIG. 16

HORIZONTAL, VERTICAL & SHEAR STRESSES
UPSTREAM FACE

GAGE #	ELEV.	STA.	WATER LOAD σ_X	WATER LOAD σ_Y	WATER LOAD τ_{XY}	WATER + EQKE LOADS σ_X	WATER + EQKE LOADS σ_Y	WATER + EQKE LOADS τ_{XY}	DEAD LOAD σ_X	DEAD LOAD σ_Y	DEAD LOAD τ_{XY}	WATER + DEAD LOAD σ_X	WATER + DEAD LOAD σ_Y	WATER + DEAD LOAD τ_{XY}	WATER+EQKE+DEAD LOAD σ_X	WATER+EQKE+DEAD LOAD σ_Y	WATER+EQKE+DEAD LOAD τ_{XY}
41	1700	4+00	-170	- 11	+ 81	- 203	- 14	+ 97	- 7	- 27	- 1	- 177	- 38	+ 80	- 210	- 41	+ 96
40	1700	8+00							- 3	- 30	+ 2						
39	1700	10+00	-462	- 47	- 43	- 553	- 56	- 51	- 4	- 40	- 1	- 466	- 87	- 44	- 557	- 96	- 52
38	1700	12+00	-322	- 42	- 42	- 385	- 51	- 51	- 2	- 31	- 2	- 324	- 73	- 44	- 387	- 82	- 53
37	1700	15+70	-104	- 22	- 66	- 124	- 27	- 78	- 6	- 35	0	- 110	- 57	- 66	- 130	- 62	- 78
36	1700	16+40	- 17	- 20	- 29	- 20	- 23	- 35	0	- 35	+ 7	- 17	- 55	- 22	- 20	- 58	- 28
43	1675	6+00	-400	- 44	+ 39	- 478	- 53	+ 46	- 1	- 13	+ 1	- 401	- 57	+ 40	- 479	- 66	+ 47
42	1675	14+00							- 2	- 17	- 1						
44	1650	3+30	-354	- 60	+ 83	- 423	- 72	+ 100	- 5	- 56	0	- 359	- 116	+ 83	- 428	- 128	+ 100
50	1600	4+00	-172	+ 32	- 22	- 205	+ 38	- 26	- 9	- 74	+ 6	- 181	- 42	- 16	- 214	- 36	- 20
49	1600	6+00	-420	+ 42	+ 33	- 502	+ 50	+ 39	+ 15	- 61	+ 5	- 405	- 19	+ 38	- 487	- 11	+ 44
48	1600	8+00	-608	+ 4	+ 47	- 726	+ 4	+ 56	+ 9	- 120	- 8	- 599	- 116	+ 39	- 717	- 116	+ 48
47	1600	10+00	-843	- 113	- 13	-1007	- 135	- 15	- 9	- 145	+ 7	- 852	- 258	- 6	-1016	- 280	- 8
46	1600	12+00	-555	- 80	- 45	- 663	- 96	- 54	+ 19	- 117	+ 2	- 536	- 197	- 43	- 644	- 213	- 52
45	1600	14+00	-268	+ 82	+ 22	- 320	+ 98	+ 26	+ 12	- 63	+ 4	- 256	+ 19	+ 26	- 308	+ 35	+ 30
56	1540	4+70	-210	- 66	+ 3	- 251	- 79	+ 4	- 60	- 125	+ 69	- 270	- 191	+ 72	- 311	- 204	+ 73
55	1540	6+00	-366	- 193	+ 46	- 438	- 230	+ 54	+ 73	- 99	+ 23	- 293	- 292	+ 69	- 365	- 329	+ 77
54	1540	8+00	-715	- 333	+ 120	- 854	- 397	+ 143	+ 33	- 134	- 33	- 682	- 467	+ 87	- 821	- 531	+ 110
53	1540	10+00	-864	- 310	- 19	-1033	- 370	- 23	- 24	- 133	+ 1	- 888	- 443	- 18	-1057	- 503	- 22
52	1540	12+00	-605	- 321	- 67	- 723	- 383	- 80	+ 40	- 127	+ 18	- 565	- 448	- 49	- 683	- 510	- 62
51	1540	14+00	-252	- 165	- 11	- 301	- 197	- 13	+ 47	- 131	- 13	- 205	- 296	- 24	- 254	- 328	- 26
61	1400	6+30	-131	+ 264	- 145	- 156	+ 315	- 174	- 49	- 493	+ 120	- 180	- 229	- 25	- 205	- 178	- 54
60	1400	8+00	-610	+ 53	- 73	- 729	+ 63	- 88	+ 5	- 408	- 57	- 605	- 355	- 130	- 724	- 345	- 145
59	1400	10+00	-964	- 14	+ 33	-1153	- 17	+ 39	- 39	- 278	- 15	-1003	- 292	+ 18	-1192	- 295	+ 24
58	1400	12+00	-567	+ 21	+ 7	- 678	+ 25	+ 9	+ 22	- 306	- 27	- 545	- 285	- 20	- 656	- 281	- 18
57	1400	13+30	-223	+ 151	+ 182	- 267	+ 180	+ 218	+ 26	- 322	- 102	- 197	- 171	+ 80	- 241	- 142	+ 116
64	1300	8+00	-233	+ 72	- 8	- 278	+ 86	- 9	- 49	- 421	- 57	- 282	- 349	- 65	- 327	- 335	- 66
63	1300	10+00	-758	+ 456	+ 22	- 906	+ 545	+ 26	- 48	- 376	- 9	- 806	+ 80	+ 13	- 954	+ 169	+ 17
62	1300	12+00	-231	+ 220	+ 74	- 276	+ 263	+ 88	- 137	- 447	- 154	- 368	- 227	- 80	- 413	- 184	- 66
65	1200	10+00	-465	+ 484	- 2	- 556	+ 578	- 3	- 100	- 404	+ 7	- 565	+ 80	+ 5	- 656	+ 174	+ 4
66	1150	10+00	-348	+ 352	- 16	- 416	+ 420	- 19	- 123	- 238	+ 27	- 471	+ 114	+ 11	- 539	+ 182	+ 8

NOTES

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CITY OF SEATTLE
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ROSS HIGH DAM MODEL STUDIES
MODEL 3 - PHASE 7

ORTHOGONAL STRESSES
UPSTREAM FACE

UNIVERSITY OF CALIFORNIA
JEROME M. RAPHAEL, FACULTY INVESTIGATOR

DRAWN: BL | CHKD: CM | APPROVED: [signature]

BERKELEY, CALIFORNIA
DATE: APRIL 1, 1972

FIG. 17

HORIZONTAL, VERTICAL & SHEAR STRESSES

DOWNSTREAM FACE

GAGE #	ELEV.	STA.	WATER LOAD			WATER + EQKE LOADS			DEAD LOAD			WATER + DEAD LOAD			WATER+EQKE + DEAD LOAD		
			σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}
1	1700	4+00	-224	+33	-11	-267	+40	-14	0	-40	+2	-224	-7	-9	-267	0	-12
2	1700	8+00	-152	+21	+11	-181	+25	+13	-9	-41	+1	-161	-20	+12	-190	-16	+14
3	1700	10+00	-202	+29	-5	-242	+34	-6	-3	-32	+1	-205	-3	-4	-245	+2	-5
4	1700	12+00	-144	+17	-6	-172	+21	-7	-4	-30	-1	-148	-13	-7	-176	-9	-8
5	1700	15+70	-365	-1	+22	-436	-1	+26	-1	-31	0	-366	-32	+22	-437	-32	+26
6	1700	16+40	-81	-1	+36	-96	-2	+42	-2	-43	+6	-83	-44	+42	-98	-45	+48
7	1675	6+00	-509	-29	+97	-608	-35	+116	-7	-36	0	-516	-65	+97	-615	-71	+116
8	1675	14+00	-486	0	-78	-581	+1	-93	-3	-26	-1	-489	-26	-79	-584	-25	-94
9	1650	3+30	-690	+28	-190	-825	+33	-227	+4	-96	+6	-686	-68	-184	-821	-63	-221
10	1600	4+00	-479	+343	+16	-572	+410	+19	+58	-97	+42	-421	+246	+58	-514	+313	+61
11	1600	6+00							-21	-87	-7						
12	1600	8+00	-593	+442	-27	-708	+528	-32	-22	-124	-8	-615	+318	-35	-730	+404	-40
13	1600	10+00	-492	+437	+19	-588	+522	+22	+24	-81	-1	-468	+356	+18	-564	+441	+21
14	1600	12+00	-484	+404	-5	-579	+483	-7	-5	-84	0	-489	+320	-5	-584	+399	-7
15	1600	14+00							+1	-107	+3						
16	1540	4+70	-442	+58	-163	-528	+70	-195	+120	-82	+38	-322	-24	-125	-408	-12	-157
17	1540	6+00							-8	-251	+16						
18	1540	8+00	-734	+421	-12	-877	+503	-14	-38	-258	-51	-772	+163	-63	-915	+245	-65
19	1540	10+00	-460	+547	+4	-550	+653	+4	+35	-152	-34	-425	+395	-30	-515	+501	-30
20	1540	12+00	-590	+431	+46	-706	+515	+56	-29	-166	+41	-619	+265	+87	-735	+349	+97
21	1540	14+00							+19	-244	+17						
22	1500	6+00	-682	-259	-329	-815	-310	-393	+13	-170	-9	-669	-429	-338	-802	-480	-402
23	1500	8+00	-744	+339	-107	-890	+406	-128	-52	-200	-29	-796	+139	-136	-942	+206	-157
24	1500	10+00	-437	+582	+9	-522	+695	+10	+22	-169	-5	-415	+413	+4	-500	+526	+5
25	1500	12+00	-639	+298	+125	-764	+356	+149	-42	-229	+51	-681	+69	+176	-806	+127	+200
26	1500	14+00	-676	-137	+287	-808	-163	+343	+64	-181	+6	-612	-318	+293	-744	-344	+349
27	1400	6+30	-801	-428	-346	-958	-511	+465	+95	-112	-26	-706	-540	-372	-863	-623	-439
28	1400	8+00	-534	-170	-238	-639	-204	-285	-68	-266	-3	-602	-436	-241	-707	-470	-288
29	1400	10+00	-439	+187	+66	-524	+223	+78	-37	-278	+25	-476	-91	+91	-561	-55	+103
30	1400	12+00	-746	-171	+336	-892	-204	+452	-18	-208	+53	-764	-379	+389	-910	-412	+455
31	1400	13+80	-387	-151	+291	-524	-181	+348	-158	-109	+20	-545	-260	+311	-682	-290	+368
32	1300	8+00	-767	-622	-486	-916	-743	-581	-37	-342	+47	-804	-964	-439	-953	-1085	-534
33	1300	10+00	-85	-140	+46	-101	-167	+55	-125	-308	+21	-210	-448	+67	-226	-475	+76
34	1300	12+00	-961	-288	+398	-1148	-344	+476	+75	-167	+41	-886	-455	+439	-1073	-511	+517
35	1200	10+00	+367	-309	+29	+439	-369	+35	-174	-209	+49	+193	-518	+78	+265	-578	+84

NOTES

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ROSS HIGH DAM MODEL STUDIES
MODEL 3 - PHASE 8

ORTHOGONAL STRESSES
DOWNSTREAM FACE

UNIVERSITY OF CALIFORNIA
JEROME M. RAPHAEL, FACULTY INVESTIGATOR

DRAWN: BL | CHKD: CM | APPROVED: [signature]

BERKELEY, CALIFORNIA
DATE: APRIL 1, 1972

FIG. 18

HORIZONTAL, VERTICAL & SHEAR STRESSES
UPSTREAM FACE

GAGE #	ELEV.	STA.	WATER LOAD			WATER + EQKE LOADS			DEAD LOAD			WATER + DEAD LOAD			WATER EQKE + DEAD LOAD		
			σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}
41	1700	4+00	-183	-17	+93	-218	-20	+111	-7	-27	-1	-190	-44	+92	-225	-47	+110
40	1700	8+00	-326	-12	+33	-390	-14	+39	-3	-30	+2	-329	-42	+35	-393	-44	+41
39	1700	10+00	-429	-34	-29	-513	-40	-35	-4	-40	-1	-433	-74	-30	-517	-80	-36
38	1700	12+00	-286	-26	-63	-342	-30	-75	-2	-31	-2	-288	-57	-65	-344	-61	-77
37	1700	15+70	-137	-15	-60	-163	-18	-72	-6	-35	0	-143	-50	-60	-169	-53	-72
36	1700	16+40	-19	-19	-28	-23	-22	-33	0	-35	+7	-19	-54	-21	-23	-57	-26
43	1675	6+00	-365	-16	+48	-436	-19	+57	-1	-13	+1	-366	-29	+49	-437	-32	+58
42	1675	14+00	-334	-34	-62	-399	-40	-74	-2	-17	-1	-336	-51	-63	-401	-57	-75
44	1650	3+30	-422	-46	+122	-504	-55	+146	-5	-56	0	-427	-102	+122	-509	-111	+146
50	1600	4+00	-418	-136	-15	-499	-162	-18	-9	-74	+6	-427	-210	-9	-508	-236	-12
49	1600	6+00							+15	-61	+5						
48	1600	8+00	-892	-494	+124	-1066	-590	+148	+9	-120	-8	-883	-614	+116	-1057	-710	+140
47	1600	10+00	-917	-371	-3	-1096	-443	-3	-9	-145	+7	-926	-516	+4	-1105	-588	+4
46	1600	12+00	-834	-465	-41	-997	-556	-49	+19	-117	+2	-815	-582	-39	-978	-673	-47
45	1600	14+00							+12	-63	+4						
56	1540	4+70	-253	-71	+70	-302	-85	+84	-60	-125	+69	-313	-196	+139	-362	-210	+153
55	1540	6+00	-549	-302	+92	-656	-361	+110	+73	-99	+23	-476	-401	+115	-583	-460	+133
54	1540	8+00	-1068	-522	+143	-1276	-623	+171	+33	-134	-33	-1035	-656	+110	-1243	-757	+138
53	1540	10+00	-1145	-478	+10	-1369	-571	+12	-24	-133	+1	-1169	-611	+11	-1393	-704	+13
52	1540	12+00	-877	-457	-97	-1048	-546	-116	+40	-127	+18	-837	-584	-79	-1008	-673	-98
51	1540	14+00	-422	-176	-24	-504	-210	-29	+47	-131	-13	-375	-307	-37	-457	-341	-42
61	1400	6+30	-130	+263	-156	-156	+314	-187	-49	-493	+120	-179	-230	-36	-205	-179	-67
60	1400	8+00	-637	+82	-85	-761	+98	-101	+5	-408	-57	-632	-326	-142	-756	-310	-158
59	1400	10+00	-987	+25	+47	-1179	+30	+57	-39	-278	-15	-1026	-253	+32	-1218	-248	+42
58	1400	12+00	-581	+51	+22	-694	+62	+26	+22	-306	-27	-559	-255	-5	-672	-244	-1
57	1400	13+30	-217	+166	+205	-259	+199	+245	+26	-322	-102	-191	-156	+103	-233	-123	+143
64	1300	8+00	-247	+51	-8	-295	+61	-9	-49	-421	-57	-296	-370	-65	-344	-360	-66
63	1300	10+00	-783	+477	+28	-935	+470	+34	-48	-376	-9	-831	+101	+19	-983	+194	+25
62	1300	12+00	-252	+241	+69	-301	+287	+83	-137	-447	-154	-389	-206	-85	-438	-160	-71
65	1200	10+00	-482	+489	-4	-576	+585	-4	-100	-404	+7	-582	+85	+3	-676	+181	+3
66	1150	10+00	-361	+353	-13	-432	+422	-15	-123	-238	+27	-484	+115	+14	-555	+184	+12

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ORTHOGONAL STRESSES
UPSTREAM FACE

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DRAWN: BL | CHKD: CM | APPROVED: J M Raphael

BERKELEY, CALIFORNIA
DATE: APRIL 1, 1972

FIG. 19

HORIZONTAL, VERTICAL & SHEAR STRESSES

DOWNSTREAM FACE

GAGE #	ELEV.	STA.	WATER LOAD			WATER + EQKE LOADS			DEAD LOAD			WATER + DEAD LOAD			WATER+EQKE +DEAD LOAD		
			σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}
1	1700	4+00	-106	-1	+17	-127	-1	+20	0	-40	+2	-106	-41	+19	-127	-41	+22
2	1700	8+00	-102	+5	+8	-122	+6	+10	-9	-41	+1	-111	-36	+9	-131	-35	+11
3	1700	10+00	-143	+6	-2	-171	+7	-2	-3	-32	+1	-146	-26	-1	-174	-25	-1
4	1700	12+00	-83	+9	-8	-99	+11	-10	-4	-30	-1	-87	-21	-9	-103	-19	-11
5	1700	15+70	-367	+6	-6	-438	+7	-7	-1	-31	0	-368	-25	-6	-439	-24	-7
6	1700	16+40	-83	+19	+36	-99	+23	+43	-2	-43	+6	-85	-24	+42	-101	-20	+49
7	1675	6+00	-235	-24	+33	-281	-29	+39	-7	-36	0	-242	-60	+33	-288	-65	+39
8	1675	14+00	-265	-8	-33	-317	-10	-40	-3	-26	-1	-268	-34	-34	-320	-36	-41
9	1650	3+30	-634	+74	-86	-758	+88	-103	+4	-96	+6	-630	-22	-80	-754	-8	-97
10	1600	4+00	-609	-6	-89	-728	-7	-107	+58	-97	+42	-551	-103	-47	-670	-104	-65
11	1600	6+00							-21	-87	-7						
12	1600	8+00	-1157	+98	+3	-1382	+117	+4	-22	-124	-8	-1179	-26	-5	-1404	-7	-4
13	1600	10+00	-1074	+16	+54	-1283	+19	+64	+24	-81	-1	-1050	-65	+53	-1259	-62	+63
14	1600	12+00	-802	+126	+37	-958	+150	+44	-5	-84	0	-807	+42	+37	-963	+66	+44
15	1600	14+00							+1	-107	+3						
16	1540	4+70	-581	-284	-310	-694	-339	-370	+120	-82	+38	-461	-366	-272	-574	-421	-332
17	1540	6+00							-8	-251	+16						
18	1540	8+00	-1066	-11	-67	-1274	-13	-80	-38	-258	-51	-1104	-269	-118	-1312	-271	-131
19	1540	10+00	-706	+145	+7	-844	+173	+8	+35	-152	-34	-671	-7	-27	-809	+21	-26
20	1540	12+00	-787	+121	+115	-940	+145	+137	-29	-166	+41	-816	-45	+156	-969	-21	+178
21	1540	14+00							+19	-244	+17						
22	1500	6+00	-871	-713	-497	-1040	-852	-594	+13	-170	-9	-858	-883	-506	-1027	-1022	-603
23	1500	8+00	-963	+2	-159	-1151	+2	-190	-52	-200	-29	-1015	-198	-188	-1203	-198	-219
24	1500	10+00	-591	+231	+20	-706	+277	+23	+22	-169	-5	-569	+62	+15	-684	+108	+18
25	1500	12+00	-778	+30	+197	-929	+36	+235	-42	-229	+51	-820	-199	+248	-971	-193	+286
26	1500	14+00	-838	-332	+357	-1002	-397	+427	+64	-181	+6	-774	-513	+363	-938	-578	+433
27	1400	6+30	-862	-515	-390	-1030	-615	-466	+95	-112	-26	-767	-627	-416	-935	-727	-492
28	1400	8+00	-598	-319	-269	-715	-381	-322	-68	-266	-3	-666	-585	-272	-783	-647	-325
29	1400	10+00	-472	+67	+73	-564	+81	+87	-37	-278	+25	-509	-211	+98	-601	-197	+112
30	1400	12+00	-811	-268	+386	-969	-321	+462	-18	-208	+53	-829	-476	+439	-987	-529	+515
31	1400	13+80	-429	-193	+307	-574	-231	+367	-158	-109	+20	-587	-302	+327	-732	-340	+387
32	1300	8+00	-792	-653	-511	-946	-781	-611	-37	-342	+47	-829	-995	-464	-983	-1123	-564
33	1300	10+00	-67	-175	+37	-80	-209	+45	-125	-308	+21	-192	-483	+58	-205	-517	+66
34	1300	12+00	-963	-242	+393	-1151	-289	+470	+75	-167	+41	-888	-409	+434	-1076	-456	+511
35	1200	10+00	+395	-317	+24	+472	-379	+29	-174	-209	+49	+221	-526	+73	+298	-588	+78

NOTES

1. STATIONS ARE PROJECTED RADIALLY FROM DISTANCES MEASURED ON AXIS OF DAM
2. ALL STRESSES ARE SURFACE STRESS IN PSI
3. σ_X IS HORIZONTAL OR ARCH STRESS
4. σ_Y IS VERTICAL OR CANTILEVER STRESS
5. τ_{XY} IS SHEAR STRESS
6. SIGNS: + IS TENSION
   − IS COMPRESSION

CITY OF SEATTLE
DEPARTMENT OF LIGHTING

INTERNATIONAL ENGINEERING COMPANY, INC.

ROSS HIGH DAM MODEL STUDIES
MODEL 3 - PHASE 9

ORTHOGONAL STRESSES
DOWNSTREAM FACE

UNIVERSITY OF CALIFORNIA
JEROME M. RAPHAEL, FACULTY INVESTIGATOR

DRAWN: BL | CHKD: CM | APPROVED: [signature]

BERKELEY, CALIFORNIA
DATE: APRIL 1, 1972

FIG. 20

HORIZONTAL, VERTICAL & SHEAR STRESSES
UPSTREAM FACE

GAGE #	ELEV.	STA.	WATER LOAD			WATER + EQKE LOADS			DEAD LOAD			WATER + DEAD LOAD			WATER + EQKE + DEAD LOAD		
			σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}	σ_X	σ_Y	τ_{XY}
41	1700	4+00	- 76	- 3	+ 51	- 91	- 3	+ 61	- 7	- 27	- 1	- 83	- 30	+ 50	- 98	- 30	+ 60
40	1700	8+00	-176	+ 3	+ 10	- 210	+ 4	+ 12	- 3	- 30	+ 2	- 179	- 27	+ 12	- 213	- 26	+ 14
39	1700	10+00	-181	- 14	- 16	- 216	- 17	- 20	- 4	- 40	- 1	- 185	- 54	- 17	- 220	- 57	- 21
38	1700	12+00	-185	- 7	- 22	- 221	- 9	- 27	- 2	- 31	- 2	- 187	- 38	- 24	- 223	- 40	- 29
37	1700	15+70	- 74	+ 4	- 27	- 88	+ 5	- 33	- 6	- 35	0	- 80	- 31	- 27	- 94	- 30	- 33
36	1700	16+40	- 1	- 30	- 37	- 1	- 36	- 44	0	- 35	+ 7	- 1	- 65	- 30	- 1	- 71	- 37
43	1675	6+00	-301	+ 9	+ 20	- 359	+ 10	+ 24	- 1	- 13	+ 1	- 302	- 4	+ 21	- 360	- 3	+ 25
42	1675	14+00	-304	- 17	- 40	- 363	- 20	- 48	- 2	- 17	- 1	- 306	- 34	- 41	- 365	- 37	- 49
44	1650	3+30	-269	+ 11	+ 65	- 322	+ 13	+ 78	- 5	- 56	0	- 274	- 45	+ 65	- 327	- 43	+ 78
50	1600	4+00	-493	+ 22	- 78	- 589	+ 26	- 94	- 9	- 74	+ 6	- 502	- 52	- 72	- 598	- 48	- 88
49	1600	6+00							+ 15	- 61	+ 5						
48	1600	8+00	-1260	- 14	+ 132	-1506	- 16	+ 157	+ 9	- 120	- 8	-1251	- 134	+ 124	-1497	- 136	+ 149
47	1600	10+00	-1329	+ 34	- 34	-1589	+ 40	- 41	- 9	- 145	+ 7	-1338	- 111	- 27	-1598	- 105	- 34
46	1600	12+00	-1099	- 524	- 108	-1313	- 626	- 129	+ 19	- 117	+ 2	-1080	- 641	- 106	-1294	- 743	- 127
45	1600	14+00							+ 12	- 63	+ 4						
56	1540	4+70	-181	+ 169	+ 5	- 216	+ 202	+ 6	- 60	- 125	+ 69	- 241	+ 44	+ 74	- 276	+ 77	+ 75
55	1540	6+00	-658	+ 90	+ 82	- 786	+ 108	+ 98	+ 73	- 99	+ 23	- 585	- 9	+ 105	- 713	+ 9	+ 121
54	1540	8+00	-1227	- 159	+ 192	-1466	- 190	+ 229	+ 33	- 134	- 33	-1194	- 293	+ 159	-1433	- 324	+ 196
53	1540	10+00	-1308	- 142	+ 33	-1563	- 170	+ 39	- 24	- 133	+ 1	-1332	- 275	+ 34	-1587	- 303	+ 40
52	1540	12+00	-1007	- 127	- 101	-1203	- 152	- 120	+ 40	- 127	+ 18	- 967	- 254	- 83	-1163	- 279	- 102
51	1540	14+00	-531	+ 54	+ 67	- 635	+ 64	+ 80	+ 47	- 131	- 13	- 484	- 77	+ 54	- 588	- 67	+ 67
61	1400	6+30	-154	+ 378	- 162	- 184	+ 451	- 194	- 49	- 493	+ 120	- 203	- 115	- 42	- 233	- 42	- 74
60	1400	8+00	-645	+ 260	- 85	- 771	+ 311	- 102	+ 5	- 408	- 57	- 640	- 148	- 142	- 766	- 97	- 159
59	1400	10+00	-994	+ 160	+ 48	-1188	+ 191	+ 58	- 39	- 278	- 15	-1033	- 118	+ 33	-1227	- 87	+ 43
58	1400	12+00	-591	+ 171	+ 33	- 706	+ 204	+ 39	+ 22	- 306	- 27	- 569	- 135	+ 6	- 684	- 102	+ 12
57	1400	13+30	-221	+ 250	+ 232	- 263	+ 299	+ 277	+ 26	- 322	- 102	- 195	- 72	+ 130	- 237	- 23	+ 175
64	1300	8+00	-229	+ 153	- 27	- 273	+ 183	- 32	- 49	- 421	- 57	- 278	- 268	- 84	- 322	- 238	- 89
63	1300	10+00	-788	+ 545	+ 20	- 942	+ 652	+ 23	- 48	- 376	- 9	- 836	+ 169	+ 11	- 990	+ 276	+ 14
62	1300	12+00	-250	+ 272	+ 65	- 299	+ 325	+ 78	- 137	- 447	- 154	- 387	- 175	- 89	- 436	- 122	- 76
65	1200	10+00	-490	+ 537	- 10	- 586	+ 641	- 12	- 100	- 404	+ 7	- 590	+ 133	- 3	- 686	+ 237	- 5
66	1150	10+00	-363	+ 373	- 22	- 434	+ 446	- 26	- 123	- 238	+ 27	- 486	+ 135	+ 5	- 557	+ 208	+ 1

NOTES

1. STATIONS ARE PROJECTED RADIALLY FROM DISTANCES MEASURED ON AXIS OF DAM
2. ALL STRESSES ARE SURFACE STRESS IN PSI
3. σ_X IS HORIZONTAL OR ARCH STRESS
4. σ_Y IS VERTICAL OR CANTILEVER STRESS
5. τ_{XY} IS SHEAR STRESS
6. SIGNS: + IS TENSION
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CITY OF SEATTLE
DEPARTMENT OF LIGHTING

INTERNATIONAL ENGINEERING COMPANY, INC.

ROSS HIGH DAM MODEL STUDIES
MODEL 3 - PHASE 9

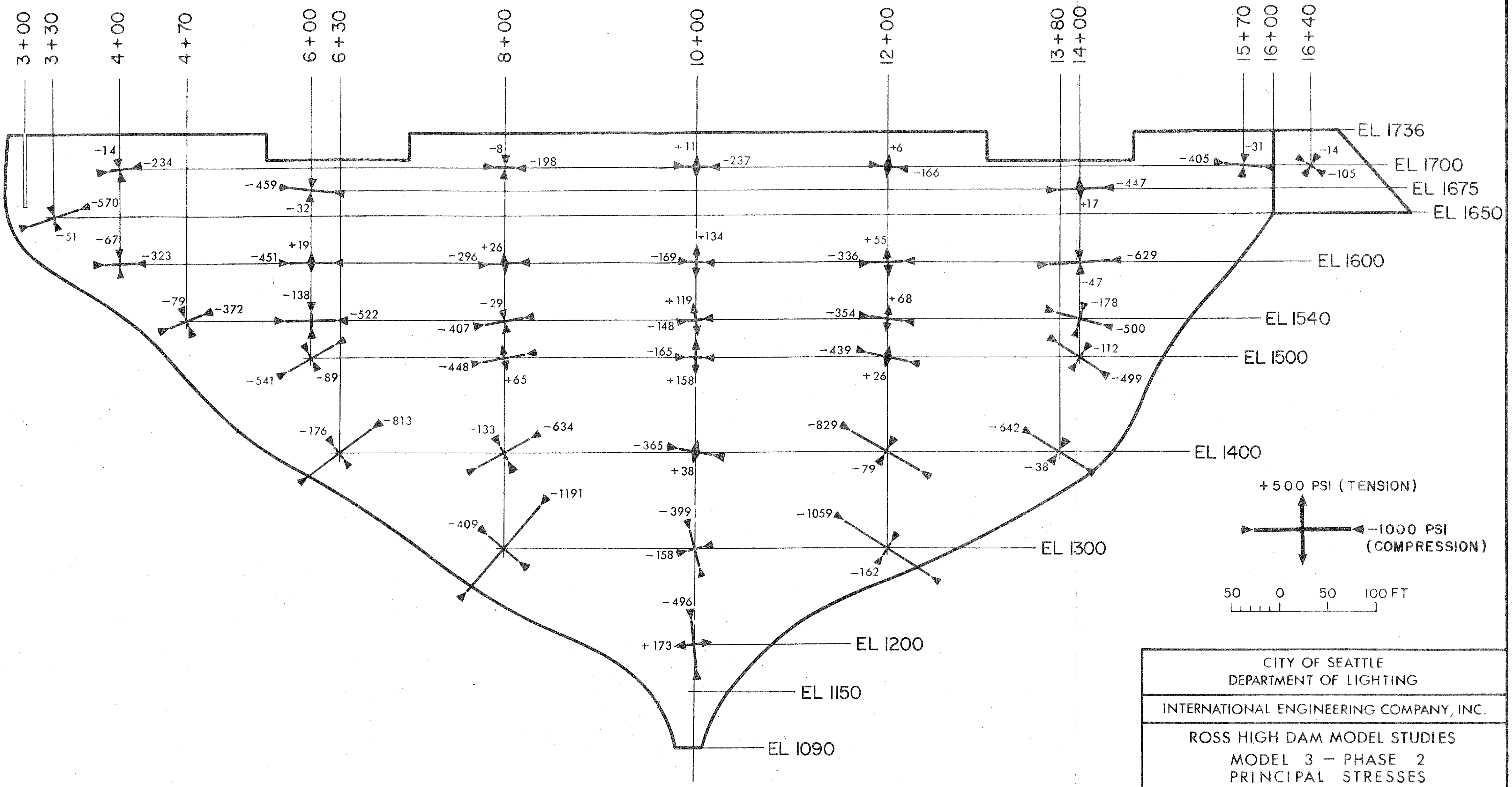
ORTHOGONAL STRESSES
UPSTREAM FACE

UNIVERSITY OF CALIFORNIA
JEROME M. RAPHAEL, FACULTY INVESTIGATOR

DRAWN: BL | CHKD: CM | APPROVED: J M Raphael

BERKELEY, CALIFORNIA
DATE: APRIL 1, 1972

FIG. 21



DOWNSTREAM FACE

LOOKING UPSTREAM

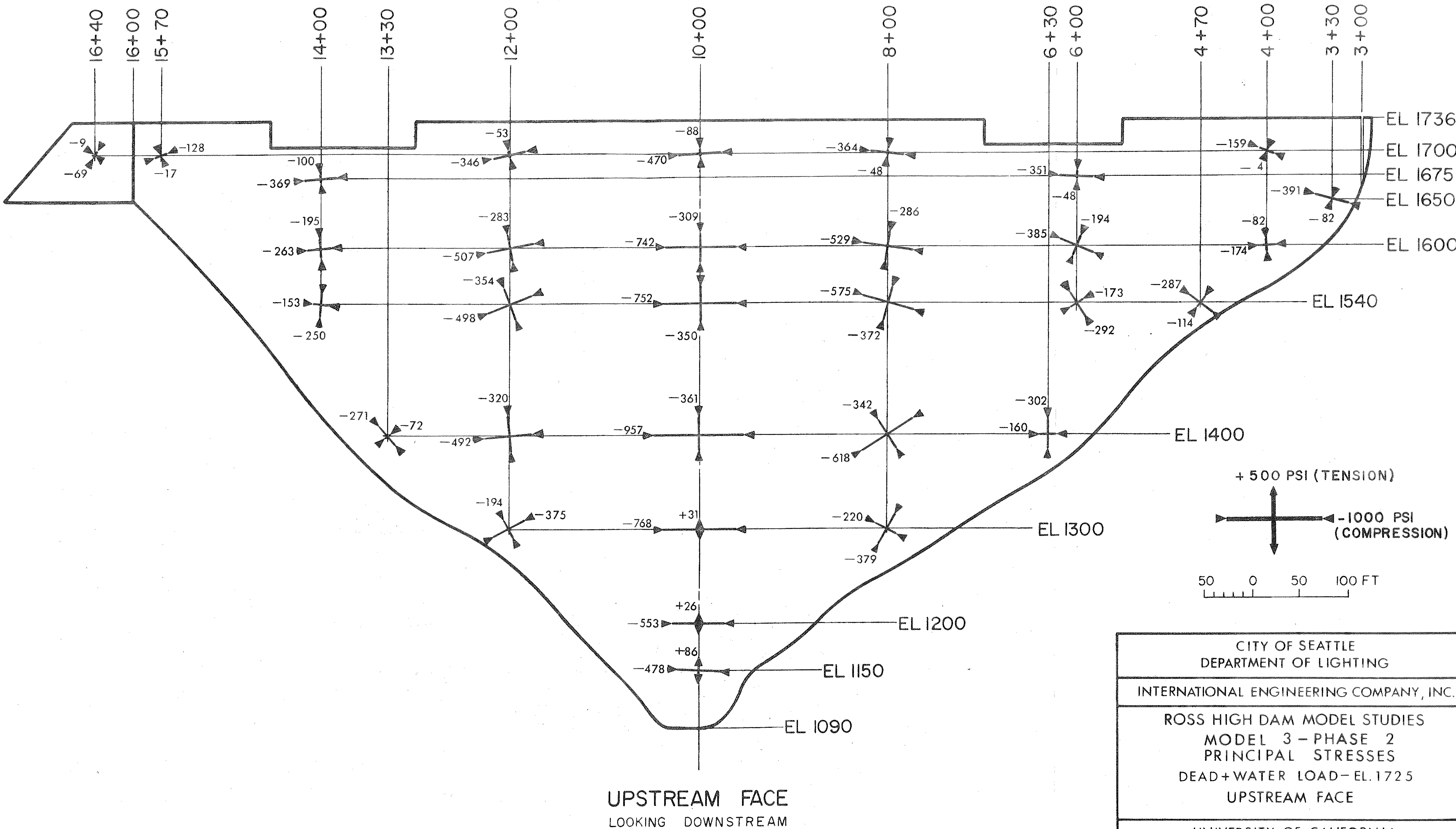
CITY OF SEATTLE
DEPARTMENT OF LIGHTING

INTERNATIONAL ENGINEERING COMPANY, INC.

ROSS HIGH DAM MODEL STUDIES
MODEL 3 — PHASE 2
PRINCIPAL STRESSES
DEAD + WATER LOAD — EL. 1725
DOWNSTREAM FACE

UNIVERSITY OF CALIFORNIA
JEROME M. RAPHAEL, FACULTY INVESTIGATOR

DRAWN: BL	CHKD: CM	APPROVED: J.M. Raphael
BERKELEY, CALIFORNIA DATE: APRIL 1, 1972		FIG. 22



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INTERNATIONAL ENGINEERING COMPANY, INC.

ROSS HIGH DAM MODEL STUDIES
MODEL 3 – PHASE 2
PRINCIPAL STRESSES
DEAD+WATER LOAD – EL. 1725
UPSTREAM FACE

UNIVERSITY OF CALIFORNIA
JEROME M. RAPHAEL, FACULTY INVESTIGATOR

DRAWN: BL	CHKD: CM	APPROVED: [signature]
BERKELEY, CALIFORNIA DATE: APRIL 1, 1972		FIG. 23

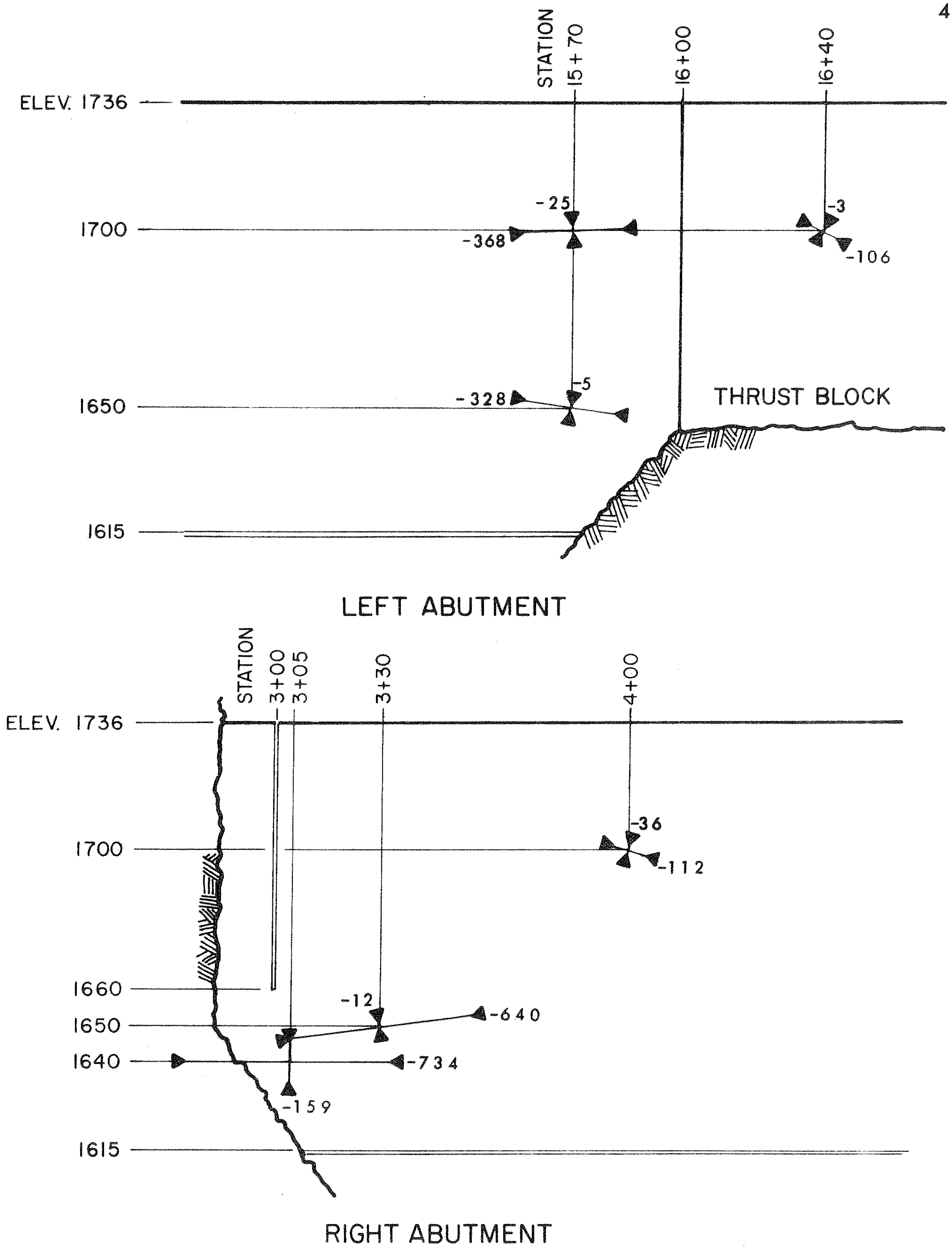
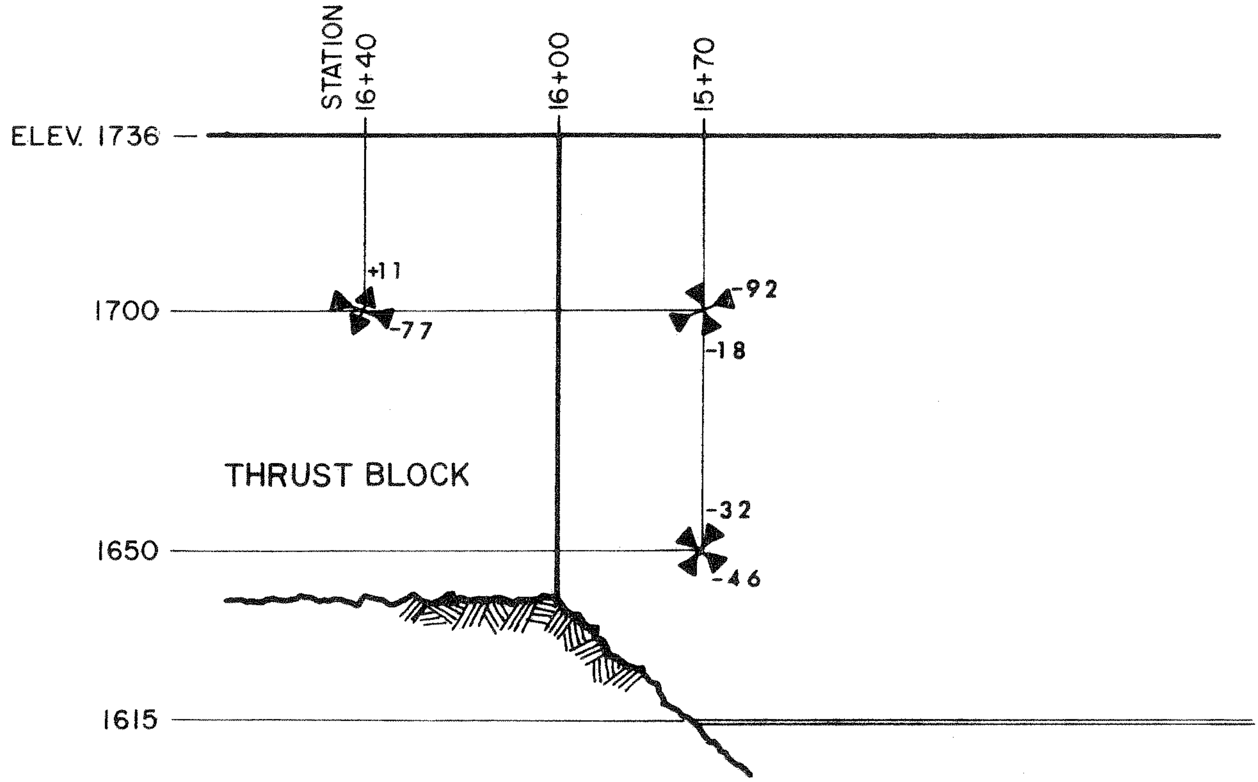
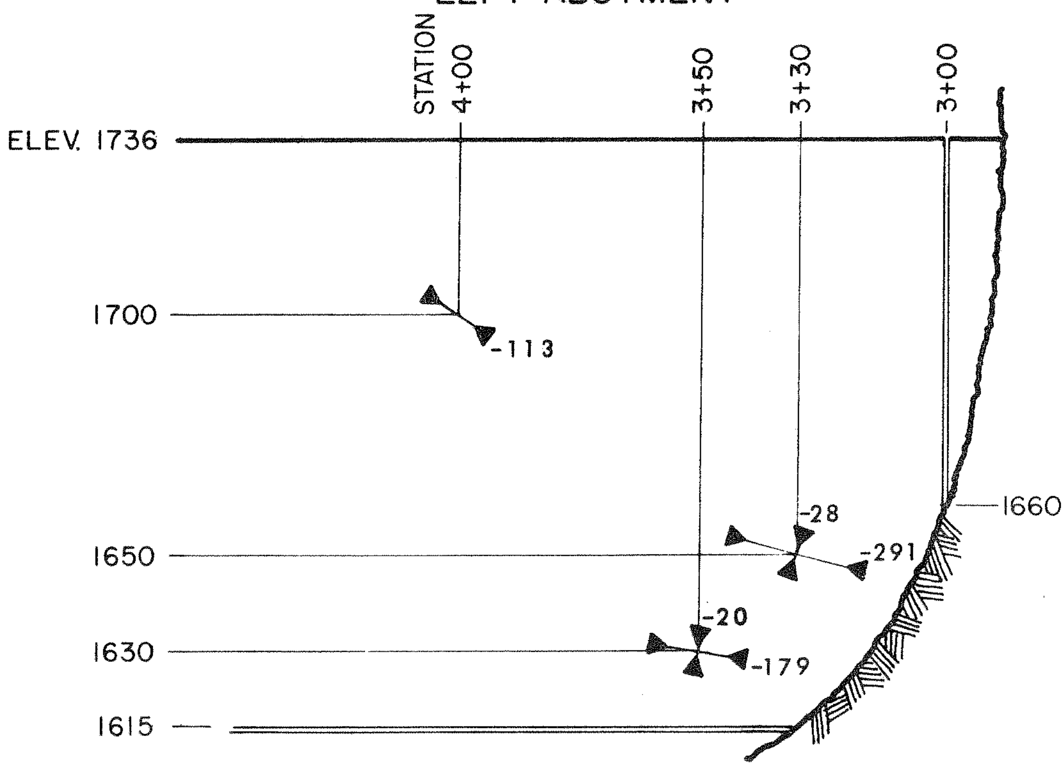


FIG. 24 - PRINCIPAL STRESSES AT ABUTMENTS

PHASE 9 - DOWNSTREAM FACE

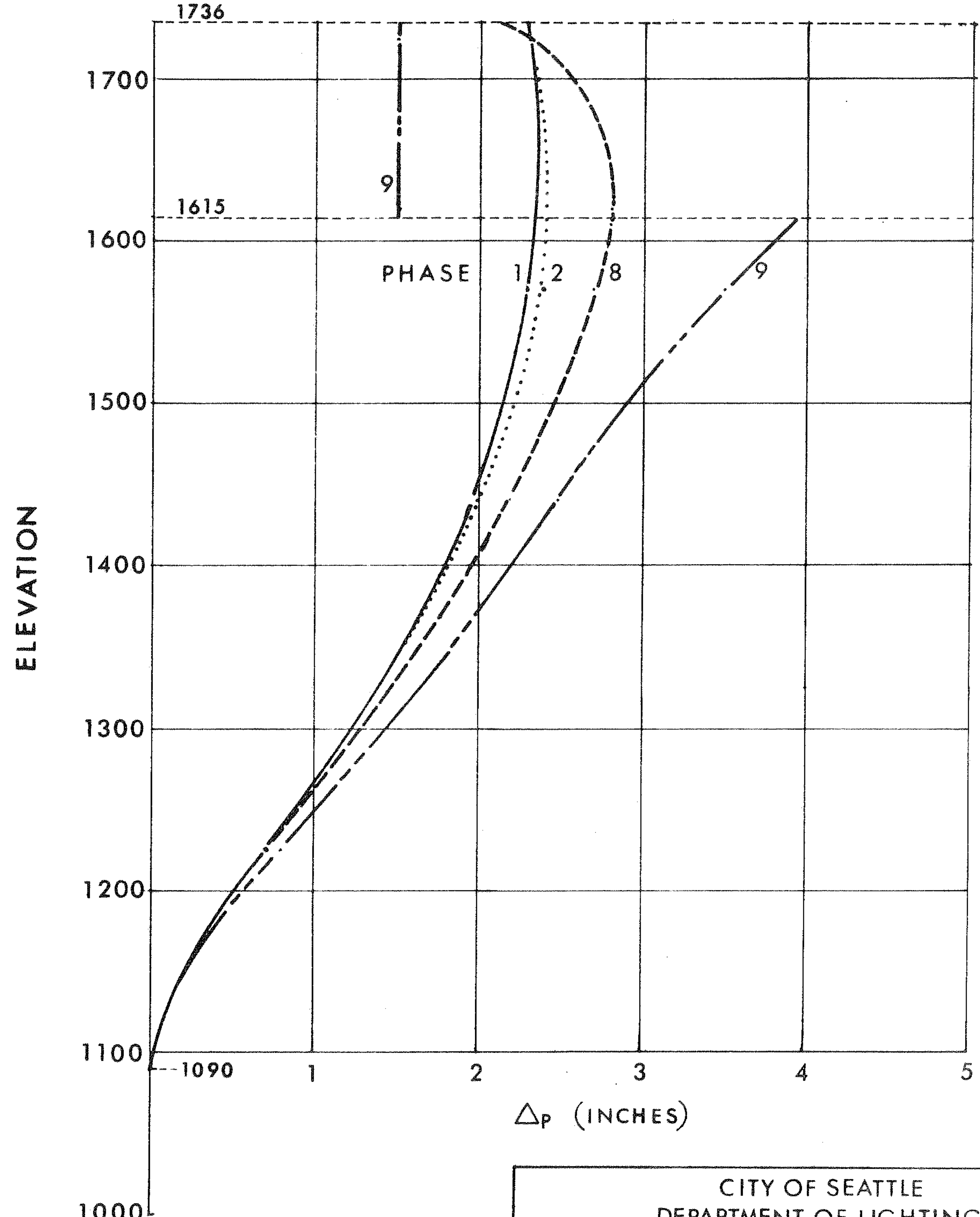


LEFT ABUTMENT



RIGHT ABUTMENT

FIG. 25 - PRINCIPAL STRESSES AT ABUTMENTS
PHASE 9 - UPSTREAM FACE



CITY OF SEATTLE
DEPARTMENT OF LIGHTING

INTERNATIONAL ENGINEERING COMPANY, INC.

ROSS HIGH DAM MODEL STUDIES

MODEL 3

RADIAL DEFLECTIONS

WATER LOAD ELEV. 1725, WITH SLOT

UNIVERSITY OF CALIFORNIA
JEROME M. RAPHAEL, FACULTY INVESTIGATOR

DRAWN: BL	CHKD: CM	APPROVED: [signature]
BERKELEY, CALIFORNIA DATE: APRIL 1, 1972		FIG. 26

APPENDIX B

TABLES

TABLE I
ROSS HIGH DAM - MODEL # 3
WATER LOAD + DEAD LOAD - ARCH STRESSES - DOWNSTREAM FACE

GAGE	ELEV.	STATION	PHASE 1	PHASE 2	PHASE 4	PHASE 5	PHASE 6	PHASE 7	PHASE 8	PHASE 9
1	1700	4+00	-399	-229	-236	-232	-249	-247	-224	-106
2	1700	8+00	-194	-198	-219	-202	-216	-169	-161	-111
3	1700	10+00	-252	-237	-266	-236	-236	-194	-205	-146
4	1700	12+00	-164	-165	-187	-169	-177	-112	-148	-87
5	1700	15+70	-428	-402	-420	-397	-451	-357	-366	-368
6	1700	16+40	-84	-79	-85	-80	-90	-61	-83	-85
7	1675	6+00	-484	-456	-479	-469	-489	-470	-516	-242
8	1675	14+00	-439	-446	-461	-449	-459	-437	-489	-268
9	1650	3+30	-355	-518	-536	-526	-632	-677	-686	-630
10	1600	4+00	-295	-322	-334	-349	-421	-449	-421	-551
11	1600	6+00	-467	-451	-468	-492				
12	1600	8+00	-304	-295	-314	-348	-548	-567	-615	-1179
13	1600	10+00	-177	-168	-175	-185	-376	-403	-468	-1050
14	1600	12+00	-338	-336	-358	-379	-457	-468	-489	-807
15	1600	14+00	-621	-627	-652	-658				
16	1540	4+70	-315	-329	-342	-335	-335	-345	-322	-461
17	1540	6+00	-488	-522	-498	-495				
18	1540	8+00	-408	-394	-421	-415	-663	-694	-772	-1104
19	1540	10+00	-160	-144	-170	-160	-316	-357	-425	-671
20	1540	12+00	-352	-348	-377	-372	-550	-585	-619	-816
21	1540	14+00	-479	-477	-496	-488				
22	1500	6+00	-427	-428	-444	-439	-598	-620	-669	-858
23	1500	8+00	-444	-430	-459	-454	-693	-716	-796	-1015
24	1500	10+00	-180	-165	-200	-191	-308	-348	-415	-569
25	1500	12+00	-421	-419	-447	-440	-592	-629	-681	-820
26	1500	14+00	-389	-384	-396	-390	-562	-576	-612	-774
27	1400	6+30	-580	-586	-605	-592	-630	-655	-706	-767
28	1400	8+00	-526	-518	-528	-523	-557	-559	-602	-666
29	1400	10+00	-371	-352	-370	-358	-380	-426	-476	-509
30	1400	12+00	-644	-638	-656	-646	-687	-720	-764	-829
31	1400	13+80	-474	-472	-489	-479	-512	-525	-545	-587
32	1300	8+00	-737	-734	-749	-739	-754	-771	-804	-829
33	1300	10+00	-185	-173	-183	-174	-177	-195	-210	-192
34	1300	12+00	-801	-790	-814	-792	-811	-823	-886	-888
35	1200	10+00	+147	+165	+172	+174	+184	+191	+193	+221

NOTES:

PHASE 1: COMPLETE
PHASE 2: VERTICAL SLOT AT STATION 3+00
PHASE 4: CONTINUOUS DOWNSTREAM HORIZONTAL SLOT AT ELEV. 1520
PHASE 5: CONTINUOUS DOWNSTREAM HORIZONTAL SLOT AT ELEV. 1615
PHASE 6: DOWNSTREAM CAP REMOVED
PHASE 7: CONTINUOUS UPSTREAM HORIZONTAL SLOT AT ELEV. 1615
PHASE 8: UPSTREAM CAP REMOVED
PHASE 9: CONTINUOUS HORIZONTAL SLOT AT 1615, ENTIRELY THROUGH DAM

II: GAGES RELOCATED ON ORIGINAL DAM

TABLE 2
ROSS HIGH DAM – MODEL # 3
WATER LOAD + DEAD LOAD – ARCH STRESSES – UPSTREAM FACE

GAGE	ELEV.	STATION	PHASE 1	PHASE 2	PHASE 4	PHASE 5	PHASE 6	PHASE 7	PHASE 8	PHASE 9
41	1700	4+00	– 209	– 138	– 146	– 142	– 174	– 177	– 190	– 83
40	1700	8+00	– 369	– 360	– 381	– 363	– 367		– 329	– 179
39	1700	10+00	– 473	– 468	– 499	– 470	– 482	– 466	– 433	– 185
38	1700	12+00	– 346	– 330	– 351	– 327	– 331	– 324	– 288	– 187
37	1700	15+70	– 106	– 114	– 114	– 121	– 113	– 110	– 143	– 80
36	1700	16+40	– 16	– 24	– 18	– 23	– 17	– 17	– 19	– 1
43	1675	6+00	– 374	– 351	– 371	– 355	– 392	– 401	– 366	– 302
42	1675	14+00	– 399	– 367	– 396	– 367	– 407		– 336	– 306
44	1650	3+30	– 260	– 371	– 379	– 376	– 379	– 359	– 427	– 274
50	1600	4+00	– 140	– 174	– 180	– 179	– 206	– 181	– 427	– 502
49	1600	6+00	– 364	– 358	– 373	– 364	– 389	– 405		
48	1600	8+00	– 535	– 524	– 544	– 542	– 595	– 599	– 883	– 1251
47	1600	10+00	– 750	– 742	– 769	– 775	– 849	– 852	– 926	– 1338
46	1600	12+00	– 515	– 499	– 517	– 511	– 556	– 536	– 815	– 1080
45	1600	14+00	– 277	– 262	– 277	– 265	– 295	– 256		
56	1540	4+70	– 191	– 225	– 225	– 224	– 278	– 270	– 313	– 241
55	1540	6+00	– 211	– 207	– 218	– 211	– 260	– 293	– 476	– 585
54	1540	8+00	– 574	– 560	– 584	– 571	– 630	– 682	– 1035	– 1194
53	1540	10+00	– 758	– 752	– 778	– 769	– 851	– 888	– 1169	– 1332
52	1540	12+00	– 495	– 483	– 502	– 488	– 537	– 565	– 837	– 967
51	1540	14+00	– 163	– 154	– 164	– 155	– 192	– 205	– 375	– 484
61	1400	6+30	– 160	– 160	– 168	– 166	– 177	– 180	– 179	– 203
60	1400	8+00	– 556	– 541	– 562	– 547	– 562	– 605	– 632	– 640
59	1400	10+00	– 963	– 957	– 976	– 960	– 974	– 1003	– 1026	– 1033
58	1400	12+00	– 496	– 491	– 513	– 502	– 511	– 545	– 559	– 569
57	1400	13+30	– 158	– 152	– 161	– 156	– 169	– 197	– 191	– 195
64	1300	8+00	– 268	– 255	– 264	– 258	– 263	– 282	– 296	– 278
63	1300	10+00	– 767	– 768	– 786	– 773	– 780	– 806	– 831	– 836
62	1300	12+00	– 323	– 337	– 350	– 340	– 350	– 368	– 389	– 387
65	1200	10+00	– 557	– 553	– 558	– 551	– 555	– 565	– 582	– 590
66	1150	10+00	– 483	– 478	– 476	– 477	– 472	– 471	– 484	– 486

NOTES:

PHASE 1: COMPLETE
PHASE 2: VERTICAL SLOT AT STATION 3+00
PHASE 4: CONTINUOUS DOWNSTREAM HORIZONTAL SLOT AT ELEV. 1520
PHASE 5: CONTINUOUS DOWNSTREAM HORIZONTAL SLOT AT ELEV. 1615
PHASE 6: DOWNSTREAM CAP REMOVED
PHASE 7: CONTINUOUS UPSTREAM HORIZONTAL SLOT AT ELEV. 1615
PHASE 8: UPSTREAM CAP REMOVED
PHASE 9: CONTINUOUS HORIZONTAL SLOT AT 1615, ENTIRELY THROUGH DAM

II: GAGES RELOCATED ON ORIGINAL DAM

TABLE 3
ROSS HIGH DAM—MODEL # 3
WATER LOAD + DEAD LOAD—CANTILEVER STRESSES—DOWNSTREAM FACE

GAGE	ELEV.	STATION	PHASE 1	PHASE 2	PHASE 4	PHASE 5	PHASE 6	PHASE 7	PHASE 8	PHASE 9
1	1700	4+00	− 19	− 19	− 19	− 19	− 12	− 7	− 7	− 41
2	1700	8+00	− 5	− 8	− 9	− 12	− 13	− 1	− 20	− 36
3	1700	10+00	+ 17	+ 11	+ 9	+ 3	+ 2	+ 12	− 3	− 26
4	1700	12+00	+ 11	+ 5	+ 3	+ 1	0	+ 10	− 13	− 21
5	1700	15+70	− 33	− 34	− 34	− 31	− 33	− 29	− 32	− 25
6	1700	16+40	− 43	− 40	− 44	− 41	− 44	− 40	− 44	− 24
7	1675	6+00	− 33	− 35	− 37	− 38	− 45	− 43	− 65	− 60
8	1675	14+00	− 7	+ 16	+ 6	+ 26	+ 19	+ 128	− 26	− 34
9	1650	3+30	− 51	− 103	− 107	− 99	− 87	− 69	− 68	− 22
10	1600	4+00	− 44	− 68	− 67	− 91	+ 91	+ 166	+ 246	− 103
11	1600	6+00	+ 22	+ 19	+ 20	− 23				
12	1600	8+00	+ 29	+ 25	+ 18	− 67	+ 145	+ 280	+ 318	− 26
13	1600	10+00	+ 146	+ 133	+ 125	− 8	+ 241	+ 340	+ 356	− 65
14	1600	12+00	+ 59	+ 55	+ 48	− 23	+ 197	+ 301	+ 320	+ 42
15	1600	14+00	− 58	− 49	− 57	− 74				
16	1540	4+70	− 93	− 121	− 126	− 123	− 44	− 83	− 24	− 366
17	1540	6+00	− 123	− 138	− 130	− 134				
18	1540	8+00	− 36	− 43	− 94	− 103	+ 28	+ 55	+ 163	− 269
19	1540	10+00	+ 123	+ 115	+ 42	+ 31	+ 272	+ 304	+ 395	− 7
20	1540	12+00	+ 68	+ 62	− 4	− 10	+ 161	+ 190	+ 265	− 45
21	1540	14+00	− 212	− 201	− 205	− 200				
22	1500	6+00	− 183	− 201	− 203	− 206	− 251	− 323	− 429	− 883
23	1500	8+00	+ 57	+ 46	− 10	− 19	+ 150	+ 172	+ 139	− 198
24	1500	10+00	+ 167	+ 158	+ 68	+ 58	+ 359	+ 400	+ 413	+ 62
25	1500	12+00	+ 12	+ 6	− 56	− 61	+ 84	+ 113	+ 69	− 199
26	1500	14+00	− 241	− 228	− 230	− 226	− 285	− 258	− 318	− 513
27	1400	6+30	− 404	− 402	− 413	− 407	− 454	− 484	− 540	− 627
28	1400	8+00	− 249	− 249	− 250	− 256	− 320	− 332	− 436	− 585
29	1400	10+00	+ 28	+ 25	+ 27	+ 16	− 30	− 26	− 91	− 211
30	1400	12+00	− 275	− 270	− 271	− 273	− 322	− 315	− 379	− 476
31	1400	13+80	− 213	− 208	− 216	− 211	− 234	− 242	− 260	− 302
32	1300	8+00	− 876	− 865	− 876	− 870	− 890	− 919	− 964	− 995
33	1300	10+00	− 391	− 384	− 385	− 385	− 403	− 409	− 448	− 483
34	1300	12+00	− 441	− 430	− 428	− 415	− 413	− 392	− 455	− 409
35	1200	10+00	− 486	− 488	− 495	− 491	− 496	− 507	− 518	− 526

NOTES:

PHASE 1: COMPLETE
PHASE 2: VERTICAL SLOT AT STATION 3+00
PHASE 4: CONTINUOUS DOWNSTREAM HORIZONTAL SLOT AT ELEV. 1520
PHASE 5: CONTINUOUS DOWNSTREAM HORIZONTAL SLOT AT ELEV. 1615
PHASE 6: DOWNSTREAM CAP REMOVED
PHASE 7: CONTINUOUS UPSTREAM HORIZONTAL SLOT AT ELEV. 1615
PHASE 8: UPSTREAM CAP REMOVED
PHASE 9: CONTINUOUS HORIZONTAL SLOT AT 1615, ENTIRELY THROUGH DAM
II: GAGES RELOCATED ON ORIGINAL DAM

TABLE 4

ROSS HIGH DAM-MODEL #3

WATER LOAD+DEAD LOAD-CANTILEVER STRESSES-UPSTREAM FACE

GAGE	ELEV.	STATION	PHASE 1	PHASE 2	PHASE 4	PHASE 5	PHASE 6	PHASE 7	PHASE 8	PHASE 9
41	1700	4+00	- 59	- 25	- 27	- 27	- 31	- 38	- 44	- 30
40	1700	8+00	- 56	- 52	- 42	- 48	- 40		- 42	- 27
39	1700	10+00	- 94	- 90	- 88	- 83	- 83	- 87	- 74	- 54
38	1700	12+00	- 71	- 68	- 66	- 65	- 64	- 73	- 57	- 38
37	1700	15+70	- 29	- 32	- 34	- 36	- 35	- 57	- 50	- 31
36	1700	16+40	- 56	- 54	- 55	- 54	- 55	- 55	- 54	- 65
43	1675	6+00	- 60	- 49	- 49	- 48	- 62	- 57	- 29	- 4
42	1675	14+00	- 82	- 102	- 90	- 100	- 101		- 51	- 34
44	1650	3+30	- 125	- 101	- 105	- 106	- 109	- 116	- 102	- 45
50	1600	4+00	- 128	- 83	- 83	- 87	- 118	- 42	- 210	- 52
49	1600	6+00	- 242	- 221	- 225	- 232	- 276	- 19		
48	1600	8+00	- 296	- 291	- 282	- 313	- 378	- 116	- 614	- 134
47	1600	10+00	- 314	- 309	- 294	- 335	- 395	- 258	- 516	- 111
46	1600	12+00	- 285	- 291	- 277	- 313	- 361	- 197	- 582	- 641
45	1600	14+00	- 171	- 195	- 183	- 204	- 245	+ 19		
56	1540	4+70	- 213	- 176	- 176	- 178	- 214	- 191	- 196	+ 44
55	1540	6+00	- 297	- 258	- 259	- 256	- 304	- 292	- 401	- 9
54	1540	8+00	- 393	- 387	- 388	- 381	- 446	- 467	- 656	- 293
53	1540	10+00	- 352	- 351	- 354	- 347	- 423	- 443	- 611	- 275
52	1540	12+00	- 364	- 370	- 370	- 368	- 425	- 448	- 584	- 254
51	1540	14+00	- 235	- 249	- 242	- 250	- 286	- 296	- 307	- 77
61	1400	6+30	- 322	- 302	- 298	- 305	- 263	- 229	- 230	- 115
60	1400	8+00	- 434	- 419	- 417	- 413	- 362	- 355	- 326	- 148
59	1400	10+00	- 364	- 362	- 349	- 350	- 289	- 292	- 253	- 118
58	1400	12+00	- 306	- 322	- 317	- 324	- 275	- 285	- 255	- 135
57	1400	13+30	- 179	- 191	- 184	- 194	- 153	- 171	- 156	- 72
64	1300	8+00	- 349	- 344	- 356	- 347	- 345	- 349	- 370	- 268
63	1300	10+00	+ 32	+ 31	+ 42	+ 34	+ 68	+ 80	+ 101	+ 163
62	1300	12+00	- 217	- 232	- 232	- 241	- 225	- 227	- 206	- 175
65	1200	10+00	+ 22	+ 26	+ 44	+ 37	+ 58	+ 80	+ 85	+ 133
66	1150	10+00	+ 77	+ 86	+ 97	+ 88	+ 98	+ 114	+ 115	+ 135

NOTES:

PHASE 1: COMPLETE
PHASE 2: VERTICAL SLOT AT STATION 3+00
PHASE 4: CONTINUOUS DOWNSTREAM HORIZONTAL SLOT AT ELEV. 1520
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#: GAGES RELOCATED ON ORIGINAL DAM