REPORT NO.
UC SESM 72-12

STRUCTURES AND MATERIALS RESEARCH
DEPARTMENT OF CIVIL ENGINEERING

STRUCTURAL MODEL INVESTIGATIONS FOR ROSS HIGH DAM

MODEL 2
THIRD STAGE AS CONSTRUCTED

BY

JEROME M. RAPHAEL

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

SEPTEMBER 1972

STRUCTURAL ENGINEERING LABORATORY
UNIVERSITY OF CALIFORNIA
BERKELEY CALIFORNIA

STRUCTURAL MODEL INVESTIGATIONS

FOR

ROSS HIGH DAM

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San Francisco, California

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STRUCTURAL MODEL INVESTIGATIONS FOR ROSS HIGH DAM

MODEL 2 - THIRD STAGE AS CONSTRUCTED

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. Since the additional concrete is to be added to the present dam which is already under a state of stress, it was necessary to test a model of the present dam, termed "Ross Dam", in order to determine its stresses prior to construction, and the additional stresses due to raising the dam and increasing the elevation of the reservoir.

This report completes a trilogy of three reports covering all phases of the model tests. Report UCSESM 71-11, Model 1 - Ross High Dam, covered the behavior of a homogeneous model of Ross Dam as raised to its ultimate height with crest elevation 1736. Report UCSESM 72-11, Model 3 - Staged Construction, also studied the dam raised to its ultimate height, but with the additional concrete

assumed more deformable than the old concrete of the low dam, and with a number of assumed structural discontinuities. The work reported here is on Model 2, a homogeneous model which represents the present Ross Dam constructed to elevation 1615 with full water load at elevation 1600, and also with water drawn down to elevation 1475 in preparation for construction of the fourth stage.

In addition, at Stage 10 during the testing of Model 3, the configuration of the lower part of the model corresponded exactly to that of Model 2. Accordingly Model 3 was tested with a load corresponding to that of Model 2, for a direct comparison of stresses.

ACKNOWLEDGMENTS

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. The testing organization was led by Engineer Charles Mercer, assisted by Research Assistant Otto Fajardo and a staff varying from four to ten technicians.

MODEL

Figure 1 shows Ross Dam as constructed to elevation 1615. This was modeled at a scale of 1:240 as shown in Figure 2. The plaster-celite model was poured between fiberglass molds on a plaster-celite block foundation cemented into a channel-shaped reinforced concrete test pit. Modulus of elasticity of the model and foundation was 250,000 psi. The structural action of the spillway opening was approximated by slots cut to the shape of the spillway crest. After drying, the model was fitted with 54 SR-4 strain gage rosettes as shown in Figs. 3 and 4. These were coupled to the SESM low-speed scanner for observations at the rate of four per second. Live loading was by means of horizontal air bags controlled by water columns, and dead load was by the method of integration using lead bricks for uniform loads at each horizontal slice. The above summary of the test method is given in greater detail in the first report of this series, "Model 1 - Ross High Dam".

SCOPE OF TESTS

The purpose for testing a model of Ross Dam constructed to Stage 3 was to provide base stresses by which to determine the incremental stresses in the dam when the fourth stage was added and loaded. Two loading conditions were important: the normal water surface elevation 1600; and the level to which the water would be drawn down prior to construction, elevation 1475. For each of these series of tests, live load was applied to the upstream face in three different load intensities, and the stress results averaged. At the conclusion of the two live load test series, Model 2 was cut down by 100-ft. increments, each stage being loaded with three cycles of uniformly distributed lead bricks to determine the dead load stresses. Finally, at Stage 10 of Model 3, water load was applied to elevation 1600 at three intensities of pressure, to check on the Model 2 tests. Strain gage layout for this last series is shown

on Figs. 5 and 6.

STRESSES

Stresses reported here are necessarily all surface stresses, as these are the only stresses measurable on structural models. They are reported in two ways, as orthogonal stresses and as principal stresses. The orthogonal stresses, i.e., arch stresses, cantilever stresses, and shears are the most useful for the purposes of this study, as they can most easily be combined algebraically with like stresses from other studies. Five loading cases are reported: water load, dead load, water plus earthquake load, water plus dead load, and water plus earthquake plus dead load. Figs. 7 through 10 show the values of orthogonal stresses on the dam for all these cases with water at the two levels of interest. The magnitude, sense and direction of the principal stresses are useful in visualizing the structural behavior of the dam as a whole under load. These are shown in Figs. 11 and 12 for dead load plus water to elevation 1600 only. Corresponding orthogonal stresses and principal stresses for Model 3 loaded to elevation 1600 are found in Figs. 13 through 16.

Comparison of stresses determined by Models 2 and 3 can be found in Tables 1 and 2 for the orthogonal stresses, for the combination of dead load plus water to elevation 1600.

Considering first Figs. 7 and 8 showing the orthogonal stresses on Model 2 with the maximum water surface elevation 1600, it can be seen that the maximum arch stress due to dead plus water load is 575 psi compression at elevation 1400 on the downstream face at the right abutment. This increases to 697 psi compression when earthquake load is added. Cantilever stresses are more varied. The maximum vertical compressive stress is 528 psi at elevation 1300 on the right abutment, increasing to 591 psi when earthquake is added. Bands of moderate vertical tension are found on the downstream face ranging from elevation 1540 down to one pip at elevation 1400, the

maximum tension being 117 psi at elevation 1500 at the centerline.

On the upstream face, all arch and cantilever stresses are compressive. The maximum arch stress for dead plus water load is 608 psi at elevation 1400 at the centerline, increasing to 722 psi when earthquake is added. Cantilever stresses are everywhere less than that, the maximum being 329 psi at elevation 1400 at station 8+00 under dead plus water load, increasing only slightly to 345 psi adding earthquake.

Corresponding orthogonal stresses for the same water surface elevation 1600 as determined on Model 3 are shown on Figs. 13 and 14, which give the stresses determined for all five loading cases. Maximum downstream stresses shift around a bit, with maximum arch stress at 468 psi compression near the base for dead plus water load, increasing to 569 psi when earthquake is added. Again the cantilever stresses show the band of vertical tension at higher elevations, with a maximum tension of 124 psi at elevation 1500 at the centerline for dead plus water load, increasing to 175 psi tension when earthquake is added. Maximum downstream compression is 516 psi at elevation 1300, right abutment, increasing to 577 psi adding earthquake.

For the upstream face, all stresses are compressive, with a maximum arch stress of 606 psi at elevation 1400 at the centerline, increasing to 719 psi adding earthquake. The maximum cantilever stress occurred at the same location, and was 322 psi, increasing to 341 psi adding earthquake.

Tables 1 and 2 have been prepared so that the orthogonal stresses in Models 2 and 3 can be compared for common locations for one loading case only, dead load plus water load to elevation 1600. Correspondence between stresses determined independently on the two models is fairly good, leading to confidence in the results.

The orthogonal stresses for the low-load case where the water is drawn

down to the construction level of elevation 1475 are shown on Figs. 9 and 10. As might be expected, stresses are fairly low for this case, everywhere being less than 300 psi compression on the downstream face, and less than 400 psi compression on the upstream face for dead plus water loads. The vertical tensile stresses that were found on the downstream face with the dam fully loaded are not found at all in the drawdown case.

The principal stresses for Ross Dam with dead load and water load to elevation 1600 are shown in Figs. 11 and 12 for Model 2 and in Figs. 15 and 16 for Model 3.

In interpreting the stresses shown, it should be recalled that there were slight but significant differences in the models, that would affect the way in which each would distribute the loads imposed on it. For Model 2, the spillway was modelled as a series of cantilevers that would carry no arch load. For Model 3, the spillway was not modelled, and hence arch action was allowed in the spillway area.

Looking first at the downstream face, maximum compressive principal stress around 730 psi is found at three locations near the abutments of the dam in Model 2. Since this is a region of rapidly varying stress due to its proximity to the foundation, the slightly smaller stresses at these locations in Model 3 may be due to differences in strain gage location. The generally higher arch stresses in Model 3 at elevation 1590 are probably due to the continuous arch in this model. The vertical tension region with a maximum tensile principal stress of 118 psi at the center at elevation 1500 is well shown. Other stresses at locations away from the above-mentioned structural features show fair correspondence.

For the upstream face, the correspondence of stresses found in Model 2 with those of Model 3 is generally good. Maximum compressive principal stress of 690 psi is found at elevation 1540 at the centerline. Minor tension is found at one location, at elevation 1400 at the left abutment.

DEFLECTION

Downstream radial deflection of the maximum cantilever of Model 2 under water load to elevation 1600 is shown on Fig. 17. The maximum deflection of 1.21 inches is matched by the maximum deflection of 1.15 inches found in Model 3, the crest of which is stiffer than that of Model 2 because of the filled-in spillway section.

DISCUSSION

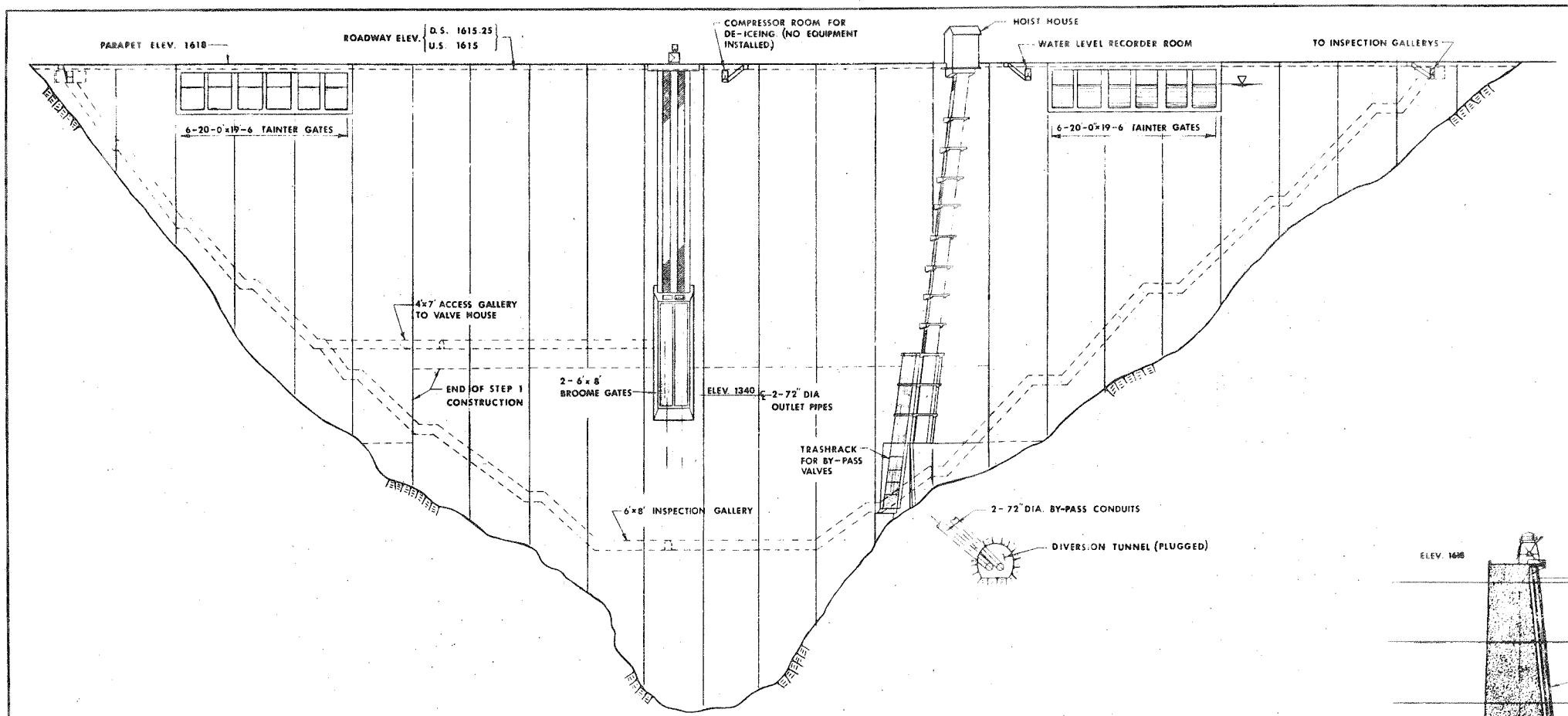
Stresses for the third stage of Ross Dam have been determined on two models, and the question arises, when differences are shown, how to interpret these values: optimistically accept the low stresses; pessimistically accept the higher stresses; or statistically average the different stresses. It will be noted that the highest principal stresses are identical on both models, and neither is cause for concern as to its magnitude. However, keeping in mind that the test on Model 2 most closely approximates the actual structural configurations of the third Stage Ross Dam, it is recommended that the Model 2 results be accepted for study, and that Model 3 results be used only for general corroborations of stresses. It should be noted that deflection which is a fairly sensitive indicator of structural behavior, is nearly identical for the two models.

CONCLUSIONS

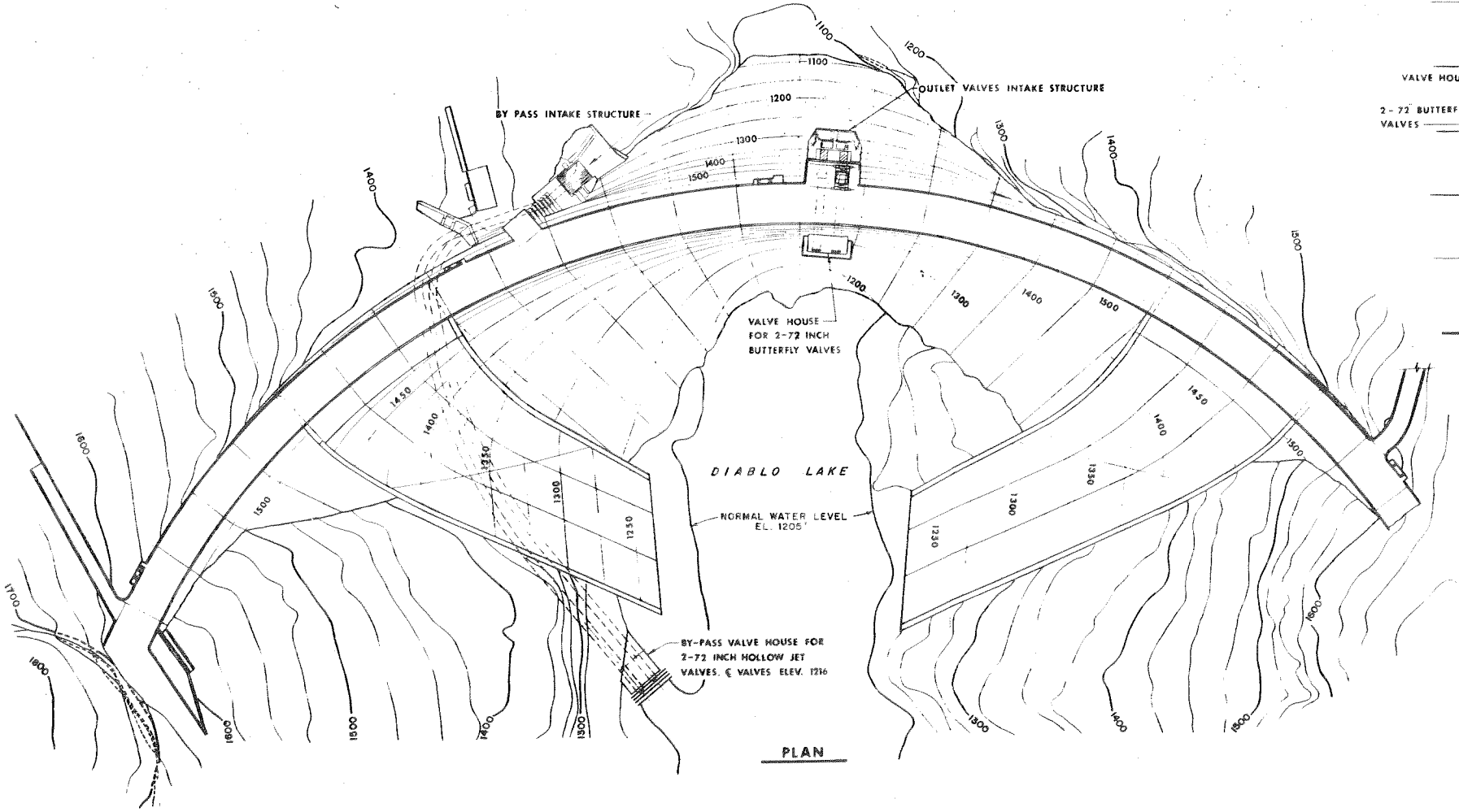
For the third stage of Ross Dam, stresses for dead load plus water load to elevation 1600 are quite moderate, the maximum compression being 608 psi, increasing to 722 psi when the Westergaard horizontal earthquake load for 0.1 g is added. Maximum orthogonal tension was 117 psi. The maximum principal stresses observed during this test were 730 psi compression and 118 psi tension for dead plus water load. While Models 2 and 3 differed somewhat in configuration, maximum stresses of the same magnitude were found in both models.

APPENDIX A

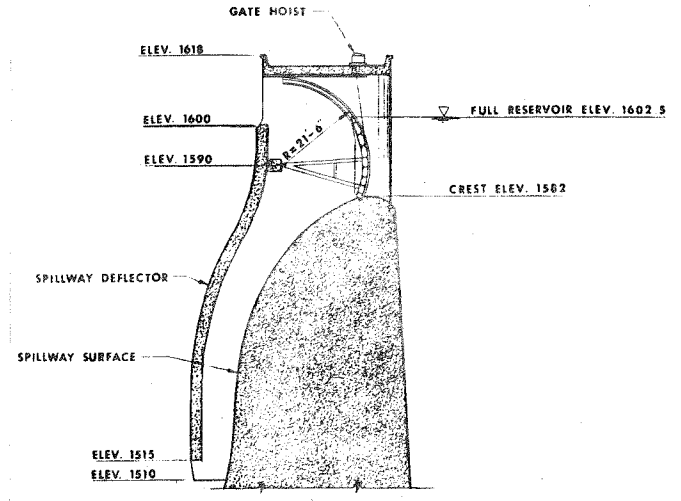
DRAWINGS



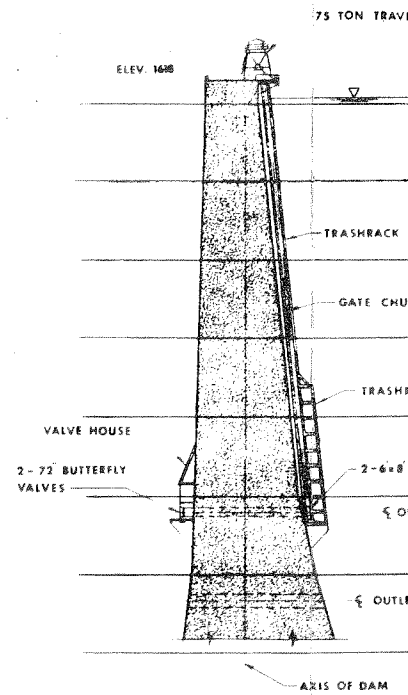
UPSTREAM ELEVATION



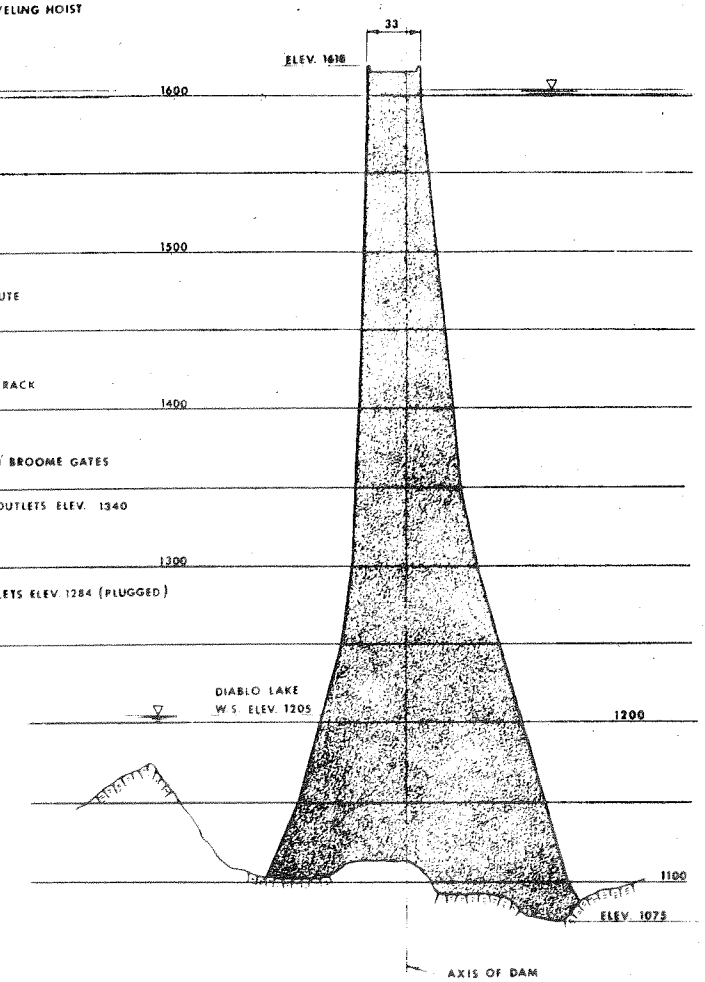
PLAN



TYPICAL SPILLWAY SECTION



SECTION THRU ELEV. 1340 OUTLET WORKS

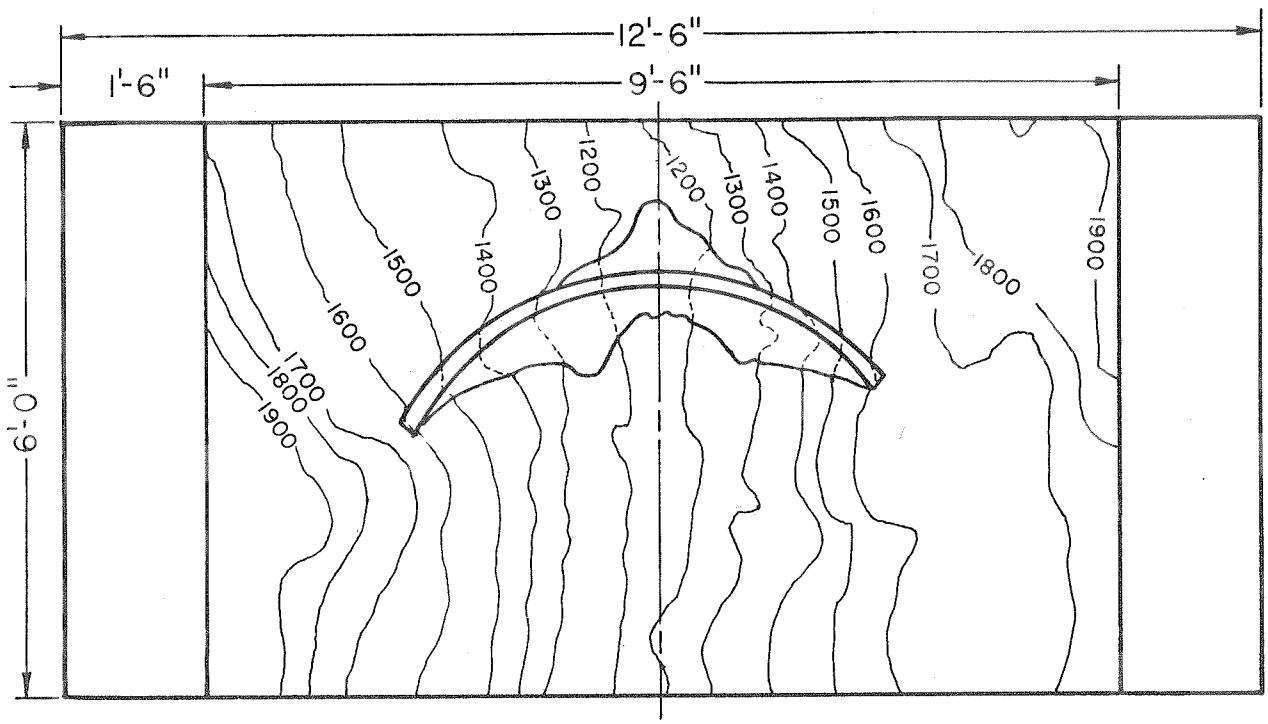


MAXIMUM SECTION

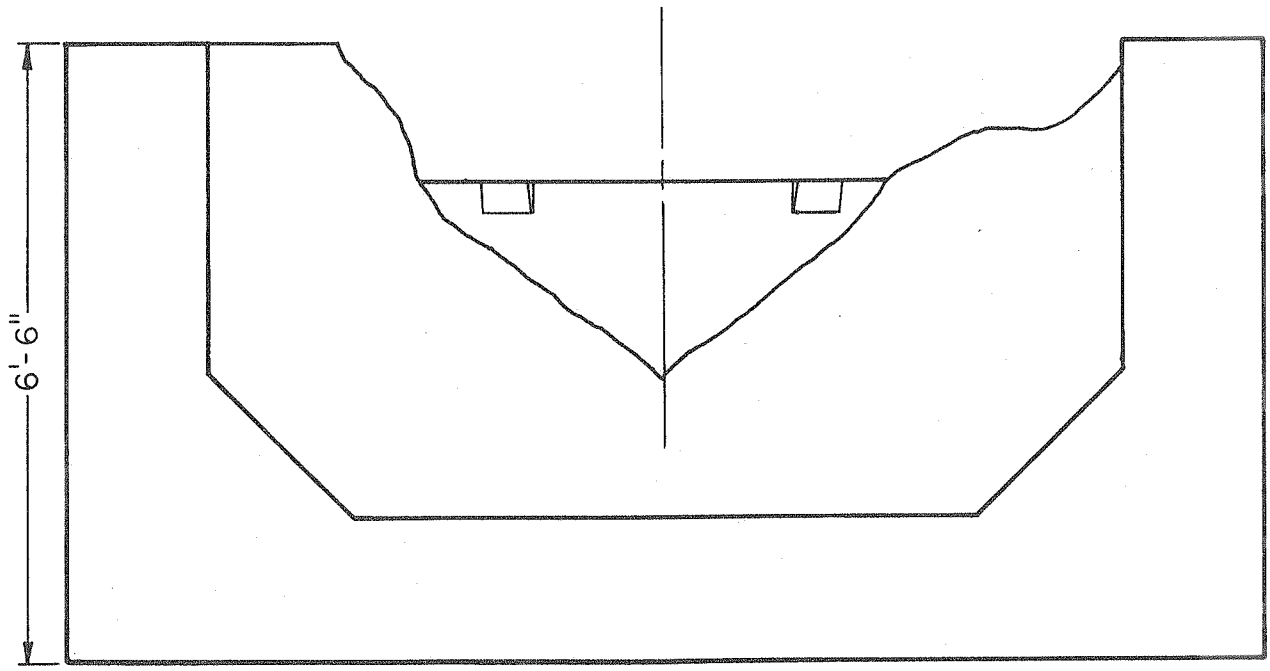
FIGURE 1

ROSS PROJECT

DAM - PLAN, ELEVATION AND SECTIONS

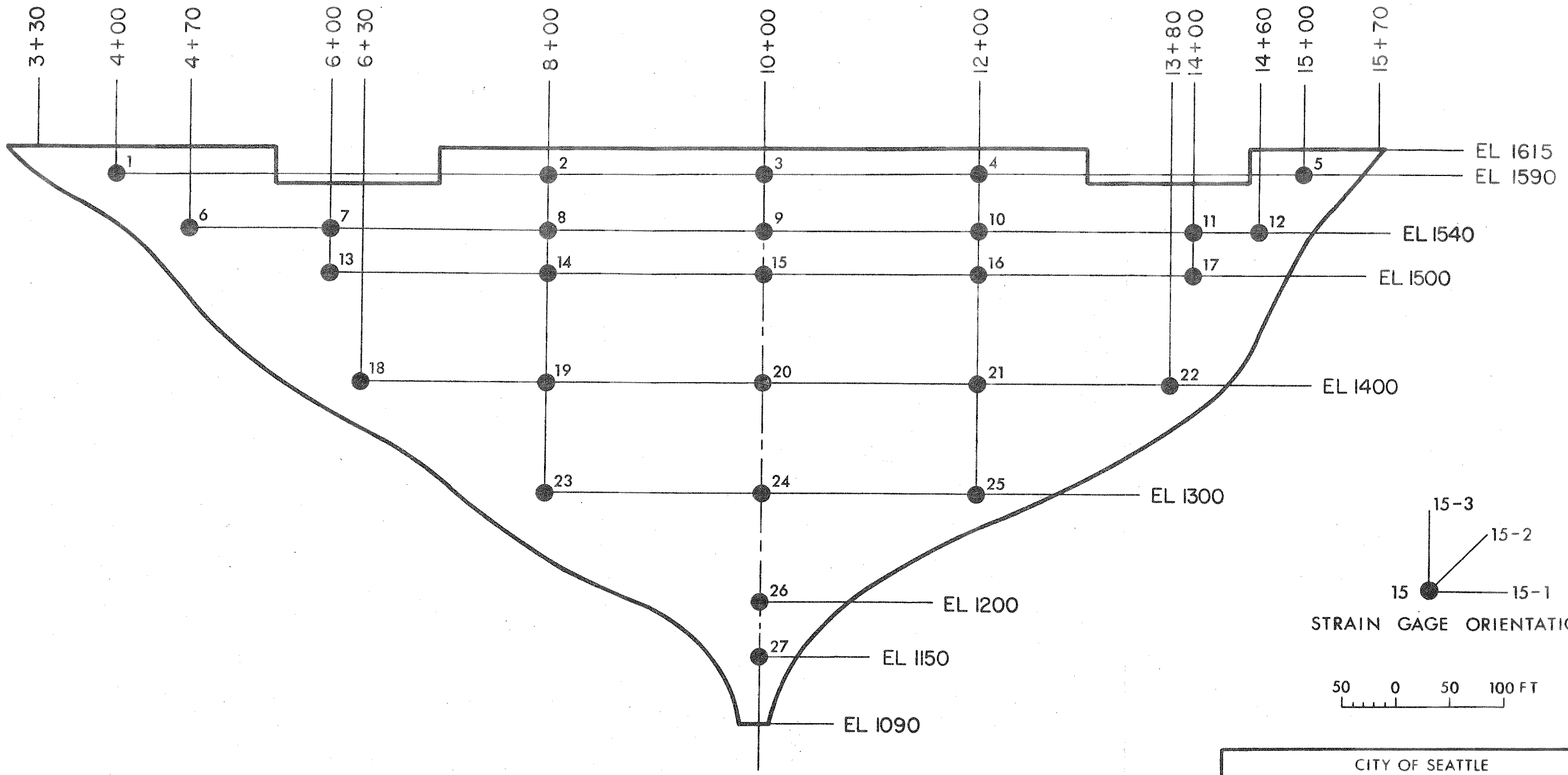


PLAN



ELEVATION

FIG. 2 MODEL DAM AND TEST PIT



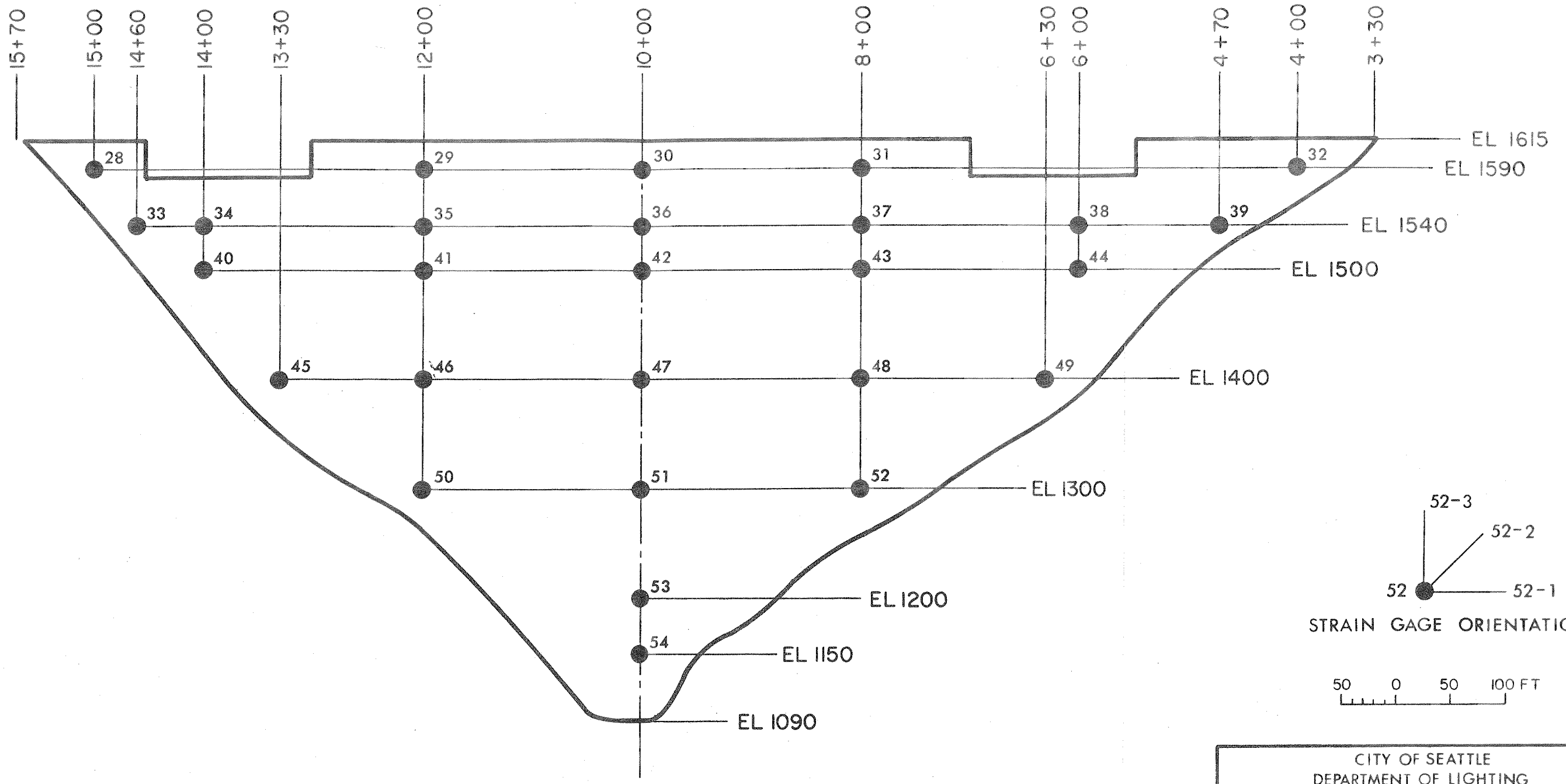
STRAIN GAGE ORIENTATION

50 0 50 100 FT

DOWNSTREAM FACE

LOOKING UPSTREAM

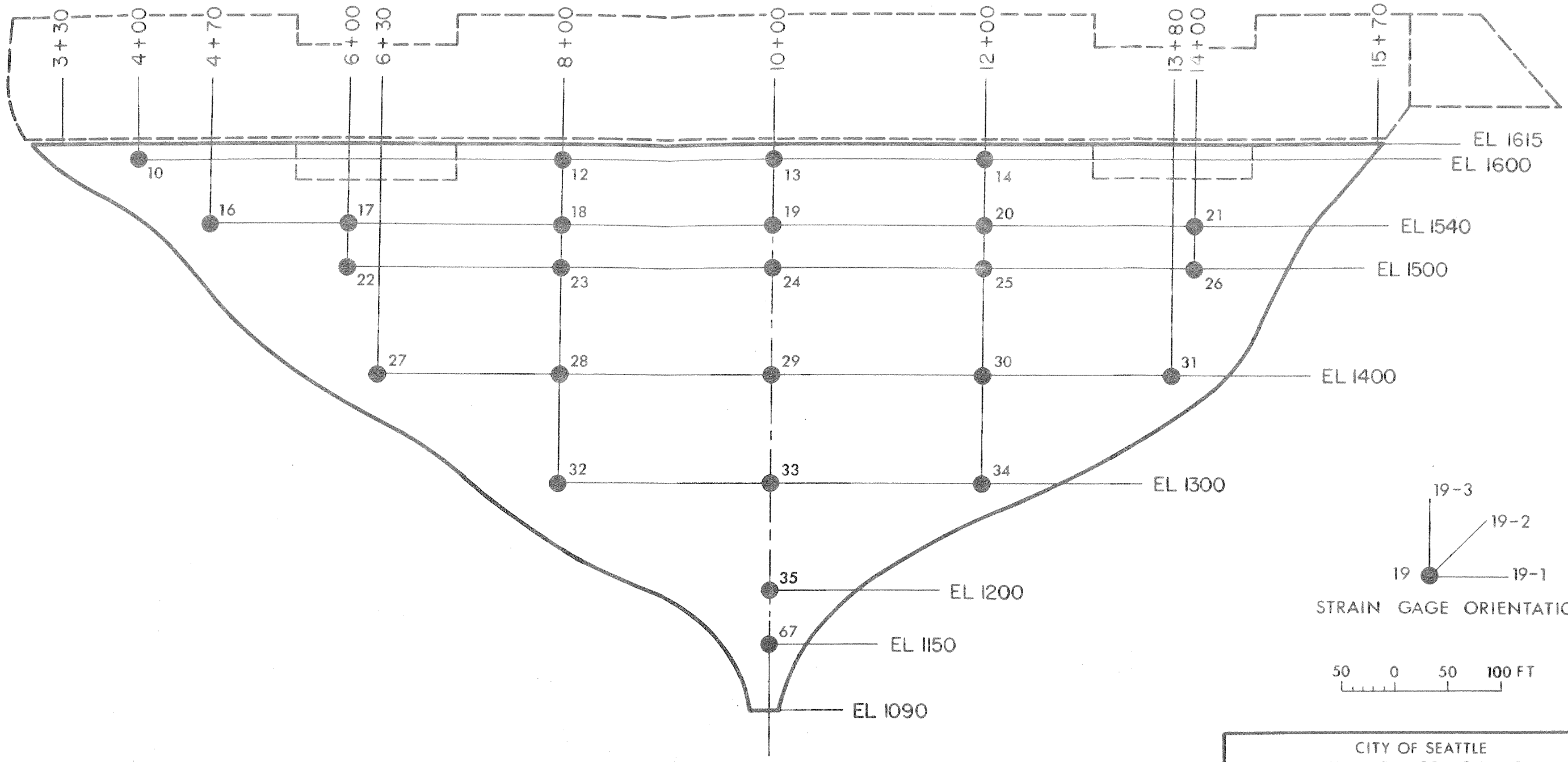
CITY OF SEATTLE DEPARTMENT OF LIGHTING
INTERNATIONAL ENGINEERING COMPANY INC.
ROSS HIGH DAM MODEL STUDIES MODEL 2 STRAIN GAGE LOCATIONS DOWNSTREAM FACE
UNIVERSITY OF CALIFORNIA JEROME M. RAPHAEL, FACULTY INVESTIGATOR
DRAWN: BL CHKD: CM APPROVED: [signature]
BERKELEY, CALIFORNIA DATE: FEB. 1, 1971 — FIG. 3



UPSTREAM FACE
LOOKING DOWNSTREAM

STRAIN GAGE ORIENTATION

CITY OF SEATTLE DEPARTMENT OF LIGHTING		
INTERNATIONAL ENGINEERING COMPANY, INC.		
ROSS HIGH DAM MODEL STUDIES MODEL 2 STRAIN GAGE LOCATIONS UPSTREAM FACE		
UNIVERSITY OF CALIFORNIA JEROME M. RAPHAEL, FACULTY INVESTIGATOR		
DRAWN: BL	CHKD: CM	APPROVED: J.M. Raphael
BERKELEY, CALIFORNIA DATE: FEB. 1, 1971		FIG. 4



DOWNSTREAM FACE

LOOKING UPSTREAM

STRAIN GAGE ORIENTATION

50 0 50 100 FT

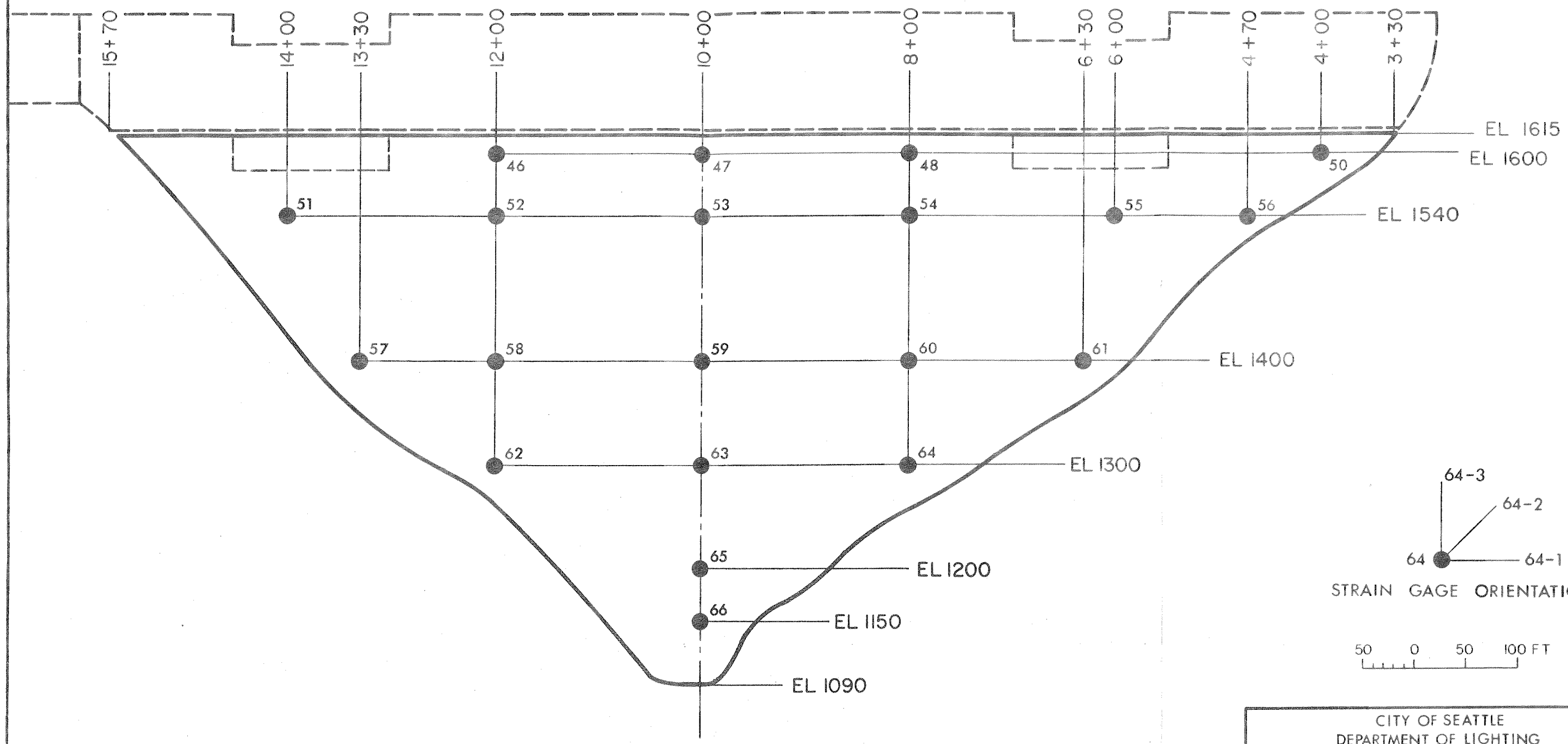
CITY OF SEATTLE
DEPARTMENT OF LIGHTING

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: B.L.	CHKD. C.M.	APPROVED: J.M. Raphael
BERKELEY, CALIFORNIA DATE: FEB. 1, 1971		FIG. 5



UPSTREAM FACE
LOOKING DOWNSTREAM

STRAIN GAGE ORIENTATION

50 0 50 100 FT

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

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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	1590	4+00	-189	+ 14	- 20	- 226	+ 17	- 24	- 5	- 20	- 1	- 194	- 6	- 21	- 231	- 3	- 25
2	1590	8+00	-200	+ 26	+ 4	- 238	+ 31	+ 5	- 2	- 21	- 1	- 202	+ 5	+ 3	- 240	+ 10	+ 4
3	1590	10+00	-242	+ 30	- 5	- 289	+ 36	- 6	0	- 30	- 4	- 242	0	- 9	- 289	+ 6	- 10
4	1590	12+00	-171	+ 22	+ 11	- 204	+ 26	+ 13	- 3	- 25	- 3	- 174	- 3	+ 8	- 207	+ 1	+ 10
5	1590	15+00	-323	+ 25	- 41	- 386	+ 30	- 49	- 1	- 24	- 1	- 324	+ 1	- 42	- 387	+ 6	- 50
6	1540	4+70	-281	+ 42	- 59	- 336	+ 51	- 71	+ 11	- 50	- 18	- 270	- 8	- 77	- 325	+ 1	- 89
7	1540	6+00	-377	+ 5	- 51	- 450	+ 7	- 60	+ 5	- 70	- 9	- 372	- 65	- 60	- 445	- 63	- 69
8	1540	8+00	-284	+ 138	- 17	- 340	+ 165	- 20	- 15	- 103	+ 4	- 299	+ 35	- 13	- 355	+ 62	- 16
9	1540	10+00	-321	+ 168	- 17	- 383	+ 200	- 20	+ 3	- 128	- 20	- 318	+ 40	- 37	- 380	+ 72	- 40
10	1540	12+00	-227	+ 118	+ 35	- 271	+ 141	+ 42	- 12	- 81	+ 4	- 239	+ 37	+ 39	- 283	+ 60	+ 46
11	1540	14+00	-328	+ 16	+ 13	- 391	+ 20	+ 16	+ 7	- 105	+ 2	- 321	- 89	+ 15	- 384	- 85	+ 18
12	1540	14+60	-340	+ 11	- 9	- 406	+ 14	- 11	+ 6	- 42	- 6	- 334	- 31	- 15	- 400	- 28	- 17
13	1500	6+00	-415	+ 29	- 98	- 496	+ 35	- 117	- 9	- 98	+ 2	- 424	- 69	- 96	- 505	- 63	- 115
14	1500	8+00	-295	+ 208	- 39	- 353	+ 249	- 47	- 34	- 138	- 14	- 329	+ 70	- 53	- 387	+ 111	- 61
15	1500	10+00	-261	+ 255	- 13	- 312	+ 304	- 15	+ 2	- 138	- 7	- 259	+ 117	- 20	- 310	+ 166	- 22
16	1500	12+00	-233	+ 176	+ 47	- 279	+ 210	+ 56	- 24	- 153	+ 18	- 257	+ 23	+ 65	- 303	+ 57	+ 74
17	1500	14+00	-343	- 29	+ 122	- 410	- 35	+ 145	+ 10	- 113	- 6	- 333	- 142	+ 116	- 400	- 148	+ 139
18	1400	6+30	-624	- 217	-267	- 746	- 260	- 319	+ 49	- 73	+ 3	- 575	- 290	- 264	- 697	- 333	- 316
19	1400	8+00	-324	+ 12	- 150	- 387	+ 15	- 179	- 47	- 134	- 14	- 371	- 122	- 164	- 434	- 119	- 193
20	1400	10+00	-195	+ 232	+ 20	- 233	+ 277	+ 23	- 16	- 182	- 8	- 211	+ 50	+ 12	- 249	+ 95	+ 15
21	1400	12+00	-394	- 25	+ 184	- 471	- 30	+ 220	- 16	- 133	+ 16	- 410	- 158	+ 200	- 487	- 163	+ 236
22	1400	13+80	-457	- 60	+ 171	- 546	- 72	+ 205	+ 65	- 92	+ 1	- 392	- 152	+ 172	- 481	- 164	+ 206
23	1300	8+00	-479	- 324	- 249	- 572	- 387	- 298	- 22	- 204	+ 37	- 501	- 528	- 212	- 594	- 591	- 261
24	1300	10+00	- 60	- 16	+ 39	- 71	- 20	+ 46	- 74	- 239	- 17	- 134	- 255	+ 22	- 145	- 259	+ 29
25	1300	12+00	-602	- 197	+ 245	- 720	- 235	+ 293	+ 52	- 165	+ 21	- 550	- 362	+ 266	- 668	- 400	+ 314
26	1200	10+00	+ 186	- 137	+ 11	+ 222	- 164	+ 10	- 166	- 237	+ 21	+ 20	- 374	+ 32	+ 56	- 401	+ 34
27	1150	10+00	+ 182	- 104	+ 37	+ 217	- 124	+ 44	- 307	- 241	+ 97	- 125	- 345	+ 134	- 90	- 365	+ 141

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 2
ORTHOGONAL STRESSES
WATER ELEVATION 1600
DOWNSTREAM FACE

UNIVERSITY OF CALIFORNIA
JEROME M. RAPHAEL, FACULTY INVESTIGATOR

DRAWN: B.L. | CHKD: C.M. | APPROVED: Jerome Raphael

BERKELEY, CALIFORNIA
DATE: FEB. 1, 1971

FIG. 7

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}
28	1590	15+00	- 64	- 11	+ 29	- 76	- 13	+ 34	+ 2	- 13	- 3	- 62	- 24	+ 26	- 74	- 26	+ 31
29	1590	12+00	-255	+ 2	- 42	-304	+ 2	- 51	- 2	- 36	+ 5	-257	- 34	- 37	-306	- 34	- 46
30	1590	10+00	-397	- 9	+ 20	-475	- 11	+ 24	- 7	- 25	- 3	-404	- 34	+ 17	-482	- 36	+ 21
31	1590	8+00	-310	- 1	+ 40	-371	- 1	+ 48	0	- 42	- 1	-310	- 43	+ 39	-371	- 43	+ 47
32	1590	4+00	- 52	0	- 18	- 62	- 1	- 22	+ 2	- 32	- 2	- 50	- 32	- 20	- 60	- 33	- 24
33	1540	14+60	- 52	- 37	- 9	- 62	- 44	- 10	+ 12	-117	+ 7	- 40	-154	- 2	- 50	-161	- 3
34	1540	14+00	-160	- 44	+ 63	-191	- 53	+ 76	+ 14	-108	+ 24	-146	-152	+ 87	-177	-161	+100
35	1540	12+00															
36	1540	10+00	-541	-134	- 33	-646	-160	- 39	- 11	-102	+ 31	-552	-236	- 2	-657	-262	- 8
37	1540	8+00	-463	-119	+ 70	-553	-142	+ 84	+ 2	- 97	+ 7	-461	-216	+ 77	-551	-239	+ 91
38	1540	6+00	-250	- 41	- 6	-298	- 49	- 7	+ 19	-115	+ 4	-231	-156	- 2	-279	-164	- 3
39	1540	4+00	-154	- 19	+ 30	-184	- 23	+ 36	- 12	-132	+ 8	-166	-151	+ 38	-196	-155	+ 44
40	1500	14+00	-126	- 63	- 5	-151	- 75	- 5	+ 12	-163	+ 3	-114	-226	- 2	-139	-238	- 2
41	1500	12+00	-441	-131	- 39	-527	-156	- 47	+ 16	-103	+ 10	-425	-234	- 29	-511	-259	- 37
42	1500	10+00	-558	-228	- 7	-666	-273	- 8	- 29	-143	+ 7	-587	-371	0	-695	-416	- 1
43	1500	8+00	-435	-140	+ 42	-520	-168	+ 50	+ 8	-119	- 4	-427	-259	+ 38	-512	-287	+ 46
44	1500	6+00	-181	- 50	- 8	-216	- 60	- 10	- 10	-158	+ 18	-191	-208	+ 10	-226	-218	+ 8
45	1400	13+30	-151	+ 12	+ 55	-180	+ 14	+ 66	- 20	-265	+183	-171	-253	+238	-200	-251	+249
46	1400	12+00	-343	- 84	+ 19	-410	-101	+ 23	+ 47	- 41	- 78	-296	-125	- 59	-363	-142	- 55
47	1400	10+00	-581	- 71	+ 4	-695	- 84	+ 5	- 27	-225	+ 2	-608	-296	+ 6	-722	-309	+ 7
48	1400	8+00	-361	- 86	+ 17	-431	-102	+ 20	- 3	-243	+ 3	-364	-329	+ 20	-434	-345	+ 23
49	1400	6+30	- 72	- 2	- 53	- 87	- 2	- 63	- 53	-268	+ 84	-125	-270	+ 31	-140	-270	+ 21
50	1300	12+00	-245	- 6	+ 30	-293	- 8	+ 36	- 34	-289	- 78	-279	-295	- 48	-327	-297	- 42
51	1300	10+00	-505	+210	+ 53	-604	+251	+ 64	- 60	-358	+ 35	-565	-148	+ 88	-664	-107	+ 99
52	1300	8+00	-177	- 14	- 18	-211	- 17	- 21	- 42	-304	- 21	-219	-318	- 39	-253	-321	- 42
53	1200	10+00	-322	+174	+ 3	-384	+209	+ 4	- 51	-285	- 14	-373	-111	- 11	-435	- 76	- 10
54	1150	10+00	-353	+118	- 5	-422	+142	- 6	-128	-292	+ 21	-481	-174	+ 16	-550	-150	+ 15

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
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   - IS COMPRESSION

CITY OF SEATTLE
DEPARTMENT OF LIGHTING

INTERNATIONAL ENGINEERING COMPANY, INC.

ROSS HIGH DAM MODEL STUDIES
MODEL 2
ORTHOGONAL STRESSES
WATER ELEVATION 1600
UPSTREAM FACE

UNIVERSITY OF CALIFORNIA
JEROME M. RAPHAEL, FACULTY INVESTIGATOR

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

BERKELEY, CALIFORNIA
DATE: FEB. 1, 1971

FIG. 8

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	1590	4+00	- 25	+ 3	+ 5	- 30	+ 3	+ 6	- 5	- 20	- 1	- 30	- 17	+ 4	- 35	- 17	+ 5
2	1590	8+00	- 11	+ 2	+ 7	- 13	+ 2	+ 8	- 2	- 21	- 1	- 13	- 19	+ 6	- 15	- 19	+ 7
3	1590	10+00	- 3	0	- 1	- 4	0	- 1	0	- 30	- 4	- 3	- 30	- 5	- 4	- 30	- 5
4	1590	12+00	- 19	+ 1	- 6	- 23	+ 1	- 7	- 3	- 25	- 3	- 22	- 24	- 9	- 26	- 24	- 10
5	1590	15+00	- 26	0	- 12	- 31	0	- 14	- 1	- 24	- 1	- 27	- 24	- 13	- 32	- 24	- 15
6	1540	4+70	- 40	+ 18	+ 7	- 48	+ 21	+ 9	+ 11	- 50	- 18	- 29	- 32	- 11	- 37	- 29	- 9
7	1540	6+00	- 62	+ 15	+ 18	- 74	+ 18	+ 21	+ 5	- 70	- 9	- 57	- 55	+ 9	- 69	- 52	+ 12
8	1540	8+00	- 39	+ 14	+ 11	- 46	+ 16	+ 13	- 15	-103	+ 4	- 54	- 89	+ 15	- 61	- 87	+ 17
9	1540	10+00	- 39	+ 10	- 4	- 46	+ 12	- 5	+ 3	-128	- 20	- 36	-118	- 24	- 43	-116	- 25
10	1540	12+00	- 44	+ 13	- 9	- 53	+ 16	- 10	- 12	- 81	+ 4	- 56	- 68	- 5	- 65	- 65	- 6
11	1540	14+00	- 63	+ 7	- 18	- 76	+ 9	- 21	+ 7	-105	+ 2	- 56	- 98	- 16	- 69	- 96	- 19
12	1540	14+60	- 66	+ 4	- 18	- 78	+ 5	- 21	+ 6	- 42	- 6	- 60	- 38	- 24	- 72	- 37	- 27
13	1500	6+00	- 80	+ 62	+ 12	- 96	+ 74	+ 15	- 9	- 98	+ 2	- 89	- 36	+ 14	-105	- 24	+ 17
14	1500	8+00	- 55	+ 54	+ 9	- 65	+ 64	+ 11	- 34	-138	- 14	- 89	- 84	- 5	- 99	- 74	- 3
15	1500	10+00	- 47	+ 38	- 8	- 57	+ 45	- 10	+ 2	-138	- 7	- 45	-100	- 15	- 55	- 93	- 17
16	1500	12+00	- 56	+ 43	- 13	- 66	+ 51	- 15	- 24	-153	+ 18	- 80	-110	+ 5	- 90	-102	+ 3
17	1500	14+00	- 62	+ 22	- 4	- 74	+ 26	- 5	+ 10	-113	- 6	- 52	- 91	- 10	- 64	- 87	- 11
18	1400	6+30	-175	- 9	- 42	-209	- 10	- 50	+ 49	- 73	+ 3	-126	- 82	- 39	-160	- 83	- 47
19	1400	8+00	- 89	+102	- 14	-107	+122	- 17	- 47	-134	- 14	-136	- 32	- 28	-154	- 12	- 31
20	1400	10+00	- 59	+142	+ 2	- 70	+169	+ 2	- 16	-182	- 8	- 75	- 40	- 6	- 86	- 13	- 6
21	1400	12+00	-120	+ 67	+ 20	-144	+ 80	+ 24	- 16	-133	+ 16	-136	- 66	+ 36	-160	- 53	+ 40
22	1400	13+80	-114	+ 9	+ 25	-136	+ 11	+ 30	+ 65	- 92	+ 1	- 49	- 83	+ 26	- 71	- 81	+ 31
23	1300	8+00	-196	- 84	- 90	-234	-100	-107	- 22	-204	+ 37	-218	-288	- 53	-256	-304	- 70
24	1300	10+00	- 24	+ 95	+ 17	- 29	+113	+ 20	- 74	-239	- 17	- 98	-144	0	-103	-126	+ 3
25	1300	12+00	-241	- 47	+ 84	-288	- 57	+101	+ 52	-165	+ 21	-189	-212	+105	-236	-222	+122
26	1200	10+00	+ 91	- 34	+ 5	+109	- 41	+ 6	-166	-237	+ 21	- 75	-271	+ 26	- 57	-278	+ 27
27	1150	10+00	+107	- 44	+ 21	+128	- 52	+ 25	-307	-241	+ 97	-200	-285	+118	-179	-293	+122

NOTES

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CITY OF SEATTLE
DEPARTMENT OF LIGHTING

INTERNATIONAL ENGINEERING COMPANY, INC.

ROSS HIGH DAM MODEL STUDIES
MODEL 2
ORTHOGONAL STRESSES
WATER ELEVATION 1475
DOWNSTREAM FACE

UNIVERSITY OF CALIFORNIA
JEROME M. RAPHAEL, FACULTY INVESTIGATOR

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

BERKELEY, CALIFORNIA
DATE: FEB. 1, 1971

FIG. 9

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}
28	1590	15+00	- 30	- 12	+ 5	- 36	- 14	+ 6	+ 2	- 13	- 3	- 28	- 25	+ 2	- 34	- 27	+ 3
29	1590	12+00	- 22	+ 2	- 9	- 26	+ 2	- 11	- 2	- 36	+ 5	- 24	- 34	- 4	- 28	- 34	- 6
30	1590	10+00	- 43	+ 1	+ 2	- 51	+ 1	+ 2	- 7	- 25	- 3	- 50	- 24	- 1	- 58	- 24	- 1
31	1590	8+00	- 33	+ 2	+ 5	- 39	+ 2	+ 6	0	- 42	- 1	- 33	- 40	+ 4	- 39	- 40	+ 5
32	1590	4+00	- 20	0	+ 1	- 23	0	+ 2	+ 2	- 32	- 2	- 18	- 32	- 1	- 21	- 32	0
33	1540	14+60	- 21	- 5	- 9	- 25	- 6	- 10	+ 12	- 117	+ 7	- 9	- 122	- 2	- 13	- 123	- 3
34	1540	14+00	- 20	- 11	+ 9	- 24	- 13	+ 11	+ 14	- 108	+ 24	- 6	- 119	+ 33	- 10	- 121	+ 35
35	1540	12+00	0	0	- 35	0	0	- 42	- 21	- 104	+ 22	- 21	- 104	- 13	- 21	- 104	- 20
36	1540	10+00	- 90	- 12	+ 32	- 108	- 14	+ 39	- 11	- 102	+ 31	- 101	- 114	+ 63	- 119	- 116	+ 70
37	1540	8+00	- 72	- 16	+ 10	- 86	- 19	+ 12	+ 2	- 97	+ 7	- 70	- 113	+ 17	- 84	- 116	+ 19
38	1540	6+00	- 18	- 4	+ 7	- 22	- 4	+ 9	+ 19	- 115	+ 4	+ 1	- 119	+ 11	- 3	- 119	+ 13
39	1540	4+00	- 35	- 11	+ 9	- 41	- 13	+ 11	- 12	- 132	+ 8	- 47	- 143	+ 17	- 53	- 145	+ 19
40	1500	14+00	- 22	- 30	- 12	- 26	- 36	- 14	+ 12	- 163	+ 3	- 10	- 193	- 9	- 14	- 199	- 11
41	1500	12+00	- 82	- 30	- 19	- 98	- 36	- 23	+ 16	- 103	+ 10	- 66	- 133	- 9	- 82	- 139	- 13
42	1500	10+00	- 4	- 18	- 50	- 5	- 22	- 59	- 29	- 143	+ 7	- 33	- 161	- 43	- 34	- 165	- 52
43	1500	8+00	- 85	- 34	+ 9	- 102	- 40	+ 11	+ 8	- 119	- 4	- 77	- 153	+ 5	- 94	- 159	+ 7
44	1500	6+00	- 25	- 30	+ 8	- 30	- 36	+ 10	- 10	- 158	+ 18	- 35	- 188	+ 26	- 40	- 194	+ 28
45	1400	13+30	- 68	- 53	- 10	- 81	- 63	- 12	- 20	- 265	+ 183	- 88	- 318	+ 173	- 101	- 328	+ 171
46	1400	12+00	- 103	- 37	- 31	- 123	- 44	- 37	+ 47	- 41	- 78	- 56	- 78	- 109	- 76	- 85	- 115
47	1400	10+00	- 221	- 107	+ 3	- 264	- 128	+ 4	- 27	- 225	+ 2	- 248	- 332	+ 5	- 291	- 353	+ 6
48	1400	8+00	- 130	- 107	+ 21	- 155	- 127	+ 25	- 3	- 243	+ 3	- 133	- 350	+ 24	- 158	- 370	+ 28
49	1400	6+30	- 24	- 46	+ 1	- 29	- 54	+ 2	- 53	- 268	+ 84	- 77	- 314	+ 85	- 82	- 322	+ 86
50	1300	12+00	- 105	- 65	- 1	- 125	- 78	- 1	- 34	- 289	- 78	- 139	- 354	- 79	- 159	- 367	- 79
51	1300	10+00	- 280	- 41	+ 38	- 335	- 49	+ 45	- 60	- 358	+ 35	- 340	- 399	+ 73	- 395	- 407	+ 80
52	1300	8+00	- 87	- 77	- 2	- 104	- 92	- 3	- 42	- 304	- 21	- 129	- 381	- 23	- 146	- 396	- 24
53	1200	10+00	- 202	+ 30	+ 2	- 241	+ 36	+ 2	- 51	- 285	- 14	- 253	- 255	- 12	- 292	- 249	- 12
54	1150	10+00	- 256	+ 23	+ 2	- 306	+ 28	+ 2	- 128	- 292	+ 21	- 384	- 269	+ 23	- 434	- 264	+ 23

NOTES

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CITY OF SEATTLE
DEPARTMENT OF LIGHTING

INTERNATIONAL ENGINEERING COMPANY, INC.

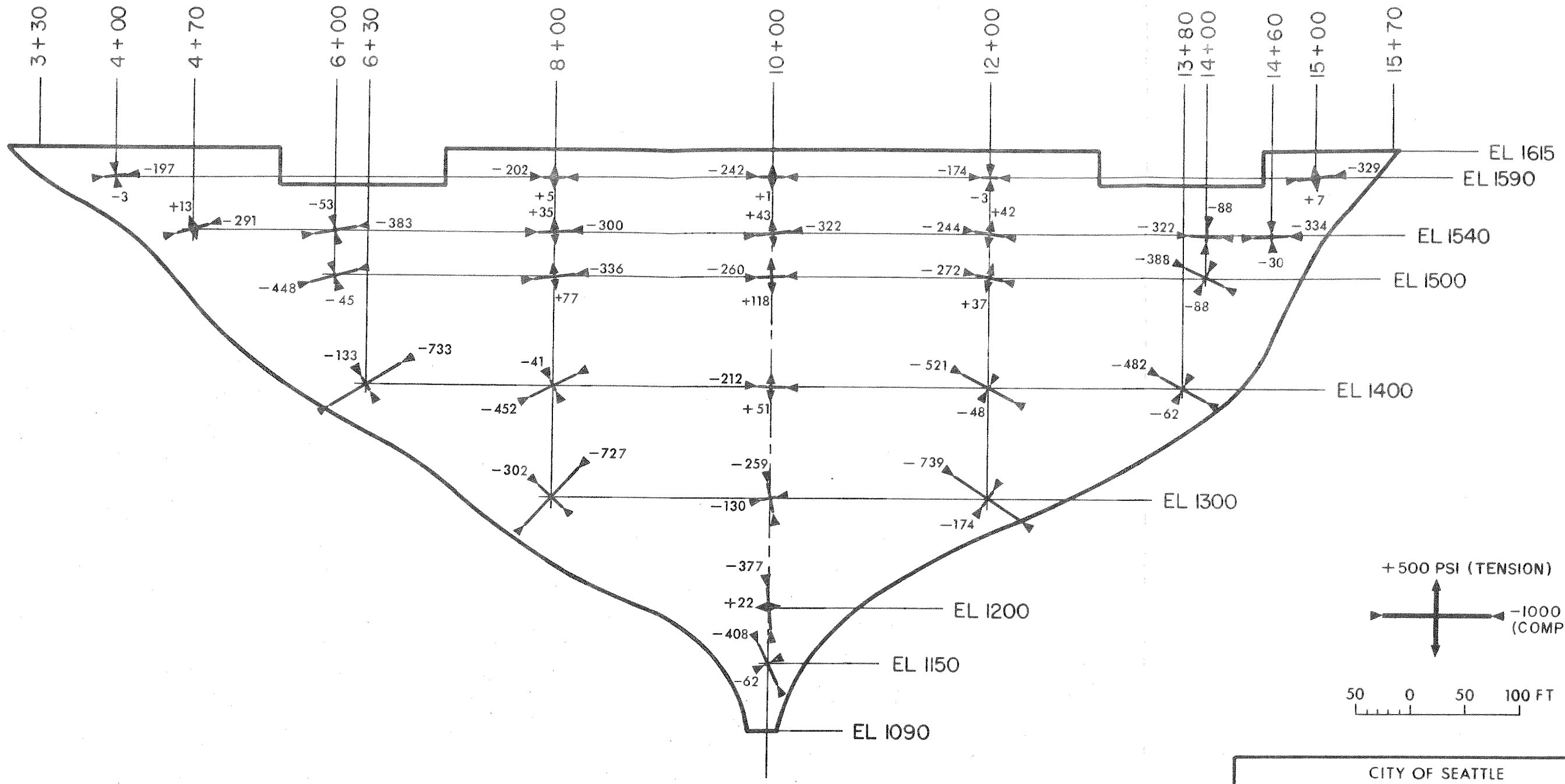
ROSS HIGH DAM MODEL STUDIES
MODEL 2
ORTHOGONAL STRESSES
WATER ELEVATION 1475
UPSTREAM FACE

UNIVERSITY OF CALIFORNIA
JEROME M. RAPHAEL, FACULTY INVESTIGATOR

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

BERKELEY, CALIFORNIA
DATE: FEB. 1, 1971

FIG. 10



DOWNSTREAM FACE

LOOKING UPSTREAM

CITY OF SEATTLE
DEPARTMENT OF LIGHTING

INTERNATIONAL ENGINEERING COMPANY INC.

ROSS HIGH DAM MODEL STUDIES

MODEL 2

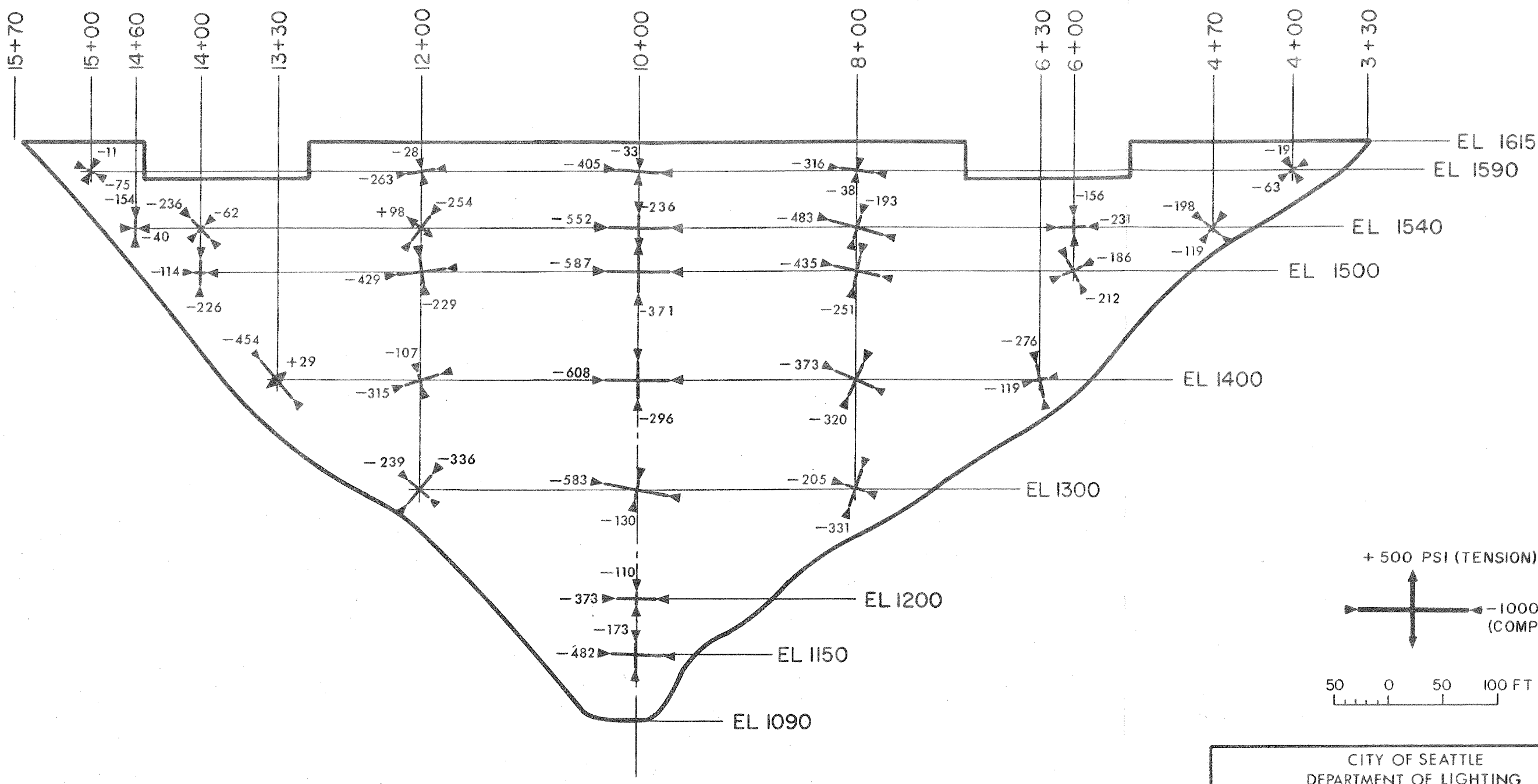
PRINCIPAL STRESSES

DEAD+WATER LOAD - EL. 1600

DOWNSTREAM FACE

UNIVERSITY OF CALIFORNIA
JEROME M. RAPHAEL, FACULTY INVESTIGATOR

DRAWN: B.L.	CHKD: C.M.	APPROVED: J.M. Raphael
BERKELEY, CALIFORNIA DATE: FEB. 1, 1971		FIG. 11



UPSTREAM FACE
LOOKING DOWNSTREAM

CITY OF SEATTLE
DEPARTMENT OF LIGHTING

INTERNATIONAL ENGINEERING COMPANY, INC.

ROSS HIGH DAM MODEL STUDIES
MODEL 2
PRINCIPAL STRESSES
DEAD + WATER LOAD - EL. 1600
UPSTREAM FACE

UNIVERSITY OF CALIFORNIA
JEROME M. RAPHAEL, FACULTY INVESTIGATOR

DRAWN: BL	CHKD: CM	APPROVED: Jerome Raphael
BERKELEY, CALIFORNIA DATE: FEB. 1, 1971		FIG. 12

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}
10	1600	4+00	-208	+ 5	- 1	-249	+ 6	- 1	- 5	- 20	- 1	-213	- 15	- 2	-254	- 14	- 2
12	1600	8+00	-257	+ 70	+ 16	-307	+ 84	+ 19	- 2	- 21	- 1	-259	+ 49	+ 15	-309	+ 63	+ 18
13	1600	10+00	-248	+ 44	+ 4	-296	+ 52	+ 5	0	- 30	- 4	-248	+ 14	0	-296	+ 22	+ 1
14	1600	12+00	-208	+ 87	- 3	-249	+104	- 4	- 3	- 25	- 3	-211	+ 62	- 6	-252	+ 79	- 7
16	1540	4+70	- 131	+ 36	- 40	-156	+ 43	- 48	+ 11	- 50	- 18	-120	- 14	- 58	-145	- 7	- 66
17	1540	6+00															
18	1540	8+00	-317	+111	- 6	-379	+133	- 7	- 15	-103	+ 4	-332	+ 8	- 2	-394	+ 30	- 3
19	1540	10+00	-205	+156	+ 7	-244	+186	+ 8	+ 3	-128	- 20	-202	+ 28	- 13	-241	+ 58	- 12
20	1540	12+00	-270	+160	+ 16	-322	+191	+ 19	- 12	- 81	+ 4	-282	+ 79	+ 20	-334	+110	+ 23
21	1540	14+00															
22	1500	6+00	-328	- 23	-144	-388	- 28	-172	+ 9	- 98	+ 2	-319	-121	-142	-379	-126	-170
23	1500	8+00	-334	+168	- 45	-399	+201	- 53	- 34	-138	- 14	-368	+ 30	- 59	-433	+ 63	- 67
24	1500	10+00	-196	+262	+ 13	-234	+313	+ 16	+ 2	-138	- 7	-194	+124	+ 6	-232	+175	+ 9
25	1500	12+00	-303	+190	+ 43	-362	+227	+ 52	- 24	-153	+ 18	-327	+ 37	+ 61	-386	+ 74	+ 70
26	1500	14+00	-316	+ 28	+ 78	-378	+ 34	+ 93	+ 10	-113	- 6	-306	- 85	+ 72	-368	- 79	+ 87
27	1400	6+30	-415	-169	-148	-496	-202	-177	+ 49	- 73	+ 3	-366	-242	-145	-447	-275	-174
28	1400	8+00	-273	+ 27	-104	-326	+ 32	-124	- 47	-134	- 14	-320	-107	-118	-373	-102	-138
29	1400	10+00	-227	+191	+ 40	-271	+228	+ 48	- 16	-182	- 8	-243	+ 9	+ 32	-287	+ 46	+ 40
30	1400	12+00	-400	+ 21	+149	-478	+ 28	+178	- 16	-133	+ 16	-416	-110	+165	-494	-105	+194
31	1400	13+80	-348	- 52	+122	-416	- 62	+146	+ 65	- 92	+ 1	-283	-114	+123	-351	-154	+147
32	1300	8+00	-433	-312	-272	-518	-373	-325	- 22	-204	+ 37	-455	-516	-235	-540	-577	-288
33	1300	10+00	- 56	+ 10	+ 16	- 67	+ 11	+ 19	- 74	-239	- 17	-130	-229	- 1	-141	-228	+ 2
34	1300	12+00	-520	- 67	+196	-621	- 80	+234	+ 52	-165	+ 21	-468	-232	+217	-569	-245	+255
35	1200	10+00	+217	-165	+ 8	+260	-197	+ 10	-166	-237	+ 21	+ 51	-402	+ 29	+ 94	-434	+ 31

NOTES

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CITY OF SEATTLE
DEPARTMENT OF LIGHTING

INTERNATIONAL ENGINEERING COMPANY, INC.

ROSS HIGH DAM MODEL STUDIES
MODEL 3
ORTHOGONAL STRESSES
WATER ELEVATION 1600
DOWNSTREAM FACE

UNIVERSITY OF CALIFORNIA
JEROME M. RAPHAEL, FACULTY INVESTIGATOR

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

BERKELEY, CALIFORNIA
DATE: FEB. 1, 1971

FIG. 13

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}
46	1600	12+00	-253	- 67	+ 13	-303	- 80	+ 15	- 2	- 36	+ 5	-255	-103	+ 18	-305	- 116	+ 20
47	1600	10+00	-353	- 8	- 6	-422	- 9	- 8	- 7	- 25	- 3	-360	- 33	- 9	-429	- 34	- 11
48	1600	8+00	-347	- 22	+ 36	-414	- 26	+ 43	0	- 42	- 1	-347	- 64	+ 35	-414	- 68	+ 42
50	1600	4+00	-103	0	- 3	-123	0	- 4	+ 2	- 32	- 2	-101	- 32	- 5	-121	- 32	- 6
51	1540	14+00	-157	- 68	- 17	-187	- 81	- 21	+ 14	-108	+ 24	-143	-176	+ 7	-173	- 189	+ 3
52	1540	12+00	-353	-149	- 42	-422	-179	- 50	- 21	-104	+ 22	-374	-253	- 20	-443	-283	- 28
53	1540	10+00	-491	-149	+ 14	-586	-178	+ 16	- 11	-102	+ 31	-502	-251	+ 45	-597	-280	+ 47
54	1540	8+00	-446	-148	+ 68	-533	-177	+ 81	+ 2	- 97	+ 7	-444	-245	+ 75	-531	-274	+ 88
55	1540	6+00	-186	- 77	+ 45	-222	- 92	+ 54	+ 19	-115	+ 4	-167	-192	+ 49	-203	-207	+ 58
56	1540	4+00	- 59	- 61	+ 24	- 71	- 73	+ 28	- 12	-132	+ 8	- 71	-193	+ 32	- 83	-205	+ 36
57	1400	13+30	-129	- 12	+ 91	-154	- 15	+108	- 20	-265	+183	-149	-277	+274	-174	-280	+291
58	1400	12+00	-337	- 83	- 10	-402	- 99	- 12	+ 47	- 41	- 78	-290	-124	- 88	-355	-140	- 90
59	1400	10+00	-579	- 97	+ 26	-692	-116	+ 31	- 27	-225	+ 2	-606	-322	+ 28	-719	-341	+ 33
60	1400	8+00	-361	- 46	- 31	-432	- 54	- 37	- 3	-243	+ 3	-364	-289	- 28	-435	-297	- 34
61	1400	6+30	- 89	+ 57	- 64	-107	+ 69	- 76	- 53	-268	+ 84	-142	-211	+ 20	-160	- 199	+ 8
62	1300	12+00	-162	+ 42	+ 29	-193	+ 50	+ 35	- 34	-289	- 78	-196	-247	- 49	-227	-239	- 43
63	1300	10+00	-527	+157	+ 9	-629	+188	+ 11	- 60	-358	+ 35	-587	-201	+ 44	-689	-170	+ 46
64	1300	8+00	-163	- 15	- 5	-194	- 17	- 6	- 42	-304	- 21	-205	-319	- 26	-236	-321	- 27
65	1200	10+00	-352	+245	- 2	-421	+293	- 3	- 51	-285	- 14	-403	- 40	- 16	-472	+ 8	- 17
66	1150	10+00	-294	+212	- 10	-351	+254	- 12	-128	-292	+ 21	-422	- 80	+ 11	-479	- 38	+ 9

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CITY OF SEATTLE
DEPARTMENT OF LIGHTING

INTERNATIONAL ENGINEERING COMPANY, INC.

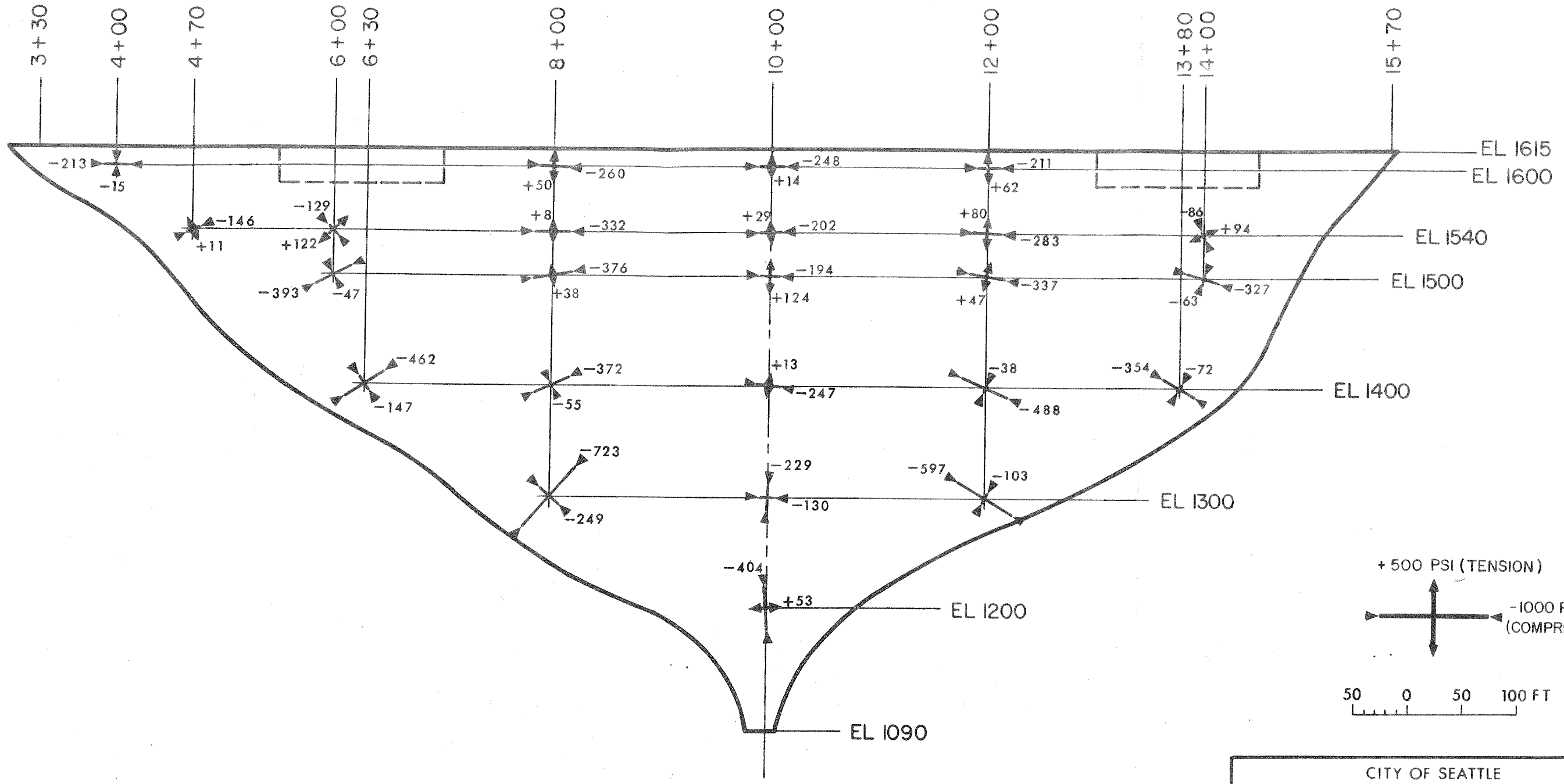
ROSS HIGH DAM MODEL STUDIES
MODEL 3
ORTHOGONAL STRESSES
WATER ELEVATION 1600
UPSTREAM FACE

UNIVERSITY OF CALIFORNIA
JEROME M. RAPHAEL, FACULTY INVESTIGATOR

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

BERKELEY, CALIFORNIA
DATE: FEB. 1, 1971

FIG. 14



DOWNSTREAM FACE

LOOKING UPSTREAM

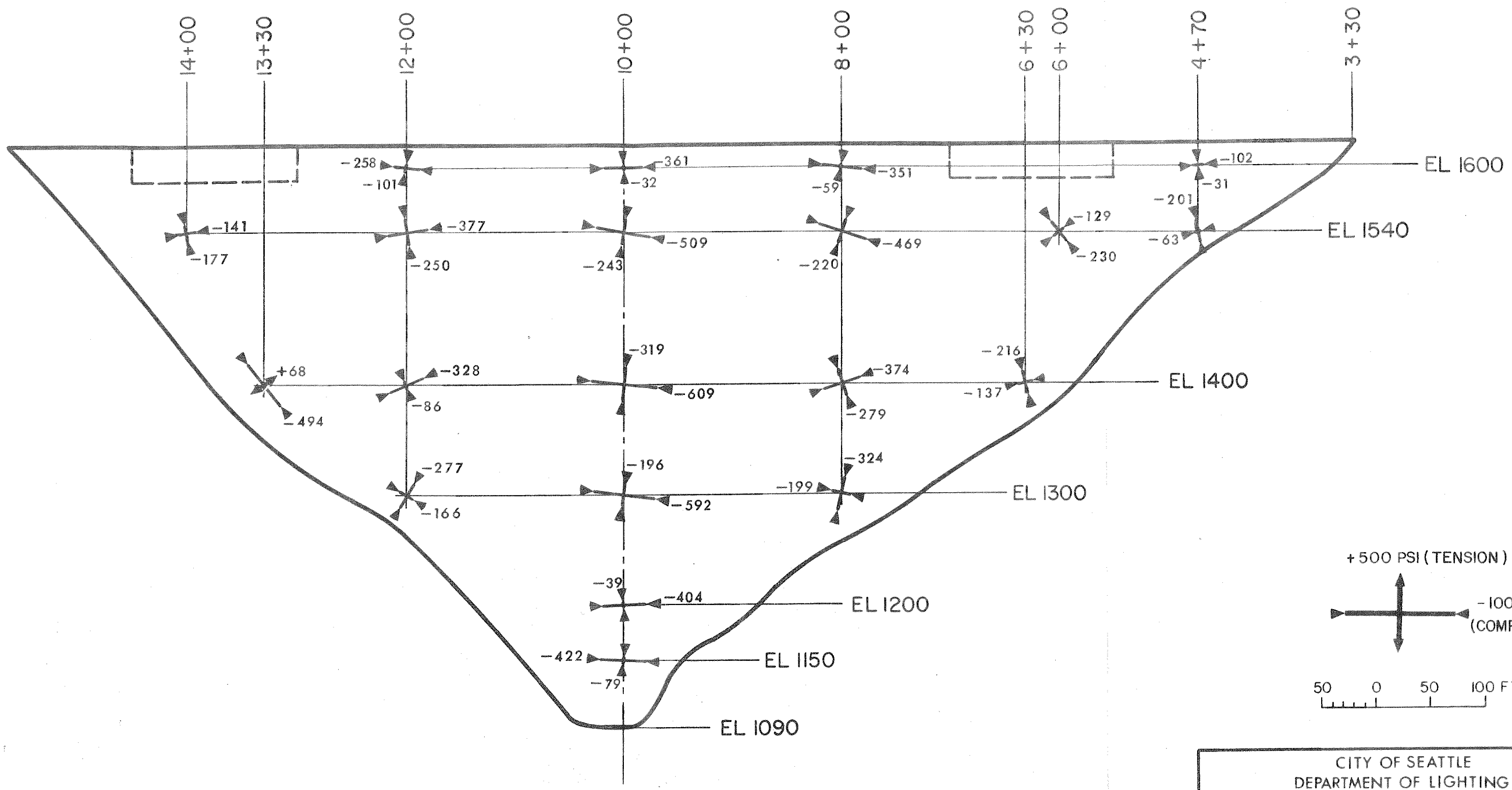
CITY OF SEATTLE
DEPARTMENT OF LIGHTING

INTERNATIONAL ENGINEERING COMPANY INC.

ROSS HIGH DAM MODEL STUDIES
MODEL 3
PRINCIPAL STRESSES
DEAD+WATER LOAD - EL. 1600
DOWNSTREAM FACE

UNIVERSITY OF CALIFORNIA
JEROME M. RAPHAEL, FACULTY INVESTIGATOR

DRAWN: BL	CHKD: CM	APPROVED: J.M. Raphael
BERKELEY, CALIFORNIA DATE: FEB. 1, 1971		FIG. 15



UPSTREAM FACE
LOOKING DOWNSTREAM

+500 PSI (TENSION)
-1000 PSI (COMPRESSION)

50 0 50 100 FT

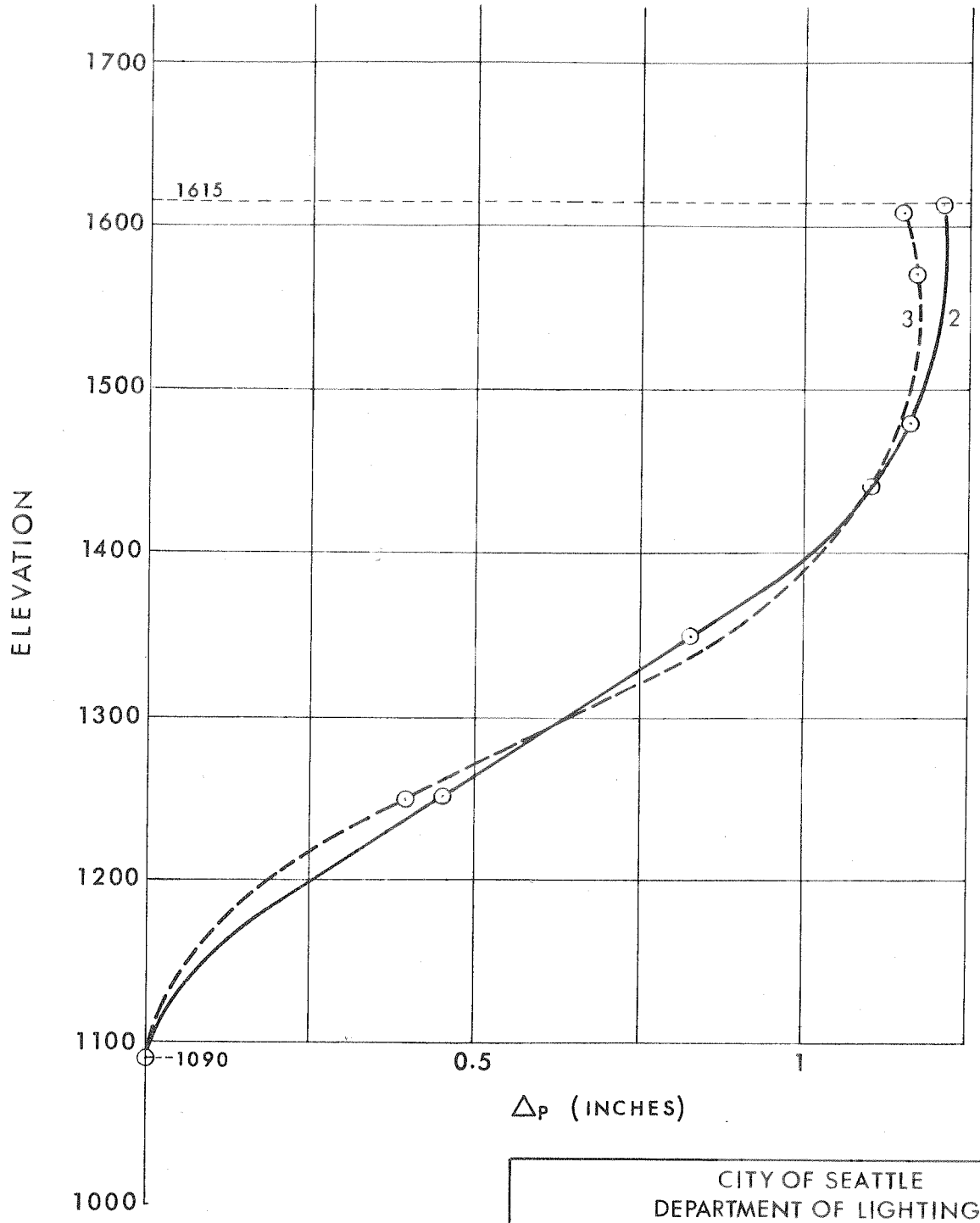
CITY OF SEATTLE
DEPARTMENT OF LIGHTING

INTERNATIONAL ENGINEERING COMPANY, INC.

ROSS HIGH DAM MODEL STUDIES
MODEL 3
PRINCIPAL STRESSES
DEAD + WATER LOAD - EL. 1600
UPSTREAM FACE

UNIVERSITY OF CALIFORNIA
JEROME M. RAPHAEL, FACULTY INVESTIGATOR

DRAWN: BL	CHKD: CM	APPROVED Jerome Raphael
BERKELEY, CALIFORNIA DATE: FEB. 1, 1971		FIG. 16



CITY OF SEATTLE
DEPARTMENT OF LIGHTING

INTERNATIONAL ENGINEERING COMPANY, INC.

ROSS HIGH DAM MODEL STUDIES

MODEL 2 & MODEL 3

RADIAL DEFLECTIONS

WATER ELEVATION 1600

UNIVERSITY OF CALIFORNIA
JEROME M. RAPHAEL, FACULTY INVESTIGATOR

DRAWN: BL	CHKD: CM	APPROVED: Jm Raphael
BERKELEY, CALIFORNIA DATE: FEB. 1, 1971		FIG. 17

APPENDIX B

TABLES

TABLE 1

COMPARISON OF STRESSES

DEAD PLUS WATER LOAD TO ELEVATION 1600

DOWNSTREAM FACE

GAGE		ELEV.		STATION	ARCH STRESSES		CANTILEVER STRESSES	
MODEL 2	MODEL 3	MODEL 2	MODEL 3		MODEL 2	MODEL 3	MODEL 2	MODEL 3
1	10	1590	1600	4+00	- 194	- 213	- 6	- 15
2	12	1590	1600	8+00	- 202	- 259	+ 5	+ 49
3	13	1590	1600	10+00	- 242	- 248	0	+ 14
4	14	1590	1600	12+00	- 174	- 211	- 3	+ 62
5		1590		15+00	- 324		+ 1	
6	16	1540		4+70	- 270	- 120	- 8	- 14
7		1540		6+00	- 372		- 65	
8	18	1540		8+00	- 299	- 332	+ 35	+ 8
9	19	1540		10+00	- 318	- 202	+ 40	+ 28
10	20	1540		12+00	- 239	- 282	+ 37	+ 79
11		1540		14+00	- 321		- 89	
12		1540		14+60	- 334		- 31	
13	22	1500		6+00	- 424	- 319	- 69	- 121
14	23	1500		8+00	- 329	- 368	+ 70	+ 30
15	24	1500		10+00	- 259	- 194	+ 117	+ 124
16	25	1500		12+00	- 257	- 327	+ 23	+ 37
17	26	1500		14+00	- 333	- 306	- 142	- 85
18	27	1400		6+30	- 575	- 366	- 290	- 242
19	28	1400		8+00	- 371	- 320	- 122	- 107
20	29	1400		10+00	- 211	- 243	+ 50	+ 9
21	30	1400		12+00	- 410	- 416	- 158	- 110
22	31	1400		13+80	- 392	- 283	- 152	- 144
23	32	1300		8+00	- 501	- 455	- 528	- 516
24	33	1300		10+00	- 134	- 130	- 255	- 229
25	34	1300		12+00	- 550	- 468	- 362	- 232
26	35	1200		10+00	+ 20	+ 51	- 374	- 402
27		1150		10+00	- 125		- 345	

TABLE 2

COMPARISON OF STRESSES

DEAD PLUS WATER LOAD TO ELEVATION 1600

UPSTREAM FACE

GAGE		ELEV.		STATION	ARCH STRESSES		CANTILEVER STRESSES	
MODEL 2	MODEL 3	MODEL 2	MODEL 3		MODEL 2	MODEL 3	MODEL 2	MODEL 3
28		1590	1600	15+00	- 62		- 24	
29	46	1590	1600	12+00	- 257	- 255	- 34	- 103
30	47	1590	1600	10+00	- 404	- 360	- 34	- 33
31	48	1590	1600	8+00	- 310	- 347	- 43	- 64
32	50	1590	1600	4+00	- 50	- 101	- 32	- 32
33		1540		14+60	- 40		- 154	
34	51	1540		14+00	- 146	- 143	- 152	- 176
	52	1540		12+00		- 374		- 253
36	53	1540		10+00	- 552	- 502	- 236	- 251
37	54	1540		8+00	- 461	- 444	- 216	- 245
38	55	1540		6+00	- 231	- 167	- 156	- 192
39	56	1540		4+00	- 166	- 71	- 151	- 193
40		1500		14+00	- 114		- 226	
41		1500		12+00	- 425		- 234	
42		1500		10+00	- 587		- 371	
43		1500		8+00	- 427		- 259	
44		1500		6+00	- 191		- 208	
45	57	1400		13+30	- 171	- 149	- 253	- 277
46	58	1400		12+00	- 296	- 290	- 125	- 124
47	59	1400		10+00	- 608	- 606	- 296	- 322
48	60	1400		8+00	- 364	- 364	- 329	- 289
49	61	1400		6+30	- 125	- 142	- 270	- 211
50	62	1300		12+00	- 279	- 196	- 295	- 247
51	63	1300		10+00	- 565	- 587	- 148	- 201
52	64	1300		8+00	- 219	- 205	- 318	- 319
53	65	1200		10+00	- 373	- 403	- 111	- 40
54	66	1150		10+00	- 481	- 422	- 174	- 80