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HYDRAULIC MODEL STUDIES OF AN ENERGY DISSIPATOR FOR A FIXED CONE VALVE AT THE UTE DAM OUTLET WORKS

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16. Abstract
Laboratory studies were made with a 1:8 scale model of Ute Dam outlet works to aid in the development of a basin-type energy dissipator. The existing outlet works is to be modified by installing a horizontal cylinder (fixed-cone) valve structure for controlling the discharge into a concrete outlet channel. Hydraulic model tests of the energy dissipator for the valve discharge revealed problems caused by submergence of the control valve, surging in the energy dissipator, and overtopping in the outlet channel. The preliminary design was modified to reduce submergence and to stabilize the flow in the energy dissipator and outlet channel.

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by
G. L. Beichley

March 1970

HYDRAULICS BRANCH
DIVISION OF RESEARCH

UNITED STATES DEPARTMENT OF THE INTERIOR * BUREAU OF RECLAMATION
Office of Chief Engineer . Denver, Colorado

ACKNOWLEDGMENT

The studies were conducted by the author and reviewed by T. J. Rhone under the supervision of Structures and Equipment Section Head W. E. Wagner and direction of former Hydraulics Branch Chief, H. M. Martin, all in the Division of Research, Office of Chief Engineer, Bureau of Reclamation.

The final plans evolved from these studies were developed through the cooperation of the New Mexico Interstate Stream Commission and the Spillways and Outlet Works Section, Dams Branch, Division of Design, Office of Chief Engineer during the period January through July 1969.

CONTENTS

PURPOSE

The studies were made to develop an acceptable energy dissipator for the outlet works.

CONCLUSIONS

1. In the initial arrangement of the energy dissipator the downstream tailwater partially submerged the control valve at the design discharge.

2. Diverging walls, ceiling, and floor and corner fillets prevented submergence of the valve.

3. Very little of the flow deflected upstream. Most of the jet followed the flaring surfaces to the 45° inward projecting surfaces of the deflector.

4. Baffles installed in the basin intercepted and spread the jet in the pool and dissipated the energy before the flow entered the canal.

5. A sloping sill at the downstream end of the basin provided a smoother transition for the flow from the basin into the outlet channel.

6. A 6-inch (15.24 centimeters) high sill in the channel 7.5 feet (2.29 meters) downstream from the basin increased flow depth in the basin and upstream end of the outlet channel, providing more efficient energy dissipation and a smoother water surface downstream.

APPLICATIONS

The energy dissipator discussed in this report was developed for an existing outlet where the elevations of the conduit and outlet channel were fixed. Although some of the principles used in containing the flow and dissipating the jet energy will be useful in future designs, a more efficient structure probably would be used at new installations where submergence of the valve is not a problem.

INTRODUCTION

Ute Dam in northeastern New Mexico, Figure 1, is part of the New Mexico Interstate Stream Commission's Canadian River Project. It is an existing structure having an overflow spillway crest and an outlet works, Figure 2. Plans are to modify the existing outlet works by installing a control structure where the 36-inch- (91.44-cm-) diameter conduit discharges into the outlet channel, Figure 4. The valve, a surplus 48-inch (121.92-cm) horizontal cylinder fixed-cone) valve from the El Vado Project, is 12 inches (30.48 cm) oversize and, therefore, requires a short transition from the 36-inch (91.44-cm) conduit to the valve. A stop to prevent a valve opening of more than about 60 percent was also required to insure retention of hydraulic control at the valve.

The outlet works is designed to discharge 275 cfs (7.79 cu m per second) with the reservoir water surface at spillway crest elevation 3760 feet (1155.19 m), 67 feet (20.42 m) above the valve centerline. Some time in the future, gates may be added to the spillway, at which time the operating head for the design flow would be increased to 97 feet (29.57 m).

Formal action for the design of the control structure by the Bureau of Reclamation was initiated by the State of New Mexico through the Bureau's Region 5 Office at Amarillo, Texas. These hydraulic model studies followed to aid in development of an acceptable energy dissipator for the discharge from the control valve.

THE MODEL

The model, built to a scale of 1:8, included the valve, the energy dissipating enclosure, and a 64-foot (15.90-m) length of the outlet channel downstream from the dissipator.

The 36-inch- (91.44-cm-) diameter conduit and transition to the 48-inch (121.92-cm) valve were not modeled. Instead, a 6-inch- (15.24-cm-) diameter supply line, which actually represented a 48-inch (121.92-cm) conduit, was used. A piezometer tap at the conduit centerline elevation one pipe diameter upstream from the valve measured the pressure head. Thus, the correct quantity of water at the proper operating head to the valve was represented in the model. The curved alinement of the 64-foot (15.90-m) length of the outlet channel was not represented in the model since it was not considered critical in the development of the energy dissipator and the model construction could be greatly simplified by using a straight channel. It was desirable to contain most of the flow within the concrete lining of the channel banks; therefore, the channel banks above the lining were not modeled except for a 3/4-inch (19.05-mm) extension to the lining which represented 9 inches (22.86 cm) of unlined rock cut.

A 6-inch (15.24-cm) horizontal cylinder (fixed-cone) valve available in the Hydraulics Branch was used to represent the prototype. This valve was similar to but not an exact model of the 48-inch (121.92-cm) El Vado valve. The major difference was in the seating arrangement for closure which was unimportant as far as hydraulic flow conditions in the energy dissipator were concerned. Another difference was that the 6-inch (15.24-cm) model valve had four vanes to support the cone, whereas the 48-inch (121.92-cm) valve has three.

INVESTIGATION

The preliminary design of the energy dissipator, Figure 5, was tested for a range of discharges up to and beyond the design flow of 275 cfs at reservoir heads of 37, 67, and 97 feet (11.27, 20.42, and 29.57 meters) above the centerline of the valve. Calculations by the designers were used to determine the pressure head at the valve and gate openings required for a range of discharges. The calculations indicated that a valve opening of approximately 60 percent would be required to discharge the design flow of 275 cfs (7.79 cu m per second) at present design operating head of 67 feet (20.42 m), Figure 6. Therefore, an adjustable stop will be placed on the valve to limit the valve opening to about 60 percent to prevent the valve from discharging more than the design capacity.

Design flow conditions in the preliminary basin and the downstream channel, Figures 7 and 8, were very unsatisfactory at both present and future design operating heads of 67 and 97 feet (20.42 and 29.56 m). The portion of the control structure around the valves should be relatively dry, and the flow leaving the dissipator to enter the outlet channel should be relatively smooth and steady. Neither was true in the operation of the preliminary design. At 67 feet (20.42 m) of head, much water splashed upstream over the valve, the valve was 50 percent submerged, and the waves in the channel downstream rose very high on the extended higher lining near the dissipator and overtopped the existing concrete lining further downstream. At the anticipated future operating head of 97 feet (29.56 m) much water sprayed from the roof over the valve. The valve submergence was reduced to approximately 25 percent, but the magnitude of the waves in the basin and outlet channel increased. At both heads the high waves frequently splashed and surged to the roof of the downstream portion of the energy dissipator and a turbulent eddy persisted under the valve.

Several modifications of the preliminary design were made and tested in arriving at the recommended design shown on Figure 4. Some of the aims of the modifications were to reduce the amount of spray traveling upstream over the valve to keep the portion of control structure around the valve relatively dry and to reduce the amount of submergence of the valve which might cause vibration or cavitation damage. Other aims were to stabilize the turbulent flow in the downstream portion of the energy dissipator; to provide steady, uniformly distributed flow from the stilling basin; and to contain the flow in the outlet channel within the walls of the existing lining extension.

The various modifications tested included: placing a large fillet at the upstream end of the dissipator under the jet to reduce the eddy and valve submergence; changing the angle of the upstream face of the deflector on the walls and ceiling from 45° to 60°, and extending the deflector across the floor to accomplish, more effectively, energy dissipation; placing all or various parts of the floor of the dissipator at higher elevations; and sloping the basin floor upward to the downstream channel.

All of these modifications partially accomplished their purpose but created other problems. For example, many of the modifications that provided better energy dissipation in the stilling basin and better flow conditions in the outlet channel increased the valve submergence. Modifications that were effective and that were used in the recommended design, Figure 4, included: (1) placing the floor of the dissipator 2.5 feet (76.20 cm) higher, which eliminated the large eddies and reduced the volume of turbulent water resulting in a smoother more steady flow from the basin: (2) shortening and streamlining the upstream portion of the dissipator by adding fillets to the lower corners and flaring the walls, ceiling, and floor from a point near the end of the valve so that the cone-shaped jet from the valve intercepted these surfaces at a flat angle and prevented spray over the valve; (3) placing the deflector at the downstream end of the flared section, 4 feet (1.22 m) closer to the valve, provided a longer stilling portion; (4) installing three large baffles in this section more effectively dissipated the energy; (5) placing a 1-1/2:1 sloping floor at the end of the basin allowed the flow to enter the channel more smoothly and increased the self-cleaning capabilities of the basin; and (6) placing a 4-foot- (1.22-m-) wide by 6-inch- (15.24-cm-) high sill in the canal 7.5 feet (2.29 m) downstream from the basin, increased the flow depth in the basin and upstream portion of the channel and reduced the wave heights in the outlet channel. These modifications made it possible to reduce the height of the additional lining on both sides of the first 20 feet (6.10 m) of the channel downstream of the dissipator by sloping the top of the linings to a minimum height of 2.5 feet (0.76 m) above the existing lining at the downstream end.

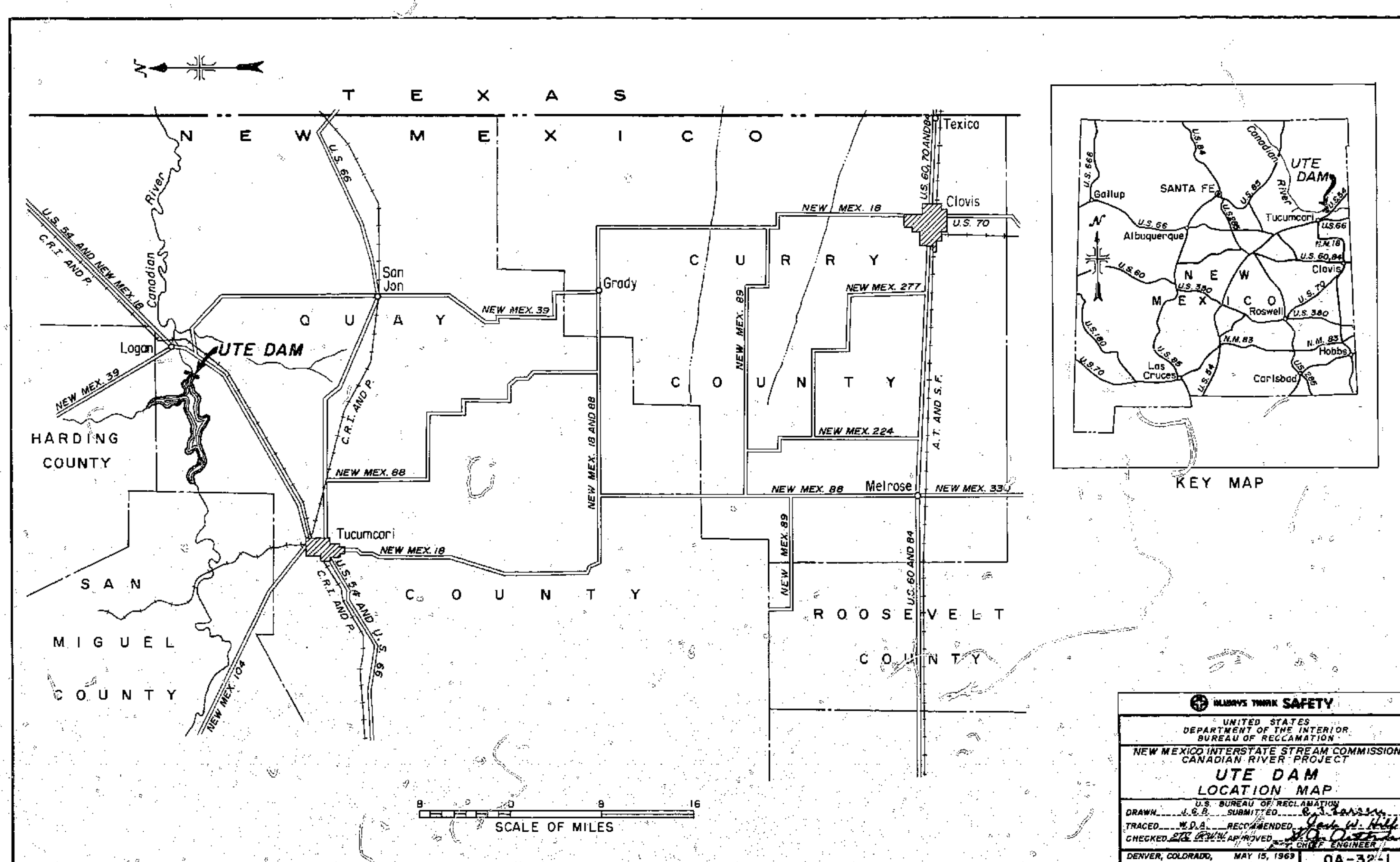
The performance of the recommended energy dissipator, Figures 9 and 10, was much improved over the performance of the preliminary design, Figures 7 and 8. At the 67-foot (20.42-m) head the water level in the upstream portion of the control structure was about 2 or 3 inches (50 or 75 mm) below the valve invert; at the 97-foot (29.57-m) head the water level was 10 to 12 inches (250 to 300 mm) below the valve. A clear plastic tube was inserted in the flow to observe the flow inside the cone-shaped jet. This observation showed that the water was well entrained with air and that the pool surface was near the elevation of valve centerline for the 67-foot (20.42-m) head and about a foot below the valve centerline for the 97-foot (29.57 m) head. Since the total head at the valve will not exceed 25 and 55 feet (7.62 and 16.76 m) for reservoir heads of 67 and 97 feet (20.42 and 29.57 m), respectively, and since the valve is adequately aerated; no cavitation or vibration in the valve is expected. Even by lowering the reservoir to elevation 3730 feet (1136.9 m), which reduced the total head at the valve to 16 feet (488 m), the water level under the valve rose only to the valve invert.

Average flow depths through the energy dissipator and the outlet channel downstream, Figure 11, showed the average velocity in the channel to be approximately 10 to 10.5 feet (3.00 to 3.2 m) per second for the design flow of 275 cfs (7.9 cu m per second) discharging from reservoir elevations 3760 feet (1136.9 m) and 3790 feet (1155.19 m). At these flows, waves occasionally overtopped the existing wall linings downstream of the lining extensions by 2 or 3 inches (50 or 75 mm). However, due to the curvature of the channel, which was not represented in the model, overtopping will be greater in the prototype. Occasional overtopping of the lining can be tolerated because the rock-cut banks extend above the lining.

Other operating conditions were observed, Figures 12 through 16, including operating with the valve 100 percent open at reservoir elevation 3790 feet (1155.71 m), Figure 12. The dissipator and channel was satisfactory in discharging at this 100 percent opening of the valve, as well as at any of the anticipated operating conditions.

BLANK SHEET

FIGURE 1



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DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

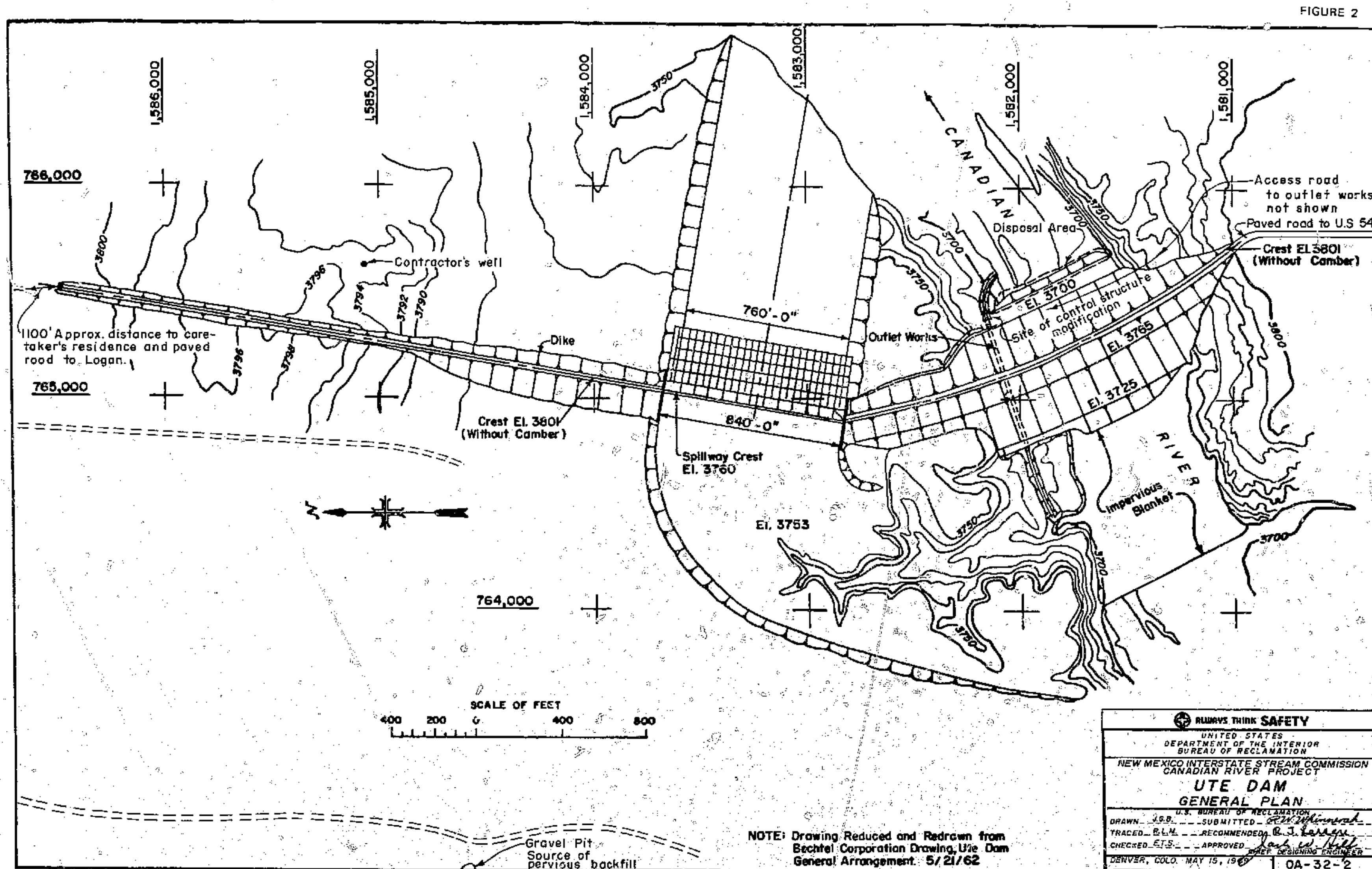
NEW MEXICO INTERSTATE STREAM COMMISSION
CANADIAN RIVER PROJECT

UTE DAM
LOCATION MAP

U.S. BUREAU OF RECLAMATION

DRAWN	J.G.B.	SUBMITTED	[illegible]
TRACED	W.D.A.	RECOMMENDED	Jack W. Hill
CHECKED	[illegible]	APPROVED	[illegible] CHIEF ENGINEER
DENVER, COLORADO,	MAY 15, 1969	0A-32-1	

FIGURE 2



766,000
765,000
764,000
1,586,000
1,585,000
1,584,000
1,583,000
1,582,000
1,581,000
1100' Approx. distance to care-taker's residence and paved road to Logan.
Contractor's well
Dike
Crest El. 3801 (Without Camber)
760'-0"
840'-0"
Spillway Crest El. 3760
El. 3753
Outlet Works
CANADIAN
RIVER
Disposal Area
El. 3700
Site of control structure modification
El. 3765
El. 3725
Impervious Blanket
Access road to outlet works not shown
Paved road to U.S 54
Crest El. 3801 (Without Camber)
Gravel Pit Source of pervious backfill
SCALE OF FEET
400 200 0 400 800
NOTE: Drawing Reduced and Redrawn from Bechtel Corporation Drawing, Ute Dam General Arrangement. 5/21/62
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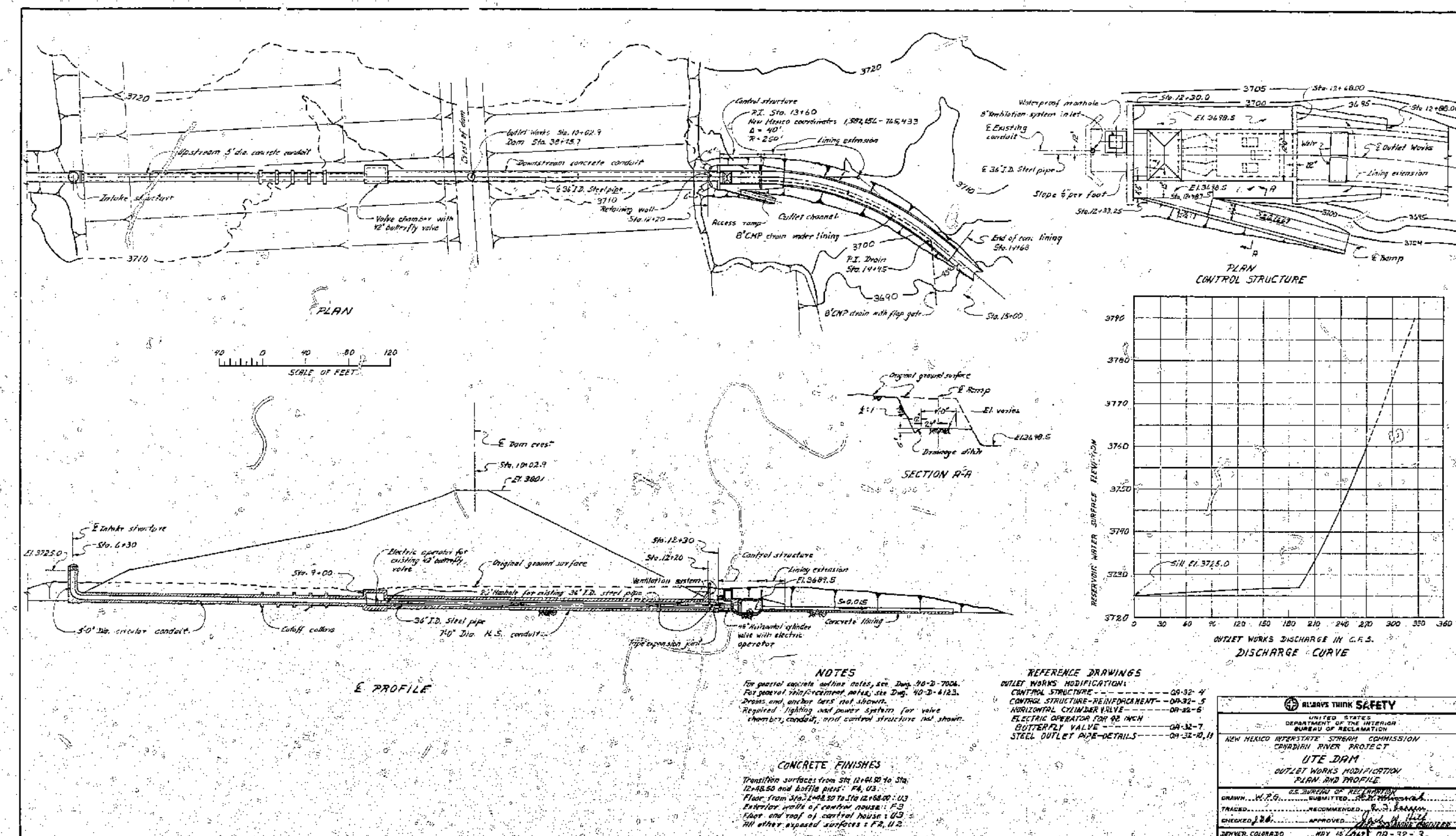
NEW MEXICO INTERSTATE STREAM COMMISSION CANADIAN RIVER PROJECT
UTE DAM
GENERAL PLAN
DENVER, COLO. MAY 15, 1969
OA-32-2


PLAN
SCALE OF FEET
PLAN
CONTROL STRUCTURE
SECTION A-A
℄ PROFILE
DISCHARGE CURVE
OUTLET WORKS DISCHARGE IN C.F.S.
RESERVOIR WATER SURFACE ELEVATION
Sill El. 3725.0
NOTES
For general concrete outline notes, see Dwg. 40-D-7006.
For general reinforcement notes, see Dwg. 40-D-6123.
Drains and anchor bars not shown.
Required lighting and power system for valve chambers, conduit, and control structure not shown.
CONCRETE FINISHES
Transition surfaces from Sta. 12+61.50 to Sta. 12+48.50 and baffle piers: F4, U3.
Floor from Sta. 12+48.50 to Sta. 12+68.00: U3
Exterior walls of control house: F3
Floor and roof of control house: U3
All other exposed surfaces: F2, U2.
REFERENCE DRAWINGS
OUTLET WORKS MODIFICATION:
CONTROL STRUCTURE - - - - - - - - - - OA-32-4
CONTROL STRUCTURE-REINFORCEMENT - - OA-32-5
HORIZONTAL CYLINDER VALVE - - - - - - OA-32-6
ELECTRIC OPERATOR FOR 42 INCH BUTTERFLY VALVE - - - - - - OA-32-7
STEEL OUTLET PIPE-DETAILS - - - - - - OA-32-10, 11
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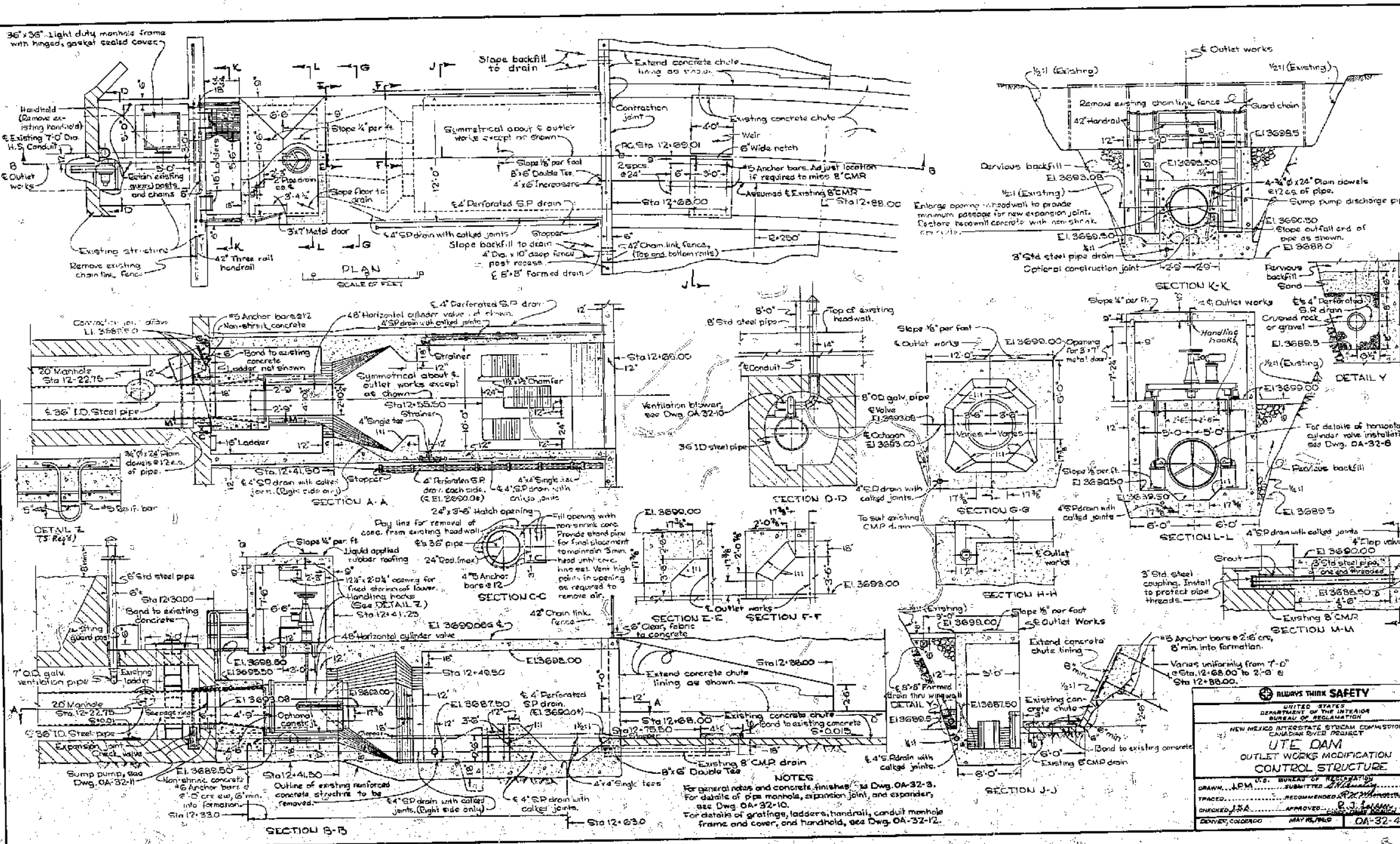
CANADIAN RIVER PROJECT
UTE DAM
OUTLET WORKS MODIFICATION
PLAN AND PROFILE
DENVER, COLORADO
OA-32-3

FIGURE 4


PLAN
SECTION A-A
SECTION B-B
SECTION C-C
SECTION D-D
SECTION E-E
SECTION F-F
SECTION G-G
SECTION H-H
SECTION J-J
SECTION K-K
SECTION L-L
SECTION M-M
DETAIL Y
DETAIL Z
NOTES
For general notes and concrete finishes, see Dwg. OA-32-3.
For details of pipe manhole, expansion joint, and expander, see Dwg. OA-32-10.
For details of gratings, ladders, handrail, conduit manhole frame and cover, and handhold, see Dwg. OA-32-12.
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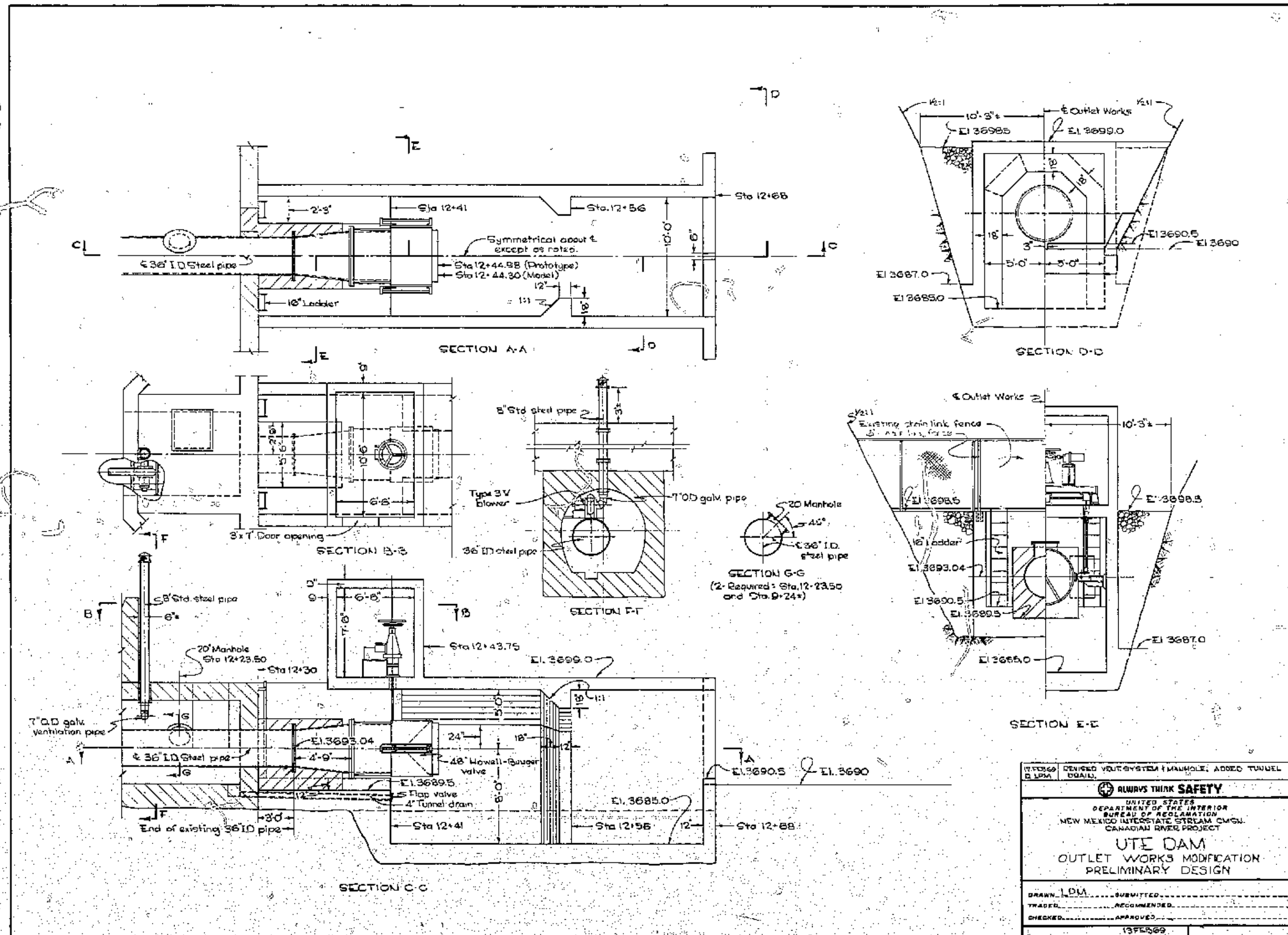
CANADIAN RIVER PROJECT
UTE DAM
OUTLET WORKS MODIFICATION
CONTROL STRUCTURE
DENVER, COLORADO
OA-32-4

FIGURE 5


SECTION A-A
SECTION B-B
SECTION C-C
SECTION D-D
SECTION E-E
SECTION F-F
SECTION G-G
(2-Required: Sta.12+23.50 and Sta.9+24±)
48" Howell-Bunger valve
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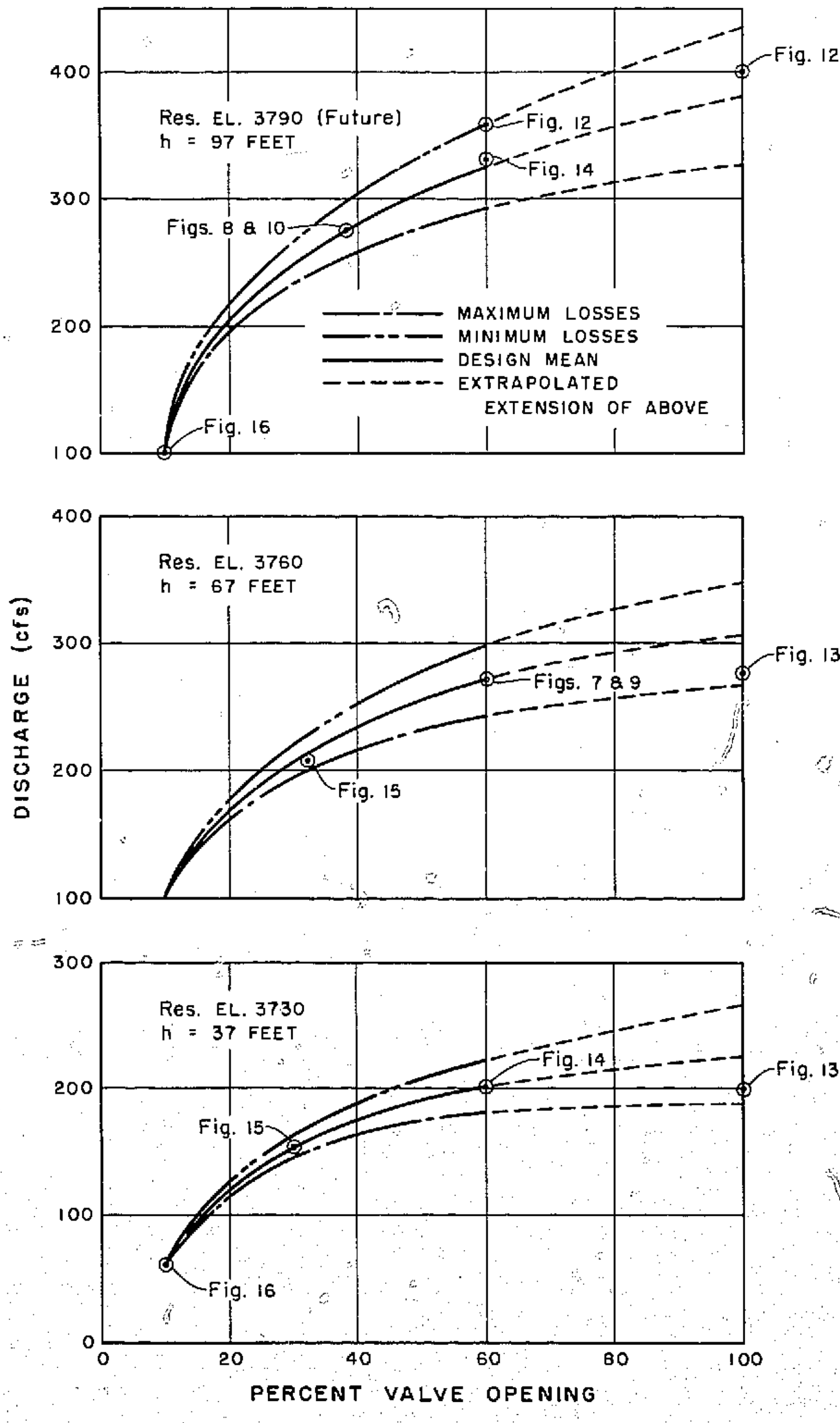
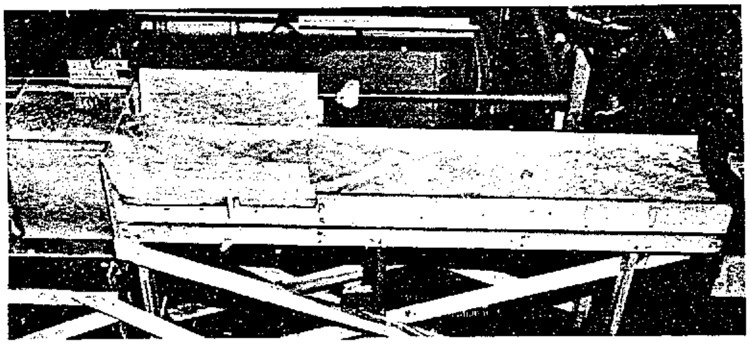
NEW MEXICO INTERSTATE STREAM COMSN.
CANADIAN RIVER PROJECT
UTE DAM
OUTLET WORKS MODIFICATION
PRELIMINARY DESIGN

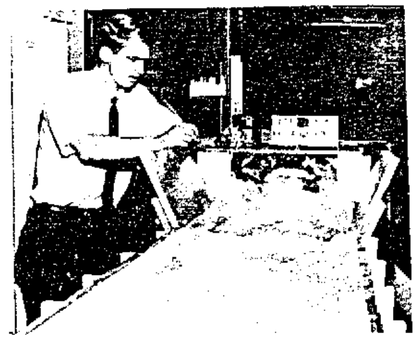


UTE DAM OUTLET WORKS
DISCHARGE VS VALVE OPENING

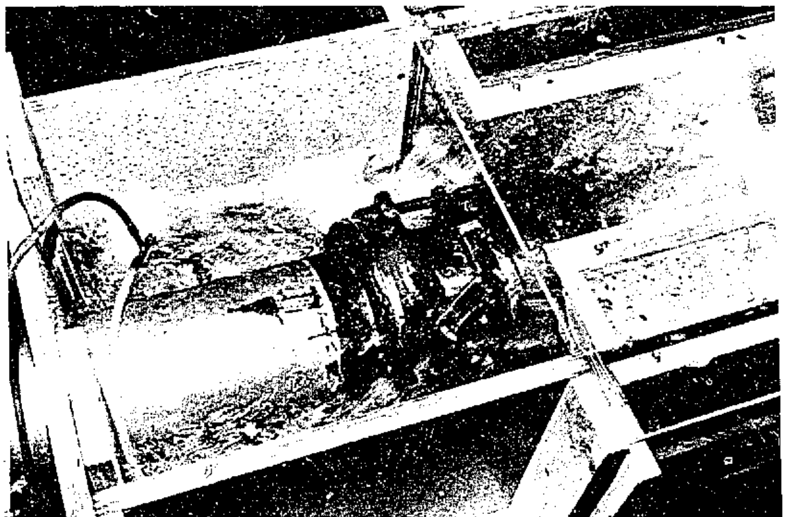
746

FIGURE 7





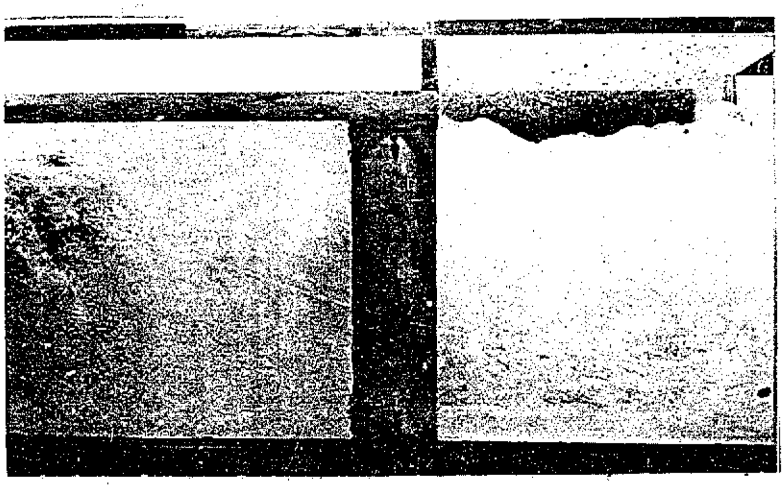
Turbulence and waves are excessive in the channel. Photos P1199-D-66228 and P1199-D-66229



NOTE:

Top of the canal lining in the downstream portion is 1-1/2 model inches higher than the top of the existing concrete lining in the prototype.

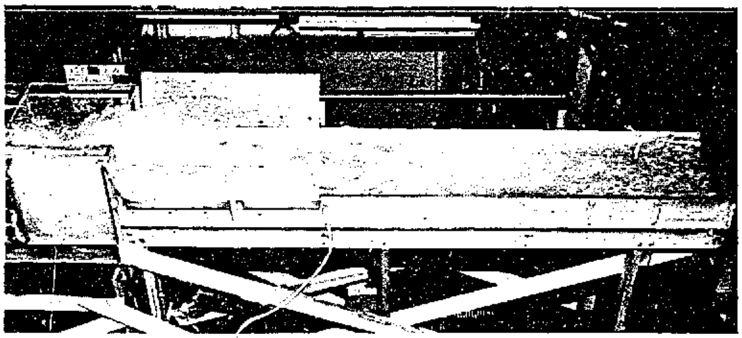
Part of the valve in the control structure is submerged by overhead spray and backwater effect. Photo P1199-D-66230



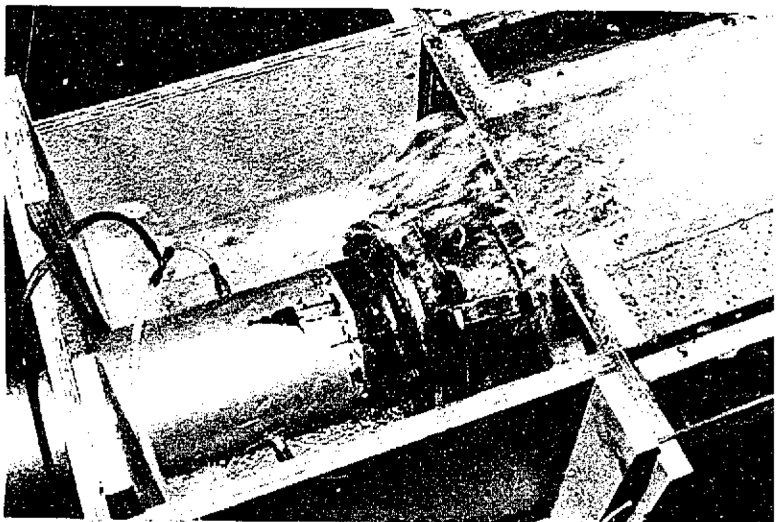
Reservoir elevation 3760. Discharging 275 cfs with the valve 60 percent open. Total head is 67 feet assuming design mean losses to valve. (See Figure 6)

Turbulence in the basin. Photo P1199-D-66231

UTE DAM OUTLET WORKS
PRELIMINARY DESIGN DISCHARGING AT DESIGN HEAD
1:8 SCALE MODEL



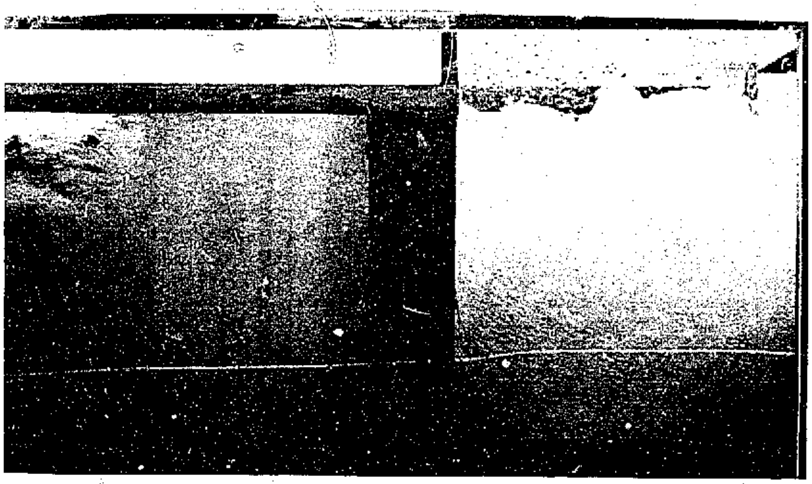

Turbulence and waves are excessive in the channel. Photos P1199-D-66232 and P1199-D-66233



NOTE:

Top of the canal lining in the downstream portion is 1-1/2 model inches higher than the top of the existing concrete lining in the prototype.

Part of the valve in the control structure is submerged by overhead spray and backwater effect. Photo P1199-D-66234

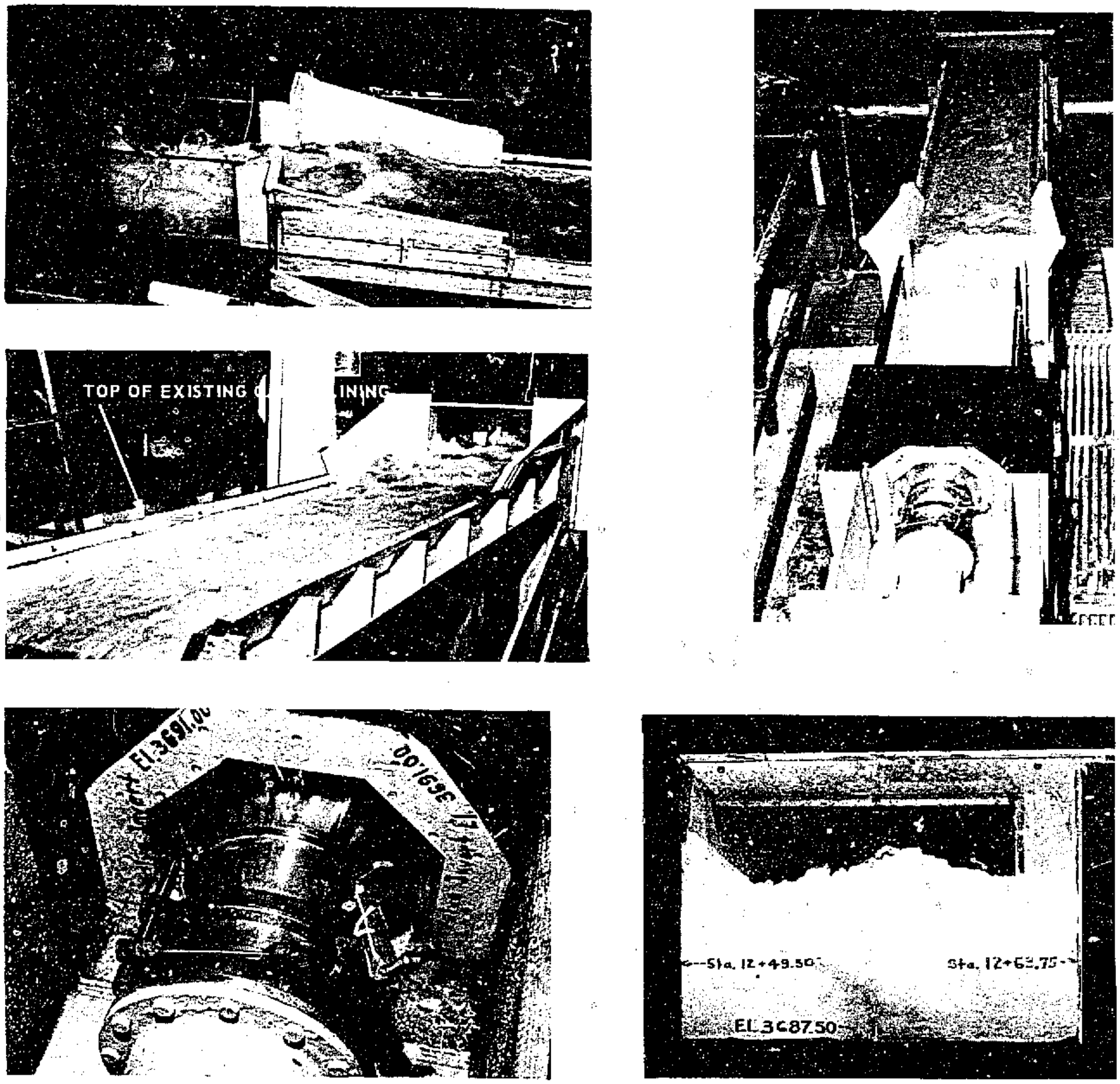


Reservoir elevation 3790. Discharging 275 cfs with the valve 60 percent open. Total head is 97 feet assuming design mean losses to valve. (See Figure 6)

Turbulence in basin. Photo P1199-D-66235

UTE DAM OUTLET WORKS
PRELIMINARY BASIN DISCHARGING AT FUTURE DESIGN HEAD
1:8 SCALE MODEL

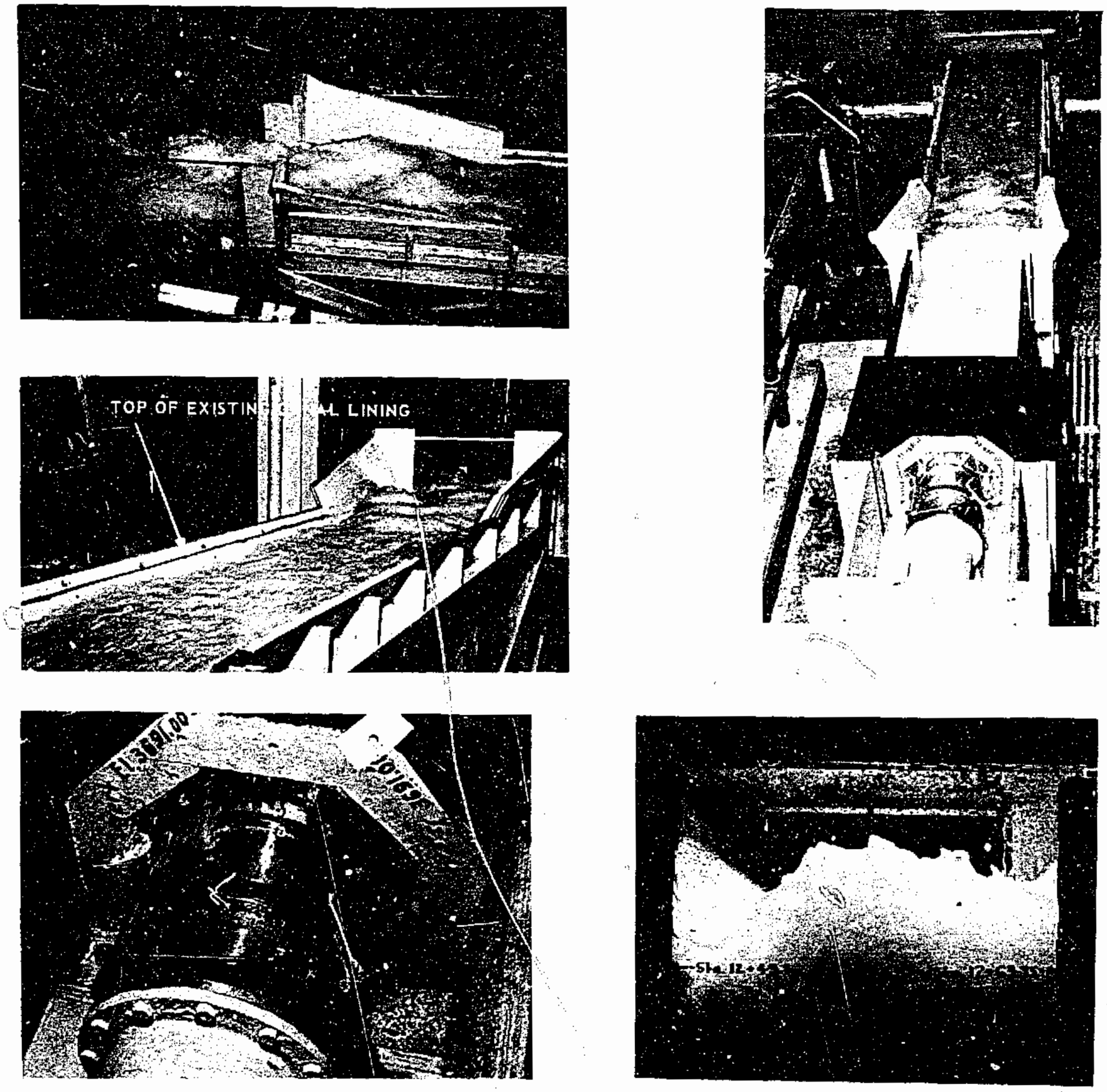
FIGURE 9



Reservoir elevation 3760 discharging
275 cfs with the valve 60 percent open.
Total head is 67 feet assuming mean losses
to valve. Compare with Figure 7.
(See Figure 6)

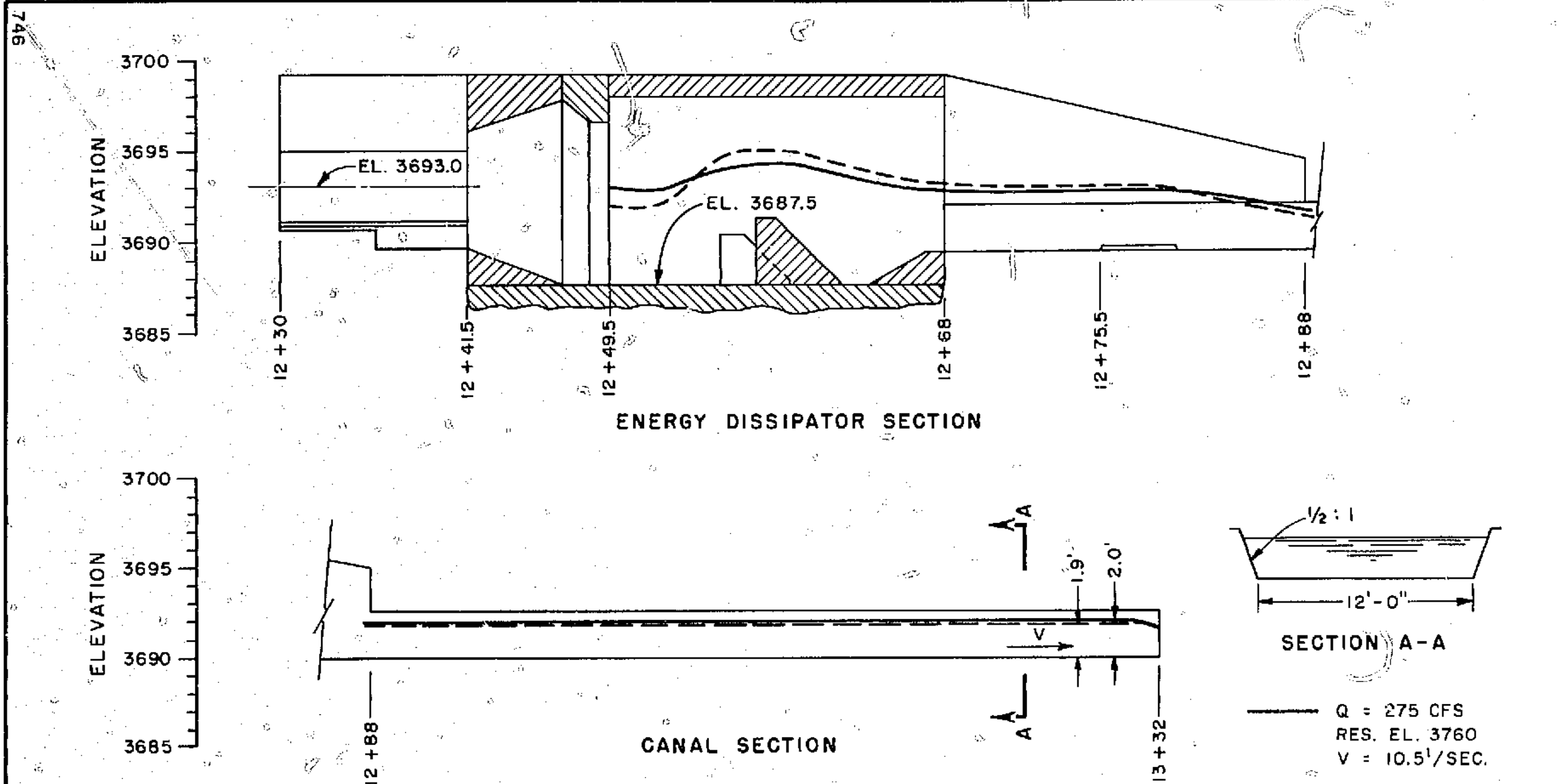
UTE DAM OUTLET WORKS
RECOMMENDED DESIGN DISCHARGING AT DESIGN HEAD
1:8 SCALE MODEL

FIGURE 10



Reservoir elevation 3790 discharging
275 cfs with the valve 37 percent open.
Total head is 97 feet assuming mean losses
to valve. Compare with Figure 8.
(See Figure 6)

UTE DAM OUTLET WORKS
RECOMMENDED DESIGN DISCHARGING AT FUTURE DESIGN HEAD
1:8 SCALE MODEL



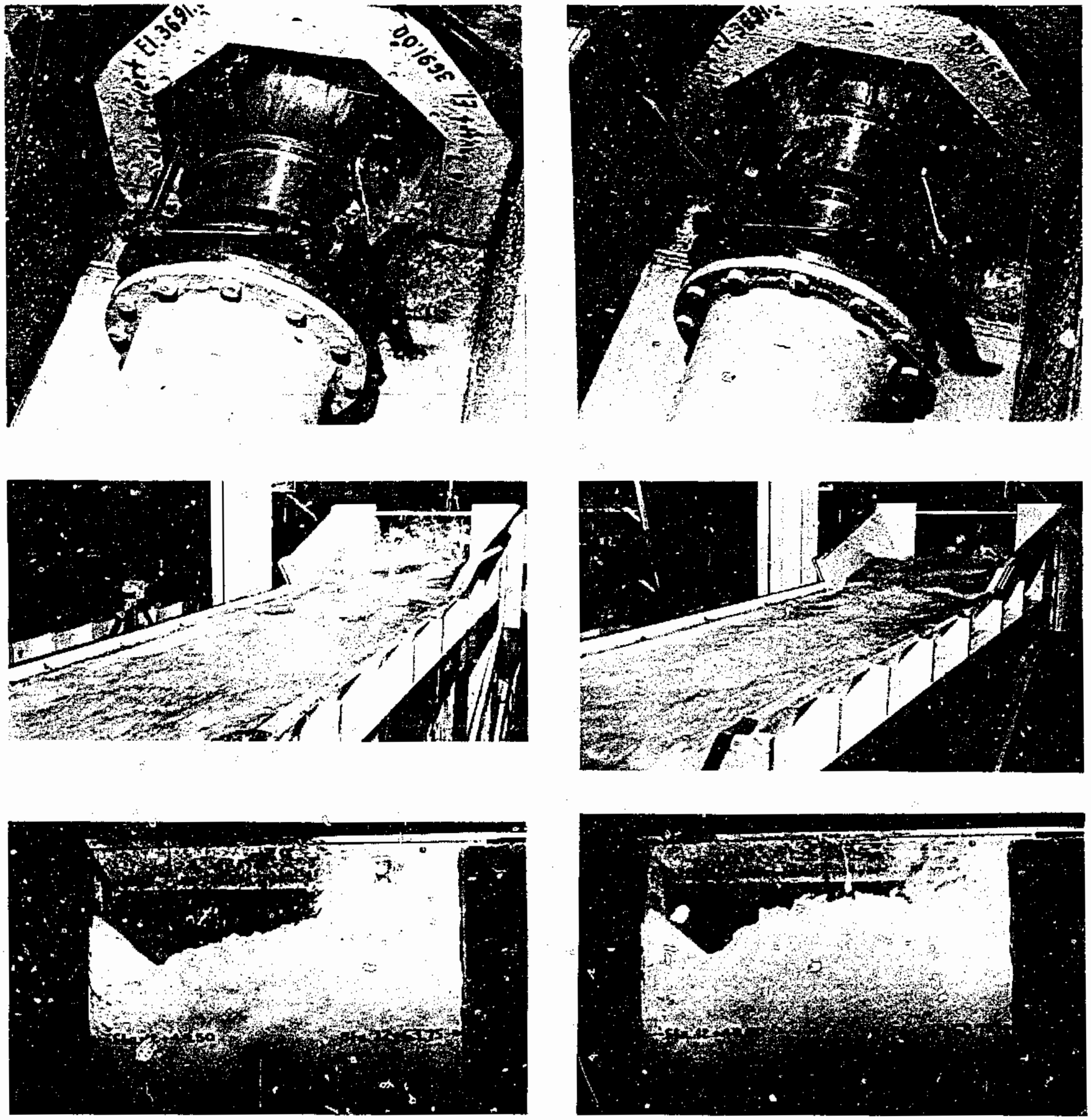
UTE DAM OUTLET WORKS

WATER SURFACE PROFILES

1 : 8 SCALE MODEL

FIGURE 11

FIGURE 12



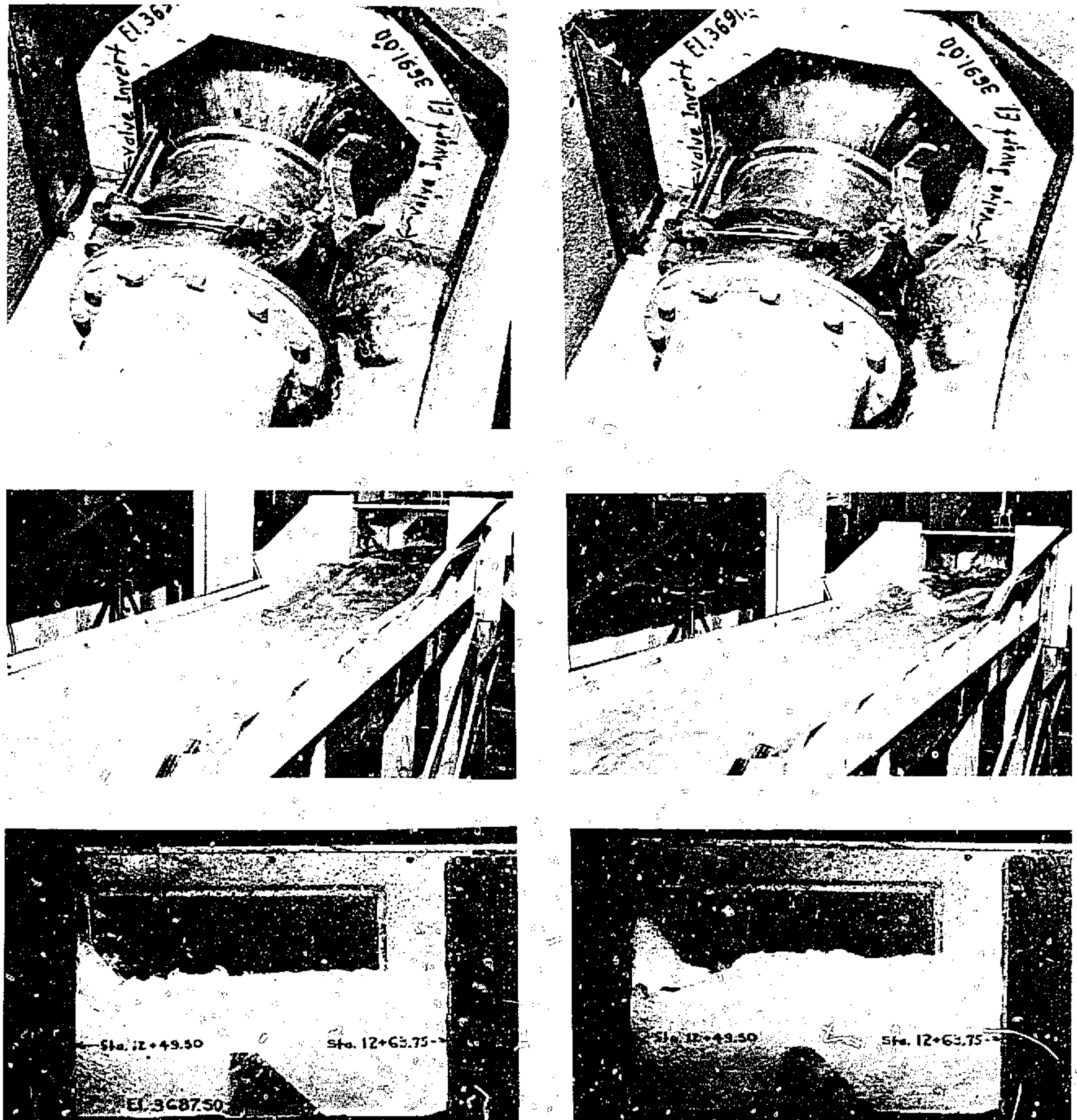
Reservoir Elevation 3790
100 Percent Valve Opening
Discharge 400 cfs

Reservoir Elevation 3790
60 Percent Valve Opening
Discharge 360 cfs

NOTE: Head losses to valve were assumed to be above the average computed values. These are not anticipated operating conditions. (See Figure 6)

UTE DAM OUTLET WORKS
FLOW IN RECOMMENDED DESIGN
1:8 SCALE MODEL

FIGURE 13



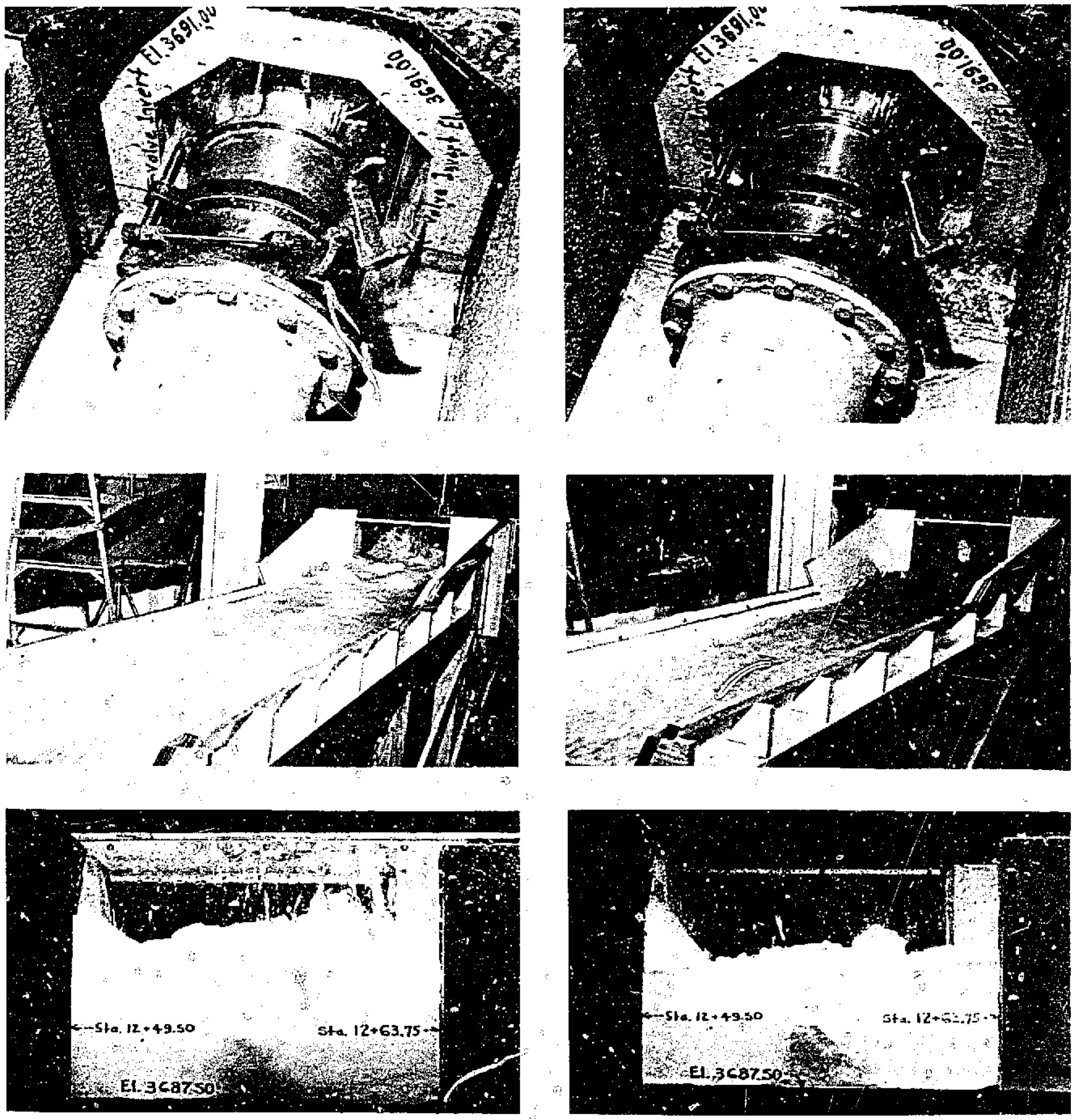
Reservoir Elevation 3730
100 Percent Valve Opening
Discharge 200 cfs

Reservoir Elevation 3760
100 Percent Valve Opening
Discharge 275 cfs

NOTE: Head losses to value were assumed to be the minimum computed values. These are not anticipated operating conditions. (See Figure 6)

UTE DAM OUTLET WORKS
FLOW IN RECOMMENDED DESIGN
1:8 SCALE MODEL

FIGURE 14



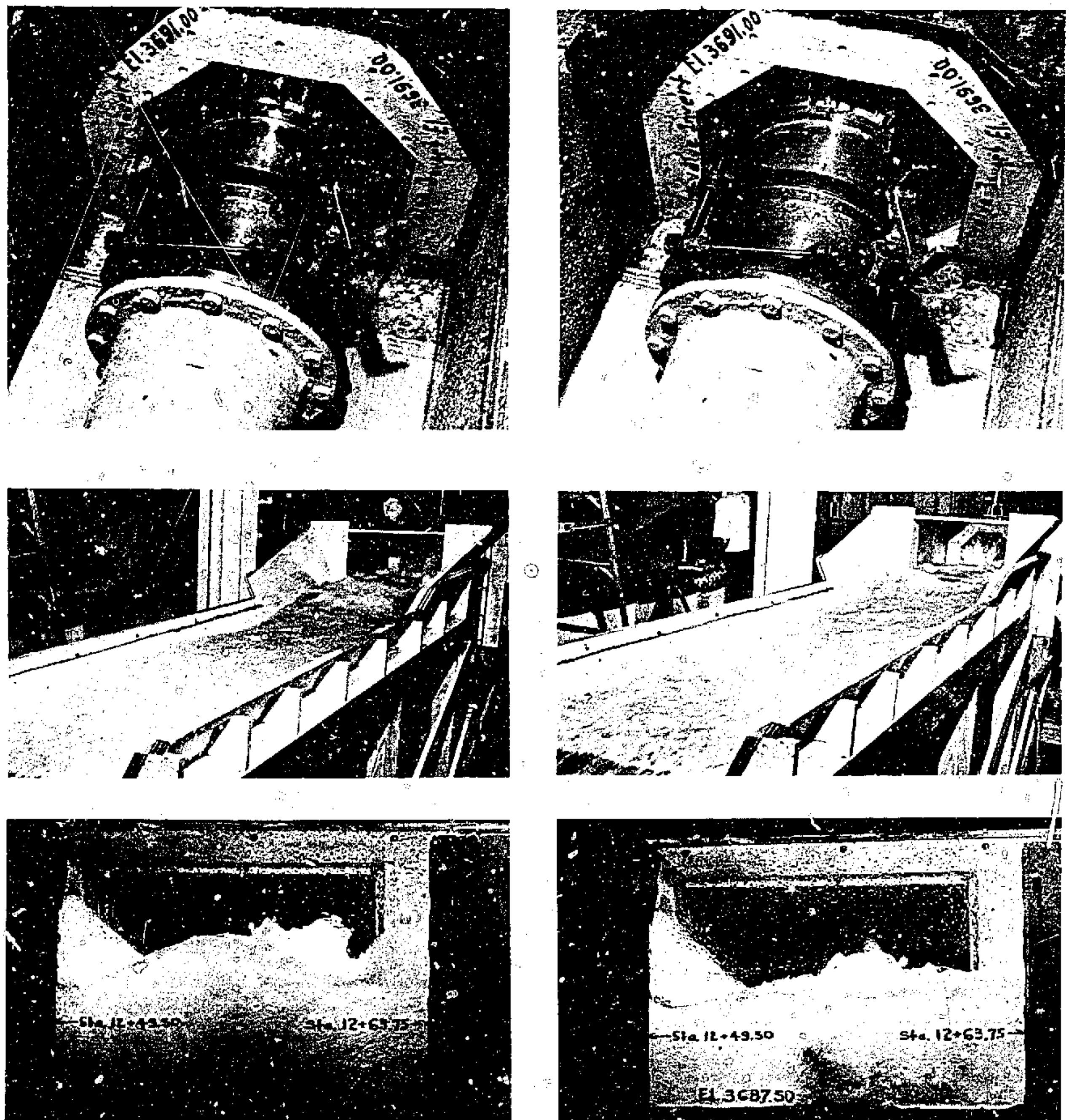
Reservoir Elevation 3790
60 Percent Valve Opening
Discharge 330 cfs

Reservoir Elevation 3730
60 Percent Valve Opening
Discharge 200 cfs

NOTE: Head losses to valve were assumed to be the average computed value (See Figure 6)

UTE DAM OUTLET WORKS
FLOW IN RECOMMENDED DESIGN
1:8 SCALE MODEL

FIGURE 15

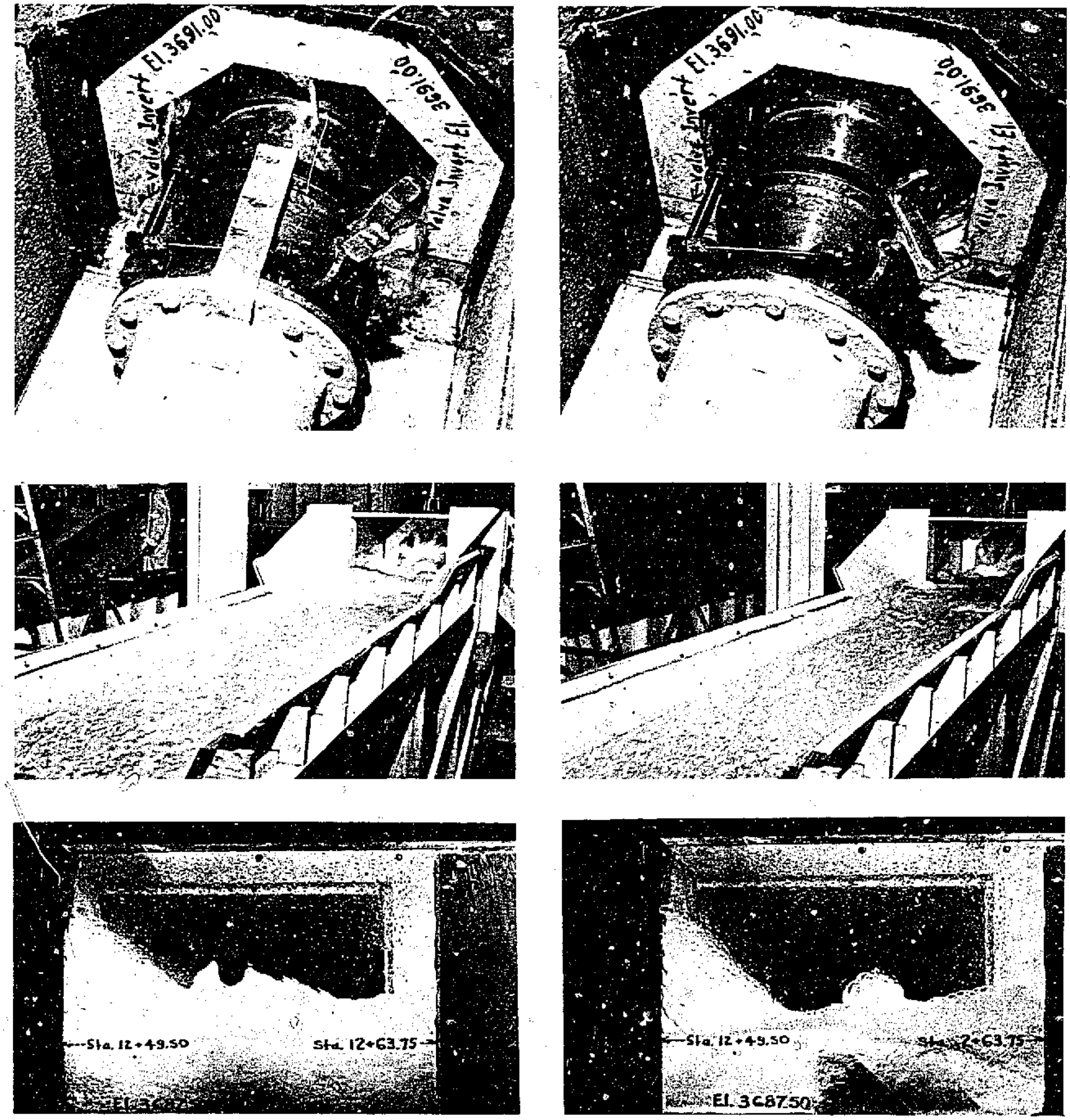


Reservoir Elevation 3760
32 Percent Valve Opening
Discharge 210 cfs

Reservoir Elevation 3730
30 Percent Valve Opening
Discharge 155 cfs

NOTE: Head losses to valve were assumed to be the average computed values. (See Figure 6)

UTE DAM OUTLET WORKS
FLOW IN RECOMMENDED DESIGN
1:8 SCALE MODEL



Reservoir Elevation 3790
10 Percent Valve Opening
Discharge 95 cfs

Reservoir Elevation 3730
10 Percent Valve Opening
Discharge 60 cfs

NOTE: Head losses to valve were assumed to be the average between the computed maximum and minimum.

UTE DAM OUTLET WORKS
FLOW IN RECOMMENDED DESIGN
1:8 SCALE MODEL

CONVERSION FACTORS--BRITISH TO METRIC UNITS OF MEASUREMENT

The following conversion factors adopted by the Bureau of Reclamation are those published by the American Society for Testing and Materials (ASTM Metric Practice Guide, E 380-68) except that additional factors (*) commonly used in the Bureau have been added. Further discussion of definitions of quantities and units is given in the ASTM Metric Practice Guide.

The metric units and conversion factors adopted by the ASTM are based on the "International System of Units" (designated SI for Systeme International d'Unites), fixed by the International Committee for Weights and Measures; this system is also known as the Giorgi or MKSA (meter-kilogram (mass)-second-ampere) system. This system has been adopted by the International Organization for Standardization in ISO Recommendation R-31.

The metric technical unit of force is the kilogram-force; this is the force which, when applied to a body having a mass of 1 kg, gives it an acceleration of 9.80665 m/sec/sec, the standard acceleration of free fall toward the earth's center for sea level at 45 deg latitude. The metric unit of force in SI units is the newton (N), which is defined as that force which, when applied to a body having a mass of 1 kg, gives it an acceleration of 1 m/sec/sec. These units must be distinguished from the (inconstant) local weight of a body having a mass of 1 kg; that is, the weight of a body is that force with which a body is attracted to the earth and is equal to the mass of a body multiplied by the acceleration due to gravity. However, because it is general practice to use "pound" rather than the technically correct term "pound-force," the term "kilogram" (or derived mass unit) has been used in this guide instead of "kilogram-force" in expressing the conversion factors for forces. The newton unit of force will find increasing use, and is essential in SI units.

Where approximate or nominal English units are used to express a value or range of values, the converted metric units in parentheses are also approximate or nominal. Where precise English units are used, the converted metric units are expressed as equally significant values.

Table I

QUANTITIES AND UNITS OF SPACE

Multiply	By	To obtain
	LENGTH	
Mil	25.4 (exactly)	Micron
Inches	25.4 (exactly)	Millimeters
	2.54 (exactly)*	Centimeters
Feet	30.48 (exactly)	Centimeters
	0.3048 (exactly)*	Meters
	0.0003048 (exactly)*	Kilometers
Yards	0.9144 (exactly)	Meters
Miles (statute)	1,609.344 (exactly)*	Meters
	1.609344 (exactly)	Kilometers
	AREA	
Square inches	6.4516 (exactly)	Square centimeters
Square feet	929.03*	Square centimeters
	0.092903	Square meters
Square yards	0.836127	Square meters
Acres	0.40469*	Hectares
	4,046.9*	Square meters
	0.0040469*	Square kilometers
Square miles	2.58999	Square kilometers
	VOLUME	
Cubic inches	16.3871	Cubic centimeters
Cubic feet	0.0283168	Cubic meters
Cubic yards	0.764555	Cubic meters
	CAPACITY	
Fluid ounces (U.S.)	29.5737	Cubic centimeters
	29.5729	Milliliters
Liquid pints (U.S.)	0.473179	Cubic decimeters
	0.473166	Liters
Quarts (U.S.)	946.358*	Cubic centimeters
	0.946331*	Liters
Gallons (U.S.)	3,785.43*	Cubic centimeters
	3.78543	Cubic decimeters
	3.78533	Liters
	0.00378543*	Cubic meters
Gallons (U.K.)	4.54609	Cubic decimeters
	4.54596	Liters
Cubic feet	28.3160	Liters
Cubic yards	764.55*	Liters
Acre-feet	1,233.5*	Cubic meters
	1,233,500*	Liters

Table II

QUANTITIES AND UNITS OF MECHANICS

Multiply	By	To obtain
MASS		
Grains (1/7,000 lb)	64.79891 (exactly)	Milligrams
Troy ounces (480 grains)	31.1035	Grams
Ounces (avdp)	28.3495	Grams
Pounds (avdp)	0.45359237 (exactly)	Kilograms
Short tons (2,000 lb)	907.185	Kilograms
	0.907185	Metric tons
Long tons (2,240 lb)	1,016.05	Kilograms
FORCE/AREA		
Pounds per square inch	0.070307	Kilograms per square centimeter
	0.689476	Newtons per square centimeter
Pounds per square foot	4.88243	Kilograms per square meter
	47.8803	Newtons per square meter
MASS/VOLUME (DENSITY)		
Ounces per cubic inch	1.72999	Grams per cubic centimeter
Pounds per cubic foot	16.0185	Kilograms per cubic meter
	0.0160185	Grams per cubic centimeter
Tons (long) per cubic yard	1.32894	Grams per cubic centimeter
MASS/CAPACITY		
Ounces per gallon (U.S.)	7.4893	Grams per liter
Ounces per gallon (U.K.)	6.2362	Grams per liter
Pounds per gallon (U.S.)	119.829	Grams per liter
Pounds per gallon (U.K.)	99.779	Grams per liter
BENDING MOMENT OR TORQUE		
Inch-pounds	0.011521	Meter-kilograms
	1.12985×10^{6}	Centimeter-dynes
Foot-pounds	0.138255	Meter-kilograms
	1.35582×10^{7}	Centimeter-dynes
Foot-pounds per inch	5.4431	Centimeter-kilograms per centimeter
Ounce-inches	72.008	Gram-centimeters
VELOCITY		
Feet per second	30.48 (exactly)	Centimeters per second
	0.3048 (exactly)*	Meters per second
Feet per year	0.965873×10^{-6}*	Centimeters per second
Miles per hour	1.609344 (exactly)	Kilometers per hour
	0.44704 (exactly)	Meters per second
ACCELERATION*		
Feet per second^2	0.3048*	Meters per second^2
FLOW		
Cubic feet per second (second-feet)	0.028317*	Cubic meters per second
Cubic feet per minute	0.4719	Liters per second
Gallons (U.S.) per minute	0.06309	Liters per second
FORCE*		
Pounds	0.453592*	Kilograms
	4.4482*	Newtons
	4.4482×10^{-5}*	Dynes

Multiply	By	To obtain
WORK AND ENERGY*		
British thermal units (Btu)	0.252*	Kilogram calories
	1,055.06	Joules
Btu per pound	2.326 (exactly)	Joules per gram
Foot-pounds	1.35582*	Joules
POWER		
Horsepower	745.700	Watts
Btu per hour	0.293071	Watts
Foot-pounds per second	1.35582	Watts
HEAT TRANSFER		
Btu in./hr ft^2 deg F (k, thermal conductivity)	1.442	Milliwatts/cm deg C
	0.1240	Kg cal/hr m deg C
Btu ft/hr ft^2 deg F	1.4880*	Kg cal m/hr m^2 deg C
Btu/hr ft^2 deg F (C, thermal conductance)	0.568	Milliwatts/cm^2 deg C
	4.882	Kg cal/hr m^2 deg C
Deg F hr ft^2/Btu (R, thermal resistance)	1.761	Deg C cm^2/milliwatt
Btu/lb deg F (c, heat capacity)	4.1868	J/g deg C
Btu/lb deg F	1.000*	Cal/gram deg C
Ft^2/hr (thermal diffusivity)	0.2581	Cm^2/sec
	0.09290*	M^2/hr
WATER VAPOR TRANSMISSION		
Grains/hr ft^2 (water vapor transmission)	16.7	Grams/24 hr m^2
Perms (permeance)	0.659	Metric perms
Perm-inches (permeability)	1.67	Metric perm-centimeters

Table III

OTHER QUANTITIES AND UNITS

Multiply	By	To obtain
Cubic feet per square foot per day (seepage)	304.8*	Liters per square meter per day
Pound-seconds per square foot (viscosity)	4.8824*	Kilogram second per square meter
Square feet per second (viscosity)	0.092903*	Square meters per second
Fahrenheit degrees (change)*	5/9 exactly	Celsius or Kelvin degrees (change)*
Volts per mil	0.03937	Kilovolts per millimeter
Lumens per square foot (foot-candles)	10.764	Lumens per square meter
Ohm-circular mils per foot	0.001662	Ohm-square millimeters per meter
Millicuries per cubic foot	35.3147*	Millicuries per cubic meter
Milliamps per square foot	10.7639*	Milliamps per square meter
Gallons per square yard	4.527219*	Liters per square meter
Pounds per inch	0.17858*	Kilograms per centimeter

GPO 858-655

ABSTRACT

Laboratory studies were made with a 1:8 scale model of Ute Dam outlet works to aid in the development of a basin-type energy dissipator. The existing outlet works is to be modified by installing a horizontal cylinder (fixed-cone) valve structure for controlling the discharge into a concrete outlet channel. Hydraulic model tests of the energy dissipator for the valve discharge revealed problems caused by submergence of the control valve, surging in the energy dissipator, and overtopping in the outlet channel. The preliminary design was modified to reduce submergence and to stabilize the flow in the energy dissipator and outlet channel.

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REC-OCE-70-11
Beichley, G L
HYDRAULIC MODEL STUDIES OF AN ENERGY DISSIPATOR FOR A FIXED CONE VALVE AT THE UTE DAM OUTLET WORKS
Bur Reclam Lab Rep REC-OCE-70-11, Hydraul Br, Mar 1970. Bureau of Reclamation, Denver, 19 p, 16 fig, 3 tab

DESCRIPTORS—/ *outlet works/ discharges/ head loss/ channels/ hydraulic models/ steady flow/ *energy dissipation/ *stilling basins/ New Mexico/ jets/ baffles/ model studies/ control structures/ discharge (water)/ hydraulic valves
IDENTIFIERS—/ New Mexico Interstate Stream Comm/ *energy dissipators/ *fixed-cone valve/ horizontal cylinder valve

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