Project Report No. 99

MODEL STUDIES - FOOTHILL FEEDER PROJECT
METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA
PART IV. SAN DIMAS RESERVOIR TURNOUT STRUCTURE

by

Alvin G. Anderson

and

David J. Anderson

Prepared for

HARZA ENGINEERING COMPANY
Chicago, Illinois

August 1968

CONTENTS

PREFACE

This report is the fourth in a series dealing with model studies of the various control structures to be used in the Foothill Feeder Tunnel of the Metropolitan Water District of Southern California. This report discusses some of the operating characteristics of the San Dimas Reservoir Turnout Structure that can be related to the results of previous experiments on the Morris Reservoir Turnout Structure (1), the Big Tujunga Gate and Spillway Structure (2), or the Regular Gate Structure (3). The physical similarities between the San Dimas Reservoir Turnout Structure and these other structures permits some conclusions and estimates regarding the performance of the San Dimas Reservoir Turnout Structure. Only general conclusions are drawn, since a detailed knowledge of the operating characteristics of the San Dimas Reservoir Turnout Structure must depend upon the results of a model study of the structure itself.

The discussion of the San Dimas Reservoir Turnout Structure covers various aspects that are similar to those investigated in the earlier experiments including gate calibrations, flow patterns, pressure fluctuations, and the operation of the emergency weirs.

The model studies of the structures for the Foothill Feeder were sponsored by the Harza Engineering Company of Chicago, Illinois, for the Metropolitan Water District of Southern California. The Harza Engineering Company was represented by David S. Louie. The study was made at the St. Anthony Falls Hydraulic Laboratory under the immediate direction of Alvin G. Anderson.

---

(1) Model Studies - Foothill Feeder Project. Metropolitan Water District of Southern California - Part III. Morris Reservoir Turnout Structure, Project Report No. 98, St. Anthony Falls Hydraulic Laboratory, August 1968.

(2) Model Studies - Foothill Feeder Project. Metropolitan Water District of Southern California - Part II. Big Tujunga Gate and Spillway Structure, Project Report No. 93, St. Anthony Falls Hydraulic Laboratory, February 1968.

(3) Model Studies - Foothill Feeder Project. Metropolitan Water District of Southern California - Part I. Regular Gate Structure, Project Report No. 91, St. Anthony Falls Hydraulic Laboratory, February 1967.

MODEL STUDIES - FOOTHILL FEEDER PROJECT
METROPOLITAN WATER DISTRICT OF SOUTHERN CALIFORNIA
PART IV. SAN DIMAS RESERVOIR TURNOUT STRUCTURE

I. INTRODUCTION

The Foothill Feeder Project of the Metropolitan Water District of Southern California consists of a large tunnel which incorporates various types of head control structures as well as other appurtenant structures. Each structure was designed to serve a prescribed function at a particular location. Since the functions were rather similar in nature, that is, to provide a differential head through the structure, the designs were of necessity also somewhat similar. This is particularly true of the San Dimas Reservoir Turnout Structure and the Morris Reservoir Turnout Structure. Detailed experiments were carried out with regard to the operation of the Morris Reservoir Turnout Structure so that some rough projections could be made as to the operation of the San Dimas Structure based upon these experimental results. It should be quite clear, however, that a detailed knowledge of the operating characteristics of the San Dimas Reservoir Turnout Structure can only be obtained by a model study in which all of the geometrical details are incorporated into the model and which is operated in accordance with the proposed operating scheme of the prototype.

Some of the flow characteristics to be expected in the San Dimas Reservoir Turnout Structure with regard to gate openings for various head differential values, patterns of flow within the structure for various modes of operation, the extent to which pressure fluctuations and gage vibrations might be a problem, and the air entrainment characteristics of flow over the emergency weirs, will be discussed in this report.

The San Dimas Reservoir Structure is designed to provide flow control in the several tunnels in conjunction with the San Dimas Reservoir as well as to provide for the rejection of water from the system by means of a spillway weir. The general features of this structure are shown in Chart 1. It consists essentially of a circular shaft 65 ft in diameter into which four tunnels are directed near the bottom with a spillway tunnel located at a higher elevation. The overall height of the structure is 107 ft. The flow enters the structure from the Glendora Tunnel or from the San Dimas Reservoir through the Reservoir Connection and leaves through either barrel of the LaVerne Pipeline or the Reservoir Connection depending upon the circumstances. The spillway weir crest is 68 ft above the invert and water will be rejected whenever the level within the structure exceeds this height. The upstream control at the exit of the Glendora Tunnel consists of a full height dividing wall fitted with three lift gates and an emergency weir 72 ft above the invert. The gate set consists of two outside gates, 6 ft-3in. wide, and a center gate, 2 ft-0 in. wide, for which the maximum gate opening is 18 ft-6 inches. The control for the LaVerne Pipeline consists of a three gate set for each barrel, each gate being 2 ft-0 in. wide and 18 ft-6 in. high. These two barrels can be operated independently or together. The San Dimas Reservoir Connection is an uncontrolled tunnel between the structure and the reservoir which would permit the San Dimas Reservoir to "float on the line" and thus control the water surface elevation within the Turnout Structure.

II. OPERATIONAL CHARACTERISTICS

A. Discharge Rating Curves

The discharge control characteristic of this structure involves the coupled effects of three sets of gates and three closely related water surface elevations which, in turn, are controlled by conditions outside of the control structure. When all of the gate sets are combined in one structure of limited size, the calibration characteristics of any one set will depend to a considerable degree on the relative position of the gates in the other sets. In order to investigate this interrelationship in the case of the Morris Reservoir Turnout Structure, a somewhat simplified analysis was made in order to delineate the approximate operating pattern. It showed in graphical form the upstream and downstream gate openings in terms of the total head drop and the head drop across the upstream and downstream gates individually. A separate graph was required for each discharge. The degree to which the actual rating curves deviated from this idealized curve was a measure of the flow patterns within the structure for the various water surface elevations and gate openings. Using some of the results of the calibration of the Morris Turnout Structure, as shown in Chart 2, as a guide one can expect that similar curves would be obtained for the San Dimas Structure. They will, however, be more complicated since the two gate sets of the LaVerne Pipeline can be operated independently. There will be so-called "No Control" lines for both the upstream and the downstream gates beyond which the individual gate sets exert no influence upon the head drop because the entire control has been taken over by a different opposite set. Since the internal geometry of the San Dimas Reservoir Turnout Structure differs somewhat from the Morris Reservoir Turnout Structure, an accurate set of calibration curves can only be obtained by measurements in a model that simulates the San Dimas Structure. However, the two structures are broadly alike and certain similarities in the nature of the flow can be expected.

It was found in the experiments of the Morris Structure that the calibration curves were independent of the tailwater elevation and depended only upon the water surface elevation within the gate chamber. As long as the tailwater elevation and the water surface elevation within the chamber were sufficiently high to completely submerge all of the gates, the flow pattern generated by the flow under the gates was similar in all essentials and the calibration curve remained the same. One of the principal differences between the Morris Reservoir Turnout Structure and the San Dimas Reservoir Turnout Structure is the expected elevation of the respective reservoirs with respect to the invert of the structure. For normal operating conditions the water surface elevation in the Morris Structure is from 90 to 110 ft above the invert, while for the San Dimas Reservoir Turnout Structure the water surface elevation within the chamber is between 40 and 60 ft above the invert. Some experiments were made in the Morris Reservoir Turnout Structure with very low tailwater elevations (El. 1082.5 and El. 1100.0 ft) that would compare with the operation of the San Dimas Structure. These data are plotted in Chart 2 which shows that similar data are obtained for tailwater elevation. It might, therefore, be expected that the calibration curves for the San Dimas Reservoir Turnout Structure will also be independent of the water surface elevation in the chamber over the normal operating range.

B. Flow Patterns Within the Gate Chamber

Because the San Dimas Reservoir Turnout Structure is more symmetrically oriented with respect to the flow from the Glendora Tunnel than the Morris Reservoir Turnout Structure, it can be expected that the flow patterns generated by various modes of operation will be less disturbed and irregular than those observed in the experiments on the Morris Structure. If the gates of both barrels of the LaVerne Pipeline are operated together, the flow pattern should be relatively undisturbed and the bifurcation nose between the two gate sets of the LaVerne Pipeline should be quite effective in dividing flow with a minimum of disturbance. The effect of the Reservoir Connection on the flow pattern is minimized by virtue of its size, location, and alignment. If the gates for Barrel No. 2 are closed so that all of the flow passes through Barrel No. 1 of the LaVerne Pipeline, it is very likely that vortex motion will be generated within the Reservoir Connection by the high velocity flow from the upstream gates. However, since the alignment of the Reservoir Connection is such that the high velocity jets cannot impinge directly upon the opening, the intensity of the vortex motion should be considerably reduced from that observed in the Morris Structure. In addition it may be expected, although to a much lesser extent, that some of the flow from the Glendora Tunnel will be deflected upwards and across the chamber at a higher elevation before it enters Barrel No. 2. It might also be expected that this pattern would eventually occur only for the maximum discharges and become relatively indistinguishable for the lower discharges. The same situation may well exist if the gates for Barrel No. 1 are closed and those in Barrel No. 2 are opened to pass the maximum discharge. If both sets are opened equally, the above described pattern would not exist and the discharge from the Glendora Tunnel would be smoothly divided between the two barrels.

The plan geometry of the San Dimas Reservoir Structure, including the overall diameter of 65 ft, the symmetrical arrangement of the two outlet barrels, the protective alignment of the Reservoir Connection, and the somewhat reduced maximum discharge through this structure, suggest strongly that the intensity of any abnormal flow pattern resulting from the geometry would be appreciably reduced from similar patterns observed in the Morris

Reservoir Turnout Structure. It can be expected that the operating characteristics with regard to gate calibration and flow pattern within the structure will be suitable. The results obtained in the Morris Reservoir Turnout Structure can be applied qualitatively to the flow pattern within the San Dimas Reservoir Turnout Structure with the general conclusion that the flow patterns will be less intense than those observed in the Morris Structure.

C. Pressure Fluctuations on Control Gates

The amplitudes and frequencies of the pressure fluctuations as measured in the Morris Reservoir Turnout Structure and the other control structures in this series suggest that gate vibration will not be a serious problem in the San Dimas Reservoir Turnout Structure. Because the gates to be used in this structure, like those previously studied, will be operated by rigid gate stems, the natural frequency of the gates is expected to be considerably higher than the significant frequencies of the fluctuations. Examination of the charts on pressure fluctuations in the Morris Reservoir Turnout Structure indicates that for all locations of the pressure transducer the power spectrum was always located in the range of frequencies well below the natural frequency of the gates. In addition to these measurements a systematic series of measurements, given in Chart 3, in which gate oscillations were measured for various natural frequencies, showed that the higher the natural frequency the smaller are the vertical oscillations of the gate. Since the natural frequencies of the 6 ft-3 in. gates and the 2 ft-0 in. gates ranges from approximately 22 to 45 cps, depending upon whether the gates are open or closed, are well above the region where appreciable vertical oscillations are found, it is expected that the effect of pressure fluctuations will be negligible. Gates which are suspended on cables or other relatively flexible systems are subject to the considerably higher vertical oscillations.

D. Flow Over the Emergency Weirs

Normally the flow through the San Dimas Reservoir Turnout Structure will be controlled by the several gate sets, but emergency weirs are provided in the event that the gates cannot be operated. The crest elevation of the emergency weir is 72 ft above the invert of the structure. From the weir crest the flow drops into the pool existing between the upstream and downstream gates. In the process air is entrained by the jet and carried down into the water. If the level is low enough and the discharge is great enough, it might be possible for some of the entrained air to be carried down into the downstream tunnels. Photos 1 and 2 show the maximum discharge over the emergency weirs in the Morris Reservoir Turnout Structure which in this regard is similar to the San Dimas Reservoir Turnout Structure. The water surface elevation in the gate chamber has been lowered to correspond approximately to the elevation in the San Dimas Structure. It is apparent from the photographs that, although the height of fall is considerably increased above that to be found in the San Dimas Structure, the jet does not penetrate sufficiently into the pool for the entrained air to be carried into the downstream tunnels. For this experiment the discharge was 1400 cfs which is the maximum to be expected in the prototype. It appears that for this structure, as well as the Morris Reservoir Turnout Structure, that the entrainment of air by emergency flow over the emergency weirs will not introduce complications in the operation of the structure.

III. CONCLUSIONS

This discussion of the hydraulics of the San Dimas Reservoir Turnout Structure is based primarily on the results of experiments on the Morris Reservoir Turnout Structure and to a lesser extent upon the results of experiments on the Big Tujunga Gate and Spillway Structure and the Regular Gate Structure which had been previously tested. The results of this comparison suggest that, as presently proposed, the San Dimas Reservoir Turnout Structure will operate at least as well as the Morris Reservoir Turnout Structure and in all probability somewhat better. It should be borne in mind, however, that this discussion is qualitative in nature and that more precise characterizations and quantitative evaluation of the various flow properties cannot be made without the use of a hydraulic model built to scale and incorporating the geometrical characteristics of the prototype. Based upon this discussion the following conclusions are suggested:

1. It is expected that the calibration curves of the San Dimas Structure will be regular and somewhat more complicated than

those obtained for the Morris Reservoir Turnout Structure, since there are two conduits in the LaVerne Pipeline which may be operated independently. The preparation of these charts can best be done by the use of a model of the structure in which discharges, head differentials, and gate openings can be measured directly.

2. It is expected that the flow patterns generated within the San Dimas Structure for various flow conditions will be similar, but with a greatly reduced intensity, to those observed in the Morris Reservoir Turnout Structure. This conclusion is based upon the greater symmetry of the flow pattern within the structure and the fact that the Reservoir Connection is somewhat smaller, and its alignment is such that the vortex motion will be minimized. If the gates of one barrel are completely closed, then it can be expected that secondary currents will develop within the chamber in which the flow on one side will be deflected upward and cross over at higher levels before entering the other barrel.

3. The pressure fluctuations on the gates which might give rise to gate vibrations will be similar to those observed on the Morris Reservoir Turnout Structure. The frequency for which the pressure fluctuations are a maximum is very appreciably less than the natural frequency of the gates themselves and consequently will have little effect upon the magnitude of gate oscillations. Evidence is presented, based upon other experiments, which shows that for the natural frequencies characteristic of the San Dimas gates, the vertical oscillations will be a minimum.

4. If and when the emergency weirs are operated, the air entrained by the jet in falling into the pool in the gate chamber will not be carried into the tunnels because of the large depth of water above the tunnel elevation. The air entrained will have been freed and can rise to the surface and into the atmosphere within the gate chamber.

5. It appears that the results obtained from previous experiments of the control structures do suggest that the flow through the San

Dimas Reservoir Turnout Structure will be smooth and relatively undisturbed, and that the structure will operate effectively to control the flow of the Glendora Tunnel at this point. All of these estimates are based upon the previous experiments. Detailed and more reliable conclusions regarding the operation of the San Dimas Structure must depend upon a model study in which the prototype flow can be simulated.

LIST OF PHOTOS

PHOTO 1 (Serial No. 168C-170) As the discharge flows over the emergency weir, the jet so formed impinges on the water within the gate chamber and entrains air as it penetrates the surface. Because of the size of the chamber, the air bubbles can rise to the surface before they are carried into the downstream tunnel.

PHOTO 2 (Serial No. 168C-171) This photo is similar to Photo 1 except that the water level in the gate chamber has been changed.

PHOTO 1 (Serial No. 168C-170) As the discharge flows over the emergency weir the jet so formed impinges on the water within the gate chamber and entrains air as it penetrates the surface. Because of the size of the chamber, the air bubbles can rise to the surface before they are carried into the downstream tunnel.

PHOTO 2 (Serial No. 168C-171) This photo is similar to Photo 1 except that the water level in the gate chamber has been changed.

Photo 1

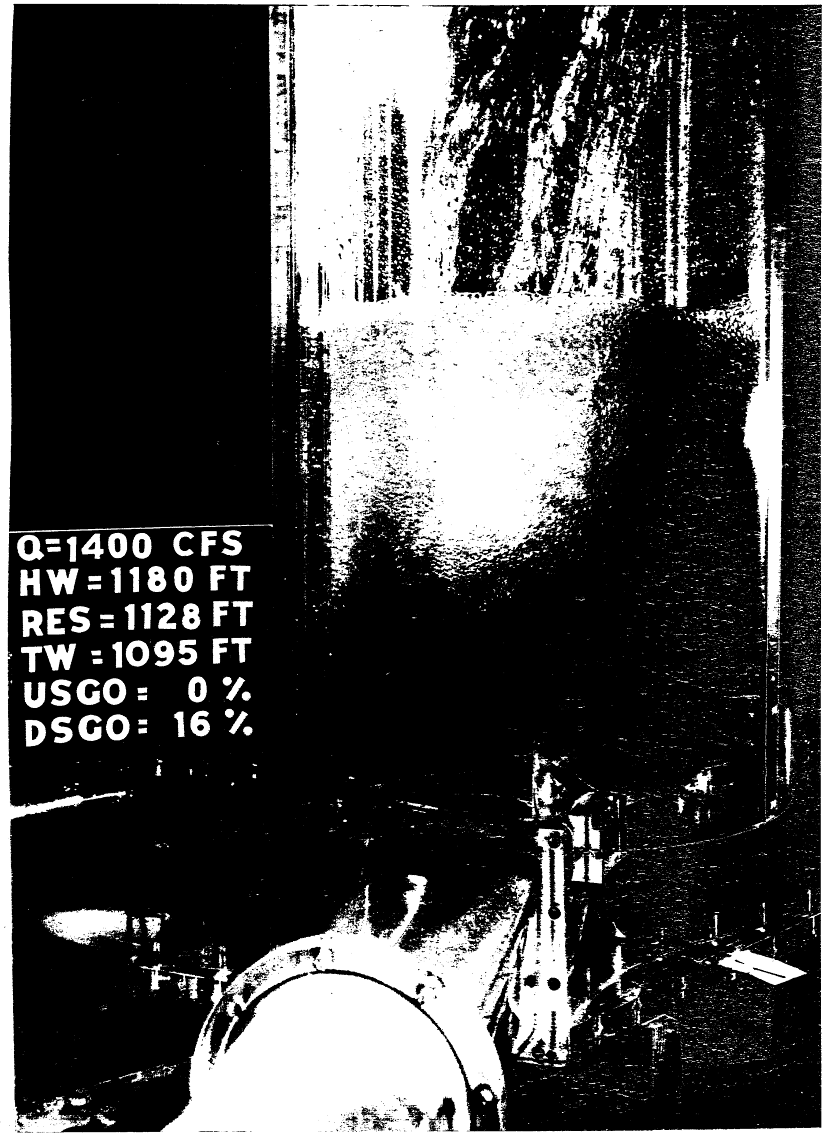
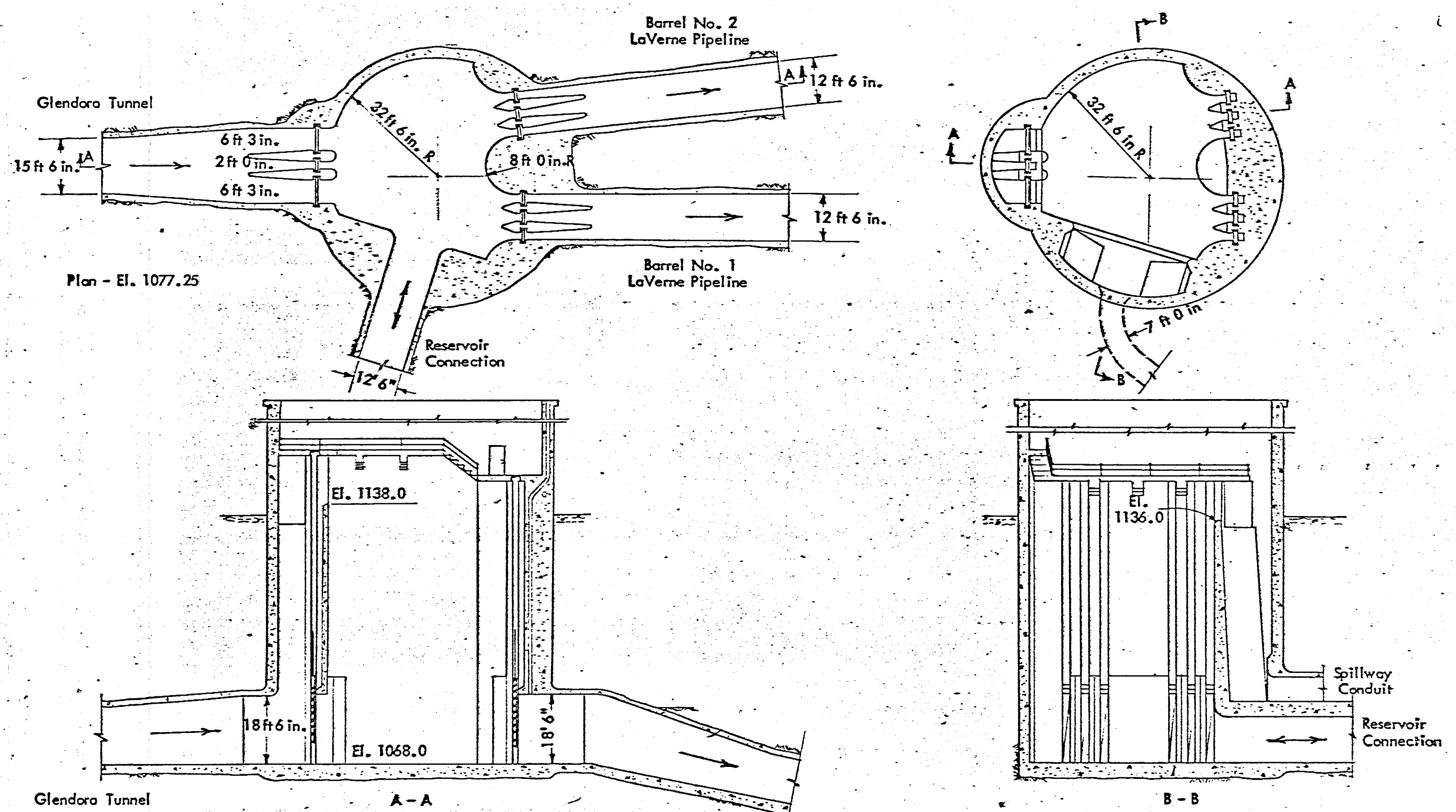


Photo 2

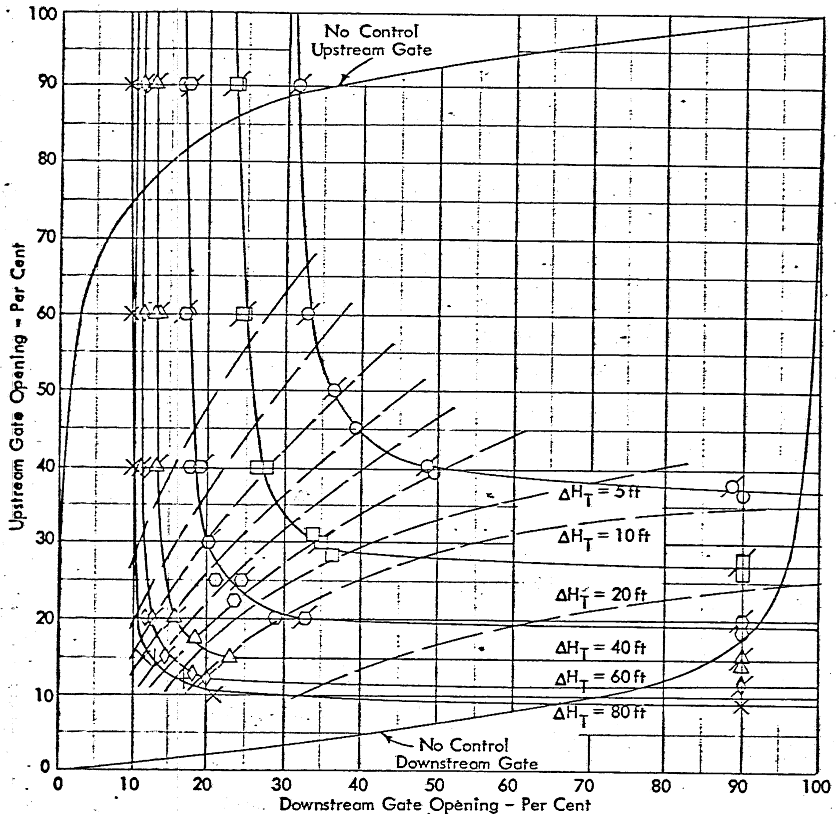
LIST OF CHARTS

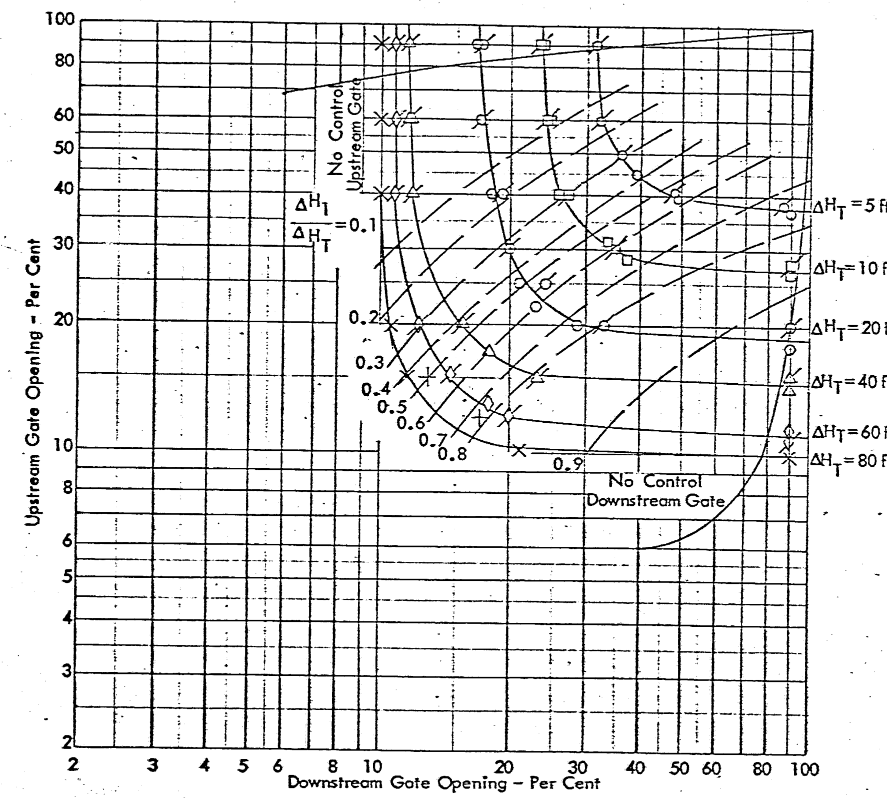


PLAN AND ELEVATION
SAN DIMAS RESERVOIR
TURNOUT STRUCTURE

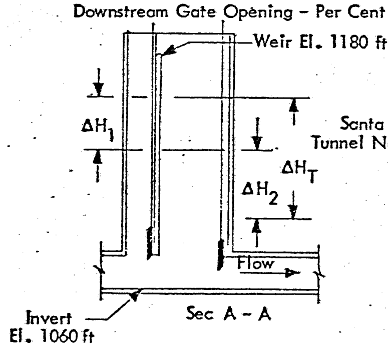
MODEL STUDIES – FOOTHILL FEEDER PROJECT Metropolitan Water Dist. of Southern California SAN DIMAS RESERVOIR TURNOUT STRUCTURE		
Harza Engineering Co., Chicago, Ill.		
SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN RP	CHECKED AGA	APPROVED
SCALE	DATE 8/9/68	NO. 1688459-234

CHART 1

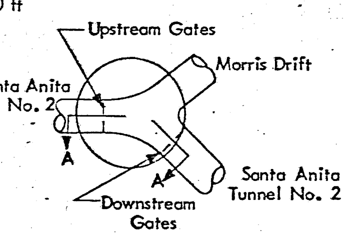




T.W. El 1100	T.W. El 1082.5	ΔH_T in Ft
×	+	80
◇ (flagged)	◇	60
△ (flagged)	△	40
⬡ (flagged)	⬡	20
□ (flagged)	□	10
○ (flagged)	○	5



Sec A - A



Notes:

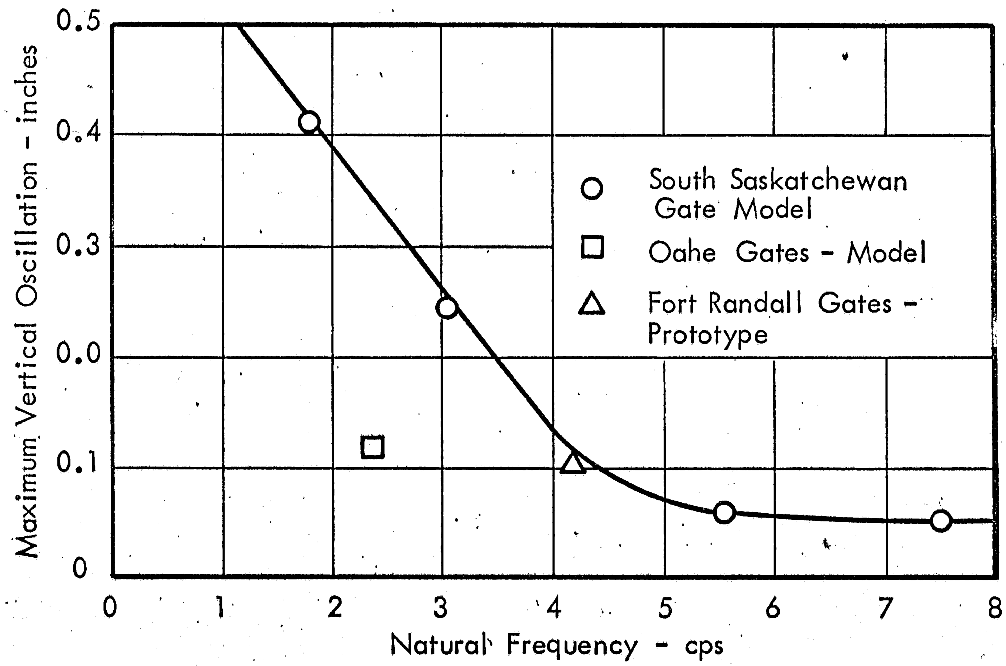
1. Q = 1550 cfs
2. T.W. Elev. 1100 ft and 1082.5 ft
3. Three gates in each set are opened equally
4. No flow in Morris Drift
5. $\Delta H_T = \Delta H_1 + \Delta H_2$
6. Tests made with low tailwater elevations comparable to San Dimas Reservoir elevations.

TOTAL HEAD DIFFERENTIAL AS A FUNCTION OF UPSTREAM AND DOWNSTREAM GATE OPENINGS-MORRIS RESERVOIR TURNOUT STRUCTURE

MODEL STUDIES- FOOTHILL FEEDER PROJECT
Metropolitan Water Dist. of Southern California
SAN DIMAS RESERVOIR TURNOUT STRUCTURE
Harza Engineering Co., Chicago, Ill.
SAINT ANTHONY FALLS HYDRAULIC LABORATORY
UNIVERSITY OF MINNESOTA

DRAWN RP	CHECKED AGA	APPROVED
SCALE	DATE 8/9/68	NO. 168B459-235

CHART 2



GATE OSCILLATIONS AS A FUNCTION OF NATURAL FREQUENCY

MODEL STUDIES - FOOTHILL FEEDER PROJECT Metropolitan Water Dist. of Southern California SAN DIMAS RESERVOIR TURNOUT STRUCTURE Harza Engineering Co., Chicago, Ill.		
SAINT ANTHONY FALLS HYDRAULIC LABORATORY UNIVERSITY OF MINNESOTA		
DRAWN RP	CHECKED AGA	APPROVED
SCALE	DATE 8/9/68	NO. 168A459-236