UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

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HYDRAULIC LABORATORY REPORT NO. 112

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MODEL WAVE STUDIES FOR CONTRA COSTA CANAL CENTRAL VALLEY PROJECT

By

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Denver, Colorado
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UNITED STATES
DEPARTMENT OF THE INTERIOR
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Branch of Design and Construction
Engineering and Geological Control
and Research Division
Denver, Colorado
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Laboratory Report No. 112
Hydraulic Laboratory
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Reviewed by:

Subject: Model Wave Studies for Contra Costa Canal, Central Valley Project.

Introduction.

The Contra Costa Canal, figure 1, is a feature of the Central Valley Project. Water is diverted from the lower Sacramento River and conveyed across the Sacramento-San Joaquin Delta to the canal intake at Rock Slough, near Knightsen, California. The canal at its intake has a capacity of 350 second-feet which is reduced in the 46-mile length to 72 second-feet at its terminus at Vine Hill Reservoir. Four pumping plants along the canal lift the water from approximately sea level to an elevation of 124 feet. It is designed to serve at least 30,000 acres of agricultural and suburban residential areas, in addition to the industrial and municipal regions between Antioch and Martinez, California.

Problem for model study.

Pump operation in the finished canal produced waves which overtopped the lining even though the ultimate pump capacity had not been reached. These waves were about 20 to 30 feet in length and 1.5 feet in amplitude. Model studies were conducted to observe the characteristics of these waves and to attempt to discover some practicable method of damping them.

Generation of waves.

A 1:24 scale model, figure 2, was constructed, consisting of a long, sheet-metal-lined channel with an enlarged pool at the downstream end. Although waves were first generated manually by a revolving paddle near the upstream end of the model canal, the correctness of length, amplitude, and velocity of the bore waves created in this manner was questionable. It was decided to duplicate the gates and transition of a pumping plant at the upstream and downstream ends of the model. By arranging the gates in such a manner that they could be simultaneously raised or lowered in any combination, it was hoped that true bore waves could be created.

Tests of this arrangement disclosed that the intensity of the waves was not as correspondingly great as those observed on the prototype when the same procedure of gate operation was followed. On the prototype structure the overtopping waves are caused by closing the gates two at a time. Closing two gates on the model formed no undulations of appreciable magnitude, and it was only when all six gates of the model pumping plant were closed that a wave of corresponding intensity was obtained.

Characteristics of model waves.

This inconsistency made it necessary to determine the characteristics of the model wave and compare them with those produced on the prototype. Differences in the procedure necessary for generation would be unimportant if the wave characteristics compared favorably, but lack of similarity in length, amplitude, and velocity would make any further testing meaningless. A grid system was therefore laid out on one wall of the model channel, and photographs taken at the instant waves passed it, figure 3.

Using these pictures, the length, amplitude, and shape of model-produced negative and positive bore waves were determined.

Positive bore waves, created by raising the upstream gates, took the form of a series of undulations of gradually diminishing intensity. The average distance between crests was 13 inches (26 feet prototype), and the maximum amplitued was 1.25 inches (1.6 feet prototype) - comparing favorably with the prototype.

Negative bore waves, created by suddenly closing the downstream gates, tended to increase in size as they traveled upstream. The average length and amplitude were 18 inches (36 feet prototype) and 1 inch (1.25 feet prototype), respectively.

The speed of these waves was approximately 2.4 feet per second (11.8 feet per second prototype) as compared to an observed velocity of 12.4 feet per second attained by the prototype waves.

Embayments.

A similar wave problem on the Stanislaus Canal in northern California had been solved by placing embayments at intervals along the canal banks. The dimensions of these recesses were such that the crests of incoming waves were deflected to fill succeeding troughs. In this manner the crests and troughs were leveled.

Embayments were, therefore, incorporated in the model, figure 2. Two were placed on opposite sides of the channel approximately 10 feet from the downstream end of the model, built in such a manner that their dimensions could easily be changed. As a first trial, the embayment floors were placed one-half inch below the normal water surface, and their side dimensions made approximately equal to one-half the wave length or six inches. The slope of the walls was made 1-1/4:1, the same as that of the sides of the canal proper. This arrangement was tested for both negative and positive bore waves. Some damping was observed in a few of the waves, but the majority were not favorably affected. The inconsistency seemed to be due to oscillations of varying frequency set up in the embayments themselves which destroyed the regular rhythm of entrance and departure of the wave crests. Under the influence of these oscillations the water leaving an embayment often augmented instead of damping a wave. Dimensions were changed several times in trying to eliminate this effect, but no satisfactory results could be obtained. Moreover, this oscillation reached such proportions that considerable freeboard would be necessary on the embayment structures. This type of solution was, therefore abandoned.

Floats.

Several types of floats, constructed of longitudinal members, longitudinal and cross members in the form of a grid, and members forming solid rafts, were tested. It was found that a solid float approximately 100 feet (prototype) in length, placed near the downstream gates, would temporarily damp out negative bore waves; however, these waves tended to reform, often acquiring, in the distance between the float and the upstream gates (1,000 feet prototype), even greater amplitude than had been attained when approaching the float. This indicated that 100-foot floats would have to be placed at intervals of not more than 1,000 feet in order to keep the wave heights with-in allowable limits.

Moreover, the performance of the floats was not satisfactory in the case of positive bore waves, created by opening the upstream gates. The first and largest of a series of these waves was seldom affected by the float, and several others of the series would also escape damping.

Considering the excessive number of floats required in the case of negative bore waves and their ineffectiveness in the case of positive bore waves, this method was not considered practicable.

Bellmouth.

It was suggested that the elimination of negative bore waves might be achieved by placing two horizontal members, one located above the other, across the canal, with the lower member on the level of the canal floor, figure 2. These members - shaped, in cross section, to resemble a bell-mouth converging downstream - would offer little resistance to the normal flow traveling downstream, because of the high coefficient (approaching unity) of such an entrance; but the negative bore waves, traveling upstream, would lose considerable energy in passing through what is essentially a square-edged orifice with diverging boundaries.

These members were located on the mutual centerline of a pair of embayments when placed on the model. The recesses, whose floor levels were at the same elevation as the floor of the canal, were used in order that the length of the horizontal members could be made 19-3/4 inches (39.5 feet prototype). This allowed, when placing the upper member 1-3/4 inches (3.5 feet prototype) above the lower member, sufficient area for the flow to pass through without difficulty when traveling downstream.

When tested, a damping effect on the negative bore waves was noticeable; but reformation began almost immediately. Apparently, the ratio between the entrance coefficients in opposite directions was not great enough to produce the desired results.

Increase of canal friction.

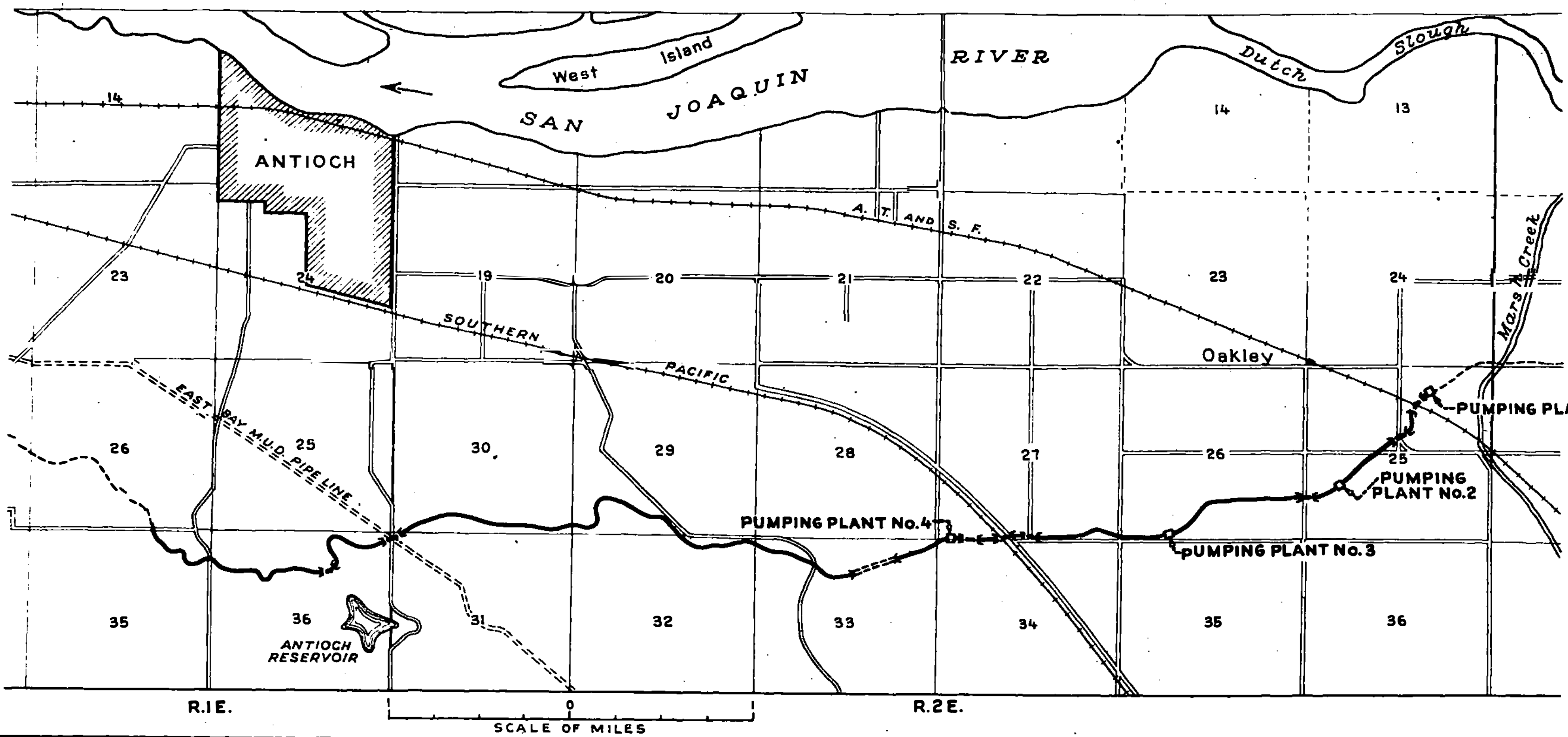
Tests conducted on the model in which the friction along the entire length of the channel was increased by small rocks and other obstacles indicated that the increased friction which would be developed eventually on the prototype by the natural roughening of the concrete linging, growth of moss, etc., would aid in eliminating the waves.

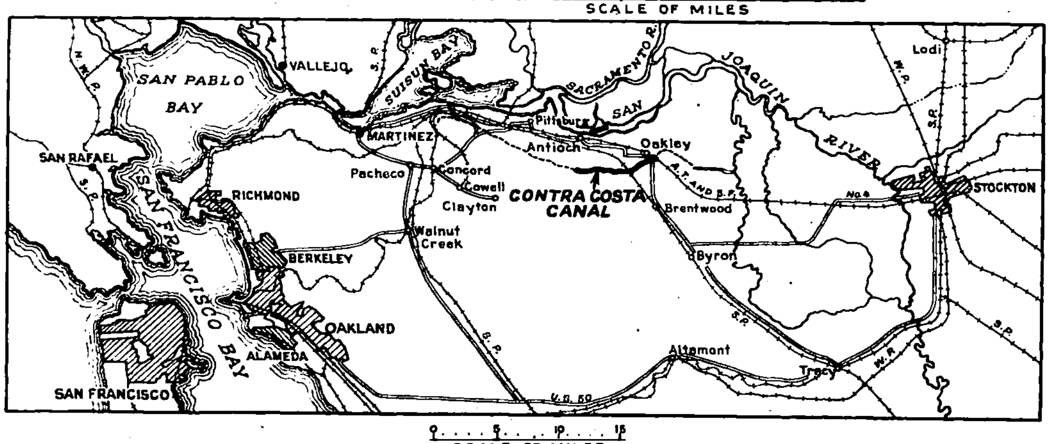
Conclusions.

(a) The inadequacy of all methods tested except that which increased the canal friction would indicate that the problem is not solely one of eliminating the waves, but also of destroying the energy which creates them.

(b) In view of the results of the model investigation, it was believed more feasible to reduce the operating depth in the canal than to employ any of the devices tested.

(c) The natural increase in roughness of the lining which occurs as the canal ages would be an everincreasing factor in destroying the energy creating the waves, thus decreasing the distance which they would travel unabated. It is probable that such a phenomenon would later permit an increase in the operating depth of the canal.





VICINITY MAP

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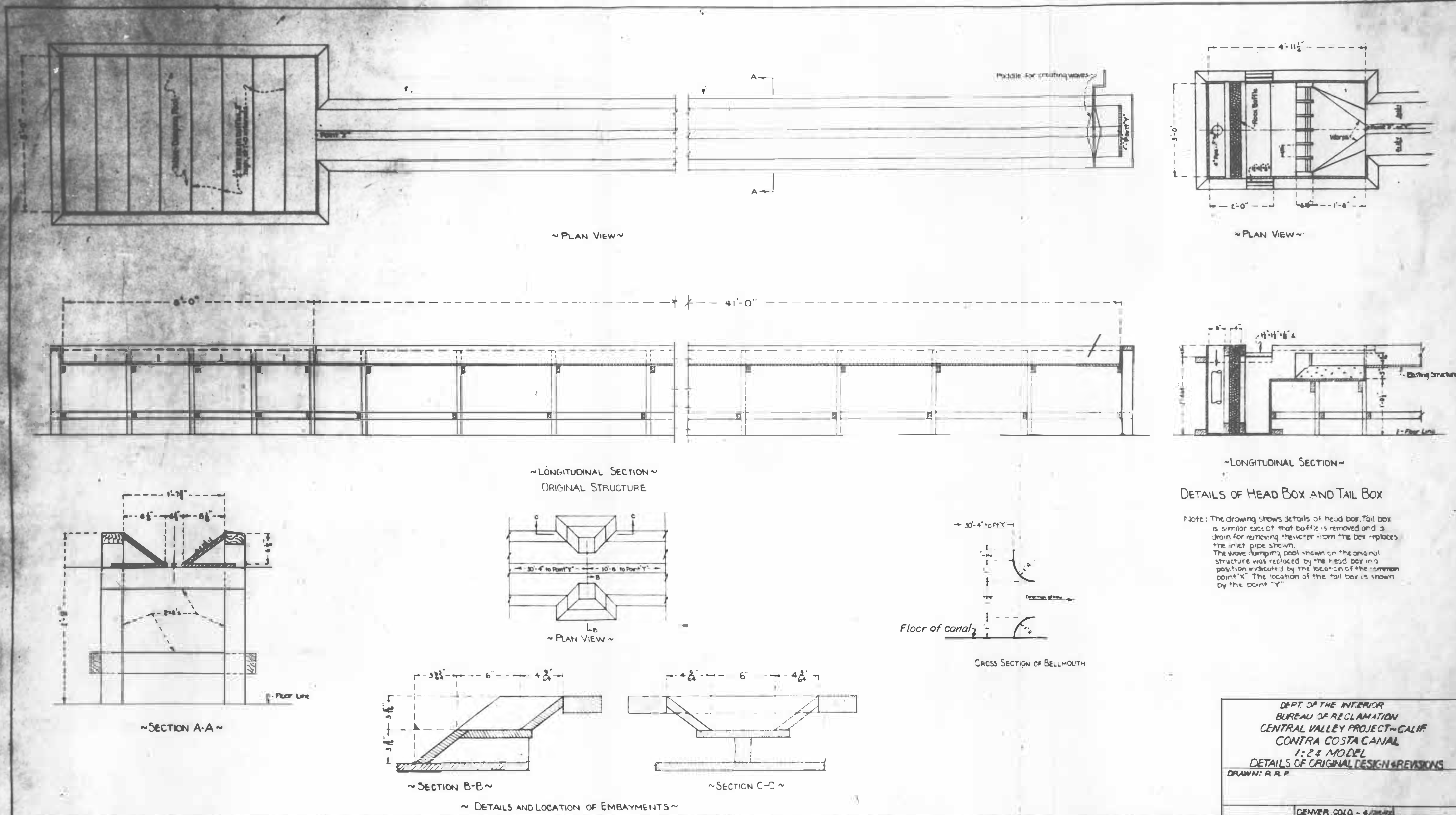
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
CENTRAL VALLEY PROJECT-CALIFORNIA
DELTA DIVISION

CONTRA COSTA CANAL
PUMPING PLANTS- Nos. 1, 2, 3 AND 4
LOCATION MAP

DRAWN: C.H.H.	SUBMITTED: H.R. McBirney
TRACED: C.M.A.	RECOMMENDED:
CHECKED:	APPROVED:
	DENVER, COLORADO. SEPT. 6, 1938

214-D-1160

DRAWING No. 1


Paddle for creating waves
A
A
~PLAN VIEW~
4'-11"
3'-0"
2'-0"
1'-8"
~PLAN VIEW~
8'-0"
41'-0"
~LONGITUDINAL SECTION~
ORIGINAL STRUCTURE
Existing Structure
Floor Line
~LONGITUDINAL SECTION~
DETAILS OF HEAD BOX AND TAIL BOX
Note: The drawing shows details of head box. Tail box is similar except that baffle is removed and a drain for removing the water from the box replaces the inlet pipe shown.
The wave damping pool shown on the original structure was replaced by the head box in a position indicated by the location of the common point "X". The location of the tail box is shown by the point "Y".
Floor Line
~SECTION A-A~
C
C
30'-4" to Point "Y"
10'-6" to Point "Y"
B
~PLAN VIEW~
6"
6"
~SECTION B-B~
~SECTION C-C~
~ DETAILS AND LOCATION OF EMBAYMENTS ~
30'-4" to Pt "Y"
Direction of flow
Floor of canal
CROSS SECTION OF BELLMOUTH
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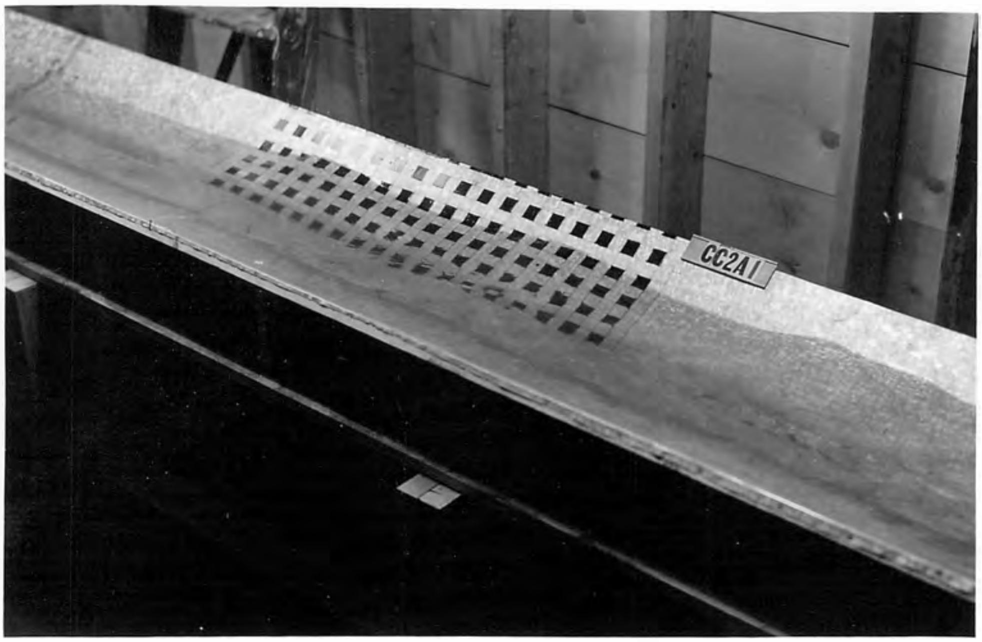
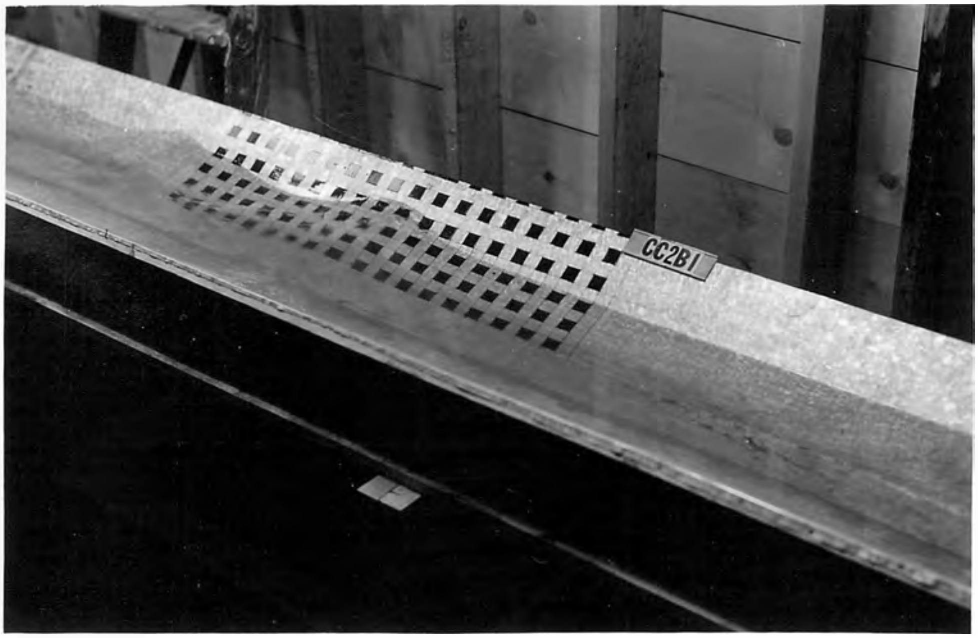
CENTRAL VALLEY PROJECT~CALIF.
CONTRA COSTA CANAL
1:24 MODEL
DETAILS OF ORIGINAL DESIGN & REVISIONS
DRAWN: R.R.P.
DENVER, COLO. - 4/



WAVE GENERATED BY CLOSING GATES AT DOWNSTREAM END OF CHANNEL



WAVE GENERATED BY OPENING GATES AT UPSTREAM END OF CHANNEL

CHARACTERISTICS OF NEGATIVE AND POSITIVE BORE WAVES

CONTRA COSTA CANAL
1:24 MODEL