UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

MILBURN DIVERSION DAM MODEL STUDY

MISSOURI RIVER BASIN PROJECT, NEBRASKA

PROGRESS REPORT NO. 4

GENERAL STUDIES OF HEADWORKS AND SLUICEWAY STRUCTURES

Hydraulic Laboratory Report No. Hyd-385

ENGINEERING LABORATORIES

OFFICE OF THE ASSISTANT COMMISSIONER AND CHIEF ENGINEER
DENVER, COLORADO

April 15, 1954

FOREWORD

Hydraulic model studies of the Milburn Diversion Dam, headworks, and sluiceway were made in the Hydraulic Laboratory, Bureau of Reclamation, Denver, Colorado. They were conducted by J. W. Short, R. A. Dodge, and P. F. Enger, under the direct supervision of E. J. Carlson. Several foreign trainees participated in the investigations and calculations. The studies and operations were started in December 1951 but were interrupted to carry on Bartley model study which had a higher priority. The Milburn model study was completed in August 1953.

The studies were made in cooperation with the Diversion Works Section, Canals Branch, Office of the Assistant Commissioner and Chief Engineer. Consequently, the laboratory was frequently visited by Messrs. A. W. Kidder, H. E. White, J. A. Hufferd, and others. Their interest in the problem led to many helpful and constructive ideas.

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UNITED STATES
DEPARTMENT OF THE INTERIOR
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Office of the Assistant Commissioner
and Chief Engineer
Engineering Laboratories
Denver, Colorado
April 15, 1954

Laboratory Report No. Hyd-385
Hydraulic Laboratory
Compiled by: R. A. Dodge
Checked by: P. F. Enger
Reviewed by: E. J. Carlson

Subject: Milburn Diversion Dam model study--Missouri River Basin Project, Nebraska--Progress Report No. 4--General Studies of headworks and sluiceway structures

SUMMARY

Milburn Diversion Dam, which is part of the Missouri River Basin Project, Nebraska, is to be built on the Middle Loup, an alluvial river and sediment control was a major consideration in the design. The Hydraulic Laboratory was authorized to make a model study to check the final arrangement of the sluiceway and headworks in regard to sediment control.

Tests were made with a 1:16 scale hydraulic model. The headworks, spillway, sluiceways, part of the earth-fill dike, and part of the river channel were represented. Besides testing the preliminary design, studies were conducted with guide walls, a tunnel, and a combination of guide walls with the tunnel.

The results of the various arrangements were expressed as concentration ratios, Co/Ch, the sediment concentration in the combined discharge of the sluiceways, spillway, and headworks divided by the sediment concentration in the headworks discharge. A summary of the concentration ratios for the designs tested can be seen in Table 1.

The concentration ratio for the preliminary design was 0.25. This ratio was low principally because more water than that which passed through the headworks was desilted. The guide wall systems resulted in concentration ratios that varied from 0.25 to 0.44. The average concentration ratio for the combination of the tunnel and guide walls was 0.92, when the discharge in the headworks and in each of the sluiceways was 100 cfs. The tunnel arrangement resulted in an average ratio 33.3 when operating at a sluiceway discharge of 310 cfs and a headworks discharge of 100 cfs.

The tunnel was recommended to be incorporated into the prototype structure. The average concentration ratio was 15.0 for the range of 102 to 410 cfs in the sluiceway and 100 cfs in the headworks. Figure 10 shows the general plan of the tunnel. The photograph in Figure 11 shows the tunnel, sluiceways, headworks, and part of the spillway.

INTRODUCTION

Milburn Diversion Dam, part of the Missouri River Basin Project, Sargent Unit, is located approximately 70 miles northeast of North Platte, Nebraska, near the town of Milburn on the Middle Loup River, Figure 1. The dam consists of an earth-fill dike approximately 15 feet high and 3,400 feet long, a concrete overflow spillway, a sluiceway unit, and Sargent Canal headworks. The design discharge for Sargent Canal is 255 cfs, and the land to be irrigated is 13,740 acres. The general plan, elevation, and sections can be seen in Figure 2. Figure 3 is the vicinity map and shows some dike and canal sections.

The Middle Loup River has an average sediment discharge of 27 acre feet per month during the irrigating season. On the basis of this quantity of sediment, it was felt that a model study was justified.

A letter of authorization, received from the Acting Regional Engineer, dated November 8, 1951, requested that a model study be made to check the final details of the headworks design from the standpoint of sediment control.

A movable bed model of the preliminary design was constructed. The model represented a portion of the river upstream from the dam, the headworks, the spillway, and the desilting basin. Besides the preliminary design, four changes were studied. The changes consisted of a tunnel, guide walls, and the tunnel combined with guide walls.

To compare the various headworks and sluiceway arrangements, data was taken and results were expressed as concentration ratios, Co/Ch, the ratios of the sediment concentrations in the combined discharges of the headworks, sluiceway, and spillway in ppm by weight to the concentrations in the headworks in ppm by weight.

GENERAL DESCRIPTION OF MODEL

A 1:16 scale hydraulic model was used to study Milbrun Diversion Dam. The model represented approximately 400 feet of the river bed upstream from the spillway and 176 feet of the compacted earth dike. The preliminary design had a desilting basin, spillway, and headworks. The spillway was 66 feet long and was divided by three 22-foot radial gates. In the changes, the portion of spillway nearest the headworks was converted into two sluiceways with radial gates. The headworks was always the same structurally but was placed near the sluiceway during Changes I through IV.

During all of the studies the model was operated at a normal water surface elevation of 2484.5 feet, the river discharge was always 793 cfs, and sand was fed so as to produce a river sediment discharge

of 438 ppm by weight. The sand feeder consisted of a large conical sheet metal hopper, a vibrating pan controlled by a rheostat, and a vaned spreader (see Figure 4). The feed was constant, and the sand was distributed evenly in the water entering the model.

The sand used in the study was produced from a loosely cemented sandstone. The stone was broken down in a hammer mill and resulted in a fine uniform sand that moved well with fairly low water velocities. The mean diameter was 0.2 mm with 90 percent retained on a No. 100 United States standard screen and 90 percent passing a No. 40 United States standard screen. Figure 5 shows the size analyses of the prototype and model sands.

Before taking data, the model was allowed to run until equilibrium was reached. When this condition was achieved, the model had established its natural bed slope, and the amount of sand entering the model was equal to the amount of sand leaving the model.

The concentrations of sand passing the headworks, sluiceway, and spillway were obtained by collecting representative samples of water with their sediment loads. For sampling, a trough with a narrow slit was passed back and forth through the nappes as shown in Figure 6a. The samples passed from the trough to the collecting tanks, Figure 6b, where the sand was allowed to settle. The volumes of the sample and the sand were then measured, and the concentrations were calculated.

THE INVESTIGATIONS

Preliminary Design

The general plan of the model for the preliminary design can be seen in Figure 7. The model represented a 176-foot portion of the compacted earth dike, a 66-foot spillway controlled by three radial gates, a desilting basin approximately 160 feet wide and 430 feet long, and the headworks to Sargent Canal.

The headworks discharge was set at 100 cfs. This discharge is equivalent to the 50 percent discharge of the flow duration curve for Sargent Canal as shown in Figure 8. Concentration samples were taken of the spillway flow. The average sediment concentration for 17 hours of operation was 249 ppm by weight or 50 percent of the sand entering the model. Assuming equilibrium, this left 50 percent deposited in the desilting basin. If the basin was operating with the concentrations the same in all the component discharges and with just the headworks flow passing into the basin, only 12.5 percent of the sand entering the model would have settled in the basin. The desilting basin had a large entrance and low velocity. Much more water than that which passed the headworks was desilted and then circulated out to pass over the spillway. Consequently, a wave of sediment traveled down the basin. Figure 9 shows how the top edge of the wave progressed with time.

The concentration ratio, Co/Ch, was 0.25. The volume of sand that deposited in the desilting basin was associated with the volume of water passing through the headworks for calculating the headworks concentration. Because of the low concentration ratio in the operation of the desilting basin, other possible designs were studied.

Change I (Tunnel Design Recommended)

The preliminary design was converted to Change I by replacing the left* spillway unit with two 11-foot sluiceways, controlled by radial gates, and adding a tunnel. As shown in Figure 10, the sluiceway floors were installed at bed elevation. The headworks was placed near the left sluiceway, and the tunnel was formed by constructing a roof at headworks crest elevation. The leading edge of the tunnel roof was a circular arc with a radius of 11 feet. The center of the arc was located at the intersection of the adjacent walls of the headworks and left sluiceway. For the prototype, it was decided that the desilting basin is to be placed downstream from the headworks. Therefore, the desilting basin was not included in this or the remaining studies. The purpose of this design was to separate the lower portion of the discharge, which contains most of the sediment, and divert it through the sluiceway. The photograph in Figure 11 shows a bar that formed on the tunnel roof and provision should be made for sluicing it.

The first run of this change was with the discharge of the headworks and each of the sluiceways equal to 102 cfs. The remainder of the water was passed over the spillways. Operating in this manner, the concentration ratio, Co/Ch, averaged 2.7 for 40 hours operation.

A series of runs was made with the right sluiceway closed. The discharge in the headworks was again 102 cfs, and the flow in the left sluiceway was varied from 205 to 410 cfs. The variation of the concentration ratio is shown in Figure 12. The graph indicates that the best left sluiceway and tunnel flow was about 310 cfs. During this run the Co/Ch ratio averaged 33.3 for 12 hours of operation. The average Co/Ch ratio over the total sluiceway discharge range tested was 15.0. This average includes the first run.

Another series of runs were conducted holding the headworks discharge at 175 cfs. This flow, Figure 8, is equaled and exceeded only 20 percent of the diversion time. The right sluiceway was closed, and the left sluiceway discharge was varied between 175 to 618 cfs. The highest average Co/Ch ratio was 6.8 for 16 hours operation and occurred at a sluiceway discharge of 250 cfs. Figure 12 shows the plot of the Co/Ch ratio versus the sluiceway discharge for this series of runs. The average Co/Ch ratio over the total sluiceway discharge range tested was 5.00

*The terms right and left are used in the usual sense, i.e. looking downstream.

Change II

Guide walls were combined with the tunnel as shown in Figures 13 and 14. The walls were circular and the radii of the right and left walls were 36 and 24 feet, respectively. Their centers were on the line extended from the left headworks wall. The right wall began at the sluiceway's center pier and terminated at an arc of 61 degrees. The left wall began at the left side of the headworks and terminated at an arc of 78 degrees. The purpose of the guide walls was to take advantage of the secondary currents formed by the forced curved path.

The model was operated for 22 hours with a discharge of 100 cfs in each of the sluiceways and in the headworks. Concentration samples were taken of spillway, sluiceway, and headworks flows. The resulting average Co/Ch ratio was 0.92.

Changes III and IV

To see how the guide walls would work alone, the tunnel of Change II was removed to form Change III. Figure 13 is a general plan of the model for the guide wall arrangement. Figure 15 shows the model of the headworks, guide walls, sluiceways, and the spillway.

For the first run, the headworks and sluiceways were set at discharges of 100 cfs. Concentration samples were taken of all the out-going discharges, and the average Co/Ch ratio was 0.25 for 12 hours operation. Attempting to improve the concentration ratio, the guide walls were operated with the right sluiceway closed. The left sluiceway was set for a discharge of 200 cfs. This procedure resulted in an average Co/Ch ratio of 0.44 for 14 hours operation.

Change IV, Figure 13, was an extension in length of the guide walls, so that the right and left walls had arcs of 80 and 85 degrees, respectively. The model was operated with the right sluiceway closed. The discharge in the left sluiceway was set at 200 cfs and the discharge in the headworks was set at 100 cfs. The average Co/Ch ratio for this run was 0.29 for 10 hours operation.

CONCLUSIONS AND RECOMMENDATIONS

The data shown in the summary chart in Table 1 shows that of the systems tested, the tunnel arrangement resulted in the most satisfactory sediment discharge characteristics. The model studies indicate that a headworks flow of about 100 cfs and a sluiceway flow of about 310 cfs resulted in the highest average Co/Ch ratio which was 33.3. The average Co/Ch over the entire range of sluiceway discharges tested was 15.0.

From the results of the model studies, the tunnel tested in Change I was used as the basis of design for the prototype structure. It is recommended that field samples be taken for various discharge conditions and analyzed to determine an optimum operating condition for the prototype structure. The tunnel was found to work best with the right sluiceway closed. However, the right sluiceway should be of value for intermittent sluicing operations.

Figure 11 shows that sand accumulated on top of the tunnel. It is suggested that the sluiceway gate be made so that it can be opened above the tunnel top for sluicing this sand.

A degradation study made by the Sedimentation Section, Hydrology Branch, concluded that the degradation downstream from Milburn Dam would be approximately 8 feet, and that this maximum would be reached sometime between 9 and 18 months. Among other assumptions, this estimate was based on the pool elevation being maintained at normal water surface elevation throughout the year. This was the only logical way the study could be made. However, by careful regulation of the gates the degradation below the dam would be reduced to a minimum. By keeping the water surface elevation as low as possible during the nonirrigation season and during the irrigation seasons of the first years when the full canal discharge would not be required, a temporary equilibrium elevation of scour downstream would be established. This equilibrium would be achieved before the total sediment storage capacity was utilized. Thus, the maximum degradation could be less than 8 feet.

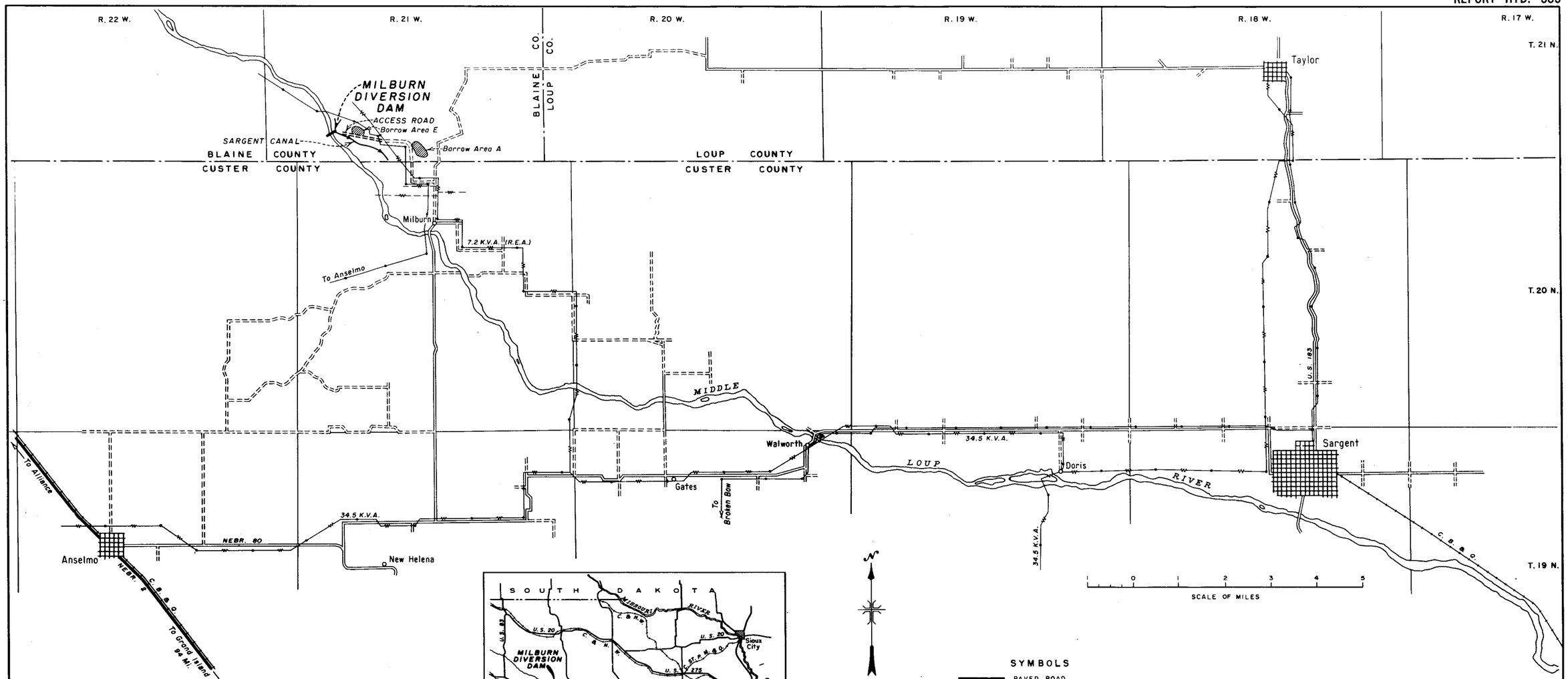
Table 1

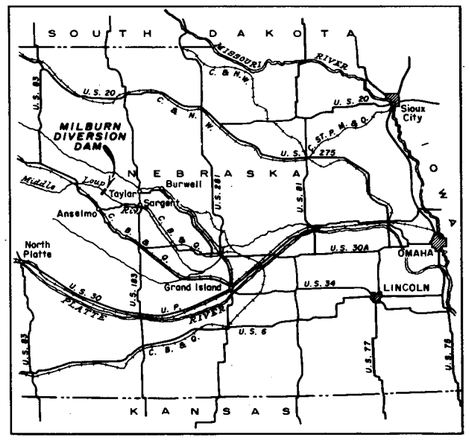
SUMMARY OF DATA

Model and Change	Headworks discharge cfs	Right sluiceway discharge cfs	Left sluiceway discharge cfs	Concentration ratio Co/Ch
Preliminary design	100	0	0	*0.25
Tunnel-I	102	102	102	2.7
	102	0	205	8.3
	102	0	307	33.3
	102	0	410	15.5
			average	15.0
	175	0	350	2.71
	175	0	525	4.25
	175	0	618	6.25
	175	0	175	6.80
			average	5.00
Tunnel and guide wall--II	100	100	100	0.92
Guide wall--III	100	0	200	0.44
	100	100	100	0.25
Guide wall--IV	100	0	200	0.29

*The volume of sand that entered the desilting basin was associated with the volume of water passing through headworks for calculating a hypothetical headworks concentration.

FIGURE 1
REPORT HYD. 385





KEY MAP

SYMBOLS

- PAVED ROAD
- IMPROVED ROAD
- UNIMPROVED ROAD
- TRAILS
- POWER LINE
- COMMUNICATION LINE
- ▲ AUTOMATIC GAGING STATION

NOTE

For more exact location of borrow areas see Dwg. 499-D-51

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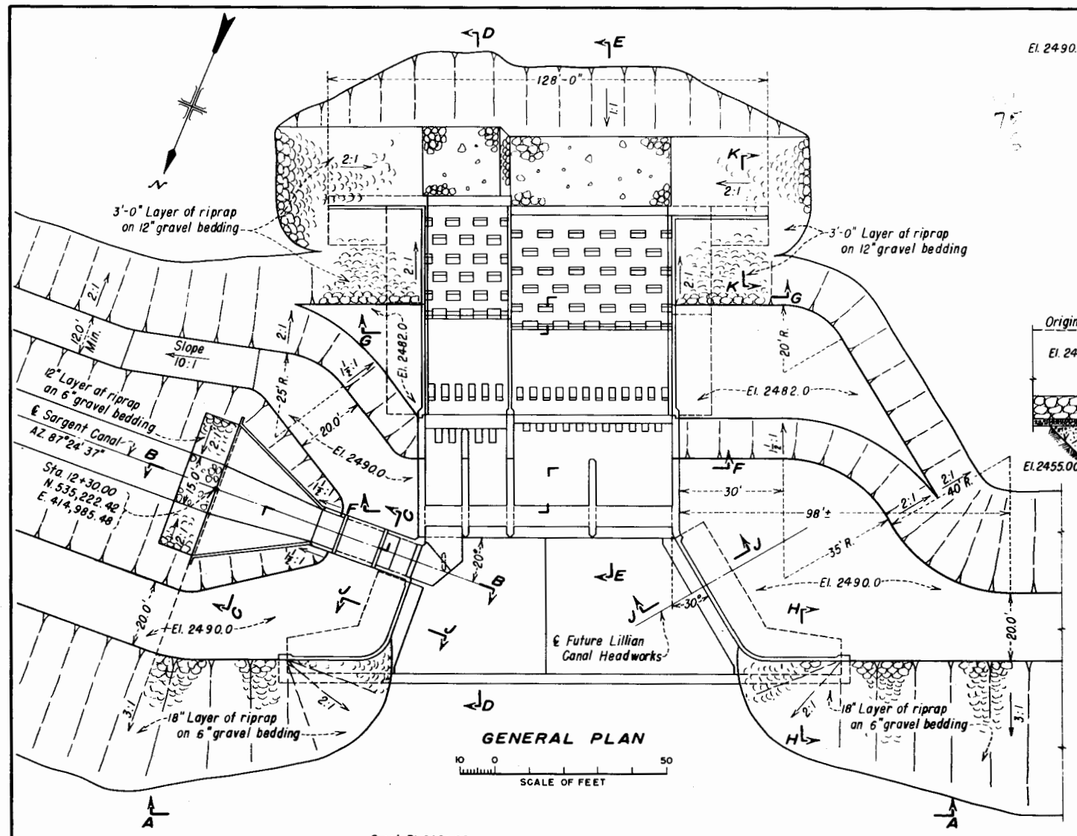
MISSOURI RIVER BASIN PROJECT
MIDDLE LOUP DIVISION-SARGENT UNIT-NEBRASKA

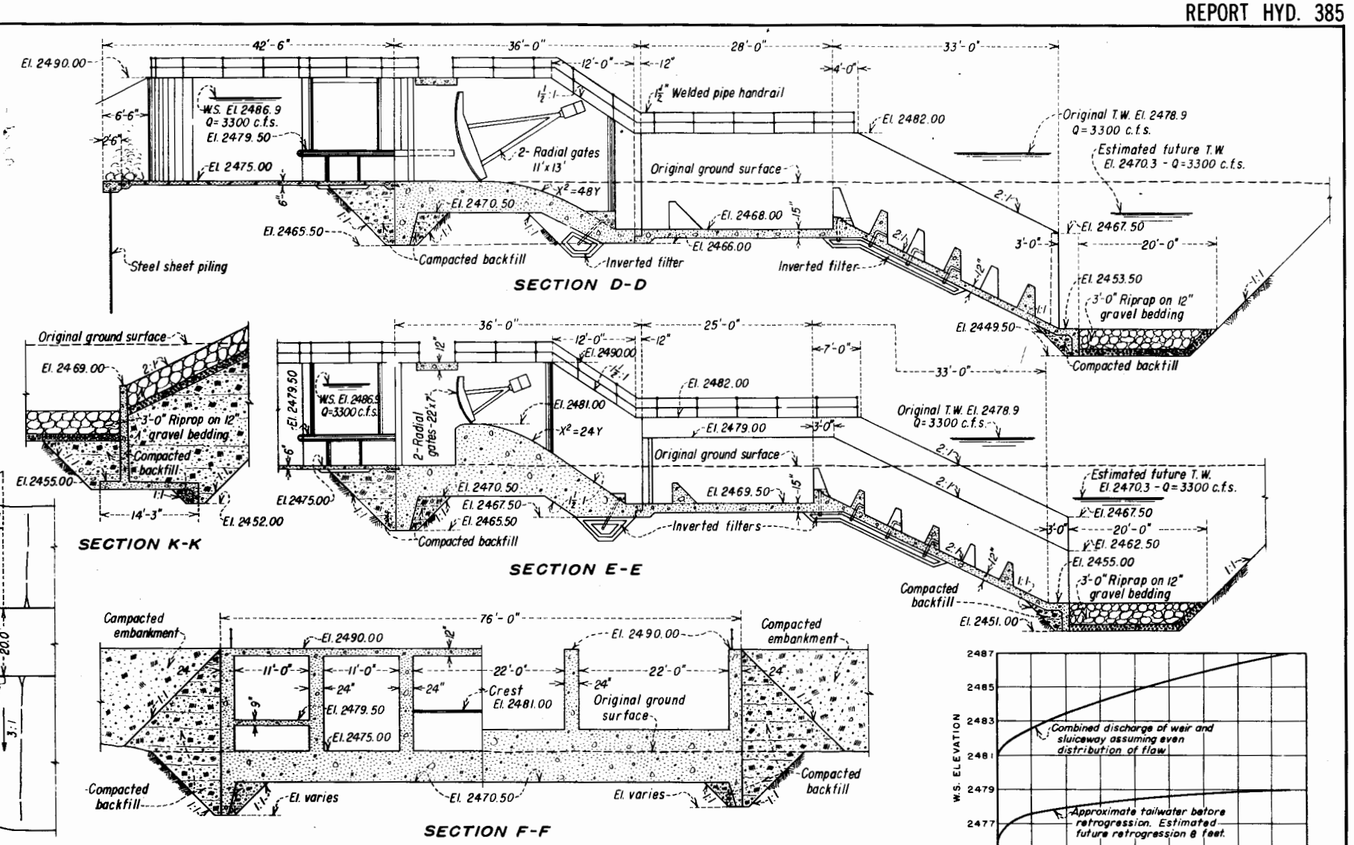
MILBURN DIVERSION DAM
LOCATION MAP

DRAWN N.E.T. SUBMITTED
TRACED B.F.W. RECOMMENDED
CHECKED APPROVED ASSOC. CHIEF ENGINEER

DENVER, COLORADO DEC. 7, 1953 | 499-D-50



GENERAL PLAN

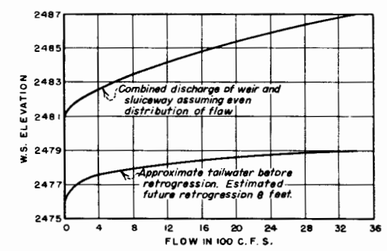


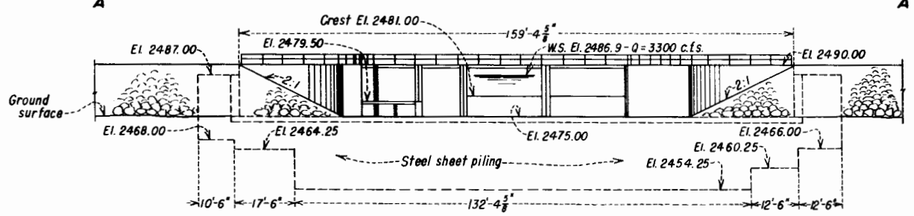
SECTION D-D

SECTION K-K

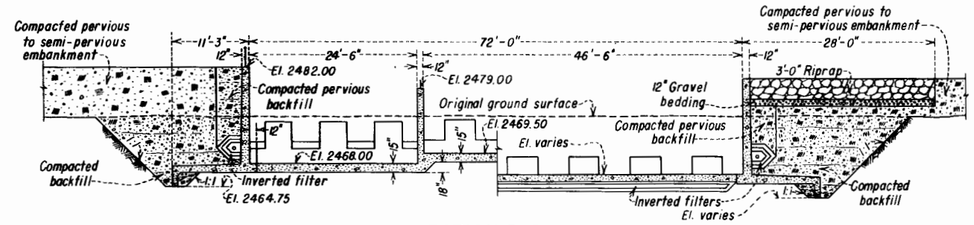
SECTION E-E

SECTION F-F

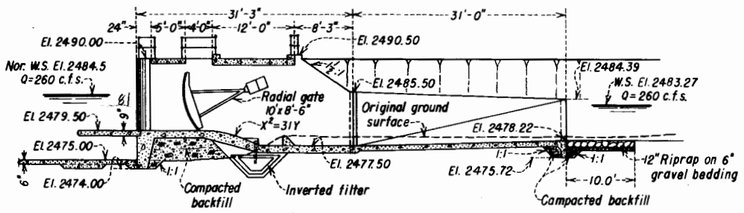




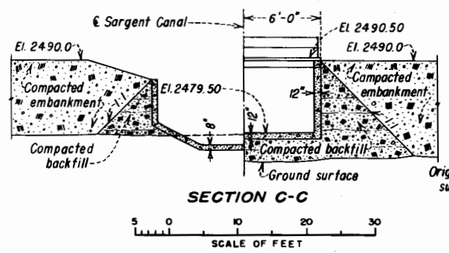
ELEVATION A-A



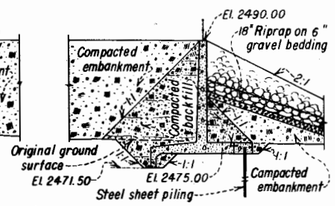
SECTION G-G



SECTION B-B



SECTION C-C



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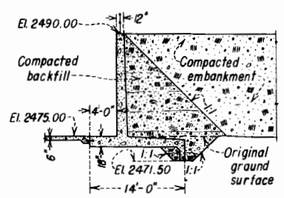

SECTION J-J

GENERAL NOTES

Concrete design based on a compressive strength of 3000 lbs. per sq. in.
Unless otherwise shown, place reinforcement so that the clear distance between face of concrete and nearest reinforcement is ½" for #5 bars and less, and 2" for #6 bars and greater; except provide a clear distance from face of concrete placed against earth or rock of 2" where slab thickness is 9" or less, and 3" where slab thickness is greater than 9".
Lap all bars 20 diameters at splices unless otherwise shown.
Dimensions are to center line of joints unless otherwise shown.
Elastic joint filler shall be securely fastened to one face of concrete.
Chamfer all exposed corners ¾" unless otherwise shown.
Concrete thickness shall vary uniformly between dimensions shown.

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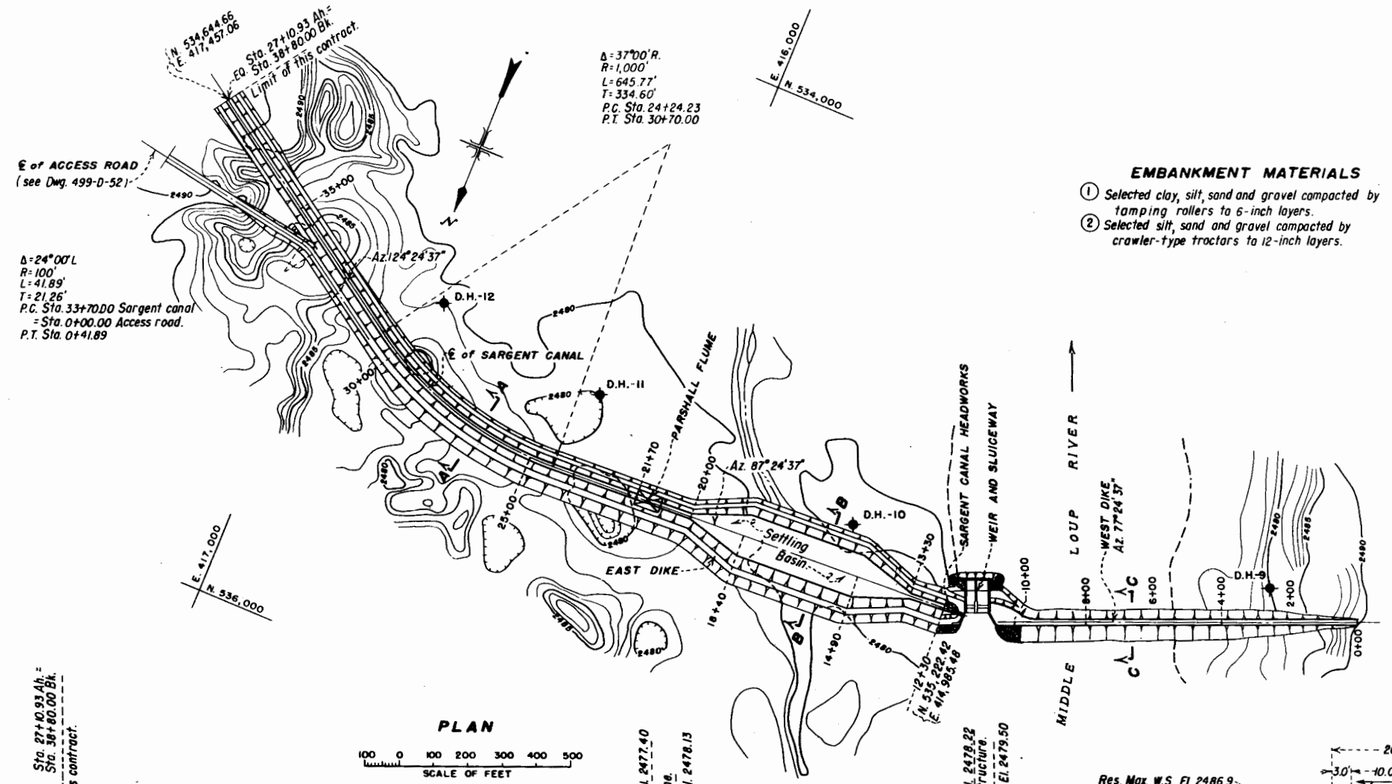
MISSOURI RIVER BASIN PROJECT
MIDDLE LOUP DIVISION - SARGENT UNIT - NEBRASKA

MILBURN DIVERSION DAM

GENERAL PLAN, ELEVATION, AND SECTIONS

DRAWN T.W.G. SUBMITTED
TRACED R.V.S. RECOMMENDED
CHECKED APPROVED ASSOC. UNIT ENGINEER
DENVER, COLORADO, DEC. 4, 1953

499-D-55

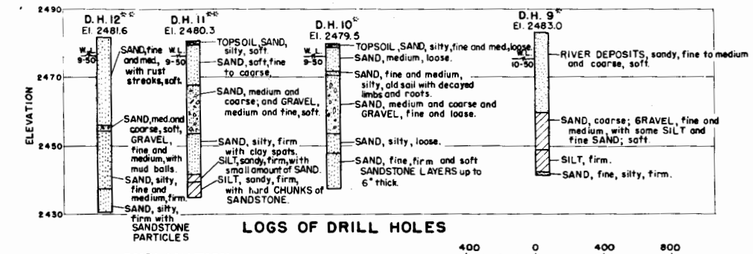


PLAN

SCALE OF FEET

EMBANKMENT MATERIALS

1. Selected clay, silt, sand and gravel compacted by tamping rollers to 6-inch layers.
2. Selected silt, sand and gravel compacted by crawler-type tractors to 12-inch layers.

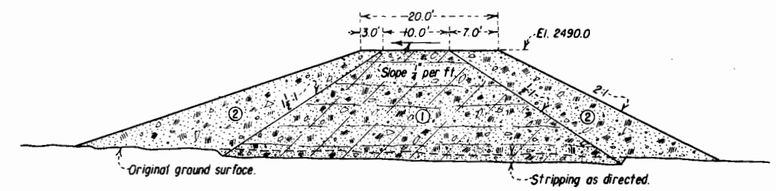


LOGS OF DRILL HOLES

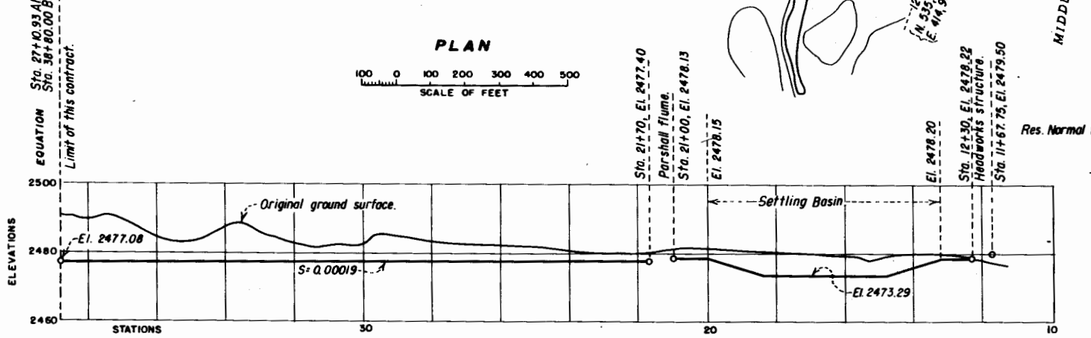
400 0 400 800
HORIZONTAL SCALE OF FEET

EXPLANATION

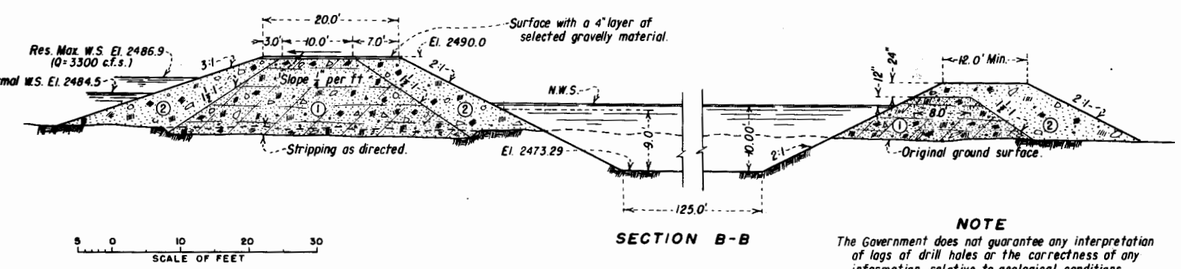
D.H.* - 10" Rotary drill hole, 6" Denison samples.
D.H.** - 2½" Wash bore hole with 2½" drive samples each 5'.
W.L. 9-50 Water Level and date measured.



SECTION C-C



CANAL PROFILE

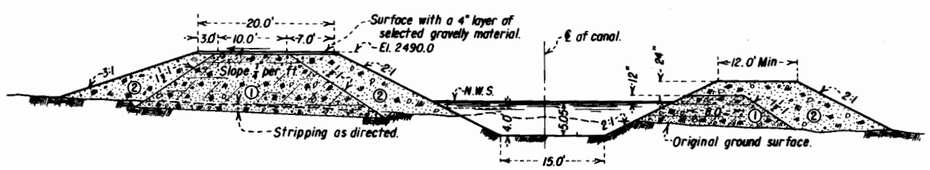


SECTION B-B

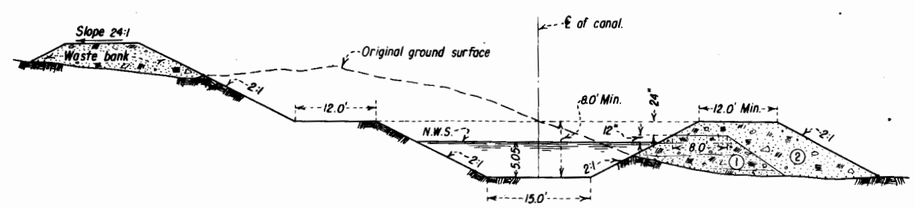
5 0 10 20 30
SCALE OF FEET

NOTE

The Government does not guarantee any interpretation of logs of drill holes or the correctness of any information relative to geological conditions. Bidders and the contractor must assume all responsibility for deductions and conclusions as to the nature of the materials to be excavated.



SECTION A-A



TYPICAL CANAL SECTION
(STA. 34+00± TO STA. 38+80)

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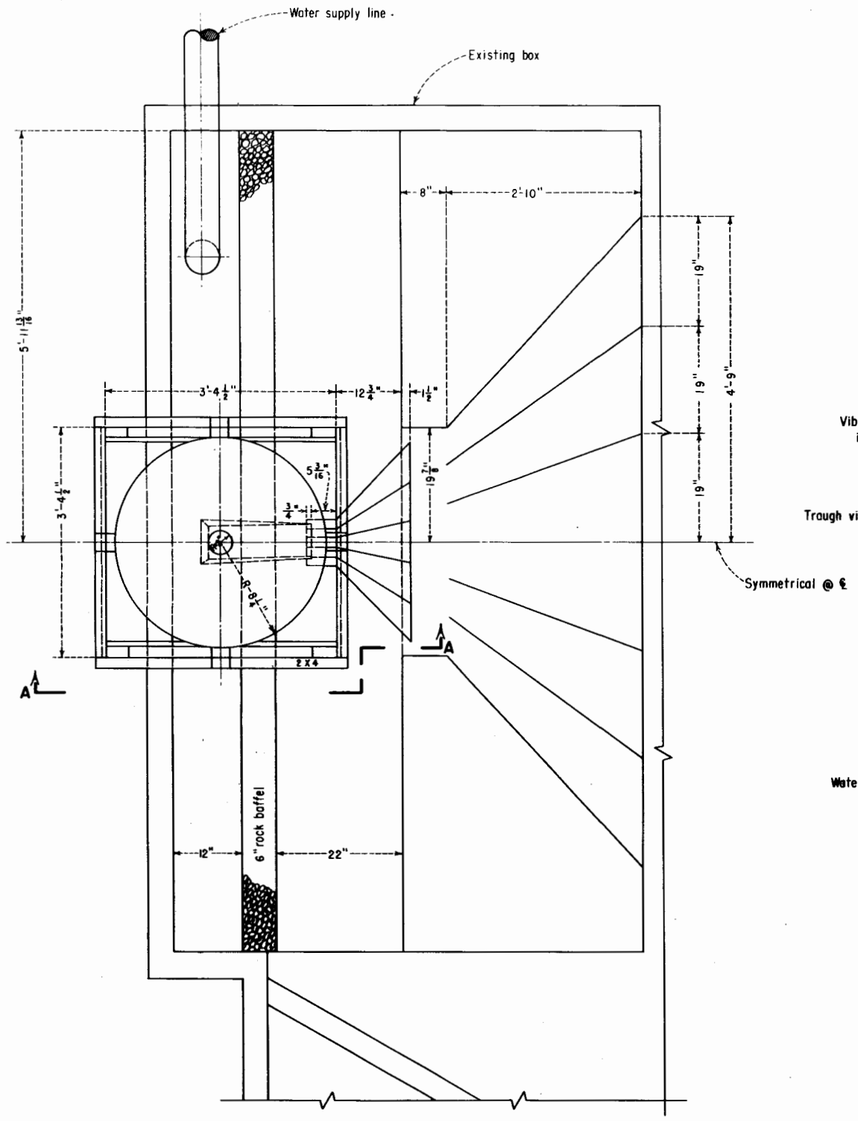
MIDDLE LOUP DIVISION - SARGENT UNIT - NEBRASKA

MILBURN DIVERSION DAM

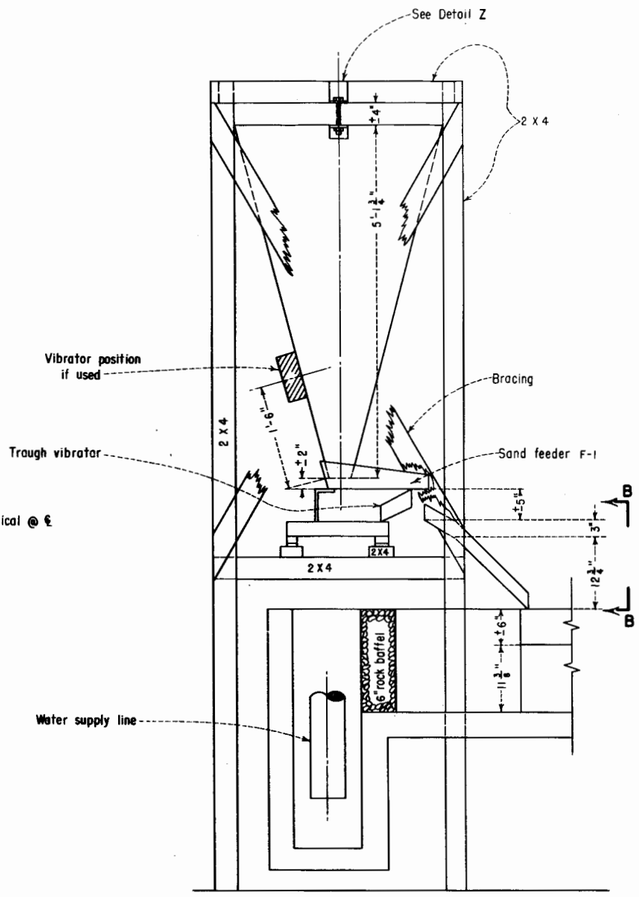
VICINITY MAP, SECTIONS AND EXPLORATION HOLES

DRAWN R.C.R. SUBMITTED
TRACED J.F.M. RECOMMENDED
CHECKED APPROVED
ASSOC. CHIEF ENGINEER
DENVER, COLORADO, DEC. 11, 1953

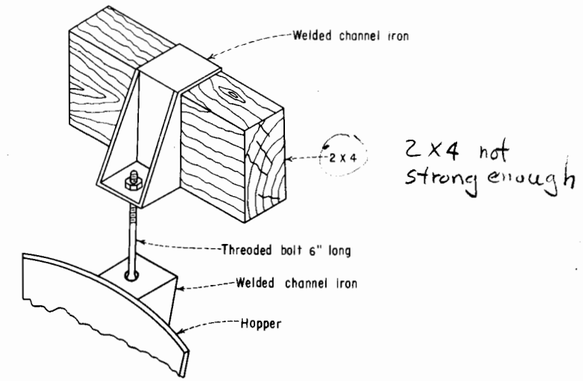
499-D-84



PLAN
HOPPER AND SAND FEEDER

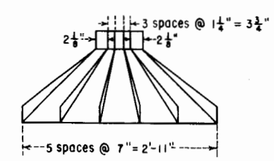


ELEVATION A-A

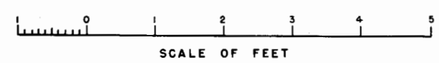


DETAIL Z
4-REQUIRED

NOTES
Bracing to be provided on all sides of hopper stand.
Structure analized for actual dimensions of standard 2 X 4 – those dimensions shown are nominal.



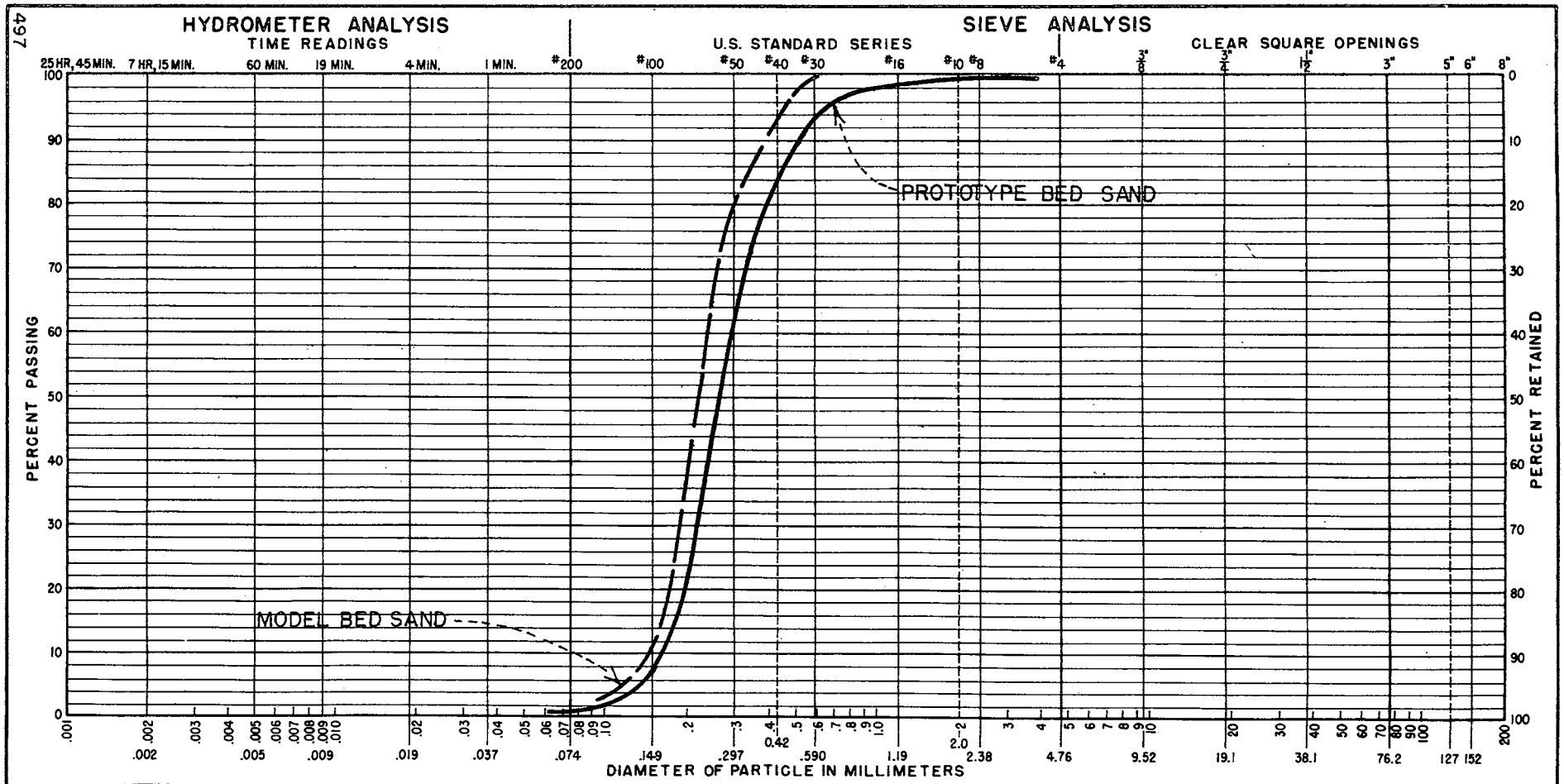
ELEVATION B-B



SCALE OF FEET

MISSOURI RIVER BASIN PROJECT
MILBURN DIVERSION DAM
SAND FEEDING SYSTEM

497



NOTES:

GRADATION TEST

MISSOURI RIVER BASIN PROJECT

MILBURN DIVERSION DAM

1:16 SCALE MODEL

GRAIN ANALYSES FOR PROTOTYPE AND MODEL SANDS

LABORATORY SAMPLE No. _____ FIELD DESIGNATION _____ EXCAVATION No. _____ DEPTH _____ FT.

FIGURE 5
REPORT HYD. 385

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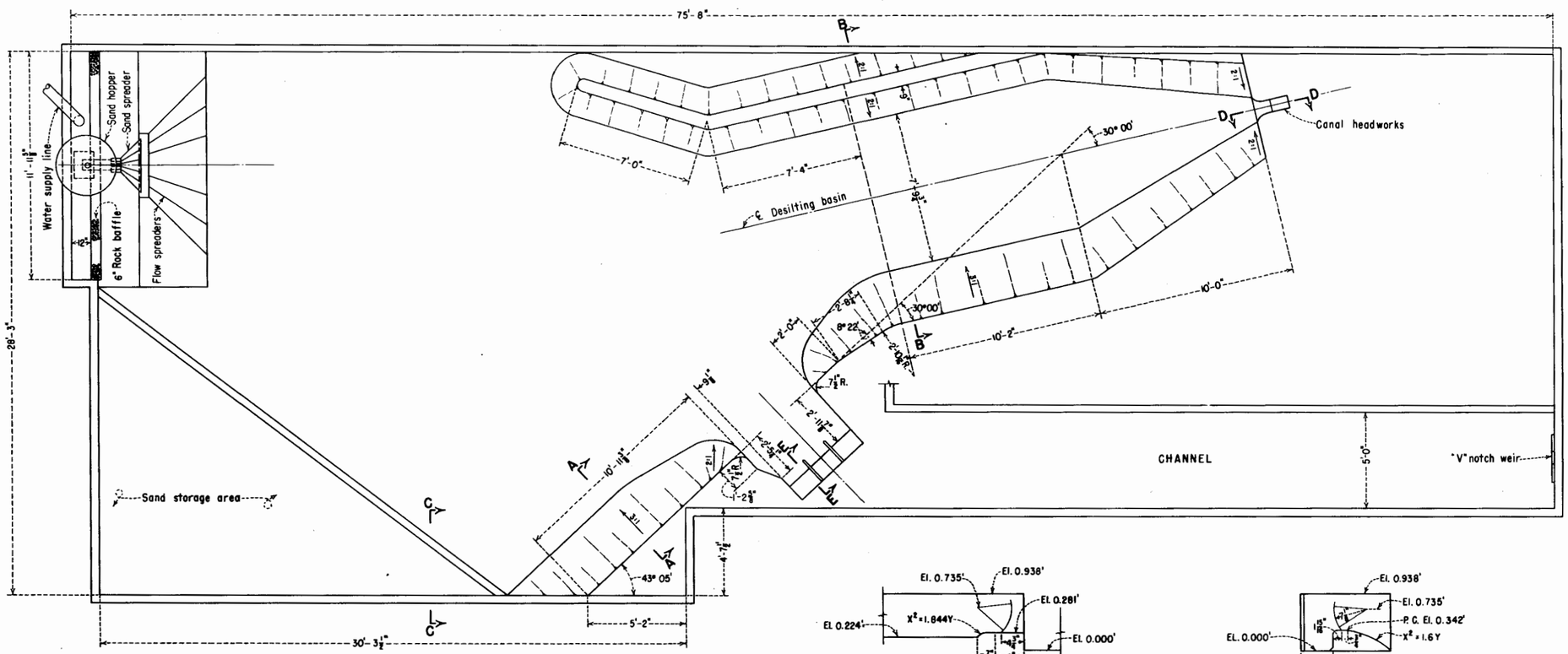
Figure 6

(a) Sampling trough passing through nappe.

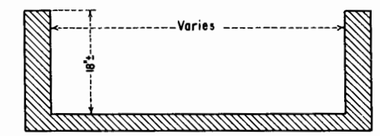
(b) Calibrated sampling tanks.

Missouri River Basin Project
MILBURN DIVERSION DAM
1:16 scale model
SAMPLING SYSTEM

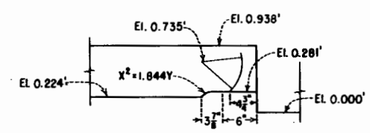


PLAN

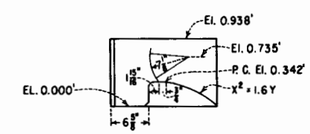
MODEL SCALE IN FEET



ELEVATION C-C



HEADWORKS - SECTION D-D

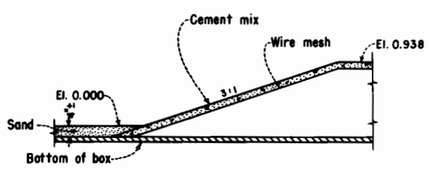


SPILLWAY - SECTION E-E

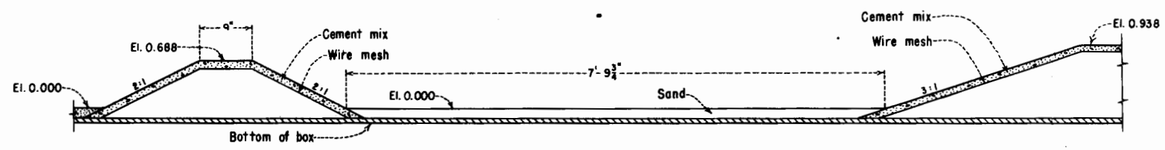
MODEL SCALE OF SECTIONS IN FEET

NOTES

Build model in existing box.
Provide access to hopper, spillway and headworks.
Use same sand for approach channel as used in Superior Cortland model.
Spillway and headworks are to be constructed as separate units.
Place sand storage separation for convenience of construction.
Sampling device to be placed after construction.



ELEVATION A-A



ELEVATION B-B

MISSOURI RIVER BASIN PROJECT

MILBURN DIVERSION DAM

PRELIMINARY DESIGN

1:16 SCALE MODEL

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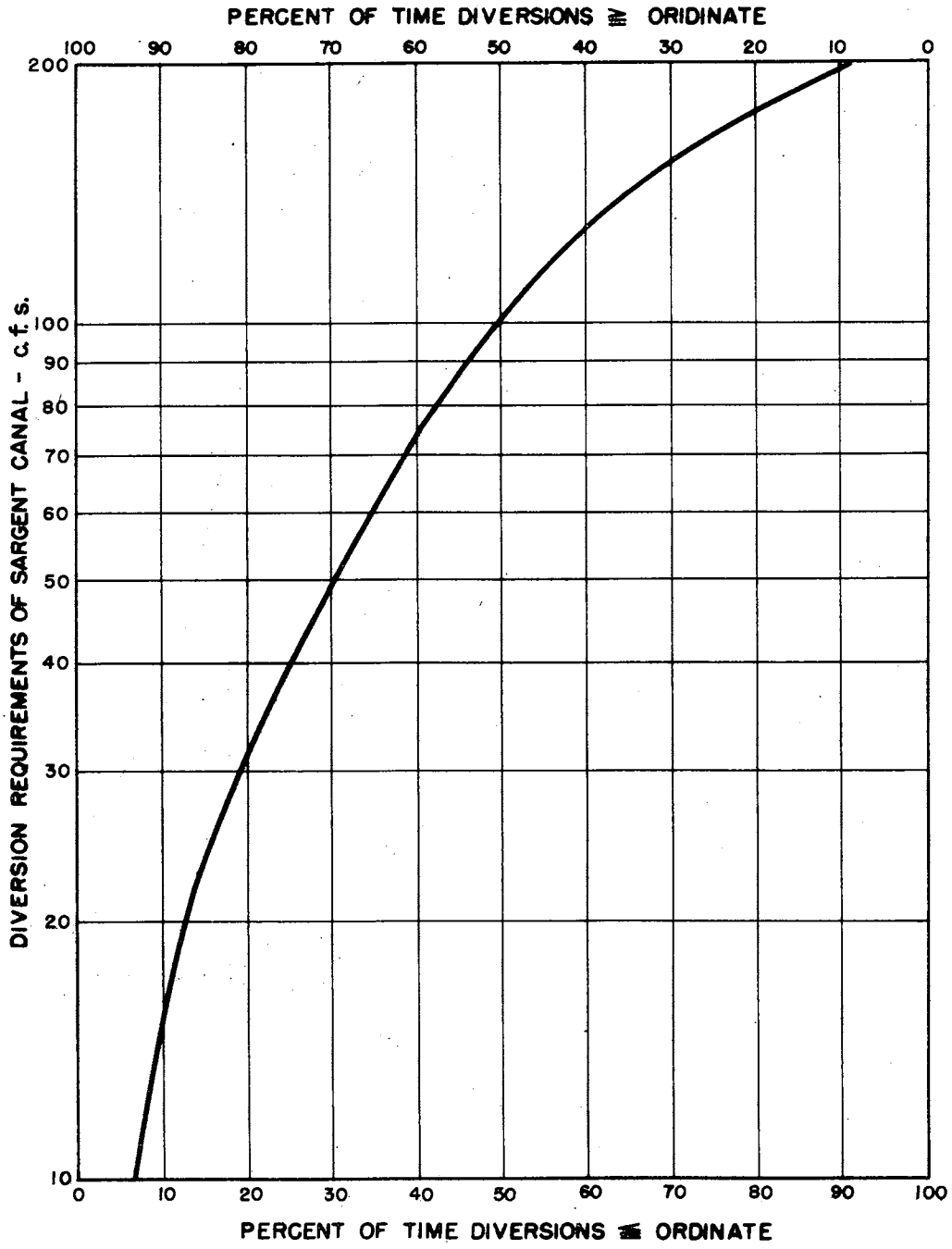
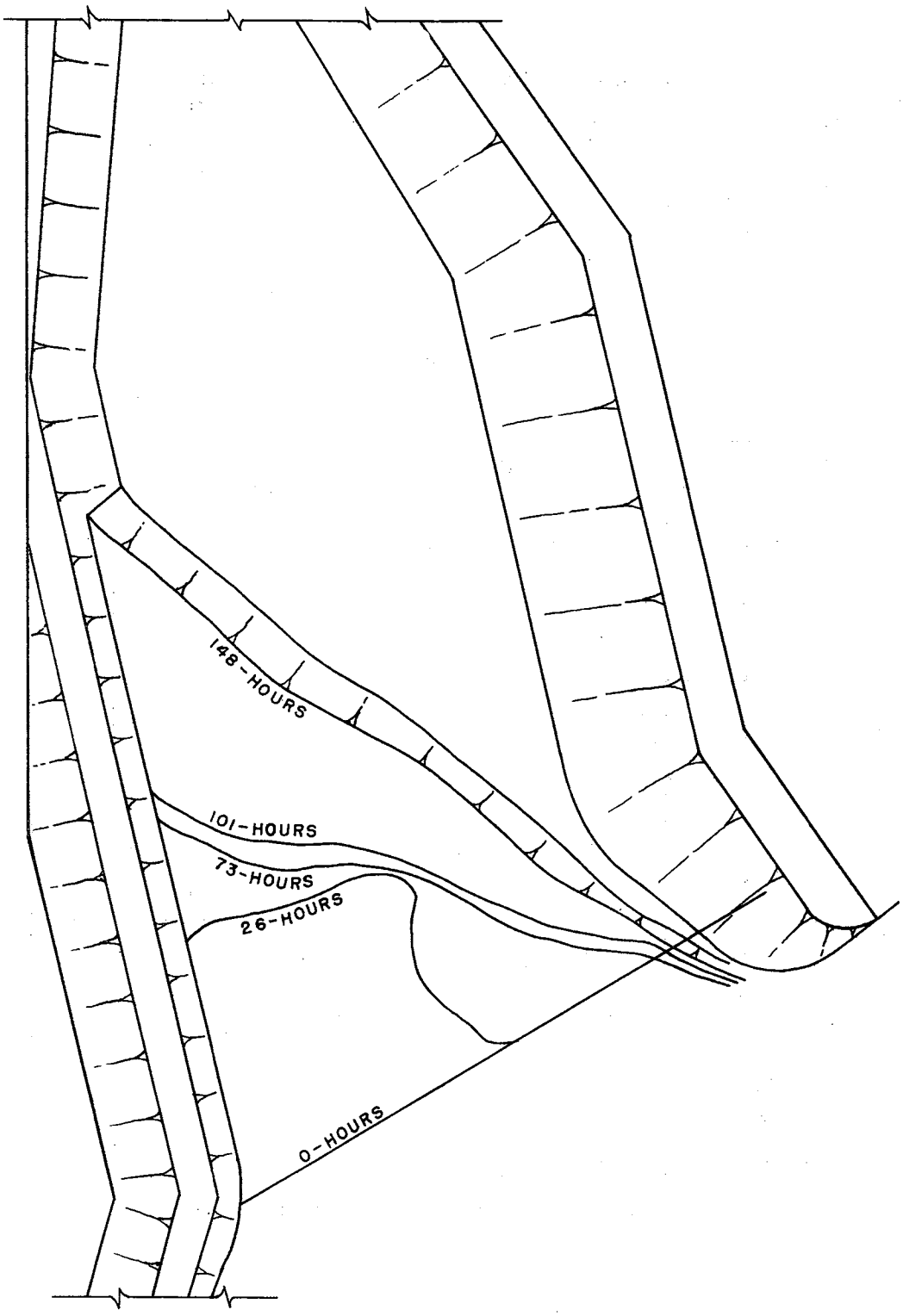


MISSOURI RIVER BASIN PROJECT

MILBURN DIVERSION DAM

FLOW DURATION CURVE FOR SARGENT CANAL

FIGURE 9
HYD. REPORT 385

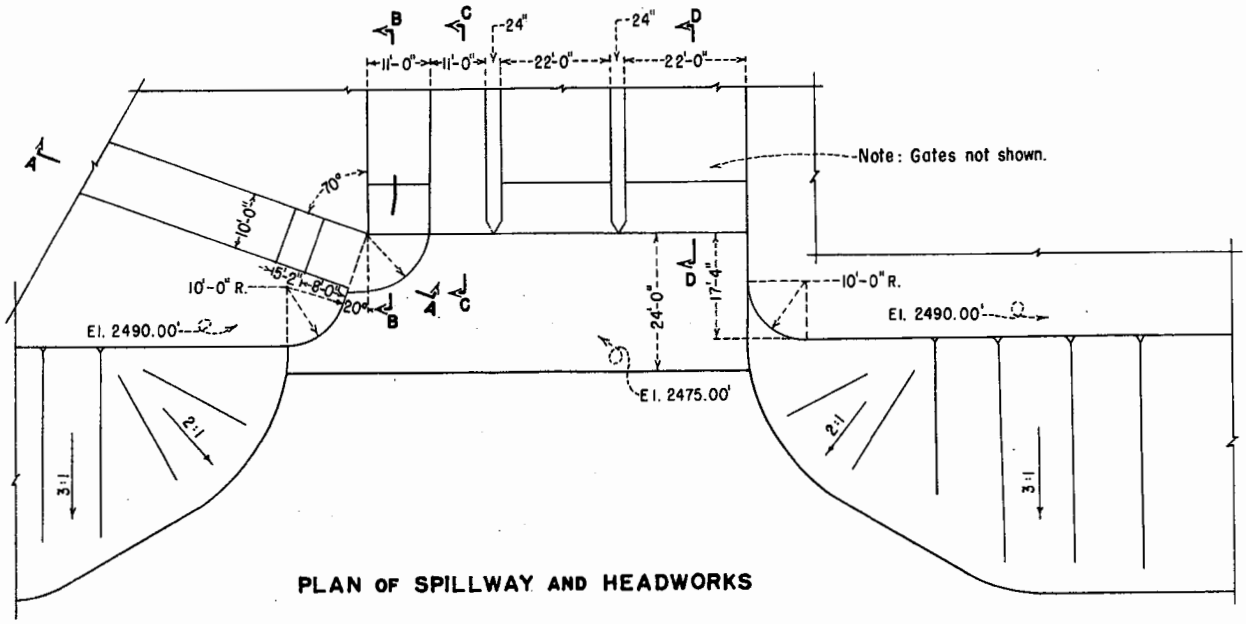


MISSOURI RIVER BASIN PROJECT

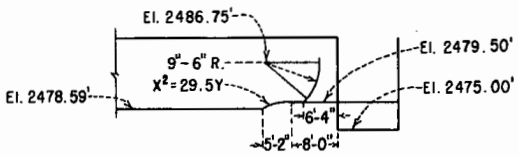
MILBURN DIVERSION DAM

PROGRESSION OF SEDIMENT IN DESILTING BASIN WITH TIME

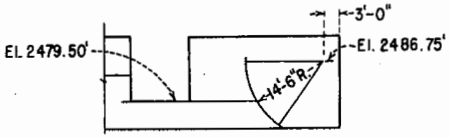
1:16 SCALE MODEL



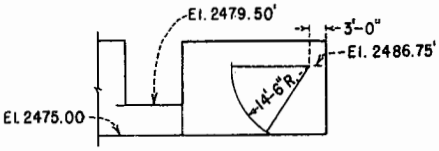
PLAN OF SPILLWAY AND HEADWORKS



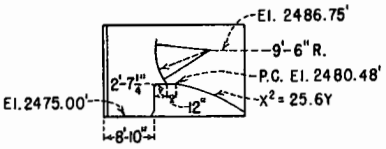
SECTION A-A



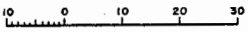
SECTION B-B



SECTION C-C



SPILLWAY CREST
SECTION D-D



SCALE IN FEET PROTOTYPE

MISSOURI RIVER BASIN PROJECT

MILBURN DIVERSION DAM

TUNNEL ARRANGEMENT - CHANGE I

1:16 SCALE MODEL

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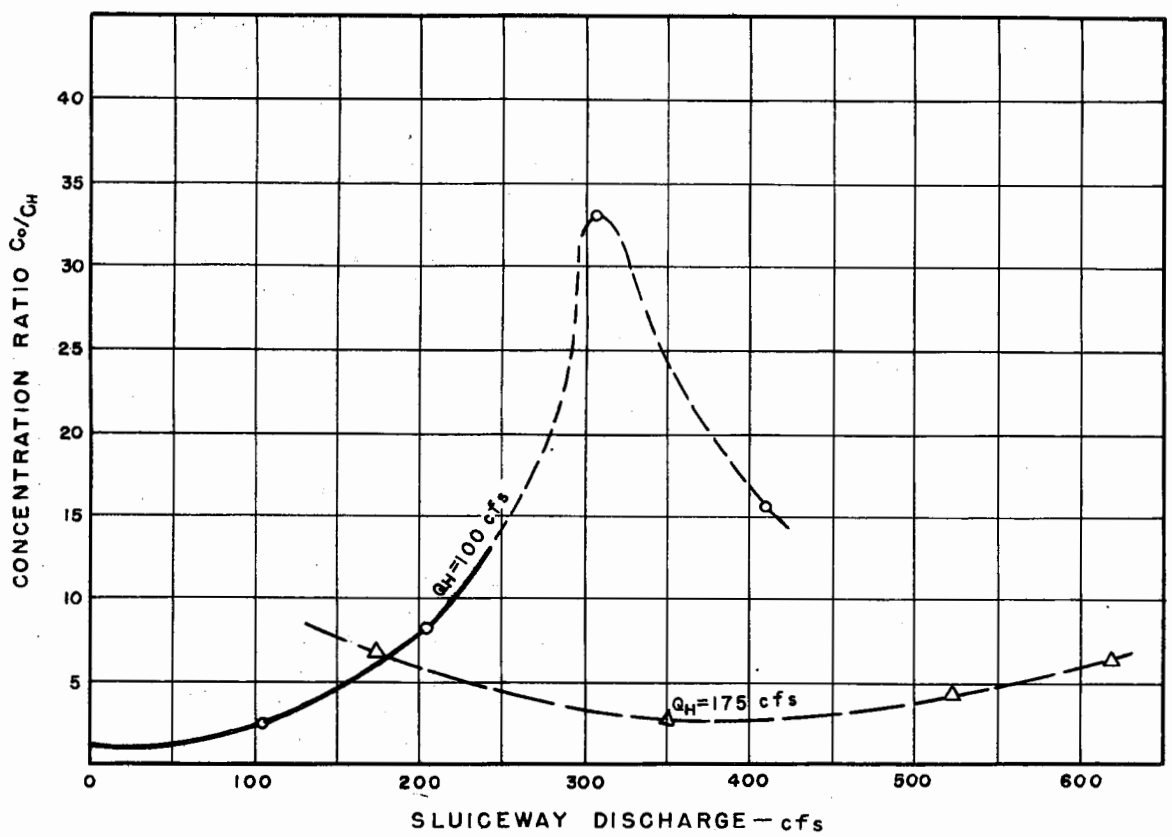
Missouri River Basin Project
MILBURN DIVERSION DAM
1:16 scale model
TUNNEL ARRANGEMENT - CHANGE I

Figure 11



NOTES

Change I. (Tunnel arrangement).
C_o = Concentration in the combined headworks, sluiceway, and spillway discharges.
C_H = Concentration in headworks discharge.
River discharge = 793 cfs.
Headworks discharge = Q_H

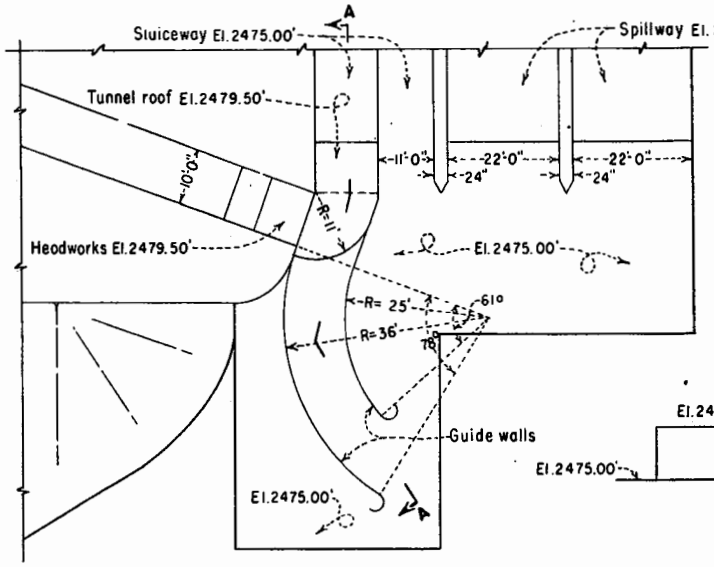
MISSOURI RIVER BASIN PROJECT

MILBURN DIVERSION DAM

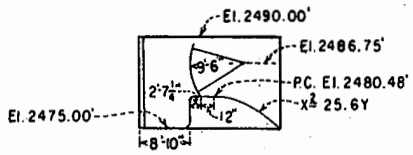
CONCENTRATION RATIO VS. SLUICEWAY DISCHARGE - CHANGE I

1:16 SCALE MODEL

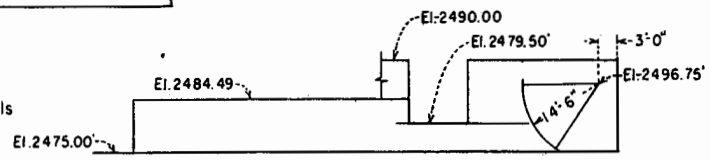
FIGURE 13
REPORT HYD. 385



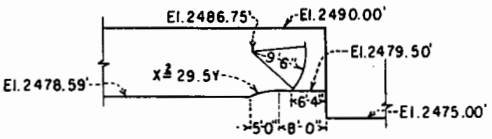
CHANGE II



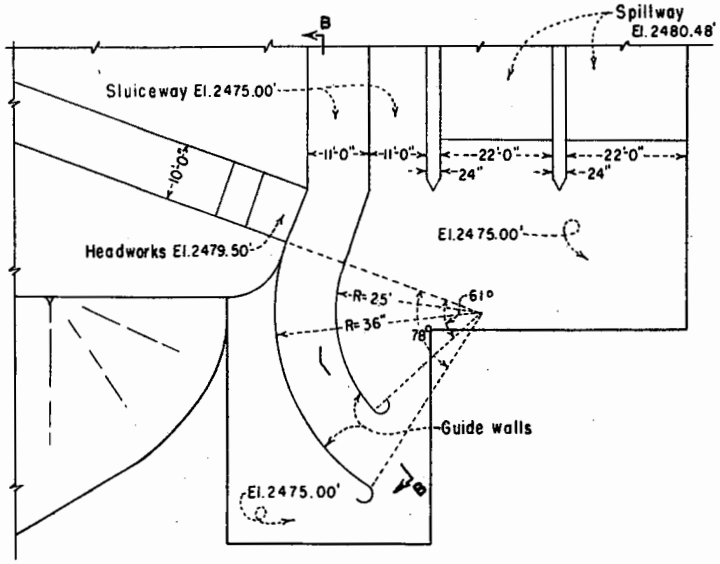
SPILLWAY SECTION



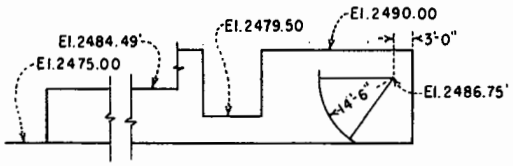
SECTION A-A



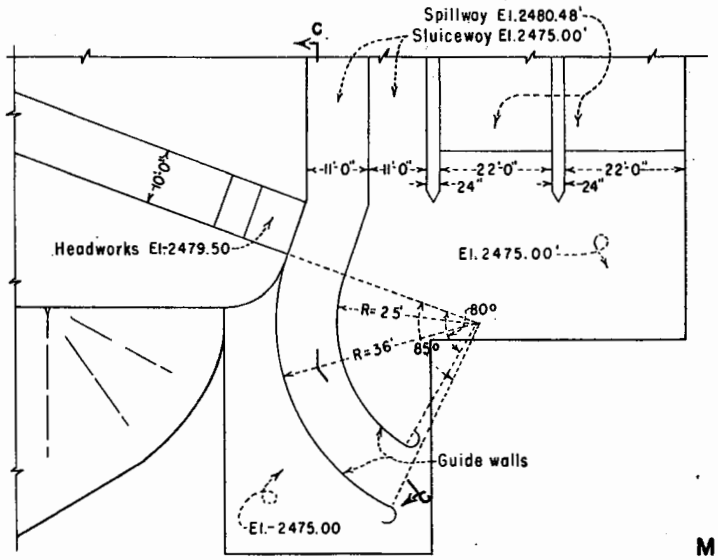
HEADWORKS SECTION



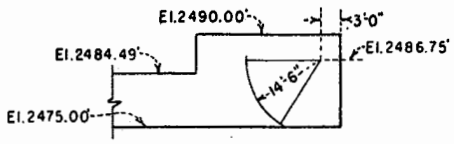
CHANGE III



SECTION B-B & C-C



CHANGE IV



SLUICEWAY SECTION

10 0 10 20 30
SCALE OF FEET
PROTOTYPE

MISSOURI RIVER BASIN PROJECT

MILBURN DIVERSION DAM

CHANGES II, III AND IV

1:16 SCALE MODEL

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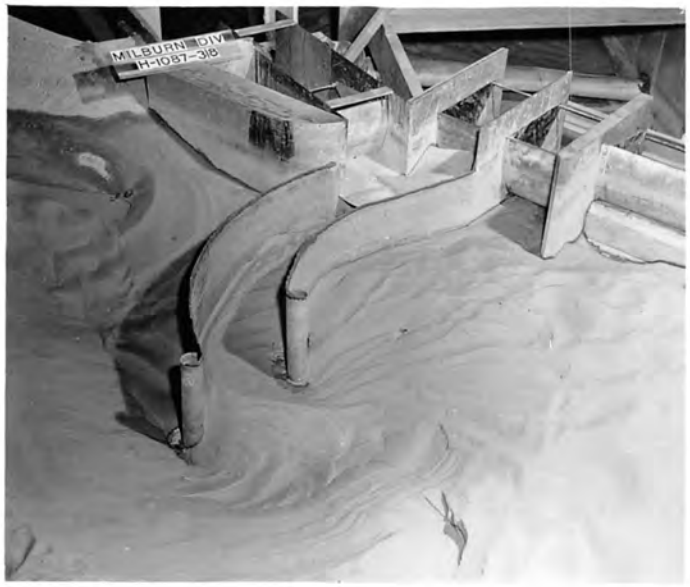

(a) Looking from upstream.

(b) Looking from downstream.

Missouri River Basin Project
MILBURN DIVERSION DAM
1:16 scale model
COMBINATION OF TUNNEL AND GUIDE WALLS - CHANGE II

Missouri River Basin Project
MILBURN DIVERSION DAM
1:16 scale model
GUIDE WALL ARRANGEMENT - CHANGE III

Figure 15