UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

PROGRESS REPORT--
SEEPAGE LOSS MEASUREMENT STUDIES
LOWER-COST CANAL LINING PROGRAM

Hydraulic Laboratory Report No. Hyd-317

ENGINEERING LABORATORIES BRANCH

DESIGN AND CONSTRUCTION DIVISION
DENVER, COLORADO

November 7, 1951

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UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

Design and Construction Division
Engineering Laboratories Branch
Denver, Colorado
November 7, 1951

Laboratory Report No. Hyd-317
Hydraulic Laboratory
Compiled by: B. R. Blackwell
Reviewed by: D. M. Lancaster
C. W. Thomas

Subject: Progress report--Seepage loss measurement studies--Lower-cost Canal Lining Program

INTRODUCTION

In most cases, accurate seepage loss measurements are very necessary in the judicious selection of reaches of canals and laterals for lining. "Before" and "after" lining seepage measurements indicate the effectiveness of the lining in reducing seepage losses. Many seepage measurements have been made in recent years by the Bureau of Reclamation, particularly since the instigation of the program to develop a lower-cost canal lining authorized by Circular Letter No. 3398 dated June 6, 1946. The results of each individual study have been described in considerable detail in technical reports, letters, and memoranda.

Further references on canal seepage losses and allied subjects may be found in Hydraulic Laboratory Report No. Hyd-88, "A Bibliography of Subjects Pertaining to Losses in Canals," November 1940 and in the bibliography contained in "Lower-cost Canal Linings--A progress report on the development of lower-cost linings for irrigation canals," Denver, Colorado, June 1948. For easy reference a brief bibliography is included in this report as Appendix A.

PURPOSE

The purpose of this report is to combine the results of the numerous loss measurements under one cover for the convenience of those who utilize the information. No new information is presented.

The seepage data in this report are given in terms of rate of seepage loss. Wherever possible, this rate is given in terms of cubic feet per square feet of wetted area per 24 hours. This report is not primarily concerned with volume of water lost nor with the rate or volume at which lining would be feasible. In considering the possibility of lining the total volume of water lost is, of course, of importance; however,

we must not overlook the fact that a low seepage rate with a small total volume of water lost may be of considerable importance, especially in areas with poor drainage conditions.

SCOPE OF THE MEASUREMENTS

The loss measurements were made for three specific purposes:

a. To evaluate the merits of various methods for determining seepage losses

b. To determine the effectiveness of different types of lining materials

c. To ascertain the need for lining.

In addition to actual loss studies, the measurements included, in many instances, the elevation of the ground-water table in the pertinent area and the water temperature. When considered necessary, the quantity of evaporation was also evaluated by utilizing information from a nearby weather station or by use of a floating pan in the irrigation canal under observation. The reader is referred to the detailed write-ups given in the references contained in this report for the above information.

Except for the experiments performed in cooperation with State Experiment Stations and at the Denver Federal Center, the studies were limited to existing canals, both new and old.

Preinvestigations conducted to predict losses from unexcavated canals were performed under the auspices of the Earth Laboratory and are not discussed in this report. In those instances where the preinvestigation procedure was applied in conjunction with the loss measurements, the latter data were furnished to appropriate personnel to enable an evaluation of the accuracy of the unproven preinvestigation method. Such evaluation will be the subject matter of a later report.

METHODS FOR MEASURING SEEPAGE LOSS

The quantity of water lost by seepage was measured by three methods; namely, (1) ponding, (2) inflow-outflow, and (3) seepage meter. Brief descriptions of the three methods follow.

Ponding Method

The ponding method is considered to be the most accurate known technique of measuring seepage losses from irrigation canals and laterals.

Seepage losses from short reaches of canal may be measured by this method with great accuracy. Seepage losses are determined by isolating a reach of canal with watertight barriers and filling the test reach of canal with water. The usual procedure is to measure the time rate of fall of the water surface in the pond. Then, knowing the physical dimensions of the pond, the seepage rate can readily be determined. A variation of this procedure consists of measuring the inflow of water required to keep the water surface in the pond at a constant elevation. Two disadvantages of the ponding method are (1) the canal must be taken out of operation during tests, and (2) the construction and the removal of the watertight barriers required in the formation of the ponds is rather costly.

Inflow-outflow Method

The inflow-outflow method of measuring seepage losses consists simply of measuring the quantity into and out of a certain reach of canal. (This latter measurement must include any extractions or obvious leaks.) The difference between the inflow and the outflow represents the seepage loss (together with the evaporation loss). Gaging stations, weirs, Parshall flumes, current meters, and other measuring devices can be used in measuring the flow. Small inaccuracies in the measuring devices can become of major concern in the accuracy of the actual seepage loss. Comparatively long reaches of canal are required for the inflow-outflow method in order that the seepage loss will be of measurable magnitude.

Seepage Meter Measurements

The seepage meter is an instrument for the measurement of seepage losses from canals and laterals. This meter may be used in flowing water during the irrigation season. In no way does the meter interfere with canal operation. The accuracy of the seepage meter in determining seepage losses is questionable although the instrument appears to have merit in indicating seepage loss trends. The paper, "Description and Suggested Aids in the Operation of the U.S.B.R. Seepage Meter--Branch of Design and Construction, Denver, August 1950," included as Appendix B, gives detailed information on the seepage meter.

Seepage Measurement Summaries

In this report the summaries of the various tests are grouped by calendar years in appendices, and are then broken down by projects. The results of similar tests performed in future years will be included as additional appendices, thereby keeping this summary report up to date. The appendices are as follows:

Appendix	Subject
A	Bibliography
B	Seepage Meter Details
C	Seepage Data--1943
D	Seepage Data--1945
E	Seepage Data--1946
F	Seepage Data--1947
G	Seepage Data--1948
H	Seepage Data--1949
I	Seepage Data--1950

The project break-down may be found in the Table of Contents.

APPENDIX A

BIBLIOGRAPHY

1. "Seepage Losses from Irrigation Channels," by Carl Rohwer and O.V.P. Stout, Technical Bulletin 38, Colorado Agricultural Experiment Station, Fort Collins, Colorado, March 1948

2. "Canal Lining Manual," by Carl Rohwer, Soil Conservation Service, November 1946

3. "Canal Lining Experiments in the Delta Area, Utah," by O. W. Israelsen and R. C. Reeve, Utah Agricultural Experiment Station Bulletin 313, June 1944

4. "Measurement of Seepage Losses in Canals," by O.V.P. Stout, Agricultural Engineering, April 1940

5. "Conveyance Losses of Water on U. S. Reclamation Service Irrigation Projects," by E. A. Moritz, Reclamation Record, April 1921

6. "Irrigation Practice and Engineering," by B. A. Etcheverry, McGraw-Hill, New York, 1915

7. "Working Data for Irrigation Engineers," by E. A. Moritz, Wiley, New York, 1915

8. "Records of Seepage Losses in Concrete Lined Canals," by H. D. Newell, Engineering and Contracting, June 7, 1915

9. "Some Records of Seepage and Evaporation Losses from Irrigation Reservoirs and Canals," by E. G. Hopson, Engineering and Contracting, November 6, 1912

APPENDIX B

DESCRIPTION AND SUGGESTED AIDS IN THE OPERATION OF THE U.S.B.R. SEEPAGE METER

Branch of Design and Construction
Denver, August 1950

The seepage meter is a modified version of the constant head permeameter and consists of a watertight seepage cup connected by a tube to a flexible bag for holding water. The cup isolates a known surface area of canal bottom. The water seeping through this area comes from the flexible bag and may be measured. The flexible bag of water, being submerged, maintains the same head on the test meter as is on the surrounding area of canal bed. Knowing the area under the meter and the loss of water from the bag for a given period of time, the seepage rate in cubic feet per square foot of wetted area per 24 hours may be easily determined.

Details of the seepage meter itself are shown on Drawing No. 8030-RH-1, Figure 1, while details of the flexible plastic bag are shown on Drawing No. 8030-RH-2, Figure 2. These drawings show the current design of seepage meter. The various changes in the design have been evolved from experience gained from field operation of the meter. The ease of operation of the meter has been improved by the various changes in its design. The standard cup depth is now taken as 12 inches as shown on the drawing. This depth is suitable for most conditions found in the field and is a minimum essential when the meter is used in very soft canal bed material. A shallower cup has been used to good advantage in canals with firm, hard bottoms and in shallow depth laterals where the 12-inch cup is too deep for satisfactory submergence of the meter. This present design of seepage meter calls for a bottom area of 2 square feet. Both larger and smaller area meters have been suggested for use under special conditions.

The success of the seepage meter in measuring seepage rates is, to a large extent, determined by the skill of the operator. The seepage meter, with the valve open to permit entrapped air to escape, is carefully forced into the canal bed at the location of the desired seepage measurement taking care to get a good seal around it. In order to release all the air in the cup the valve should be submerged. This operation must be performed very carefully in order not to disturb the canal bed any more than necessary. The meter may be forced into the canal by standing on it, by driving, or by pressing. After the meter is firmly in place the valve is closed.

The flexible seepage bag is partly filled with water, weighed, and connected to the tubing leading to the seepage cup. A hose clamp, located adjacent to the seepage bag neck, is kept closed so that no water is lost from the bag until the start of the test. The bag should

be only partly filled with water so that no initial pressure exists in the bag that would cause an increase in the effective head on the area of canal being tested under the seepage meter. Further care should be taken in eliminating all air from the tube connecting the seepage cup with the seepage bag. A small amount of air in the seepage bag itself is not harmful, although care should be taken to expel the major portion of the air prior to the weighing of the bag.

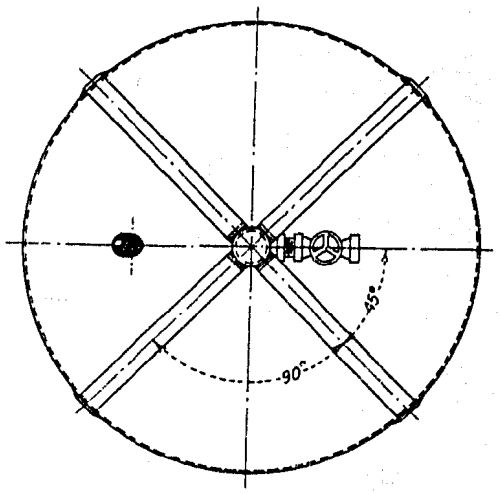
Once the seepage meter is in place, the seepage bag partly filled with water, weighed and connected to the seepage meter cup, the meter is ready for the actual seepage measurement. The bag must be submerged to insure equal pressures inside and outside the cup. With the bag in position the hose clamp is released and the starting time for the run is recorded.

Care must be taken not to exert pressure on the bag as this would result in an increased head acting inside the seepage cup. In canals with high velocities the bag should be protected from the impact of the velocity. The run is concluded by closing the hose clamp at the mouth of the bag. The bag should not be elevated above the water surface at any time during the test. To do so would increase the effective head on the meter and vitiate the results.

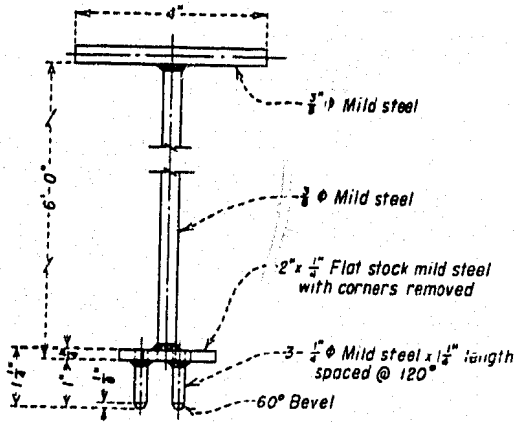
For usual conditions 60 minutes has been found to be a very satisfactory length of time to complete one test. In canals of very high seepage rate, this time may have to be reduced so that the test will be concluded prior to the time the seepage bag empties.

In special cases where a poor seal around the meter cup is suspected, the water in the seepage bag may be dyed. If a leak is present the dye will act as an indicator and the meter can be reset.

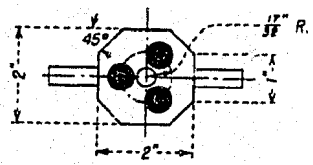
For ease of recording the seepage meter data, a standard "Seepage Meter Data Sheet" has been prepared. A copy of this data sheet, "Form DCT-27, 11-49, Bureau of Reclamation" is attached as Figure 3.



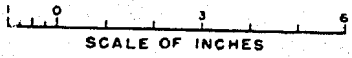
PLAN



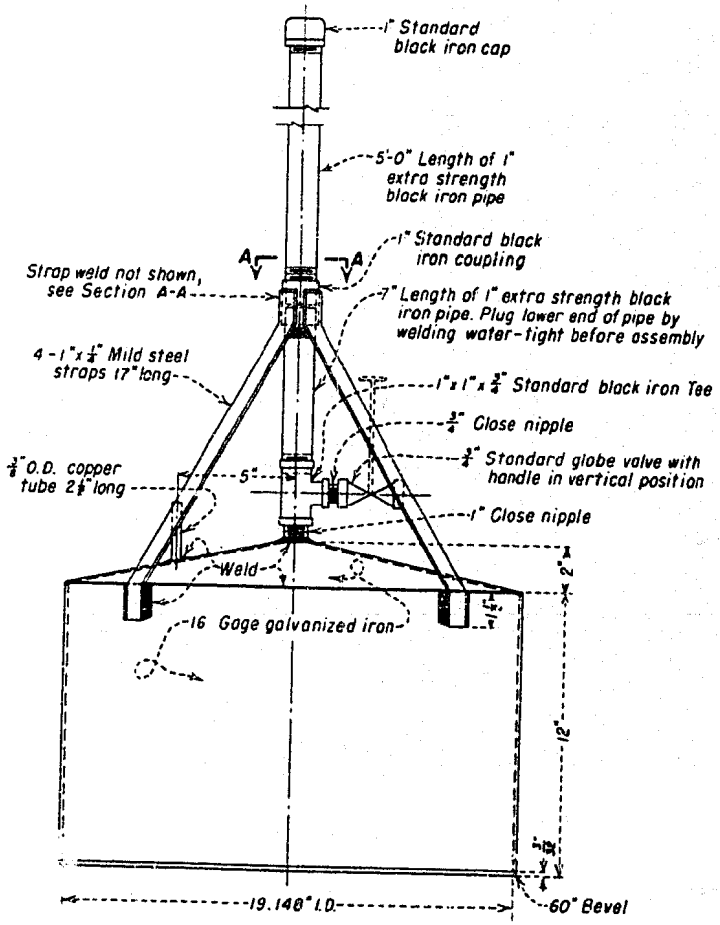
ELEVATION



BOTTOM VIEW
VALVE HANDLE EXTENSION



SCALE OF INCHES



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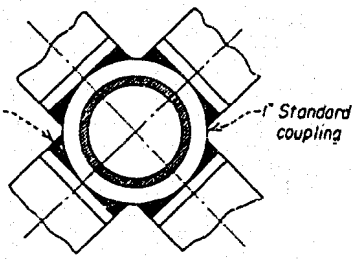
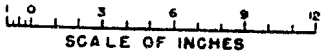
SEEPAGE METER



SECTION A-A



SCALE OF INCHES

250

NOTES

Paint all exposed parts, except brass, with aluminum paint.
All welds on seepage meter, except welds on straps, to be water-tight.
All parts of valve handle extension to be welded together using appropriate size welds.

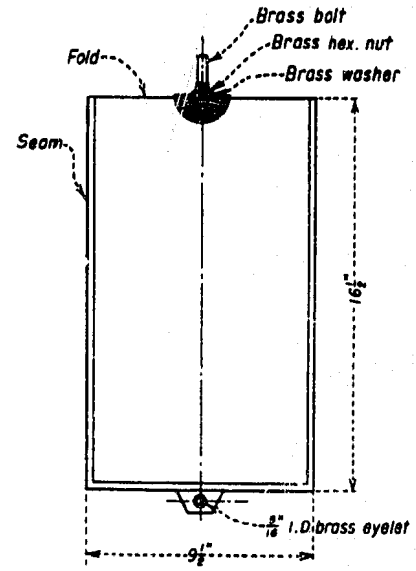
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

LOWER COST CANAL LINING PROGRAM

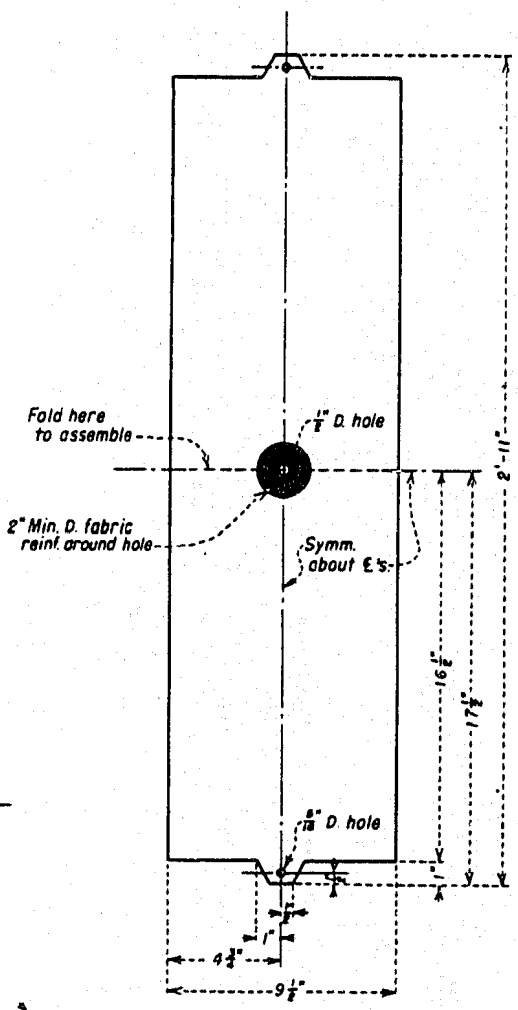
SEEPAGE METER
AND VALVE HANDLE EXTENSION

DRAWN A.J.A. SUBMITTED Charles W. Thomas
TRACED E.V.M. RECOMMENDED
CHECKED R.B.-C.O.D. APPROVED
DENVER, COLORADO — APRIL 28, 1950

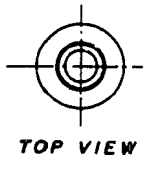
8030-RH-1



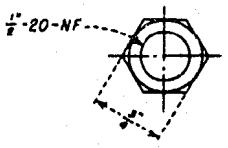
ASSEMBLED PLASTIC BAG
With appurtenant parts



CUT-OUT PATTERN
For Plastic Bag



TOP VIEW



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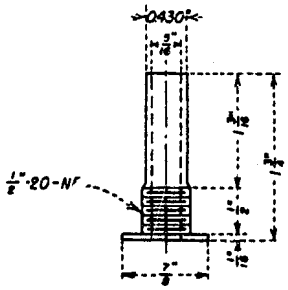
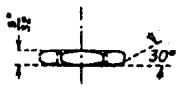
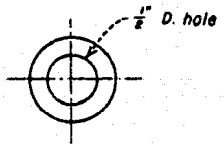


ELEVATION



ELEVATION
BRASS, HEXAGON NUT



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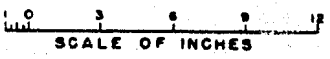
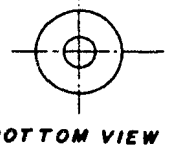
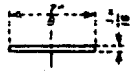




BOTTOM VIEW
BRASS BOLT
Make from ⅞" O.D. brass



ELEVATION
BRASS WASHER

UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
LOWER COST CANAL LINING PROGRAM

PLASTIC BAG WITH BRASS FITTING FOR SEEPAGE METER

DRAWN	A.V.A.	SUBMITTED	Chas. W. Thomas
TRACED	E.V.M.	RECOMMENDED	
CHECKED	R.S.-O.O.O.	APPROVED	

DENVER, COLORADO — APRIL 21, 1950 | 8030-RH-2

Form DCT-27
11-49
Bureau of Reclamation

SEEPAGE METER DATA SHEET

Project_____ Canal_____ Sheet ____ of ____

Meter Depth_____ Meter Area_____ Weather_____

Variation of WS from Normal_____ Design Capacity_____

Percent Cut_____ Fill_____ Soil Type_____

Observer_____ Date_____

Station	Temperature		Water Depth	Water Bag Weights			Time (Min.)			Seepage Loss c.f./s.f./24 hrs.	Remarks
	Air	Water		Initial	Final	Loss	Initial	Final	Net		

FIGURE 3

APPENDIX C

INFLOW-OUTFLOW TESTS--1943
CHINO VALLEY PROJECT--ARIZONA

Seepage losses on the Chino Valley Main Canal were determined by the inflow-outflow method. Gaging stations, calibrated by current meters, were located at each end of the Main Canal. The upper gage was located immediately below the point where the 36-inch concrete pipe discharged into the canal. The lower gage was located 600 feet above the first diversion from the canal. The total length of this test section was 56,475 feet or 10.70 miles. Ten-day averages of discharge at the gaging stations were utilized in determining the seepage losses. Thirteen such ten-day periods cover the 1943 irrigation season. Three 10-day periods in 1942 and eight in 1941 are also included, making a total of 24 10-day periods. The average inflow into the canal was 12.72 second feet. The average loss was 4.14 second feet or 32.5 percent for the 10.70 miles or 3.04 percent per mile.

Reference: Region 3 Project Planning Report No. 3-8b.9-0, Chino Valley Project, Arizona, dated April 1946.

APPENDIX D

PONDING AND INFLOW-OUTFLOW TESTS--1945
GILA PROJECT--ARIZONA

Seepage measurements were made on three unlined canals of the Yuma Mesa Division of the Gila Project. The results of these tests are summarized in the following table. The seepage losses are expressed in cubic feet per square foot of wetted area per 24 hours.

Canal	Method	Depth of water	Seepage loss
B-3.7-1.8S	Ponding	0.85 foot	1.31
A-6.5W	Ponding	1.01 feet	3.30
B-3.8-3.3S	Inflow-outflow	0.70 foot	3.02

In addition to the above tests, seepage measurements were also made in farm ditches and in earth laterals. Recorded losses in the farm ditches varied between 11 and 25 percent per mile. In the earth laterals the losses varied between 0.95 and 6.39 cubic feet per square foot of wetted area per 24 hours.

Other seepage tests, using the inflow-outflow method with current meters to measure the flow, were conducted prior to the above tests, but the results were not recorded in the following reference.

Reference: Memorandum to Acting Construction Engineer, Gila Project, dated August 17, 1945, from L. J. Booher, Yuma, Arizona, subject "Seepage losses from Earth Canals on the Yuma Mesa-Gila Project." This memorandum was transmitted from Acting Construction Engineer to Regional Director, subject "Seepage losses on Yuma Mesa Division--Gila Project," dated September 25, 1945, at Yuma, Arizona.

APPENDIX E

INFLOW-OUTFLOW TESTS--1946
KENDRICK PROJECT--WYOMING

Seepage loss measurements, using the inflow-outflow method with current meters for measuring the discharge, were made in the Casper Canal and in the principal laterals under this canal during the 1946 irrigation season. The Casper Canal was divided into the following five reaches:

Reach	Stationing	Checked depth in the reach
1	0+00 to 651+00	3.5 feet
2	651+00 to 1076+00	3.6 feet
3	1076+00 to 1569+00	3.7 feet
4	1569+00 to 2120+00	4.0 feet
5	2120+00 to 2565+00	5.0 feet

Seepage losses are summarized in the following table for both the Casper Canal and the laterals.

Canal	Length of reach	A. F. for the season		Percent loss	
		Inflow	Loss	Total	Per mile
Main-1	10.76 miles	9975	1246	12.49	1.16
-2	7.58	8227	393	4.78	0.63
-3	9.11	7746	1117	14.42	1.58
-4	9.92	6220	1135	18.25	1.84
-5	7.30	3960	1235	31.19	4.25
Lat -41	1.73	269.9	114.5	56.17	32.47
156	2.35	284.6	44.9	15.80	6.72
174	3.85	220.6	64.2	29.10	7.56
218	6.30	403.3	341.6	84.70	13.44
232	2.14	79.9	29.4	36.80	17.20
239	1.83	123.9	33.1	26.70	14.59
256	6.26	1125.6	794.3	70.57	11.27
256-21R	3.40	366.8	39.6	10.79	3.17
256-74L	4.27	293.9	199.7	67.95	15.91

Reference: Memorandum for District Manager, Casper, Wyoming, dated April 3, 1947, subject "Canal and laterals seepage loss and wave action studies--Kendrick Project."

INFLOW-OUTFLOW TESTS--1946
MIRAGE FLATS PROJECT--NEBRASKA

In September 1946 two inflow-outflow measurements were made for determining seepage losses from the 692.5-foot section of the Main Canal from Station 468+22 to Station 475+14. Temporary Cipolletti weirs with 3-foot crests were installed at each end of the test reach for measuring the discharge. Depth in the canal during the tests was about 50 percent of the design depth of 4 feet 1.8 inches. The design discharge for this reach of canal is 220 second feet, with a bottom width of 16 feet. The side slopes were 1-1/2 to 1. Water was turned into the test reach of canal at 4 p.m. September 28, while observations were made in the morning and in the afternoon of September 29. The following table summarizes the results of these tests:

Observation No.	Discharges in second feet			
	Upstream weir	Downstream weir	Total losses	Loss per mile
1	6.353	6.274	0.079	0.60
2	6.184	5.003	0.191	1.46

Reference: Field trip report to Chief Engineer through Chief, Engineering and Geological Control and Research Division from Dale M. Lancaster and V. S. Meissner, subject "Seepage Investigations--Mirage Flats Project."

INFLOW-OUTFLOW TESTS--1946
PROVO RIVER PROJECT--UTAH

Seepage losses from four reaches of the Provo Reservoir Canal were measured by the inflow-outflow method, using current meters. Reach 1, nearly 60,000 feet long, contained 2,000 feet of compacted clay lining and 3,300 feet of loose clay lining. Reach 2, 8,700 feet long, contained 7,950 feet of silted lining. Reaches 3 and 4 were unlined. The data obtained from these tests are summarized in the following table:

Reach No.	Stationing	Seepage losses per mile	
		Second feet	Percent
1	82+00 to 665+48	0.86	0.44
2	665+48 to 752+50	3.63	2.67
3	752+50 to 1040+00	0.81	0.65
4	1040+00 to 1150+00	3.71	3.54

Reference: Letter (report) to Project Engineer, Provo River Project, from Engineers R. W. Jennings and J. R. Bingham, subject "Lower-cost Canal Lining--Provo River Project, Utah." Letter of transmittal to Regional Director, from Project Engineer dated November 6, 1947, subject "Transmittal of report 'Lower-cost Canal Lining'--Provo River Project, Utah."

APPENDIX F

SEEPAGE METER AND INFLOW-OUTFLOW TESTS--1947
GILA PROJECT--ARIZONA

Seepage meter and inflow-outflow seepage measurements were made in two reaches of B-3.7-1.8S canal, Yuma Mesa Division, Gila Project, during December 1947. Four seepage meter settings were made in the upper reach of canal while three meter settings were made in the downstream reach. The seepage losses are expressed in terms of second feet per 1,000 feet of canal length.

Method	Seepage losses	
	0 to 19+20	19+20 to 32+57
Inflow-outflow	0.39	4.55
Inflow-outflow	0.34	4.41
Inflow-outflow	0.10	4.00
Seepage meter	0.06	0.22

Seepage losses from the reach of canal between Station 0 and Station 19+20 were also obtained in 1945, see Appendix C, although the seepage rates are expressed in different units.

Reference: Memorandum to Superintendent, Gila Project, from Engineer R. E. Goss, Lower Colorado River District, Yuma, Arizona, subject "Seepage Losses from Canals--Yuma Mesa, Gila Project," dated February 6, 1948.

INFLOW-OUTFLOW TESTS--1947
PROVO RIVER PROJECT--UTAH

During 1947, repeat seepage measurements were made in the four reaches of the Provo Reservoir Canal tested in 1946. As in the 1946 tests, these measurements were made with current meters using the inflow-outflow method. Results are summarized in the following table and comparisons are made with the 1946 results:

Reach	Stationing	Seepage losses per mile		Percent of 1946 rates
		Second feet	Percent	
1	82+00 to 665+48	1.25	0.62	140
2	665+48 to 752+50	3.03	2.12	80
3	752+50 to 1040+00	1.14	0.86	130
4	1040+00 to 1150+00	1.09	1.04	30

Two of the reaches showed an increased seepage loss and two a decreased seepage loss from 1946 to 1947. The average for all four reaches in 1946 was 0.72 percent per mile and in 1947 the loss was 0.68 percent per mile or 95 percent of the 1946 losses.

Reference: Letter (report) to Project Engineer, Provo River Project, from Engineers R. W. Jennings and J. R. Bingham, subject "Lower-cost Canal Lining--Provo River Project, Utah." Letter of transmittal to Regional Director from Project Engineer dated November 6, 1947, subject "Transmittal of report 'Lower-cost Canal Lining'--Provo River Project."

APPENDIX G

RESEARCH--1948
ENGINEERING EXPERIMENT STATION
UNIVERSITY OF IDAHO

During 1948, seepage measurements were made in the Main Canal of the Rathdrum Prairie Project, Idaho. This work, known as "Special Research Project No. 20" was performed by personnel from the Engineering Experiment Station of the University of Idaho with the Soil Conservation Service and the Bureau of Reclamation, Region 1, cooperating. These seepage loss measurements were made using (1) the inflow-outflow method, and (2) the seepage meter. Both clay-lined and unlined reaches of canal were tested. The seepage rates obtained are summarized in the following table:

Reach	Lining	Stationing	Water depth	Loss--cfs/mile	
				Inflow-outflow	Seepage meter
1	Compacted clay 6-in gravel cover	3+71 to 91+50	3.0	0+	0.02
2	7,050 ft unlined 2,000 ft compacted clay	91+50 to 182+00	2.5	1.33	1.14
3	Unlined	182+00 to 205+50	2.5	3.32	1.15
4	Loose clay--4 inches thick	210+50 to 236+50	1.6	0.51	0.08

This research project is being continued with special emphasis on the seepage meter.

Reference: Report "Methods of Evaluating Seepage Losses from Irrigation Canals," by C. C. Warnick, Engineering Experiment Station, University of Idaho, April 1949.

RESEARCH--1948
UTAH AGRICULTURAL EXPERIMENT STATION

The following seepage measurement studies were made by the Utah Agricultural Experiment Station with the Soil Conservation Service and the Bureau of Reclamation cooperating:

(1) Provo River Reservoir Canal--unlined. Insufficient accuracy was obtained by the inflow-outflow method utilizing current meters to give reliable seepage losses.

(2) Richmond Irrigation Company Canal--unlined.

(a) Original canal--inflow-outflow measurements indicated 51-percent loss in 1,800 feet. Ponding tests showed a maximum seepage loss, at a depth of 1.0 feet, of 16 cubic feet per square foot of wetted area per 24 hours.

(b) Relocated Canal--ponding tests, at a depth of 2.0 feet indicated a maximum seepage rate of 6 cubic feet per square foot of wetted area per 24 hours.

(3) Cache County Canals--permeameter tests results were as follows:

Canal	Permeability K-feet per year		
	Bottom	East slope	West slope
Logan, Hyde Park, and Smithfield	3	51	51
Lewiston East Branch	20	52	51
Lewiston West Branch	27	112	173

(4) Experimental linings at the River Laboratory:

Material	Permeability K-feet per year	
	Bottom	Side slopes
Trenton sandy loam plus 5 parts bentonite	12	285
Trenton sandy loam plus 2 parts bentonite	580	580
Mendon silt loam plus salt	108	730

Reference: "Utah Cooperative Canal Lining Studies, Progress Report for 1948, River Laboratory Investigations, Fabrics for Canal Linings, Canal Seepage Studies, North Logan Field Test, Richmond Field Test," dated January 1949.

PONDING TESTS--1948
W. C. AUSTIN PROJECT--OKLAHOMA

Ponding tests were made on three reaches of the W. C. Austin Lateral West 11.5 with soil-cement linings. The lining was placed with a 4.0-foot bottom, 1-1/2 to 1 side slope, and a vertical height of 3.0 feet. The results of these tests are summarized in the following table:

Stationing	Cement content	Seepage rate
211+00 to 223+00	11.0%	0.14 cubic foot per square
197+15 to 211+00	15.5%	0.03 foot of wetted area
223+00 to 237+75	17.5%	0.07 per 24 hours

One unlined reach of lateral immediately downstream of the lined reaches, Station 237+75 to Station 249+75, was ponded. This 1,200 feet of unlined lateral had been dry for 2 months. Water was not available for priming, therefore the seepage rate indicated by ponding is probably somewhat higher than would be expected during normal operation. The average of the ponding tests for this reach of unlined lateral was 0.95 cubic foot per square foot of wetted area per 24 hours.

Reference: Memorandum to Project Engineer, W. C. Austin Project, from R. C. Brummett dated December 13, 1948, subject "Report on Tests of Seepage Losses in the Plastic Soil-Cement Lining in West 11.5 Lateral, Station 196+96.5 to Station 241+76, Lower-Cost Lining program--W. C. Austin Project."

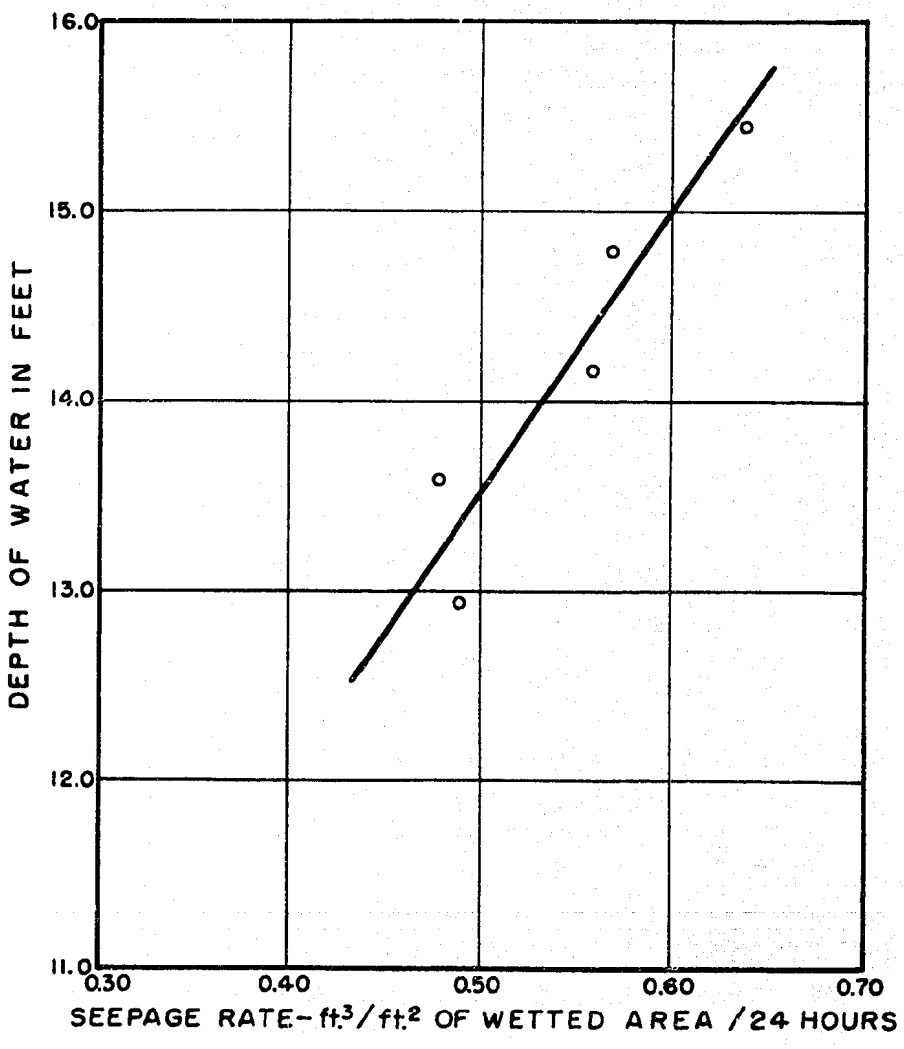
APPENDIX H

PONDING TESTS--1949
CENTRAL VALLEY PROJECT--FRIANT-KERN CANAL--CALIFORNIA

Ponding tests were performed during 1949 on the Stokes Mountain Section (Station 2963+73 to Station 3004+98) of the Friant-Kern Canal. This reach of canal, concrete lined in 1947, was selected because of the serious cracking in the lining caused by the underlying expansive clays. The bottom width of the canal was 36.0 feet, the side slopes 1-1/4 to 1 with a maximum water depth of 16 feet. Figure 4 shows a plot of depth of water versus seepage rate for the pond. The maximum seepage rate measured was about 0.64 cubic foot per square foot of wetted area per 24 hours.

Reference: "Report on Expansive Clays of the Friant-Kern Canal," by J. J. Waddel, Earthwork Control Engineer, Friant-Kern Canal, Central Valley Project, dated September 12, 1949.

FIGURE 4



CENTRAL VALLEY PROJECT—CALIFORNIA

PONDING TEST - 1949

STATION 2963+73 TO 3004+98—CONCRETE LINED

FRIANT—KERN CANAL

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RESEARCH--1949
COLORADO AGRICULTURAL EXPERIMENT STATION
COLORADO A AND M COLLEGE

The Soil Conservation Service, in cooperation with the Colorado Agricultural Experiment Station and the Bureau of Reclamation, initiated, in 1949, a project entitled "The Study of Seepage Losses from Irrigation Channels." This project was carried on in Fort Collins, Colorado, with Carl Rohwer of the Soil Conservation Service as Project Supervisor. Emphasis was placed on the seepage meter as an instrument for the measuring of seepage losses from irrigation canals and laterals.

The seepage ring procedure was selected for the testing of the seepage meter. An 18-foot-diameter outer ring with a 6-foot-diameter center ring was constructed. Seepage losses from the two areas were obtained for depths of water of 24, 18, 12, and 4 inches. Under certain conditions the seepage rate from the inner ring was greater than the rate from the outer ring.

A 12-inch-diameter seepage meter was placed inside the center ring and the rates obtained with the meter were compared with the rates obtained in the ring. Twenty different tests were made in the period from November 12 to December 10, 1949. The seepage meter indicated seepage rates from 20 to 116 percent of the seepage ring rates with an average of 64 percent. The correlation of seepage rate with temperature, barometric pressure, and ground-water table is discussed in the report on this project.

This project continues into calendar year 1950.

References: "Progress Report on the Study of Seepage Losses from Irrigation Channels," by Carl Rohwer, Soil Conservation Service, Fort Collins, Colorado, dated April 26, 1950, and "Report on Soils, Horticultural Plot Seepage Experiment," by Ralph L. Rollins, Colorado A&M College, Fort Collins, Colorado, dated July 7, 1950.

RESEARCH--1949
ENGINEERING EXPERIMENT STATION
UNIVERSITY OF IDAHO

Seepage studies, "Special Research Project No. 20," Engineering Experiment Station, University of Idaho, were continued during 1949, the Bureau of Reclamation, Region 1, and the Soil Conservation Service cooperating. In addition to the continuation of the inflow-outflow tests and seepage meter studies in the Main Canal, ponding and seepage meter tests were performed in a farm lateral taking water out of Lateral 20.8 of the Rathdrum Prairie Project.

The following table presents the seepage meter results for the current year (1949) and compares them with the results obtained in 1948 in the same reaches of the Main Canal of the Rathdrum Prairie Project.

Reach	Lining	Approx discharge	Seepage loss--cfs/mile	
			1948	1949
1	Compacted clay 6-in gravel cover	50 second feet	0.02	0.01
2	7,050 ft unlined 2,000 ft compacted clay	22 second feet	1.14	1.56
3	Unlined	15 second feet	1.15	1.02
4	Loose clay--4 inches thick	7 second feet	0.08	0.11

A comparison of seepage loss measurements by the inflow-outflow method and by the seepage meter is as follows for Reaches 2 and 3, Main Canal:

Reach	Seepage loss in cfs	
	Inflow-outflow	Seepage meter
2	0.66	0.52
3	1.24	0.51

A summary of the ponding and seepage meter tests in a farm lateral taking water out of Lateral 20.8, Rathdrum Prairie Project, follows. This ponded reach was 65 feet long.

Condition of the lateral	Seepage rate in cfs/mile	
	Ponding	Seepage meter
Natural channel condition	1.5	0.7
Reshaped channel, bottom width 2.0 feet. 2 to 1 side slopes	1.0	0.7
2-in layer of bauxite clay over reshaped channel	0.2	0.1

In addition to the above studies, work was commenced on a large seepage meter test tank to be used in research work on the seepage meter.

Reference: Report, "Methods of Evaluating Seepage Losses from Irrigation Canals," by C. C. Warnick, Engineering Experiment Station, University of Idaho, April 1950.

RESEARCH--1949
UTAH AGRICULTURAL EXPERIMENT STATION

The cooperative seepage studies made by the Utah Agricultural Experiment Station, the Soil Conservation Service, and the Bureau of Reclamation, started in 1948, were continued in 1949. The progress report cited below indicates that the emphasis of these studies has been placed on the effectiveness of various canal linings. The following lining materials have been under investigation: soil, soil bentonite mixtures, soil treated with oil and other agents, rubberized and wax-coated fabrics, asphalt, and concrete. The materials are first given a laboratory test. The more promising materials are then given model tests in the River Laboratory, followed by field installation and testing. The tests are being continued and conclusions will be drawn at the completion of the studies.

Reference: "Conveyance Loss and Canal Lining Investigations," by C. W. Lauritzen and O. W. Israelson, A Progress Report for In-service Use, Utah Agricultural Experiment Station, June 1949.

PONDING, SEEPAGE METER, AND INFLOW-OUTFLOW TEST--1949
NORTH PLATTE PROJECT--WYOMING-NEBRASKA

At the close of the 1949 irrigation season on the North Platte Project, ponding tests were performed on the Fort Laramie Canal (six ponds totaling 11,176 feet in length), on Lateral 29.4 (three ponds totaling 1,834 feet), on Lateral 90.4 (six ponds totaling 6,567 feet), and on Lateral 24A (six ponds totaling 5,038 feet). All reaches of canal tested were unlined, although some 9,000 feet of the Fort Laramie Canal (Ponds 1, 2, 3, and 4) were portland cement pressure grouted (Specifications No. 2600) immediately prior to the ponding tests.

Normal operating depth for the Fort Laramie Canal along the reach ponded is about 9 feet for a discharge of about 1,200 second feet. Normal operating depths in the laterals ponded vary between 1.5 and 2.0 feet.

Plot of seepage rates (cubic feet per square foot of wetted area per 24 hours) versus depth of water in the pond in feet together with the stationings of the various ponds are shown in Figure 5 for the Fort Laramie Canal and in Figures 6, 7, and 8 for the laterals.

Two sets of seepage meter measurements were made on the North Platte Project during 1949. The first set was taken in flowing water during the regular irrigation season while the second set was taken concurrently with the ponding tests in the still water of the ponds.

Figures 9, 10, and 11 show plots of each individual seepage meter measurement in the Fort Laramie Canal while Figures 12, 13, 14, and 15 show similar data for seepage meter settings in the laterals.

Table 1 summarizes the seepage meter results in flowing water and compares them with the ponding results. Table 2 presents similar data for the seepage meter tests in the ponds.

Inflow-outflow measurements were made by project personnel for the reach of Fort Laramie Canal between miles 35.0 and 39.7. The seepage losses obtained from these data, together with other related data, are shown in Figure 16.

Reference: Hydraulic Laboratory Report No. Hyd-297, dated January 15, 1951, subject "Seepage Measurements--Lower-cost Canal Lining Program--North Platte Project, Wyoming-Nebraska."

Table 1

NORTH PLATTE PROJECT--WYOMING
SEEPAGE MEASUREMENTS

Seepage Meter in Still Water

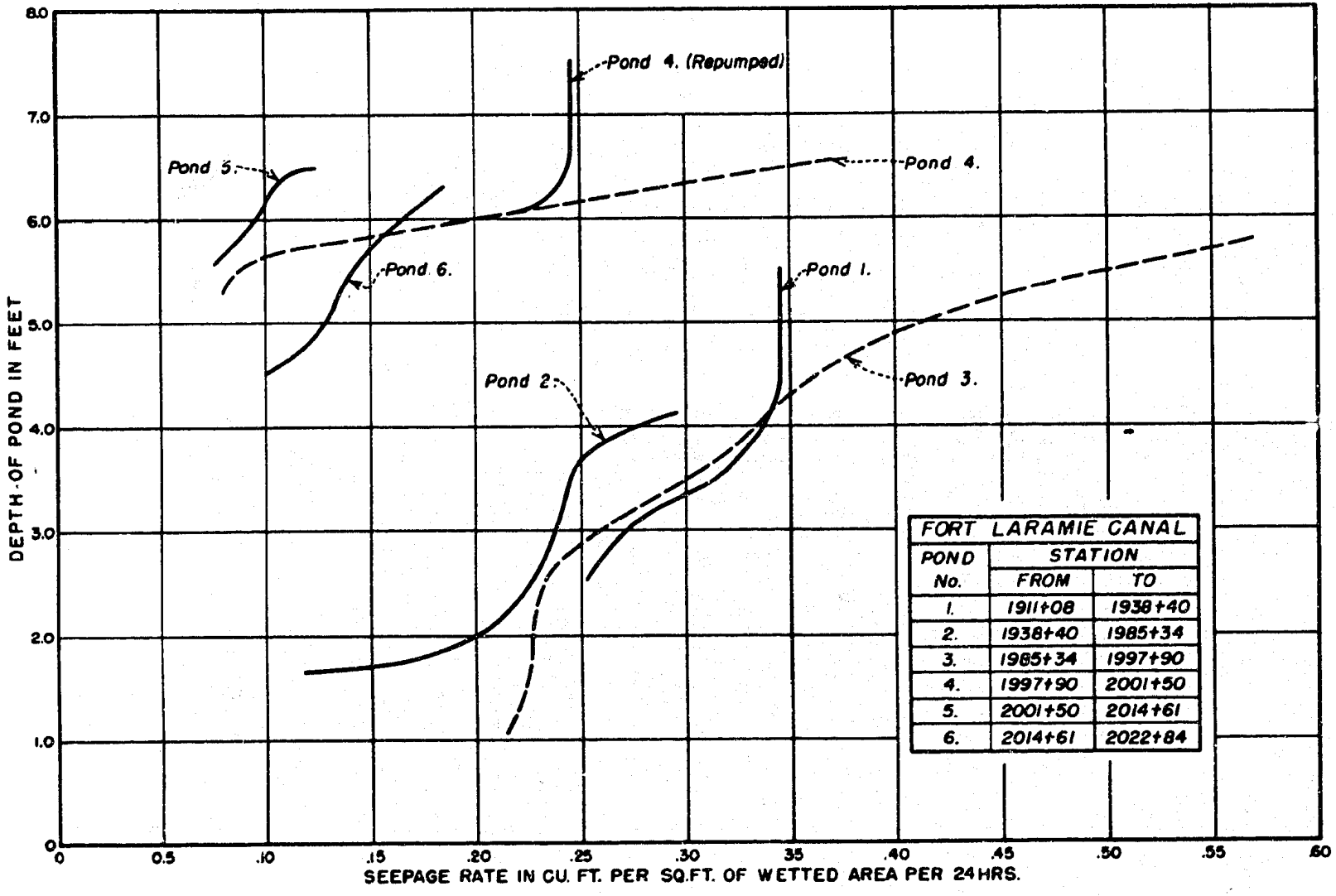
Pond No.	No. of meter settings	Seepage rate by meter: Maximum	Minimum	Average	Rate by ponding	Variation Rate	Variation Percent
Fort Laramie Canal							
1	26	0.93	0.08	0.46	0.26	+0.20	+77
2	42	1.27	0.02	0.32	0.21	+0.11	+52
3	28	1.05	0.02	0.25	0.33	-0.08	-24
4	16	0.37	0.01	0.10	0.15	-0.05	-33
5	35	0.25	0.01	0.10	0.12	-0.02	-17
6	15	0.57	0.01	0.20	0.17	+0.03	+18
Lateral 29.4							
1	11	0.57	0.01	0.25	0.36	-0.11	-31
2	4	0.46	0.22	0.31	0.28	+0.03	+11
3	14	0.69	0.08	0.28	0.21	+0.07	+33
Lateral 90.4							
1	3	1.45	0.21	0.69	0.48	+0.21	+44
2	6	0.44	0.04	0.15	0.42	-0.27	-64
3	4	0.62	0.06	0.25	0.20	+0.05	+25
4	2	0.04	0.02	0.03	0.28	-0.25	-89
5	2	0.08	0.07	0.08	0.13	-0.05	-38
Lateral 24A							
1	14	3.67	0.02	1.70	0.76	+0.94	+124
2	4	2.31	0.54	1.82	0.58	+1.24	+214
3	3	0.44	0.09	0.26	0.30	-0.04	-13
4	3	0.62	0.27	1.01	0.49	+0.52	+106
5	6	0.30	0.18	0.23	0.44	-0.21	-48
6	2	0.30	0.13	0.22	0.31	-0.09	-29

Table 2

NORTH PLATTE PROJECT--WYOMING
SEEPACE MEASUREMENTS

Seepage Meter in Flowing Water

Pond No.	No. of meter settings	Seepage meter in flowing water	Seepage rate from ponding tests	Differences based on ponding rate: Rate	Differences based on ponding rate: Percent
Fort Laramie Canal					
1	35	0.87	0.35	+0.52	+149
2	0	--	0.30	--	--
3	10	0.33	0.40	-0.07	-18
4	11	0.23	0.25	-0.02	-8
5	7	0.16	0.13	+0.03	+23
6	9	0.12	0.18	-0.06	-33
Lateral 29.4					
1	6	0.47	0.38	+0.11	+29
2	8	0.40	0.30	+0.10	+33
3	2	0.52	0.24	+0.28	+117
Lateral 90.4					
1	4	0.42	0.64	-0.22	-34
2	6	0.42	0.50	-0.08	-16
3	0	--	0.25	--	--
4	1	0.22	0.45	-0.23	-51
5	2	0.01	0.15	-0.14	-93
6	0	--	--	--	--
Lateral 24A					
1	5	3.35	0.87	+2.48	+285
2	2	2.07	0.59	+1.48	+251
3	1	1.34	0.36	+0.98	+272
4	3	1.61	0.57	+1.04	+182
5	1	0.42	0.59	-0.17	-29
6	3	1.25	0.38	+0.87	+229



FORT LARAMIE CANAL		
POND No.	STATION FROM	STATION TO
1.	1911+08	1938+40
2.	1938+40	1985+34
3.	1985+34	1997+90
4.	1997+90	2001+50
5.	2001+50	2014+61
6.	2014+61	2022+84

NORTH PLATTE PROJECT-WYOMING-NEBRASKA

1949 SEEPAGE STUDIES

PONDING TESTS-FORT LARAMIE CANAL

FIGURE 5
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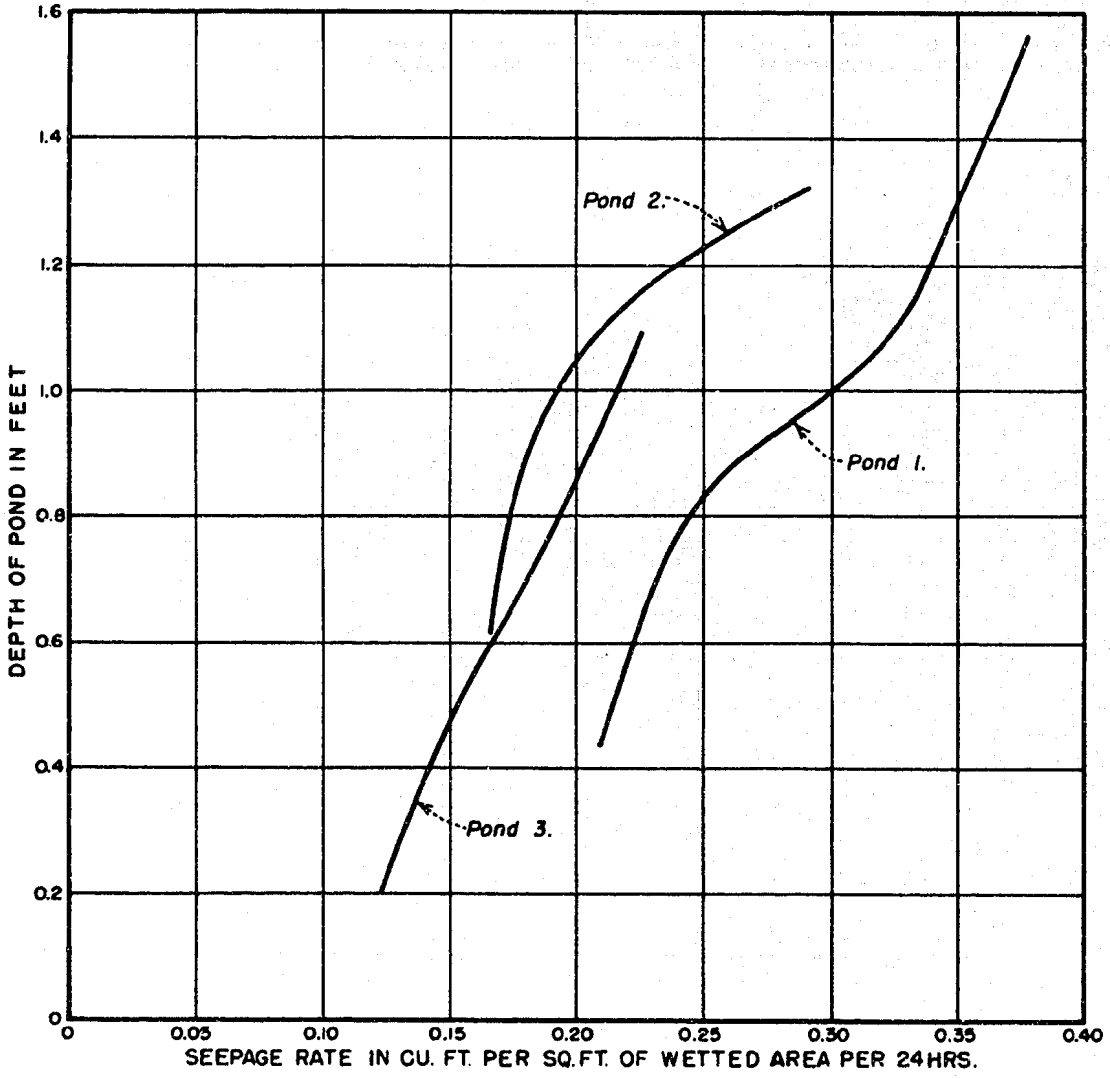

LATERAL 29.4		
POND No.	STATION	
	FROM	TO
1.	6+10	11+98
2.	11+98	21+82
3.	21+82	24+44

NORTH PLATTE PROJECT-WYOMING-NEBRASKA

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PONDING TESTS - FORT LARAMIE LATERAL 29.4

FIGURE 6
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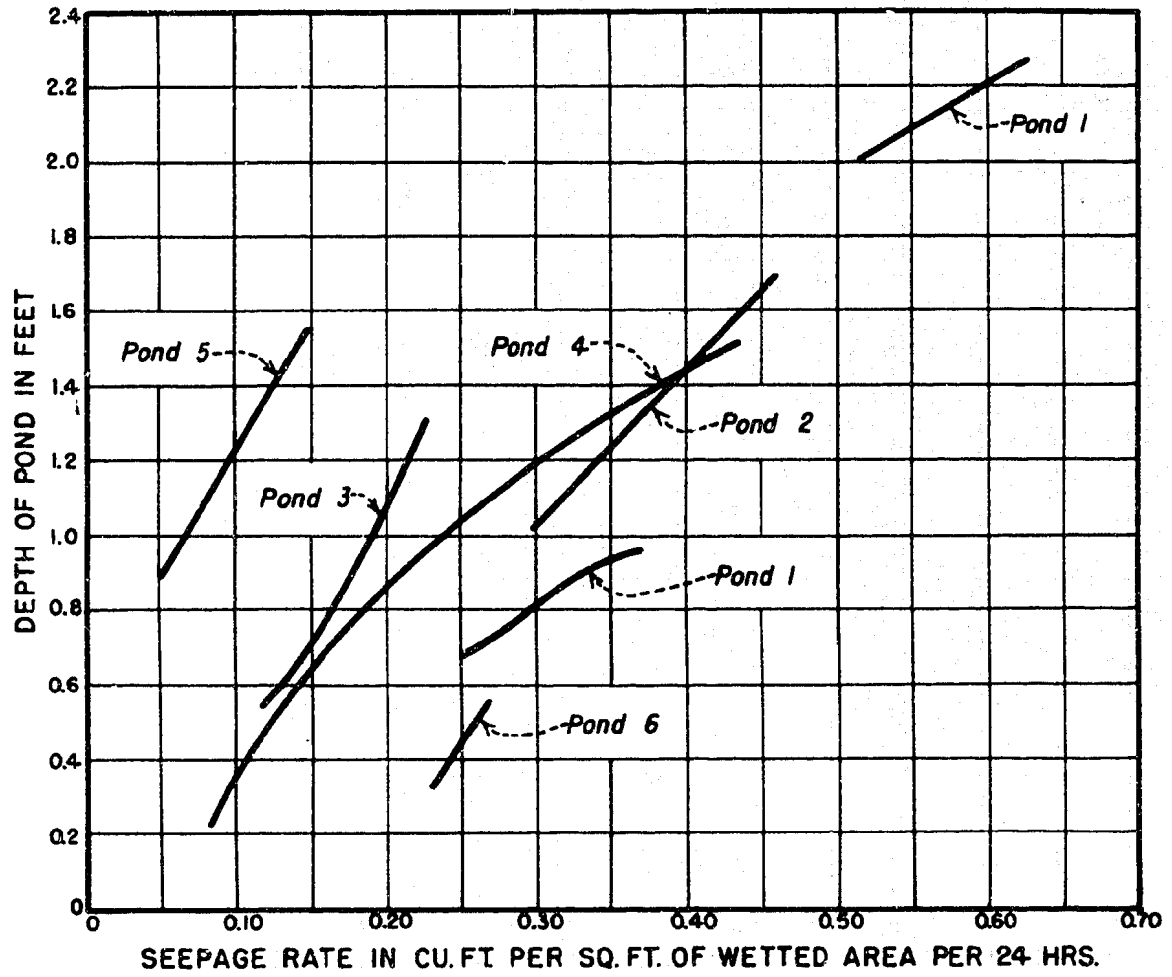
LATERAL 90.4		
POND No.	STATION	
	FROM	TO
1	130+18	139+97
2	145+00	172+74
3	172+74	184+46
4	197+36	201+81
5	201+81	210+44
6	228+04	231+38



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NORTH PLATTE PROJECT-WYOMING-NEBRASKA

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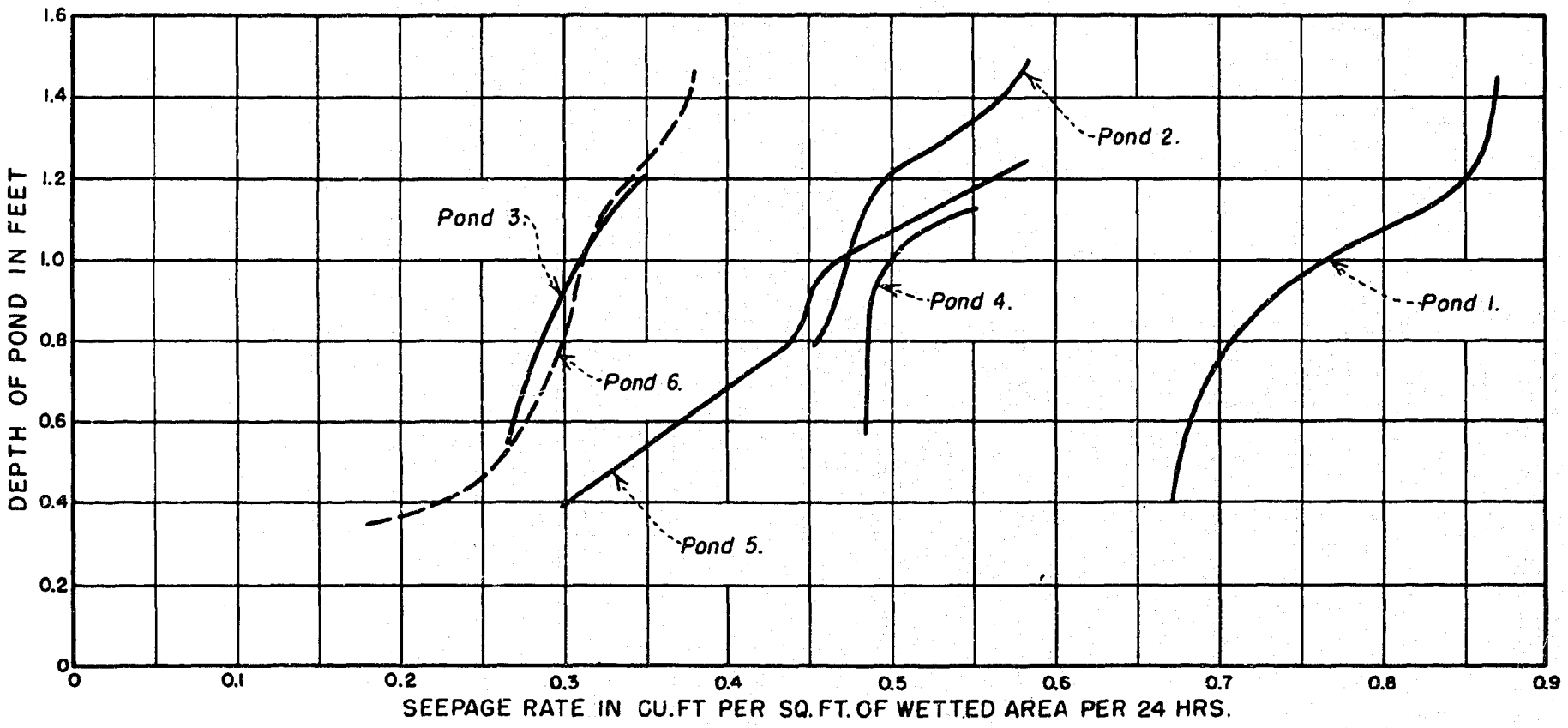
PONDING TESTS

FORT LARAMIE LATERAL 90.4

FIGURE 7
REPORT HYD. 317



LATERAL 24A					
POND No.	STATION		POND No.	STATION	
	FROM	TO		FROM	TO
1.	0+89	7+34	4.	21+67	36+46
2.	7+34	15+44	5.	36+46	44+05
3.	15+44	21+67	6.	44+05	51+27

NORTH PLATTE PROJECT-WYOMING-NEBRASKA

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PONDING TESTS-INTERSTATE LATERAL 24A

FIGURE 8
REPORT HYD. 317

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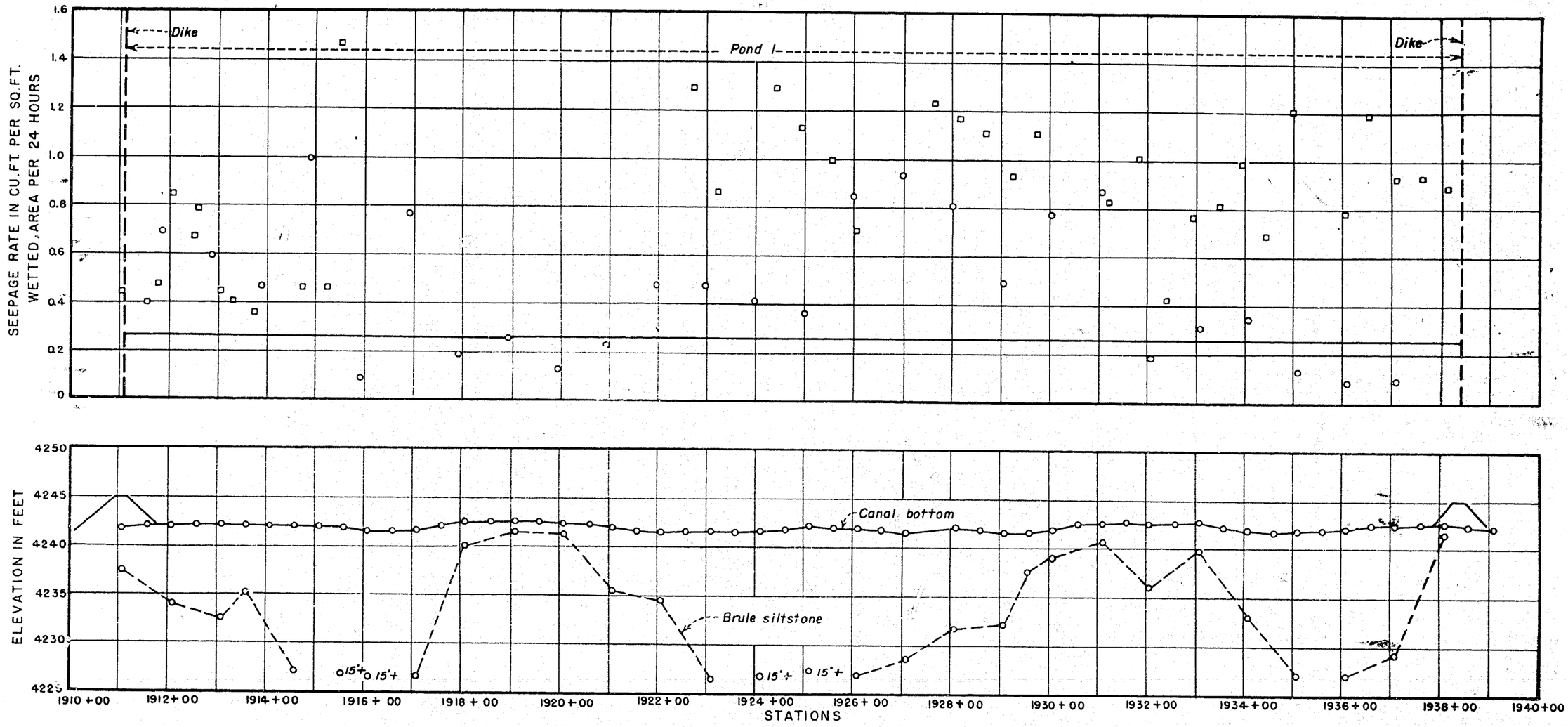
FIGURE 9
REPORT HYD. 317



EXPLANATION

- Seepage meter in flowing water.
- Seepage meter in pond.
- Seepage rate by ponding test for the same time interval as the seepage meter test.
- Canal bottom.
- Top of brule clay.

NORTH PLATTE PROJECT - WYOMING - NEBRASKA

1949 SEEPAGE STUDIES

SEEPAGE METER TESTS - FORT LARAMIE CANAL POND I

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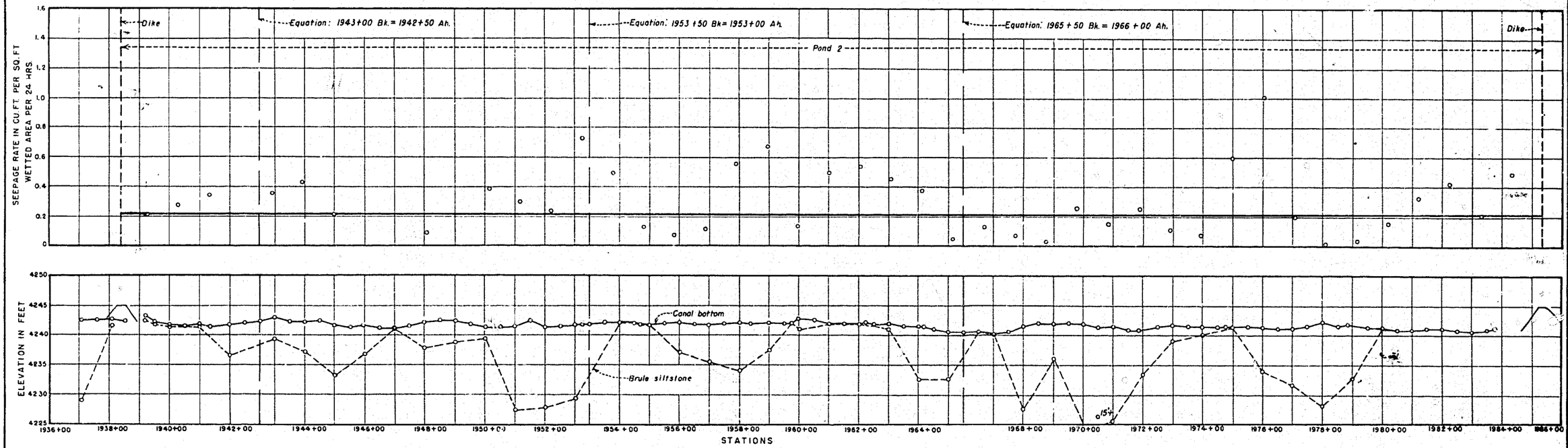
FIGURE 10
REPORT HYD. 317



EXPLANATION

- Seepage meter in pond
- Seepage rate by ponding test for the same time interval as the seepage meter test
- Canal bottom
- Top of brule clay.

NORTH PLATTE PROJECT-WYOMING-NEBRASKA
1949 SEEPAGE STUDIES
SEEPAGE METER TESTS-FORT LARAMIE CANAL
POND 2.

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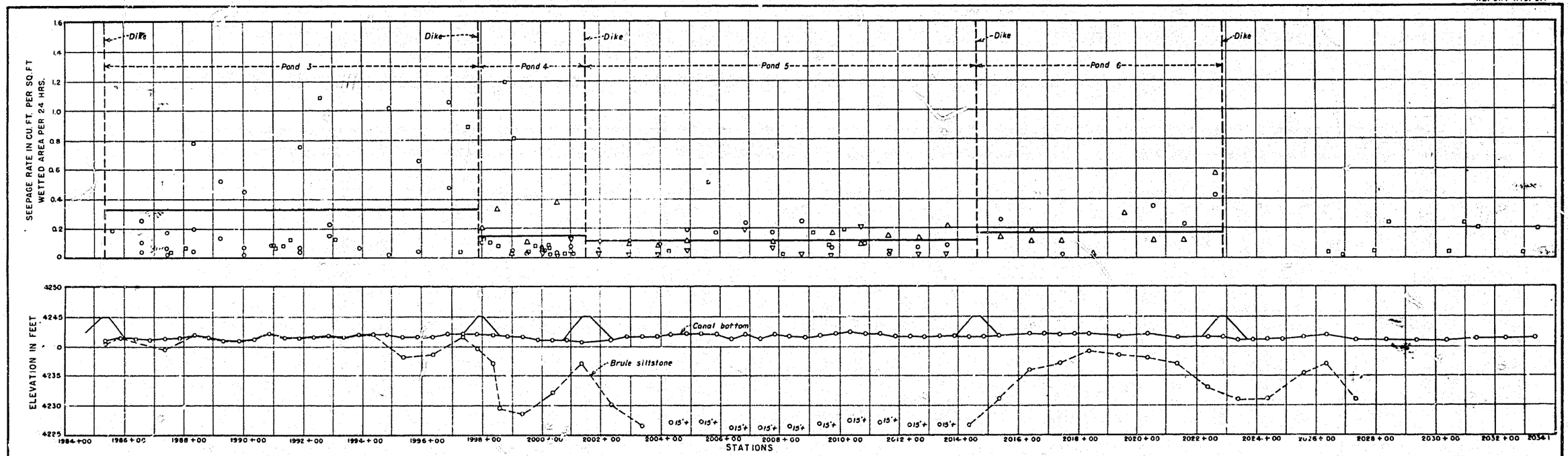
FIGURE 11
REPORT HYD. 317



EXPLANATION

- Seepage meter in flowing water.
- Seepage meter in ponds
- Seepage meter in right bank of pond
- Seepage meter in left bank of pond
- Seepage rate by ponding test for the same time interval as the seepage meter test.
- Canal bottom
- Top of brule clay

NORTH PLATTE PROJECT - WYOMING - NEBRASKA

1949 SEEPAGE STUDIES

SEEPAGE METER TESTS - FORT LARAMIE CANAL
PONDS 3, 4, 5 AND 6

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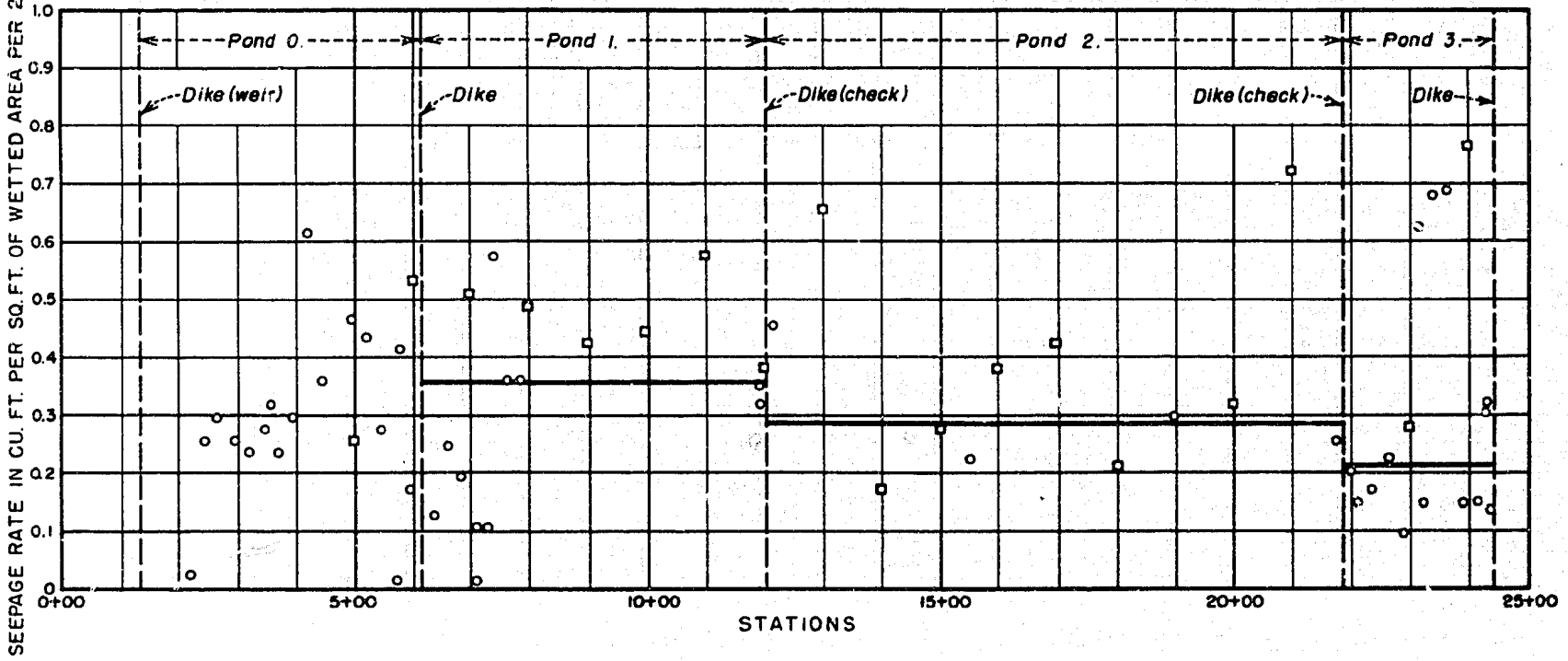

EXPLANATION

- □ Seepage meter in flowing water.
- ○ Seepage meter in ponds.
- —— Seepage rate by ponding tests for the same time interval as the seepage meter tests.

NORTH PLATTE PROJECT-WYOMING-NEBRASKA

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SEEPAGE METER TESTS-FORT LARAMIE LATERAL 29.4

FIGURE 12
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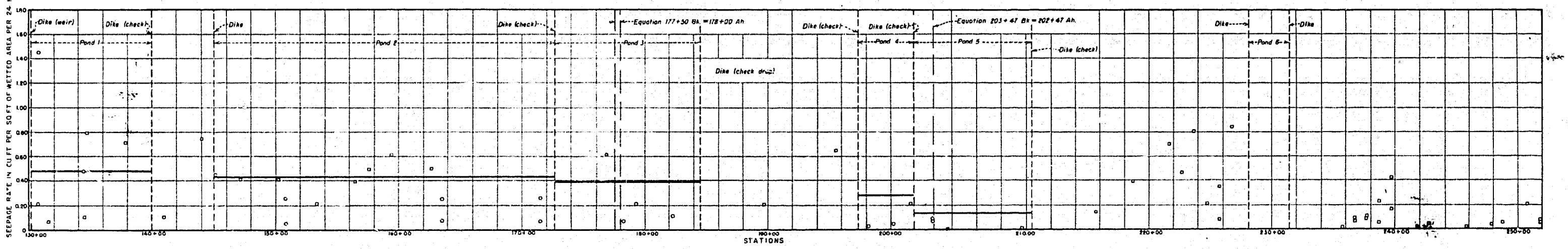
FIGURE 13
REPORT NYO. 317



EXPLANATION

- Seepage meter in flowing water.
- Seepage meter in ponds
- Seepage rate by ponding tests for the same time interval as the seepage meter tests

NORTH PLATTE PROJECT - WYOMING-NEBRASKA
1949 SEEPAGE STUDIES
SEEPAGE METER TESTS - FORT LARAMIE LATERAL 90.6

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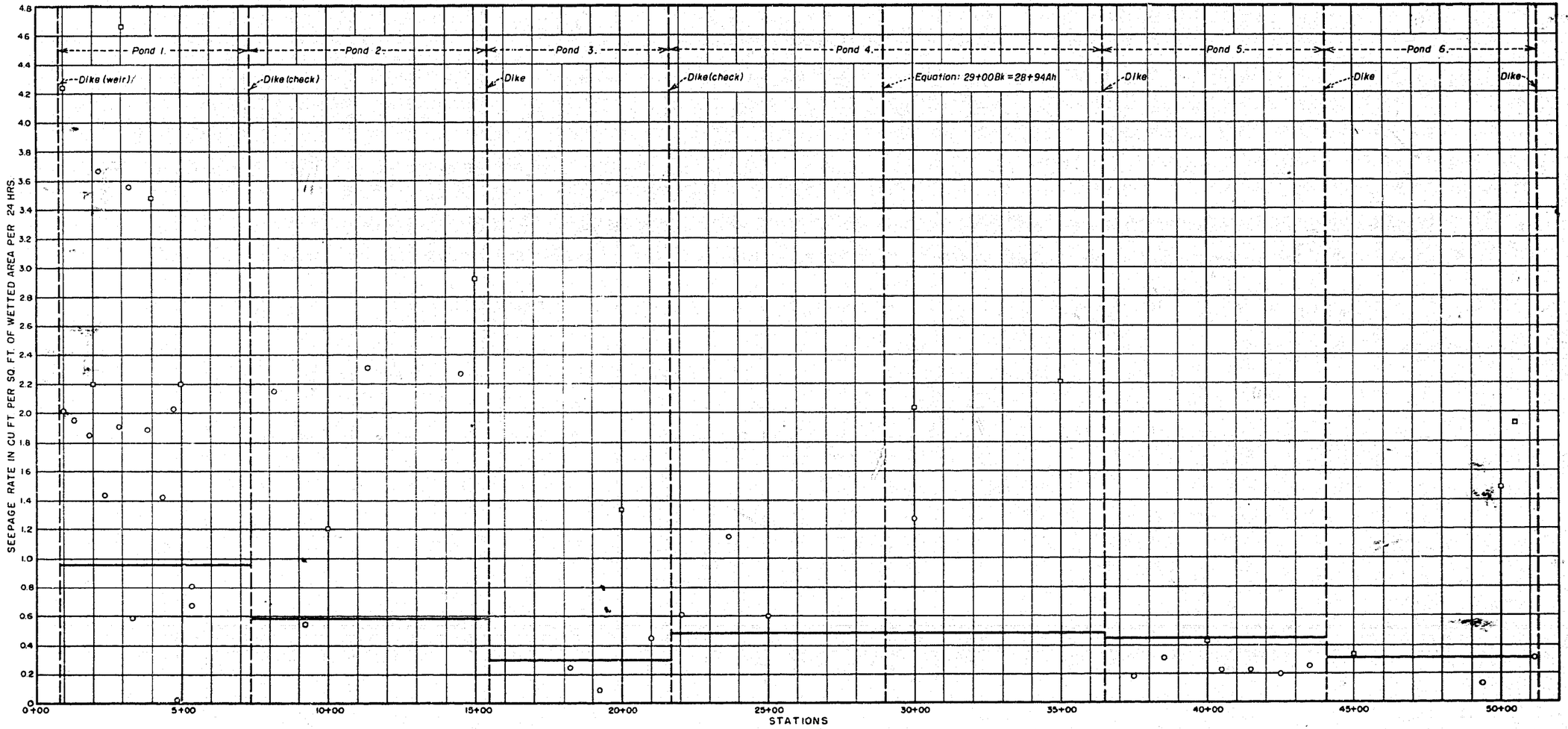
FIGURE 14
REPORT HYD. 317



EXPLANATION

- □ Seepage meter in flowing water.
- ○ Seepage meter in ponds.
- —— Seepage rate by ponding test for the same time interval as the seepage meter tests.

NORTH PLATTE PROJECT-WYOMING-NEBRASKA
1949 SEEPAGE STUDIES
SEEPAGE METER TESTS-INTERSTATE LATERAL 24A

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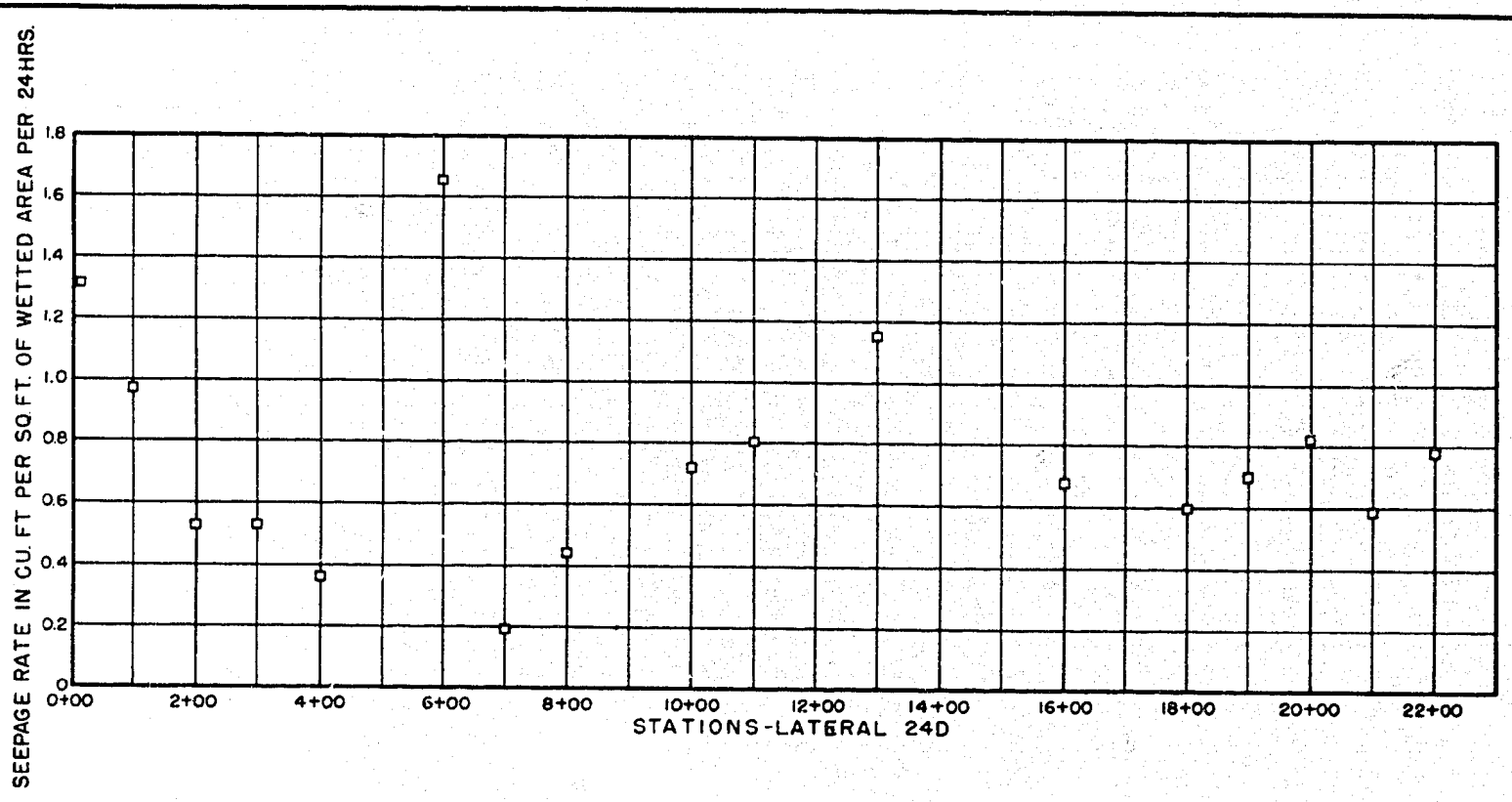
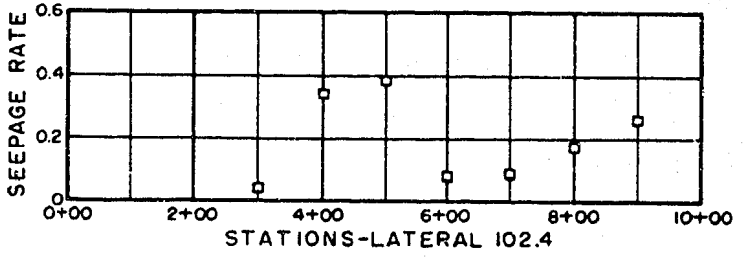
H.G.A. 3-8-50





EXPLANATION

□ Seepage meter in flowing water.

NORTH PLATTE PROJECT-WYOMING-NEBRASKA

1949 SEEPAGE STUDIES

SEEPAGE METER TESTS-FORT LARAMIE LATERAL 102.4 AND INTERSTATE LATERAL 24D

FIGURE 15
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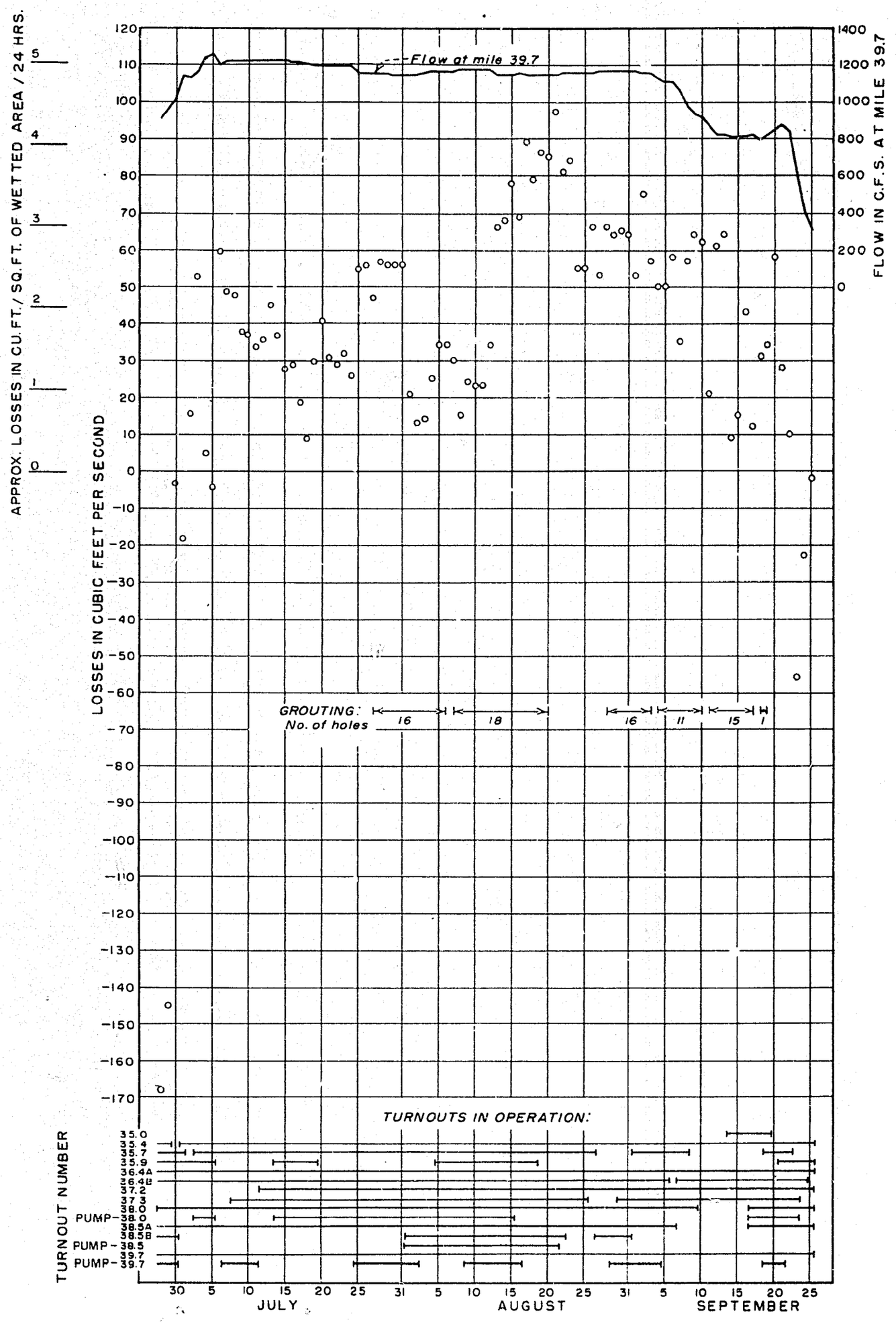
P.S. 3-8-50



NORTH PLATTE PROJECT – WYOMING – NEBRASKA

1949 SEEPAGE STUDIES

LOSSES BY INFLOW – OUTFLOW MEASUREMENTS

MILE 35.0 TO 39.7 – FORT LARAMIE CANAL

FIGURE 16
REPORT HYD. 317

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R.S. 3-7-50

INFLOW-OUTFLOW AND SEEPAGE METER TESTS--1949
RIO GRANDE PROJECT--NEW MEXICO-TEXAS

Seepage losses were determined in the West Side Canal by two methods; namely, (1) inflow-outflow (using weirs), and (2) seepage meter. The results of these tests are summarized in the following table where seepage rates are expressed in terms of ft^3/ft^2 of wetted area per 24 hours:

Stationing	Reach No.	Lining	Length in feet	Seepage rates	
				Inflow-outflow	Seepage meter
50+84					
	1	6% concrete	22,248	0.83	
273+32					
	2	70% concrete	4,144	-0.50	0.16
314+76					
	3	70% concrete	2,811	0.26	
342+87					
	4	Unlined	9,401	0.76	0.69
436+88					
	5	Unlined	25,991	2.10	1.42
696+79					

These reaches of canal have a maximum capacity of about 750 second feet.

Reference: "Report on the West Side Canal Seepage Investigation, October-November 1949," Rio Grande Project, New Mexico-Texas.

PONDING TESTS--1949
SHOSHONE PROJECT--WYOMING

Seepage measurements were made by the ponding method in adjacent lined and unlined reaches of Lateral R-4-S, Shoshone Project. Buried asphaltic membrane lining was installed in the reach of canal between Stations 60+70 and 71+11 prior to the tests.

The results of the ponding tests are as follows:

Stationing	Canal	Depth	Seepage rate
50+63 to 60+58	Unlined	1.8 feet	1.20 ft^3/ft^2 of wetted
60+70 to 71+11	Lined	1.8 feet	0.10 area per 24 hours

In conjunction with the ponding tests, experiments were performed in "preinvestigation studies" using a constant head well permeameter.

Reference: Letter dated January 15, 1951, to District Manager, Cody, Wyoming, from Head, Research and Geology Division, subject "Interpretation of seepage loss tests made in Lateral R-4-S, Shoshone Project, Wyoming."

PONDING AND SEEPAGE METER TESTS--1949
TUCUMCARI PROJECT--NEW MEXICO

Ponding tests were made on three reaches of the Conchas Canal at the close of the 1949 irrigation season. All three reaches of the canal had the following properties:

Design discharge	700 second feet
Bottom width	24 feet
Side slopes	1-1/2 to 1
Bottom slope	0.0001
Design depth	8.65 feet

The following data define the reaches (ponds) tested:

Pond No.	Stationing From	Stationing To	Type of lining
1	2043+60	2072+60	Clay lined--Specifications No. 1076--as part of the original construction program
2	2518+40	2562+00	Unlined
3	2562+40	2587+00	Clay lined on the left side and bottom only by project forces

A silt blanket from 1 to 6 inches thick, deposited during normal operation (max Q 400 second feet) of the canal over the past four irrigation seasons, covered the ponded reaches of the canal.

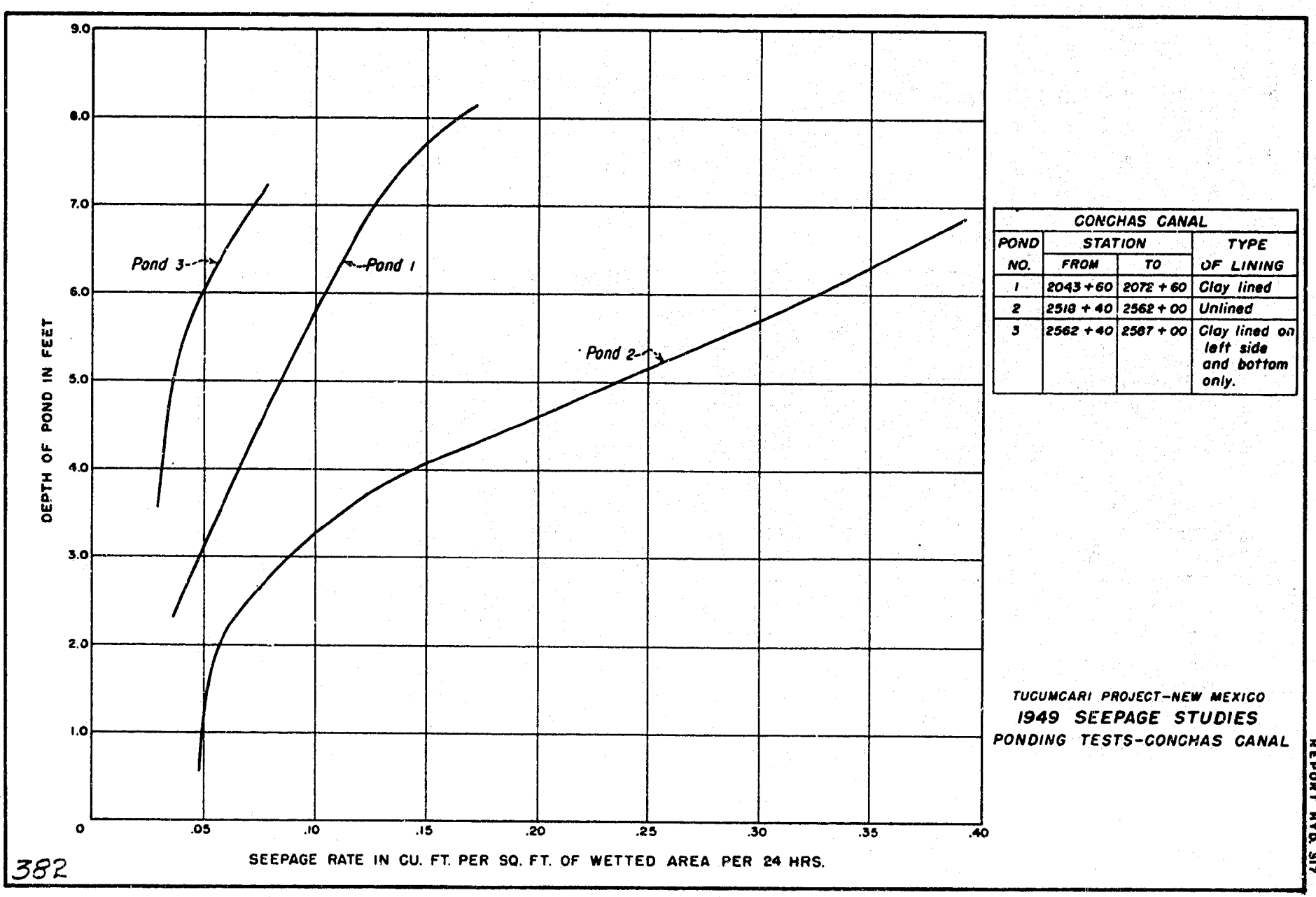
Seepage rates in cubic feet per square foot of wetted area per 24 hours are plotted against the depth of water in feet in Figure 17 for all three ponds.

Seepage meter readings were taken in two of the ponded reaches of the Conchas Canal. It should be noted that these seepage meter tests were made at comparatively shallow depths in the ponds. The following table summarizes the seepage meter results and compares them with the ponding results:

Pond No.	Depth (in feet)	Rate by seepage meter: L slope	Centerline	R slope	Avg	Rate by ponding	Difference: Rate	Percent
2	2.3	0.09	0.11	0.10	0.10	0.07	+0.03	+43
3	4.0	0.04	0.06	0.05	0.05	0.03	+0.02	+67

Figure 18 shows plots of individual seepage meter readings.

Reference: Hydraulic Laboratory Report No. Hyd-303 dated February 16, 1951, subject "Seepage measurements--Lower-cost Canal Lining Program--Tucumcari Project, New Mexico."



CONCHAS CANAL			
POND NO.	STATION FROM	STATION TO	TYPE OF LINING
1	2043 + 60	2072 + 60	Clay lined
2	2518 + 40	2562 + 00	Unlined
3	2562 + 40	2587 + 00	Clay lined on left side and bottom only.

TUCUMCARI PROJECT–NEW MEXICO

1949 SEEPAGE STUDIES

PONDING TESTS–CONCHAS CANAL

FIGURE 17
REPORT NO. 317

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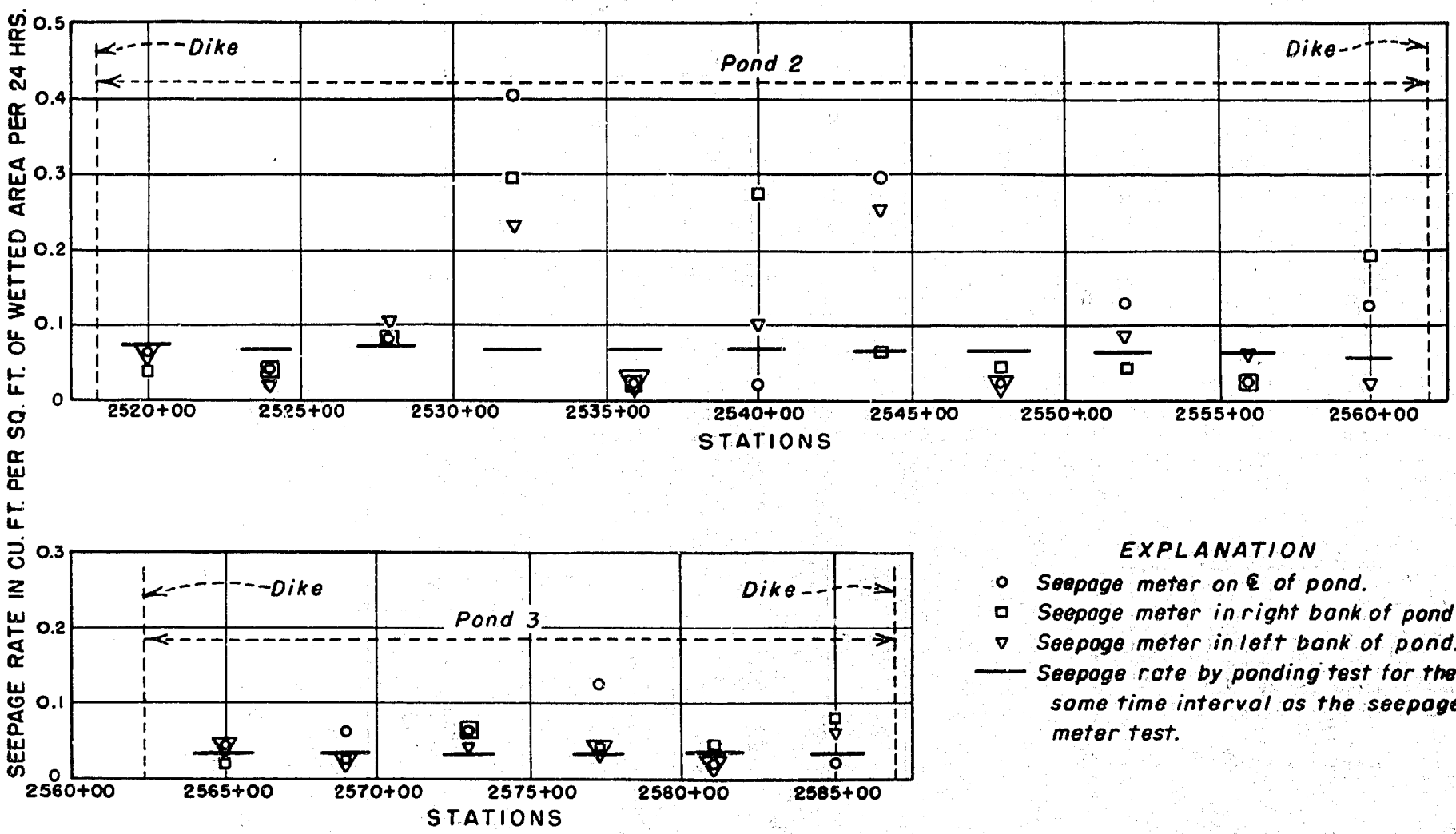

EXPLANATION

- ○ *Seepage meter on ℄ of pond.*
- □ *Seepage meter in right bank of pond.*
- ▽ *Seepage meter in left bank of pond.*
- —— *Seepage rate by ponding test for the same time interval as the seepage meter test.*

TUCUMCARI PROJECT-NEW MEXICO

1949 SEEPAGE STUDIES

SEEPAGE METER TESTS-CONCHAS CANAL

FIGURE 18
REPORT HYD. 317

PONDING TESTS--1949
W. C. AUSTIN PROJECT--OKLAHOMA

Ponding tests were made in the same three reaches of soil-cement-lined West 11.5 lateral, W. C. Austin Project, tested in 1948. The following table summarizes the results and compares them with the 1948 tests:

Cement content	Seepage rate		Increase	
	1948	1949	Rate	Percent
11.0	0.14	0.20	0.06	43
15.5	0.03	0.06	0.03	100
17.5	0.07	0.11	0.04	57

The seepage rates are expressed in cubic feet per square foot of wetted area per 24 hours. Visual inspection showed that the lining with the lowest cement content showed the most deterioration after 1 year of service. The 1948 ponding test on the nearby unlined section was not repeated in 1949.

Reference: Letter to Chief Engineer from Regional Director, Amarillo, Texas, dated November 17, 1949, subject "Quarterly Report--Lower Cost Canal Lining, Region 5, F.Y. 1950."

APPENDIX I

PONDING AND SEEPAGE METER TESTS--1950
BUFFALO RAPIDS PROJECT--MONTANA

Seepage meter tests were made in the unlined Glendive Canal during the 1950 irrigation season, followed by ponding tests at the close of the irrigation season. The following table gives the location of the ponds and summarizes the results obtained by ponding and with the seepage meter. Seepage rates are expressed in terms of ft^3/ft^2 of wetted area per 24 hours:

Stationing	Pond No.	Length in ft	Normal Q in sec ft	Ponding avg rate	Seepage meter		
					Avg rate	Difference	Percent
583+32 to 619+20	2A	3,538	140	0.32	2.56	+2.24	+700
633+78 to 654+34	2B	2,056	140	0.33	1.33	+0.80	+242
884+28 to 937+66	3	5,338	115	0.11	1.07	+0.96	+873
1188+32 to 1226+47	4	3,815	90	0.09	0.92	+0.83	+922

Reference: "Canal Seepage Studies on the Buffalo Rapids Irrigation Project in Montana," Yellowstone District, Hydrology Section of the Engineering Division, Billings, Montana, December 1950.

PONDING AND SEEPAGE METER TESTS--1950
DENVER OFFICE--EXPERIMENTAL CANAL FARM

Ponding and seepage meter tests were conducted on Canals No. 4 and 5 of the Experimental Canal Farm at the Denver Federal Center. Both canals were slightly over 100 feet long, had 2.0-foot bottom widths, with side slopes of 1-3/4 to 1. Successive fillings of the ponds were made until the seepage rates became constant. Final seepage rates in cubic feet per square foot of wetted area per 24 hours were as follows:

	Depth	Seepage rate
Canal No. 4	1.84 feet	0.48
Canal No. 5	2.17 feet	0.55

Four groups of six seepage meter settings were made in Canal No. 4 while two groups of six meter settings were made in Canal No. 5. The following table summarizes these data and compares the meter results with the results from the ponding tests:

	Seepage meter	Ponding	Difference	
			Rate	Percent
Canal No. 4	0.40	1.20	-0.80	-67
	0.13	0.78	-0.65	-83
	0.04	0.58	-0.54	-93
	0.11	0.45	-0.34	-76
Canal No. 5	0.19	0.89	-0.70	-79
	0.05	0.52	-0.47	-90

Reference: Memorandum to the Files dated December 4, 1950, from D. C. Walter, subject "Seepage studies on canals #4 and #5, Experimental Canal Farm, D.F.C."

PONDING TESTS--1950
GILA PROJECT--ARIZONA

Ponding tests were made in three laterals on the Yuma Mesa Division of the Gila Project. All three of the reaches tested were lined. Seepage loss data prior to lining are not available. The following table summarizes the descriptions of the ponds and the results of the tests:

Lateral No.	Length of pond	Type of lining	Losses*	
			Evaporation	Seepage
B-3.7-1.8	615	Troweled gunite	0.03	0.03
A-8.9-N	1,226	Untroweled gunite	0.03	0.04
A-5.0-N	628	Troweled soil-cement	0.03	0.04

*Ft^3/ft^2 of wetted area per 24 hours.

Reference: Letter dated October 31, 1950, to Chief Engineer, Denver, Colorado, from Regional Director, Boulder City, Nevada, subject "Quarterly review of progress on Lower-cost Canal Lining Program, Region 3."

PONDING TESTS--1950
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*Ft^3/ft^2 of wetted area per 24 hours.

Reference: Letter dated October 31, 1950, to Chief Engineer, Denver, Colorado, from Regional Director, Boulder City, Nevada, subject "Quarterly review of progress on Lower-cost Canal Lining Program, Region 3."

PONDING TESTS--1950
KLAMATH PROJECT, OREGON

Ponding tests were made in Lateral N-16 located in the Panhandle section of the Coppock Bay area of the Tule Lake Division about 40 miles southeast of Klamath Falls. The purpose of the tests was to determine the effectiveness of a reach of buried prefabricated asphalt membrane lining. Adjacent reaches of canal, one lined and the other unlined, were tested. The ponding tests indicated a loss of 2.35 cubic feet per square foot of wetted area per 24 hours in the unlined reach, while the corresponding rate in the adjacent lined reach was 0.51. The depth of water in the canal was 5.5 feet.

The above tests indicate that for the conditions found on this lateral the buried prefabricated asphalt membrane lining reduced the seepage by nearly 80 percent. The report from the project indicates that the seepage could be further reduced by revising the technique of sealing the joints in the lining.

Reference: "Report on the seepage test of the experimental buried prefabricated asphalt membrane lining test section in the N-16 Lateral of the Klamath Project," by Brooks O. Custer, Klamath Project, dated January 1951.

SEEPAGE METER TESTS--1950
NORTH PLATTE PROJECT--WYOMING-NEBRASKA

The seepage measurement program was continued on the North Platte Project during calendar year 1950 by the Soil and Moisture Conservation Group. The work was limited to seepage meter measurements, ground-water observations, and the measurement of seepage streams from the Fort Laramie Canal from mile 13.0 to the Lingle Power Plant.

A total of 44,000 feet of canal and lateral was covered by 440 seepage meter tests. All seepage meter settings were 100 feet apart. A summary of the seepage meter tests follows:

Canal	Length in feet	Average loss--ft^3/ft^2 of wetted area/24 hr
Lateral 58.7	19,700	0.79
West Bald Peak	11,300	1.85
Lateral 36.4	1,600	2.86
East Bald Peak	5,900	2.90
Northport Canal	3,700	5.20
Lateral 54.6	1,900	8.05

According to the report by the project office, ground-water observations along the Fort Laramie Canal near the Barthel Farm indicated a greatly lowered ground-water table opposite the buried asphaltic membrane lining installed in 1949 and either no change or a slight increase in the ground-water table elevation along the reach of Fort Laramie Canal treated by portland cement grouting in 1949.

A total of 2.6 second feet of discharge was measured in 13 seepage streams adjacent to the Fort Laramie Canal between mile 13.0 and the Lingle Power Plant. A portable V-notch weir was used in obtaining these measurements.

Reference: Report "Soil and Moisture Conservation Seepage Program for the North Platte Project, Wyoming-Nebraska," by R. D. Mason dated March 1951 at Torrington, Wyoming.

PONDING TESTS--1950
ORLAND PROJECT--CALIFORNIA

Seepage losses were measured in an 894-foot pond in Lateral 100, North Diversion System, Orland Project. This seepage test was made prior to cleaning the canal and before the experimental linings were installed. The reach of canal tested had the following properties:

Length	894	feet
Bottom width	15.4	feet
Top width	23.8	feet
Discharge	125	second feet
Water depth	3.2	feet

The performance of this test was considerably handicapped by rain that fell on 7 of the 11 testing days. These tests, corrected for rainfall, indicate an average seepage rate of 0.14 cubic foot per square foot of wetted area per 24 hours for this reach of canal.

Reference: A table prepared by the Chico District Office, heading "Seepage test data, Lateral No. 100, North Diversion System--Orland Project."

PONDING AND SEEPAGE METER TESTS--1950
RIVERTON PROJECT--WYOMING

During the Summer of 1950, the newly constructed reach of Wyoming Canal between the Muddy Ridge Tunnel and the Muddy Creek Siphon was divided into six ponds and seepage losses were obtained. The stationing, together with the lengths of the ponds, was as follows:

Pond No.	Stationing From	Stationing To	Length in feet
1	1659+71	1754+34	9,463
2	1754+66	1801+00	4,634
3	1801+34	1896+59	9,525
4	1896+91	1964+50	6,759
5	1974+82	1985+50	1,068
6	1986+43	2000+50	1,407

The canal in the above reaches had the following properties:

Design discharge	566 second feet
Bottom width	24 feet
Side slopes	2 to 1
Bottom slope	0.0002
Design depth	6.2 feet

All ponds were filled three times in order to thoroughly prime this reach of canal. In all ponds the seepage rate decreased with each successive filling of the ponds. The seepage rates obtained during the third and final filling were accepted as most nearly indicating the seepage rate to be expected during the normal operation of the canal.

The seepage rate in cubic feet per square foot of wetted area per 24 hours is plotted against depth of water in feet for the three fillings in each of the six ponds as shown in Figures 19 through 24.

In addition to the above ponding tests, measurements were also made in the following three reaches of the Wyoming Canal located between Muddy Creek Siphon and the end of the excavated canal at Station 2560+00:

Pond No.	Stationing From	Stationing To	Length in feet
7	2242+18	2247+50	[illegible]32
8	2261+83	2275+00	1,317
9	2394+81	2406+00	[illegible],119

The following properties apply to these ponds:

Design discharge	420 second feet
Bottom width	22 feet
Side slopes	1-1/2 to 1
Bottom slope	0.0002
Design depth	5.7 feet

The final seepage rates obtained from these ponding tests are as follows:

Pond No.	Seepage rate
7	0.29
8	0.35
9	4.79

Ponding tests were also performed on the reach of Lateral 44.69 from Station 23+00 to Station 31+50. This reach of lateral had the following properties:

Design discharge	24 second feet
Bottom width	4.0 feet
Side slopes	1-1/2 to 1
Bottom slope	0.001
Design depth	1.8 feet

The seepage rate was found to be 0.96 cubic foot per square foot of wetted area per 24 hours.

Seepage meter tests were made in conjunction with the ponding tests in Ponds 1 through 6. Plots of individual seepage meter settings are shown in Figures 25 and 26, while Table 3 shows a summary of the seepage meter data and compares the results with the ponding results.

Ponding test results obtained from this study are being used in the evaluation of the well permeameter as an instrument for predicting seepage losses from proposed canals. Well permeameter tests were made in and adjacent to the canal reaches that were later ponded. Results of this study will be published by personnel of the Earth Laboratory.

Reference: Hydraulic Laboratory Report No. Hyd-306 dated March 12, 1951, subject "Seepage measurements--Lower-cost Canal Lining Program--Riverton Project, Wyoming."

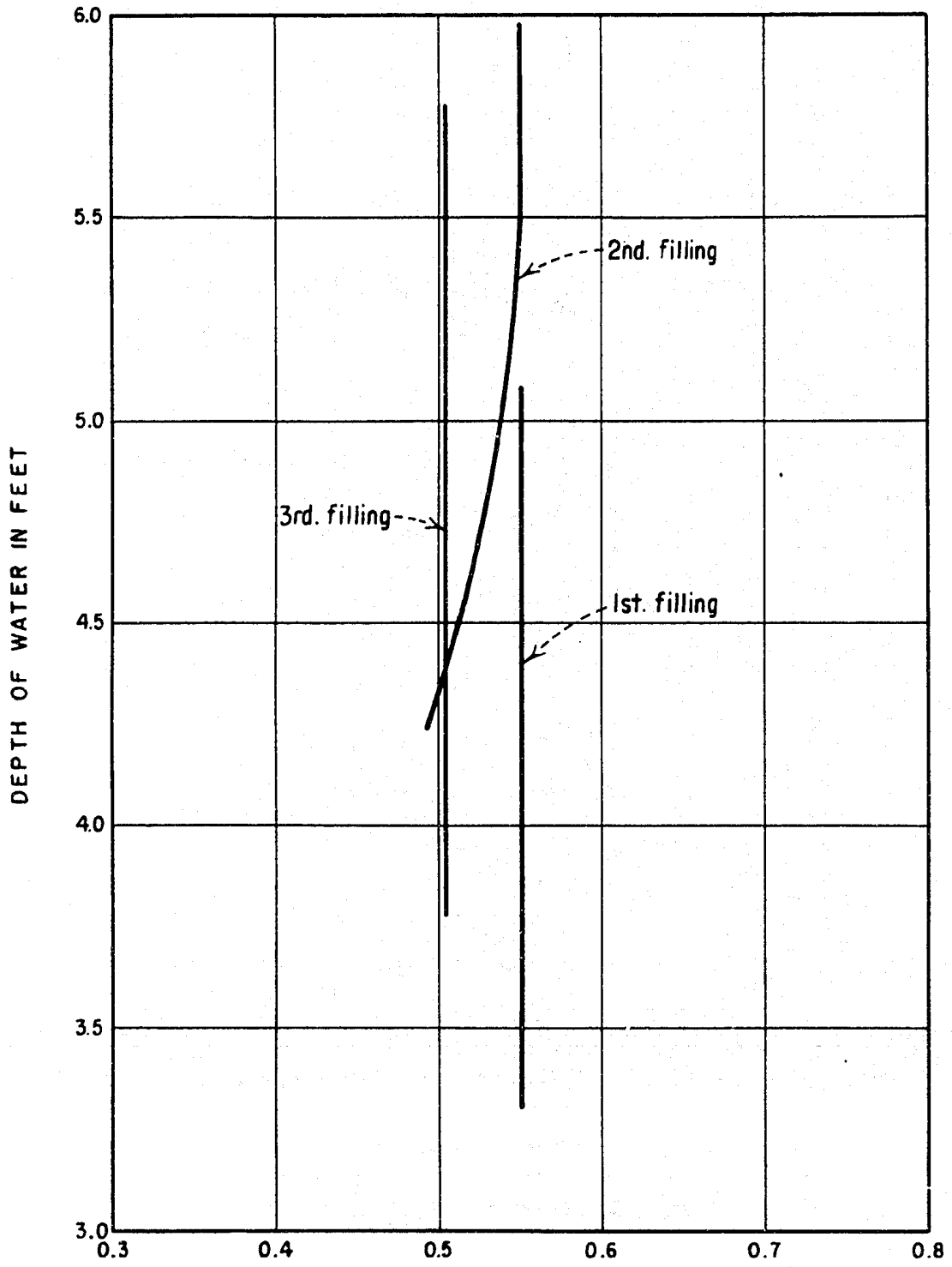
RIVERTON PROJECT--WYOMING CANAL
1950 Seepage Measurement Studies
Comparison of Results by Seepage Meter and by Ponding

Location	Number of settings	Average depth	Rate by seepage meter Max.	Min.	Ay.	Av.	Rate by ponding	Difference in rates	% difference ref. ponding
Pond No. 1--First Filling (May 29-June 1)									
Right bank	7	3.70	1.40	0.03	0.38				
Left bank	7	3.20	0.92	0.04	0.38	0.40	0.55	-0.15	- 27
Bottom	14	4.66	1.92	0.04	0.42				
Pond No. 1--Between First and Second Filling (June 2)									
Right bank	1	3.70	0.07	0.07	0.07				
Left bank	2	3.58	0.06	0.00	0.03	0.07	0.55*	-0.48	- 87
Bottom	3	5.98	0.27	0.01	0.10				
Pond No. 1--Following Third Filling (June 15-16)									
Right bank	7	2.05	1.89	0.01	0.56				
Left bank	7	2.35	0.40	0.01	0.16	0.42	0.50*	-0.08	- 16
Bottom	14	2.67	1.79+	0.00	0.48				
Pond No. 2--Prior to First Filling (May 24-26)									
Right bank	5	3.47	1.17	0.40	0.68				
Left bank	5	3.79	0.50	0.23	0.37	0.48	0.57*	-0.09	- 16
Bottom	10	6.91	0.44	0.31	0.38				
Pond No. 2--First Filling (May 29)									
Right bank	2	3.85	0.50	0.37	0.44				
Left bank	2	3.10	0.24	0.18	0.21	0.35	0.57	-0.22	- 39
Bottom	3	7.15	0.44	0.34	0.40				
Pond No. 2--Following Third Filling (June 15-19)									
Right bank	7	2.74	2.75	0.04	1.05				
Left bank	7	2.82	1.32	0.01	0.44	0.88	0.40*	+0.48	+120
Bottom	14	4.16	2.19	0.18	1.01				
Pond No. 3--Second Filling (June 5-8)									
Right bank	11	3.62	1.98	0.03	0.48				
Left bank	11	3.73	0.52	0.02	0.29	0.43	0.63	-0.20	- 33
Bottom	22	5.54	1.66	0.00	0.48				
Pond No. 3--Third Filling (June 10-14)									
Right bank	4	3.31	0.51	0.02	0.28				
Left bank	4	2.99	0.52	0.07	0.26	0.28	0.60	-0.32	- 53
Bottom	10	4.03	0.46	0.01	0.28				
Pond No. 4--Second Filling (June 5-8)									
Right bank	5	3.69	0.65	0.06	0.30				
Left bank	5	3.29	0.58	0.00	0.24	0.34	0.39	-0.05	- 13
Bottom	10	4.93	0.59	0.01	0.40				
Pond No. 4--Between Second and Third Fillings (June 9)									
Right bank	2	3.40	0.32	0.08	0.20				
Left bank	1	2.85	0.18	0.18	0.18	0.27	0.37*	-0.10	- 27
Bottom	4	6.71	0.48	0.08	0.33				
Pond No. 4--Third Filling (June 10-14)									
Right bank	4	3.28	1.22	0.06	0.42				
Left bank	4	3.58	1.74	0.02	0.53	0.37	0.35	+0.02	+ 6
Bottom	8	5.26	0.51	0.06	0.26				
Pond No. 5--Between Second and Third Fillings (June 9)									
Right bank	1	3.05	0.41	0.41	0.41				
Left bank	1	3.50	0.72	0.72	0.72	0.42	0.49*	-0.07	- 14
Bottom	4	4.81	0.77	0.17	0.35				
Pond No. 5--Third Filling (June 10-14)									
Right bank	2	4.00	1.41	0.03	0.72				
Left bank	2	3.58	0.42	0.15	0.28	0.64	0.47	+0.14	+ 30
Bottom	4	5.79	1.64	0.43	0.78				
Pond No. 6--Prior to First Filling (May 22-24)									
Right bank	4	2.28	1.40	0.29	0.92				
Left bank	4	2.60	1.25	0.02	0.65	0.62	0.50*	+0.12	+ 24
Bottom	10	3.88	0.63	0.08	0.28				
Pond No. 6--Between Second and Third Fillings (June 9)									
Right bank	1	3.95	0.11	0.11	0.11				
Left bank	1	3.45	0.00	0.00	0.00	0.20	0.40*	-0.20	- 50
Bottom	2	4.53	0.46	0.22	0.34				
Pond No. 6--Third Filling (June 10-14)									
Right bank	4	3.35	0.62	0.00	0.36				
Left bank	3	4.06	1.05	0.52	0.72	0.38	0.45	-0.07	- 16
Bottom	8	5.01	0.62	0.04	0.30				

*Estimated values.

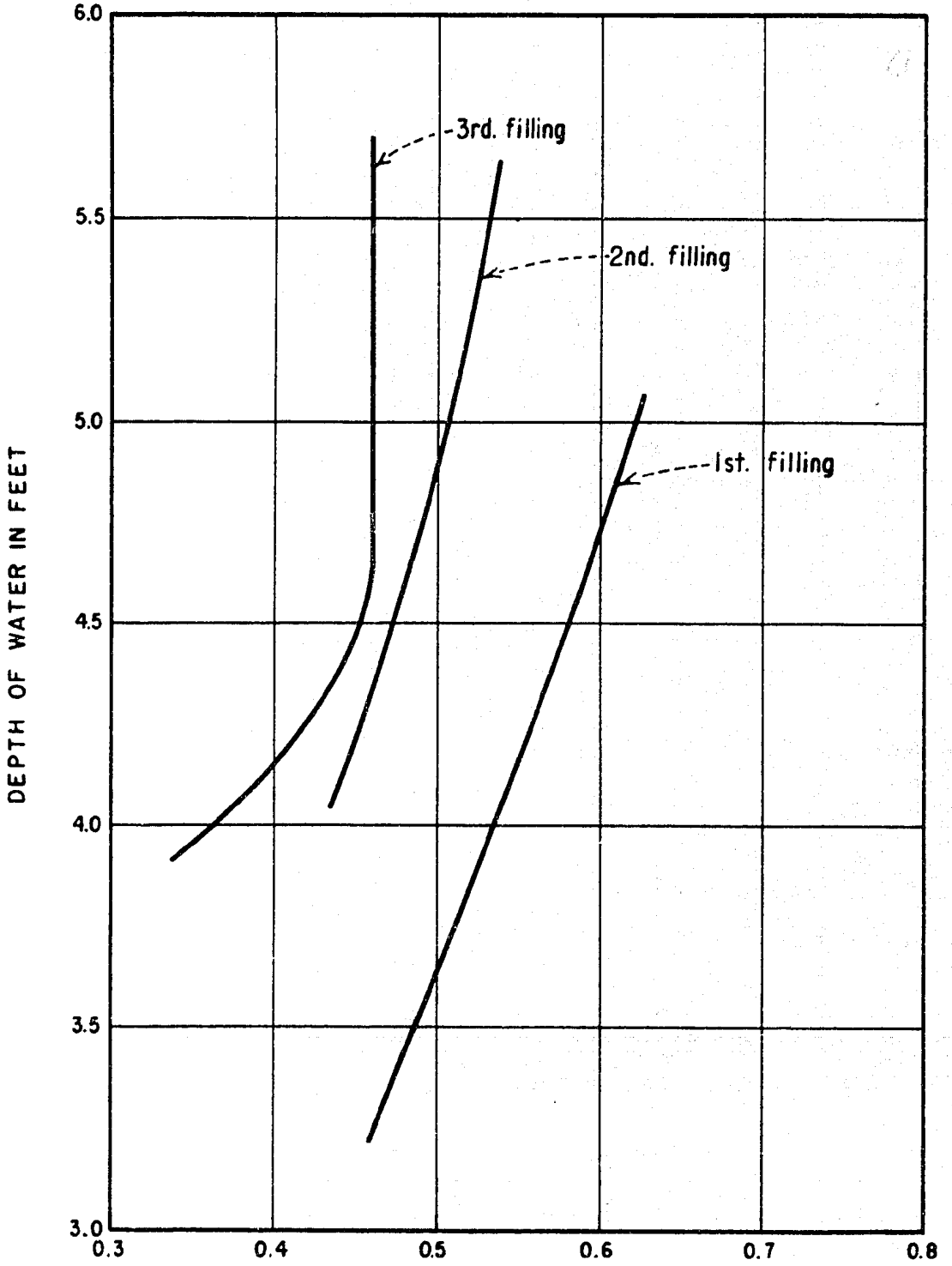
TABLE 3

FIGURE 19
REPORT HYD. 317



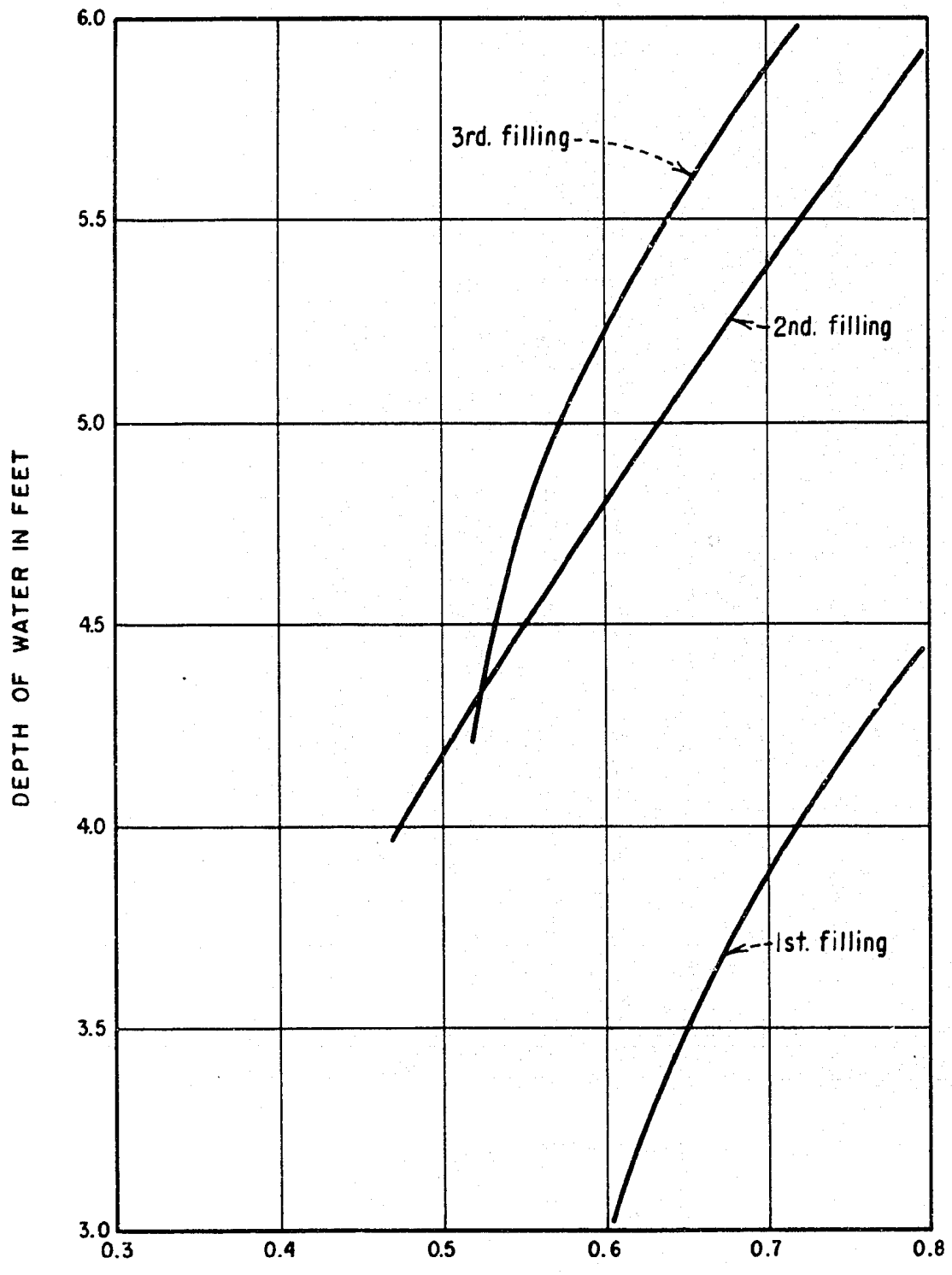
RIVERTON PROJECT - WYOMING
1950 SEEPAGE STUDIES
WYOMING CANAL - POND 1

FIGURE 20
REPORT HYD. 317



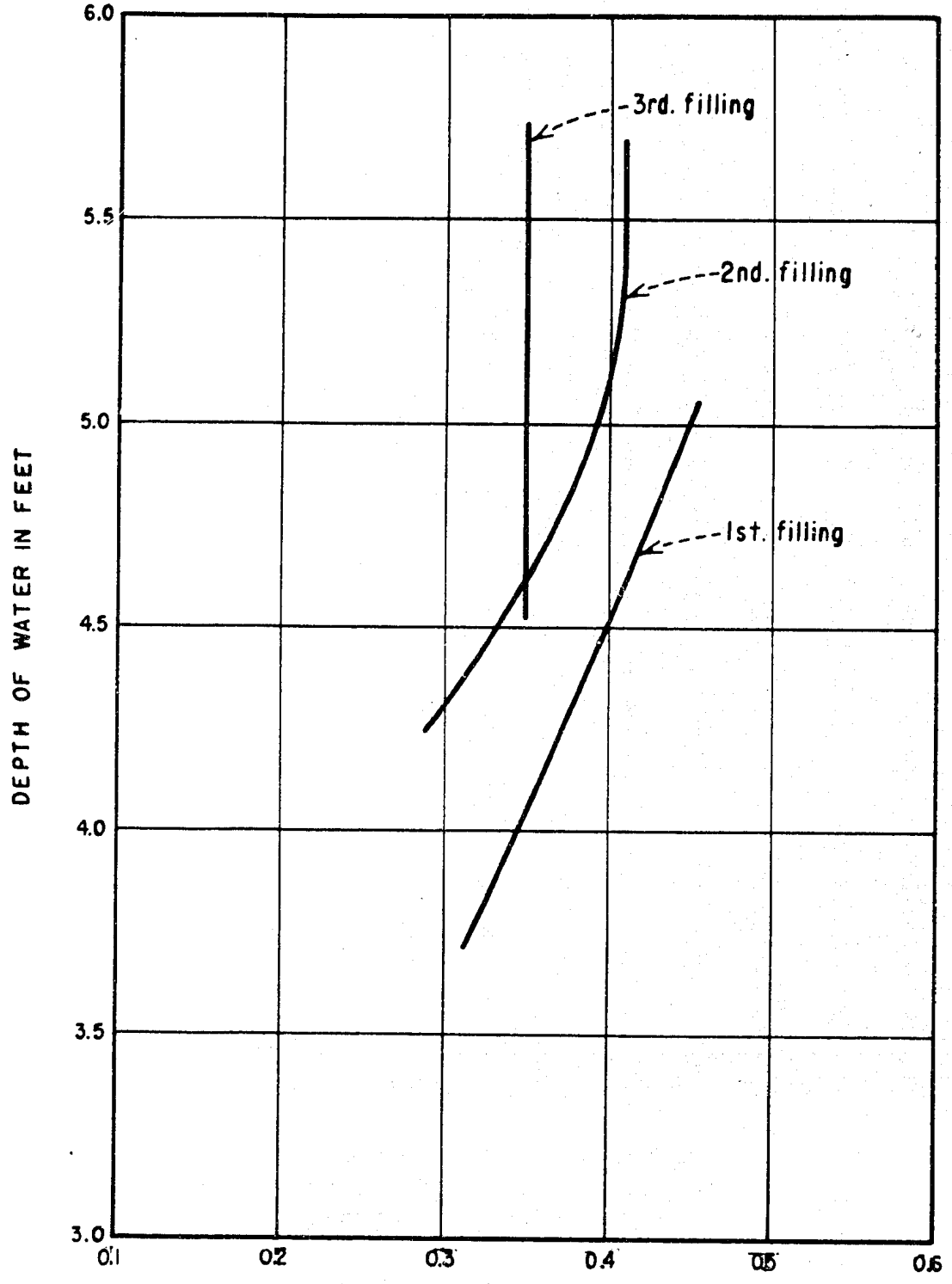
RIVERTON PROJECT - WYOMING
1950 SEEPAGE STUDIES
WYOMING CANAL - POND 2

FIGURE 21
REPORT HYD. 317



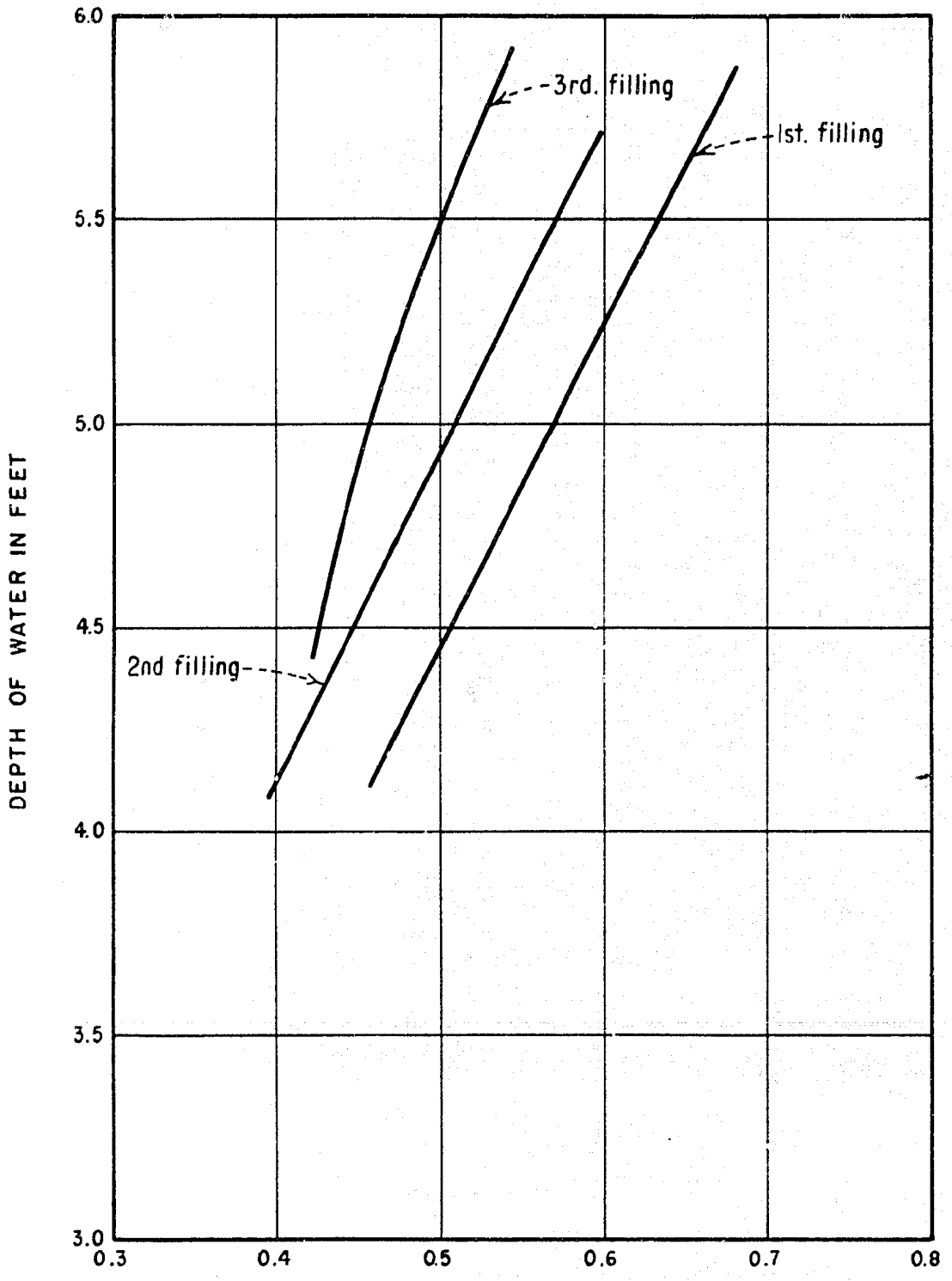
RIVERTON PROJECT - WYOMING
1950 SEEPAGE STUDIES
WYOMING CANAL – POND 3

FIGURE 22
REPORT HYD. 317



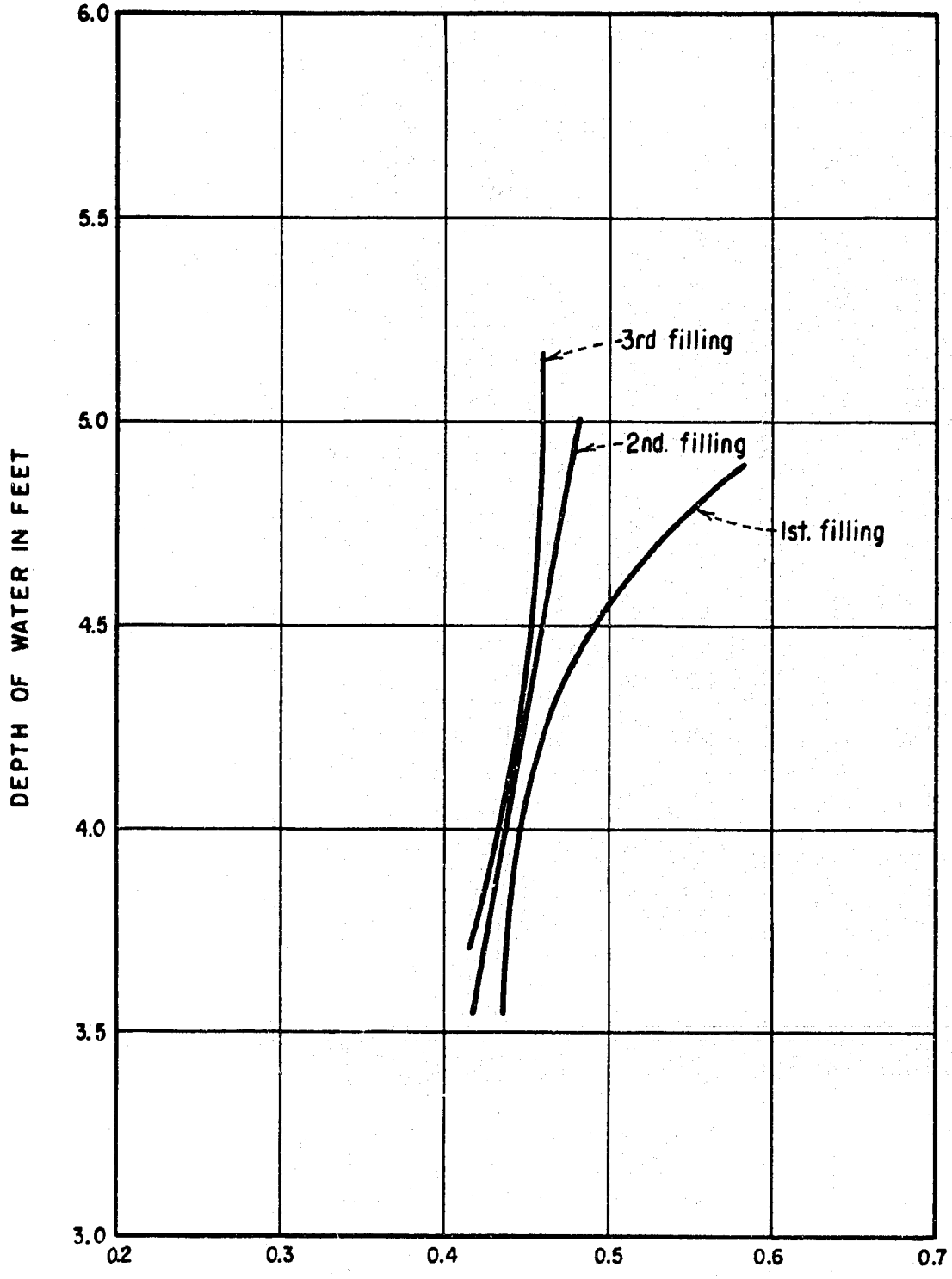
RIVERTON PROJECT - WYOMING
1950 SEEPAGE STUDIES
WYOMING CANAL - POND 4

FIGURE 23
REPORT HYD. 317



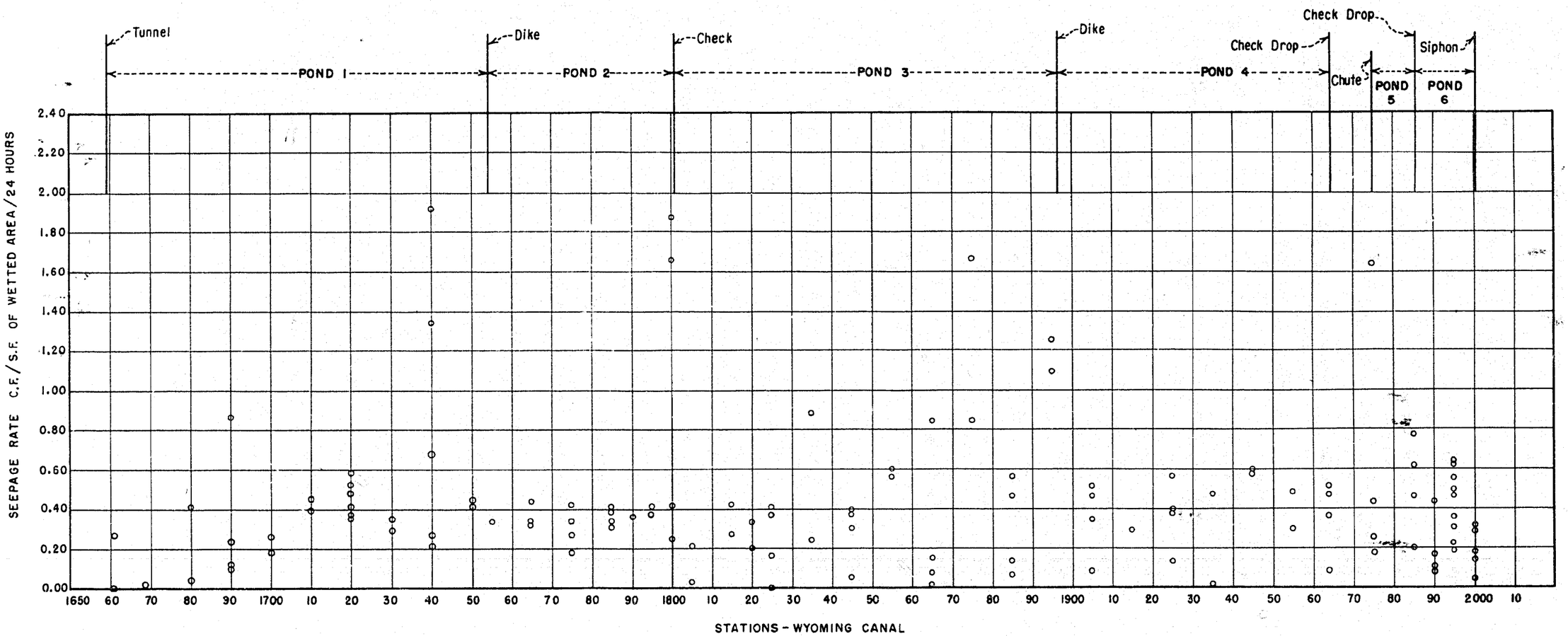
RIVERTON PROJECT - WYOMING
1950 SEEPAGE STUDIES
WYOMING CANAL - POND 5

FIGURE 24
REPORT HYD. 317



RIVERTON PROJECT - WYOMING
1950 SEEPAGE STUDIES
WYOMING CANAL - POND 6

FIGURE 25
REPORT HYD. 317



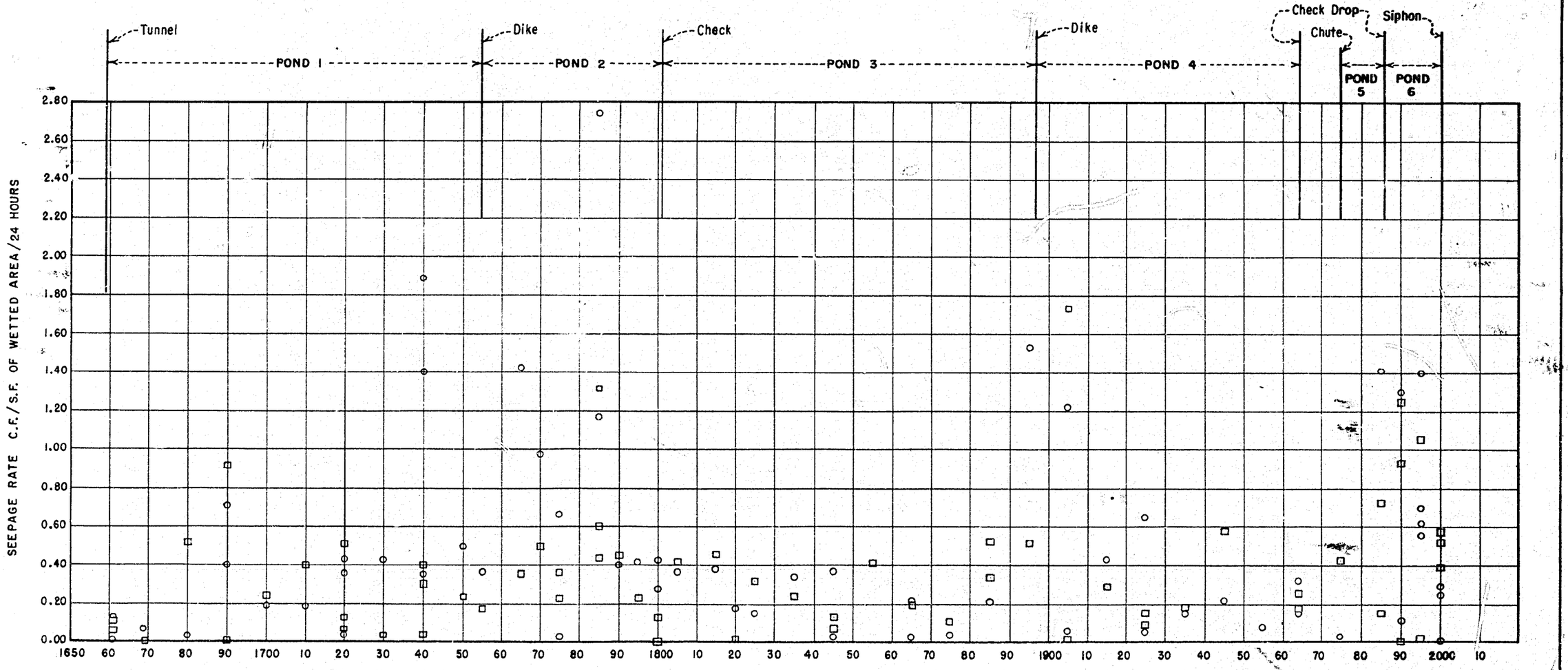
EXPLANATION

o METER SETTINGS ON BOTTOM OF CANAL

RIVERTON PROJECT-WYOMING
1950 SEEPAGE STUDIES
SEEPAGE METER TESTS

381

FIGURE 26
REPORT HYD. 317



EXPLANATION
○ METER SETTINGS ON RIGHT SIDE SLOPE
□ METER SETTINGS ON LEFT SIDE SLOPE

RIVERTON PROJECT-WYOMING
1950 SEEPAGE STUDIES
SEEPAGE METER TESTS

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SEEPAGE METER AND INFLOW-OUTFLOW TESTS--1950
SALT RIVER PROJECT, ARIZONA

Seepage measurements, utilizing two seepage meters on loan from the Bureau of Reclamation plus two constructed on the job, were made by personnel of the Salt River Valley Water Users' Association on canals and laterals of the Salt River Project. Thirty-nine of the approximately 1,300 miles of canals and laterals on the project were tested with the seepage meter. The reaches tested were selected because they were thought to have large seepage losses. All tests were made in flowing water at intervals of one-quarter mile, and all tests were of 30-minute duration. The results of this study were utilized in the selection of reaches for lining.

Data were obtained for a comparison between seepage meter results and seepage losses obtained by the inflow-outflow method. Sparling meters were used to measure the flow at each end of the 1-mile reach of canal at the Hannah ranch that was selected for these tests. Five seepage meter settings were made in this test reach. The inflow-outflow method indicated a loss of 1.69 acre feet per day against 1.18 acre feet per day by the seepage meter. These tests indicate that the loss by seepage meter is 70 percent of the loss as measured by the inflow-outflow method.

The report on these tests concluded that for this project a seepage loss greater than 0.176 acre foot per day per 1,000 feet would justify a gunite lining. This conclusion is based on the fact that the repayment contract would be interest-free and on the assumption that the gunite lining will be maintenance-free for 20 years. For the reach of canal (High Line Canal) under consideration, 0.176 acre foot per day per 1,000 feet amounts to about 0.5 cubic foot per square foot of wetted area per 24 hours, assuming an average wetted perimeter of 16 feet.

Reference: Report signed by Don Womack dated September 12, 1950, and transmitted from H. Shipley, Engineer, to R. J. McMullin, Manager of the Salt River Valley Water Users' Association, date: December 8, 1950.

PONDING AND SEEPAGE METER TESTS--1950
W. C. AUSTIN PROJECT--OKLAHOMA

Ponding tests were made on Altus 6.8 lateral both prior to and after lining with prefabricated fiberglass-asphalt membrane lining. The before-lining tests were conducted after the canal had been over-excavated to receive the lining. After the canal was lined the base width was 3.0 feet, the side slopes were 2 to 1, the bottom slope was 0.0025, and the canal capacity was 10 second feet. The ponding results are summarized in the following table where seepage rates are expressed in terms of ft^3/ft^2 of wetted area per 24 hours:

Before lining	Depth	Rate	After lining	Depth	Rate
Sta 2+50 to 8+33	0.53	0.71	Sta 5+84 to 9+08	0.47	0.10
Sta 8+33 to 12+16	1.42	1.54	Sta 9+08 to 12+16	0.66	0.08

Seepage meter tests were made in the ponds prior to lining. The following table summarizes these results and compares them with the results from the ponding tests:

Before lining	Ponding	Seepage meter	Difference	
			Rate	Percent
Sta 2+50 to 8+33	0.80	0.56	-0.24	-30
Sta 8+33 to 12+16	1.50	2.82	+1.32	+88

References: Letter to Project Engineer, W. C. Austin Project from R. C. Burmmett, Engineer, dated August 16, 1950, subject "Prefab canal lining installation--L.C.C.L. Program," and a memorandum to Chairman, Lower-cost Canal Lining Committee, from J. A. Callan and C. W. Thomas dated January 22, 1951, subject "Prefabricated asphalt membrane canal lining installation--W. C. Austin Project."

RESEARCH--1950
ENGINEERING EXPERIMENT STATION
UNIVERSITY OF IDAHO

"Special Research Project No. 20A" was conducted by the Engineering Experiment Station of the University of Idaho with Region 1, Bureau of Reclamation, and the Soil Conservation Service cooperating. Under this project ponding and seepage meter tests were made in three reaches of canal prior to lining and ponding tests were made in two of the reaches after lining. The lining used was a buried prefabricated asphaltic membrane sold under the trade name of "Fiberglas Canal Liner" and manufactured by the Owens-Corning Fiberglas Corporation and consisted of a Fiberglas mat impregnated with asphalt cement having a softening point of approximately 220° F. The lining was laid in strips transverse to the canal centerline with 3-inch laps sealed with an RC-1 cut-back asphalt.

Two reaches of canal in the Black Canyon Unit of the Boise Project and one reach of canal in the Post Falls Irrigation District were also selected for testing. In the Black Canyon Unit, a 300-foot reach in Lateral 9.9 of the "C" Line East Canal and a 150-foot reach in Lateral 0.1-1.0 of the Willow Creek Pump Lateral were tested, as well as a 200-foot reach of the Kulm Farm Lateral, Post Falls Irrigation District.

The results of the seepage measurement tests are as follows:

	Unlined		Lined
Lateral	Ponding	Meter	Ponding
Lat 9.9	0.54	0.36	0.056
Lat 0.1-1.0	0.72	0.28	0.040
Kulm Lateral	0.74	--	--

Seepage rates are expressed in cubic feet per square foot of wetted area per 24 hours. The rates by seepage meter have been "corrected" for depth. The rate obtained directly with the meter was divided by the depth of water at the meter and multiplied by the average depth of water in the canal cross section. This correction assumes that the seepage rate varies directly with depth of water.

Reference: "A Study of Canal Linings for Controlling Seepage Losses," by C. C. Warnick, Engineering Experiment Station, University of Idaho, dated February 1951.

RESEARCH--1950
COLORADO AGRICULTURAL EXPERIMENT STATION
COLORADO A AND M COLLEGE

This project, "The Study of Seepage Losses from Irrigation Canals," a joint venture by the Soil Conservation Service, the Colorado Agricultural Experiment Station, and the Bureau of Reclamation, was continued through the year 1950.

The reference report describing these seepage studies at Fort Collins disclosed several interesting features. For instance, tests on a clay loam and a sandy loam soil revealed that the seepage rates "did not differ materially at the time the tests were discontinued in November. At both sites the rates at the beginning of the tests were much higher than they were at the end. Time is probably the most important factor in determining the seepage rates." Although previously determined from other studies, the Fort Collins tests showed conclusively that the seepage rate is not proportional to the depth of water in the canal. "The rate is proportional to the depth of water plus the length of soil column required to use up the head available."

Another conclusion stated in the report is that "experiments with the seepage meter, which measures the actual seepage rate, indicate that consistent results can be obtained with this device." Again, the time factor seems to be very important. For the tests under discussion, the meter was left undisturbed for a period of several days. It must be realized, however, that, for the Fort Collins tests, the meter was utilized in stagnant water, whereas, if the meter is left undisturbed in flowing water, erosive action may undermine the seepage cup.

Some startling information was also obtained from observations on ground-water wells adjacent to the seepage test areas, indicating the need for additional studies.

This project will be continued in 1951.

Reference: "Study of Seepage Losses from Irrigation Channels, 1950," by Carl Rohwer, Soil Conservation Service, Fort Collins, Colorado.

PONDING AND SEEPAGE METER TESTS--1950
CENTRAL VALLEY PROJECT--CALIFORNIA--FRIANT-KERN CANAL

Two reaches of the Friant-Kern Canal were isolated and seepage measurements were made. The reach from Station 3644+07 to Station 3673+56 was concrete lined, while the reach from Station 2791+20 to Station 2820+24 had a heavy compacted earth lining. Both of these linings were in excellent condition.

The physical dimensions of the ponds, together with the ponding and seepage meter results, are shown in the following table:

	Earth-lined reach	Concrete-lined reach
Bottom width	64.0 feet	36.0 feet
Side slopes	1-1/2 to 1	1-1/4 to 1
Depth	17.2 feet	17.5 feet
Length of ponds	2,904 feet	2,949 feet
Ponding rate (avg)	0.067	0.070
Seepage meter (avg)	0.064	--

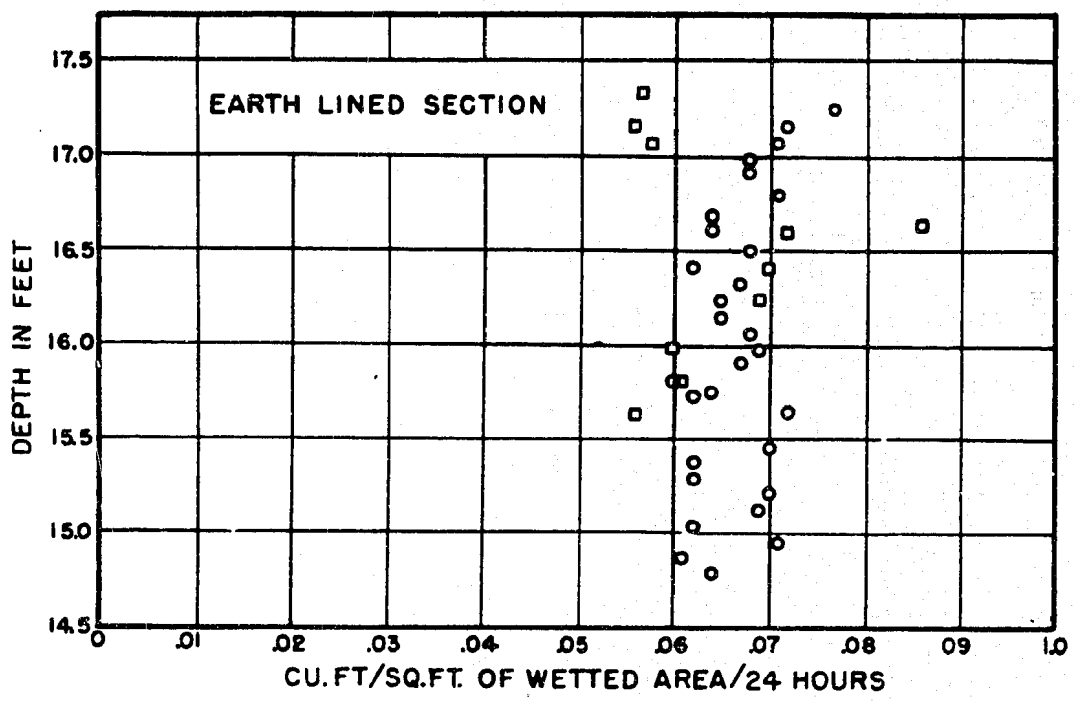
The seepage rates are expressed in terms of cubic feet per square foot of wetted area per 24 hours. The variation of seepage rate with depth for both ponds is shown in Figure 27.

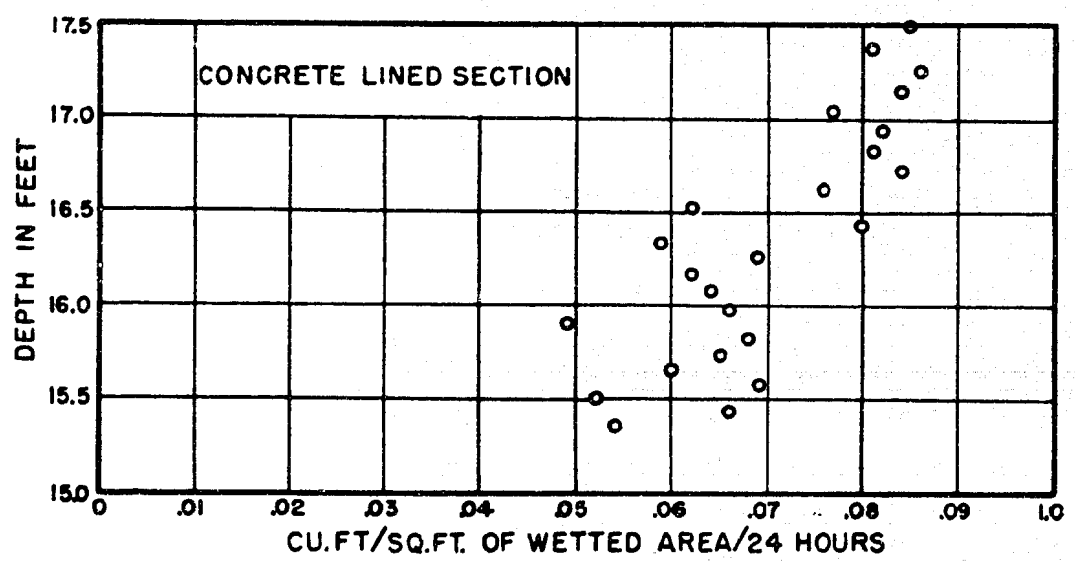
While the seepage rate from the concrete-lined canal is about 4 percent greater than the rate from the earth-lined reach, the total volume of water lost from the earth-lined canal per unit length is about 30 percent greater than that from the concrete-lined canal due to the larger cross section required to carry the same discharge.

Seepage data were also obtained using the open pipe permeameter, the well permeameter, and by making laboratory tests on undisturbed soil samples. These tests are discussed in the reference report.

Reference: "Seepage Studies in the Friant-Kern Canal, Central Valley Project, California," by J. J. Waddell, dated June 25, 1951.

FIGURE 27





o Ponding

□ Seepage meter

CENTRAL VALLEY PROJECT — CALIFORNIA

FRIANT-KERN CANAL

1950 SEEPAGE STUDIES

PONDING AND SEEPAGE METER RESULTS

INFLOW-OUTFLOW TESTS--1950
MEEKER CANAL--FRENCHMAN-CAMBRIDGE DIVISION--KANSAS

Seepage loss measurements using the inflow-outflow method were made on the Meeker Canal between miles 5.8 and 10.5. The capacity of this reach of canal is about 35 second feet. Discharge measurements were recorded during the entire 1950 irrigation season. Two 36-inch metal Parshall flumes were installed in the Meeker Canal for obtaining inflow-outflow measurement at the extremities of the test reach. The amount of water leaving the test section through farm turnouts was measured with two 9-inch Parshall flumes.

A total volume of 5,132 acre feet entered the test reach from April 16 through September 30, 1950. About 411 acre feet, or 8 percent, was lost in transit in this 4.7-mile reach of Meeker Canal. The highest loss for any one month was 15.8 percent at the beginning of the irrigation season in April. The lowest loss, 3.2 percent, occurred at close of the irrigation season during the month of September.

Plans are underway to continue these studies in 1951. Cross-sectional data will then be obtained and losses can then be expressed in cubic feet per square foot of wetted area per 24 hours.

Reference: "Canal Loss Studies, Meeker Canal, Frenchman-Cambridge Division," Kansas River District, October 1950.

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