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UNITED STATES
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SEEPAGE MEASUREMENTS--LOWER-COST CANAL LINING PROGRAM--NORTH PLATTE PROJECT WYOMING-NEBRASKA

Hydraulic Laboratory Report No. Hyd-297

RESEARCH AND GEOLOGY DIVISION

BRANCH OF DESIGN AND CONSTRUCTION
DENVER, COLORADO

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Laboratory Report No. Hyd-297
Hydraulic Laboratory
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Reviewed by: C. W. Thomas
D. M. Lancaster
N. P. Nelson

Subject: Seepage measurements--Lower-cost Canal Lining Program--
North Platte Project, Wyoming-Nebraska

PURPOSE

The purpose of this report is to present the results of the seepage studies, conducted in connection with the Lower-cost Canal Lining Program, on the North Platte Project, Wyoming-Nebraska, during the latter half of 1949. Various associated data of interest in connection with the measurement of seepage losses from irrigation canals and laterals are also included.

PERSONNEL

The seepage studies described in this report were conducted under the general direction of N. P. Nelson, Superintendent of Water and Land, North Platte River District, while immediate field supervision was under James L. Doyle, Soil and Moisture Engineer, Torrington, Wyoming. Five of the seven dikes constructed in the Fort Laramie Canal for the ponding tests were built under a contract administered by C. H. Radar, Construction Engineer, North Platte Project, Torrington, Wyoming. The two remaining dikes were constructed by the Goshen Irrigation District, represented by Harry Kelley, Manager of the District. Technical assistance was supplied from the office of the Chief Engineer, Branch of Design and Construction, by Engineers C. W. Thomas, D. M. Lancaster, and B. R. Blackwell.

SYNOPSIS

The loss by seepage from numerous sections of certain irrigation channels in the North Platte Project was determined simultaneously by two methods; namely, (1) the ponding procedure and (2) by utilization of a seepage meter. Hence, the merits of the seepage meter were evaluated by comparing the results with those obtained by the ponding technique which is accepted as an accurate method. The measurements were made in six sections of the Fort Laramie Canal, three in Lateral 29.4, six in Lateral 90.4, and six in Lateral 24A. All sections were unlined except four sections of the Fort Laramie Canal where portland cement grouting had been done prior to the ponding tests.

The highest seepage rate measured by ponding in the Fort Laramie Canal was 0.57 cubic foot per square foot of wetted area per 24 hours, while the section with the lowest rate indicated a loss of 0.13. The highest seepage rate obtained from a lateral by the same procedure was 0.87 cubic foot per square foot of wetted area per 24 hours while the section with the lowest seepage rate indicated a loss of 0.13. Throughout this report seepage rate is expressed in cubic feet per square foot of wetted area per 24 hours.

In addition to seepage meter observations in all ponds, similar readings were taken, in many cases, in the same sections under operating conditions. Over 160 seepage meter settings were made in ponds of the Fort Laramie Canal and approximately 75 were made in the laterals while 116 were obtained under operating conditions prior to the ponding studies. Averages of the seepage meter readings were compared with the ponding results for the same period of time and a comparison was also made with the results obtained under operating conditions.

For the Fort Laramie Canal, the differences in the seepage rates as measured by ponding and simultaneously by seepage meter varied between 0.02 and 0.20 cubic foot per square foot of wetted area per 24 hours. The percent variations ranged from -17 to +77. The difference in rates determined by the seepage meter under operating conditions and by the ponding procedure varied between 0.02 and 0.59. The percent variation was from -33 to +149. Similar comparisons in the laterals showed variations from -93 to +285 percent. Further correlation data and perhaps revisions in the meter or changes in technique are required before the seepage meter can be considered a reliable instrument for the measurement of seepage losses.

Project forces computed losses from the section of the Fort Laramie Canal between miles 35.0 and 39.7 (which included the ponded sections) by the inflow-outflow method. Rating stations, calibrated by current meter, were used in the main canal while the flow through turnouts was measured by weirs. Due to the inaccuracies of the measuring devices results varied from a loss of 98 cubic feet per second to a gain of 168 cubic feet per second.

The opportunity did not exist to determine the seepage loss from the portion of the Fort Laramie Canal that was pressure grouted on the downhill side (Specifications No. 2600) prior to the grouting operation. However, field measurements after the completion of the grouting operation indicated maximum rates between 0.25 and 0.57 cubic foot per square foot of wetted area per 24 hours. The section which received the greatest density of grout showed the highest seepage rate of any section tested in the Fort Laramie Canal.

A portion of the Fort Laramie Canal was lined with buried asphalt membrane (Specifications No. 2660) immediately after the completion of the seepage tests. Results of the ponding tests in this section indicated maximum seepage rates between 0.13 and 0.25. Since the contract for the lining was awarded prior to the seepage studies, it was necessary to select the sections of canal for lining without the benefit of accurate seepage data.

Parts of Laterals 29.4 and 90.4 were lined with concrete after the completion of the seepage studies. Seepage rates in these two laterals varied between 0.15 and 0.64. Lateral 24A, not scheduled for lining, showed seepage rates which varied between 0.36 and 0.87. As was true with the Fort Laramie Canal, the sections of lateral to be lined were selected without benefit of accurate seepage loss measurements.

CONCLUSIONS

The field measurements revealed that the seepage loss from the sections scheduled for lining is not greater than should normally be expected from an unlined canal. The loss should be ascertained prior to the decision to install canal linings, enabling the judicious selection of the reaches to be lined.

It is not possible from these studies to determine which section of the Fort Laramie Canal is contributing to the high water table in the Barthel farmyard. A more comprehensive program to identify the critical reach would require the segregation and individual testing of small portions of the canal.

RECOMMENDATIONS

As a result of the seepage studies on the North Platte Project during 1949 it is recommended that:

1. Seepage measurements be made sufficiently in advance of construction schedules to permit the judicious selection of reaches of canal and lateral to be lined.

2. Additional research be performed relative to the use of the seepage meter to improve its accuracy. A considerable amount has been performed since the conclusion of these studies.

3. Existing water-measuring devices not to be used to evaluate losses by seepage.

4. The effectiveness of the linings presently under contract be determined as soon as practicable after installation.

INTRODUCTION

The North Platte Project is located in southeastern Wyoming and northwestern Nebraska along the North Platte River. The diversion works for this project are at Whalen Dam near Guernsey, Wyoming. The lower extremity of the irrigated area is located about 20 miles downstream from Northport, Nebraska. The sections of canals and laterals investigated are shown on the location map, Figure 1. The entire program of seepage loss measurements described in this report was conducted as part of the Lower-cost Canal Lining Program.

Testing by ponding is the most accurate technique known for the determination of seepage losses from irrigation canals and laterals. This method requires the construction of dikes (or the utilization of existing canal structures) at each end of the section of canal to be ponded, the filling of the ponds with water, and the observation of the drop of water surface with time. Hook gages reading to the nearest 0.001 foot were used for the water-surface observations. The hook gages were read from one to four or five times a day, depending on the depth of water in the pond and on the rate of drop of the water surface. Evaporation as well as leakage was taken into consideration. An accurate cross-sectional survey was made for obtaining the physical dimensions required in computing the rate of seepage which is expressed in cubic feet per square foot of wetted area per 24 hours.

A device known as a seepage meter was used in conjunction with the ponding tests to obtain supplemental seepage loss data as well as to evaluate the merits of the meter as an instrument for measuring seepage losses. These measurements were taken in flowing water during the irrigation season and in the ponds.

FORT LARAMIE CANAL PONDING TESTS

Seven dikes were constructed in the Fort Laramie Canal, forming six ponds, covering in its entirety the canal between Stations 1911+08 and 2022+84 (miles 36.2 to 38.3). This section of canal is adjacent to the Barthel farm where seepage was great enough to raise the ground water table and inundate the barnyard during the irrigation season. Figure 2 shows the location of the ponds and other pertinent data. The stationing of the dikes and the lengths of the ponds are shown in the following table:

Dike		Pond	
No.	Station	No.	Length
1	1911+08		
		1	2,732
2	1938+40		
		2	4,694
3	1985+34		
		3	1,256
4	1997+90		
		4	360
5	2001+50		
		5	1,311
6	2014+61		
		6	823
7	2022+84		

The dikes were located at strategic positions along the canal to isolate the various elevations of the contact between the silt and the underlying Brule siltstone.(1) Pond 1 contained a silt-Brule siltstone contact that varied in elevation from 1 foot to over 15 feet below the bottom of the canal, Figure 3. Pond 2, filled to a depth of only 4.1 feet by gravity (no pumping) was formed incidental to the other ponds. In this pond, Figure 4, the Brule siltstone was exposed in the bottom of the canal in several places while in other areas the silt-Brule siltstone contact was more than 15 feet below the canal bottom. Pond 3 had Brule siltstone exposed in the bottom of the canal over the major portion of its length. Pond 4 had a silt cover over the Brule siltstone ranging in thickness from 4 to 12 feet while Pond 5 had a deep cover of silt that exceeded 15 feet in depth. Pond 6 had a silt cover over the Brule siltstone ranging in thickness from 3 to 10 feet. Figure 5 shows the profiles for Ponds 3 through 6.

The portland cement pressure grouting in the Fort Laramie Canal (Specifications No. 2600) recommended by a Consulting Board composed of H. W. Bashore, W. R. Young, and H. D. Comstock in a letter to the Chief Engineer dated November 19, 1948, (Appendix A) was installed just prior to the ponding studies while a buried asphalt membrane lining (Specifications No. 2660) was to be placed in a reach of the Fort Laramie Canal immediately after the completion of the field measurements.

Construction of the Dikes

All seven of the dikes in the Fort Laramie Canal were constructed of earth material found adjacent to each dike location. A drag-line and a bulldozer were used to move the material into place. Compaction

(1) This Brule formation, popularly called "Brule Clay," is primarily a siltstone weathering to a silt. Therefore, in this report, this formation is called Brule Siltstone.

was performed with the bulldozer. Two of the dikes were constructed in a dry ditch while the remaining ones were installed in 2 or 3 feet of water stored in the canal to reduce the amount of pumping necessary for the filling of the ponds. The top widths of the completed dikes varied from 15 to 18 feet with the sides conforming to the angle of repose of the material. Since it had been decided that the maximum water surface in the ponds would be approximately 2 feet below the normal operating level of the canal, the top of the dikes, allowing 1 to 2 feet freeboard, corresponded approximately to the normal water-surface elevation.

In conjunction with the construction of the dikes all turnout gates in the ponded sections were closed and the intake side filled with earth to make them tight. Figure 2 shows the location of the dikes and the ponds.

Filling of the Ponds

Both gravity flow and pumping were used in the filling of the seepage ponds in the Fort Laramie Canal. Pond 2 was the only one filled by gravity flow alone resulting in a maximum depth of only 4.1 feet. Pond 6 was filled in its entirety by pumping while the remaining four ponds were partially filled by gravity prior to the completion of the corresponding upstream dike. Then, after the construction of the appropriate dike, the remaining volume in the pond was filled by pumping water from the canal immediately upstream.

Effect of Evaporation

Evaporation data from a Class A pan were available at Whalen Dam through October 18. However, the ponding studies on the Fort Laramie Canal were made immediately following this date while the pan was out of operation. From the information available an evaporation rate of 0.006 foot per 24 hours was selected as being applicable to these studies. This assumed evaporation rate resulted in a reduction in the seepage rate by ponding of less than 2 percent.

Daily evaporation data were available during the entire time of the ponding tests in the laterals. The effect of evaporation on these tests is discussed elsewhere in this report

Leaks Through Dikes and Structures

The sole opportunity for observing leaks through a Fort Laramie Canal dike was at Dike 7, the canal on the downstream side being dry. This face of the dike remained dry during the entire time that Pond 6 was operative. Hence it is reasonable to assume that all dikes were watertight. The only observed leak through a canal structure in the ponded area was through turnout 38.0 but the quantity of water lost was insignificant.

Computation Procedures

The general procedure followed in computing seepage losses from the ponds required the plotting of the canal cross sections, from which the average width and wetted perimeter were determined. The widths and wetted perimeters for each pond were plotted against elevation of water surface. In conjunction with these plots a curve of water-surface elevation in the pond versus time was also required. The following formula was then used for computing the seepage loss:

$$\text{Seepage rate} = \frac{(\text{Width})\ (\text{Length})\ (\text{Drop in water surface in 24 hrs})}{(\text{Wetted perimeter})\ (\text{Length})}$$

The width, wetted perimeter, and drop in water surface for a given 24-hour period were obtained from the above-mentioned curves while the lengths in the formula cancel out. The seepage rate thus obtained was expressed in cubic feet per square foot of wetted area per 24 hours.

RESULTS OF THE PONDING TESTS IN THE FORT LARAMIE CANAL

The results of the ponding tests in the Fort Laramie Canal are shown in Figure 6 where seepage rate is plotted against water depth for each of the six ponds. With the exception of Pond 4, all ponds were filled only once. Pond 4, filled to a depth of 6.6 feet the first time, was later repumped to a depth of 7.5 feet. Field conditions, together with a lack of time, prevented the refilling of the other ponds. There was a period of only 2 weeks when the canal was dry between the end of the irrigation season and the flowing of water into the canal for the ponding tests, hence the loss by bank storage is considered negligible.

Variation of Seepage Rate With Depth

Reference to Figure 6 showing seepage rate plotted against depth indicates that the rate tends to increase with an increase of depth of water in the canal. In the case of Pond 4 (repumped) and Pond 1 (both thoroughly primed prior to the ponding), the seepage rates remain constant for changes in depth with the higher elevations of water surface.

Variation of Seepage Rate With Elevation of Ground-water Table

Ground-water data, Figures 7 to 12, inclusive, show the ground-water elevations for the 1949 irrigation season obtained by utilizing ground-water wells located adjacent to the ponded sections. The locations of the ground-water wells are shown in Figure 2.

In general, a ground-water table that fluctuates rapidly when the canal is filled or emptied indicates a rather high seepage rate while a slowly fluctuating ground-water table usually indicates a lower rate.

Comparative plots of seepage rate versus depth of water and depth to ground-water table are shown in Figures 13 and 14 for Ponds 4 and 6, respectively. The ground-water table was below the canal bottom during the tests in Pond 6 and was above for Pond 4. The maximum variation in ground-water elevation was 1.4 feet for these tests. In both cases the seepage rates follow essentially the same pattern whether they are plotted against depth of water in the canal or depth to the ground-water table.

Seepage Rates in the Sections Grouted and Scheduled for Membrane Lining

Grouting operations (Specifications No. 2600) were carried out prior to the ponding tests in the areas included in Ponds 1, 2, 3, and 4. An examination of Figure 6 (seepage rate versus depth of water in the ponds) shows that Ponds 1 and 3 with the highest density of grouting had higher seepage rates than Ponds 2 and 4.

In contrast to the higher seepage rates in the areas that were grouted, lower seepage rates were obtained in Ponds 5 and 6. The reach of canal included in Ponds 4, 5, and 6 was lined with buried asphaltic membrane under Specifications No. 2660, Figure 2, after the completion of these tests.

Seepage Rates in the Silt and Brule Siltstone Areas

The lowest seepage rate from a Fort Laramie pond, 0.13 cubic foot per square foot of wetted area per 24 hours, was found in Pond 5. Fifteen or more feet of silt covers the Brule siltstone in this entire reach of canal. The highest seepage rate, 0.57 cubic foot per square foot of wetted area per 24 hours, was obtained in Pond 3 where the Brule siltstone was exposed in the bottom of the canal for practically the entire length of the pond. These data indicate that the silt overlying the Brule siltstone is less conductive to high seepage losses than the Brule siltstone itself. This concurs with the opinion of Messrs. Bashore, Young, and Comstock in their report to the Chief Engineer dated November 19, 1948, Appendix A.

LATERAL PONDING TESTS

Ponding tests were made in Laterals 29.4, 90.4, and 24A. The following table shows the stationing and the lengths of the ponds:

Lateral No.	Pond No.	Stations		Length of pond
		From	To	
29.4	1	6+10	11+98	588
	2	11+98	21+82	984
	3	21+82	24+44	262
90.4	1	130+18	139+97	979
	2	145+00	172+74	2,774
	3	172+74	184+46	1,172
	4	197+36	201+81	445
	5	201+81	210+44	863
	6	228+04	231+38	334
24A	1	0+89	7+34	645
	2	7+34	15+44	810
	3	15+44	21+67	623
	4	21+67	36+46	1,479
	5	36+46	44+05	759
	6	44+05	51+27	722

Formation of the Ponds

Wherever possible, check structures were utilized in the formation of the ponds. Canvas was placed on the upstream side of the structure and covered with earth to make the structure watertight. Provision was made over each structure for a spillway. Where canal structures were not available, earth dikes were constructed. Canvas was also used in the construction of the earth dikes for watertightness as well as for the purpose of providing a spillway over the top of the dike. All turnout gates in the ponded sections of the laterals were closed and the intakes filled with earth to prevent leakage. All ponds in the laterals were filled by gravity flow.

Effect of Evaporation

The seepage rates obtained by ponding tests on the laterals were corrected for evaporation. Daily evaporation data were available during the entire time of the ponding tests. The effect of evaporation on the seepage rates obtained from the ponding tests varied from 1 to 20 percent.

Leaks Through Dikes and Structures

Once the turnout gates in the ponds were made watertight there was very little difficulty in keeping them tight. Two opportunities, however, presented themselves for the measurement of leaks through canal structures. The remaining structures and dikes were either watertight or were located in such a way that made observations on leakage impossible. Leaks through the check structure at the downstream end of Pond 1 and the structure between Ponds 2 and 3, Lateral 90.4, were measured and the seepage rates corrected accordingly. These corrections ranged from 3 to 34 percent.

RESULTS OF THE PONDING TESTS IN LATERALS

The results of the ponding tests on Laterals 29.4, 90.4, and 24A are shown in Figures 15, 16, and 17, respectively. The figures show the seepage rate plotted against depth of water for each pond.

Lateral 29.4

The highest seepage rate found in Lateral 29.4 amounted to slightly less than 0.40 cubic foot per square foot of wetted area per 24 hours. The decision to line this lateral (Specifications No. 2705) was made prior to the ponding studies. The apparent reasons for the selection of this lateral for lining included the appearance, during the irrigation season, of water in the basement of a farmhouse adjacent to the lateral at Station 15+00 and to seepage areas west of the lateral in the triangular area between the lateral and the Fort Laramie Canal. If these conditions still persist after the lateral is lined, the seepage is probably coming from the Fort Laramie Canal instead of from the lateral.

Lateral 90.4

The highest seepage rate found in Lateral 90.4 amounted to slightly less than 0.65 cubic foot per square foot of wetted area per 24 hours. Several seepage areas appear below this reach of lateral. The ponded sections of this lateral are scheduled for concrete lining.

Lateral 24A

The highest seepage rate found in Lateral 24A (the highest found on the project) amounted to slightly less than 0.90 cubic foot per square foot of wetted area per 24 hours. Several seepage areas appeared in the field adjacent to the lateral. This lateral is not scheduled for lining at the present time.

SEEPAGE METER STUDIES

Figures 18 and 19 show the details of the seepage meter while Figure 20 is a photograph of the instrument in its present stage of development. This meter is a modified version of the constant head permeameter and consists of a watertight seepage cup connected with 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 bag, being submerged, maintains the same head on the test area under the meter as on the surrounding area of canal. Knowing the area under the meter (2 square feet) 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. Form "DCT-27, 11-49, Bureau of Reclamation," Figure 21, was used for recording the data. This meter may be used in flowing water during the irrigation season.

Results of the Seepage Meter Studies in the Ponds

Fort Laramie Canal. Figures 3, 4, and 5 show the seepage meter results for the Fort Laramie Canal both in flowing water and in the ponds. The following table summarizes the results of these tests and compares the results with those found simultaneously from the ponding procedure. The seepage rates are expressed in cubic feet per square foot of wetted area per 24 hours:

Pond No.	No. of meter settings	Seepage rate by meter			Rate by ponding	Variation	
		Maximum	Minimum	Average		Rate	Percent
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

Laterals. The results of the seepage meter measurements made in conjunction with the ponding studies in the laterals are shown in Figures 22, 23, and 24. The data are summarized and the meter results compared with ponding results in the following tables:

Lateral 29.4

Pond No.	No. of settings	Seepage rate by meter			Rate by ponding	Variation	
		Maximum	Minimum	Average		Rate	Percent
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

Pond No.	No. of settings	Seepage rate by meter			Rate by ponding	Variation	
		Maximum	Minimum	Average		Rate	Percent
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

Pond No.	No. of settings	Seepage rate by meter			Rate by ponding	Variation	
		Maximum	Minimum	Average		Rate	Percent
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

Results of the Seepage Meter Studies in Flowing Water

About 170 seepage meter settings were made in flowing water in the canals and laterals of the North Platte Project during the 1949 irrigation season prior to the ponding studies. The majority of these settings were made in reaches of canal that were later ponded, therefore offering an opportunity to compare seepage measurements by ponding with measurements by seepage meter in flowing water. The seepage meter gave results varying from 93 percent less than to 285 percent greater than the results from the ponding tests. The following tables summarize these data. The seepage rates are expressed in cubic feet per square foot of wetted area per 24 hours.

	Pond No.	No. of meter settings	Seepage meter in flowing water	Seepage rate from ponding tests	Differences based on ponding rate	
					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

The results of the seepage meter tests in flowing water in laterals 24D and 102.4 are shown in Figure 25. Ponding tests were not conducted on these two laterals.

Use of the Seepage Meter

The seepage meter in its present stage of development cannot be considered an accurate instrument for the measurement of seepage losses. However, if the results are judiciously interpreted, the seepage meter may be utilized to indicate seepage trends.

EFFECTIVENESS OF THE PORTLAND CEMENT PRESSURE GROUTING

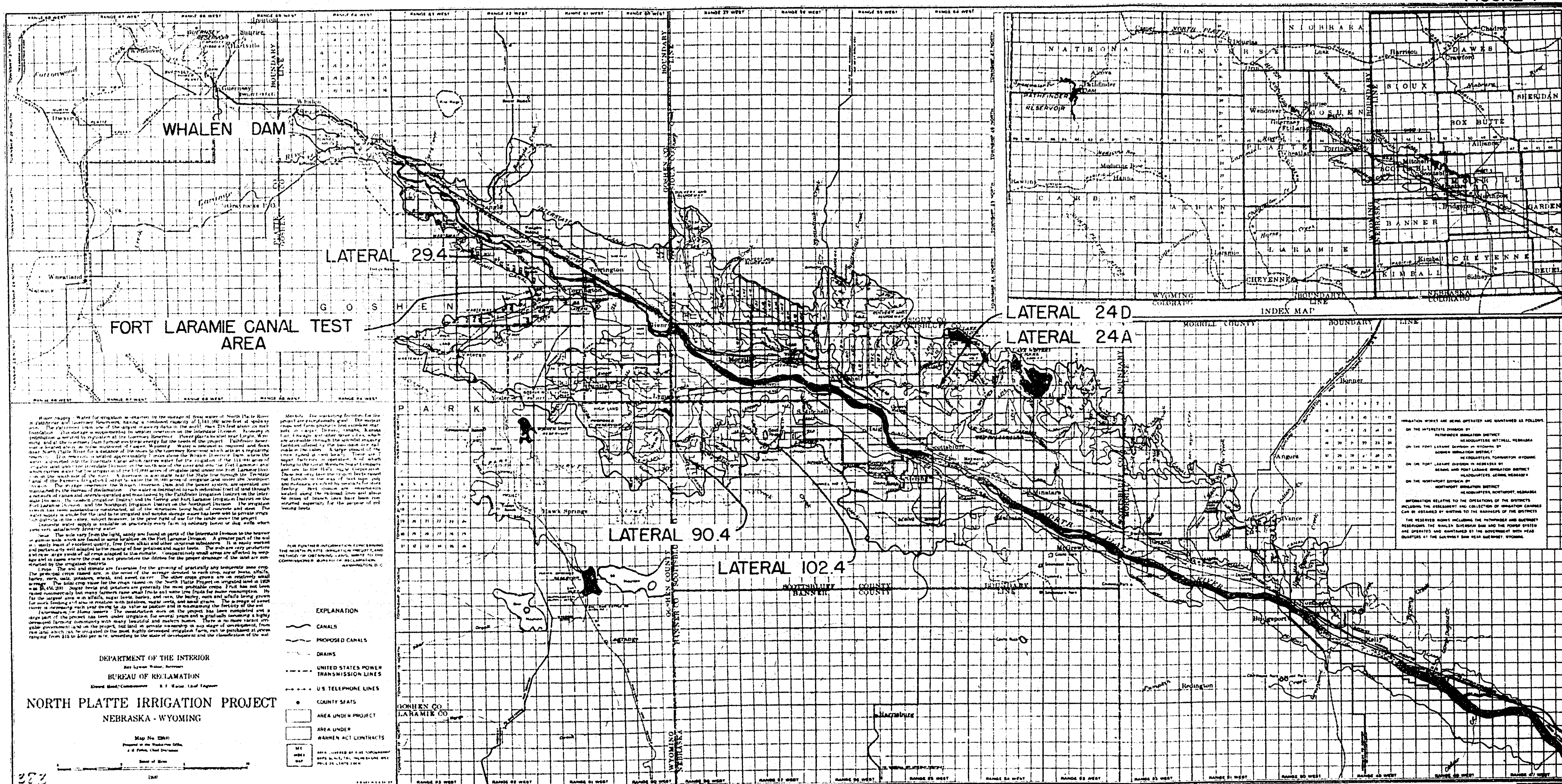
Inasmuch as no ponding tests were performed prior to the portland cement pressure grouting operation in the Fort Laramie Canal (Specifications No. 2600) the ponding tests show the seepage rate after the grouting operation and will not indicate the effectiveness of the grouting in reducing the seepage losses. Neither can the inflow-outflow data be used to indicate the effectiveness of the grouting. These inflow-outflow measurements are discussed elsewhere in this report. Ground-water observations, Figures 7 through 12, were made both before and after the grouting operations. While these data show that the ground-water table was dropping during or immediately after the grouting operation, the canal discharge during this same period decreased from 1,300 second-feet to zero. Considering the long intervals of time between the ground-water readings and the coinciding of the completion of the grouting and the reducing of the canal flow to zero, it is impossible to evaluate, from these data, the effectiveness of the grouting in reducing seepage losses.

INFLOW-OUTFLOW MEASUREMENTS

Inflow-outflow measurements were made by project personnel for the Fort Laramie Canal between miles 35.0 and 39.7 during the 1949 irrigation season, together with observations of the discharge through the 15 turnouts in this reach of canal. Three of the turnouts are pump lifts while the remaining 12 are by gravity flow. Gaging stations at miles 35.0 and 39.7 on the Fort Laramie Canal were utilized. These gaging stations had been previously calibrated by current meter. The outflow through the various turnouts were measured by weirs.

The losses in cubic feet per second obtained from these data together with the outflow discharge at mile 39.7, the turnout operating schedule, and the grouting schedule (Specifications No. 2600) are shown in Figure 26. The extremely wide range of results from the inflow-outflow data (168 second-feet gain to 97 second-feet loss) indicates the unreliability of these data. Figures 27 through 30 are photographs of four of the weirs used to obtain these measurements.

FIGURE I



WHALEN DAM
LATERAL 29.4
FORT LARAMIE CANAL TEST AREA
LATERAL 24 D
LATERAL 24 A
LATERAL 90.4
LATERAL 102.4
GOSHEN
PARK
INDEX MAP
EXPLANATION
CANALS
PROPOSED CANALS
DRAINS
UNITED STATES POWER TRANSMISSION LINES
U.S. TELEPHONE LINES
COUNTY SEATS
AREA UNDER PROJECT
AREA UNDER WARREN ACT CONTRACTS
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
NORTH PLATTE IRRIGATION PROJECT
NEBRASKA - WYOMING

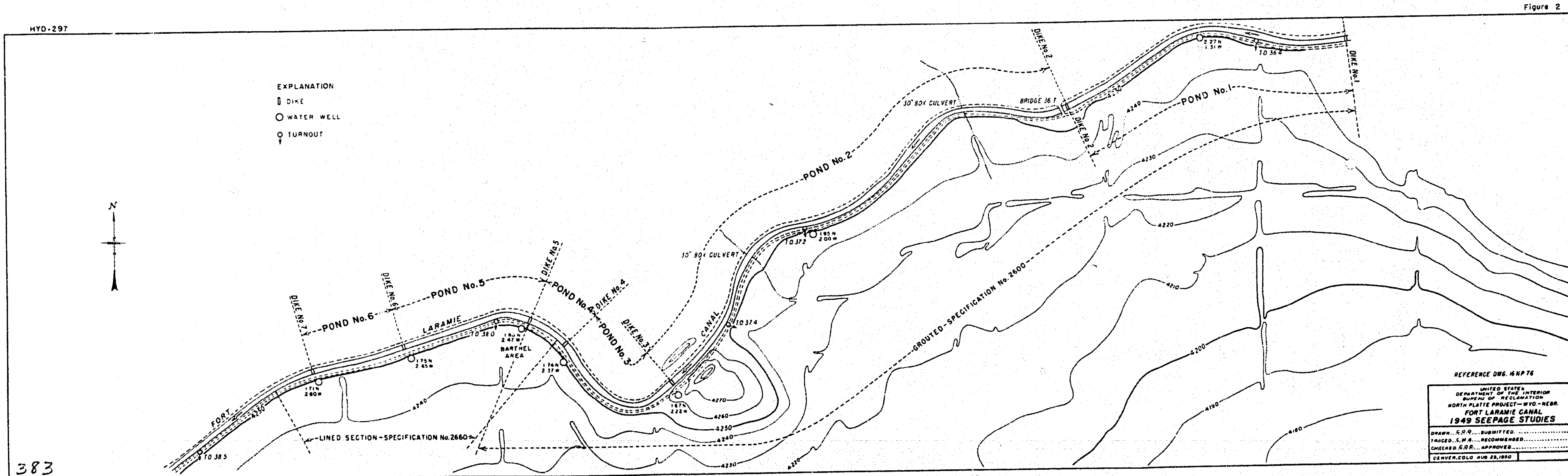
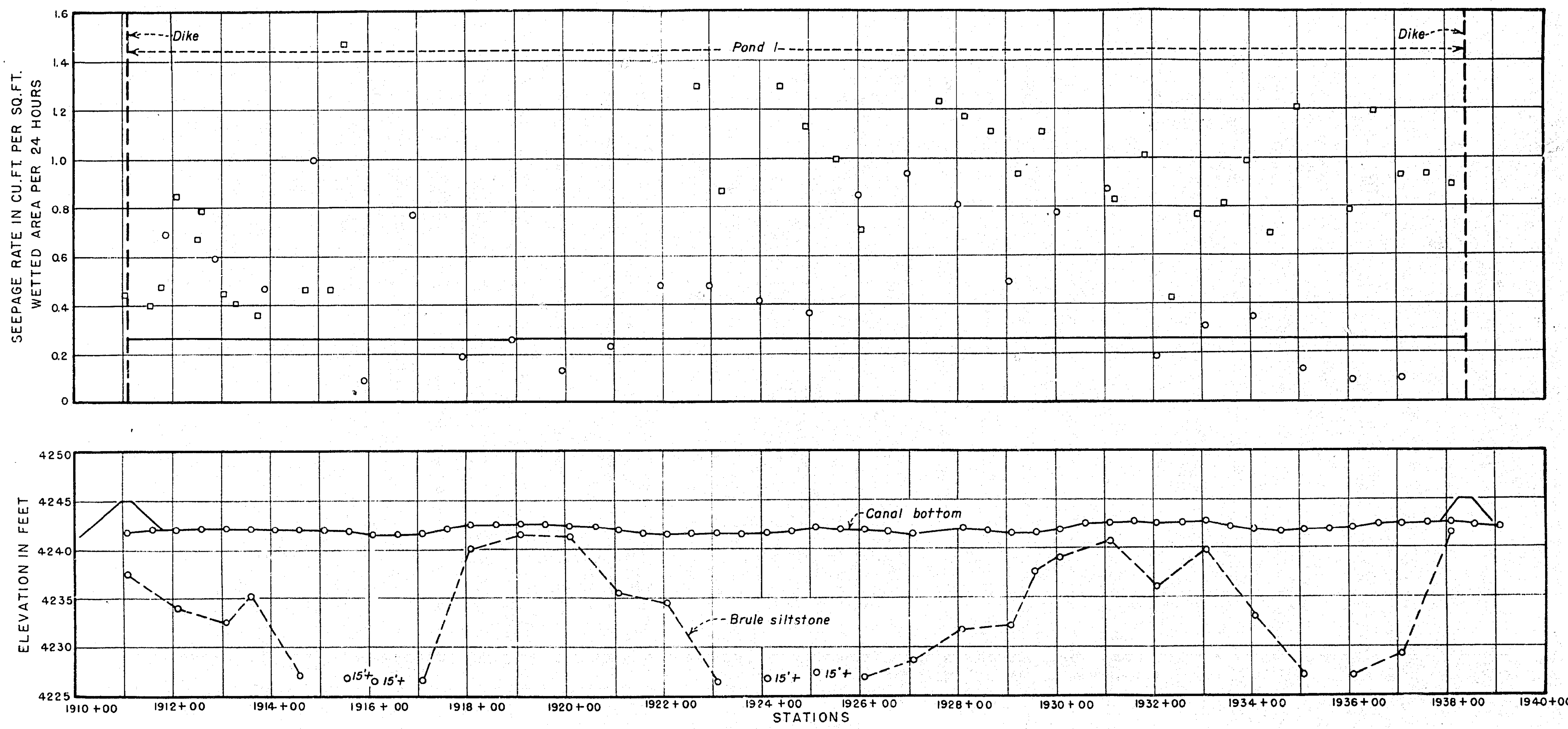

EXPLANATION
DIKE
WATER WELL
TURNOUT
N
FORT LARAMIE CANAL
POND No.1
POND No.2
POND No.3
POND No.4
POND No.5
POND No.6
DIKE No.1
DIKE No.2
DIKE No.3
DIKE No.4
DIKE No.5
DIKE No.6
DIKE No.7
30" BOX CULVERT
BRIDGE 36.7
BARTHEL AREA
GROUTED-SPECIFICATION No. 2600
LINED SECTION-SPECIFICATION No.2660
TO 364
TO 372
TO 374
TO 380
TO 385
4270
4260
4250
4240
4230
4220
4210
4200
4190
4180
REFERENCE DWG. 16 KP 76
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
NORTH PLATTE PROJECT—WYO.-NEBR.
FORT LARAMIE CANAL
1949 SEEPAGE STUDIES
DRAWN..C.O.Q....SUBMITTED.
TRACED..C.M.A....RECOMMENDED
CHECKED.C.Q.R....APPROVED
DENVER,COLO AUG 25,1950
383

FIGURE 3



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.
- o—o Canal bottom.
- o- -o Top of brule clay.

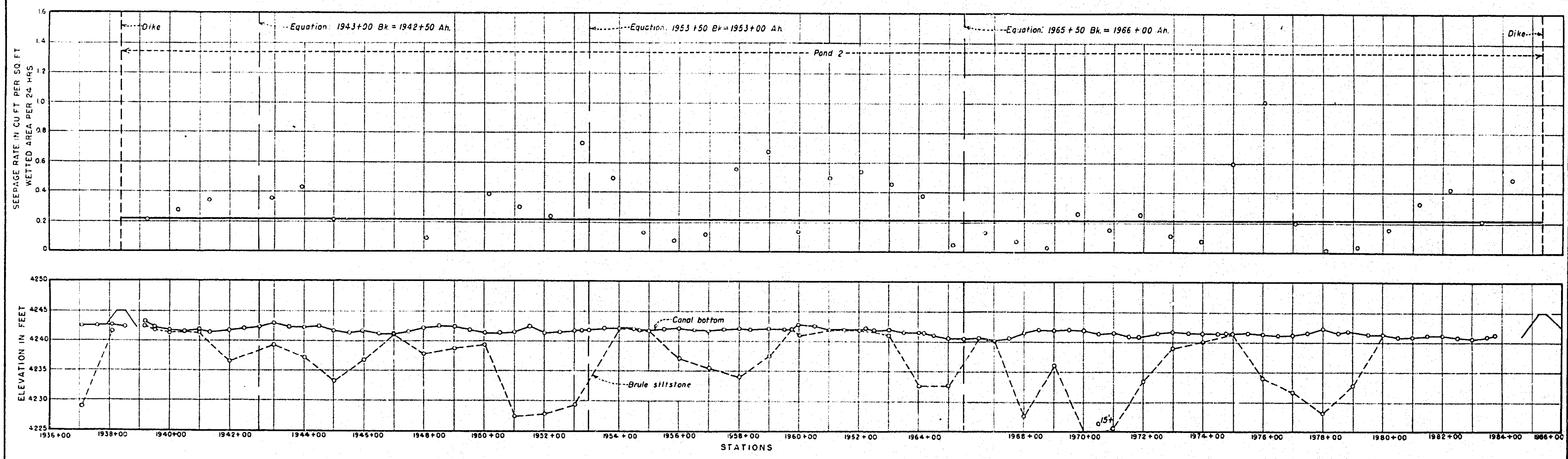
NORTH PLATTE PROJECT-WYOMING-NEBRASKA

1949 SEEPAGE STUDIES

SEEPAGE METER TESTS-FORT LARAMIE CANAL POND 1

383
N.G.R. 3-8-50

FIGURE 4



EXPLANATION

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

NORTH PLATTE PROJECT-WYOMING-NEBRASKA

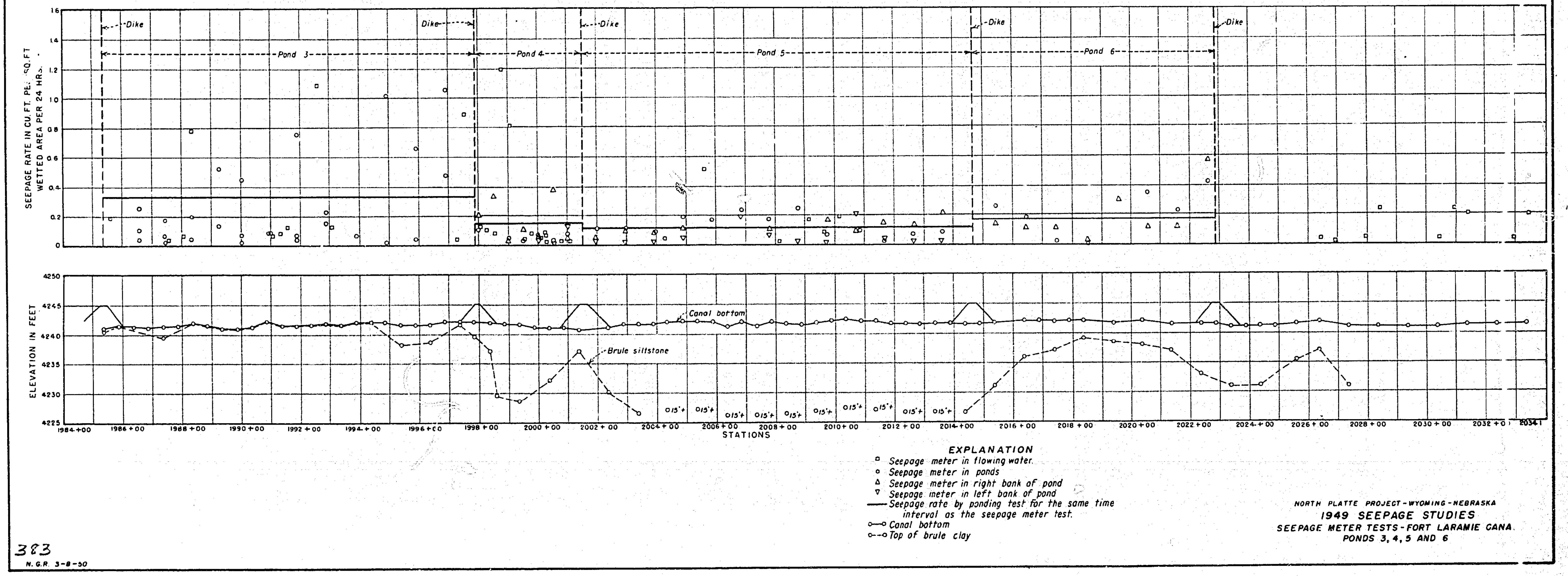
1949 SEEPAGE STUDIES

SEEPAGE METER TESTS-FORT LARAMIE CANAL

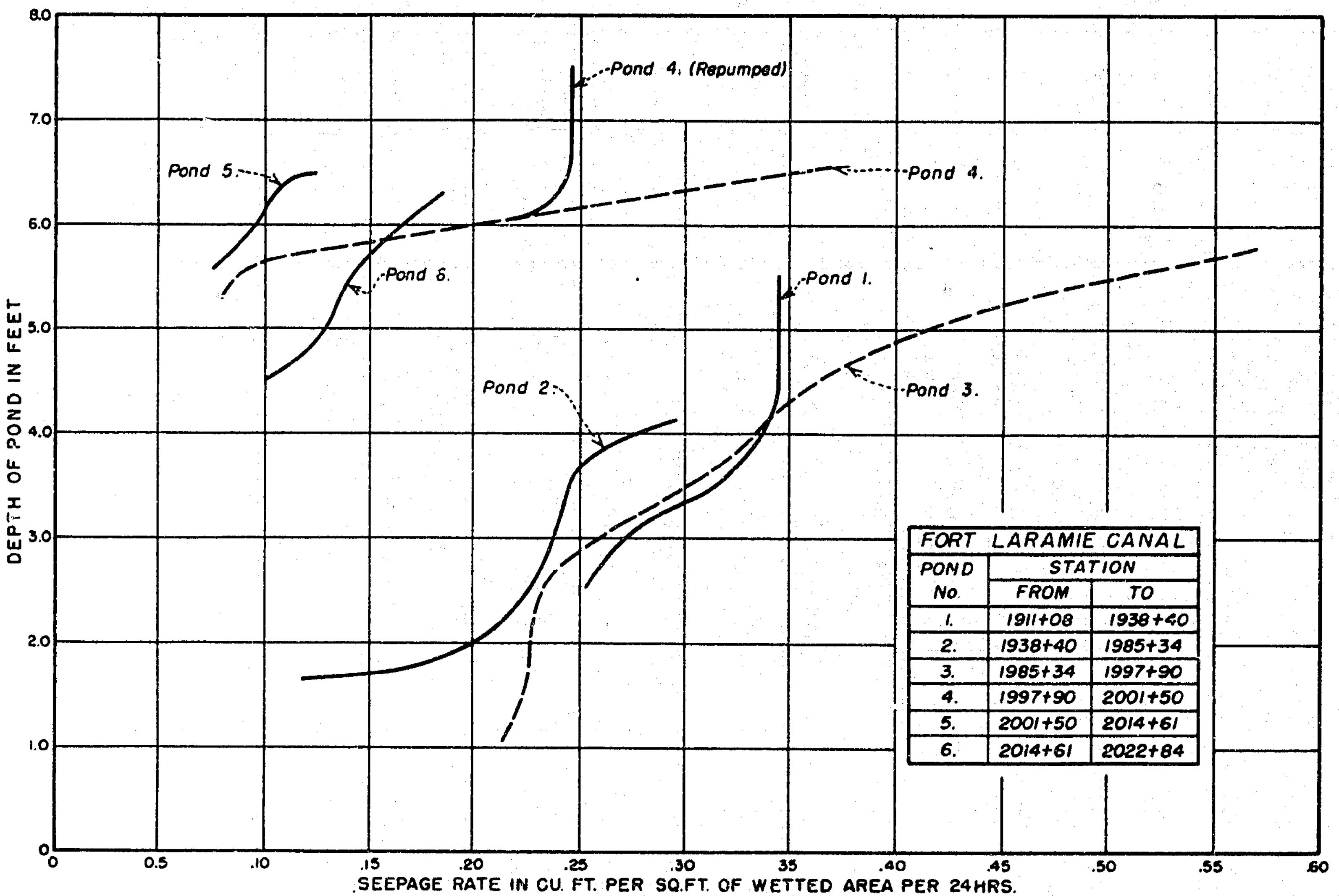
POND 2.

383

N.G.R. 3-8-50



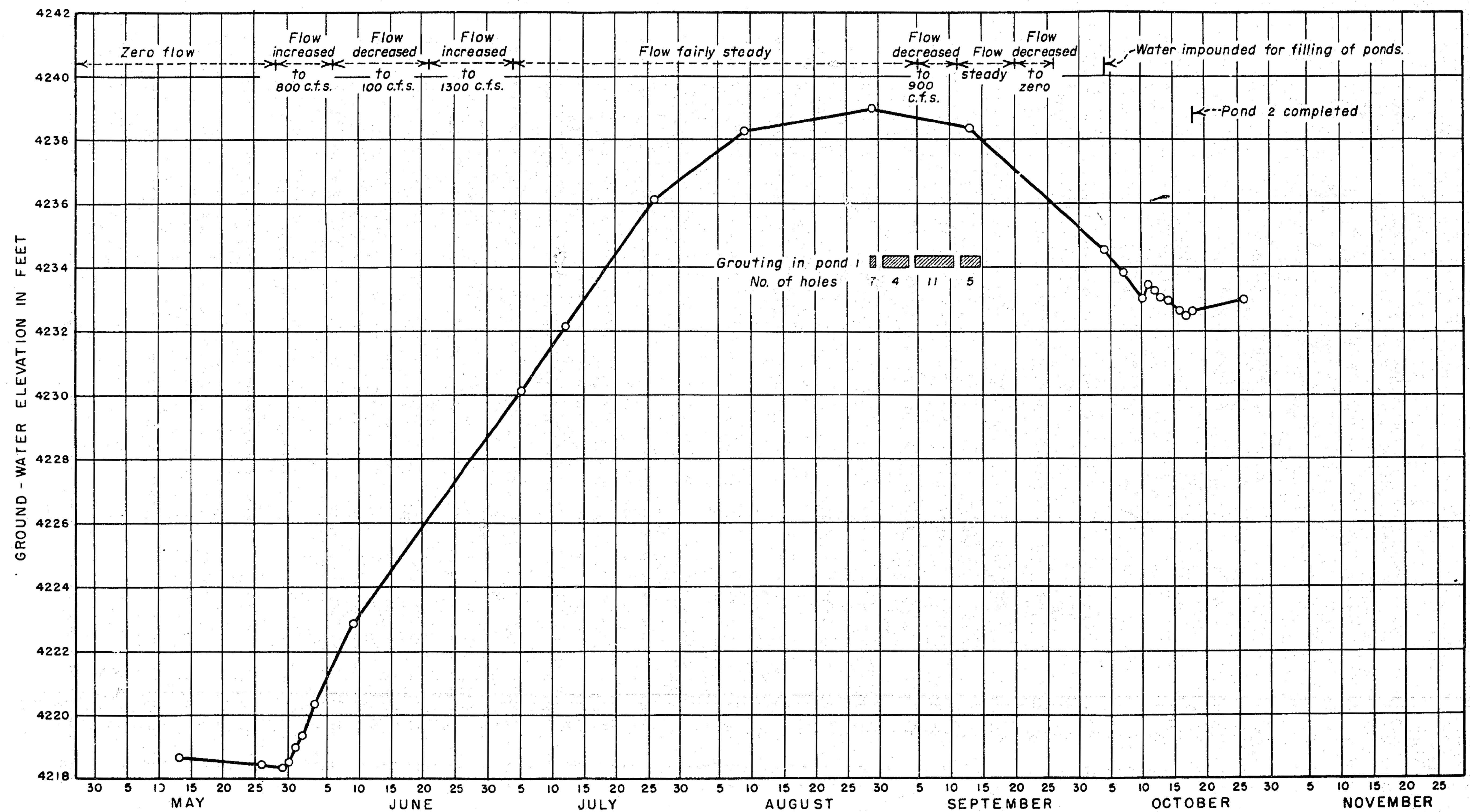
NORTH PLATTE PROJECT-WYOMING-NEBRASKA
1949 SEEPAGE STUDIES
SEEPAGE METER TESTS-FORT LARAMIE CANA.
PONDS 3, 4, 5 AND 6



FORT LARAMIE CANAL		
POND No.	STATION	
	FROM	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

383
D.C.W. 3-2-50



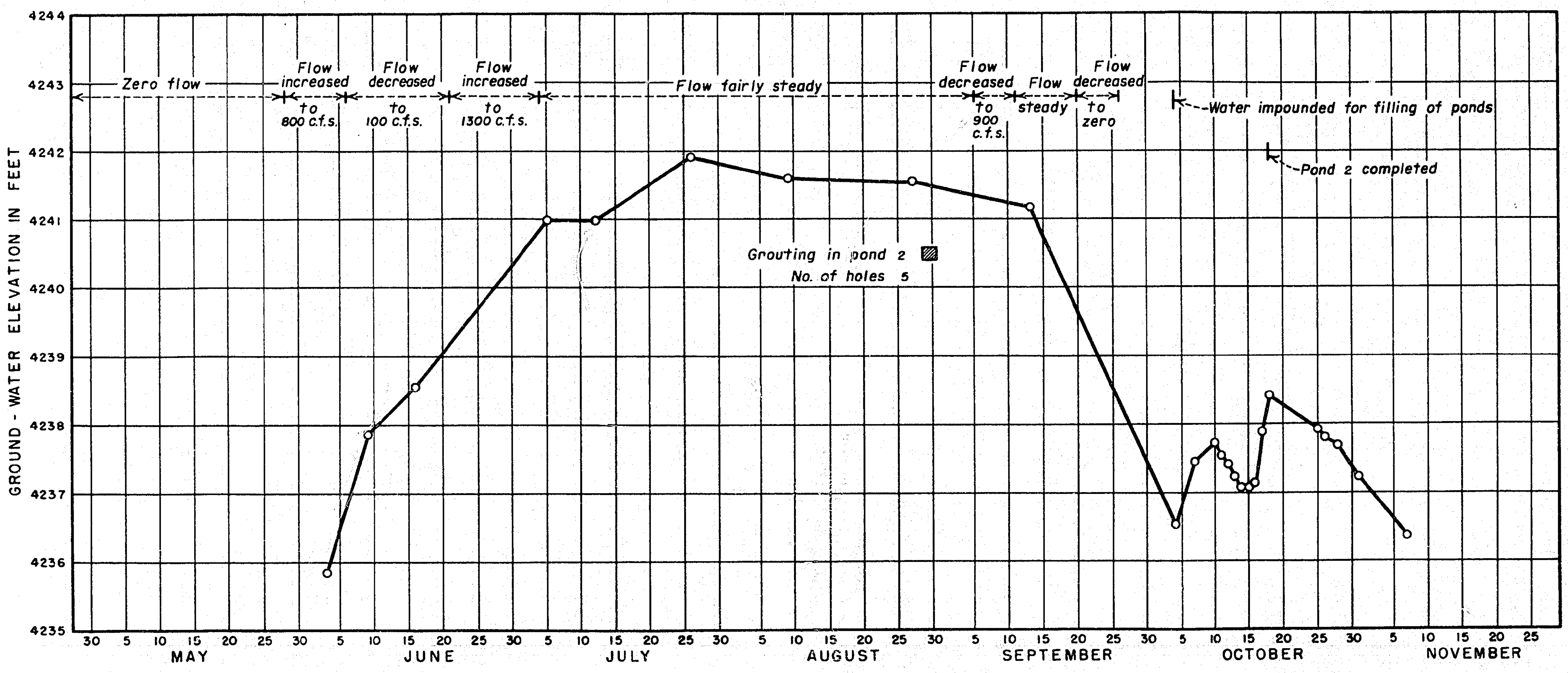
NORTH PLATTE PROJECT—WYOMING—NEBRASKA

1949 SEEPAGE STUDIES

GROUND-WATER WELL 2.27N.-1.31W.

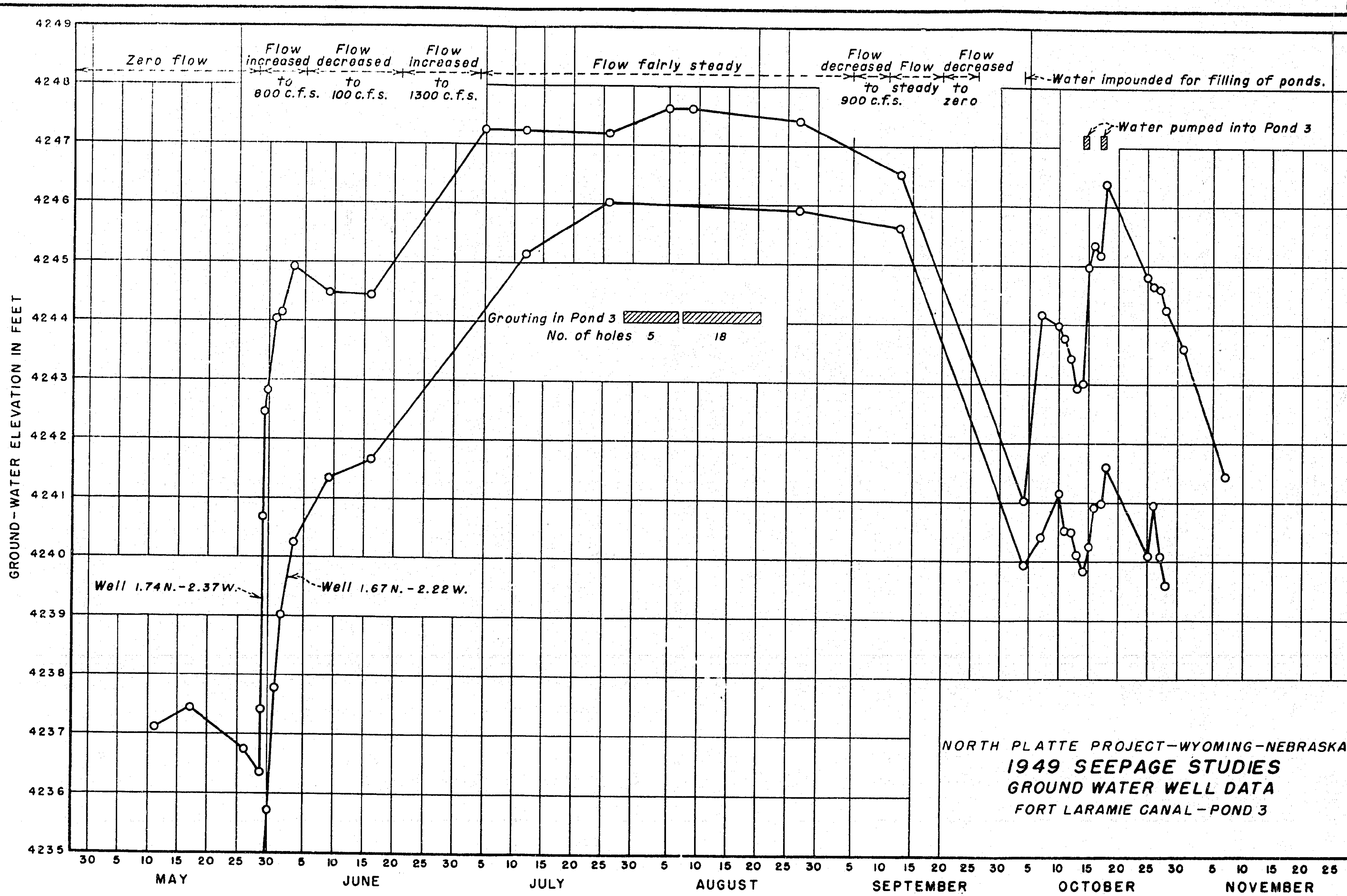
FORT LARAMIE CANAL—POND 1

383
P.S. 3-10-50



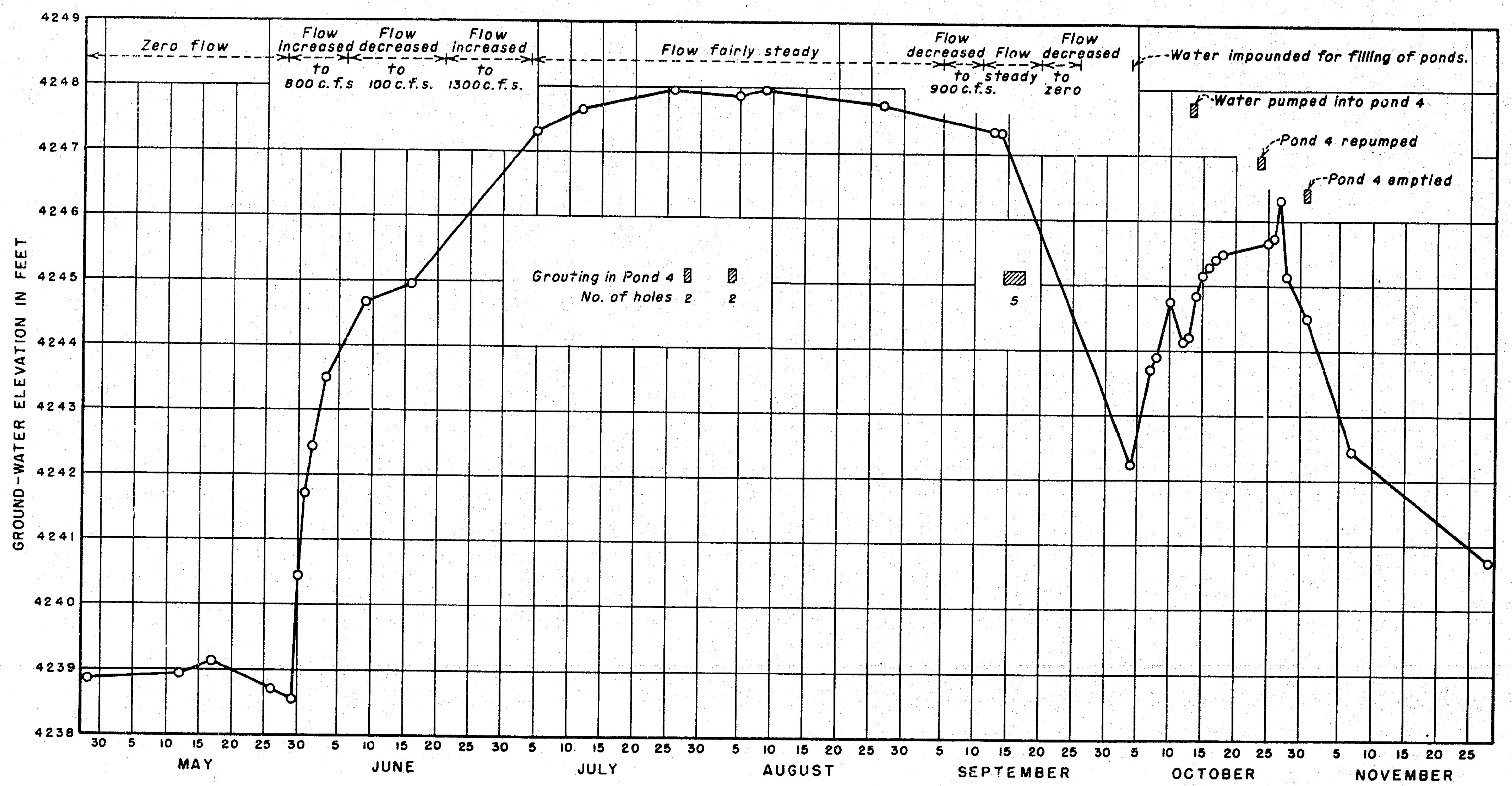
NORTH PLATTE PROJECT—WYOMING—NEBRASKA
1949 SEEPAGE STUDIES
GROUND-WATER WELL 1.95 N. – 2.00 W.
FORT LARAMIE CANAL – POND 2

383
P.S. 3-13-50



NORTH PLATTE PROJECT—WYOMING—NEBRASKA
1949 SEEPAGE STUDIES
GROUND WATER WELL DATA
FORT LARAMIE CANAL—POND 3

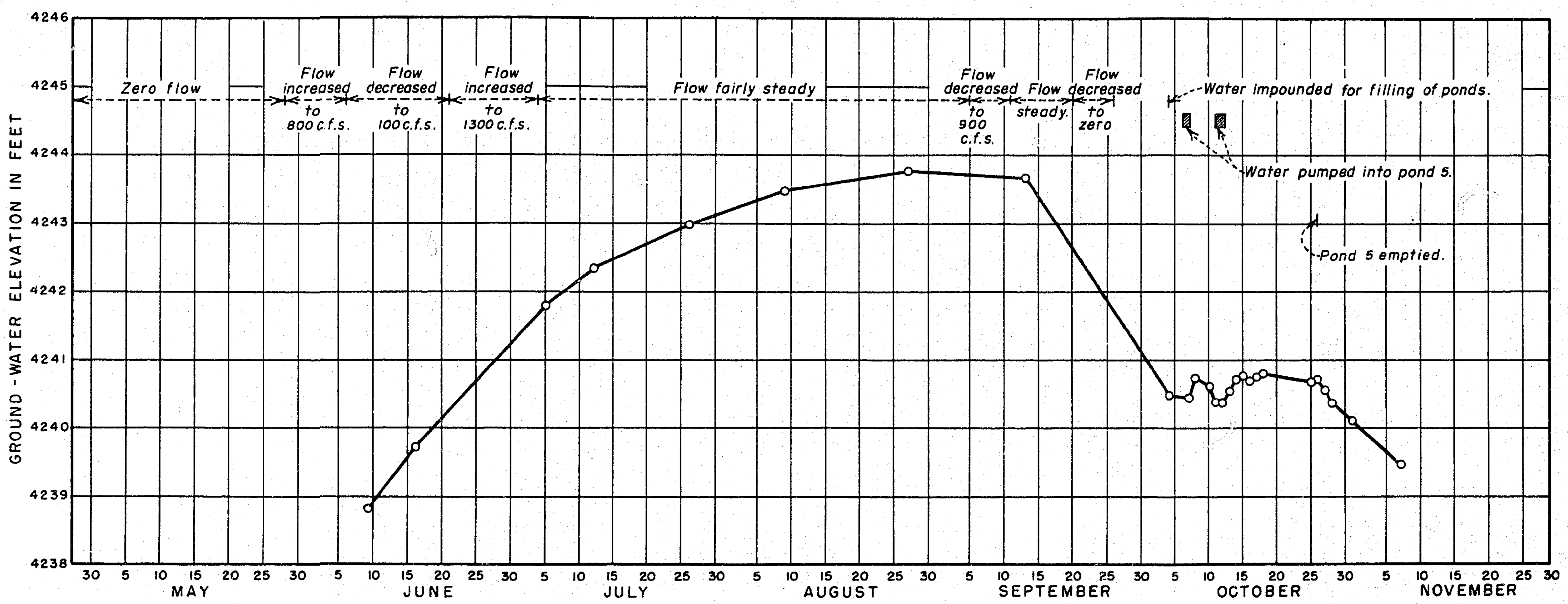
383
3-13-50 P.S.



NOTE
This reach of canal is to be lined with buried asphaltic membrane lining under Spec. No. 2660.

NORTH PLATTE PROJECT–WYOMING–NEBRASKA
1949 SEEPAGE STUDIES
GROUND-WATER WELL 1.80N.–2.47W
FORT LARAMIE CANAL–POND 4

383
3-8-50 P.S.



NOTE

No grouting was performed in this reach of canal. It is to be lined with buried asphaltic membrane lining under Spec. No. 2660.

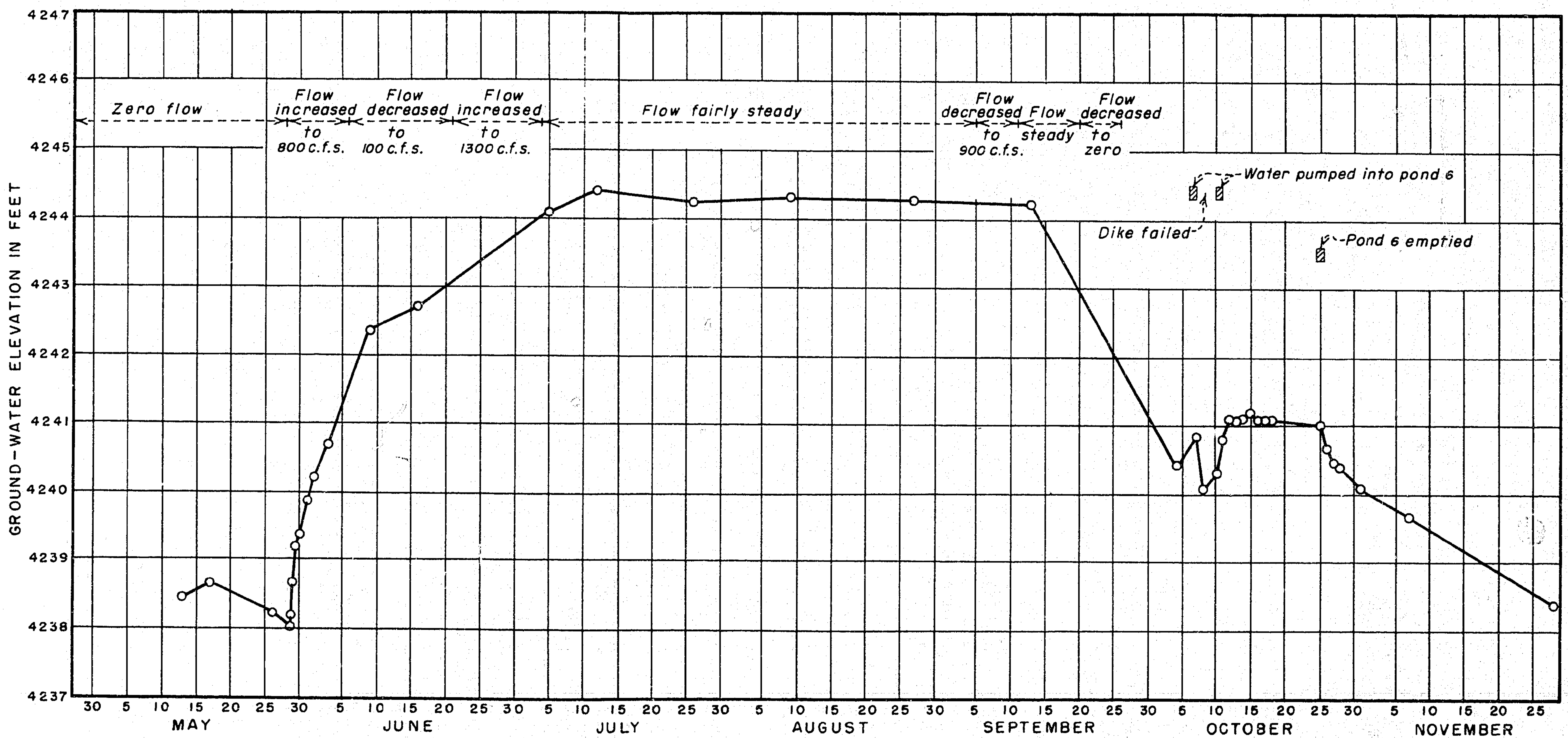
NORTH PLATTE PROJECT-WYOMING-NEBRASKA

1949 SEEPAGE STUDIES

GROUND-WATER WELL 1.75N-2.65W

FORT LARAMIE CANAL — POND 5

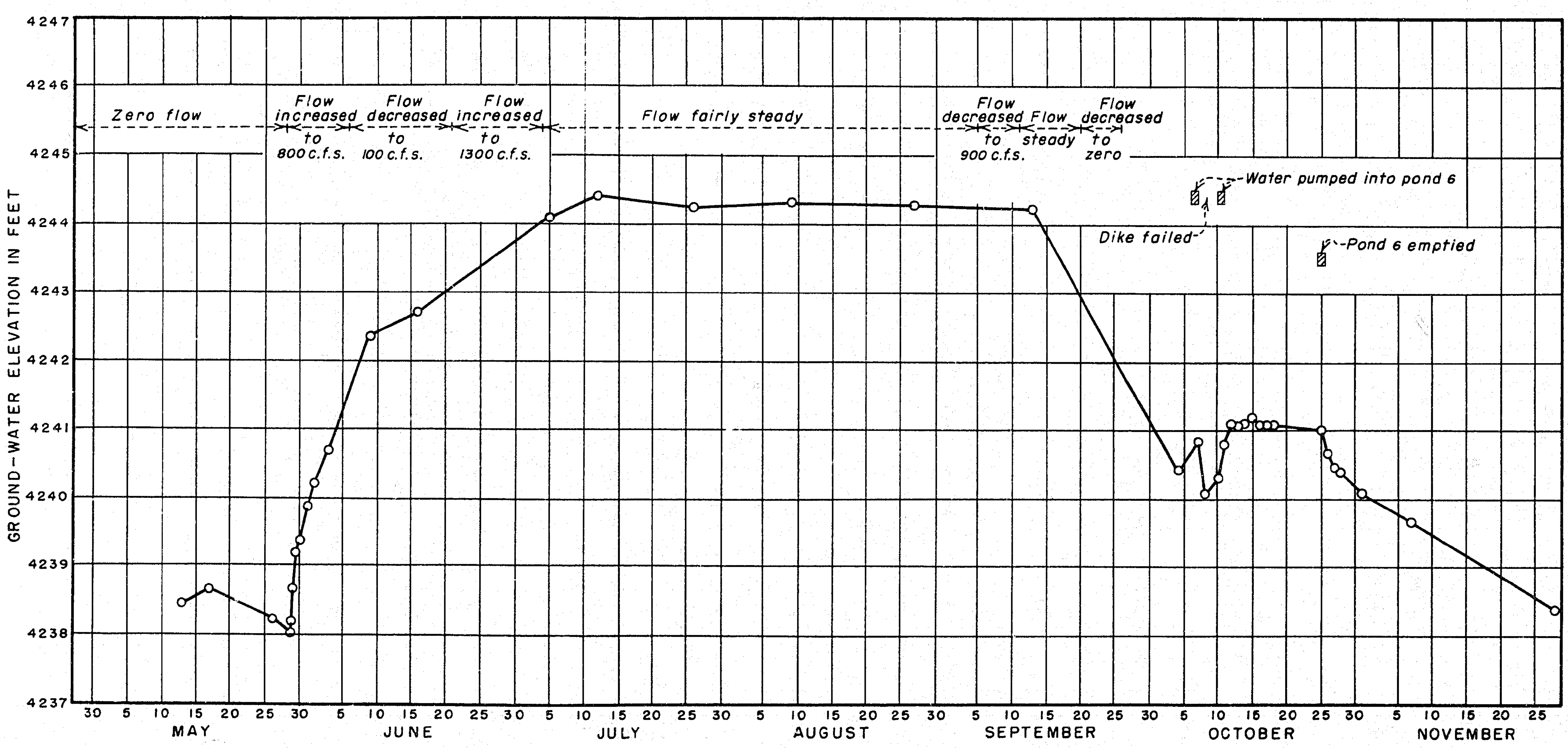
383
P.S. 3-9-50



NOTE
No. grouting was performed in this reach of canal. It is to be lined with buried asphaltic membrane lining under Spec. No. 266c.

NORTH PLATTE PROJECT—WYOMING—NEBRASKA
1949 SEEPAGE STUDIES
GROUND-WATER WELL 1.71 N – 2.80W
FORT LARAMIE CANAL—POND 6

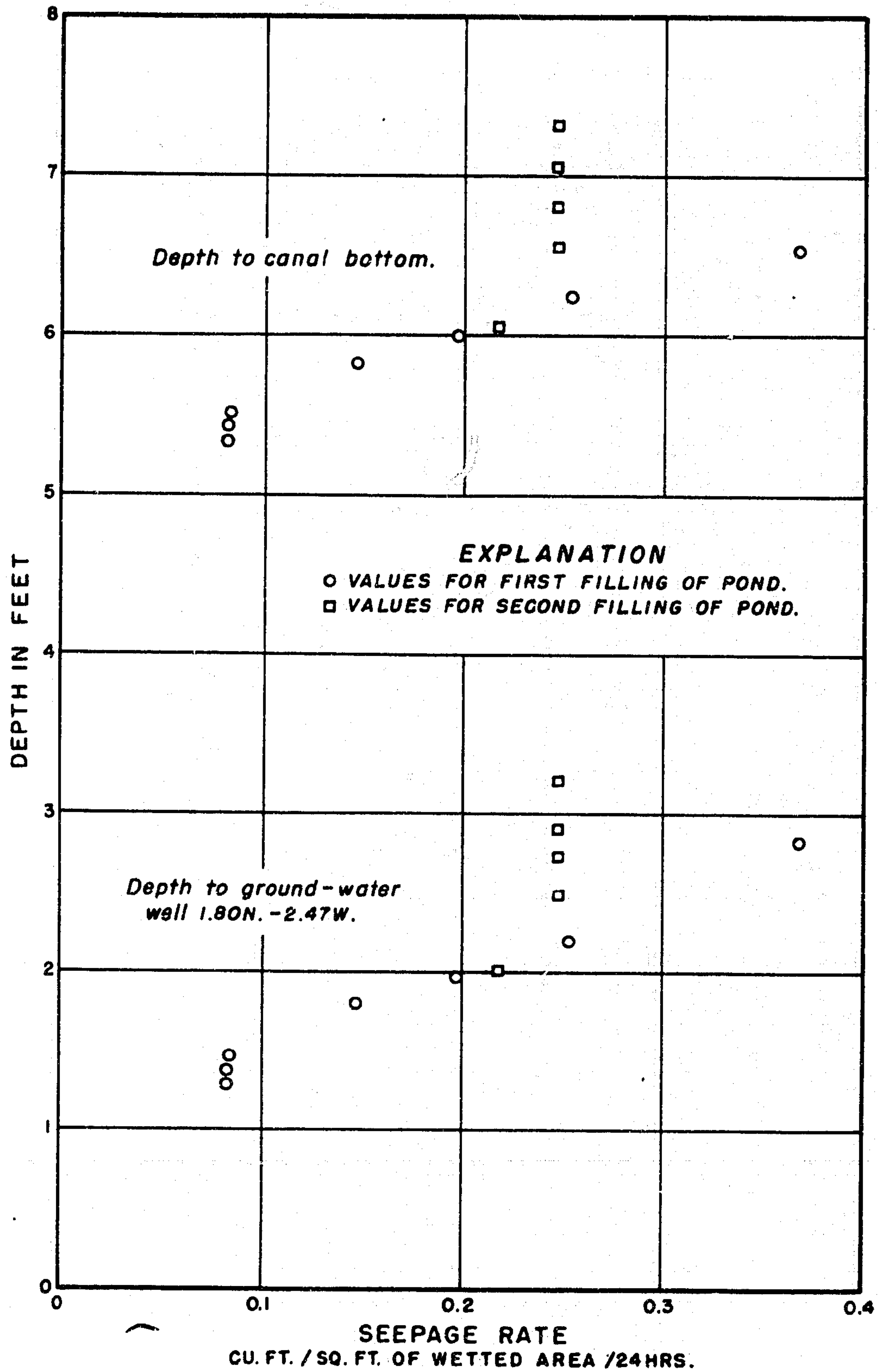
383
3-10-50 P.S.



NOTE
No. grouting was performed in this reach of canal. It is to be lined with buried asphaltic membrane lining under Spec. No. 2660.

NORTH PLATTE PROJECT—WYOMING—NEBRASKA
1949 SEEPAGE STUDIES
GROUND-WATER WELL 1.71 N – 2.80 W
FORT LARAMIE CANAL—POND 6

383
3-10-50 P.S.



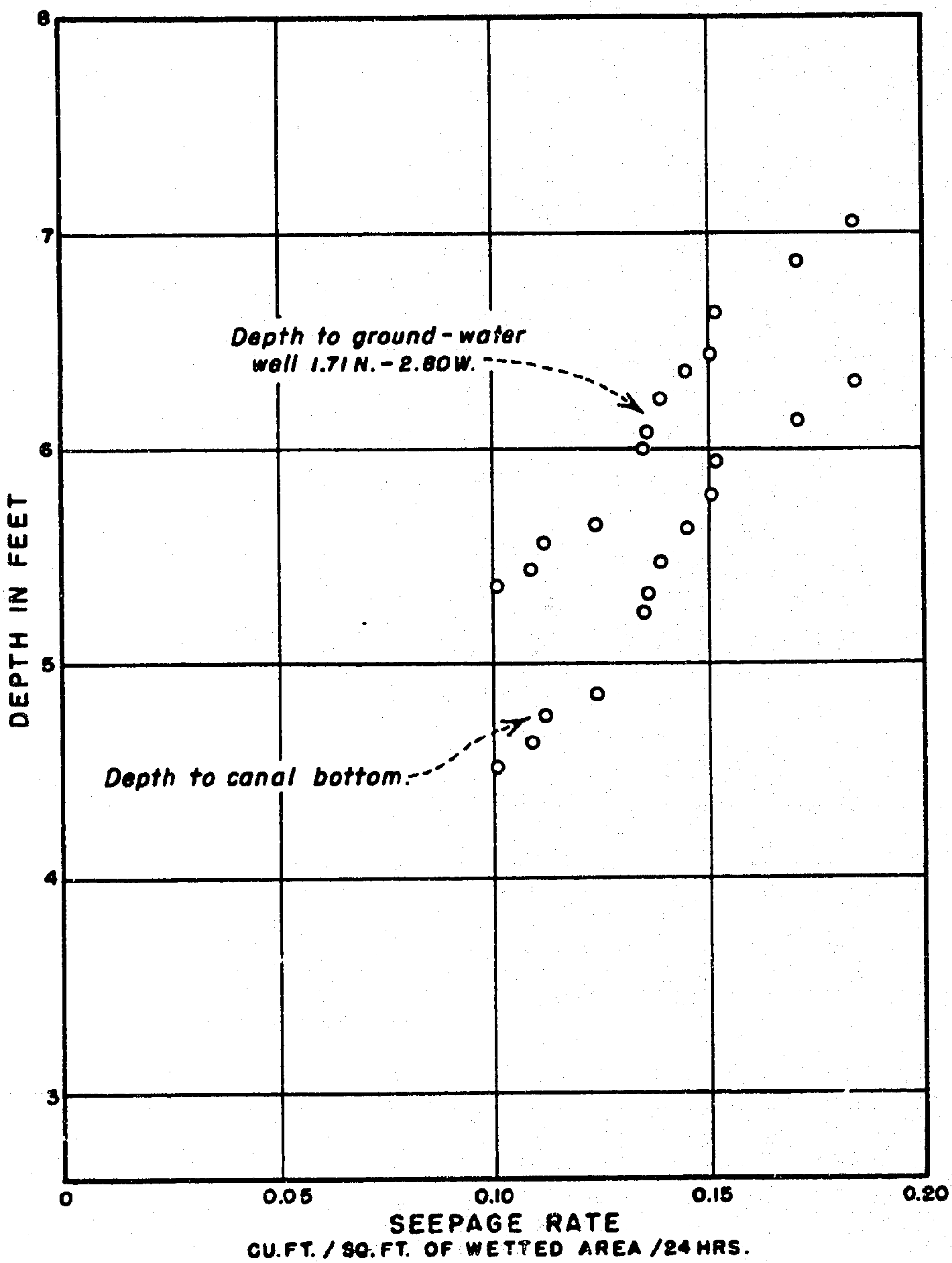
NORTH PLATTE PROJECT—WYOMING—NEBRASKA

1949 SEEPAGE STUDIES

PONDING TEST—FORT LARAMIE CANAL—POND 4

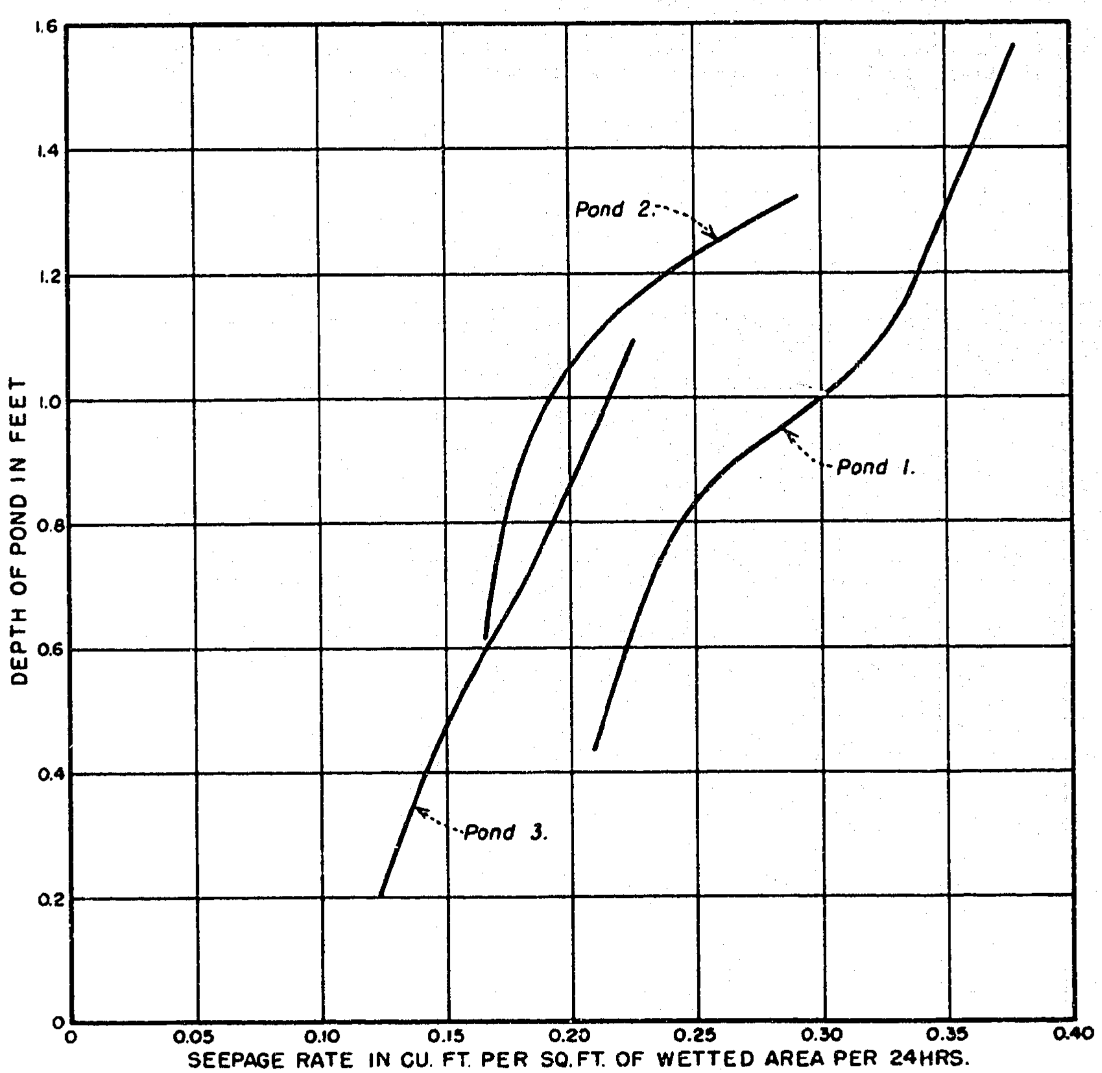
383

P.S. 3-14-50



NORTH PLATTE PROJECT—WYOMING—NEBRASKA
1949 SEEPAGE STUDIES
PONDING TEST—FORT LARAMIE CANAL—POND 6

383
P.S. 3-15-50



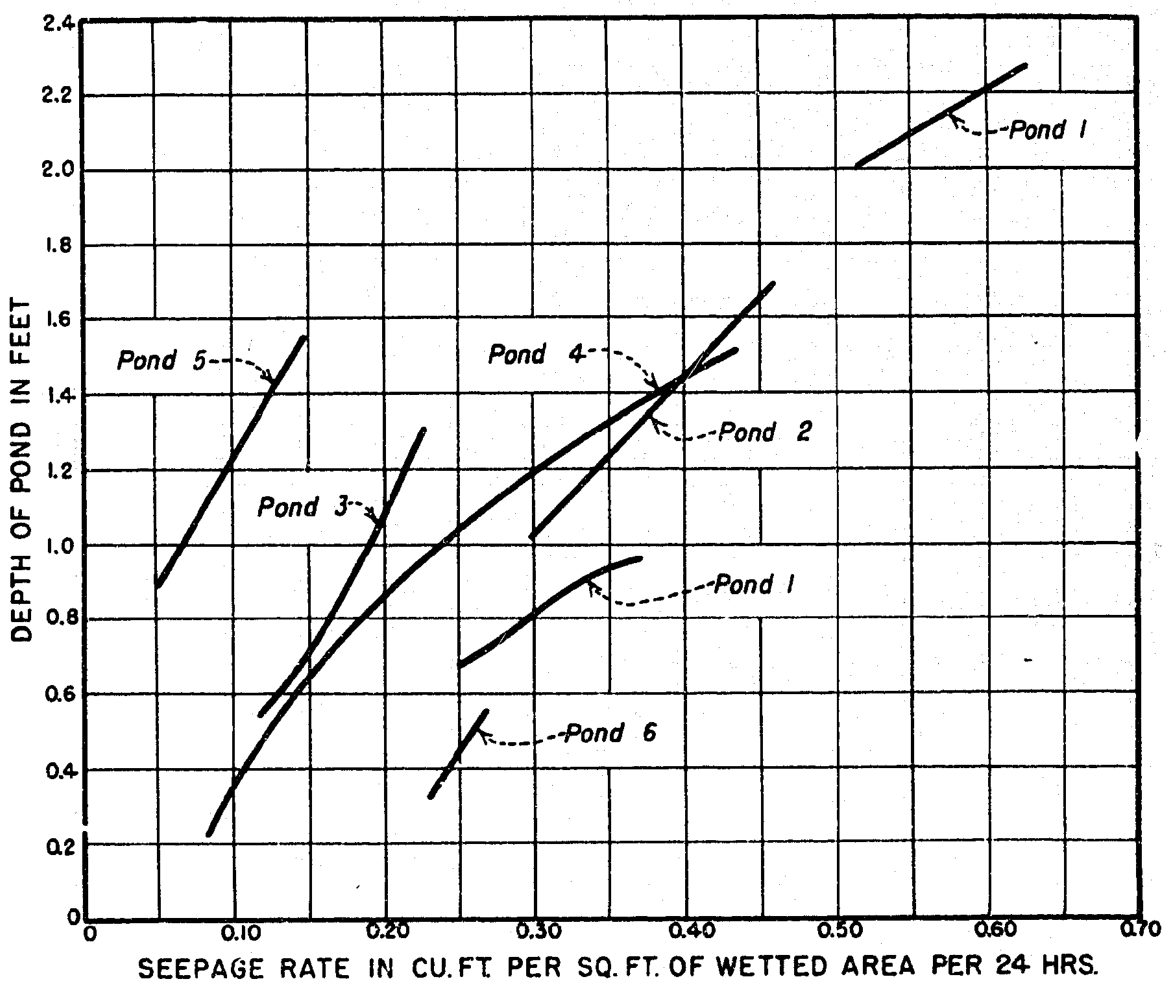
LATERAL 29.4		
POND No.	STATION	
	FROM	TO
1.	6+10	11+98
2.	11+98	21+82
3.	21+82	24+44

383
D.C.W. 3-2-50

NORTH PLATTE PROJECT-WYOMING-NEBRASKA
1949 SEEPAGE STUDIES
PONDING TESTS - FORT LARAMIE LATERAL 29.4

FIGURE 15

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



NORTH PLATTE PROJECT-WYOMING-NEBRASKA

1949 SEEPAGE STUDIES

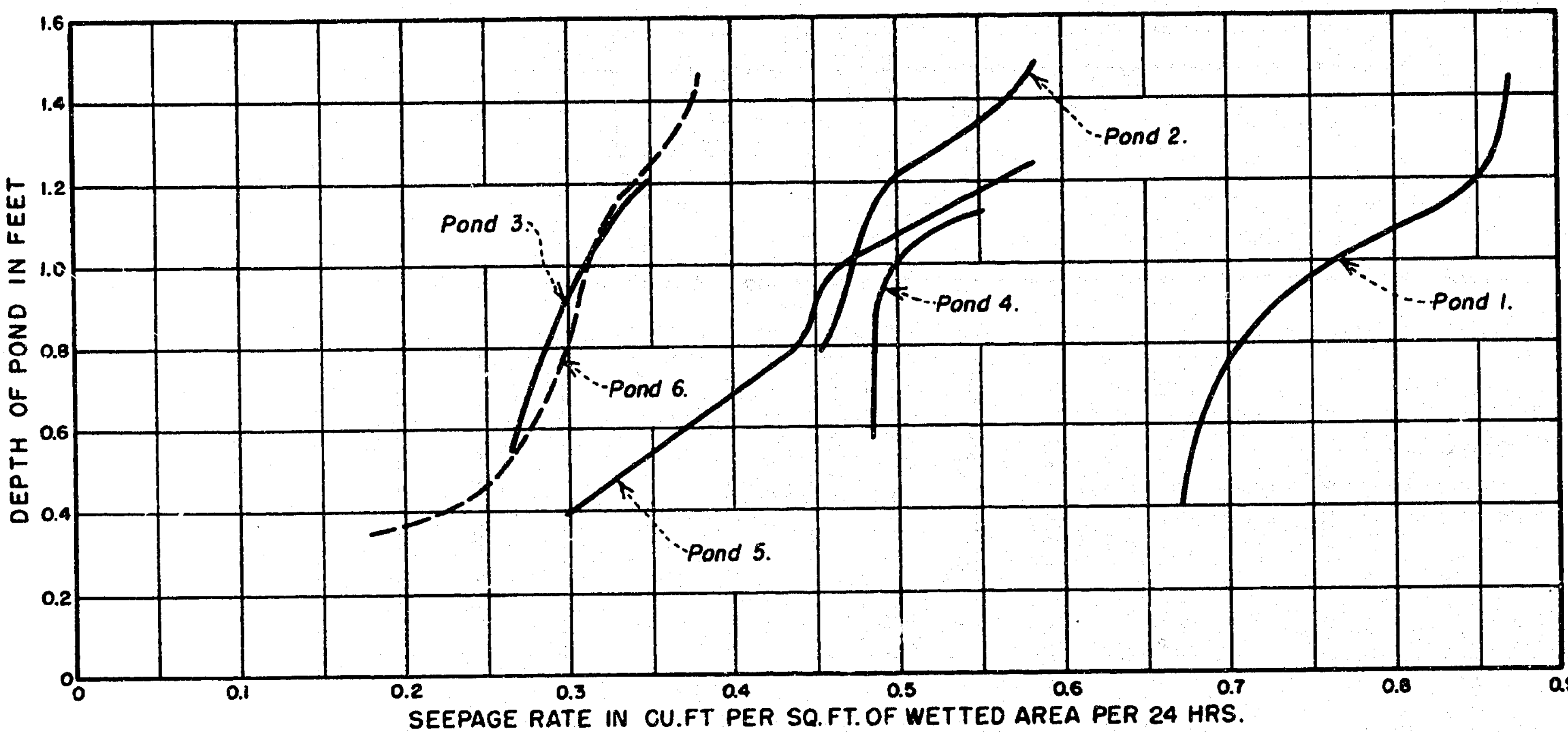
PONDING TESTS

FORT LARAMIE LATERAL 90.4

383
N.G.R. 3-2-50

HYD-297

FIGURE 16



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

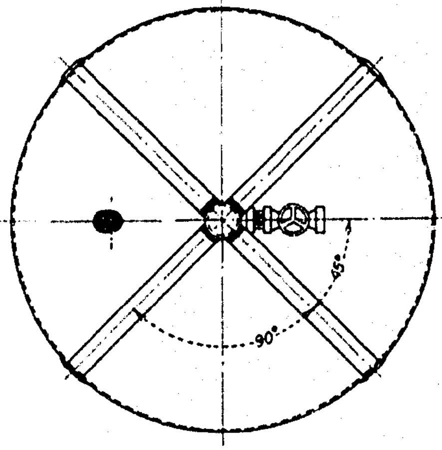
1949 SEEPAGE STUDIES

PONDING TESTS-INTERSTATE LATERAL 24A

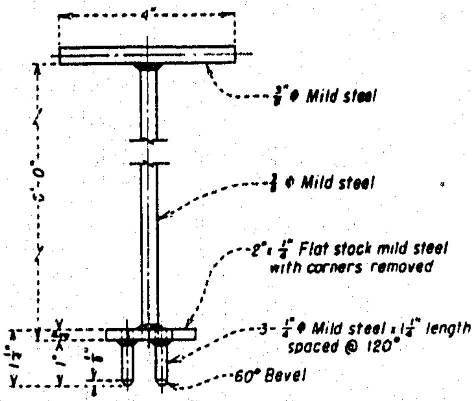
383

D.C.W. 3-2-50

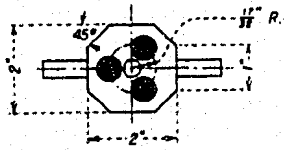
FIGURE 17



PLAN



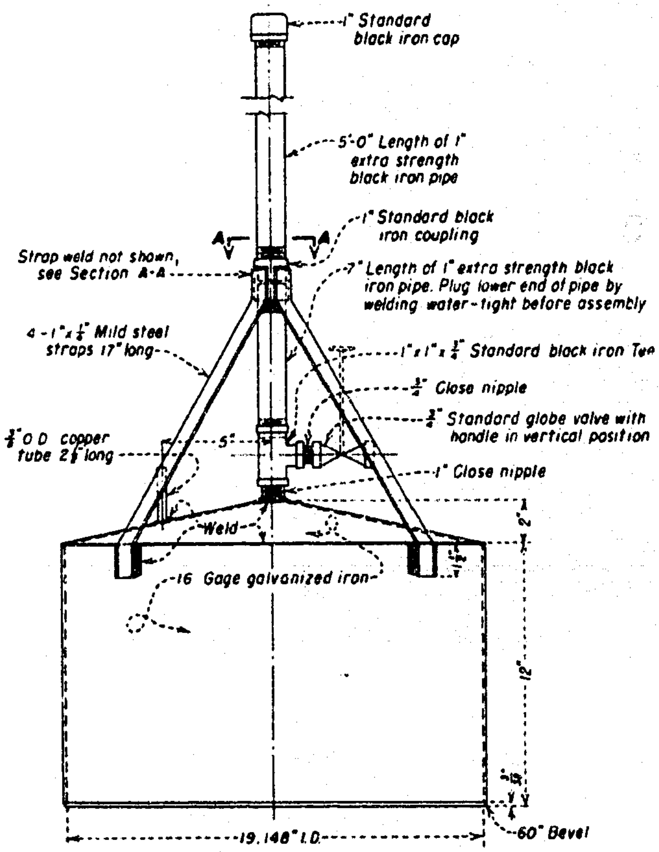
ELEVATION



BOTTOM VIEW

VALVE HANDLE EXTENSION

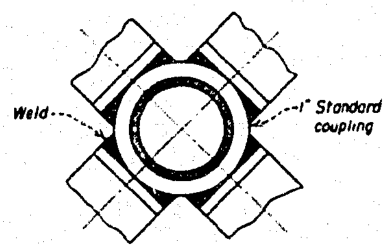
SCALE OF INCHES



ELEVATION

SEEPAGE METER.

SCALE OF INCHES



SECTION A-A

NOTES

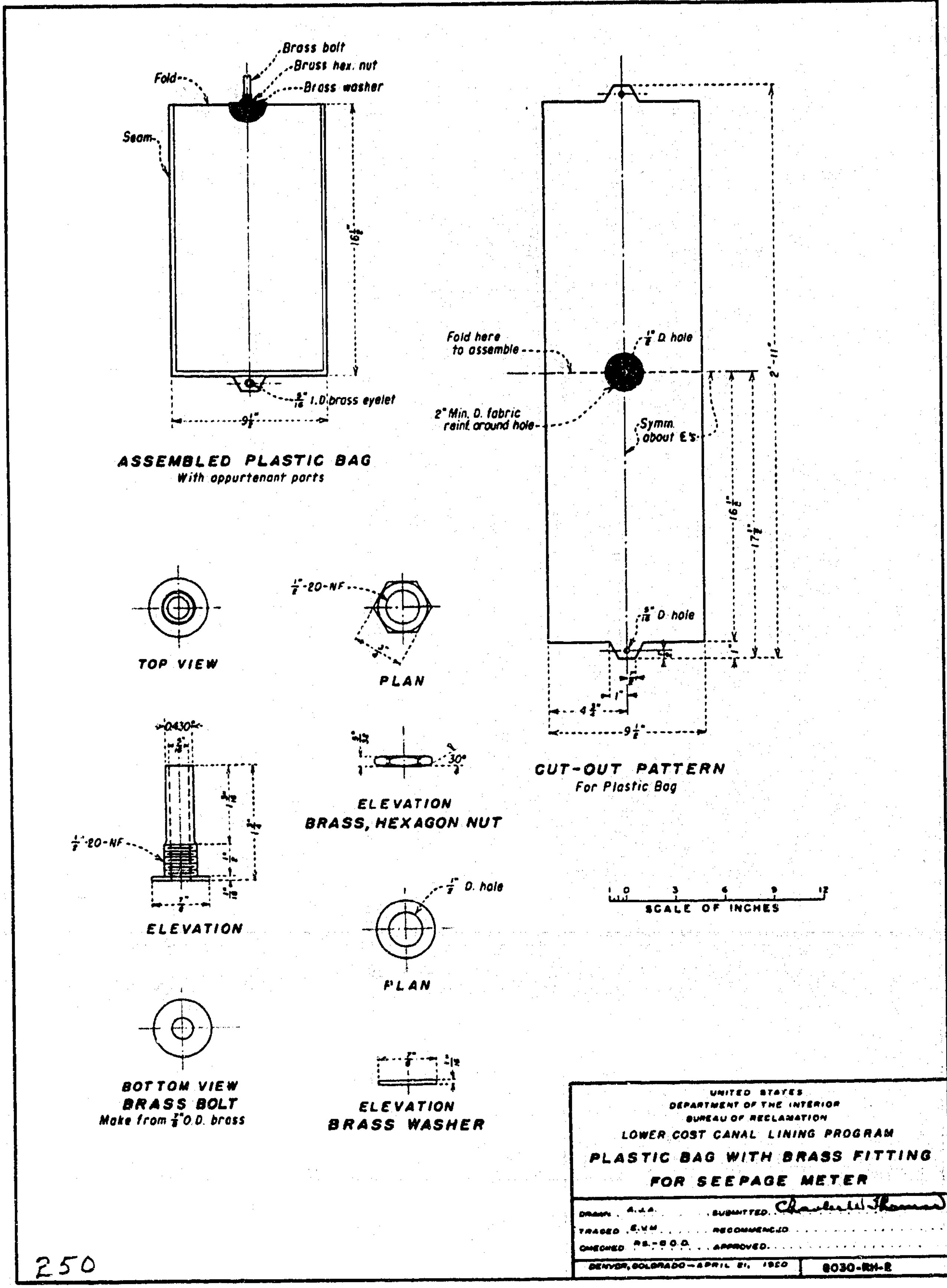
Paint all exposed parts, except brass, with aluminum paint.
All welds on seepage meter, except welds on straps, to be water-tight.
All parts of valve handle extension to be welded together using appropriate size welds.

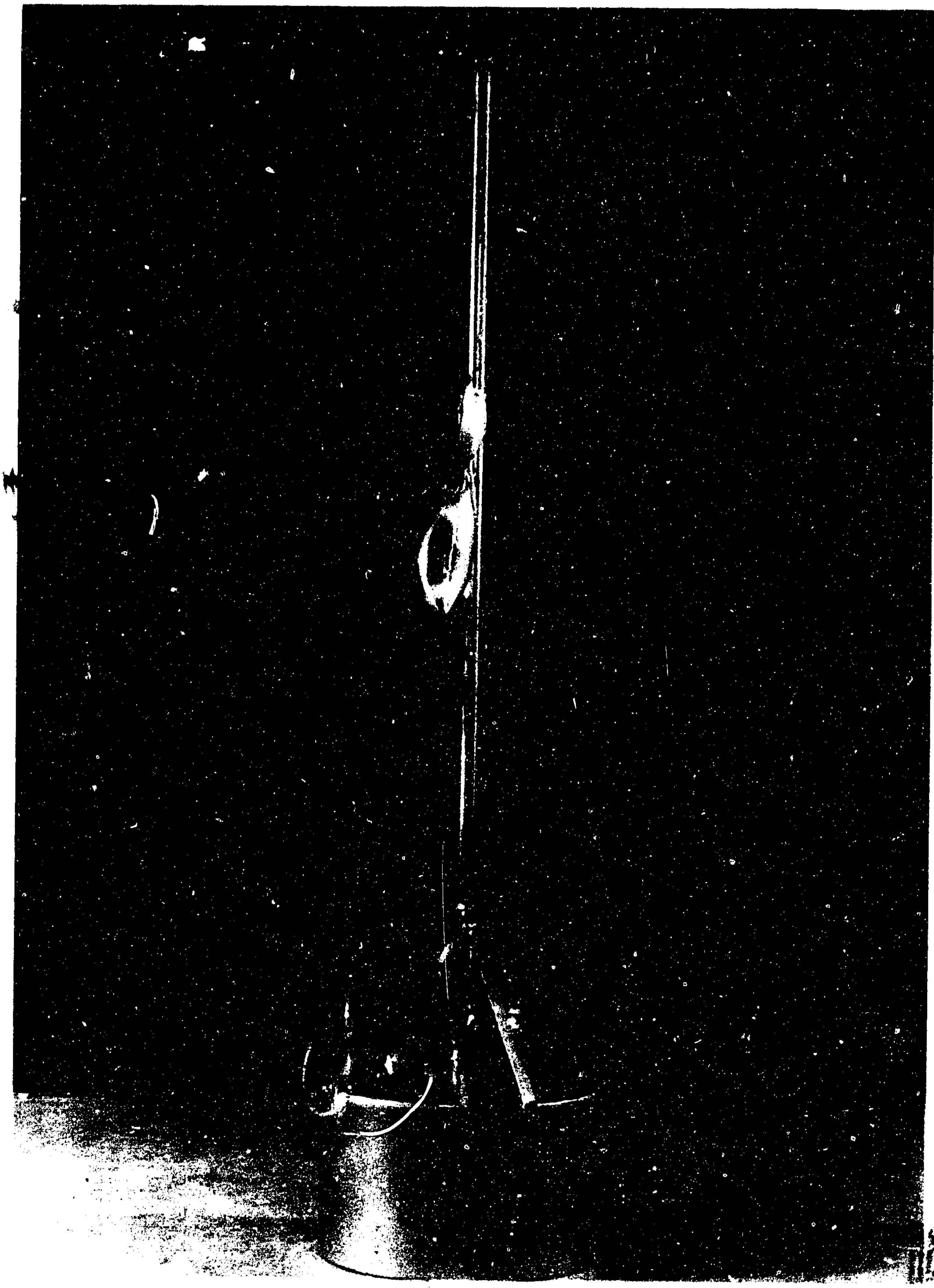
UNITED STATES
DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION
LOWER COST CANAL LINING PROGRAM

SEEPAGE METER
AND VALVE HANDLE EXTENSION

DRAWN A.J.A.	SUBMITTED Charles W. Thomas		
TRACED E.V.H.	RECOMMENDED		
CHECKED R.S.-C.O.O.	APPROVED		
DENVER, COLORADO — APRIL 26, 1950		8030-RH-1	

FIGURE 19


Brass bolt
Brass hex. nut
Brass washer
Fold
Seam
I.D. brass eyelet
ASSEMBLED PLASTIC BAG
With appurtenant parts
Fold here to assemble
D. hole
2" Min. D. fabric reinf. around hole
Symm. about ℄'s
D. hole
CUT-OUT PATTERN
For Plastic Bag
TOP VIEW
-20-NF
PLAN
0.430"
-20-NF
ELEVATION
ELEVATION
BRASS, HEXAGON NUT
30°
D. hole
PLAN
SCALE OF INCHES
0 3 6 9 12
BOTTOM VIEW
BRASS BOLT
Make from 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
SUBMITTED
TRACED
RECOMMENDED
CHECKED
APPROVED
DENVER, COLORADO—APRIL 21, 1950
8030-RH-2



SEEPAGE METER

Form DCT-27
11-49
Bureau of Reclamation

SEEPAGE METER DATA SHEET

Project ______________________ Canal ______________________ Sheet ____ of ____

Meter Depth ______________ Meter Area ______________ Weather ______________

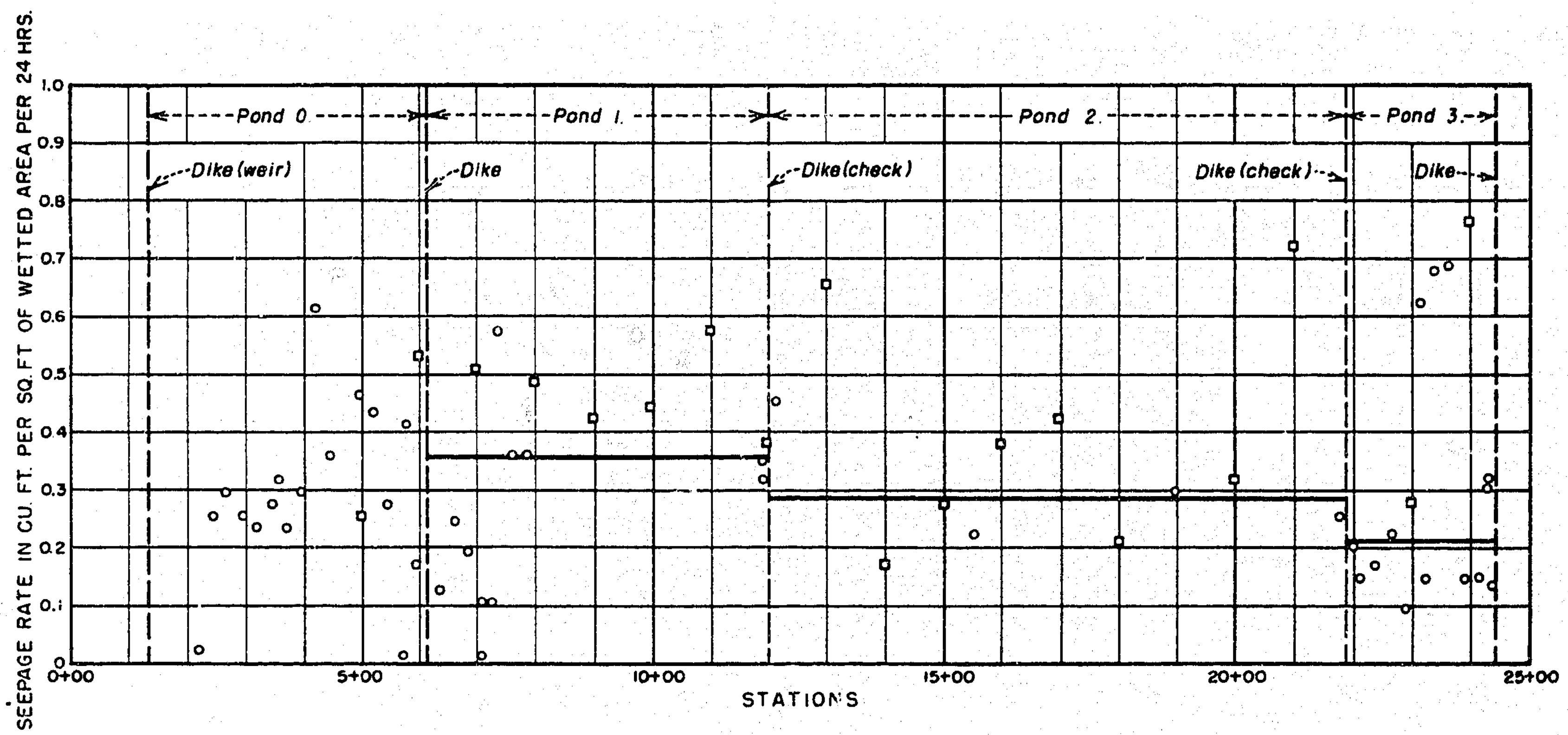
Variation of WS from Normal ______________________________ Design Capacity __________

Percent Cut __________ Fill ______________ Soil Type ______________

Observer ______________________________ Date ______________

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

FIGURE 21



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.

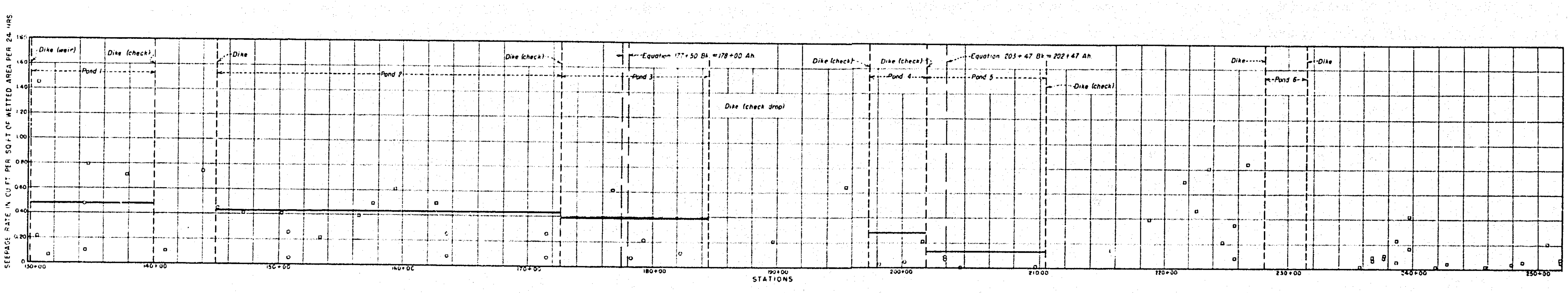
NORTH PLATTE PROJECT-WYOMING-NEBRASKA

1949 SEEPAGE STUDIES

SEEPAGE METER TESTS-FORT LARAMIE LATERAL 29.4

383

D.C.W. 3-8-50



EXPLANATION

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

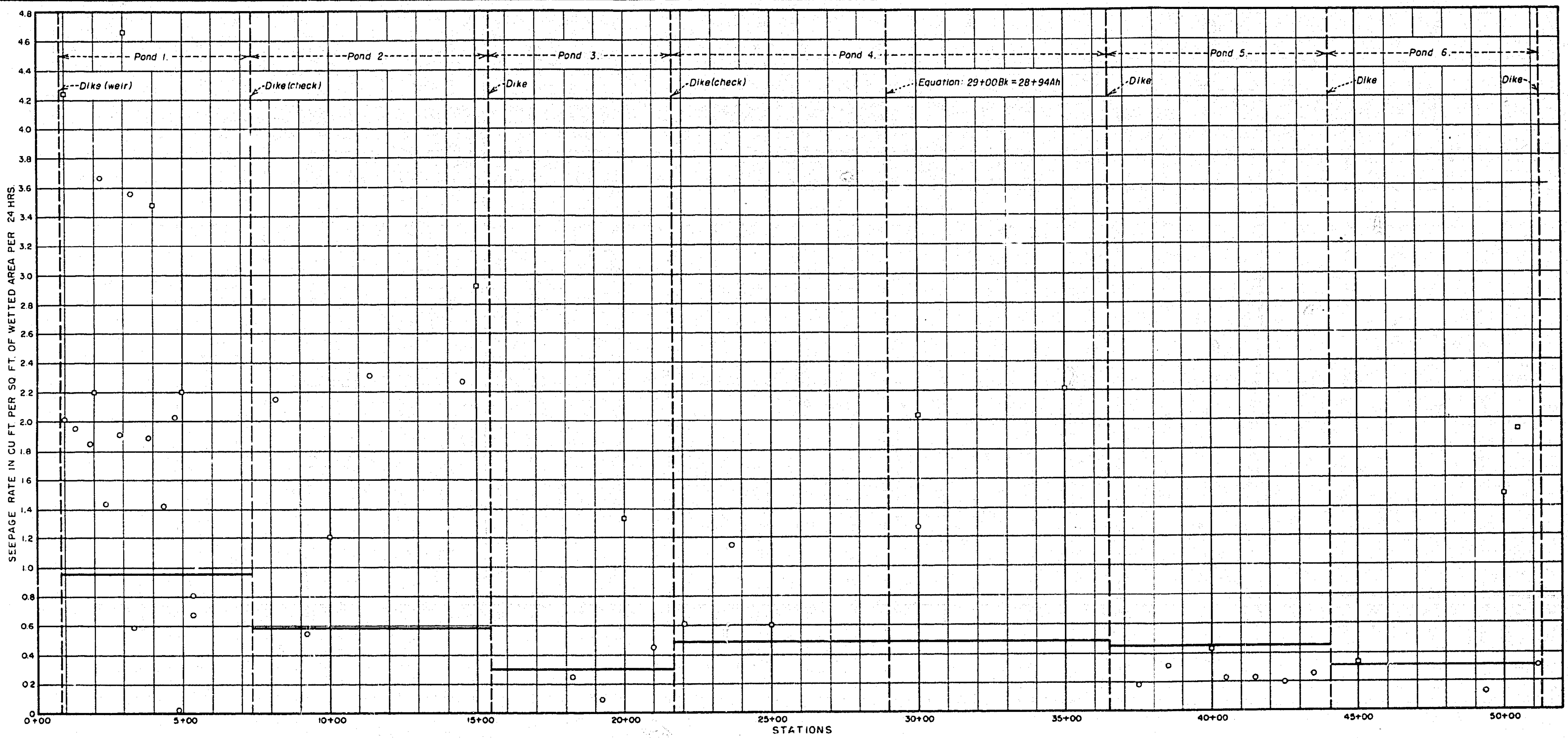
NORTH PLATTE PROJECT-WYOMING-NEBRASKA

1949 SEEPAGE STUDIES

SEEPAGE METER TESTS-FORT LARAMIE LATERAL 90.4

383

DC# 3-8-50

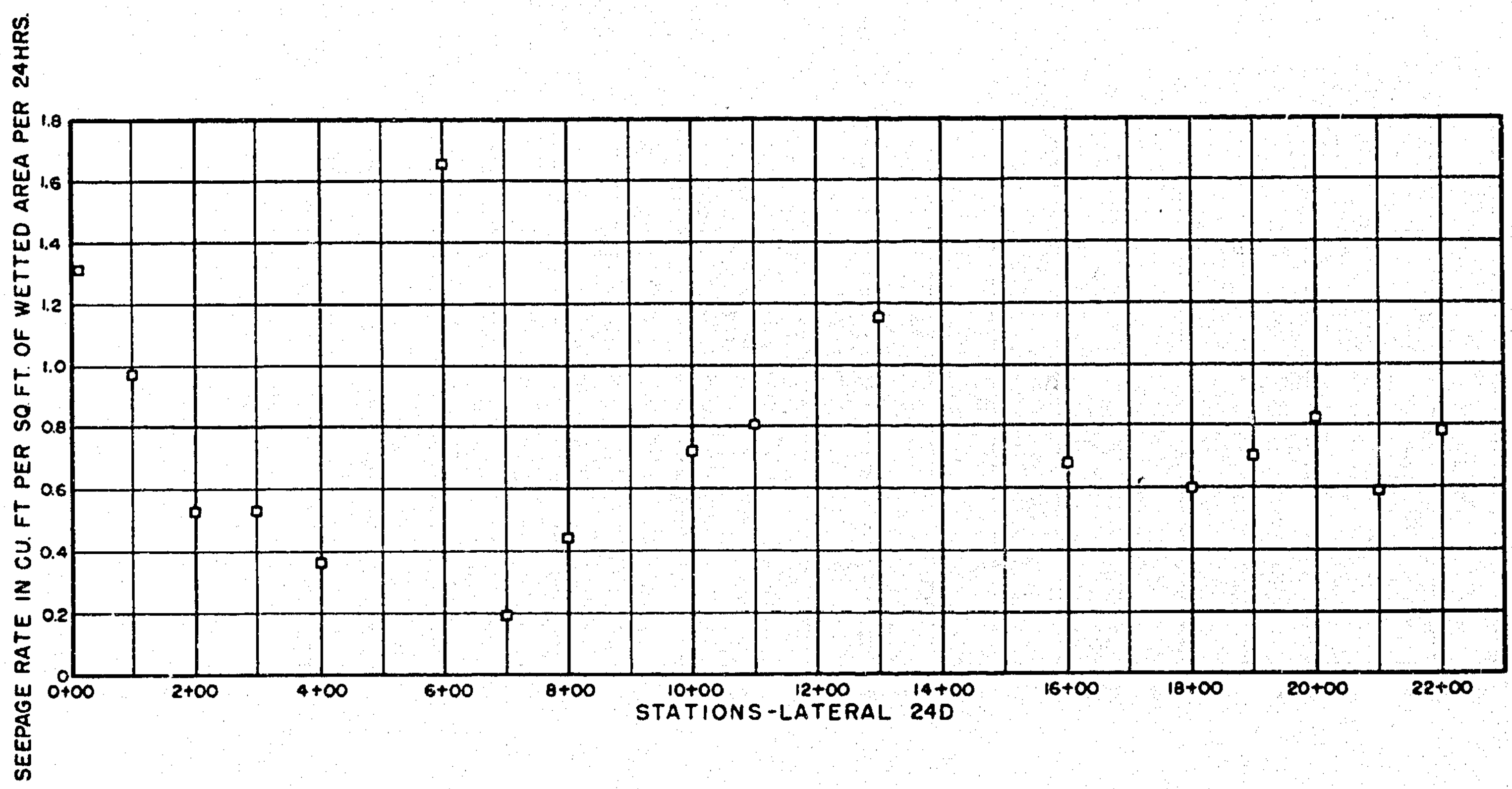


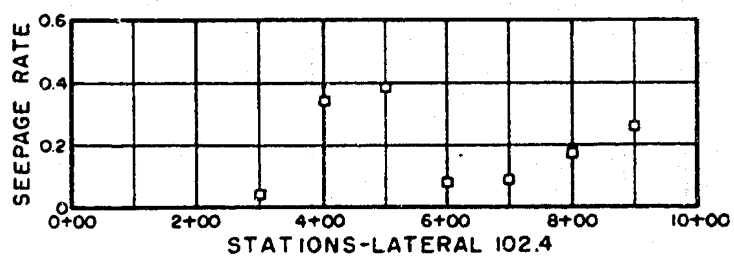
EXPLANATION

□ 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

383
H.G.A 3-8-50





EXPLANATION

▫ *Seepage meter in flowing water.*

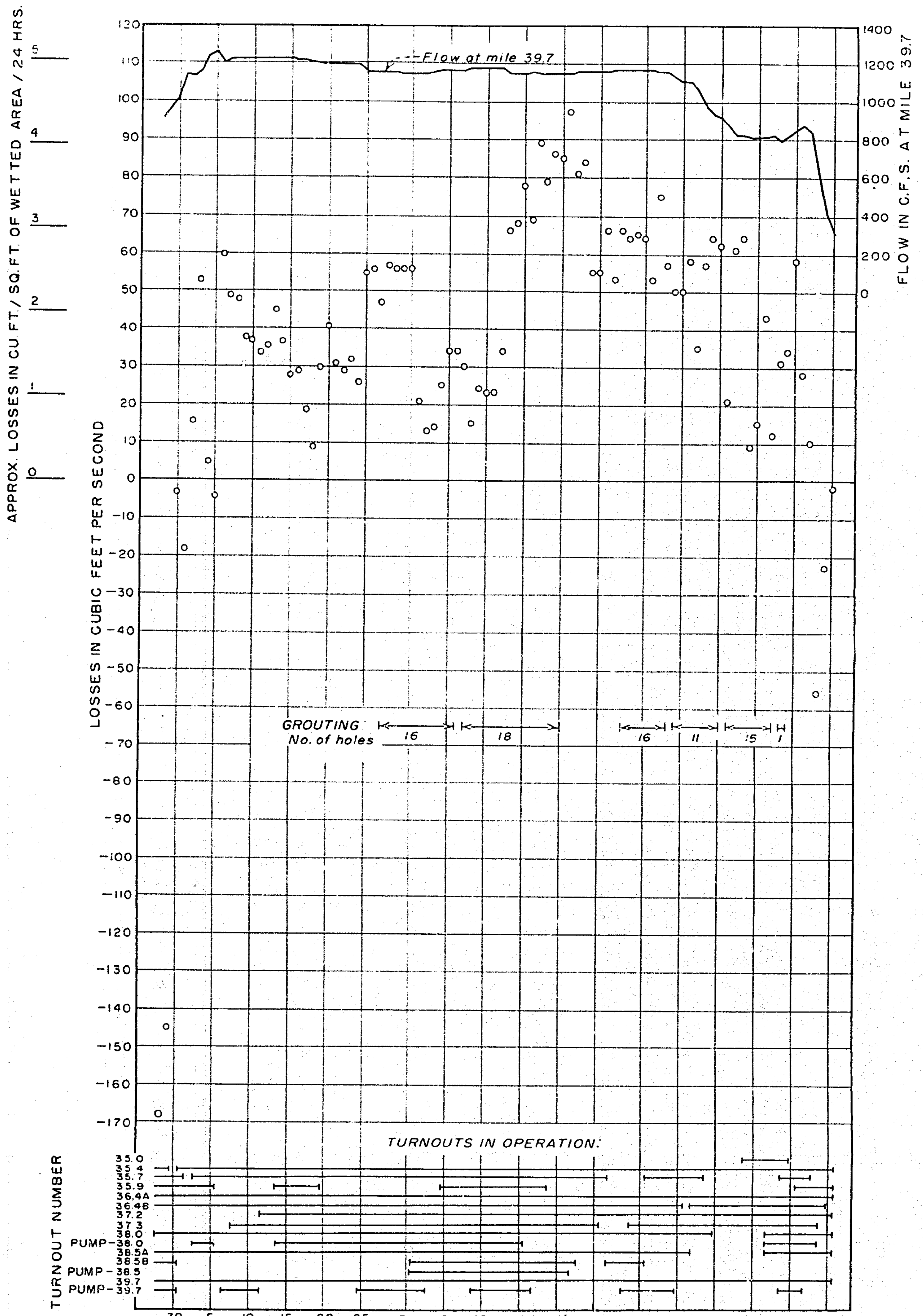
NORTH PLATTE PROJECT-WYOMING-NEBRASKA

1949 SEEPAGE STUDIES

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

383

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

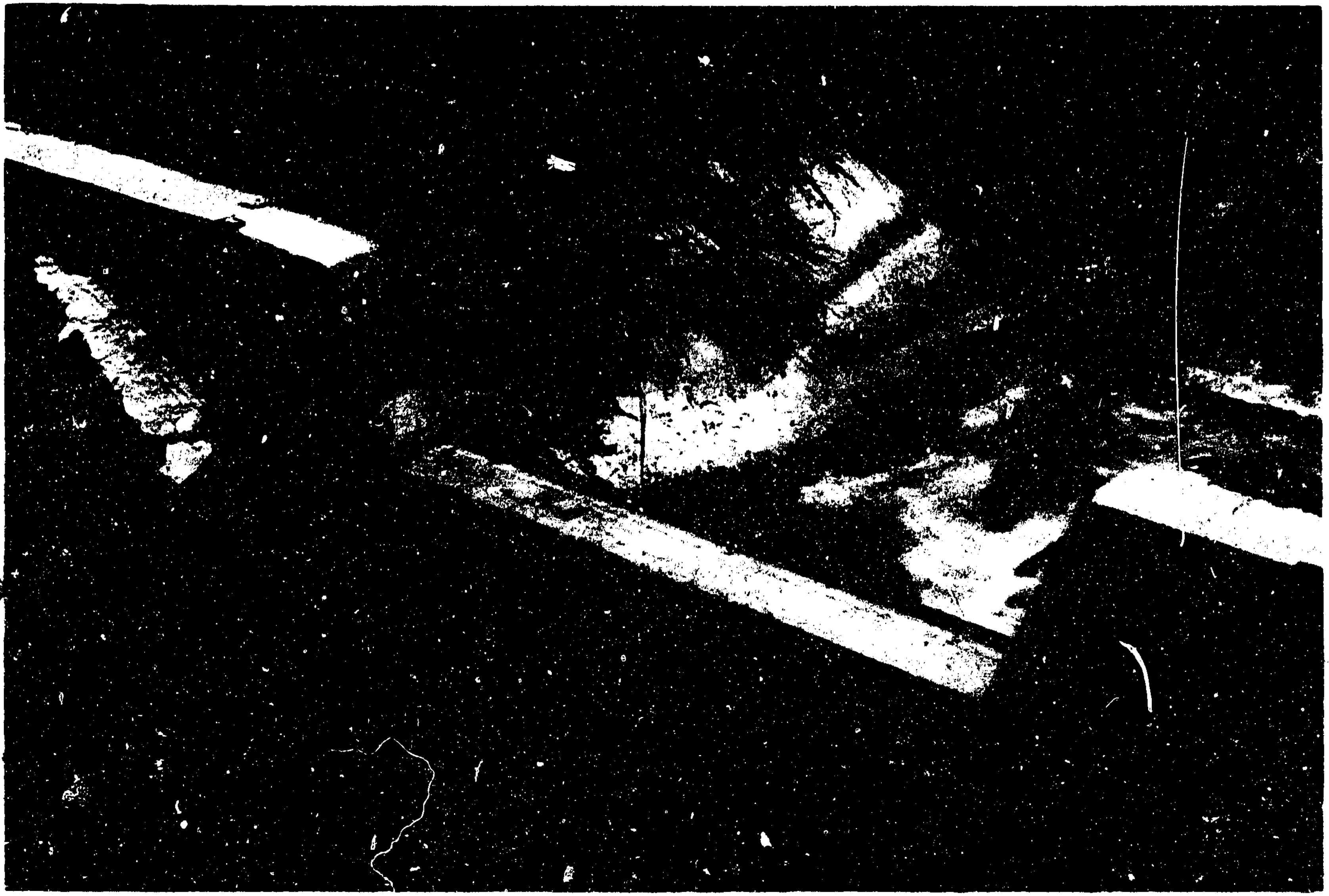
383
P.S. 3-7-50

FIGURE 26

HYD-297

FIGURE 27

Two-foot Cipoletti weir on Lateral 35.0, Fort Laramie Canal. The wooden weir crest is installed backwards and is in a poor state of repair. The staff gage is located too close to the weir and the upstream pool needs cleaning out. The photograph was taken on June 22, 1949. (H-844-3)



Six-foot Cipoletti weir in Lateral 35.4. This weir is installed backwards. Note the drain under the weir for sluicing out the upstream pool. This photograph was taken on June 22, 1949. (H-844-6)

FIGURE 28

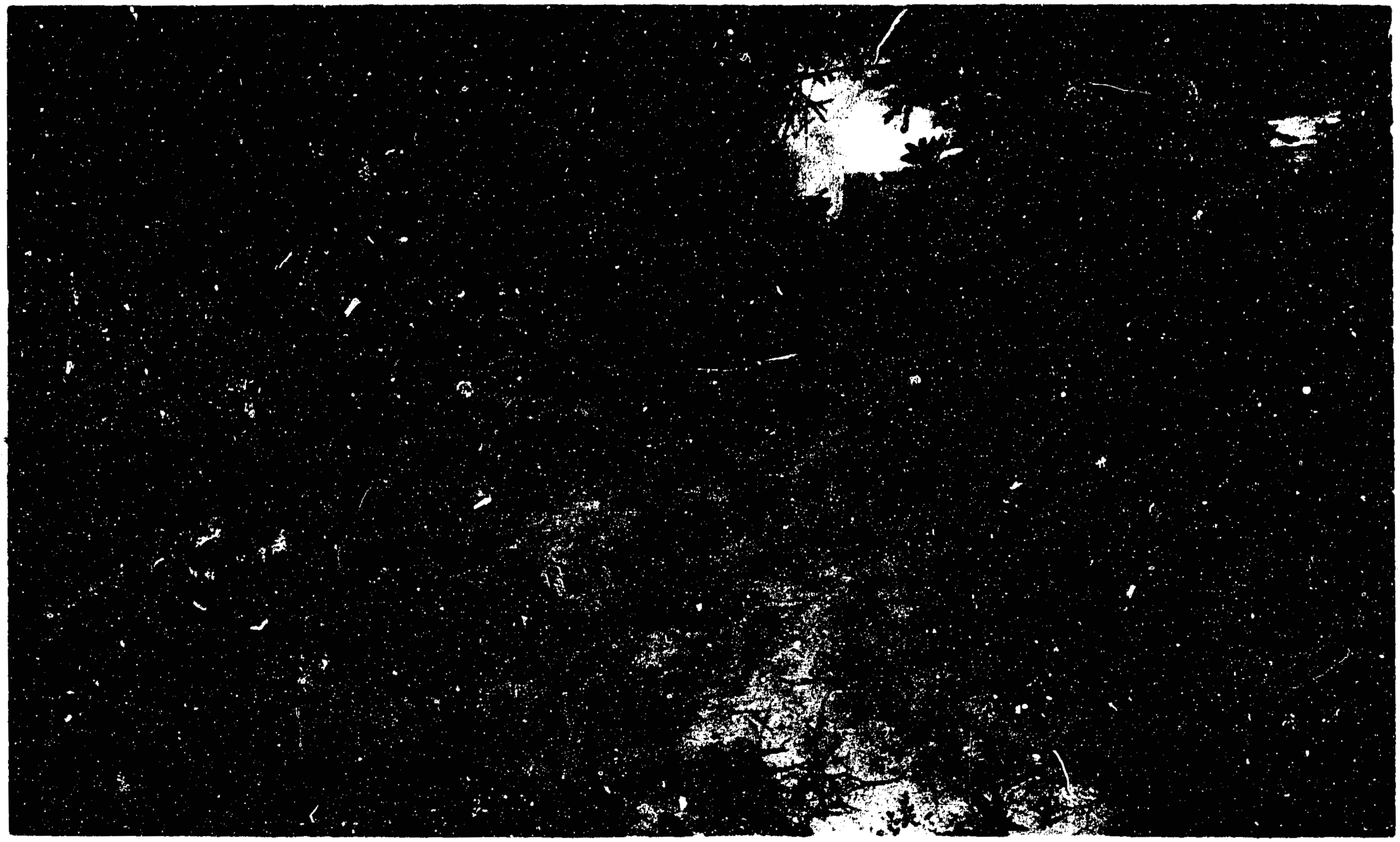
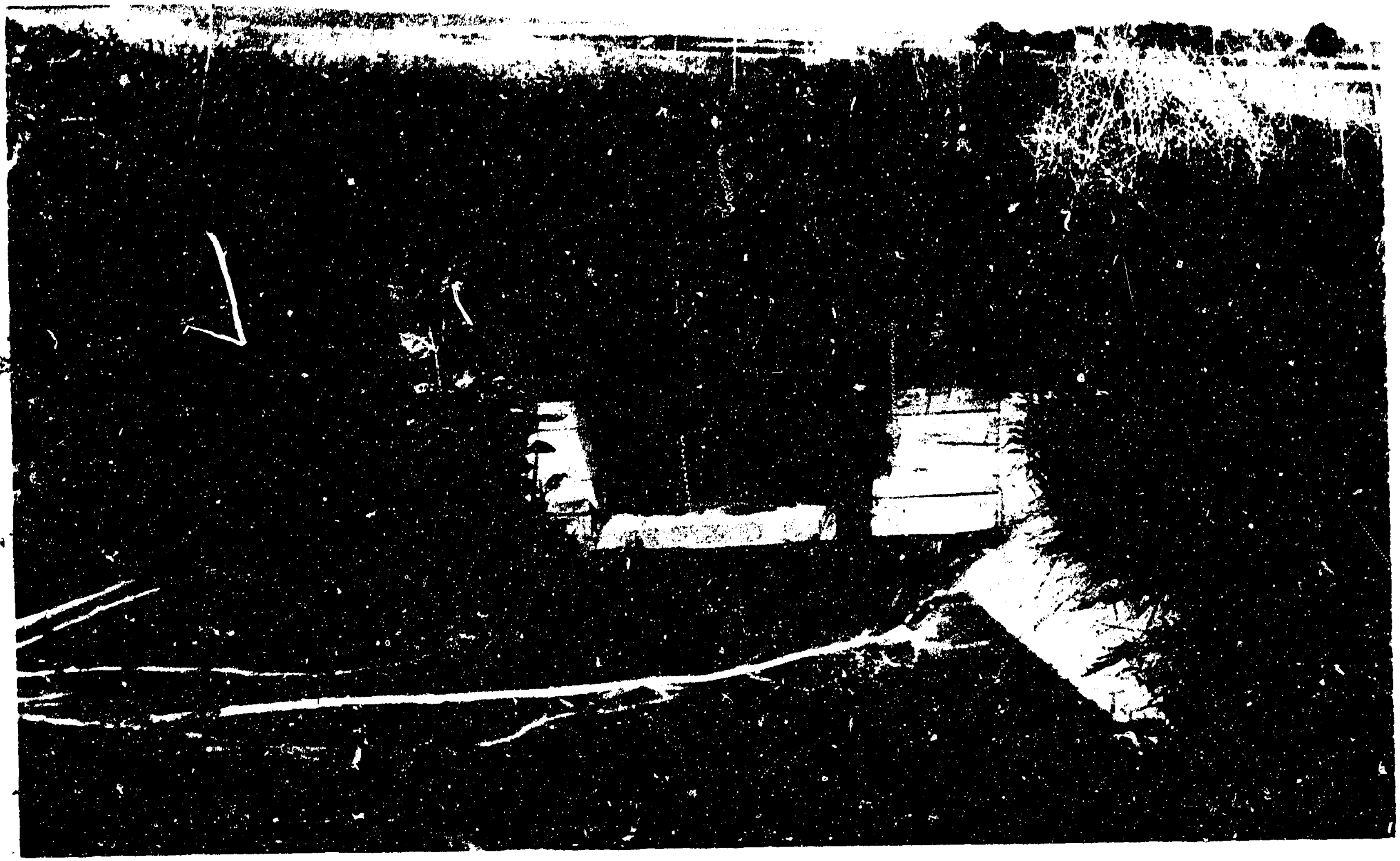


FIGURE 29

Two-foot Cipoletti weir on Lateral 35.9. This weir actually measured 23-3/4 inches. The weir gage is improperly located. There are four bolts that hold the weir plate to the bulkhead. There are several leaks around the weir plate. The upstream pool is badly silted up. June 22, 1949. (H-844-7)



Three-foot Cipoletti weir on Lateral 38.5. The upstream pool is badly silted and overgrown with vegetation. The weir blade is made of wood. This photograph was taken on June 22, 1949.

(H-844-1)

FIGURE 30

APPENDIX A

Mitchell, Nebraska

November 19, 1948

Mr. L. N. McClellan, Chief Engineer,
U. S. Bureau of Reclamation,
Denver Federal Center,
Denver, Colorado

Dear Mr. McClellan:

Responsive to your letter of November 10, 1948, addressed to the Chairman, during the afternoon of November 15 this Board examined the Fort Laramie Canal between miles 34.8 and 38.0 and, more specifically, that section immediately north of the Julius Barthel ranch or farm. The Board was accompanied by Mr. Burky of the Canal Division of your office and I. J. Matthews, District Manager, of the Casper office.

Leakage from various places along this canal has waterlogged several hundred acres of fine irrigated land: some of it has been rendered wholly unproductive and much of it can be farmed only with great care and inconvenience. The field examination showed quite clearly that water is not lost appreciably in the earth cuts or embankments but in the brule clay cuts. The safety of the canal in operation is not questioned as it is located well in the ground. The embankments were constructed with a diaphragm of selected material for that part of the perimeter in contact with the water and care was taken during construction to prevent the accumulation of the larger pieces of indurated materials from forming a natural drain at the bottom of any part of the embankments. The embankments are thoroughly seasoned, as this part of the canal has been in operation for nearly 30 years.

During the early years of operation, the North Platte River water carried a considerable amount of silt which, when diverted into the canals, had a sealing effect. However, after the storage of water in the Guernsey Reservoir was begun, the silt was dropped in the reservoir and clear water was diverted into the canal. During the ensuing years, the silt which had been deposited on the hard brule clay slopes gradually failed to maintain its position, particularly where in the brule clay the slopes had been excavated steeper than 1-1/2:1 for economy in construction. Wet spots began to show up below the canal where there was no evidence of leakage in the earlier years when the silt was in place.

Brule clay is a sedimentary formation which, in its natural bed, resembles rock in hardness. It requires loosening with powder to expedite excavation even with heavy dragline buckets. In its natural bed it shows definite layers and seams. It can be assumed that the use of explosives when the deeper cuts were excavated loosened the seams in the unexcavated sides of the cuts.

Mr. Matthews stated that the rehabilitation measures proposed for reducing the water losses from the canal consisted of the installation of concrete lining. Apparently plans have not been far enough advanced to indicate the thickness of concrete; whether the concrete will be plain or reinforced; whether the concrete would be placed continuous or with joints and, if the latter, at what spacing; or whether drainage is to be provided and, if so, what type of drainage.

The Board is of the opinion that the following measures will cure the leakage problem, named in order of preference and probably overall economy:

(a) Pressure grouting the left-hand side of the brule clay cuts.

(b) Shaping the side slopes of the brule clay cuts to a slope not steeper than 1-1/2:1 and placing thereon an earth or clay lining about 12 inches in thickness.

(c) Constructing several miles of drainage ditches to connect with the main Cherry Creek Drain which, in turn, empties into the North Platte River.

(d) Concrete lining.

These measures are now discussed in reverse order.

(d) Concrete lining placed in this section will not be damaged by settlement of the foundation because it has been subjected to water pressure for many years. It is not likely to be broken up by hydrostatic pressure caused by excessive rainfall if precaution is taken to prevent damage resulting from freezing of the foundation.

Concrete lining will be subjected to alternate freezing and thawing unless laid on a foundation which is completely free draining. Unless this heaving action is prevented, the lining will be broken and gradually disintegrate even with careful patching and replacing.

If concrete lining is to be placed, it should be laid on a foundation, sides and bottom, of gravel 6 inches to 8 inches in thickness with a tile drain in the center of the invert having a free outlet. Use of this method of insuring the life of the lining will be quite expensive, and the Board does not recommend the use of concrete lining in this instance.

(c) The construction of drainage ditches in a system which has been in operation as long as this one is an admission that the canal leakage must go on forever and that it is the most economical way of handling an unpleasant situation. They necessitate public and private bridges and water crossings, must be cleaned and maintained, use land which should grow crops, provide breeding places for pests and interfere with the farmers' operations. This alternative is not recommended by the Board.

(b) An earth lining of selected materials, if placed on side slopes not steeper than 1-1/2:1, provides a flexible member of reasonable water tighness. The degree of water tighness depends to a large extent on the suitability of available materials. It is not damaged by freezing and is particularly adapted to a canal of low velocity such as the Fort Laramie Canal. While its first cost and annual maintenance are comparatively low, it is not recommended for installation for the situation in question unless the preferred plan of pressure grouting is proven, by trial, to be impracticable. If the earth lining is finally adopted, consideration should be given to the incorporation of a diaphram of sprayed on asphalt as suggested in the Holtz-Benson-Hosig report of May 19, 1948, over a part of the length of canal to be treated. Should the lining of the side slopes only fail to stop the leakage, consideration should be given to lining the invert also.

(a) Pressure grouting the rock seams and fissures in dam foundations and abutments has been a successful construction procedure for many years. The chairman of this Board was in charge of grouting the brule clay foundation of the Minatare Dam in 1915. The North Platte Project history for that year should furnish details of this operation which was highly successful in reducing leakage through the brule clay foundation.

RECOMMENDATIONS

1. It is the recommendation of this Board that low pressure grouting plan (a), be tried in a portion of the brule clay cuts on the Fort Laramie Canal. It is suggested that holes 4 inches in diameter be drilled along the left bank at 20-foot centers and to a depth of 10 feet below the invert of the canal; that these holes be tested under water pressure to determine the rate of leakage and whether water pumped into one hole finds its way into other holes; that the holes be grouted under pressure; that two or three holes be drilled into the grouted area to depth of 30 feet below the invert of the canal and that they be tested under water pressure, using expanding packers, to determine the effectiveness of the grouting at 10-foot intervals and the rate of leakage in the three 10-foot intervals; and that if pressure grouting to depth of 10 feet below the canal invert is not fully effective the program be repeated, at the same location, using holes drilled to 20 or 30 feet below canal invert, depending on the information obtained from the two or three test holes mentioned above.

The drilling can be done wi[illegible] lard well drilling machine. The make-up of the grout will have to [illegible] ed by the "take" of each hold. In some cases the seams and c[illegible] be so small that water and cement only can be used. The spaci[illegible] and the grouting pressure should be varied as experience dicta[illegible] lan has promise of being the most effective, as well as the m[illegible] cal, in reducing canal leakage in brule clay cuts. It can be [illegible] with either a full canal or an empty one. When accomplished [illegible] permanent.

2. If grouting of the brule clay [illegible] be feasible, it is recommended that it be adopted.

3. If grouting of the brule clay is found to be infeasible, either from a physical or financial standpoint, it is recommended that the earth lining, plan (b) be adopted.

Respectfully,

H. W. Bashore, Chairman.

Walker R. Young.

H. D. Comstock

CC-H. W. Bashore (2)
W. R. Young
H. D. Comstock
Commissioner
Reg. Dir., Denver, Colo.
Dist. Mgr., Casper, Wyo. (2)

BC-Nalder
McBirney
Burky
Blanks

APPROVED: December 8, 1948

L. N. McClellan
Chief Engineer