FOREWORD

The following reports on Seepage Losses from Canals in Texas are original copies in the files of the State Board of Water Engineers and the Division of Irrigation, Soil Conservation Service, U. S. Department of Agriculture, Austin, Texas; and, heretofore, have never been published nor made available for distribution:

Estimate of Seepage Loss from Proposed Main Canal of Starr County Water Control and Improvement District No. One, by R. G. Hemphill.

Leakage of Water from Irrigation Channels and Concrete Lined Canals in the Lower Rio Grande Valley of Texas, by O. A. Faris.

Canal Losses on San Benito Irrigation Project (Cameron County Water Improvement District No. Two) by O. A. Faris.

Miscellaneous Data on Seepage Losses from Canals in Texas for 1921. (Bexar-Medina-Atascosa Counties Water Improvement District No. One) by H. C. Pritchett.

Miscellaneous Data on Seepage Losses from Canals in Texas for 1922. (United Irrigation District - Hidalgo County Water Control and Improvement District No. 7) by H. C. Pritchett.

Dean W. Bloodgood
Irrigation Engineer
Division of Irrigation
Soil Conservation Service
U. S. Department of Agriculture

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U. S. DEPARTMENT OF AGRICULTURE
BUREAU OF PUBLIC ROADS
DIVISION OF AGRICULTURAL ENGINEERING
S. H. McCrory, Chief
W. W. McLaughlin, Associate Chief

ESTIMATE OF SEEPAGE LOSS FROM PROPOSED MAIN CANAL OF STARR COUNTY WATER CONTROL & IMPROVEMENT DIST. NO. 1

R. G. Hemphill
Associate Irrigation Engineer

Prepared under the direction of W. W. McLaughlin, Associate Chief.

San Antonio November 28, 1927

PROBABLE SEEPAGE LOSS FROM EARTH CANAL ON PROPOSED LOCATION OF MAIN CANAL OF STARR COUNTY WATER CONTROL AND IMPROVEMENT DISTRICT NO. 1

This report covers an investigation which had for its main object an estimate of the probable seepage loss from an earth canal on the proposed line of the main canal of the Starr County Water Control and Improvement District No. 1. The investigation was made at the request of the Texas State Board of Water Engineers.

The Starr County Water Control and Improvement District No. 1 comprises irrigable lands lying in a narrow strip not exceeding 4½ miles in width along the north bank of the Rio Grande between the towns of Roma and LaGrulla in Starr County, Texas. After its organization the District filed with the State Board of Water Engineers an application for a permit with tentative plans for a main canal 47 miles long with a capacity of 200 second feet, to head at Roma and to be supplied by pumping from the Rio Grande through a lift of 63 feet. After a hearing, the Board, on September 29, 1926, entered an order granting a permit carrying 76,210 acre feet annually for the 38,105 acres of the District, but with the following proviso:

> Provided that all canals and laterals used for the distribution of water on this system shall be lined with concrete except such portions of said canals and laterals as may be exempted from this requirement by the Board of Water Engineers.

Since the Board is required to pass on the plans of the proposed system of an irrigation district before bonds for construction are approved, the tentative plans were examined by the Board and a new line for a part of the main canal was advised. By providing

a short tunnel, syphons for long draws, and a few small second-lift or booster plants, the new line, without sacrificing any considerable acreage, reduces the lift at Roma from 63 to 38 feet and shortens the main canal by 12 miles. The end of the Board's line at Station 874 joins the original line at Station 1515.

The nature of the condition attaching to the permit led the District to examine the soil and subsoil along the proposed line of the main canal. This work was done by J. H. Selleck, an assistant of the contracting engineer for the District. Mr. Selleck states that he proceeded along the line exploring with a soil auger and sinking test pits as each substantial change of soil was encountered. These pits are about 4 feet in depth and more than 25 were put down.

The organizers of the District have protested that the requirement carried by the permit puts upon the District an unduly severe burden and are not inclined to proceed with the development of the project unless the requirement is eliminated or modified to a very substantial degree.

In accordance with the request of the Board of Water Engineers, the writer in company with C. S. Clark, member of the Board, made a trip to Rio Grande City, headquarters of the District, and inspected the proposed location of the main canal. The majority of the test pits were visited and samples of soil at 1 foot and 4 feet below the surface were taken. Several pits were filled with water from recent rains and our limited time made it necessary also to skip several

pits near the lower end of the line where, according to Mr. Selleck, the changes in soil were not great.

Location of Pits.

Before beginning the trip along the line of the canal, the writer asked the contracting engineer of the District and his assistant for maps by which the locations of the test pits could be fixed, but was informed that no maps were available for field use. The party then drove along the line and samples were taken from 19 pits. These samples were marked to show the consecutive number of the pit sampled and carried notations referring to any available nearby physical features by which their locations could later be determined. So far as the writer could see, the pits were not marked in any way. At the end of the trip the attention of the contracting engineer and his assistant was again called to the necessity for data to fix the locations of the pits sampled, and they agreed to forward the data immediately. This they failed to do. Two weeks later, in response to a letter again requesting the data, the following list of locations was received:

SOIL TEST HOLES-STATION NUMBERS

RIO GRANDE CITY TO ROMA.

For projection on line laid out by Board of Water Engineers.

Holes.				
1-West.	700+00	Sample taken	Porcion 77;	Camargo.
2-West	622-00	" "	" 76;	"
3-West	587-00	Full of water	" 75,	"

4-West.	562-00	Full of water	Porcion	75;	Camargo.	
5- "	527-00	Sample taken	"	74,	"	
6- "	458-00	" "	"	72,	"	(South of Hwy)
7- "	445-20	" "	"	72;	"	" " "
8- "	394-00	" "	"	71,	"	" " "
9- "	352-00	" "	"	70,	"	(North of Hwy)
10- "	281-75	No sample taken	"	78,	Meir.	
11- "	240-00	Sample taken	"	77,	"	
12- "	200-00	Full of water	"	76;	"	
13- "	169-00	" " "	"	75,	"	
14- "	99-80	" " "	"	74,	"	
15- "	17-00	Sample taken	"	72,	"	

RIO GRANDE CITY TO EASTERN END OF DISTRICT.

1-East.	824-00	Sample taken	Porcion	80,	Camargo.	(N.& edge City)
2- "	864-00	Washed out	"	81,	"	(Olmos creek)

END OF WATER BOARD MAP

Start at Canal Line laid out on profile and alignment map beginning with sheet 14 of 29.

3-East.	1596-00	Sample taken	Porcion	81;	Camargo	
4- "	1662-00	" "	"	82;	"	
5- "	1737-00	" "	"	83;	"	
6- "	1861-00	" "	"	86,	"	
7- "	1987-00	" "	"	90;	"	
8- "	2174-00	" "	"	93;	"	(on road to La Grulla)
9- "	2347-00	" "	"	95,	"	(near Rio Grande River)

This list accounted for only 17 of the 19 pits sampled. The contracting engineer of the district was therefore requested to have his assistant go over his records and supply the missing locations. In reply to this request it was stated that one omitted location was Station 2033 and that the other was probably Station 2114. The tone of the reply, together with the original failure of the contracting engineer

to forward the data promptly as agreed, made it clear that no serious effort had been or would be made to furnish the correct locations. With the proper source of information thus closed, in order to tie in the samples to the pits from which they were taken it was necessary to depend on such information as had been furnished and such checks as were afforded by maps of the International Boundary Commission and maps on file in the office of the Board of Water Engineers. The pits sampled and their locations as determined from the available data are given below. It should be noted that some of the pits were in the brush with no distinguishing feature which could be used for identification, and that the writer was dependent upon local members of the party for names of communities and numbers of porcions.

Pit Sampled	Marking of sample to Identify Pit	Station Number
10th West	First pit east of Roma	17-00
9th West	Pit north of highway and west of Moreno. . .	240-00
8th West	First pit south of highway and west of Rosita	281-75
7th West	Pit at Rosita.	352-00
6th West	. . . . .	394-00
5th West	. . . . .	445-20
4th West	First pit south of highway from Rio Grande City to Roma.	458-00
3rd West	. . . . .	527-00
2nd West	. . . . .	622-00

Pit Sampled	Marking of Sample to Identify Pit	Station Number
1st West	Pit in Porcion 77	700-00
0	Pit at north edge of Rio Grande City.	824-00
1st East	. . . . .	1596-00
2nd East	Pit west of Santa Cruz. First or second pit east of Olmos Creek. Porcion 82	1662-00
3rd East	Pit on Porcion 83 at highway	1737-00
4th East	Pit on Porcion 84	1861-00
5th East	Pit on Porcion 88. Third pit from railway and highway crossing	1987-00
6th East	First pit east of Garcia	2033-00
7th East	Second pit on road to La Grulla. Second pit northwest of La Grulla	2174-00
8th East	Last pit. Near river	2347-00

Of the sampled pits west of Rio Grande City, the location of the eighth is doubtful. Of the sampled pits east of Rio Grande City, the locations of the first to sixth, inclusive, are doubtful. The first pit sampled may have been at Station 864 instead of Station 1596, in which case the locations of the six as shown above are shifted one pit eastward. An estimate of seepage losses involving these doubtful locations will carry as high a degree of accuracy as is warranted by other more or less indeterminate factors, but the Board of Water Engineers is not justified in accepting the locations as a basis for releasing from the proviso of the permit any portion of the main canal.

Mechanical Analyses of Samples.

Mechanical analyses of the soil samples were made in the silt laboratory at Austin, the greater part of the work being done by O. A. Faris and Dow Warren. The laboratory is not completely equipped for such work. A motor driven shaker was improvised; the State Health Department kindly furnished a microscope; and stage and eye-piece micrometers were secured through the courtesy of the Botany Department of the University of Texas. Samples weighing either 10 or 25 grams were put in 8-ounce bottles, 100 c.c. of distilled water and a few drops of ammonia added, and the bottle shaken for 12 to 24 hours. The sands were then screened out with a 280-mesh screen, dried, and separated into grades with 20-, 40-, 60-, and 160-mesh screens. The clay and silt were separated by repeatedly washing and drawing off the water containing the clay in suspension after microscopic tests had shown that the silt had settled. The separates were filtered and weights were determined after drying in an electric oven at 110 c. The result of the analyses follow:

Pit at Station 17-00

Depth: 1 Foot	Percent	Depth: 4 Feet	Percent
Gravel	0.2	Gravel	0.1
Coarse sand	0.1	Coarse sand	0.1
Medium sand	0.2	Medium sand	0.1
Fine sand	27.2	Fine sand	13.8
Very fine sand	20.7	Very fine sand	22.0
Silt	40.7	Silt	52.1
Clay	10.9	Clay	11.7
	100.0		100.0
Classification: Loam		Classification: Silt Loam	

Pit at Station 240-00

Depth: 1 Foot

	Percent
Gravel	0.1
Coarse sand	0.2
Medium sand	0.4
Fine sand	1.9
Very fine sand	3.0
Silt	44.6
Clay	49.7
	99.9

Classification: Clay

Depth: 4 Feet

	Percent
Gravel	0.1
Coarse sand	0.2
Medium sand	0.2
Fine sand	0.5
Very fine sand	1.2
Silt	72.7
Clay	25.1
	100.0

Classification: Silty clay loam

Pit at Station 281-75

Depth: 1 Foot

	Percent
Gravel	0.4
Coarse sand	0.9
Medium sand	17.7
Fine sand	45.3
Very fine sand	8.1
Silt	11.8
Clay	15.8
	100.0

Classification: Sandy Loam

Depth: 4 feet

	Percent
Gravel	0.9
Coarse sand	0.8
Medium sand	20.8
Fine sand	47.1
Very fine sand	7.8
Silt	7.1
Clay	15.4
	99.9

Classification: Sandy loam

Pit at Station 352-00

Depth: 1 Foot

	Percent
Gravel	0.4
Coarse sand	0.3
Medium sand	0.5
Fine sand	1.4
Very fine sand	1.7
Silt	52.1
Clay	43.6
	100.0

Classification: Clay

Depth: 4 Feet

	Percent
Gravel	0.0
Coarse sand	0.0
Medium sand	0.2
Fine sand	0.7
Very fine sand	12.9
Silt	64.7
Clay	21.5
	100.0

Classification: Silty clay loam

Pit at Station 394-00

Depth: 1 Foot	Percent	Depth: 4 Feet	Percent
Gravel	0.5	Gravel	0.1
Coarse sand	0.7	Coarse sand	0.1
Medium sand	0.5	Medium sand	0.2
Fine sand	2.0	Fine sand	0.8
Very fine sand	4.4	Very fine sand	4.7
Silt	63.5	Silt	66.3
Clay	28.4	Clay	27.8
	100.0		100.0
Classification: Silty Clay loam		Classification: Silty clay loam	

Pit at Station 445-20

Depth: 1 Foot	Percent	Depth: 4 Feet	Percent
Gravel	5.3	Gravel	1.7
Coarse sand	0.4	Coarse sand	0.8
Medium sand	2.6	Medium sand	14.1
Fine sand	34.3	Fine sand	49.4
Very fine sand	9.4	Very fine sand	8.1
Silt	24.8	Silt	8.2
Clay	23.2	Clay	17.7
	100.0		100.0
Classification: Clay Loam		Classification: Fine sandy loam	

Pit at Station 458-00

Depth: 1 Foot	Percent	Depth: 4 Feet	Percent
Gravel	0.6	Gravel	0.6
Coarse sand	0.9	Coarse sand	43.2
Medium sand	21.4	Medium sand	4.2
Fine sand	45.8	Fine sand	23.9
Very fine sand	7.5	Very fine sand	4.4
Silt	8.7	Silt	7.5
Clay	15.1	Clay	16.2
	100.0		100.0
Classification: Fine sandy loam		Classification: Sandy loam	

Pit at Station 527-00

Depth: 1 Foot	Percent	Depth: 3 Feet	Percent
Gravel	0.2	Gravel	0.8
Coarse sand	0.9	Coarse sand	0.7
Medium sand	9.7	Medium sand	8.2
Fine sand	43.4	Fine sand	32.4
Very fine sand	17.2	Very fine sand	11.4
Silt	11.4	Silt	18.4
Clay	17.1	Clay	28.1
	99.9		100.0
Classification: Fine sandy loam		Classification: Clay loam	

Pit at Station 622-00

Depth: 1 Foot	Percent	Depth: 4 Feet	Percent
Gravel	0.3	Gravel	1.0
Coarse sand	0.8	Coarse sand	0.7
Medium sand	13.7	Medium sand	9.4
Fine sand	46.4	Fine sand	42.5
Very fine sand	10.2	Very fine sand	14.7
Silt	16.8	Silt	15.3
Clay	11.8	Clay	16.4
	100.0		100.0
Classification: Fine sandy loam		Classification: Fine sandy loam	

Pit at Station 700-00

Depth: 1 Foot	Percent	Depth: 4 Feet	Percent
Gravel	0.3	Gravel	0.8
Coarse sand	0.5	Coarse sand	0.4
Medium sand	5.5	Medium sand	3.3
Fine sand	52.4	Fine sand	40.4
Very fine sand	13.6	Very fine sand	18.1
Silt	14.4	Silt	16.0
Clay	13.3	Clay	21.0
	100.0		100.0
Classification: Fine sandy loam		Classification: Clay loam	

Pit at Station 824-00

Depth: 1 Foot

	Percent
Gravel	15.5
Coarse sand	4.0
Medium sand	5.0
Fine sand	14.6
Very fine sand	5.1
Silt	23.2
Clay	32.6
	100.0

Classification: Clay

Depth: 4 Feet

	Percent
Gravel	43.3
Coarse sand	2.9
Medium sand	3.9
Fine sand	12.6
Very fine sand	4.1
Silt	11.0
Clay	22.2
	100.0

Classification: Clay loam

Pit at Station 1596-00

Depth: 1 Foot

	Percent
Gravel	4.6
Coarse sand	1.0
Medium sand	2.3
Fine sand	18.2
Very fine sand	15.6
Silt	35.7
Clay	22.6
	100.0

Classification: Clay loam

Depth: 4 Feet

	Percent
Gravel	7.2
Coarse sand	0.8
Medium sand	0.8
Fine sand	6.7
Very fine sand	7.2
Silt	22.1
Clay	55.2
	100.0

Classification: Clay

Pit at Station 1662-00

Depth: 1 Foot

	Percent
Gravel	5.1
Coarse sand	1.8
Medium sand	9.1
Fine sand	25.9
Very fine sand	10.2
Silt	31.7
Clay	16.2
	100.0

Classification: Sandy loam

Depth: 4 Feet

	Percent
Gravel	20.2
Coarse sand	4.3
Medium sand	6.1
Fine sand	19.8
Very fine sand	14.8
Silt	20.8
Clay	14.0
	100.0

Classification: Sandy loam

Pit at Station 1737-00

Depth: 1 Foot	Percent
Gravel	0.3
Coarse sand	0.5
Medium sand	0.7
Fine sand	3.7
Very fine sand	3.4
Silt	40.1
Clay	51.3
	100.0

Classification: Clay

Depth: 4 Feet	Percent
Gravel	0.0
Coarse sand	0.2
Medium sand	0.2
Fine sand	1.0
Very fine sand	4.3
Silt	10.4
Clay	83.9
	100.0

Classification: Clay

Pit at Station 1861-00

Depth: 1 Foot	Percent
Gravel	0.4
Coarse sand	0.9
Medium sand	1.3
Fine sand	0.1
Very fine sand	6.7
Silt	58.0
Clay	32.6
	100.0

Classification: Clay

Depth: 4 Feet	Percent
Gravel	0.1
Coarse sand	0.2
Medium sand	0.3
Fine sand	0.0
Very fine sand	18.5
Silt	61.6
Clay	19.3
	100.0

Classification: Silt loam

Pit at Station 1987-00

Depth: 1 Foot	Percent
Gravel	0.0
Coarse sand	0.0
Medium sand	0.0
Fine sand	1.1
Very fine sand	18.6
Silt	67.9
Clay	12.4
	100.0

Classification: Silt loam

Depth: 4 Feet	Percent
Gravel	0.1
Coarse sand	0.2
Medium sand	0.5
Fine sand	1.6
Very fine snad	22.5
Silt	55.3
Clay	19.8
	100.0

Classification: Silt loam

Pit at Station 2033-00

Depth: 1¼ Foot

	Percent
Gravel	32.5
Coarse sand	0.6
Medium sand	1.1
Fine sand	8.4
Very fine sand	7.1
Silt	16.0
Clay	34.3
	100.0

Classification: Sandy clay

Depth: 4 Feet

	Percent
Gravel	7.4
Coarse sand	24.1
Medium sand	9.7
Fine sand	16.2
Very fine sand	9.6
Silt	12.3
Clay	20.7
	100.0

Classification: Clay loam

Pit at Station 2174-00

Depth: 1 Foot

	Percent
Gravel	0.4
Coarse sand	1.1
Medium sand	1.1
Fine sand	0.9
Very fine sand	1.9
Silt	45.1
Clay	49.5
	100.0

Classification: Clay

Depth: 4 Feet

	Percent
Gravel	0.0
Coarse sand	0.0
Medium sand	0.0
Fine sand	0.0
Very fine sand	0.0
Silt	66.9
Clay	33.1
	100.0

Classification: Clay

Pit at Station 2347-00

Depth: 1 Foot

	Percent
Gravel	0.2
Coarse sand	0.3
Medium sand	0.4
Fine sand	1.4
Very fine sand	1.4
Silt	29.7
Clay	66.5
	99.9

Classification: Clay

Depth: 4 Feet

	Percent
Gravel	0.3
Coarse sand	0.0
Medium sand	0.0
Fine sand	0.7
Very fine sand	21.0
Silt	51.4
Clay	26.6
	100.0

Classification: Silty clay loam

On the basis of these results and subject to the care taken in the original exploring of the subsoil and the accuracy of the locations of the pits as furnished, the various sections of the canal will be in the types of soil shown below.

Sections by Stations	Surface Soil	Subsoil
0-00 to 17-00	Loam	Silt loam
17-00 to 240-00	Clay	Silty clay loam
240-00 to 281-75	Sandy loam	Sandy loam
281-75 to 352-00	Clay	Silty clay loam
352-00 to 394-00	Silty clay loam	Silty clay loam
394-00 to 445-20	Clay loam	Fine sandy loam
445-20 to 458-00	Sandy loam	Fine sandy loam
458-00 to 527-00	Fine sandy loam	Clay loam
527-00 to 622-00	Fine sandy loam	Fine sandy loam
622-00 to 700-00	Fine sandy loam	Clay loam
700-00 to 824-00	Clay	Clay loam
824-00 to 1596-00	Clay loam	Clay
1596-00 to 1662-00	Sandy loam	Sandy loam
1662-00 to 1737-00	Clay	Clay
1737-00 to 1861-00	Clay	Silt loam
1861-00 to 1987-00	Silt loam	Silt loam
1987-00 to 2033-00	Sandy clay	Clay loam
2033-00 to 2174-00	Clay	Clay
2174-00 to 2365-00	Clay	Silty clay loam

Some gravel and coarse sand were found in practically all pits sampled. At Stations 458, 824, and 2033 they were found in such large amounts as to require ordinarily that the soil be classified as gravelly. The indications were, however, that the areas of gravel at these stations were very small local deposits and, except in one instance, the mechanical analyses of the samples showed that the coarse material was associated with a high percentage of clay and other fine materials. For these reasons the writer believed that for the purpose of computing seepage losses a classification of gravelly soil was not justified.

Factors Affecting Seepage Losses.

The seepage loss from an earth canal depends on many factors, among which may be mentioned as having a marked influence:

1. Character of soil forming bottom and banks.
2. Subsurface conditions, in so far as they affect drainage and the ground water table.
3. The age of the canal, and the amount and fineness of the material carried in suspension.
4. The flow of water in the canal and its depth and velocity.
5. The relation between the wetted perimeter and other hydraulic elements of the canal, particularly the discharge.
6. The temperature of the water and soil.

The majority of these factors are taken into consideration in arriving at the probable loss in the proposed canal. The effect of some of them can be estimated with a fair degree of accuracy while the available data permits consideration of the others only in a general way. In this locality, where the temperature of both soil and water is high for the greater part of the year, a relatively high rate of seepage is to be expected. On the other hand, the Rio Grande carries at all times much very fine material which lodges in the pores of the bottom and banks of canals and effects a large reduction in losses provided the annual cleaning does not remove the sealed surface. The method by which the soil of the area to be served was built up indicates that when the canal is excavated irregular beds or areas of very gravelly or sandy soils may be encountered below the surface. Such beds often connect directly with the channel of the stream and by permitting the rapid passage of percolating water are responsible for excessively heavy seepage losses. In the absence of data to show depth of

cut and character of subsoil at close intervals between the test pits, it is not possible to estimate the probable loss from this source.

Rate of Loss in Different Soils

Investigators who have made seepage loss determinations have been handicapped by their inability to control and determine such factors as uniformity of soil, colloidal content, and subsurface conditions. Measurements of losses therefore show a considerable range for soils of the same type. Measurements made in the lower Rio Grande valley showed losses in fine sandy loam ranging from 1 to 4 cubic feet per square foot per day, and indicated an average loss of between 1.25 and 1.50 cubic feet. Losses in clay were in some instances as low as 0.09 cubic foot but the majority ranged between 0.20 and 0.30 cubic foot. On the basis of all available data, and assuming a seasoned canal, it is believed that seepage losses in the various soils of the district, expressed in terms of cubic feet per day per square foot of wetted area, will be as follows:

Clay	0.20 cu. ft.
Silty clay loam	0.30 cu. ft.
Clay loam	0.40 cu. ft.
Silt loam	0.60 cu. ft.
Loam	1.00 cu. ft.
Fine sandy loam	1.25 cu. ft.
Sandy loam	1.50 cu. ft.

Rate of Loss in Sections of Proposed Canal.

Applying the foregoing rates of loss and bringing together sections in which the rate is about the same, the weighted rate of

loss in the several sections of the canal, expressed in cubic feet per square foot per day, is found to be as shown below.

Sections by Stations	Length of Section Feet	Rate of Loss Cubic Feet
0-00 to 240-00	24,000	0.30
240-00 to 281-75	4,175	1.50
281-75 to 394-00	11,225	0.27
394-00 to 700-00	30,600	0.98
700-00 to 1596-00	25,500	0.30
1596-00 to 1662-00	6,600	1.50
1662-00 to 2365-00	70,300	0.33

Rate of Flow in Canal.

There is an area of about 450,000 acres of riparian land on the American side of the Rio Grande now provided with irrigation facilities, and a substantial additional riparian acreage is subject to irrigation. Under the recent decision of the Supreme Court all this land is entitled to share on an equal basis in the normal flow of the stream which is estimated not to exceed 3500 second feet. Even if no portion of this normal flow is diverted to Mexican territory the supply is inadequate for the acreage and the canals of the Valley will be dependent on their appropriation rights in the flood water of the stream. Since the District's appropriation right will be junior to appropriation rights of 450,000 acres downstream, the District canal should have sufficient

capacity to take advantage of the short, sharp floods which fairly often break long low-stage periods for a few days. The tentative plans call for a canal of a capacity of only 200 second feet, which, if 80 percent of the District lands are actually irrigated, must serve 30,000 acres. In view of the above facts and the character of the water demand of the large area of shallow-rooted crops which will probably be grown, it is believed that no consideration of reduced construction costs warrants a main canal of such relatively small capacity.

Apparently it is the intention to construct a main canal of the same capacity throughout its length and the plans submitted show only two earth sections. The features of these sections are given below. For this estimate of losses it is assumed that the 12-foot bottom will extend to Station 1596-00, and the 14-foot bottom from that point to the lower end.

	Upper	Lower
Bottom width in feet	12	14
Side slopes	2:1	2:1
Top width in feet	37	38
Depth in feet	6.5	6
Depth of water in feet	4.7	4
Grade	0.0002	0.0003
Friction coefficient	0.0225	0.0225
Velocity in feet per second	1.95	2.32
Capacity in second feet	196	204

According to plans submitted the pumping plant will consist

of 5 units, each with a capacity of 18,000 gallons per minute, or 40 second-feet. So far as limited by the pumping equipment under efficient operation the discharge at the head of the canal may be approximately 40, 80, 120, 160, or 200 second feet, depending on the number of units in operation.

The monthly distribution of the demand to be expected may be arrived at on the basis of the demand under two valley canals for which records are available for an aggregate of about $4\frac{1}{2}$ years. Under the first canal truck crops predominated while the second canal irrigated large areas of citrus fruit and cotton. In the table below the monthly demand under each of the two canals is shown as a percentage of the total demand, and the derived estimate for the District canal is given as a percentage and in acre feet. The February and May demands under the second canal were considerably above normal due to an unusually large acreage of cotton, while the demand during the fall months was much reduced by rains. Due allowance is made for these conditions.

Month	1st Canal	2nd Canal	District Canal	
	Percent	Percent	Percent	Acre feet
January	5	12	8	6100
February	9	21	12	9100
March	13	13	13	9900
April	12	6	13	9900
May	8	22	12	9100
June	7	6	6	4600
July	8	10	9	6900
August	9	6	7	5300
September	8	1	5	3800
October	6	1	5	3800
November	7	1	5	3800
December	8	1	5	3800
Total	100	100	100	76,100

The rate of flow required to meet the monthly demand will vary with the rainfall, crops grown, method of canal operation, and other factors. It is estimated that the demand in January, February, March, April, May, and July will be met with a discharge of 200 second feet flowing approximately 132 days. A part of the light demand in the latter part of the year will require a discharge of 40 second feet for an aggregate of about 50 days. The remainder of the total annual demand will be met with a discharge of 140 second feet flowing about

72 days. On this basis the total annual demand of 76,200 acre feet will be supplied at an average rate of 150 second feet in 256.6 days.

The writer has no data covering the irrigable acreage served by the various laterals. To allow for diversions an assumed loss of 20 percent in the entire canal was deducted and the remaining flow was distributed to the various sections of the canal in proportion to the acres of land lying immediately under the sections.

First Estimate of Loss.

In the following tabulation the data and assumptions previously made are brought together and the losses in the various sections computed for a flow of 150 second feet for 256.6 days under a system of continuous delivery to water users.

Station 0-00 to Station 240-00

Discharge	150 second feet
Wetted perimeter	30.3 feet
Length of section	24,000 feet
Wetted area	727,200 square feet
Loss per square foot per day	0.30 cubic feet
Total loss per day	218,160 cubic feet
Total loss in 256.6 days	1285 acre feet
Rate of loss	2.53 second feet

Station 240-00 to Station 281-75

Deducting loss of 2.53 second feet and allowing about 14½ second feet for diversion in the section above leaves an average flow of 133 second feet to be carried.

Station 240-00 to Station 281-75 (Continued)

Discharge	133 second feet
Wetted perimeter	29.2 feet
Length of section	4175 feet
Wetted area	121,910 square feet
Loss per square foot per day	1.50 cubic feet
Total loss per day	182,860 cubic feet
Total loss in 256.6 days	1077 acre feet
Rate of loss	2.12 second feet

Station 281-75 to Station 394-00

Deducting loss of 2.12 second feet and diversions of about 6 second feet in the section above leaves an average flow of 125 second feet to be carried.

Discharge	125 second feet
Wetted perimeter	28.7 feet
Length of section	11,225 feet
Wetted area	322,160 square feet
Loss per square foot per day	0.27 cubic feet
Total loss per day	86,980 cubic feet
Total loss in 256.6 days	512 acre feet
Rate of loss	1.01 second feet

Station 394-00 to Station 700-00

Deducting the loss of 1.01 second feet and diversions of about 4 second feet in the section above leaves an average flow of 120 second feet to be carried.

Discharge	120 second feet
Wetted perimeter	28.4 feet
Length of section	30,600 feet
Wetted area	869,040 square feet
Loss per square foot per day	0.98 cubic feet
Total loss per day	851,660 cubic feet
Total loss in 256.6 days	5017 acre feet
Rate of loss	9.86 second feet

Station 700-00 to Station 1596-00

Deducting the loss of 9.86 second feet and a diversion of about 17 second feet in the section above leaves an average flow of 93 second feet to be carried.

Discharge	93	second feet
Wetted perimeter	26.3	feet
Length of section	25,500	feet
Wetted area	670,650	square feet
Loss per square foot per day	0.30	cubic foot
Total loss per day	201,195	cubic feet
Total loss in 256.6 days	1185	acre feet
Rate of loss	2.33	second feet

Station 1596-00 to Station 1662-00

Deducting the loss of 2.33 second feet and a diversion of about 12 second feet in the section above leaves an average flow of 79 second feet to be carried.

Discharge	79	second feet
Wetted perimeter	24.9	feet
Length of section	6600	feet
Wetted area	164,340	square feet
Loss per square foot per day	1.50	cubic feet
Total loss per day	246,510	cubic feet
Total loss in 256.6 days	1452	acre feet
Rate of loss	2.85	second feet

Station 1662-00 to Station 2365-00

Deducting the loss of 2.85 second feet and a diversion of about 12 second feet in the section above leaves an average flow of 64 second feet to be carried at the upper end of this section.

Discharge	64	second feet
Wetted perimeter	23.8	feet
Length of section	70,300	feet
Wetted area	1,673,140	square feet
Loss per square foot per day	0.33	cubic foot
Total loss per day	552,136	cubic feet
Total loss in 256.6 days	3253	acre feet
Rate of loss	6.39	second feet

Summary.

Sections by Stations	Loss Acre Feet
0-11 to 240-00	1285
240-00 to 281-75	1077
281-75 to 394-00	512
394-00 to 700-00	5017
700-00 to 1596-00	1185
1596-00 to 1662-00	1452
1662-00 to 2365-00	3253
Total	13,781

Second Estimate of Loss

For the greater part of the year, delivery of a continuous flow to users will not be practical nor economical and a system of rotation will be used. Under these circumstances, full heads of different sizes may be carried without diversions as far, at least, as Station 1662. To allow for these conditions, a system of rotation delivery was assumed and losses have been estimated separately for discharges of 200 second feet for 132 days, 140 second feet for 72 days, and 40 second feet for 50 days. This estimate is given in detail below.

Station 0-00 to Station 240-00

Discharge	200 second feet
Wetted perimeter	33.3 feet
Length of section	24,000 feet
Wetted area	799,200 square feet
Loss per square foot per day	0.30 cubic foot
Total loss per day	239,760 cubic feet
Total loss in 132 days	727 acre feet
Rate of loss	2.77 second feet
Discharge	140 second feet
Wetted perimeter	29.7 feet
Length of section	24,000 feet
Wetted area	712,800 square feet
Loss per square foot per day	0.30 cubic foot
Total loss per day	213,840 cubic feet
Total loss in 72 days	353 acre feet
Rate of loss	2.48 second feet
Discharge	40 second feet
Wetted perimeter	21.3 feet
Length of section	24,000 feet
Wetted area	511,200 square feet
Loss per square foot per day	0.30 cubic foot
Total loss per day	153,360 cubic feet
Total loss in 50 days	176 acre feet
Rate of loss	1.77 second feet

Aggregate loss in section 1256 acre feet

Station 240-00 to Station 281-75

Discharge	197	second feet
Wetted perimeter	33.1	feet
Length of section	4175	feet
Wetted area	138,190	square feet
Loss per square foot per day	1.50	cubic feet
Total loss per day	207,285	cubic feet
Total loss in 132 days	628	acre feet
Rate of loss	2.40	second feet
Discharge	138	second feet
Wetted perimeter	29.6	feet
Length of section	4175	feet
Wetted area	123,580	square feet
Loss per square foot per day	1.50	cubic feet
Total loss per day	185,370	cubic feet
Total loss in 72 days	306	acre feet
Rate of loss	2.15	second feet
Discharge	38	second feet
Wetted perimeter	21.0	feet
Length of section	4175	feet
Wetted area	87,675	square feet
Loss per square foot per day	1.50	cubic feet
Total loss per day	131,510	cubic feet
Total loss in 50 days	151	acre feet
Rate of loss	1.52	second feet

Aggregate loss in section 1085 acre feet

Station 281-75 to Station 394-00

Discharge	195	second feet
Wetted perimeter	33.0	feet
Length of section	11,225	feet
Wetted area	370,420	square feet
Loss per square foot per day	0.27	cubic foot
Total loss per day	100,010	cubic feet
Total loss in 132 days	303	acre feet
Rate of loss	1.16	second feet
Discharge	135	second feet
Wetted perimeter	29.4	feet
Length of section	11,225	feet
Wetted area	330,010	square feet
Loss per square foot per day	0.27	cubic foot
Total loss per day	89,120	cubic feet
Total loss in 72 days	147	acre feet
Rate of loss	1.03	second feet
Discharge	37	second feet
Wetted perimeter	20.9	feet
Length of section	11,225	feet
Wetted area	234,600	square feet
Loss per square foot per day	0.27	cubic foot
Total loss per day	63,340	cubic feet
Total loss in 50 days	73	acre feet
Rate of loss	0.73	second feet

Aggregate loss in section 523 acre feet

Station 394-00 to Station 700-00

Discharge	194	second feet
Wetted perimeter	33.0	feet
Length of section	30,600	feet
Wetted area	1,009,800	square feet
Loss per square foot per day	0.98	cubic foot
Total loss per day	989,600	cubic feet
Total loss in 132 days	2999	acre feet
Rate of loss	11.45	second feet
Discharge	134	second feet
Wetted perimeter	29.3	feet
Length of section	30,600	feet
Wetted area	896,580	square feet
Loss per square foot per day	0.98	cubic feet
Total loss per day	878,700	cubic feet
Total loss in 72 days	1452	acre feet
Rate of loss	10.17	second feet
Discharge	36	second feet
Wetted perimeter	20.7	feet
Length of section	30,600	feet
Wetted area	633,420	square feet
Loss per square foot per day	0.98	cubic foot
Total loss per day	620,750	cubic feet
Total loss in 50 days	713	acre feet
Rate of loss	7.18	second feet

Aggregate loss in section 5164 acre feet

Station 700-00 to Station 1596-00

Discharge	183	second feet
Wetted perimeter	32.3	feet
Length of section	25,500	feet
Wetted area	823,640	square feet
Loss per square foot per day	0.30	cubic foot
Total loss per day	247,100	cubic feet
Total loss in 132 days	749	acre feet
Rate of loss	2.86	second feet
Discharge	124	second feet
Wetted perimeter	28.6	feet
Length of section	25,500	feet
Wetted area	729,300	square feet
Loss per square foot per day	0.30	cubic foot
Total loss per day	217,900	cubic feet
Total loss in 72 days	362	acre feet
Rate of loss	2.53	second feet
Discharge	29	second feet
Wetted perimeter	19.5	feet
Length of section	25,500	feet
Wetted area	497,240	square feet
Loss per square foot per day	0.30	cubic foot
Total loss per day	149,200	cubic feet
Total loss in 50 days	171	acre feet
Rate of loss	1.73	second feet

Aggregate loss in section 1282 acre feet.

Station 1596-00 to Station 1662-00

Discharge	180	second feet
Wetted perimeter	30.7	feet
Length of section	6600	feet
Wetted area	202,620	square feet
Loss per square foot per day	1.50	cubic feet
Total loss per day	303,930	cubic feet
Total loss in 132 days	921	acre feet
Rate of loss	3.52	second feet
Discharge	121	second feet
Wetted perimeter	25.4	feet
Length of section	6600	feet
Wetted area	167,640	square feet
Loss per square foot per day	1.50	cubic feet
Total loss per day	251,460	cubic feet
Total loss in 72 days	416	acre feet
Rate of loss	2.91	second feet
Discharge	27	second feet
Wetted perimeter	20.4	feet
Length of section	6600	feet
Wetted area	134,640	square feet
Loss per square foot per day	1.50	cubic feet
Total loss per day	201,960	cubic feet
Total loss in 50 days	232	acre feet
Rate of loss	2.34	second feet

Aggregate loss in section 1569 acre feet

Station 1662-00 to Station 2365-00

Discharge	176	second feet
Wetted perimeter (Average)	25.6	feet
Length of section	70,300	feet
Wetted area	1,799,700	square feet
Loss per square foot per day	0.33	cubic foot
Total loss per day	593,900	cubic feet
Total loss in 132 days	1801	acre feet
Rate of loss	6.87	second feet
Discharge	118	second feet
Wetted perimeter (Average)	24.0	feet
Length of section	70,300	feet
Wetted area	1,687,200	square feet
Loss per square foot per day	0.33	cubic foot
Total loss per day	556,780	cubic feet
Total loss in 72 days	920	acre feet
Rate of loss	6.44	second feet
Discharge	25	second feet
Wetted perimeter (Average)	20.5	feet
Length of section	70,300	feet
Wetted area	1,441,200	square feet
Loss per square foot per day	0.33	cubic foot
Total loss per day	436,720	cubic feet
Total loss in 50 days	501	acre feet
Rate of loss	5.05	second feet

Aggregate loss in section 3222 acre feet

Summary.

Sections by Stations	Loss Acre feet
0-00 to 240-00	1256
240-00 to 281-75	1085
281-75 to 394-00	523
394-00 to 700-00	5164
700-00 to 1596-00	1282
1596-00 to 1662-00	1569
1662-00 to 2365-00	3222
Total	14,101

With the discharge of 200 second feet flowing 132 days, a total of 52,272 acre feet, the loss is 8130 acre feet, or 16 percent. The discharge of 140 second feet flowing 72 days, a total of 19,958 acre feet, shows a loss of 3960 acre feet or 20 percent. With the discharge of 40 second feet flowing 50 days, a total of 3960 acre feet, the loss is 2017 acre feet or 51 percent. The aggregate loss does not, however, differ very materially from that shown by the first estimate.

Estimate Based on Survey of Bureau of Soils.

The U. S. Bureau of Soils in 1909 made a reconnoissance survey of south Texas and prepared a soil map which included the lands of the Starr County District.* Maps showing the results of

*U. S. Department of Agriculture, Bureau of Soils; Field Operations 1909; Reconnoissance Soil Survey of South Texas, by George N. Coffey and Party

a reconnoissance survey do not detail minor variations of soil nor are the boundaries of the areas occupied by different classes of soil shown with more than approximate accuracy, but it was considered advisable to make an estimate based on this report and map.

By plotting approximate boundaries of soil areas on maps of the Board of Water Engineers it was found that the canal line falls in areas of Laredo silt loam, Brennan fine sandy loam, and gravelly soil. The report notes that, particularly in the vicinity of Sam Fordyce, the areas mapped as silt loam contain large bodies of silty clay loam which it was not practical to separate. It is assumed, therefore, that the seepage loss in these areas will be 0.45 cubic foot per square foot of wetted area per day, the average of the losses in silt loam and silty clay loam. The interstitial material in the gravelly soils is not classified but it is assumed that the gravelly sections near the head of the canal will lose water at the same rate as a loam, and that the rate of loss in the section at the lower end of the line will be the same as in the silt loam. The tabulation below shows the class of soil in which each

section of the canal will fall and gives for the section the assumed rate of seepage loss expressed in terms of cubic feet per square foot of wetted area per day.

Sections by Stations	Soil	Rate of Loss
0 to 40	Gravelly	1.00
40 to 70	Silt loam	.45
70 to 90	Gravelly	1.00
90 to 385	Silt loam	.45
385 to 400	Gravelly	1.00
400 to 485	Fine sandy loam	1.25
485 to 530	Silt loam	.45
530 to 750	Fine sandy loam	1.25
750 to 2020	Silt loam	.45
2020 to 2150	Gravelly	.45
2150 to 2365	Silt loam	.45

Assuming an average flow of 150 second feet for 256.6 days and using the same method of computing, it is estimated that the loss will be 21,003 acre feet, or approximately 50 percent greater than is shown by the other estimates. The samples from the test pits lead the writer to believe this estimate is too high. The loss from the head of the canal to Station 750 is practically the same by the three estimates. The relatively high loss below that station shown by this estimate is due to the fact that the map and report do not take into account the areas of clay which occur in that section along with the silt loam and the silty clay loam. The lower rate of loss in these areas of clay would produce a substantial reduction in the estimated loss for that portion of the canal.

Probable Loss in the Canal

In the tabulation below the losses as determined by the first two estimates are shown by sections with the average of the two. This average is accepted as the probable loss in the canal when in full operation. The three sections with the highest rates of seepage, Stations 240 to 281, 394 to 700 and 1596 to 1662, show an aggregate loss of 7681 acre feet, or more than half the total estimated loss.

Sections by Stations	Loss		
	First Method Acre Feet	Second Method Acre Feet	Average Acre Feet
0-00 to 240-00	1285	1256	1270
240-00 to 281-75	1077	1085	1081
281-75 to 394-00	512	523	518
394-00 to 700-00	5017	5164	5090
700-00 to 1596-00	1185	1282	1234
1596-00 to 1662-00	1452	1569	1510
1662-00 to 2365-00	3253	3222	3238
Total	13781	14101	13941

Concrete Lining for District Canal.

The loss through a concrete lining depends upon its density, thickness, joints, cracks, and the soil upon which it is placed, and will amount to only 5 to 25 percent of the loss from an earth canal in the same location. A lining in the proposed main canal of the Starr County District, if moderately well maintained, should reduce the loss by 85 percent at least. On this basis, lining the entire main would bring about a saving of 11,850 acre feet of water, which, for a season of 256.6 days, is equivalent to a constant flow of 23 second feet.

In order to arrive at a rough estimate of the cost of lining the canal, the following section is assumed: Bottom, 6 feet; depth of water, 5.5 feet; side slopes, 1½ to 1; grade, 0.0002; coefficient of friction, 0.015; discharge, 230 second feet. Below station 874, the cross section is reduced, side slopes changed to 1 to 1, and the depth decreased to allow for the increased grade, the heavier soil, and the decreasing discharge to be carried. With a vertical freeboard of 1 foot the perimeter will vary from 29.5 feet at the head to 17.2 feet at the lower end. Assuming a unit cost of 10 cents per square foot, the total cost of lining the main canal will be approximately $430,000.

By establishing a sinking fund drawing 4½ percent interest, an indebtedness of $430,000 on which 6 percent interest is paid can be extinguished in 20 years by annual payments of $39,500. Since the District contains 38,105 acres an annual assessment of $1.04

per acre for 20 years will cover the entire cost. If, in order to reduce charges in the early stages of the project, the setting up of a sinking fund is deferred, interest charges on the indebtedness can be met by an annual assessment of only 65 cents per acre.

Before the project of lining the canal can be declared feasible and justified it must be shown that the benefits derived will offset this cost. The chief offset is perhaps the value of the water recovered. Disregarding the flat rate, water charges of irrigation systems in the Valley below ranged from $1 to $4 and averaged $3.15 per acre per irrigation in 1921. Charges have since been lowered but the present average is not less than $2 per acre and there is little likelihood of any large reduction in the future. Measurements made in the Valley several years ago showed the average depth of irrigation to be about 6 inches. The cost of two applications or 1 acre foot of water can be fixed, therefore, at $4. At that rate the 11,850 acre feet recovered by lining the canal if delivered to the users under the canal will bring in about $45,000, or more than enough each year to cover the annual cost of the lining. One system of the Valley offers water at $2 per acre foot, and at that rate the income from the recovered water would offset more than half the cost of the lining.

Another important offset is involved in the cost of pumping water. Data showing the actual cost of pumping in the Lower Rio Grande Valley are not available but it is believed that 3 cents per acre foot per foot of lift is a reasonable figure. At that rate,

pumping the estimated loss of 13,941 acre feet through a lift of 38 feet will cost $15,890 each year. Of this wasted expenditure, 85 percent, or $13,500, will be recovered by lining the canal.

These two items alone are sufficient to offset the cost of the lining, but the District will derive in addition several other valuable benefits. The lining will reduce the cost of maintenance; will lead to efficient operation of the canal; will decrease the area which may be expected to require drainage facilities in addition to District mains; and will constitute an insurance against crop loss by preventing certain classes of breaks and by permitting quick distribution and full use of such heads as may be obtained during periods of water shortage. It would be difficult to reduce these advantages to definite figures but their importance cannot be questioned.

From the standpoint of the District a vital consideration is the adequacy of the water supply of 76, 210 acre feet carried by the permit, which, it may be stated, is at the same rate per acre as others granted by the Board of Water Engineers. The loss in the main canal has been estimated at 13,941 acre feet, or 18 percent. Due to the small heads carried and other adverse conditions, the losses in laterals and farm ditches will be relatively higher and should be estimated at not less than 22 percent. Deducting these losses by seepage and disregarding evaporation and operation losses there is left a balance of 45,700 acre feet to serve the net acreage of 30,000 acres, or 1.52 acre feet per acre. This is below the

quantity required for the Lower Rio Grande Valley according to Dr. Samuel Fortier who, in an unpublished report, * fixes the minimum

*Irrigation Requirements of the Arid and Semi-Arid Lands of the Southwest: Samuel Fortier, Senior Irrigation Engineer, U. S.Dept. Agriculture.

net requirement at 1.75 acre feet per acre. A rapid development of the project would bring out this deficiency very soon, and no better way than lining the canal could then be found to increase the supply available to the users under the canal.

There seems to be no reason to believe that the District lands cannot bear the cost of the lining. These lands are now valued at $5 per acre. Similar land under irrigation lower down the river rarely sells for less than $150 an acre and much of it has been sold "in the brush", or raw, at $300 to $400 per acre. Many farmers paying these prices have failed but a majority have managed to pull through the lean years and a great many are making a fine profit when returns are averaged for a period of several seasons. The bona fide settler who acquires land in the District will be able to make an excellent average profit on a valuation of $150 an acre. Above that valuation the element of uncertainty increases. It is assumed that very few of the present owners of the land in the District intend to hold and develop their land. The majority will take the handsome profit which lies between the present valuation of $5 an acre and the price which may be obtained for the land under irrigation after selling charges of a colonization agent are deducted. Those

owners who do hold their land will find it easy to make it produce a large profit over and above the amount required to cover interest on a $5 valuation and the cost of the system, including the lining. The bona fide farmer who buys land in the District will pay a price which will be governed chiefly by "what the traffic will bear" and only slightly, if at all, by the bonded indebtedness on the land. If he gets into financial difficulties his troubles will be due, therefore, to paying an excessive price for the land and not to the relatively small increase in assessments chargeable to the lining.

It appears from the foregoing that the lands of the District can bear the cost of the lining; that the lining is necessary to insure an adequate supply of water for the entire acreage covered by the permit; and that the direct and indirect benefits derived from the lining will more than offset its cost. Without going into the question of the proper utilization of a State-owned resource, or the question of the interests of holders of prior rights along the river, the writer is led to believe that the Board of Water Engineers is justified in requiring the lining of the entire canal.

Partial Lining.

It is scarcely ever possible to bring the entire area of an irrigation project under cultivation immediately, and under the best conditions some of the land must be idle for several years. During this period the proportion of the current cost which the idle land should produce must be met by payments out of the capital of its

owner or by shifting the burden to any productive land he may have. The settler with plenty of extra capital is rare and the developing of a profitable irrigated farm from raw land is usually a long process attended by more or less financial stress. It is often, therefore, good policy to keep charges down to a minimum until a substantial part of the land of a project is brought to the productive stage. In the case of the Starr County District a reduction in annual assessments could be made for several years by lining only the more porous sections of the canal and leaving the remainder to be lined at some future date.

Three sections of the proposed canal, Stations 240 to 281, 394 to 700, and 1596 to 1662, show heavy rates of seepage, the estimated aggregate loss in the three being 7681 acre feet. Lining these sections will effect a recovery of 6530 acre feet of water, which is equivalent to a flow of 13 second feet throughout the season. The estimated cost of lining the sections is $118,000. Annual payments of $10,840 will pay 6 percent interest on that indebtedness and provide a sinking fund which will extinguish the debt in 20 years. This annual payment will require an assessment of 28 cents per acre on the 38,105 acres of the District. Assuming that the full water supply is diverted and used, pumping costs recovered would amount to $7450 and the water made available for use would have a value of more than $25,000, an aggregate of $32,450. Thus the benefits from these two items alone would amount to three times the cost. If only a part of the annual supply of water were

pumped and used, the benefits would still be more than sufficient to offset the cost.

It has been shown that by deferring assessments for a sinking fund and paying only interest charges, the cost of lining the entire main canal can be handled for a few years with an assessment of only 65 cents per acre. On the same basis the cost of lining only the three most porous sections of the canal can be handled with an assessment of 19 cents per acre. This comparatively small difference between assessments for the full lining and the partial lining, the potential productiveness of the District lands, the high price at which they will be sold, and the benefits derived from lining the entire canal leads to the conclusion that the full lining rather than the partial lining will best meet the legitimate interests and rights of all concerned.

LEAKAGE OF WATER FROM IRRIGATION CHANNELS AND CONCRETE LINED CANALS IN THE LOWER RIO GRANDE OF TEXAS

A Progress Report of Cooperative Investigations
U. S. Department of Agriculture
Bureau of Agricultural Engineering and Texas Board of Water Engineers

By
O. A. Faris
Associate Irrigation Engineer

Austin, Texas

1933

LEAKAGE OF WATER FROM IRRIGATION CHANNELS AND CONCRETE LINED CANALS IN THE LOWER RIO GRANDE VALLEY OF TEXAS

By
O. A. Faris

One of the problems of much importance in irrigation is that of leakage of water from canals and channels. Silt in sufficient quantity, carried into and deposited in earthen channels is effective in reducing materially the loss of water by percolation through the soil. In the process of cleaning such channels, the silt seal is generally disturbed to the extent that considerable leakage takes place during the time another seal is being deposited.

In many localities where the water supply is limited and the land of high value, canals have been lined with concrete to conserve the water supply and prevent the contribution to the ground water through direct leakage and percolation. Generally these linings are made of hand placed concrete or gunite. In some instances expansion joints are constructed in order to control the location of the contraction cracks and in others the expansion cracks are omitted so the contraction cracks occur at random. Cracks opened by contraction are conducive to direct leakage.

During January 1932, leakage tests 1/ were made in the lower Rio Grande Valley of Texas on one earthen reach of the Cuates Resaca used for conveyance and storage of water, one reach of hand placed reinforced concrete lining without expansion joints, one reach of

1/ Cooperative investigations, United States Department of Agriculture, Bureau of Agricultural Engineering and the Texas Board of Water Engineers. Cameron County Water Improvement Districts Nos.1 and 11 and Hidalgo County Water Control & Improvement District No.6 assisted in the investigation by furnishing labor and water.

hand placed concrete lining without reinforcing or expansion joints, one reach of reinforced gunite lining without expansion joints and one reach of reinforced, hand placed concrete lining with expansion joints spaced 12 feet.

The reaches tested were closed by dams carefully constructed of sacks filled with earth and faced with loose earth. The subsidence of the water surface was measured to 0.001 foot with hook gages. Evaporation was measured in a standard Weather Bureau pan and after being reduced to open water conditions, was applied in computing the net loss by leakage. The total wind movement was determined by anemometer readings and the temperature of the surface water was taken daily.

CUATES RESACA

The reach of the Cuates Resaca tested was 8020 feet in length, had a surface area of 51.58 acres and a wetted bottom area of 54.42 acres 2/. The test was continued 72 hours. The net loss on the basis of depth in feet per square foot of wet area in 24 hours was 0.004 foot. The very low loss is believed to be due to the sealing effect of the silt deposit on the wet area and the proximity to sea level. (The average elevation of the bottom of the reach is estimated as 10 feet above sea level and the maximum depth of water as 5 feet). The average wind movement was 5.4 miles per hour and the temperature of the surface water varied from 71 to 75 degrees Fahrenheit.

2/ V. L. Conrad, Consulting Engineer, Brownsville, Texas.

CANAL EAST OF BLOCKS 28, 29, 34, 35, 40 and 41. SECTION 3,UNIT 3, CAMERON COUNTY WATER IMPROVEMENT DISTRICT NO. 11

The reach of hand placed reinforced concrete lining without expansion joints was 2510 feet in length. (Fig.1 is a section) The concrete was float finished, 2 inches in thickness and the mix was 1 part cement, $2\frac{1}{4}$ parts sand and 1 3/4 parts gravel. The reinforcing was 12 and 14 gauge wire, with mesh 6 by 8 inches. There were 191 transverse contraction cracks varying in width from zero to 1/16 inch. The silt deposit had been removed from the canal recently. The test was continued 40 hours. The net loss on the basis of depth in feet, per square foot of wet area in 24 hours was 0.146 foot. The average wind movement was 4.4 miles per hour and the temperature of the surface water varied from 71 to 73 degrees Fahrenheit.

The earth was removed from the back side of the lining at one of the open contraction cracks. Moisture was observed just below the top of the canal bank and near the elevation of the water surface in the canal, the soil was thoroughly saturated. When the excavation was carried below the elevation of water surface, water streamed through the crack.

For comparison, the earth was excavated back of the lining at one of the cracks which could be seen on the surface but was not open. The soil was damp but no free water appeared on the back side of the lining.

THE LOWER END OF LATERAL 26, CAMERON COUNTY WATER IMPROVEMENT DISTRICT NUMBER ONE

The reach of hand placed concrete lining without expansion joints

and without reinforcing was 729 feet in length. (Section Fig.2). The concrete was trowel finished, 1 3/4 inches in thickness and the mix was 1 part cement, 2½ parts sand and 5 parts gravel. There were 7 transverse cracks per 100 feet and a single longitudinal crack in the bottom throughout its length. The test was continued 37.5 hours. The net loss on the basis of depth in feet, per square foot of wet area in 24 hours was 0.430 foot. This heavy loss was due to the longitudinal crack in the bottom of the reach. The average wind movement was 4.6 miles per hour and the temperature of the surface water was from 71 to 73 degrees Fahrenheit.

LATERAL NO. 26,CAMERON COUNTY WATER IMPROVEMENT DISTRICT NO. 1,IMMEDIATELY ABOVE THE HAND PLACED LINING DESCRIBED ABOVE

The reach of gunite lining with reinforcing and without expansion joints was 1700 feet in length. (Section Fig.2). The gunite was gun finished, 1 inch in thickness and the mix was 1 part cement to 4½ parts sand. The reinforcing consisted of 12 gauge wire with meshes 4 by 8 inches. There were 15 transverse contraction cracks per 100 feet ranging in width from zero to 1/16 inch. The test was continued 37.5 hours. The net loss on the basis of depth in feet, per square foot of wet area in 24 hours was 0.125 foot. The average wind movement was 4.6 miles per hour and the temperature of the surface water ranged from 71 to 73 degrees Fahrenheit.

LATERAL C FROM HEAD TO STATION 12 PLUS 90, HIDALGO COUNTY WATER CONTROL AND IMPROVEMENT DISTRICT NO. 6

The reach of hand placed concrete lining with reinforcing and ex-

pansion joints was 1285 feet in length. The concrete was trowel finished, 1 3/4 inch in thickness and the mix was 1 part cement, 2 parts aand and 3½ parts gravel. The reinforcing consisted of 12 gauge wire with mesh 4 by 8 inches. The expansion joints were made by a groove ¼ inch wide and 1½ inches deep at intervals of 12 feet. The groove was poured full of hot asphalt. There were no cracks except transverse at part of the expansion joints. The test was continued 42.5 hours. The net loss on the basis of depth in feet, per square foot of wet area in 24 hours was 0.129 foot. The average wind movement was 4.6 miles per hour and the temperature of the surface water ranged from 71 to 73 degrees Fahrenheit. (See Fig. 3 for section)

The earth was excavated on the back side of the lining at one of the open expansion joints. The soil was saturated near and below the elevation of water surface and when the earth was removed below the elevation of the water surface in the canal, water streams through the open crack.

For comparison, the earth was excavated at one of the expansion joints which showed no opening. The excavation was extended to the bottom of the section and after remaining open 19 hours, showed no sign of leakage through the joint or the body of the slab.

From the limited investigation it appears that leakage of water from canals lined with either gunite or hand placed concrete of the quality tested, is confined to open cracks. These open cracks may be open expansion joints, open contraction cracks or longitudinal cracks caused by omission of reinforcing or the placing of lining on unsettled fills or a combination of both. It is very probable that with an

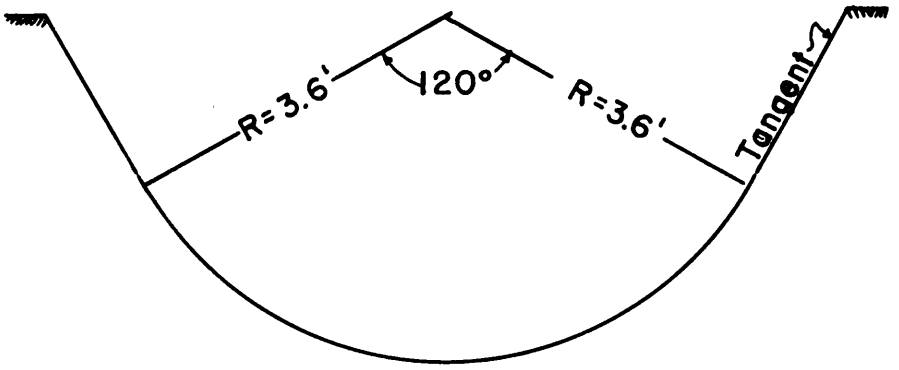

Fig. 1 - Section of hand placed concrete lined canal with reinforcing, Cameron County Water Improvement District number eleven

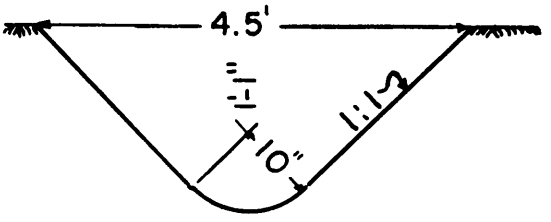

Fig. 2 — Section of hand placed concrete lined canal without reinforcing and gunite lined canal with reinforcing Cameron County Water Improvement District No. one

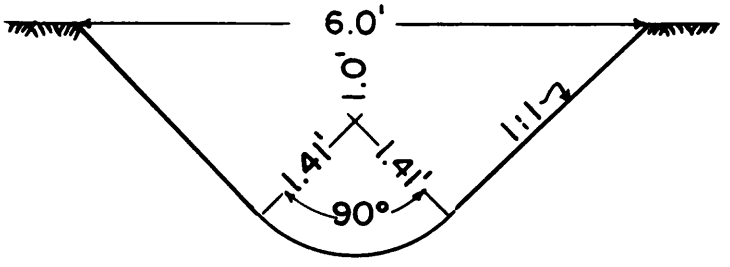

Fig. 3. - Section of hand placed concrete lined canal with reinforcing, Hidalgo County Water Control & Improvement District number six

increase to summer temperature, the transverse cracks will close to the extent that leakage will be practically eliminated. There is little likelihood, however, that the longitudinal cracks will close to any effective degree with an increase in temperature.

In the reach of lining with expansion joints spaced 12 feet, all contraction cracks were confined to the joints. It would be of much value to construct experimental reaches of lining in the Valley, with expansion joints irregularly spaced in order to determine the maximum spacing which will confine contraction to the constructed joints.

O. A. FARIS

LATERAL B5, STATION 13 plus 50 to 26 plus 00, HIDALGO WATER CONTROL & IMPROVEMENT DISTRICT NO. 6

This reach of hand placed concrete lining with reinforcing and expansion joints was 1250 feet in length. Fig. 4 shows a cross-section. The concrete was trowel finished 1 3/4 inches in thickness and the mixwas 1 part cement, 2 parts sand and $3\frac{1}{2}$ parts gravel. The reinforcing consisted of 12 gauge wire with mesh 4 by 8 inches. The expansion joints were made by a groove $\frac{1}{4}$ inch wide and $1\frac{1}{2}$ inches deep, at intervals of 12 feet. The groove was poured full of hot asphalt. At the beginning of the test, water stood 2 inches below the top of the lining at the lower end of the reach and 6 inches below at the upper end. The test was continued 24 hours. The net loss on the basis of depth in feet, per square foot of wet area in 24 hours was 0.300 foot. The average wind movement was 3.4 miles per hour and the temperature of the surface water ranged from 61 to 82 degrees Fahrenheit.

On January 17, 1932, the earth was excavated at one of the expansion joints which showed no opening, in a reach of lateral C, this system. The excavation was extended to the bottom of the section and after remaining open 26 days, showed no sign of leakage through the joint or the body of the slab.

After 24 hours, moisture cones showed in plan on the tops of the canal banks. Their apexes were opposite the open expansion joints and their sides sloped toward the middle of the slabs.

There were 86 open and 19 closed expansion joints in this reach of canal. This test was made February 11 and 12, 1932.

LATERAL 4M, HIDALGO COUNTY WATER CONTROL & IMPROVEMENT DISTRICT NO. 1

This reach of broom finished gunite lining, 1 inch thick was composed of 1 part cement to 4½ parts sand. Its cross-section is shown in fig. 5. Reinforcing consisted of 4 by 8 inch wire mesh, 12 and 14 gage. The reach tested extended from station 90 plus 20 to 102 plus 20. No expansion joints were constructed. There were 33 transverse contraction cracks in the reach, ranging in width from zero to 3/16 inch. There was a deposit of silt, approximately 1 inch in thickness in the invert and extending about 6 inches vertically up the sides. The test was continued 27 hours. The net loss on the basis of depth in feet per square foot of wet area in 24 hours was 0.080 foot. The average wind movement was 10.6 miles per hour and the temperature of the surface water varied from 69 to 78 degrees, Fahrenheit. This test was made February 9,10,and 11,1932.

The earth was excavated on the back side of the lining at an open expansion joint. The soil was saturated near and below the water surface elevation and when the earth was removed below the elevation of the water surface, water streamed through the crack.

For comparison, the earth was excavated back of one of the cracks which showed no opening. The soil below the elevation of water surface was moist but no free water appeared after standing open 14 hours.

These tests, as well as those made during January 1932, and reported under the heading, Leakage of Water From Irrigation Channels and Concrete Lined Canals in the Lower Rio Grande Valley of Texas, indicate that the leakage of water from canals lined with either gunite or hand placed concrete of the quality tested, is confined to open expansion joints or open contraction cracks.

Mr. R. S. Fessenden, General Manager & Chief Engineer of Hidalgo-Cameron Counties Water Control & Improvement District No. 9, called attention to a reach of gunite lined canal which had been leaking through contraction cracks to the extent that water stood in the borrow pits at the toes of the embankments and the edge of a citrus orchard near by. Following the repair of the contraction cracks, the water in the borrow pits and orchard disappeared.

Mr. Fessenden's method of repairing the contraction cracks is interesting. With a straight spade, he excavated the earth from the back side of the gunite lining, opposite the crack. The excavation is 7 inches long at the back side of the lining, 4 inches deep at right angles to the lining and 5 inches long on the soil side. (See Fig.6) A piece of light weight sheet iron (stove pipe material) was creased to fit the excavation and carefully inserted. A mixture of 1 part cement and 4 parts sand mixed quite wet was then placed in the cavity between the back of the lining and the metal and spaded until the mixture appeared on the face of the lining on the inside of the canal section. The spading causes the light metal to conform to the irregularities in the earth excavation. The method is effective in closing the cracks and stopping the leakage, but I fear that when the temperature rises and expansion takes place with no place to go, buckling of the lining will result.

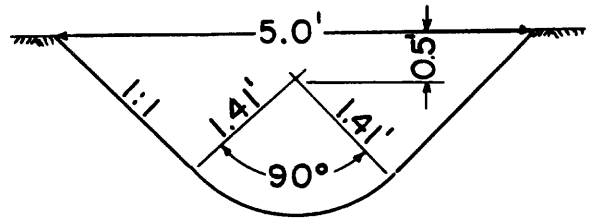

Fig. 4 - Section of hand placed concrete lined canal with reinforcing, Hidalgo County Water Control & Improvement District number six

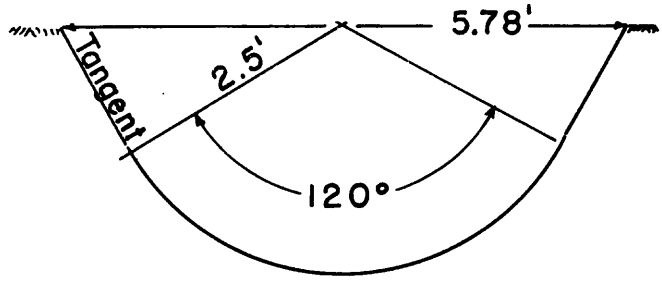

Fig. 5 - Section of gunite canal lining with reinforcing, Hidalgo County Water Control & Improvement District No. 1

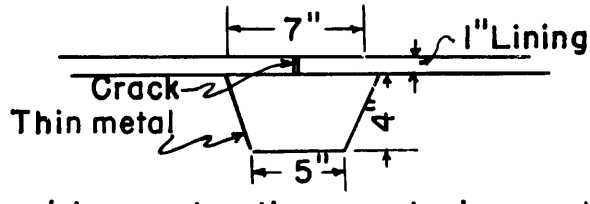

Fig. 6 - Plan of repairing contraction cracks in canal lining, Hidalgo-Cameron Counties Water Control & Improvement District number nine

Apr.

CANAL LOSSES ON SAN BENITO IRRIGATION PROJECT

(CAMERON COUNTY WATER IMPROVEMENT DISTRICT NO. 2)

A Progress Report of Cooperative Irrigation Investigations
Division of Agricultural Engineering
U. S. Department of Agriculture and Board of Water Engineers
State of Texas

By

O. A. Faris
Civil Engineer

San Benito, Texas
November 8, 1923

CANAL LOSSES

After a number of trials of determining the seepage losses from the canals by making measurements with a current meter, it was apparent, that, owing to the manner of operation and the reservoir nature of the channels, this method would be satisfactory in a few cases only.

In one instance water was turned into a canal two and one half miles in length at 6:00 A.M. Measurement at the lower end at 6:00 P.M. indicated that water was still being stored in the canal, altho, flow had been practically uniform and continuous thru-out the entire day.

In a few cases the flow was continuous and fairly uniform. After a number of trials the following results were obtained:-

Canal	Date	Loss cu.ft. per sq.ft. wet A in 24 hrs.	Loss pct per mile	Loss pct of amt diverted.
Rt.Hi Line	8-28-23	.306	1.20	3.4
do	8-30-23	.299	1.20	3.4
9 A	9-18-23	.366	5.50	8.0
9 A	9-26-23	.367	10.90	15.9
Rt.Fresnos	8-21-23	.310	4.00	8.1
do	8-22-23	.294	4.19	8.6
do	8-23-23	.322	4.50	9.1
Average		.323	4.50	8.1

In making current meter measurements, it was necessary to select contracted sections in flumes or checks, as the average canal sections were so large that the velocities were too low to measure.

To illustrate the storage capacity and low velocities, a seepage test was made on canal "Q". A section between two checks 6700 feet apart was selected. The average cross-sectional area between the checks was 57.15 square feet and the wet area was 270 550 square feet. Weir boards were placed in the checks and carefully puddled to prevent leakage. After thirty six hours continuous flow over the weirs, the flow was practically uniform. Measurements showed 2.70 second feet passing over the upper weir and 1.91 second feet passing over the lower weir, indicating a loss of .79 second feet. This

gives a loss of .254 cubic feet per square foot of wet area in twenty-four hours.

On canals where the velocities were too low to measure with a current meter and where the flow was not steady or uniform, dead water seepage tests were made. Owing to the fact that the velocities, under actual working conditions are so extremely low, dead water seepage tests should give results equal to actual working conditions.

In making dead water seepage tests, it was necessary to select sections of canal between checks which could be quickly and effectively puddled as operation could not as a rule, be interrupted more than one day at a time.

The lower check of a selected section was carefully puddled, the section filled with water and then the upper check puddled with the same care. The drop of the water surface was determined by reading staff gages at each end of the section tested. The wet area in square feet and volume lost in cubic feet were calculated from cross-sections taken at each end of the section and at intermediate points where change of cross-sectional area was apparent. The duration of the test was determined by reading the time at the beginning and ending of the test.

DEAD WATER SEEPAGE TESTS.

Canal	Date	Length of section feet	Av.loss cu.ft. per sq.ft. wet area in 24 hours.
S	7-26-23	4800	.253
S-6	8- 8-23	1700	.091
S-6	8-15-23	1900	.091
F	8-17-23	1850	.460
D	9- 6-23	3800	.230
E-4	9- 7-23	550	3.884*
R	9-20-23	3960	.134
T-6	9-28-23	1620	.392
V-1	10-23-23	1060	1.336*

*These canals are used intermittently and do not contain a great amount of silt, it being deposited in the large sections of the main canals from which the water was drawn.

The silt carried by the Rio Grande water is very effective in sealing the wetted surface of canals and other water ways, making it almost impervious.

In order to get some idea of the effect of silt in sealing the wet area of the water ways against the percolation of water, a test was made with two open metal cylinders, hereinafter described under the heading of cylinder tests. A place was selected between a canal and a drain ditch with its bottom grade 10 feet below the surface of the ground. This place was selected in order to get away from the effect of a high ground water table. The cylinders, twenty-four inches in length were driven 4½ inches into the ground. Silt was taken from the bottom of a near by canal and placed to a depth of one inch in one of the cylinders. Both cylinders were then filled with water so that the water surface in both cylinders stood 19½ inches above the natural ground surface at the beginning of the test. Hourly readings were made for 8 hours and a final reading after 23 hours, showed that the water surface in the cylinder with no silt had dropped 7½ inches while in the cylinder with one inch of silt it had dropped but 3/4 inch, a ratio of about 10 to 1.

TABLE SHOWING LOSS FEET IN DEPTH PER SQUARE FOOT OF WET AREA IN 24 HOURS AND AVERAGE FOR ALL TESTS.

Canal	Wet area sq.feet.	Cu ft. lost in 24 hours	Loss ft.in depth in 24 hrs. per sq.ft. of wet area
S-6	14908	1368	.091
Do	19400	1755	.0905
Do	39762	3622	.091
V-1	5300	7082	1.336
T-6	11024	4343	.393
R	40722	5492	.134
R	25773	3470	.134
E-4	3446	13384	3.884
D	53724	14996	.280
D	7645	2224	.290
F	21035	9682	.460
8	16956	4332	.255
8	29760	7512	.252
Rt. Fresnos	153300	46174	.310
Do	151100	44431	.294
Do	151100	48787	.322
Rt Hi Line	474855	145490	.306
Do	442485	131551	.299
9-A	156840	57499	.366
9-A	132840	48787	.367

Average loss feet in depth per square foot wet area in 24 hours 0.308.

CYLINDER TESTS

A number of tests were made with two cylinders, made of 18 gauge smooth galvenized metal. One cylinder was eight and the other twelve inches in diameter and both twenty-four inches in length and having soldered joints to prevent leakage.

The cylinders were driven from two to six inches into the sloping banks or bottom of the channel and filled with water. The surface of the water in the cylinders at the beginning of the test stood from four to twelve inches above the water surface in the channel. The tests were continued, as a rule, over a twenty-four hour period and measurements made to ascertain the fall of the water surface. The cylinders were covered to prevent birds and other animals from drinking out of them and to exclude rain.

RESULTS OF CYLINDER TESTS

Date	Channel	Loss feet in depth in 24 hours 8 inch cylinder	12 inch cylinder
8- 6-23	Resaca	.0445	.0623
8- 7-23	"	.0275	.0275
8-10-23	"	.180	.180
8-11-23	"	.010	.010
8-12-23	"	.010	.010
8-13-23	"	.010	.010
8-14-23	"	.010	.010
8-15-23	"	.010	.010
8-16-23	"	.010	.010
8-17-23	"	.010	.010
8-18-23	"	.010	.010
8-19-23	"	.010	.010
8-20-23	"	.010	.010
8-21-23	"	.010	.010
8-22-23	"	.240	.230
8-23-23	"	.010	.010
8-24-23	"	.010	.010
8-25-23	"	.010	.010
8-26-23	"	.019	.019
8-28-23	"	.019	.019
Average		.0335	.0339

CYLINDER TESTS, Results continued...

Date	Channel	Loss feet in depth in 24 hours 8 inch cylindor	12 inch cylinder
8-29-23	Lateral D	.010	.020
8-30-23	"	.030	.030
8-31-23	"	.030	.026
9- 3-23	"	.094	.078
9- 4-23	"	.115	
9- 5-23	"	.146	
9- 6-23	"		.020
Average		.071	.035
9- 7-23	Lateral E-4	4.08	.240
9-12-23	Lateral B.	.302	.190
9-13-23	"	.375	.083
9-14-23	"	.310	.070
9-14-23	"	.666	.250
9-15-23	"	.440	.220
9-17-23	"		.210
9-18-23	"	.014	.014
9-19-23	"	.037	.010
9-20-23	"	.030	.010
Average		.272	.117
9-21-23	Lateral R.	.036	.041
9-22-23	"	.020	.010
9-23-23	"	.013	.025
9-24-23	"	.083	.023
9-25-23	"	.005	.015
9-26-23	"	.005	.012
Average		.027	.021
9-28-23	Lateral T-6	.062	.031
9-29-23	"	.100	
10-1 -23	"	.078	.032
Average		.080	.031
10-2- 23	Lateral T-1	.036	.042
10-22-23	Lateral V-1*	.047	.016
10-23-23	" *	.042	.016
10-24-23	" #	.615	.641
10-25-23	" #	.604	.610
10-29-23	Lateral V	.054	.242
10-30-23	"	.031	.141
10-31-23	"	.052	.125

CYLINDER TESTS, Results continued...

*In bottom of section, above check, shows silt deposit.
#In bottom of section, just below check where high velocity has prevented silt deposit.

SEEPAGE LOSS FROM THE RESACA

It was not possible to run a seepage test on any section of the resaca. Owing to the design of the waterways thru the dams, it was impossible to make meter measurements and impracticable to shut the water off in order to make a dead water test. The average seepage loss, feet in depth per square foot of wet area in twenty four hours as indicated by forty cylinder tests is .0337.

By a process of elimination the loss per square foot of wet area in twenty four hours was determined from the total acre feet pumped during June and July 1923.

Total acre feet pumped during June and July 1923		10088.
Net duty, average all tests, feet in depth	.279	
Total acres irrigated during June and July 1923	7068.	
Acre feet used at the fields		1972
Wet area in canals acres	396.	
Average loss in canals feet in depth, per square foot of wet area in 24 hours	.308.	
Total seepage loss in canals acre feet in 46.75 days (Pumps operated 46.75 days during June and July 1923)		5703.
Average loss in farm ditches, percent of amount diverted 34.3. Therefore loss in farm ditches acre feet		1029.
Then loss in resaca in 46.75 days acre feet was		1384.

The wet area of the resaca in acres (estimated) is 727.

The loss of 1384 acre feet in 46.75 days from the resaca is equal to a loss of 29.6 acre feet in 24 hours, amounting to a depth of .040 feet.

The rain fall for June and July 1923 was 2.51 and 4.71 inches respectively or a total of .60 feet. Assuming a catchment area of the canals as 50 percent greater than the wet area and the resaca as 10 percent greater than its wet area, the total acre feet supplied by rainfall was 836.

The total loss on 1123 acres of wet area in 14.25 days during the time the pumps were not running, taking the loss in depth on the wet area of the canals as .308 in 24 hours and in the resaca as .040, was 2152 acre feet. Deducting 836 acre feet, that supplied by rain fall, the loss of pumped water in 14.25 days was 1316 acre feet.

Assuming the drop in the water surface of the canals and resaca as uniform during the 14.25 days the pumps were not running, the fall in the water surface would have been 1.17 feet.

In order to supply the towns and farmsteads with domestic water, it was necessary to maintain the water surface in the distribution system within about one foot of normal and to do this when there was no demand for irrigation water, it was observed that it required practically, the continuous operation of the 36 inch pumping unit which delivered approximately 72 second foot.

LOSSES FROM FARM LATERALS.

A number of tests were run to determine the loss from farm laterals between the points of diversion from the Districts distribution system and the fields.

Name	Length of test Section feet	Loss cu.ft. per sq.ft. wet A. 24 hr.	Loss, percent of amt. diverted.
Albritton	2420	5.04	44
Moore	1320	6.70	22
Johnson	850	9.02	31.6
Wagner	1800	1.22	13
Wasson	3240	4.75	50.9
Moyer	1550	3.25	28.3
Lunningham	2187	12.10	90
Blocks 1 & 2	3960	4.48	53.4
Scogin	2366	5.22	30.7
McCain	2895	7.05	34.9
Houghtaling	2800	9.84	71.4

All the loss in the Lunningham and Houghtaling laterals should not be charged to seepage, as a great part of it was due to deferred maintenance. Openings, where water has been turned into the furrows in the fields nearer the head gate had not been properly refilled, permitting water to waste directly thru them.

Eliminating the Lunningham and Houghtaling laterals as not being representative of usual practice the average loss in percent of the amount diverted is 34.3.

The percentage of loss could be reduced by the proper construction and maintenance of the farm laterals. In most instances the banks of the farm laterals are entirely too thin to prevent excessive seepage, vegetation is not removed from the water area and little attention is paid to the burrowing of animals in the banks.

The Wanger lateral is an example of a properly constructed and maintained farm lateral, altho' at the time the test was made some loss could have been prevented by improving an under crossing of the highway.

TRANSPORTATION LOSSES
LATERAL "J".

Canal system. San Benito. Date. November 24, 1923. Observer. O.A.F. Location of section. Lateral "J" from head to check near east line Block #57, San Benito sub-division. Type of soil. Black resaca silt. Condition of canal prism. Fairly uniform. Amount and character of vegetation. Part affected by grass weeds and overhanging growth. Weather. Cloudy. Remarks. Water was being forced thru the lateral to water some high ground at the extreme lower end. All intermediate checks were open. Water surface thruout the section was about one foot higher than under ordinary operating conditions. Water was observed running over the banks in a number of places and all of the eleven delivery gates were leaking.

Discharge at head of lateral second feet	11.96
Discharge at lower end of section second feet	3.98

Loss of 7.98 second feet equals 695217 cubic feet in 24 hrs.

Wet area in canal prism square feet	133158.00
Loss cubic feet per sq. ft. wet area in 24 hrs.	5.22

Length of section 11300 feet.

TRANSPORTATION
LOSSES
SAN BENITO IRRIGATION SYSTEM

Channels	Length Miles	Wetted Area Acres	Av. loss in depth on wet area all tests	Total loss 24 hours acre feet	Total loss Second feet
Canals	217	396	.308	122.0	53.46
Resaca	20	727	.0312	22.68	11.34

CYLINDER TEST LATERAL E-1

This lateral has a three foot bottom width, two to one inside slopes and will carry water to a depth of two feet. The land which it waters has not been cultivated for two years on account of salt and water-logged condition and the ditch has not had water in it for two years. A test well shows the ground water table to be 2.6 feet below the bottom grade. The cylinders were inserted about four inches and filled with water to a depth of 20 inches. Readings were taken at 24 hour periods. Cylinders designated by number. Numbers 1 and 2 being 12 inch and numbers 3 and 4 8 inch.

LOSS FEET IN DEPTH IN 24 HOURS.

DATE	NO. 1	No. 2	No. 3	No. 4
1-1-24	.031	.041		
1-2-24	.062	.031	.016	
1-3-24	.057	.047	.005	.031
Average	.050	.040	.011	.031

Excavated about three inches of black silt from the bottom of the ditch and reset the cylinders in the natural formation, a reddish clay.

1-4-24	.552	.925	.448	1.552
1-5-24	.463	.567*	.531	.250*
1-6-24	.427	.614	.573	.240
Average	.481	.702	.517	.681

Moved cylinders up the ditch about a hundred yards.

1-7-24	.166	.260	.198	.047
1-8-24	.130	.219	.219	.042
1-9-24	.114*	.692*	.078*	.078
1-10-24	.088	.370	.068	.057
1-11-24	.130	.568	.099	.052
1-13-24 av.2 da.	.177	.609	.094	.062
1-14-24	.166	.583	.083	.073
Average	.138	.471	.119	.058

*Cylinders driven more.

Cylinder number two had a crimp in its cutting edge which evidently made a direct connection with the porous stratum below.

Farm Ditch Losses 1-31-24 C. A. Faris

Farmers Name.	Length of Ditch feet	Loss percent of amount diverted.	Loss cubic per sq.ft. wet area in 24 hrs.
Geo. Moore	1320	22.0	6.70*
S. E. Albritton	2420	44.0	5.04
D. G. Wagner	1800	13.2	1.23
R.Johnson	850	31.6	9.02*
L. R. Wasson	3240	50.9	4.75
H. P. Moyer	1550	28.3	3.25
T.Lunningham	2187	90.0	12.13*
R. Haughtaling	2800	71.4	9.84*
Lat. C-5	3960	53.4	4.48#
J. A. Scogin	2366	30.7	5.22
Geo. McCain	2895	34.9	7.05

Lat. C-5 is in about the same condition and constructed in the same manner as the average farm ditch.

*Should not all be charged as seepage as water wasted over banks and thru openings which could be closed easily.

CANAL LOSSES.

Canal system. San Benito. Date. January 22,1924. Observer. O.A.F. Location of section. All of lateral Q-1 and H. P. Moyer's farm ditch. Type of soil. Heavy grayish soil. Condition of canal prism. Fairly uniform. Amount and character of vegetation. Large amount of course vegetation in Q-1. Weather. Cloudy drizzle rain. Remarks: This test was made to determine the relation of the amount of water reaching the field and the amount diverted from the main canal into the sub lateral at the head. The loss as determined includes seepage, leakage of six service gates, and direct run-off waste at the end of Lateral Q-1. Mexican irrigator is permitted to divert water from the main canal to the sub lateral.

Discharge at the head of Q-1 second feet 1.89

Discharge at the head of H. P. Moyer's field ditch sec. ft. .59

Applying the loss in this field ditch as determined January 19 or 28.2 percent the amount of water reaching the field would be .42 second feet or a loss of 1.47 second feet from all causes in one mile of Q-1 lateral and 1550 feet of Moyer's field ditch. Loss in percent of the amount diverted at the head of Q-1 77.7. The water was checked up considerably higher in Q-1 than was necessary for diversion into the Moyer ditch.

DEAD WATER SEEPAGE TEST.

Canal system. San Benito. Date. September 6,1923. Observer. O.A.F. Location of section. Lateral "D" between checks Nos. 307-318. Type of soil. Dark brown clay. Condition of canal prism. Fairly uniform. Amount and character of vegetation. Little vegetation. Time water was turned into section. This section is kept full of water continuously. Was shut off at upper check at 9:30 A. M. Weather. Clear, slight wind.

Section	Dist. Apart ft.	Gage	Time	Wetted Perimeter Sec.1	Wetted Perimeter Sec.2	Wet Area sq.ft.	Water Surface sq.ft.	Volume Lost cu.ft.	Loss cu.ft. Per sq.ft. Wet Area in 24 hours
		3.10	AM 11:00	16.28	16.56		47190		
1 & 2	3300		PM			53724		3749	.279
		3.02	5:00	16.08	16.20		46530		
			AM						
2 & 3		3.10	11:00	16.56	14.30		7000		
	500		PM			7645		556	.289
		3.02	5:00	16.20	14.10		6890		

Average loss in cubic feet per square foot of wet area .280 in 24 hours.

DEAD WATER SEEPAGE TEST.

Canal system. San Benito. Date. September 7,1923. Observer. O.A.F. Location of section. Lateral E-4 between checks 301-302. Type of soil. Light silty loam. Condition of canal prism. Uniform. Amount and character of vegetation. Free from vegetation. Time water was turned into section. 9:00 A. M. Weather. Clear. Remarks. Water table as shown by well in close proximity is about 11 feet below the ground surface. The water table is kept down by a drain ditch about one-fourth mile east and an old Resaca within about 300 feet of the upper end of the section. This canal is used only for irrigation and is absolutely free from silt, water being taken from Lateral E. after the silt in suspension has been deposited.

Section	Dist. Apart ft.	Gage	Time	Wetted Perimeter Sec.1	Wetted Perimeter Sec.2	Wet Area sq.ft.	Water Surface sq.ft.	Volume Lost cu.ft.	Loss cu.ft. per sq.ft. Wet Area 24 hours
		1.50	10:45	5.80	880		3713		
1 & 2	550					3446		1673	3.884
		.98	1:45	3.90	6.56		2723		

DEAD WATER SEEPAGE TEST

Canal system. San Benito. Date. September 19, 20, 1923. Observer. O.A.F. Location of section. Lateral "R" between check No. 303 and end of lateral. Type of soil. Grayish clay. Condition of canal prism. Fairly uniform. Amount and character of vegetation. Few tules some moss. Time water was turned into the section. Water is kept in this section continuously. Was shut off at check No. 303 at 10:00 A. M. Weather. Fair, slight wind.

Section	Dist. Apart ft.	Gage	Time	Wetted Perimeter Sec.1	Wetted Perimeter Sec.2	Wet Area sq.ft.	Water Surface sq.ft.	Volume Lost cu.ft.	Loss cu.ft. per sq.ft. Wet area in 24 hours
			AM						
		2.50	10:00	14.30	17.20		40920		
1 & 2	2640		PM			40722		1602	.134
		2.46	5:00	14.00	16.20		39204		
				Sec.2	Sec.3				
		2.50	10:00	17.20	22.50		25740		
2 & 3	1320					25773		1012	.134
		2.46	5:00	16.20	22.20		24882		

Average loss in cubic feet per square foot of wet area in 24 hours. .134

DEAD WATER SEEPAGE TEST.

Canal system. San Benito. Date. September 27,28,1923. Observer. O.A.F. Location of section. Lateral T-6 between checks Nos. 301-302. Type of soil. Heavy black silty loam. Condition of canal prism. Fairly uniform. Amount and character of vegetation. Green with grass, streamer moss and other acquatic growth. Time water was turned into section. A small head of water is kept in this canal for domestic purposes continually. Turned head in for test at 8:30 A. M. September 27. Owing to the vegetation it required over four hours for the water to travel less than a mile and fill the section. Weather. Clear, slight wind. Remarks. The big loss above gage 1.14 is due to two conditions; 1st. Burrowing animals. Their holes could be seen at several places along this section; 2nd. Little or no silt on the slopes above this gage height.

Section	Dist. Apart ft.	Gage	Time	Wetted Perimeter Sec.1	Wetted Perimeter Sec.2	Wet Area sq.ft.	Water Surface sq.ft.	Volume Lost cu.ft.	Loss cu.ft. per sq.ft. wet area 24 hours
		1.30	2:00P	7.90	7.60		11907		
1 & 2	1620					11671		1792	1.219
		1.14	5:00P	6.84	6.70		10490		
		1.14	5:00P	6.84	6.70		10490		
1 & 2	1620					10230		1465	.229
		.99	8:00A	5.92	5.80		9040		
		1.30	2:00P	7.90	7.60		11907		
1 & 2	1620					11024		3247	.392
		.99	8:00A	5.92	5.80		9040		

Average loss in cubic feet per square foot of wet area in 24 hrs. .392.

DEAD WATER SEEPAGE TEST.

Canal system. San Benito. Date. October 23,1923. Observer. O.A.F. Location of section. Lateral V-1 between first check and drain ditch crossing. Type of soil. Brownish loam. Condition of prism. Fairly uniform, no silt. Amount and character of vegetation. Some overhanging grass and brush. Time water was turned into section. 9:30 A. M. Weather. Fair.

Section	Dist. Apart ft.	Gage	Time	Wetted Perimeter Sec.1	Wetted Perimeter Sec.2	Wet Area sq.ft.	Water Surface sq.ft.	Volume Lost cu.ft.	Loss cu.ft. per sq.ft. Wet Area in 24 hours
		1.06	11:30	5.15	5.87		5035		
1 & 2	1060					5300		1623	1.336
		.71	5:00	4.15	4.83		4240		

Average loss in cubic feet per square foot of wet area in 24 hours equals 1.336.

This canal is used intermittently.

BLIND STUB SEEPAGE TEST.

Canal system. San Benito. Date. July 26,1923. Observer. O.A.F. Location of section. Lateral #8 between checks 301 and 302. Type of soil. Black resaca silt. Condition of canal prism. Good shape and reasonably uniform. Amount and character of vegetation. Few water reeds in prism and some overhanging brush and grass along banks. Time water was turned into section. Water is kept in this section continuously. Water was shut off at upper end at 10:00 A. M. Weather. Clear, slight wind.

Sections	Dist. Apart ft.	Gage	Time	Wetted Perimeter Sec.1	Wetted Perimeter Sec.2	Wet Area sq.ft.	Water Surf sq.ft.	Volume Lost Cu.ft.	Loss cu.ft. per sq.ft. in 24 hours
1 & 2	1800	4.78	11:0	9.22	9.82	16956	15642		
		4.71	5:0	9.02	9.62		15300	1083	0.255
				Sec.2	Sec.3				
2 & 3	3000	4.78	11:0	9.82	10.22		27075		
		4.71	5:0	9.62	10.02	29760	26580	1878	0.252

Average loss in cubic feet per square foot of wetted area in 24 hours 0.253.

BLIND STUB SEEPAGE TEST.

Canal system. San Benito. Date. August 7,8,1923. Observer. O.A.F. Location of section. Lateral "S 6". From lower end back 1700 feet. Type of soil. Heavy silt some sand. Condition of canal prism. Fairly uniform. Amount and character of vegetation. One-fourth the distance tules and water hyacinths. Time water was turned into the section. Water is kept in this section continuously. For this test water was shut off at 2:50 P. M. August 7. Test ended at 8:20 A. M. August 8, 1923. Weather. Clear, slight wind. Remarks. This canal is wholly in excavation and is really a storage reservoir being supplied at the upper end by a section 100 feet long; only two feet in width.

Sections	Dist. Apart ft.	Gage	Time	Wetted Perimeter Sec.1	Wetted Perimeter Sec.2	Wet Area sq.ft.	Water Surf sq.ft.	Volume Lost cu.ft.	Loss cu.ft. per sq.ft. in 24 hours
		3.60	PM 2:50	16.45	21.12		14400		
1 & 2	800		AM			14908		998	.0917
		3.53	8:20	16.25	20.72		14100		
		3.60	PM 2:50	21.12	22.34		18450		
2 & 3	900		AM			19400		1280	.0905
		3.53	8:20	20.72	22.04		18117		

Average loss in cubic feet per square foot of wetted area in 24 hours .0910.

BLIND STUB SEEPAGE TEST.

Canal system. San Benito. Date. August 14,15,1923. Observer. O.A.F. Location of section. Lateral "S 6" from the head to a point 1900 feet down stream. Type of soil. Heavy silt some sand. Condition of prism. Failry uniform. Amount and character of vegetation. Much vegetation tule and water hyacinths. Time water was turned into section. Water is kept in this section continuously. Was shut off at 10:40 A. M. August 14, 1923. Test ended at 9:40 A. M. August 15, 1923. Weather. Clear, windy. Remarks: This canal is wholly in excavation and is really a storage reservoir being supplied at the upper end by a section 100 feet long only two feet in width.

Section	Dist. Apart ft.	Gage	Time	Wetted Perimeter Sec.1	Wetted Perimeter Sec.2	Wet Area sq.ft.	Water Surface sq.ft.	Volume Lost cu.ft.	Loss cu.ft. per sq.ft. wet area 24 hrs.
		1.20	AM 10:40	20.60	21.56		38950		
1 & 2	1900		AM			39762		3471	.091
		1.11	9:40	20.26	21.30		38190		

BLIND STUB SEEPAGE TEST.

Canal system. San Benito. Date. August 17,1923. Observer. O.A.F. Location of section. Lateral "F" 1850 above check No. 302. Type of soil. Chocolate colored clay. Condition of canal prism. Good shape and reasonably uniform. Amount and character of vegetation. A small maount of grass in bottom and on sides. Time water was turned into section. 11:30 A. M.. Weather. Clear, slight wind.

Section	Dist. Apart ft.	Gage	Time	Wetted Perimeter Sec.1	Wetted Perimeter Sec.2	Wet Area sq.ft.	Water Surface sq.ft.	Volume Lost cu.ft.	Loss cu.ft. per sq.ft. 24 hours
1 & 2	1850	2.55	AM 11:30	11.50	11.70	21035	18685	2017	
		2.44	4:30	10.98	11.30		17991		.46

Average loss in cubic feet per square foot of wetted area in 24 hours 0.46.

SEEPAGE TEST.

Canal system. San Benito. Date. August 21,22,23, 1923. Observer. O. A. F. Location of section. Right Fresnos Canal from a section about 75 feet below steel bridge across the Resaca and the flume over Lateral 18. Type of soil. Clay loam red and dark. Condition of canal prism. Fairly uniform. Amount and character of vegetation. Mostly overhanging grass and brush. Weather. Fair. Remarks. Water is kept in this section continuously.

AUGUST 21.

Discharge at upper section sec. ft.	6.54
Discharge at lower section sec. ft.	6.01
Loss sec. feet	.53
.53 sec. ft. equals 46174 cu. ft. in 24 hours.	
Wet area equals 153300 sq. ft.	
Loss cu. ft. per sq. ft. of wet area in 24 hours	.310
Loss in percent per mile	4.0
Loss in percent of amount diverted	8.1

AUGUST 22.

Discharge at upper section sec. ft.	5.93
Discharge at lower section sec. ft.	5.42
Loss sec. ft.	.51
.51 sec. ft. equals 44431 cu. ft. in 24 hours.	
Loss cu. ft. per sq. ft. of wet area in 24 hours	.294
Loss in percent per mile	4.19
Loss in percent of amount diverted	8.6
Wet area equals 151100 sq. ft.	

AUGUST 23.

Discharge at upper section sec. ft.	6.01
Discharge at lower section sec. ft.	5.45
Loss sec. ft.	.56
.56 sec. ft. equals 48787 cu. ft. in 24 hours.	
Wet area equals 151100 sq. ft.	
Loss cu. ft. per sq. ft. wet area in 24 hours	.322
Loss percent per mile	4.5
Loss percent of amount diverted	9.1

SEEPAGE TEST.

Canal system. San Benito. Date. August 28, 1923. Observer. O.A.F. Location of section. Right High Line Canal between flume over Low Line Canal and a point ¼ mile above the head of Lateral # 8. Type of soil. Black Resaca silt. Condition of Canal Prism. Large deposits of silt. Amount and character of vegetation. Little vegetation except overhanging along banks. Weather. Clear, slight wind. Water is kept in this section continuously.

Discharge at flume over Low Line sec. ft.	48.81
Discharge at lower end of section " " .	43.34
Diversions " ".	3.80
Loss " ".	1.67
Loss cubic feet in 24 hours	145490.00
Wetted area square feet	474855.00
Loss cu. ft. per sq. ft. wet area in 24 hrs.	.306
Loss percent per mile	1.2
Loss percent of the amount diverted	3.4

SEEPAGE TEST.

Canal system. San Benito. Date. August 30, 1923. Observer. O.A.F. Location of section. Right High Line Canal between flume over Low Line Canal and a point ¼ mile above head of Lateral # 8. Type of soil. Black Resaca silt. Condition of Canal Prism. Large deposits of silt. Amount and character of vegetation. Little vegetation except overhanging along banks. Weather. Clear, slight wind. Water is kept in this section continuously.

Discharge at flume over Low Line	sec. ft.	43.43
Discharge at lower end of section	" "	37.62
Diversions	" "	4.30
Loss	" "	1.51
Loss cubic feet in 24 hours		131551.00
Wetted area square feet		442485.00
Loss cu. ft. per sq. ft. wet area 24 hrs.		.299
Loss percent per mile		1.2
Loss percent of amount diverted		3.4

SEEPAGE TEST.

Canal system. San Benito. Date. September 18, 1923, Observer. O. A. F. Location of section. Lateral 9-A between head and check near lock # 3. Type of soil. Part reddish clay; part black Resaca silt. Condition of canal prism. Heavy deposits of silt. Amount and character of vegetation. Considerable vegetation consisting of tules and water grass. Weather. Clear. Remarks. Water is kept in this section continuously.

Discharge at head of canal in second feet	8.16
Discharge at lower end section " "	6.66
Diversions " "	.84
Loss " "	.66
Loss cubic feet in 24 hours	57499.00
Wet area square feet	156840.00
Loss cu. ft. per sq. ft. wet area in 24 hours	.366
Loss percent per mile	5.5
Loss in percent of the amount diverted	8.0

SEEPAGE TEST.

Canal system. San Benito. Date. September 26,1923.

Observer. O. A. F. Location of section. Lateral 9-A between head and check near lock # 3. Type of soil. Part reddish clay, part black Resaca silt. Condition of canal prism. Heavy deposits of silt. Amount and character of vegetation. Considerable vegetation consisting of tules and water grass. Weather. Clear.

Remarks. Water is kept in this section continuously.

Discharge at head of canal in sec. ft.	3.52
Discharge at lower end of section in sec. ft.	2.96
Diversions None.	
Loss in second feet.	.56
Loss in cubic feet in 24 hours	48787.00
Wet area in square feet	132840.00
Loss cu. ft. per sq. ft. wet area in 24 hrs.	0.367
Loss in percent per mile	10.9
Loss in percent of the amount diverted	15.9

FARM LATERAL SEEPAGE TEST.

Canal system. San Benito. Date. January 9,1924. Observer. O.A.F. Location of section. Geo. Moore and G. W. Haughtaling farm lateral along east side Block 201 San Benito sub-division. Type of soil. Chocolate colored clay. Condition of canal prism. Fairly uniform. Amount and character of vegetation. Some grass. Weather. Clear and windy. Remarks. Water could be seen coming thru the banks thru small holes made by cray-fish or burrowing animals. Direct leakage thru an old drain box under the ditch was noticeable.

Discharge at head of lateral second feet		2.04
Discharge at lower end of section second feet		1.15
Diversion Geo. Moores ditch	" "	.44
Loss	" "	.45
Loss cubic feet in 24 hours		39204.00
Wet area square feet		5850.00
Loss cu. ft. per sq. ft. wet area in 24 hours		6.70
Loss percent in one-fourth mile		22.00

FARM LATERAL SEEPAGE TEST.

Canal system. San Benito. Date. January 15,1924. Observer. O.A.F. Location of section. Along the east side of block 49 and the south side of block 40 San Benito sub-division. S. E. Albritton's ditch. Type of soil. Chocolate colored clay. Condition of canal prism. Fairly uniform. Amount and character of vegetation. Little grass. Weather. Cloudy. Remarks. Water seeped thru the banks and ran into the gutter at the side of the road.

Discharge at the head of lateral second feet	1.27
Discharge at lower end of section " "	.71
Loss " "	.56
Loss cubic feet in 24 hours	48787.00
Wet area square feet	9680.00
Loss cu. ft. per sq. ft. wet area in 24 hours	5.04
Loss percent in 2420 feet	44.00

FARM LATERAL SEEPAGE TEST.

Canal system. San Benito. Date. January 17,1924. Observer. O.A.F. Location of section. N.W. ¼ Block 81 San Benito Sub-division. D. G. Wagner ditch. Type of soil. Red colored clayey. Condition of canal prism. Uniform and well constructed. Amount and character of vegetation. Heavy growth of short grass. Weather. Partly cloudy. Remarks. Practically all the loss was due to seepage. One pipe under highway was leaking slightly.

Discharge at the head of ditch second feet	1.44
Discharge at lower end of section " "	1.25
Loss " "	.19
Loss cubic feet in 24 hours	16553.00
Wet area square feet	13500.00
Loss cu. ft. per sq. ft; wet area 24 hours	1.226
Loss percent in 1800 feet	13.2

FARM LATERAL SEEPAGE TEST.

Canal system. San Benito. Date. January 18, 1924. Observer. O.A.F. Location of section. Block 65 El Fresnal Sub-division, Roy Johnson's field ditch. Type of soil. Grayish colored. Condition of prism. Fairly uniform. Amount and character of vegetation. Some grass. Weather. Partly cloudy windy. Remarks. Ditch banks entirely too thin. Water could be seen coming thru the banks.

Discharge at head of ditch second feet	1.39
Discharge at field " "	.95
Loss " "	.44
Loss cubic feet in 24 hours	38333.00
Wet area square feet	4250.00
Loss cu. ft. per sq. ft. wet area in 24 hours	9.02
Loss percent in 850 feet	31.6

FARM LATERAL SEEPAGE TEST.

Canal system. San Benito. Date. January 18,1924. Observer. O.A.F. Location of section. L. R. Wasson ditch Block 216 San Benito subdivision. Type of soil. Red clayey and light resaca silt. Condition of canal prism. Fairly uniform. Amount and character of vegetation. A good carpet of short grass. Weather. Partly cloudy. Remarks. For about 1600 feet this ditch runs thru some heavily salted Land which has a red color. As the ditch approaches an old resaca which provides drainage the salt has not reached the ground surface and the soil is a light silt.

Discharge at the head of the ditch	second feet	1.63
Discharge at the field	" "	.80
Loss	" "	.83
Loss cubic feet in 24 hours		72310.00
Wet area square feet		15228.00
Loss cu. ft. per sq. ft. wet area in 24 hours		4.748
Loss percent in 3240 feet		50.9

FARM LATERAL SEEPAGE TEST.

Canal system. San Benito. Date. January 19,1924. Observer. O.A.F. Location of section. East ½ Block 224 San Benito Sub-division H. P. Moyer farm ditch. Nature of soil. Heavy grayish soil. Condition of canal prism. Fairly uniform. Amount and character of vegetation. Heavy growth of grass. Weather. Cloudy. Remarks. Ditch banks entirely too thin permitting water to seep thru easily.

Discharge at head of ditch, second feet	.92
Discharge at the field " "	.66
Loss " "	.26
Loss cubic feet in 24 hours	22651.00
Wet area square feet	6975.00
Loss cu. ft. per sq. ft. wet area in 24 hours	3.25
Loss percent in 1550 feet	28.26

FARM LATERAL SEEPAGE TEST.

Canal system. San Benito. Date. January 22,1924. Observer. O.A.F. Location of section. N. E. ¼ Block 12 San Benito subdivision. Thos. Lunningham tenant. Type of soil. Chocolate colored soil. Condition of canal prism. Fairly uniform. Amount and character of vegetation. Heavy growth of grass. Cloudy weather. Remarks. This test illustrates the excessive waste when some farmers are permitted to open their head gates. Too much water was diverted and owing to the grassy condition of the canal or farm ditch it ran over the top of the banks. Openings which had been made in the banks for diverting to the field had not been properly filled permitting much water to be lost.

Discharge at the head of the ditch	second feet	1.72
Discharge at the field	" "	.18
Loss	" "	1.54
Loss cubic feet in 24 hours		134165.00
Wet area square feet		11056.00
Loss cu. ft. per sq. ft. wet area in 24 hours		12.134 *
Loss percent in 2187 feet		90.00

*This should not be charged to wet area as a great amount of it was running over the banks and thoroly saturating a strip of ground several feet wide on each side of the ditch.

FARM LATERAL SEEPAGE TEST.

Canal system. San Benito. Date. January 25, 1924. Observer. O.A.F. Location of section. Ralph Haughtaling's farm lateral along the east side of block 208 San Benito sub-division. Type of soil. Red colored clay soil. Condition of canal prism. Fairly uniform. Amount and character of vegetation. Some grass. Weather. Cloudy. Remarks. Ditch in bad shape.

Discharge at the head of the lateral	second feet	2.63
Discharge at field	" "	.75
Loss	" "	1.88
Loss cubic feet in 24 hours		163786.00
Wet area square feet		16640.00
Loss cu. ft. per sq. ft. wet area in 24 hours		9.84
Loss percent in 2800 feet		71.4

FARM LATERAL SEEPAGE TEST.

Canal system. San Benito. Date. January 26,1924. Observer. O.A.F. Location of section. Lateral C-5 San Benito Canal system. Type of soil. Dark colored silty loam. Condition of canal prism. Fairly uniform. Amount and character of vegetation. Considerable grass. Weather. Cloudy. Remarks. This lateral compares favorably with all farm laterals.

Discharge at head of lateral second feet	1.89
Discharge at the lower end " "	.88
Loss " "	1.01
Loss cubic feet in 24 hours	87991.00
Wet area square feet	19536.00
Loss cu. ft. per sq. ft. of wet area in 24 hours.	4.48
Loss percent in 3960 feet	53.4

FARM LATERAL SEEPAGE TEST.

Canal system. San Benito. Date. January 29,1924. Observer. O. A. F. Location of section. End of lateral E-6 to SW ¼ block 255 San Benito Irrigated Lands Co. sub-division. Type of soil. Chocolate colored loam. Condition of canal prism. Tramped badly by live-stock. Amount and character of vegetation. Considerable grass. Weather. Cloudy. Remarks. This canal is almost entirely in excavation and has a good fall.

Discharge at the head of the lateral	second feet	2.06
Discharge at the field	" "	1.24
Loss	" "	.82
Loss Cubic feet in 24 hours		71438.00
Wet area square feet		10133.00
Loss cu. ft. per sq. ft. wet area in 24 hours		7.05
Loss percent in 2895 feet		34.9

FARM LATERAL SEEPAGE TEST.

Canal system. San Benito. Date. January 29,1924. Observer. O.A.F. Location of section. J. A. Scogin farm lateral blocks 46 and 56 San Benito sub-division. Type of soil. Chocolate colored loam. Condition of canal prism. Fairly uniform. Amount and character of vegetation. Considerable grass and weeds. Weather. Cloudy. Remarks. Lower measurement taken at the upper end of a 500 foot fill newly constructed. This fill was loosing a large amount of water. Was unable to get measurement at lower end of fill owing to low velocity.

Discharge at head of lateral second feet	2.44
Discharge at lower end of section " "	1.69
Loss " "	.75
Loss cubic feet in 24 hours	65340.00
Wet area square feet	12507.00
Loss cu. ft. per sq. ft. wet area in 24 hours	5.224
Loss percent in 2366 feet	30.7

MISCELLANEOUS DATA ON SEEPAGE LOSSES FROM CANALS IN TEXAS FOR 1921

(BEXAR-MEDINA-ATASCOSA COUNTIES WATER IMPROVEMENT DISTRICT NO. 1)

By

H. C. Pritchett and V. H. Clements

Engineers, Texas Board of Water Engineers

MISCELLANEOUS DATA ON SEEPAGE LOSSES FROM CANALS IN TEXAS FOR 1921

(Bexar-Medina-Atascosa Counties Water Improvement District No. 1)

Spot ratings to determine seepage losses were made on several of the laterals and field ditches whenever suitable lengths of sections could be found. The following tabulated data show the results obtained from ratings made during the months of May, June, July, August, September and October, 1921.

Date	Canal	Length of ditch Miles	Discharge at head of ditch Sec.ft.	Seepage Loss Sec. ft.	Seepage Loss Percent	Seepage Loss Percent per Mi.	Cu.ft. per sq.ft. of wetted area per 24 hours	Slope
5-9-21	Ft. Ewell	.824	2.71	.30	11			
6-9-21	C		5.27	.62	12			
6-17-21	Ft. Ewell	.824	1.83	.35*	19*			
6-17-21	"	.824	.72	.36*	50*			
6-18-21	"	.824	1.52	.25*	16*			
6-21-21	"		3.36	.09*	3*			
6-24-21	Lat. A-4		1.09	.28	26			
6-24-21	Ft. Ewell	.824	11.12	.33	3			
6-29-21	A-5	.89	6.11	.60	10			
7-16-21	Natalia	2.52	6.98	.16	2.29	.92	.079	.000455
7-27-21	Natalia	2.52	8.10	.46	5.68	2.25	.22	.000455
7-6-21	A-5	.89	3.74	.46	12.3	14.15	.9997	.0001257
7-9-21	"	.89	1.49	.39*				
7-11-21	"	.89	2.19	.24	10.95	12.6	.61	.001338
7-13-21	"	.91	2.04	.19	9.32	10.24	.482	
7-21-21	M. Ruiz	.31	.39	.01	2.57	8.29	.108	.00147
7-21-21	Herring	.802	1.54	.305	19.8	24.72	.966	.001398
7-12-21	Ft. Ewell	.824	5.05	.63	12.47	15.15	2.408	.00484
7-8-21	C-6		2.77	.41	14.8			
7-12-21	"		2.55	.02	.785			
8-12-21	Natalia	2.52	8.27	.29		1.50	.139	.000445
8-19-21	"	2.52	6.83	.82		5.05	.426	.000450
8-17-21	"	2.52	6.24	.17*				
8-24-21	A-5	.91	2.36	.27		12.58	.761	.00187
8-1-21	"	.91	3.08	.30		10.71	.571	.00173
8-23-21	"	.91	2.29	.21*				
8-19-21	M. Ruiz	.31	.22	.07*				
8-22-21	M. Ruiz	.31	.28	.03*				
8-2-21	Ft. Ewell	.82	3.16	.20*				
8-15-21	"	.82	4.43	.72*				
8-16-21	"	.82	5.61	.15*				
8-18-21	"	.82	3.50	.24*				
8-8-21	Herring	.802	.61	.09		18.40	.301	
8-5-21	Johnson	.328	1.29	.03		7.09	.259	.00264
9-3-21	Natalia	2.52	7.52	.81		4.40	.385	.00045
9-23-21	"	2.52	4.25	1.10		11.40	.566	.00048
9-27-21	A-5	.91	1.00	.19*				
9-2-21	C-6	.64	2.76	.46		26.05	1.75	.000575
9-6-21	Johnson	.33	.74	.10		40.70	1.66	.00272
9-8-21	C-6	.64	1.73	.11*				
9-7-21	D-2	4.10	2.81	.81		7.85	.33	
9-21-21	"	4.10	1.46	.72		16.30	.34	
9-22-21	"	4.10	1.42	.49		9.90	.23	
9-23-21	"	4.10	3.28	.68		5.50	.28	

Date	Canal	Length of ditch	Discharge at head of ditch	Seepage Loss			Cu.ft. per sq.ft. of wetted area per 24 hours	Slope
		Miles	Sec.ft.	Sec. ft.	Percent.	Percent. per Mi.		
9-26-21	D-2	4.10	2.16	.62		7.90	.27	
9-27-21	"	4.10	2.17	.66		8.50	.28	
9-28-21	"	4.10	2.18	.76		10.00	.34	
9-29-21	"	4.10	1.91	.75		11.50	.33	
10-7-21	"	4.10	1.51	.46		8.50	.214	
10-10-21	"	4.10	3.69	.97		7.25	.39	
10-15-21	Johnson	.328	1.02	.21		63.20	2.698	
10-17-21	"	.328	1.02	.10		29.90	1.298	
10-15-21	A-4	1.94	2.78	.21		4.00	.198	
10-17-21	A-4	1.94	4.82	.53		5.50	.455	
10-18-21	"	1.94	2.48	.08		2.50	.079	
10-19-21	"	1.94	2.44	.10		2.00	.095	
10-21-21	"	1.94	2.40	.41*				
10-10-21	Mata	.865	.96	.13		15.67	.346	
10-19-21	"	.865	1.00	.16		20.42	.482	
10-20-21	"	.865	.52	.12		26.70	.354	
10-21-21	King	.88	1.35	.02*				
10-22-21	"	.88	1.30	.02		1.75	.078	
10-24-21	"	.88	1.97	.01		.578	.036	
10-24-21	"	.88	1.71	.09*				
10-24-21	"	.88	1.86	.31*				
10-25-21	"	.88	2.48	.24*				
10-25-21	"	.88	2.89	.02		.758	.068	
10-25-21	"	.88	2.62	.10*				
10-27-21	A-3	2.39	4.07	.21		2.10	.116	
10-27-21	"	2.39	4.21	.18		2.00	.099	
10-28-21	"	2.39	4.21	.02		.198	.011	

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MISCELLANEOUS DATA ON SEEPAGE LOSSES FROM CANALS IN TEXAS FOR 1922

(United Irrigation District - Hidalgo County Water Control and Improvement District No. 7)

By

H. C. Pritchett
Engineer, Texas Board of Water Engineers

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MISCELLANEOUS DATA ON SEEPAGE LOSSES FROM CANALS

IN TEXAS FOR 1922

(United Irrigation District - Hidalgo County
Water Control and Improvement District No. 7)

June, 1922

Shary Third Lift				
At head (Measured over weir)			41.56	
Diversion	5.21			
End	16.77		21.98	
			19.58	Loss in 2 miles
At head (measured over weir)			37.40	
Diversions 6.94 and 2.45		9.39		
End		16.85	26.24	
			11.16	Loss in 1 mile

July, 1922

Mission Third Lift				
Head (at 3 mi. road)			49.63	
Diversions	13.51			
End (at 5 mi.road)	21.31		34.82	
		Loss	14.81	
Head (at 6-3/4 mi.)			12.26	
End (at 7 mi. & R.R.)			9.52	
		Loss	2.74	
Shary Third Lift:				
Head (5 mi. road)			32.09	(falling
End (7 mi. line)			8.88	head)
		Loss	23.21	
Wilson				
Head (headgate)			34.67	
Diversions	5.93			
End (Shary Blvd.)	20.59		26.52	
		Loss	8.15	
Head (head gate)			28.24	
End (Shary Blvd.)			26.24	
		Loss	2.00	
Bryan				
Head (½ mi. below 2nd lift)			70.61	
Diversions	13.31			
End (near Shary Rd.)	66.94		79.95	
		Loss	9.34	
Head (½ mi.below 2nd lift			66.26	
Diversions		11.48		
End (near Shary 3rd lift		53.74	65.22	
		Loss	1.04	

Davis		
Head (head gate)		11.45
End (near siphon)		8.31
	Loss	3.14
Sweeney and Olson		
Head (head gate)		5.33
End (gate south of 25 mi. road)		4.33
	Loss	1.00

August, 1922

Canal	Head		End	Loss
Doughty	3.85		3.49	.36
4 mile	11.44		13.89	2.45*
Grangeno	36.86		34.63	2.23
Bryan	72.30		70.08	
		leak	.40	1.82
Main (2nd lift)	74.90		65.80	9.18
Bryan	65.30		49.07	16.73*

(*) Change of stage during measurement.