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A. C. TRUE, Director.

TIDAL MARSHES AND THEIR
RECLAMATION.

BY

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LETTER OF TRANSMITTAL

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
Washington, D. C., February 28, 1911.

SIR: I have the honor to transmit herewith a manuscript upon "Tidal Marshes and Their Reclamation," prepared by George M. Warren, drainage engineer, under the direction of C. G. Elliott, chief of drainage investigations.

Mr. Warren has made a thorough study of the subject and has presented it in a comprehensive manner. His investigations are valuable and throw light on some of the heretofore obscure points connected with the profitable reclamation of tidal marshes. Actual field conditions have been critically examined and the deductions are based upon data secured upon the ground. Except as otherwise noted, all maps, plans, and diagrams were prepared by Mr. Warren and many of the photographs were taken by him.

Among many who have kindly given of their time, furnished teams, or assisted in other ways thanks are hereby especially extended to Harry Hayward, director of the State Experiment Station, Newark, Del.; William J. Beck, Delaware City, Del.; Oliver H. Tomlinson, Dorchester, N. J.; D. Woodruff Boggs, civil engineer, Bricksboro, N. J.; Edward L. Gandy, Mauricetown, N. J.; Dr. Stephen Henry, Marshfield, Mass.; Prof. W. F. Ganong, Smith College, Northampton, Mass.; L. D. Baker, jr., Wellfleet, Mass.; Whitman & Howard, civil engineers, Boston, Mass.; John F. Herbin, Wolfville, Nova Scotia; Gustavus Bishop, Greenwich, Nova Scotia; W. C. Milner, Halifax, Nova Scotia; Mayor J. M. Curry, Amherst, Nova Scotia; Thomas Estabrooks and William B. Fawcett, Sackville, New Brunswick; William B. Mackenzie, chief engineer of Intercolonial Railway of Canada, Moncton, New Brunswick.

The growing scarcity of good upland farms and the rapidly increasing population and consequent demand for good trucking lands near the large cities, particularly on the Atlantic coast, make the reclamation of tidal lands an increasingly important subject.

I therefore recommend that this manuscript be published as Bulletin No. 240 of this office.

Respectfully,

A. C. TRUE,
Director.

HON. JAMES WILSON,
Secretary of Agriculture.

[Bull. 240]

(3)

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CONTENTS.

	Page.
Introduction.....	9
Definition of terms.....	11
Field work.....	11
Tides.....	11
Marshes.....	16
Descriptions of the four reclamations investigated.....	19
Marsh land near Delaware City, New Castle County, Del.	19
History and description.....	19
Tides.....	19
Soil and subsoil.....	19
Levee.....	21
Sluice.....	22
Ditches.....	24
Rainfall and ground water.....	25
Anthrax.....	26
Crops.....	27
Financial.....	27
Summary.....	29
Marsh lands on St. Georges Creek, New Castle County, Del.	30
History and description.....	30
Levee.....	31
Sluice.....	32
Ditches.....	33
Crops.....	33
Financial.....	33
Summary.....	34
Marsh lands near Dorchester, Cumberland County, N. J.	34
History and description.....	34
Tides.....	35
Soil and subsoil.....	36
Levee.....	37
Sluices.....	38
Ditches.....	39
Rainfall and ground water.....	41
Crops and their value.....	43
Value of lands.....	45
Summary.....	46
Marsh land near Mauricetown, Cumberland County, N. J.	47
History and description.....	47
Soil and subsoil.....	47
Levee.....	48
Sluices.....	49
Ditches.....	50
Crops.....	51

Descriptions of the four reclamations investigated—Continued.

Marsh land near Mauricetown, Cumberland County, N. J.—Cont'd.	Page.
Value of lands.....	52
Actual cost.....	52
Summary.....	53
Bench marks.....	53
General summary and discussion.....	53
Sluices.....	53
Levees.....	55
Ditches.....	55
Soil.....	55
Ground water.....	56
Vegetation and relation to water table.....	56
Treatment of land and crops grown.....	56
Financial.....	57
Sanitary.....	57
Reasons for poor progress and causes of failure.....	58
Important questions to be decided before reclaiming.....	58
The design and construction of drainage works.....	59
Levees.....	59
Ditches and sluices.....	61
Drainage by pumping.....	63
General observations.....	63
Pumps.....	64
Power.....	66
Supplemental investigations.....	67
Marsh lands at Green Harbor, Marshfield, Plymouth County, Mass.....	67
History and description.....	67
Tides.....	73
Drainage conditions.....	74
Soil.....	74
Dike and sluice.....	75
Crops.....	76
Financial.....	77
Conclusion.....	77
Diked lands at Wellfleet, Barnstable County, Mass.....	78
Geography.....	78
History.....	79
Description.....	80
Dike and sluice.....	81
Ditches.....	83
The marsh lands of Nova Scotia and New Brunswick.....	83
Geography and extent.....	83
Climate.....	85
Tides.....	86
Soil.....	88
Dikes.....	90
Sluices.....	92
Ditches.....	93
Bogs and warping.....	93
Crops and their value.....	96
Land values.....	98
"Marsh act".....	98
Conclusion.....	98

ILLUSTRATIONS.

PLATES.

PLATE		Page.
I.	Fig. 1.—Levee and inclosed pasture land. Fig. 2.—Levee, field, and foreshore. Colburn marsh lands, Delaware City, Del....	18
II.	Fig. 1.—Land end of sluice at low tide. Fig. 2.—Example of a lateral drainage ditch. Colburn marsh lands, Delaware City, Del.....	22
III.	Fig. 1.—Rock-facing for protection of levee and foreshore, St. Georges Marsh Co., Newcastle County, Del. Fig. 2.—Methods of levee protection and sluice 4, Maurice River, Dorchester, N. J.....	30
IV.	Fig. 1.—At ordinary high tide (twice daily) July, 1903, from Mauricetown bridge easterly along highway, Dorchester, N. J. Fig. 2.—Same during new construction work, December, 1903.	34
V.	Fig. 1.—Plowing on land 1.2 feet above mean low tide in Maurice River. Fig. 2.—Strawberry field 2.2 feet above mean low tide. Marsh lands of Alfred H. Lupton, Dorchester, N. J.....	34
VI.	Fig. 1.—Ditch system and protected fields and woodland. Fig. 2.—Stacking corn shocks for winter feeding. Marsh lands of Howard Compton, Dorchester, N. J.....	34
VII.	Fig. 1.—Cornfields and 58-bushel load of corn grown on land 2 feet above mean low tide in Maurice River. Fig. 2.—Levee and pile and brush protection, Maurice River. Marsh lands of Howard Compton, Dorchester, N. J.....	34
VIII.	Fig. 1.—Main ditch leading to sluice 1. Fig. 2.—Clearing and burning brush and stumps in cedar swamp. Marsh lands of the Mauricetown Banking Co., Mauricetown, N. J.....	38
IX.	Fig. 1.—Sluices 8 and 9, showing formation of ice below ordinary high water mark. Fig. 2.—Sluice 8, showing gate slightly open, how the weight of the gate retards the discharge and the liability to interference from ice. Marsh lands of the Mauricetown Banking Co., Mauricetown, N. J.....	50
X.	Fig. 1.—Main ditch leading to sluice 4, example of a choked ditch. Fig. 2.—Lateral ditch near sluice 3, example of a clear ditch. Marsh lands of the Mauricetown Banking Co., Mauricetown, N. J.....	50
XI.	Fig. 1.—Dike and land end of sluice at low tide. Fig. 2.—Japanese millet grown on land about 7 feet above mean low water. Marsh lands at Green Harbor, Mass.....	76
XII.	General view of dike at low tide, showing method of protection. Diked lands at Wellfleet, Mass.	80
XIII.	Fig. 1.—Outer end of sluice at low tide, showing granite quarry grout facing. Diked lands at Wellfleet, Mass. Fig. 2.—Diking operations, showing method of placing material. Diked lands at South Wellfleet, Mass.....	80

	Page.
PLATE XIV. Fig. 1. —Waterside, showing method of picket and heading brush protection, aboideau. Fig. 2. —Land side, showing layers of brush and ordinary height of interior water, aboideau. Discharge Creek, Grand Pre, Nova Scotia.....	90
XV. Fig. 1. —Sluice under construction and device for sealing the seat and preventing leakage by Arthur A. Hicks, Upper Sackville, New Brunswick. Fig. 2. —Tantramar River, New Brunswick, at half tide, showing foreshore, running dike, and hay barns in the distance.....	92
XVI. Fig. 1. —Power-driven machine for freeing channels of sedges and salt grasses, Miseguash marsh, New Brunswick. Fig. 2. —Haying on warped fresh-water bogs, upper reaches of Miseguash River, New Brunswick.....	96

TEXT FIGURES.

FIG. 1. Diagram showing predicted and actual time and height of tide in Delaware Bay, July 1909, and influence of moon and winds.....	13
2. Diagram showing vertical rate of ebb and flood for 6 hours 13 minutes, with tidal ranges of 1 to 10 feet.....	16
3. Map showing marsh lands of estate of Arthur Colburn, Delaware City, Newcastle County, Del.....	18
4. Cross section of levee near north end Colburn estate, Delaware City, Del.....	20
5. Cross section of levee at Reedy Point, Colburn estate, Delaware City, Del.....	20
6. Cross section through levee on center line of sluice, Colburn estate, Delaware City, Del.....	21
7. Cross section of sluice, Colburn estate, Delaware City, Del.....	22
8. Diagram showing rise and fall of tide and ditch water and sluice leakage and discharge Colburn estate, Delaware City, Del.....	23
9. Map of portion of St. Georges Marsh Co.'s land, Delaware City, Del....	30
10. Map of drainage area tributary to St. Georges sluice, Delaware City, Del.....	30
11. Cross section of levee, St. Georges Marsh Co., Delaware City, Del....	31
12. Map of marsh lands owned by Howard Compton, Alfred H. Lupton, and others, near Dorchester, Cumberland County, N. J.....	34
13. Sections of levees, and sluices between Dorchester and Mauricetown, Maurice River Township, Cumberland County, N. J.....	36
14. Profiles showing position of ground water in November, 1909, on lines M-N, O-P, and Q-R, of fig. 12, Dorchester, N. J.....	40
15. Map of Mauricetown Banking Co.'s Land, Mauricetown, Cumberland County, N. J.....	46
16. Sections of levees and sluices Mauricetown Banking Co., Mauricetown, N. J.....	48
17. Showing the time in hours and minutes sluices play for tidal ranges of 2 to 10 feet, together with the clear openings of sluice and minimum bottom widths of main ditch necessary to drain marsh land.....	62
18. Map of Green Harbor River, and adjacent coast line, showing reclaimed marshes, Marshfield, Mass.....	66
19. Sections of dike and details of sluice and gate chamber, Wellfleet, Mass.....	80
20. Diagram showing form of bore, Petitcodiac River, Moncton, New Brunswick.....	87
21. Cross section of dikes Nova Scotia.....	90

[Bull. 240]

TIDAL MARSHES AND THEIR RECLAMATION.

INTRODUCTION.

The embanking of tidal marshes and their use for agricultural purposes date back to antiquity. For upward of three centuries the coastal countries of Europe, particularly those bordering on the North Sea, have been engaged in this practice and have developed in the polders of the Netherlands and the fen lands of England the finest agricultural lands in Europe, and drainage works of greater magnitude than elsewhere in the world.

In this country the reclaiming of tidal marshes extends back about 150 years, but the results obtained have not been wholly satisfactory. The comparatively few permanent successes have been accompanied by so many failures that many people have become discouraged and skeptical as to the practicability of such reclamations.

The Department of Agriculture, cognizant of the indifferent successes and appreciating the great importance of the subject, has gathered, published, and disseminated much useful information on tidal marsh lands. The principal departmental publications upon the subject are, "Tidal Marshes of the United States," by D. M. Nesbit, issued in 1885;¹ "Reclamation of Salt Marsh Lands," by Thomas H. Means, revised edition issued in 1903;² and "Reclamation of Tide Lands," by J. O. Wright, issued in 1907.³

The Nesbit report of 1885 contains 244 pages, and, from data secured by correspondence with landowners and other interested parties, describes the status of marsh reclamation work along the whole length of the Atlantic, Gulf, and Pacific coasts. There are interesting descriptions of drainage works in Nova Scotia, New Brunswick, and the State of Washington, and quotations from the reports of the State geologist of New Jersey for the years 1869 and 1870, giving general accounts of reclamation work in that State, in England, and in Holland. Other sections of the bulletin cover briefly the historical, physical, legislative, and business aspects of the subject.

¹ U. S. Dept. Agr., Misc. Spec. Rpt. No. 7.

² U. S. Dept. Agr., Bur. Soils Circ. 8, rev.

³ U. S. Dept. Agr., Office Expt. Stas. Rpt. 1906, pp. 373-397.

The Means report of 1903 is a 10-page circular which had its inception in the desire to rid the tidal marshes of the mosquito pest. It contains valuable suggestions relative to the drainage, preparation, cultivation, chemistry, and agricultural value of marsh land.

The Wright report of 1907 contains about 30 pages and treats briefly of the history, objects, results, and causes of failure of tidal-marsh reclamation, and gives pertinent suggestions relative to methods of doing the work; the location, dimensions, and protection of dikes; the construction of sluice gates and pumping plants; and the drainage and treatment of the soil. Drawings are shown for a three-flume concrete and a three-flume wooden sluice with bills of material for each.

The population of the United States is increasing rapidly, and in one State now exceeds 500 to the square mile. Due to this fact, there is a growing scarcity of good upland farms and a widespread inquiry for detailed information on various phases of marsh-reclamation work. Under these circumstances the Department of Agriculture, through drainage investigations of the Office of Experiment Stations, has sought by critical study into certain engineering and agricultural problems involved to further advance the cause of tidal-marsh reclamation and to deduce practical, up-to-date rules for the guidance of those having in charge the design or construction of drainage works in seacoast marshes. An effort has been made to secure accurate information, to treat the subject in a more detailed manner, and to bring out points not covered, or at most only suggested, in the previous publications. The importance of the subject is recognized everywhere. The inherent fertility of much of this land, its exemption from the evil effects of prolonged droughts, and its proximity to the populous seaboard cities, emphasize this importance. Not alone are the agricultural possibilities almost boundless, but the health, comfort, and well-being of thousands of people must inevitably be promoted.

For the purpose of obtaining reliable and first-hand information, numerous marshes in different States have been investigated. Four reclamations have been surveyed, current-meter measurements made of the sluice discharges, notes plotted, and the results studied in detail, as follows:

1. Marsh land belonging to the estate of Arthur Colburn, Delaware City, New Castle County, Del.
2. Marsh land of the St. Georges Marsh Co., New Castle County, Del.
3. Marsh lands belonging to Howard Compton, Alfred H. Lupton, and others, Dorchester, Cumberland County, N. J.
4. Marsh land of the Mauricetown Banking Co., Mauricetown, Cumberland County, N. J.

[Bull. 240]

DEFINITION OF TERMS.

It is thought well at this point to give definitions of some of the terms which will be used in the following discussion.

"Tidal marsh" will be taken to mean any marsh subject to the influences of tidal waters, whether those waters are salt, brackish, or fresh.

"Foreshore" will be considered as the strip of land between the levee and the river or sea.

"Outside" and "without" will be considered as on the river side of the levee.

"Inside" and "within" will be considered as on the land side of the levee.

"M. L. W." is an abbreviation for mean low water; it will be considered as the established mean low water of the river or sea in the locality which may be under consideration, irrespective of whether it is the mean of all the low waters or merely of the lower low waters. It is the datum or plane of reference for levels; its numerical value is zero.

"Elevation" will be considered as distance above mean low water; with a minus sign, as distance below mean low water.

"Second-feet" is an abbreviation for "cubic feet per second."

"Run-off" or "discharge" is the volume of water flowing in a stream or ditch.

"Rainfall" is expressed in depth in inches.

FIELD WORK.

The surveys were made during the summer and fall of 1909. Distances were measured by stadia. Levels were run with a transit and are referred to mean low water in the Delaware or Maurice Rivers. The velocity measurements of sluice leakage and discharge were made with a small Price current meter, the integration method being employed.

Before proceeding to detailed descriptions of the four reclamations already referred to, brief general discussions bearing on the action of tides and the formation of marshes will, it is hoped, prove of interest and value.

TIDES.

In the world of nature few phenomena are more complex than those of the tides. According to the uncorrected equilibrium theory of Newton, elaborated by Laplace, and accepted by most writers for many years after their time, the earth was conceived as a rotating globe covered with a hypothetical sheet of water or by zonal seas, the depth being assumed as uniform, or depending upon latitude but

[Bull. 240]

not upon longitude. In such a sea the attraction of the moon would create a wave about 7 inches in height, with a width halfway around the world, and cause a corresponding rise of the waters on the opposite side of the earth. In like manner the sun's attraction would create a wave about 3 inches in height.

In order to fit this theory to the conditions as existing in nature, it was supposed that the tidal wave had its origin in the great ocean area of the globe, the South Pacific and Antarctic Oceans, that it moved from east to west, impinging against the easterly coasts of continents, and that in completing the circuit of the earth a period of time was consumed which varied with the ocean's depth and with the interposition of continents and islands.

The observed conditions of the tide in different parts of the world are so at variance with those formerly supposed to exist that later investigators have discarded or greatly modified the former theories.

The most advanced thought of to-day regards certain of the oceans under the influence of gravity, the earth's rotation, and the horizontal pull of the moon and sun as oscillating areas, that certain areas of the oceans have the right depth and the right length between land barriers, so that the free periods of oscillation of their waters are in approximate unison with the tide-producing influences, and that there exist points of complete or partial rest called nodal points or spots of no tide, somewhat analogous to the conditions in a vibrating violin string. Actual measurements of depth in the North Sea have shown the existence and location of nodal points, and research indicates that in the open seas far removed from land there may be tides of from 2 to 10 feet in height, conditions which formerly were believed impossible.

In illustrating the forces which tend to deflect a particle moving on the earth's surface, Prof. G. H. Darwin says:¹

When, in the Northern Hemisphere, water moves from north to south it passes from a place where the surface of the earth is moving slower to where it is moving quicker. Then, as the water goes to the south, it carries with it only the velocity adapted to the northern latitude, and so gets left behind by the earth. Since the earth spins from west to east, a southerly current acquires a westward trend. Conversely, when water is carried northward of its proper latitude it leaves the earth behind and is carried eastward. Hence the water can not oscillate northward and southward without at the same time oscillating eastward and westward.

The oscillating oceans create ocean eddies and currents which transmit the oscillations into all the seas and bays of the earth, causing a constant circulation of oceanic waters, and it is a matter of fact

¹ Manual of Tides. Part IVb, Cotidal Lines for the World, by R. A. Harris. U. S. Coast and Geodetic Survey Rpt. 1904, Appendix 5, pp. 315-400.

[Bull. 240]

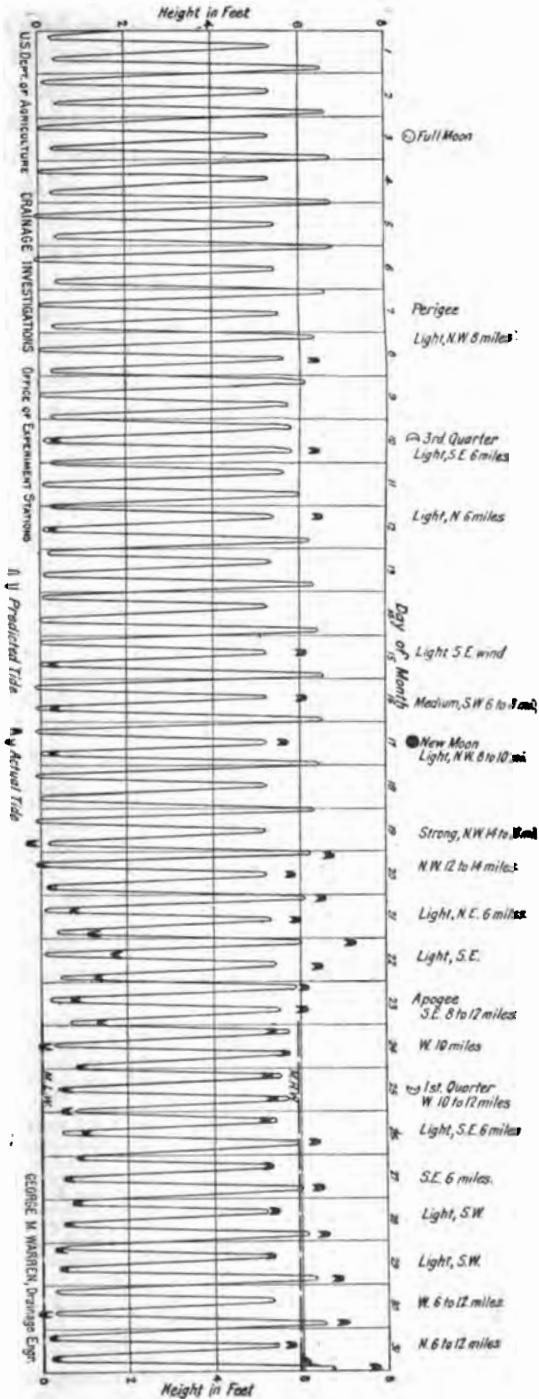
and observance that there is always a tendency for the cold waters of the poles to approach the equator, from which the warm waters tend to drift toward the poles.

Late investigations in Germany have demonstrated tidal movements in the earth's crust itself.

With respect to the sun, the earth revolves on its axis in 24 hours, which is the solar day; with respect to the moon, the earth revolves in about 24 hours and 51 minutes, which is the lunar day. Thus there are two solar and two lunar tides each day, but as the influence of the sun as a tide-producing agency is only about four-tenths that of the moon, the solar tides are noticeable principally through their effect in increasing or diminishing the lunar tides. The period required for the moon to pass from a given phase to the same phase again is 29 days 12 hours.

[Bull. 240]

FIG. 1.—Diagram showing predicted and actual time and height of tide in Delaware Bay, July, 1899, and influence of moon and winds.



Soon after passing those points in her journey known as "new moon" and "full moon," that is, when the sun and moon are in the same or opposite parts of the heavens, the two tidal effects are united, and the tides rise higher and fall lower than usual, and are known as "spring tides." At the "quarters" the tides tend to neutralize by the crest of the lunar wave falling in the hollow of the solar wave, and the rise and fall are diminished and are known as "neap tides."

Every 12 hours and 25 minutes, on the average, twice each lunar day, will therefore be a period of high water, and 6 hours and 13 minutes later will be a period of low water.

Notwithstanding the time and height of tides are governed by inexorable laws, both are strongly affected by the force and direction of the wind and the depth and contour of the shore. The diagram (fig. 1), based on the published tide tables of the United States Coast and Geodetic Survey, shows the preponderant influence of the moon and the effect of winds. In Delaware Bay a northwesterly wind favors a low tide, and a southwesterly wind favors a high tide. It will be noted from the diagram that the prevailing winds were southerly and consequently the tides high for the greater part of the month.

Within rivers and streams the tidal undulation or wave becomes a true current, the ebb requiring more time than the flood on account of the fresh water which has been held back. The velocity of the ebb or flood attains a maximum at a time about half way between the high and low "stands" of the tide. The range of the tide, a controlling factor in gravity drainage, varies widely at different places, as is shown by the following table, a number of the selections being in localities where marsh reclamation has been extensive.

Mean range of tide at different places.

Place.	Feet.	Place.	Feet.
Sackville, New Brunswick.....	39.6	Wilmington, N. C.....	2.4
Annapolis, Nova Scotia.....	25.1	Charleston, S. C.....	5.2
Portland, Me.....	8.9	Savannah, Ga.....	6.8
Portsmouth, N. H.....	9.2	St. Augustine, Fla.....	4.2
Boston, Mass.....	9.6	Key West, Fla.....	1.2
Plymouth, Mass.....	9.6	Mobile, Ala.....	.5
Providence, R. I.....	4.4	Biloxi Light, Miss.....	.3
New London, Conn.....	2.5	Port Eads, La.....	.1
Oyster Bay, N. Y.....	7.3	Galveston, Tex.....	.5
Newark, N. J.....	5.0	San Francisco, Cal.....	4.0
Salem, N. J.....	6.4	Astoria, Oreg.....	6.4
Mauricetown, N. J.....	5.2	Seattle, Wash.....	7.7
Delaware City, Del.....	5.9	Hull, England.....	16.3
Old Point Comfort, Va.....	2.5	Harlingen, Netherlands.....	4.2

The highest tides in the world are found in the spring ranges of 50.5 feet in the Basin of Minas, Bay of Fundy, and 45.6 feet in the Gallegos River on the southeastern coast of Patagonia.

From the above table it is seen that gravity drainage, which is the simplest and least expensive form, is more frequently practicable

along the North Atlantic and North Pacific coasts than in the Southern States; the Gulf marshes can not be drained in this way.

Thorough knowledge concerning the tides has numerous practical applications, such as deciding on grade of sluices, height of levees, and opportune time for special construction or repairs. For instance, the most favorable time for making small repairs on a sluice would be when a strong offshore wind came at new or full moon. A severe storm at this time of the month would be an indication of what the height of the dike should be. Construction work which required a cofferdam would encounter the smallest fluctuation of tide when the moon was on the first or third quarter.

It is a matter of general knowledge that the theoretical oscillations of the tide are represented by a simple cosine curve. Such curves for tides having a rise and fall of 1 to 10 feet, which are the practical limits of mean range in the United States, have been plotted and are shown in the diagram (fig. 2).

Example of application.—Required the time of opening and the period of play of a sluice, the ditch water being 2 feet above low water outside and the range of the tide 8 feet.

From the right-hand vertical line follow down the curve which starts at 8 until the horizontal line passing through 2 is intersected. At this instant the tide and ditch water are at the same level and the gates about to open. From the intersection follow vertically downward to the bottom horizontal line, and time is noted as about 2 hours and 4 minutes before low water. This is the approximate time the sluice would play, assuming the interior water to have been discharged by the sluice to approximately the level of mean low water.

Sea water weighs about 64.1 pounds per cubic foot, 1.6 pounds, or $2\frac{1}{2}$ per cent more than ordinary river water. It contains about 3.5 per cent by weight of mineral matter in solution, of which approximately four-fifths, or $1\frac{1}{4}$ pounds per cubic foot, is common salt.

According to Regnault¹ and Dittmar,² the mean composition of sea water is as follows:

Mean composition of sea water.

Constituents.	Regnault.	Dittmar.
	<i>Per cent.</i>	<i>Per cent.</i>
Sodium chlorid (common salt).....	2.700	2.721
Magnesium chlorid (bittern).....	.360	.381
Magnesium sulphate (Epsom salt).....	.230	.186
Calcium sulphate (gypsum).....	.140	.126
Potassium chlorid.....	.070	.....
Potassium sulphate.....	.....	.086
Calcium carbonate (limestone).....	.003	.012
Magnesium bromid.....	.002	.008
Water (and loss in analysis).....	96.495	96.500
Total.....	100.000	100.000

¹ Soils, by E. W. Hilgard. New York and London, 1907, p. 26.

² Report on the Scientific Results of the Voyage of H. M. S. Challenger during the Years 1873-76. Physics and Chemistry—Vol. I. Part I.—Report on the Composition of Ocean-Water, by William Dittmar. London, 1884.

While the waters of the ocean contain in solution appreciable quantities of many of the elements, and it is surmised, though not proven, that all the known elements may be represented, yet at considerable distances from land the waters are clear and almost entirely free from suspended matter.

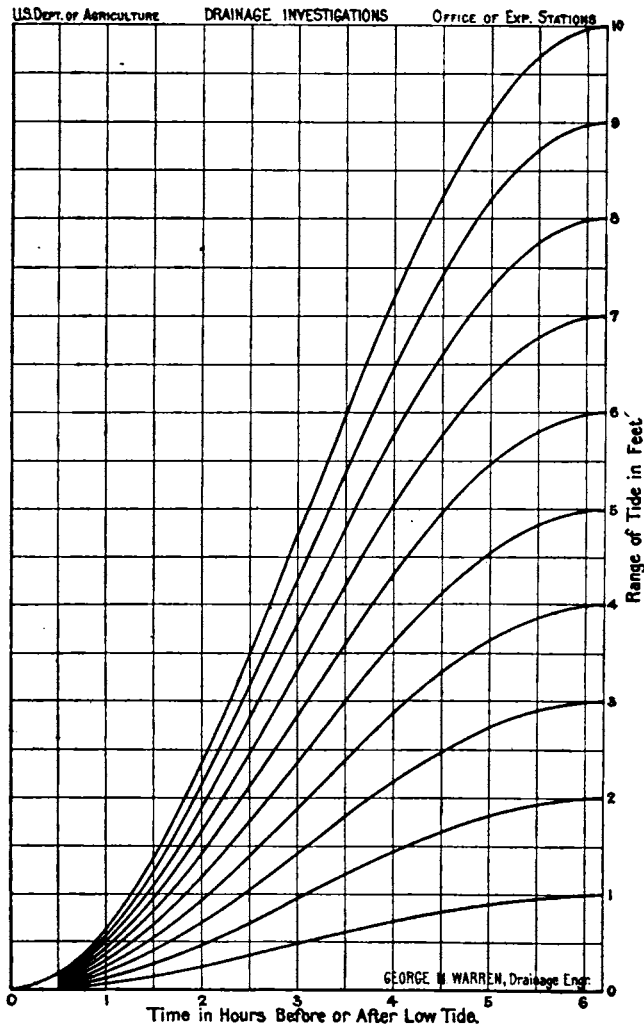


FIG. 2.—Diagram showing vertical rate of ebb and flood for 6 hours 13 minutes, with tidal ranges of 1 to 10 feet.

MARSHES.

Marshes have their youth and old age, existing in all stages of development. Some are old river or lake bottoms filled with the undecomposed vegetable accumulation of ages. These peat marshes, when decomposition is more advanced, become the muck beds so fre-

[Bull. 240]

quently seen along our coasts. The reclamation of such lands should be undertaken with caution. If possessed of sufficient earthy material, they may become extremely fertile, especially adapted to the growing of potatoes, celery, cabbage, and onions, but their shrinkage and consolidation when drained and aerated is very large, and as a foundation for sluices and embankments they are unstable.

Another type of marsh exists as a barren waste of sand, almost devoid of vegetation. Their reclamation is not likely to be financially successful, as the expense of putting the land in a productive condition is very great, and sand as an embanking material is most treacherous.

Still another type of marsh is that found behind barrier beaches along outer coasts and in other locations subject to violent wave action.

Through long-continued mechanical action of the waves on an exposed coast the bowlders, pebbles, and sand are ground into exceedingly fine particles, of which the greater portion is carried by the undertow into the sea, but an appreciable quantity remains to be swept by waves and currents into the indentations and inlets of the shore. Moreover, such inlets or estuaries have a tendency to become closed by ridges or barriers of sand heaped up by the sea and the action of winds. The tidal marshes formed in this way are very extensive, but their reclamation is often difficult, because free outfall channels are not easily constructed and maintained.

Soil is disintegrated rock, and its formation is in progress everywhere through various chemical and mechanical agencies. From the spot of its origin, perhaps hundreds of miles inland, moving water is the vehicle which is ceaselessly conveying it to its resting place to form the fourth and, to the agriculturist, the most important type of marsh. Without the instrumentality of the tides, the fine sand, silt, and clay which is being constantly brought down by rivers would be carried out to sea and lost to man's use forever. The descending fresh water, with its accumulation of detritus, is met and forced back by the comparatively clear water of the flood tide; before the next ebb occurs the silt-laden water has been forced to spread out over the low marshes, and a portion of the suspended matter is deposited. The heavier particles deposit first, thus building up most rapidly the marsh adjacent to the river; the finer, lighter particles are carried farther toward the uplands, and here the marsh-building process is much slower. With the lapse of time enormous areas have in this way been raised, so that they are only submerged by storm tides, and in this condition offer inviting prospects for reclamation and development.

The rate of tidal deposit varies greatly. A heavily wooded watershed, or one in which the agricultural development has been small,

will generally be drained by a comparatively clear river, and the marshes will, in consequence, build up very slowly.

Most soils shrink when deprived of their water. Experience, both in this country and abroad, has shown that where marshes have been drained there is a long continued shrinkage or subsidence of the land, the amount of which varies with the depth and character of the soil, being more in those of a peaty or mucky nature, and less in clay, silt, or sand. Approximate subsidences noted in several reclamations are as follows: Green Harbor, Mass., between 1872 and 1908, about 2 feet; Hackensack Meadows, N. J., between 1869 and 1887, from 3 to 3.5 feet; Cohansey Creek, Cumberland County, N. J., from 2½ to 3 feet; Mays Landing, N. J., about 1 foot; Salem, N. J., 3½ to 4½ feet; Whittlesey, England, 7 feet in 18 years, and in the old reclamations, it is said, the subsidence is still going on at the rate of an inch per year. The drainage of the fen lands has, with the lapse of time, been accomplished only through an ever increased use of pumps. In planning drainage works this tendency to subsidence must be fully appreciated as, if long continued, the ditches become more and more ineffective, and thereafter the water can only be removed by pumping. Failure to discern the shrinkage of marsh soils has caused many to believe that the tides rise higher than in former years, but there is no evidence that such is the case.

The following mechanical and chemical analyses of tidal-marsh soils from the vicinity of Oyster Bay, N. Y., are given as probably typical of extensive areas along the Atlantic coast. These analyses are taken from "Reclamation of Salt Marsh Lands" issued in 1903.¹

Mechanical and chemical analyses of tide-marsh soils from Oyster Bay, N. Y.

Sample No.	Locality of soil.	Sand.	Silt.	Clay.	Lime CaO.	Potash K ₂ O.	Phosphoric acid P ₂ O ₅ .	Organic matter.	Soluble in water.
5379	Mud from tidal flat, west end Lloyds Harbor, 0-6 inches ²	<i>Per ct.</i> 13.2	<i>Per ct.</i> 44.8	<i>Per ct.</i> 42.0	<i>Per ct.</i> 0.43	<i>Per ct.</i> 0.57	<i>Per ct.</i> 0.16	<i>Per ct.</i> 7.18	<i>Per ct.</i> 2.16
5374	Sod and grass roots from outer marsh, Center Island, 0-36 inches.....							29.00	4.07
5375	Eel-grass clay from outer marsh, Center Island, 26-66 inches ³	28.0	44.9	27.1	.31	.57	.14	5.36	2.55
5376	Sod taken from inner marsh, Center Island, 0-12 inches.....							34.70	1.87
5377	Decomposing sod from inner marsh, Center Island, 12-24 inches.....							25.49	3.87
5378	Eel-grass clay from inner marsh, Center Island, 24-72 inches ⁴	38.0	37.1	24.9	.41	.68	.12	10.90	3.56

¹ U. S. Dept. Agr., Bur. Soils Circ. 8, rev.

² High tide covered this flat 4 to 5 feet deep.

³ This marsh was covered at high tide.

⁴ The drainage of the inner marsh was in progress, but the marsh had been accidentally covered several times with salt water.

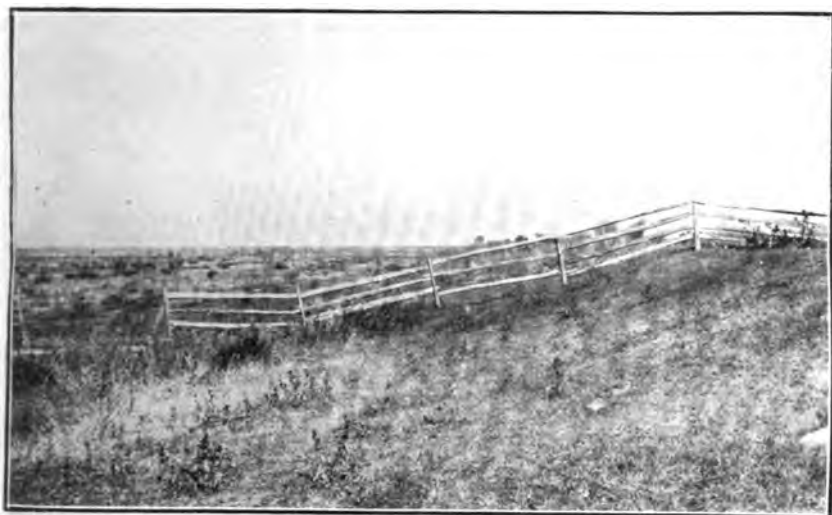


FIG. 1.—LEVEE AND ENCLOSED PASTURE LAND.



FIG. 2.—LEVEE, FIELD, AND FORESHORE.

COLBURN MARSH LANDS, DELAWARE CITY, DEL., NOVEMBER 1 1909.

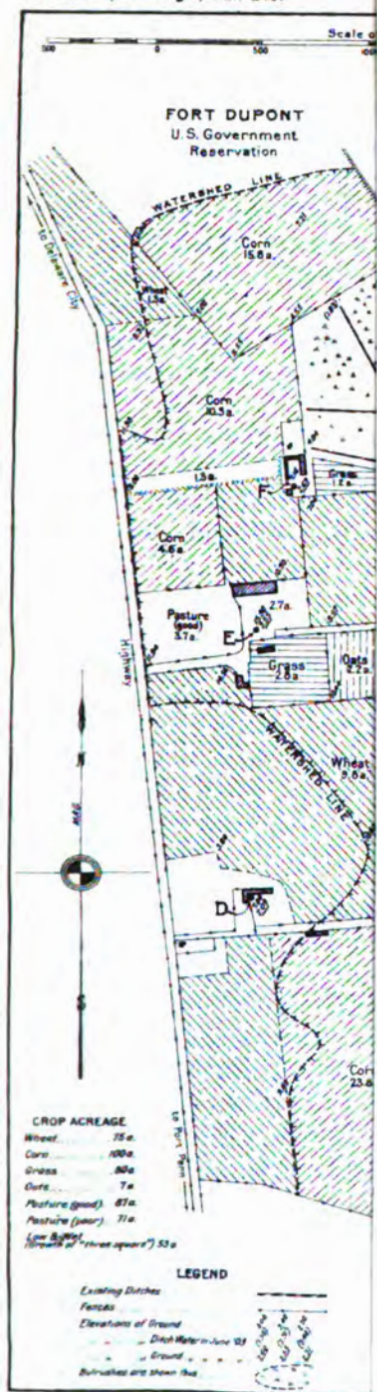


Fig. 3r—Map showing α

DESCRIPTIONS OF THE FOUR RECLAMATIONS INVESTIGATED.

MARSH LAND NEAR DELAWARE CITY, NEW CASTLE COUNTY, DEL.

HISTORY AND DESCRIPTION.

The marsh land here considered comprises about three-fifths of the 515 acres making up three farms on the west side of the Delaware River, and situated about 1 mile south of Delaware City, Del.

First reclaimed in the early fifties, the levee was raised and the present sluice built in 1894. Cultivation has been practically continuous for over half a century and to-day the lands are carrying 110 head of cattle and 21 horses. (For plan of lands showing levee, ditch system, topographic features, and crops raised in 1909 see fig. 3.)

The tributary drainage area contains about 488 acres and varies from 1.6 to 16 feet above mean low water. The interior marsh has a dishing or "saucer-shaped" profile. Near the levee the land is from 2.5 to 4.0 feet above datum, the lower portions being in pasture (see Pl. I, fig. 1), and the higher in hay or corn. About 800 feet inland is a well-defined chain of low areas containing collectively 53 acres, and having an almost uniform elevation of 1.7 feet; this land is covered with three-square sedge. Continuing westerly, successive fields being in grass, corn, and wheat, the ground rises to the drainage line, 9 to 11 feet above datum. The foreshore averages about 200 feet wide and is covered with a rank growth of reeds and marsh grass; near the levee it has generally been raised by deposit to ordinary high-water mark. (See Pl. I, fig. 2.)

TIDES.

The mean range of the tide is 5.9 feet; the rise takes place in about 5½ hours and the fall in about 6½ hours. About once a year it may be expected that the tide will reach elevation 9. Within recent years elevation 9.52 was noted, which is several inches above the greater length of the levee. Extreme high water, so far as known, is elevation 11, reached in October, 1878. Extreme low water is believed to be about 2.8 feet below datum. The Delaware River at this point is only slightly brackish, though it is probable that the small rainfall and lessened flow of 1909 allowed the saline water to ascend farther than usual.

SOIL AND SUBSOIL.

The soil, as deposited by the tide, is a plastic, silty clay, and weighs about 86 pounds per cubic foot. When wet it has a bluish color, and when dry is a light gray and is commonly designated as "blue mud" or "gray mud" by farmers and marsh men. Deprived of all moisture except atmospheric, the soil shrinks from 30 to 40 per cent of its volume, and each cubic foot parts with about 35 pounds of water,

[Bp11. 240]

or 41 per cent by weight. Its interstitial space under field conditions is about 56 per cent of its volume.

Within the levee the soil is stiffer, and its mottled appearance and the wiry nature of the vegetation attest imperfect aeration and drainage. Test pits and sounding show a diminishing depth of "blue mud" approaching the uplands, where a clay loam 12 to 15 inches in thickness was usually followed by a muck or peat formation.

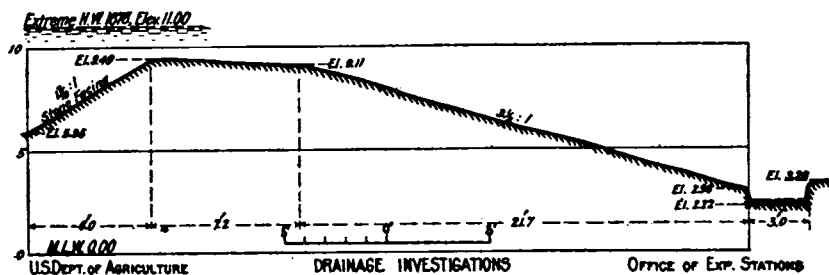


FIG. 4.—Cross section of levee near north end Colburn estate, Delaware City, Del.

There is evidence that near the levee the soil is very deep. Three test borings on the river front, made in 1906 by the Chesapeake and Delaware Canal Commission at Delaware City, St. Augustine pier, and Appoquinimink River, which points are situated respectively $1\frac{1}{2}$ miles northerly, 3 and 5 miles southerly from the Colburn marsh, showed the following stratifications:

At Delaware City.—For 31 feet, soft blue mud containing wood and vegetable matter; next 10 feet, blue mud and sand, mixed in about

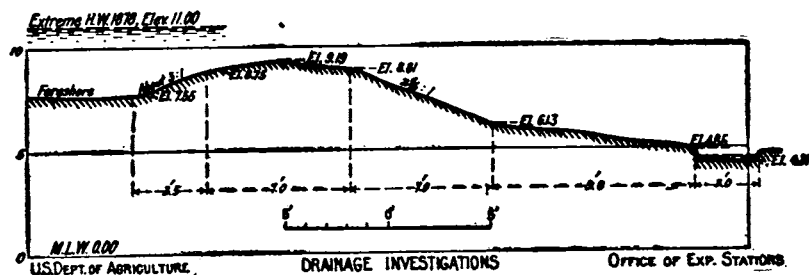


FIG. 5.—Cross section of levee at Reedy Point, Colburn estate, Delaware City, Del.

equal proportions; next 12 feet, very soft blue mud; and next 3 feet, green sand and mud; driving more difficult, and pipe drawn at 56 feet.

At St. Augustine pier.—For 22 feet, blue mud; easy driving; next 38 feet, coarse, green, almost black sand, which became finer as depth increased, making driving more difficult; pipe drawn at 60 feet.

At Appoquinimink River.—For 80 feet, stiff blue mud; pipe driven and drawn in one day.

[Bull. 240]

The natural fertility of the Colburn marshes is unquestioned, for they have been tilled many years with little or no artificial fertilization, and without apparent exhaustion of the soil.

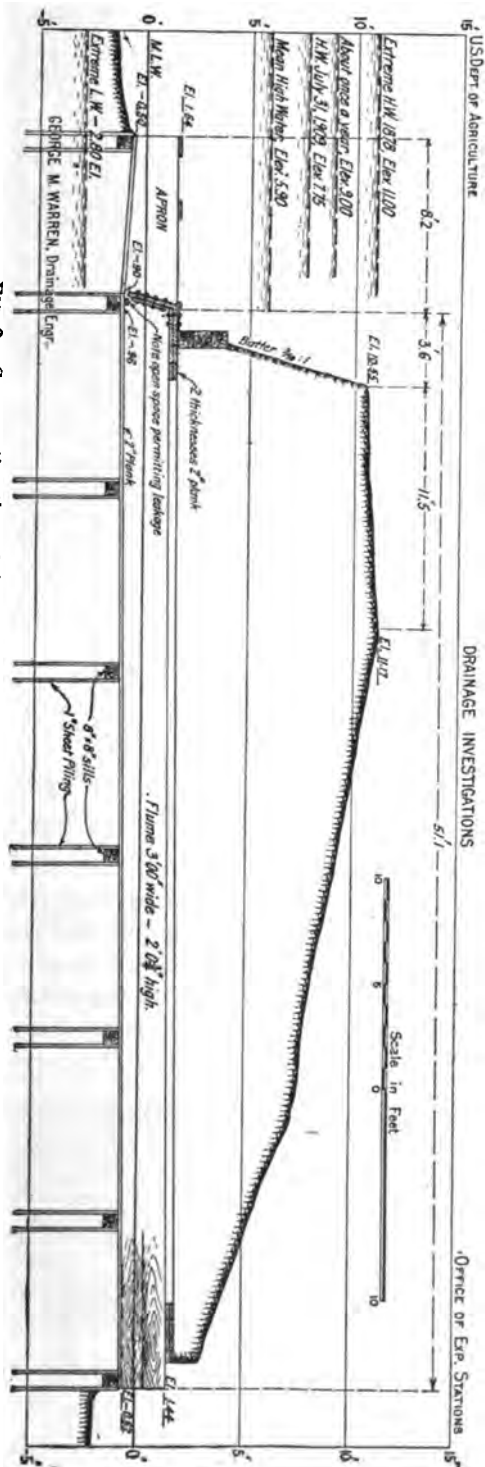
LEVEE.

Cross sections of the levee shown in Plate I, giving heights, widths, and slopes, are shown in figures 4, 5, and 6.

The foundation of the levee is believed to be the natural surface of the marsh without other treatment than the cutting and removal of the vegetation upon it. The top and slopes have a good growth of grass but have not been kept sufficiently free from weeds, thus harboring burrowing animals. The condition of the stone facing in places emphasizes the importance of suitable backing. Wave action, by removal of some of the fine material, has left spaces into which the stones have settled. As crushed stone or screened gravel would be too expensive for general use, it is believed that oyster shells would make an excellent substitute. These can be landed in barges at the dock in Delaware City for 3¼ cents per bushel.

[Bull. 240]

FIG. 6.—Cross section through levee on center line of sluice, Colburn estate, Delaware City, Del.



SLUICE.

The sluice (see Pl. II, fig. 1) is of timber construction 51 by 7 feet, outside dimensions. Figures 6 and 7 show its construction in detail and its present grade. The gates are double thickness, 2-inch unmatched plank, have strap hinges and are unweighted. Near the center of each gate is an opening about 5 by 8 inches, fitted with copper slide working in horizontal copper grooves for admitting river water as needed during times of drought. Both gates seat poorly, permitting large leakage from the river. A strip is missing from the bottom of the southerly gate, with the result that when closed there is an open space beneath its whole length, admitting large quantities of river water.

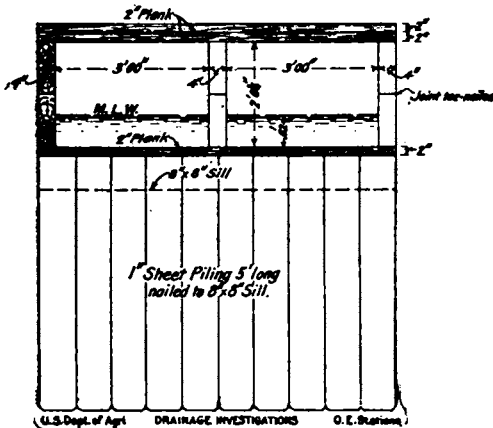


FIG. 7.—Cross section of sluice, Colburn estate, Delaware City, Del.

Figure 8 shows graphically the rise and fall of the tide and the ditch water, the times being plotted as abscissas and the heights as ordinates. Beneath is plotted the sluice leakage or discharge in second-feet at the corresponding moment.

The leakage of September 2 and the discharge of August 6 are illustrated for the reason that on those dates the quantities measured approximately represent the normal workings of the sluice during the summer season.

The following table shows length of time the sluice leaked or played, the rise or fall of the ditch water during that time, the maximum and average rates of flow, and the total leakage or discharge for the period and on the dates given:

Leakage and discharge of sluices.

Date.	Time.	Rise or fall of ditch water.	Rate of flow.		Total leakage from river.	Total discharge to river.
			Maximum.	Average.		
1909:	Hrs. min.	Feet.	Sec.-feet.	Sec.-feet.	Cubic feet.	Cubic feet.
July 28.....	2 42	1.01	28.35	16.76	.....	162,907
Aug. 6.....	10 00	1.08	13.28	6.68	240,480	.....
Do.....	2 19	.82	31.19	20.98	.....	174,973
Aug. 12.....	1 56	.62	28.09	20.15	.....	140,244
Aug. 18.....	9 30	.32	6.98	5.11	174,762	.....
Do.....	2 30	.73	34.18	24.09	.....	216,810
Aug. 30.....	2 40	1.01	23.11	14.00	.....	134,400
Sept. 1.....	3 12	1.25	29.13	15.69	.....	180,748
Sept. 2.....	9 24	1.23	6.75	4.83	163,447	.....
Averages:						
Leakage.....	9 38	.88	9.00	5.54	.....	.....
Discharge.....	2 33	.91	29.01	18.61	.....	168,347

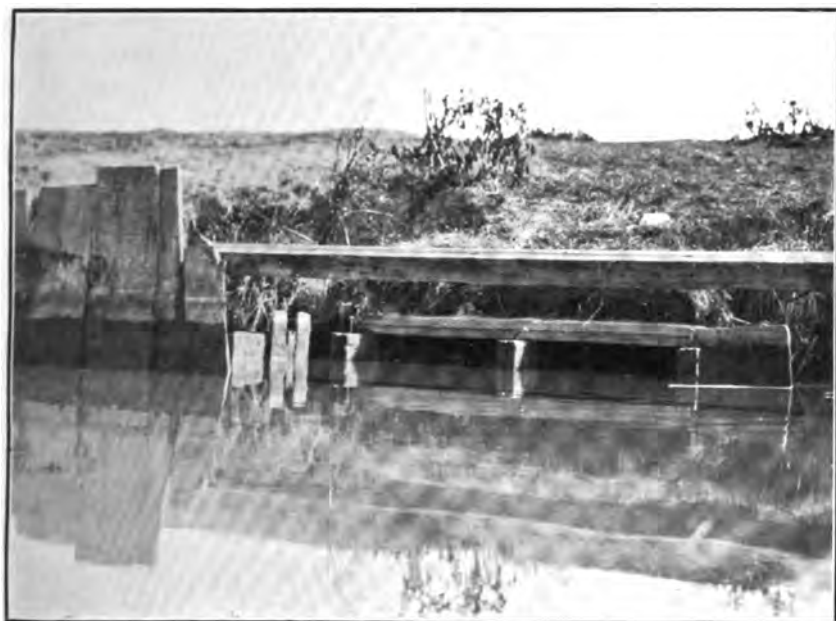


FIG. 1.—LAND END OF SLUICE AT LOW TIDE.

[Horizontal marks about half way up on the sheeting indicate height to which ditch water ordinarily rises.]



FIG. 2.—EXAMPLE OF A LATERAL DRAINAGE DITCH.

COLBURN MARSH LANDS, DELAWARE CITY, DEL., NOVEMBER 1, 1909.

The abnormal leakage of August 6 (249,480 cubic feet) was caused by the northerly gate becoming stuck for about one hour in a partially opened position. From gaugings of the ditch water covering a considerable period, it is very probable that the leakage of September 2 (163,447 cubic feet) is about the usual quantity. Taking the normal leakage between periods of sluice play as 163,447 cubic feet and the normal discharge as 168,347 cubic feet, it is seen that the former amounts to about 97 per cent of the latter. The difference in these quantities, 4,900 cubic feet, represents the amount of water which enters the land by seepage and percolation from the river, and by movement of the upland ground water, during a period averaging

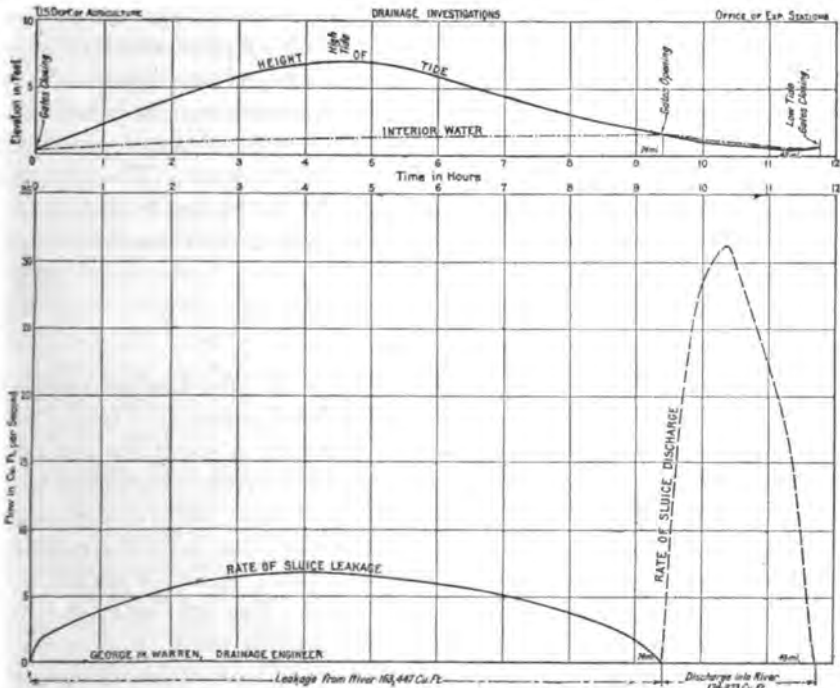


FIG. 8.—Diagram showing rise and fall of tide and ditch water and sluice leakage and discharge, Colburn estate, Delaware City, Del.

about 9 hours and 38 minutes, evaporation being neglected. This is at the rate of about 10 cubic feet per acre of drainage area, twice daily.

Determinations were made of the value of coefficient c in the following formula for sluice discharge:

$$q = ca \sqrt{2gh}, \text{ in which}$$

q =quantity in second-feet

c =coefficient of discharge

a =area of cross section of flow in square feet

h =head in feet

g =acceleration of gravity=32.16

[Bull. 240]

The results show that for unweighted, wooden, flap gates in complete submergence, or where the emergence does not exceed about 15 per cent of the vertical height of the gate, this coefficient has a value of 0.64. As the tide recedes further, the submergence and buoyancy of the gates are diminished; gradually approaching the seating position, successive inclinations and the dead weight of the gates become constantly increasing factors in the retardation of the flow. (See Pl. IX, fig. 2, p. 50.) In consequence, the coefficient of discharge lessens rapidly and near low tide averaged about 0.46.

The coefficients for very small heads are not well determined. The difficulties of making precise gaugings of head in tidal waters and of securing simultaneous velocity measurements are obvious. Any error, however slight, during the first or last minutes of play, affects the coefficient beyond all proportion to the real size or importance of the error. From 30 to 50 seconds are absolutely necessary for a satisfactory current-meter measurement; and this interval of time is sufficient to change the head a full hundredth of a foot or more. The average head under which the sluice discharged, from the beginning to the end of play, was found from observations and deductions to be very close to two-thirds of the maximum head.

DITCHES.

The drainage is secured by about 11.4 miles of open ditches, varying in width from 3 to 24 feet, and in depth from 6 inches to 4 feet. The width averages about 12 feet and the ditch area is about 5.3 per cent of the area of the marsh land. They are badly silted and choked with rank growths of cattails and other weeds, so that effective drainage, with two or three exceptions, is prevented. Indeed, in this condition and with the large sluice leakage which exists, the very object for which the ditches were intended is defeated. For during each tidal cycle the leakage has $9\frac{1}{2}$ to 10 hours in which to work its way back into the choked ditches; the subsequent period of sluice discharge, about $2\frac{1}{2}$ hours, is much too short to remove more than a very small percentage of this water. It is, therefore, and its appearance is confirmation, virtually a stagnant water. To establish the truth of these assertions gaugings were made to the water surface in certain clear ditches, and in others not free. It was found that in a clear ditch (Pl. II, fig. 2), at a point 3,600 feet from the sluice, a movement was observable in 10 minutes after the gates began to open; in 12 minutes the flow was pronounced; in 30 minutes the mean velocity had risen to 15 feet per minute; in 60 minutes the maximum mean velocity of 21.6 feet per minute had been reached; for 3 hours the velocity averaged about 15 feet per minute; and the water surface fell 1.12 feet while the gates were open.

[Bull. 240]

At a point 300 feet from the one just referred to, but in a choked ditch the fall was less than one-quarter of an inch, notwithstanding and at a point 750 feet farther from the sluice up the obstructed ditch the fall was less than one-quarter of an inch, notwithstanding the period of sluice play, 3 hours, was considerably longer than the average. The water which started toward the sluice 10 minutes after the gates opened did not cover the distance of 3,600 feet during the period of play. About 2 hours and 15 minutes were consumed in covering the 2,050 feet of lateral ditch; the remaining 35 minutes of sluice action was much too short, and the flow too feeble to cover the 1,550 feet of main ditch.

The trampling of cattle and the small box-culvert bridges have, in certain instances, forced the drainage through long, circuitous routes, and have even dammed it altogether. Near the northerly end of the lands is an area of pasturage and grassland containing over 40 acres, where the ditch water is permanently held at about elevation 1.7. The large sluice leakage taxes the storage capacity of the ditches to the utmost. With the interior water rising twice a day to elevation 1.6, it is clear that any additional leakage or rainfall, except such small quantity as might fall, be collected, and discharged during the short interval when the sluice is in action, will go largely to flood the areas of three-square sedge, from which its principal escape is by evaporation, or as taken up by vegetation. The total holding capacity of these ditches, between elevations 0 and 1.6, is about 178,000 cubic feet. With the sluice leakage averaging 163,447 cubic feet, and seepage and percolation amounting to 4,900 cubic feet between operations of the sluice, it is obvious that any additional leakage or collected rainfall in excess of 9,643 cubic feet will be forced outside the ditches and over the low areas.

If we should assume that 21 per cent of the precipitation constituted the run-off, which would seem to be fair, in view of the known gravitational space of the soil, the character of the drainage area, and the position of the ground water, it is seen that this reserve storage capacity of 9,643 cubic feet would be obliterated after 37 minutes of a rainfall amounting to 1 inch in 24 hours. These figures illustrate the utterly inadequate storage capacity and the futility under present conditions of preventing a concentration of storm water in the "saucer" shaped low areas.

RAINFALL AND GROUND WATER.

A study of the rainfall records, kept at Delaware City since July 1, 1902, shows that for a period of 86 consecutive months to September 1, 1909, there were 81 days when the precipitation exceeded 1 inch in 24 hours, 9 when it exceeded 2 inches, 4 when it exceeded 3 inches,

[Bull. 240]

and 2 when it exceeded 4 inches. Both of the rainfalls exceeding 4 inches came in September, a season of the year when not likely to harm crops and when the water table is usually approaching its lowest stage. The annual rainfall of about 44 inches is well distributed. The monthly average of 3.7 inches will, in the long run, be surpassed during the months of June, July, August, and September. The year 1909, from January to September, was one of the driest for many years. The rainfall during the summer and its effect on the ground water are shown by the following table:

Rainfall and elevations of ground water at six points shown on the plan (fig. 3).

Date.	Rainfall.	A.	B.	C.	D.	E.	F.
		<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>
1909:							
June 18.....	11 showers in June totaled 3.51 inches, the last falling on the 28th.	.....	.....	2.21	.....	.....	.....
June 28.....		.....	1.62	.....	.....	.....	.....
June 29.....		1.61	.....	.....	.....	.....	.....
July 10.....		.....	.....	.....	2.09	2.65	.....
July 12.....	.....	.....	.....	.....	2.09	2.65	2.70
July 14.....	.....	.....	.43	.....	1.93	2.57	2.63
July 15.....	.....	.....	.44	.....	1.96	2.55	2.65
July 16.....	.....	.94	.41	.....	.....	2.53	.....
July 17.....	.....	.84	.32	.....	.....	.....	.....
July 18.....	.....	.75	.....	.....	.....	.....	.....
July 20.....	.....	.23	.....	.....	.....	.....	.....
July 23.....	0.62 inch.....	.....	.....	.....	.....	.....	.....
Aug. 12.....	.....	-.40	.....	.....	.....	.....	.....
Aug. 16 and 17.....	1.05 inches.....	.....	.....	.....	.....	.....	.....
Aug. 18.....	.....	1.73	.47	.....	.....	.....	.....
Aug. 21.....	.....	.81	.....	-.15	1.12	1.73	1.65
Sept. 2.....	.....	.....	-.11	.....	.....	.....	.....
Sept. 7.....	.....	-.73	-.22	-.44	.87	1.25	1.02

The conclusions to be drawn from this table and from other measurements made are: (1) The water table is practically unaffected by the fluctuations of the tide during a single day. (2) The wet conditions of spring will raise the ground water to between elevations 1.6 and 2.2 over the greater part of the marsh and about a foot higher in the upland a half mile from the river. (3) The large fluctuation in the water table at A was caused by overflow of the ditches and concentration of water which fell elsewhere in the low areas. (4) The low head on the ground water proves the upland drainage to be slow in motion and small in amount. (5) In summers of very small rainfall capillarity and evaporation may lower the water table considerably below mean low water, against the combined percolation and seepage from land, river, and ditches.

ANTHRAX.

This virulent and fatal disease has cost the farmers along the Delaware River large numbers of cattle. It is generally supposed to have first been communicated in this locality through the wastes from the morocco factories of Wilmington and Philadelphia.¹ The

¹ U. S. Dept. Agr., Farmers' Bul. 439, "Anthrax," pp. 7, 10.

danger of outbreak among cattle which graze upon embanked lands is much less than among those which frequent unreclaimed marshes. So far as known there has never been a case of anthrax on the Colburn farms.

CROPS.

The staple crops on the Colburn lands are wheat, corn, and hay. Oats, rye, potatoes, and garden truck have been raised to some extent. Ordinary and actual yields upon fields of different elevations are shown in the following table:

Crops and yield in different years upon fields of various elevations.

Crop.	Elevation of land above M. L. W.	Yield per acre.	Remarks.
	<i>Feet.</i>		
Wheat.....	4 or more.....	21 bushels.....	Actual yield, year 1909, slightly less than ordinary yield.
Do.....	3 to 4.....	15 bushels.....	Do.
Do.....	4.....	37 bushels.....	Unusually favorable climatic conditions, year 1897, estimated.
Corn.....	3.5 or more.....	50 bushels.....	Ordinary average yield.
Do.....	2.5 to 3.5.....	25 bushels.....	Do.
Do.....	2.7 to 4.0.....	21.5 bushels.....	Actual yield, year 1908.
Hay—timothy and clover.....	3 to 4.....	1½ tons.....	Ordinary average crop.
Hay—red top, white clover, bent grass.....	2 to 3.....	1½ tons.....	Do.
Oats.....	10.....	44 bushels.....	Actual yield, year 1909.
Do.....	3.5.....	31 bushels.....	Do.

Below the elevations at which the above crops were raised were found pasturage at elevations from 2 to 3 feet, and three-square sedge grows from 1.3 to 2 feet.

Rye, potatoes, and tomatoes of fine quality have been raised on land 2.4 feet above mean low water.

Phosphate is generally applied to the wheat fields at the rate of 200 pounds per acre, but none of the marsh receives any artificial fertilization, as fertilizers are said to produce a rank growth of crops which fail to mature properly.

The live stock is turned on to the pasture about April 15 and gets little or no other feed until November 1. It is said that cattle derive considerable benefit in the spring from the three-square sedge, which at that season is young and tender, and that cows which graze upon marsh lands yield milk of superior quality.

FINANCIAL.

Using the assessed valuations, believed to be fair market values, as a basis, it is estimated that the value of the land comprised within the drainage area of the Colburn lands is as follows.

[Bull. 240]

Value of land in the Colburn area.

Upland, 179 acres, at \$45 per acre.....	\$8,055
High marsh, 256 acres, at \$30 per acre.....	7,680
Low marsh, 53 acres, at \$20 per acre.....	1,060
Total	16,795

Foreshore lands are assessed at \$1 per acre.

Through the kindness of Mr. William J. Beck, manager of these farms for the Colburn estate, it is possible to present the following table of the actual cash receipts. It does not include a probable income of \$300 or \$400 per year realized by the tenants from poultry and hogs.

Actual cash receipts, exclusive of those obtained from poultry and hogs, from the Colburn area.

Year.	Milk.	Wheat.	Corn.	Hay.	Tomatoes.	Miscellaneous.	Total cash receipts.
1898.....	\$2,010.80	\$1,544.86	\$243.56	\$76.80	\$261.56	\$55.50	\$4,193.08
1899.....	2,608.06	1,138.36	370.82	183.74	699.52	113.40	5,113.90
1900.....	3,373.52	1,682.32	419.02	448.30	321.98	21.00	6,266.14
1901.....	3,418.30	1,431.54	649.72	387.00	227.04	.....	6,113.60
1908.....	3,143.74	1,000.04	142.36	168.80	160.92	22.78	4,638.64
1909.....	(¹)	1,728.50	(¹)	(¹)	(¹)	(¹)	.....
Average.....	2,910.88	1,420.94	365.10	252.93	334.20	42.54	5,265.07

¹ Returns not obtainable at the time survey was made.

The following is submitted as probably a fair estimate of the yearly balance:

RECEIPTS.

Average for 1898, 1899, 1900, 1901, 1908..... \$5,265.07

EXPENDITURES.

Interest on invested capital, \$35,877, at 5 per cent.....	\$1,793.85
Taxes, \$20 per thousand, on \$23,580.....	471.60
Insurance.....	50.00
Wages.....	1,650.00
Supplies.....	250.00
Repairs to buildings and fences.....	225.00
Maintenance of embankment and ditches.....	250.00
Depreciation.....	50.00

Total.....	4,740.45
Surplus.....	524.62

The invested capital is estimated as follows:

Original cost of land.....	\$2,000.00
Cost of reclamation.....	16,552.00
Cost of buildings.....	10,000.00
Cattle, 110 head at \$25 per head.....	2,750.00
Horses, 21 head at \$75 per head.....	1,575.00
Machinery and tools.....	3,000.00

Total.....	35,877.00

[Bull. 240]

ESTIMATED COST.

The estimated cost of reclaiming the Colburn marshes is as follows:

River embankment, 7,216 lineal feet, at \$1 per foot...	\$7, 216. 00
Return bank, 1,940 linear feet, at 50 cents per foot...	970. 00
Stone facing (in place), 725 cubic yards, at \$2.10 per yard	1, 522. 50
Ditches, earth excavation, 64,440 cubic yards, at 8 cents per yard.....	5, 155. 20
Sluice (complete).....	900. 00
Allow for contingencies, 5 per cent.....	788. 19
Total.....	16, 551. 89

This estimate is based on prices prevailing at the time the work was done. Labor then was \$1 to \$1.10 per day of 10 hours, and stone could be landed in barges near the embankment for \$1.25 per perch. At the present time labor is \$1.50 for 9 hours, and stone costs \$1.75 per perch on the barge.

SUMMARY.

The following is a summary of the information obtained by the investigation and the conclusions arrived at:

(1) The top of the levee, 9 to 11 feet above mean low water, is below the storm tide of October, 1878, and has been reached in more recent years. It is unsafe. Its estimated cost, including sluice, is about \$6,900 per mile.

(2) The area of sluice opening is 12.11 square feet, or 1 square foot to each 40 acres of drainage area. This is insufficient to properly drain the land at times of heavy rainfall or adverse winds. The maximum observed discharge was 34.18 second-feet and the corresponding head 0.30 of a foot. The average observed discharge was 18.61 second-feet. Sluice leakage amounts to 97 per cent of all the water discharged. The coefficient of discharge of sluices with unweighted flap gates in complete submergence is 0.64.

(3) The ditches for the most part are so silted and choked that adequate storage capacity and proper drainage of the land are prevented. The ditch water (see Pl. II, fig. 1) rises twice daily to elevation 1.6, and in many ditches is virtually held near that elevation. In the best ditch (see Pl. II, fig. 2) the hydraulic gradient rises to about 7 inches per mile, which is fully double what good engineering practice would recommend for drainage ditches in tidal marshes.

(4) The soil will produce good yields of wheat, oats, rye, potatoes, and tomatoes, but the uncertainty of crops on the lower areas has led to their more extensive use for grass and pasturage.

(5) The reclamation of the marsh has cost about \$54 per acre; based on the whole drainage area the cost is about \$34 per acre. A fair return on the investment is being obtained.

MARSH LANDS ON ST. GEORGES CREEK, NEWCASTLE COUNTY, DEL.

HISTORY AND DESCRIPTION.

These lands comprise an area of about 17.5 square miles, drained by St. Georges Creek, Newcastle County, Del. The charter of the St. Georges Marsh Co. is dated 1762, and it is probable that the first attempts at diking were begun about that date. Except for short intervals, the marshes have been exempt from tidal overflow for upwards of 148 years. During the record-breaking storm of October, 1878, the levee was breached, and for a period of about 6 months the interior marsh was inundated. The deposit of new soil in that short time is said to have had a most beneficial effect upon crops.

The lands (figs. 9 and 10) have a frontage on the Delaware River

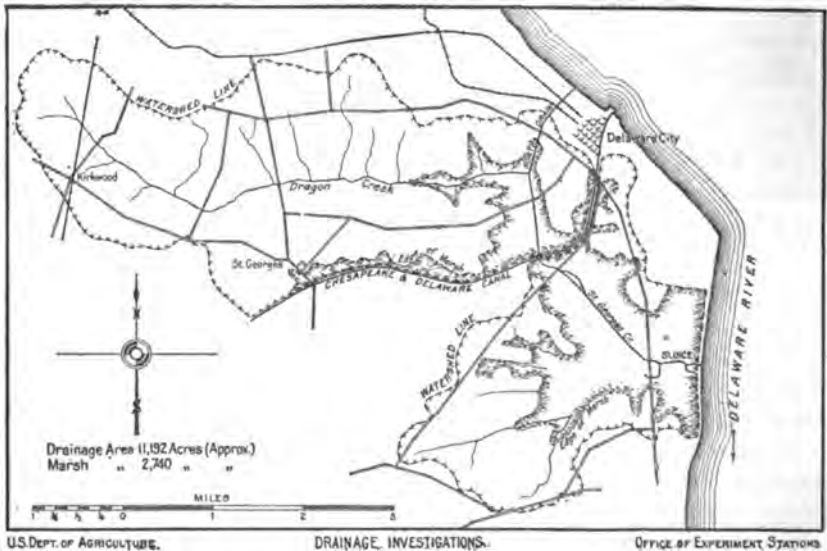


FIG. 10.—Map of drainage area tributary to St. Georges sluice, Delaware City, Del.

of about $1\frac{1}{2}$ miles and extend westerly about 8 miles. St. Georges Creek and watershed are crossed by the Delaware and Chesapeake Canal, the waters of which are about 7.66 feet above mean low water in Delaware River; the creek is conveyed by culvert beneath the canal. It is stated that no less than seven different sluices have been built since the organization of the company. When found to be too small or in poor repair it has been deemed the less expensive to abandon them and build anew.

Some years ago a pumping plant was installed near the present sluice at an expense of about \$10,000. This project ended in failure, but whether because of the volume of water to be handled, the expense of operation, or the subsidence of the meadows, or a combination of the three is not now certain. The drainage area tributary to

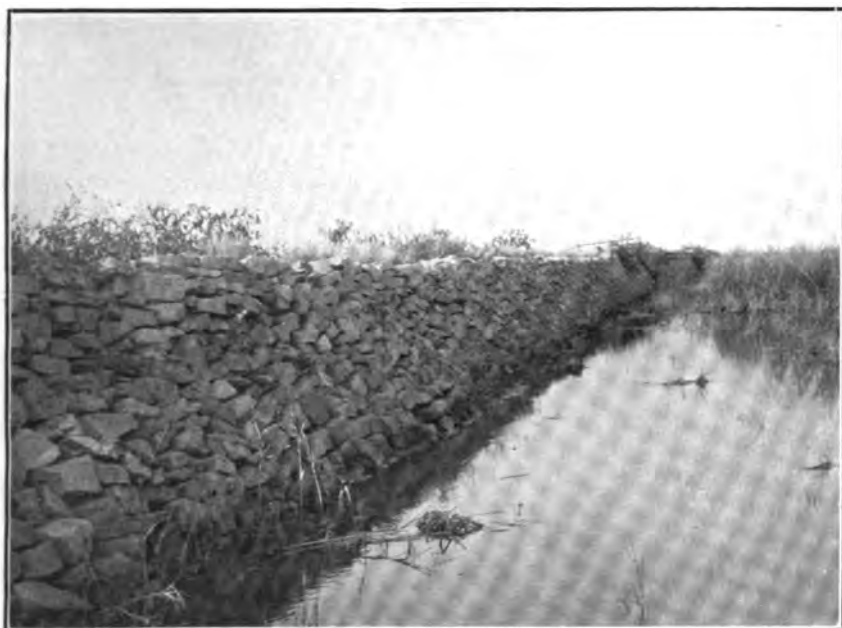


FIG. 1.—ROCK-FACING FOR PROTECTION OF LEVEE AND FORESHORE AT HALF-TIDE LEVEL, ST. GEORGES MARSH CO., NEW CASTLE COUNTY, DEL., NOVEMBER 1, 1909.



FIG. 2.—METHODS OF LEVEE PROTECTION AND SLUICE 4 AT LOW TIDE IN MAURICE RIVER, DORCHESTER, N. J., NOVEMBER 12, 1909.

[Cord-wood protection is on lands of Alfred H. Lupton; plank bulkhead is on lands of Richard Camp.]



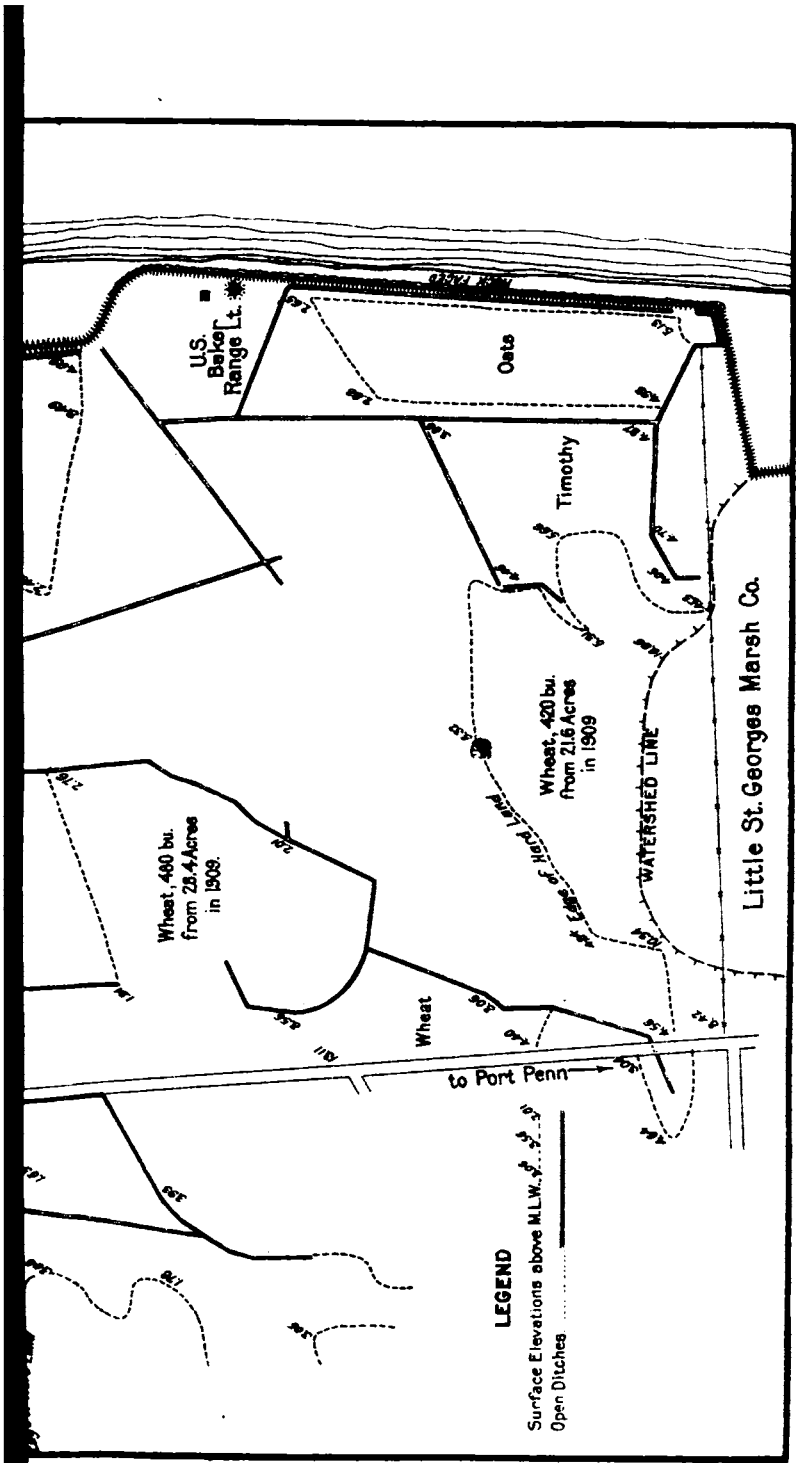


Fig. 9.—Map of portion of St. Georges Marsh Co.'s land, Delaware City, Del.

THE NORRIS PETERS CO. WASHINGTON, D. C.

the St. Georges sluice contains 11,192 acres, of which about 2,700 or 2,800 acres constitute the marsh proper.

The foreshore averages about 150 feet in width and has generally been built up by tidal deposit close to ordinary high-water mark. The interior lands show a wide diversity of elevation and vegetation. Immediately within the levee the marsh generally varies from 3 to 4 feet above mean low water, but near the creek drops to 2 feet or less, and near the southerly boundary rises to 5 feet.

Going westerly from the river the land becomes lower, and beyond the Delaware City-Port Penn Road stretch many hundred acres of marsh 0.75 to 1 foot above datum, covered with a rank growth of reeds and cat-tails and incapable, except when frozen over, of sustaining the weight of a man. Soundings have been made in this marsh to a depth of 40 feet without touching firm bottom. To the north of the Chesapeake & Delaware Canal are a number of thousand acres drained by Dragon Creek. A considerable portion of this drainage

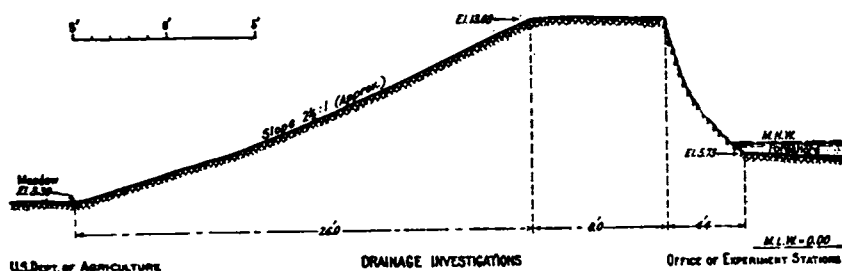


FIG. 11.—Cross section of levee, St. Georges Marsh Co., Delaware City, Del.

was formerly conveyed by the north drain, so called, to the Delaware River, but the breaching of the levee at that point and the abandonment of the north sluice have forced this flow to seek an outlet through the St. Georges sluice. The uplands rise to heights of 60 to 80 feet above mean low water.

LEVEE.

The river levee is about 8,125 feet in length, of which 6,400 feet are rock faced. A cross section is shown in figure 11. The top is about 8 feet wide and from 10 to 14 feet above mean low water or 4 to 8 feet above ordinary high water. The slope on the land side is about $2\frac{1}{2}$ to 1 and has a firm, well-rooted sod. The top is covered with pokeberry and other weeds. The rock facing (see Pl. III, fig. 1) rises by a curved batter to a height of 8 feet in a horizontal distance of 4.4 feet. It is $3\frac{1}{2}$ feet thick at the base and 1 foot at the top, and has no foundation other than the natural surface of the marsh. It is in good repair.

[Bull. 240]

SLUICE.

The sluice is about 42 feet long and 36 feet wide. It is divided into six flumes each about $2\frac{1}{2}$ feet high and $5\frac{1}{2}$ feet wide; the aggregate area of sluice opening is 80.41 square feet. The floor at the land end on the northerly side is 2.30 feet and on the southerly side 2.49 feet below datum, which would place the crown of the sluice practically at mean low water. Men who assisted in its construction state that the floor as built was at mean low water; its settlement, therefore, has been about $2\frac{1}{2}$ feet. The top and bottom are 2-inch unmatched plank; the sides are 6 inches thick. The foundation is stated to be 1-inch sheeting cut in 5-foot lengths driven along both sides and ends and forming, with a 6-inch by 6-inch mudsill, a complete rectangle. The gates are made of $2\frac{1}{2}$ -inch unmatched plank.

Two-inch by six-inch cleats about 1 foot from either end of the gate are fastened with three-sixteenth-inch carriage bolts, and three bolts passing through gate and cleat secure the strap hinges, which are three-fourths inch thick, $2\frac{1}{2}$ inches wide, and about 2 feet 10 inches long. This sluice is said to have been built in 1879 at a cost of \$3,000.

Only one complete determination of the discharge of the sluice was made. On October 8, 1909, at 12.05 p. m., the interior water stood at elevation 1.37; the sluice began to play and continued for 1 hour 28 minutes, during which time 439,560 cubic feet were discharged. The interior water lowered but 0.03 of a foot, though the tide fell from elevation 1.37 to 1.05 during the period; had the tide fallen to ordinary low-water stage, the sluice would have played fully twice as long a time. The maximum head was 0.23 of a foot; the maximum and average rates of discharge were 123.4 and 83.25 second-feet, respectively. The coefficient of discharge averaged 0.39.

The leakage was measured for a period of 2 hours 12 minutes following the closing of the gates, and in that time amounted to the enormous quantity of 356,400 cubic feet, or at the average rate of 45 second-feet. It is highly improbable that the average rate would have been less than 45 second-feet had measurements been continued over the full period of say 9 hours. Upon that assumption the leakage between successive operations of the sluice is seen to be the enormous quantity of 1,458,000 cubic feet or more. The northerly gate was in very bad repair and admitted about 36 per cent of the total sluice leakage; the next gate southerly admitted 14 per cent; the next, 14 per cent; the next, 11 per cent; the next, 8 per cent; and the southerly gate about 17 per cent.

With these conditions of sluice leakage, therefore, is it to be wondered that the farmers are discouraged at the agricultural and financial showing of the St. Georges marshes? One can but admire the

persistency of the men who in the face of adverse circumstances and meager returns have kept these works intact for nearly a century and a half.

DITCHES.

The main creek as far as examined has ample width and depth, the bottom generally being from 5 to 6 feet below mean low water.

The ditches are filled with cat-tails and other growths and are practically abandoned.

CROPS.

Very little of value is grown upon land which is below an elevation of 3 feet. Near the southeasterly corner of the marsh a 9-acre field, averaging about 4 feet above mean low water and planted to oats, failed entirely. Just westerly was a field having an average elevation of about 4.5 feet which yielded, it was stated, 2 tons of timothy to the acre.

A wheat field containing 21.6 acres yielded 420 bushels, an average of nearly $19\frac{1}{2}$ bushels per acre; this field was the beginning of the uplands and ranged from 4.5 to 11 feet above datum.

Another containing 28.4 acres near the Port Penn Road, ranging from 2 to 13 feet above datum, but the average elevation of which was lower than the first wheat field, yielded 480 bushels, or at the rate of 16.9 bushels per acre. Corn planted on land 2.5 to 3.5 feet above mean low water did not make a satisfactory showing; in places it was fair and at other locations in the same field was almost entirely lacking.

Certain lands situated 2 to 3 feet above datum showed excellent pasturage. Between elevations 1.5 and 2 there was a varied growth of weeds and tall, wiry marsh grass. At elevation 1.3 were many acres of three-square sedge, while below elevation 1 there was a rank growth of worthless reeds and cat-tails.

FINANCIAL.

The amount of money which has been expended upon the St. Georges reclamation since its inception can never be determined. It is a large sum. An examination of the treasurer's books shows that the company expended the sum of \$83,409.13 for construction and maintenance of levee and sluices between January 1, 1870, and January 21, 1909. For many years the county of New Castle, in consideration of the protection afforded to several miles of highway, has contributed, on an average, about \$400 per year toward the maintenance of the levee and sluice, while the company's assessment on the marsh owners has yielded, on the average for the last 10 years, about

\$1,000 per year. A disinterested board of commissioners, elected by the stockholders at the annual meeting, fix all valuations and assessments. Assessments become a lien on the marsh land and on the hay, stock, or other personal property upon it.

The cat-tail marshes have a nominal value of \$1 per acre. It is probable that the levee, facing, and sluice would to-day cost about \$22,000. Including sluice, this is about \$14,300 per mile.

SUMMARY.

(1) That there has been a considerable but unknown amount of subsidence in the surface of the marsh is highly probable. Many hundred acres now covered with reeds and cat-tails can not be drained by gravity. The only hope lies in drainage by pumping or in raising the land by hydraulic dredging or by the slower process of natural deposit by the tide.

(2) Large areas adjacent to the uplands can be greatly improved, either for pasturage or dry-land crops, by checking the extraordinary sluice leakage and cleaning and deepening the ditches.

(3) The clear opening of sluice is 80.41 square feet, or 1 square foot to each 139 acres of drainage area. This size is insufficient.

MARSH LANDS NEAR DORCHESTER, CUMBERLAND COUNTY, N. J.

HISTORY AND DESCRIPTION.

These lands are situated on the east side of the Maurice River about 1 mile north of Dorchester, Maurice River Township, Cumberland County, N. J. (See fig. 12.)

The reclaimed marsh comprises 176.5 acres owned by seven different parties. It was first embanked in 1808, but has been out to tide at intervals for many years. Its condition as late as the summer of 1903 is shown in Plate IV, figure 1.

The present levee was built in part by dredge in 1903, and the highway forming the northern boundary of the tract was built the same year. (See Pl. IV, fig. 2.) The transformation which has been wrought by this reclamation is well depicted by the series of views shown in Plates IV, V, VI, and VII, figure 1. The contributing drainage area contains about 2,180 acres, has a frontage on the river of 1.2 miles, and extends easterly therefrom about $2\frac{1}{2}$ miles. Only about 176.5 acres near the river have been put to agricultural purposes; the remaining area consists largely of woodland, varying from wet and swampy at elevation 3 to hills having summits upwards of 50 feet above mean low water.

The drainage from 2,014 acres is collected by Beaver Brook, which, running by tortuous course, is discharged by sluice 2 into the river.

[Bull. 240]



FIG. 1.—AT ORDINARY HIGH TIDE (TWICE DAILY) JULY, 1903.
[Note the lean of the telegraph poles along the old marsh road.]

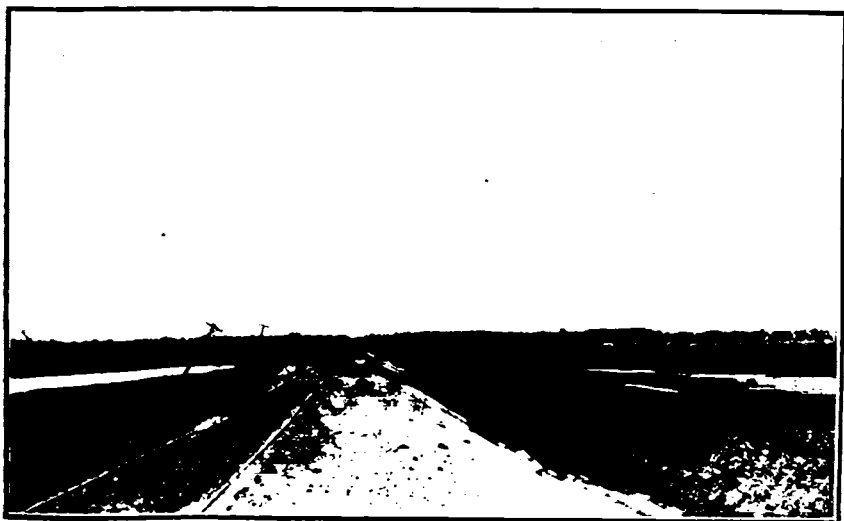


FIG. 2.—DURING NEW CONSTRUCTION WORK, DECEMBER, 1903.
[Note the wave or roll of marsh soil along the right toe of embankment and the lean of telegraph poles on the left.]

VIEWS FROM MAURICETOWN BRIDGE, EASTERLY ALONG HIGHWAY,
DORCHESTER, N. J. MARSH LAND OF ALFRED H. LUPTON IS IN
THE FOREGROUND ON THE RIGHT; HOWARD COMPTON'S IN THE
BACKGROUND.



FIG. 1.—PLOWING ON LAND 1.2 FEET ABOVE MEAN LOW TIDE IN MAURICE RIVER, NOVEMBER 12, 1909.



FIG. 2.—STRAWBERRY FIELD 2.2 FEET ABOVE MEAN LOW TIDE IN MAURICE RIVER, NOVEMBER 2, 1909.

MARSH LANDS OF ALFRED H. LUPTON, DORCHESTER, N. J.



FIG. 1.—DITCH SYSTEM AND PROTECTED FIELDS AND WOODLAND, NOVEMBER 2, 1909.



FIG. 2.—STACKING CORN SHOCKS FOR WINTER FEEDING, NOVEMBER 12, 1909.
MARSH LANDS OF HOWARD COMPTON, DORCHESTER, N. J.



FIG. 1.—CORN FIELDS AND 58-BUSHEL LOAD OF CORN GROWN ON LAND 2 FEET ABOVE MEAN LOW TIDE IN MAURICE RIVER, NOVEMBER 13, 1909.

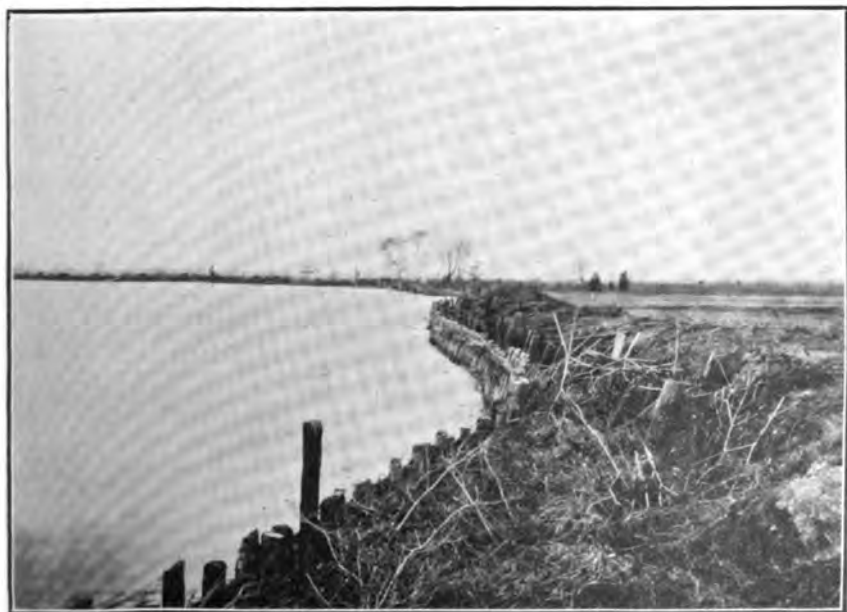


FIG. 2.—LEVEE AND PILE AND BRUSH PROTECTION, MAURICE RIVER, NOVEMBER 2, 1909.
MARSH LANDS OF HOWARD COMPTON, DORCHESTER, N. J.

Small black text at the top of the right margin.

Wood

Brook

Water

Wood

Small black text at the bottom of the right margin.

Mauri
S



Lupton, and others.

Forty-nine acres belonging to Howard Compton in the southeasterly part of the tract are generally 2 to 3 feet above datum.

Near the center of the marsh is a low return bank, extending from the river levee to the highway. To the westerly of this return bank is the 91-acre farm of Alfred H. Lupton, which varies from 1 to 3.5 feet above datum, and to the easterly are parcels of 12.4 acres, 12.1 acres, and 5.4 acres, owned by Richard Camp, Charles T. Grassman, and George Blisard, respectively.

The Camp tract is from 1.75 to 3 feet above datum, the Grassman from 1.5 to 1.9, and the Blisard from 1.5 to 2.

In the northeasterly corner of the marsh is a parcel of 4 acres belonging to D. W. Boggs and varying from 1.5 to 2 feet above datum. A triangular-shaped parcel of 2.4 acres near the southeasterly corner, belonging to Eliza West, is from 3 to 3.5 feet above datum.

The interior lands at the river levee are generally from 2.5 to 3.5 feet above datum. Going from the river the land falls about 1 foot in a distance of 600 feet, at which approximate distance the lowest area is usually found. This low marsh varies from elevation 1 foot or less on land of Lupton to 2.5 feet on the better parts of the Compton land, but probably averages about 1.7 feet above datum. From this low area the marsh rises gradually as we go northerly to the highway or easterly to the woodland.

TIDES.

There being no established bench marks in the vicinity of Dorchester which were known to be referred to mean low water, the height of the tide at 8.57 a. m., October 2, was arbitrarily chosen as such datum.

At that time it was the belief of those familiar with the Maurice River that an average low tide prevailed, and it was assumed as mean low water.

The mean range observed was 5.62 feet.

From the testimony of citizens it is probable that extreme high water is about elevation 7.62; the lowest tide observed was -1, on November 11.

The flood continued for about 6 hours 11 minutes and the ebb for 6 hours 19 minutes.

The vertical movement of the tides averaged about 0.9 of a foot per hour; at half tide it was about 1.1 feet per hour, and about 1½ hours before low and at the time when the sluices generally would begin to play it was about 0.7 of a foot per hour. The Maurice River at this point, about 11 miles by water from Delaware Bay, is only slightly brackish.

[Bull. 240]

SOIL AND SUBSOIL.

The soil is a stiff, grayish, silty clay often mottled in appearance, and all tests with blue litmus paper showed more or less pronounced acid reaction. Tilled and with the humus incorporated in it, it has a very dark-brown color and possesses great fertility. This stratum of silty clay varies in thickness from a few inches near the woodland to probably as much as 10 or 12 feet at the levee.

Tests made in 1902 along the line of the highway leading to Mauricetown by Mr. D. W. Boggs, civil engineer, and at points indicated on the plan (see fig. 12, p. 34) show a firm, gritty bottom at depths of from 9 to 57 feet below the surface of the marsh. These soundings were made with small-sized wrought-iron pipes, and one or two men had no difficulty in pushing the pipe by hand to the depths shown on the plan. Mr. Boggs found that in general the stratification was as follows: For the first 10 or 12 feet, a grayish, silty clay through which the pipe went without any great difficulty; for the next 8 feet a very soft mud and slime through which the pipe would almost drop by reason of its own weight; for the next 6 feet a partially decomposed vegetable deposit offering a somewhat greater resistance to the pipe than the last-mentioned stratum. Continuing downward the 8-foot and 6-foot layers as just described were encountered in rotation to the firm bottom.

The inability of this marsh soil to sustain any considerable load is well illustrated by the happenings during and subsequent to the time of construction of the new highway.

In a total distance of about 5,100 feet the estimated quantity of sand filling required for this highway was about 42,000 cubic yards. The quantity actually taken from the borrow pits and placed in this embankment to bring it to the established grade was 139,125 cubic yards. Ninety-seven thousand one hundred and twenty-five cubic yards, therefore, represented the compression and displacement of the marsh soil beneath the base of the roadway up to the time of the completion of the construction work in 1903. Since that time a further settlement equivalent to 10,000 cubic yards has taken place, so that at present, of the 139,125 cubic yards of sand deposited, 107,125 cubic yards are below the surface of the marsh and only 32,000 cubic yards are above.

This large settlement and displacement has taken place over a strip of marsh approximately 5,100 feet long and 51 feet wide, and where the anticipated load was not over 1,100 pounds per square foot.

Plate IV, figure 2, shows how, under the weight of the embankment and construction trains, a wave or roll of marsh soil 7 to 8 feet in height was created along each toe, and how the bottoms of the tele-

[Bull. 240]

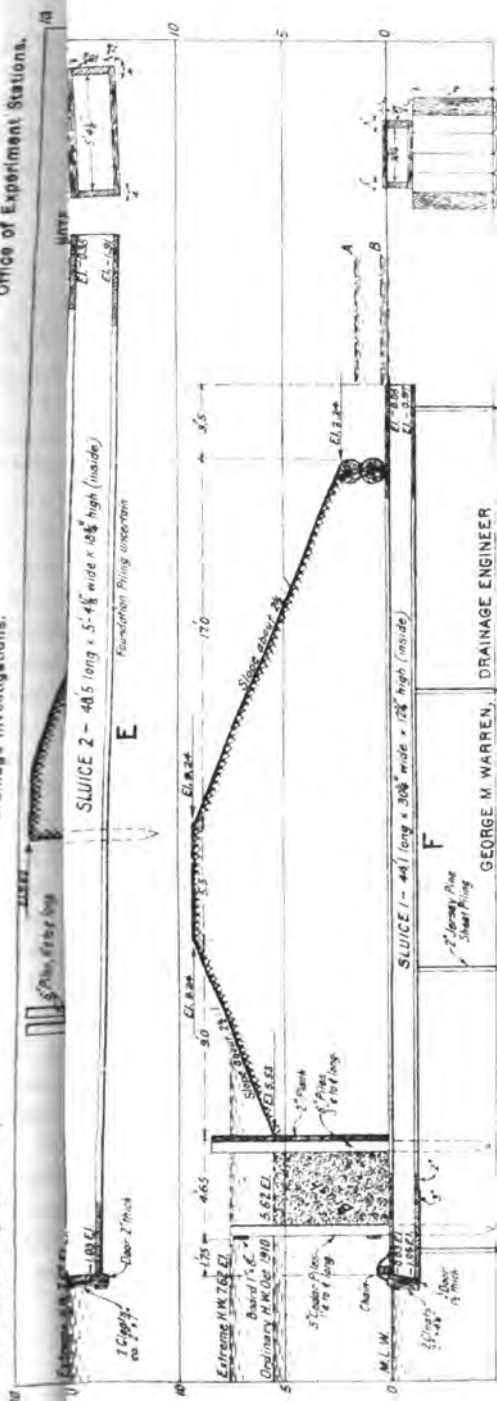


Fig. 13.—Sections of levee and sluices between Dorchester and Maudslow, Naurice River township, Cumberland County, N. J.

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graph poles were pushed away from the fill. It is said that on one occasion the embankment and construction cars settled 7 feet in a single night, and that piles 72 feet in length were driven to support the West Jersey & Seashore Railroad track over Beaver Brook. A water-bearing sand shows in the bottom of the ditch along the edge of the woodland near the southeasterly corner of the Compton marsh.

LEVEE.

Six cross sections of the river levee are shown in figure 13, A, B, C, D, E, and F. There is no foreshore, as may be seen from Plate VII, figure 2.

The top width of the levee averages about 5.5 feet and its elevation from 8 to 9.5 feet above datum.

The slopes and the methods of shore protection vary greatly. On the Compton land both slopes are about $2\frac{1}{2}$ to 1, and protection (see Pl. VII, fig. 2) on the river side is afforded by a double line of 5-inch to 6-inch piles, the intervening space, about 18 inches, being filled with brush; to the inside face of the inner row of piles is spiked a 2-inch plank bulkhead up to above extreme high water. Levee and protection are in a fair state of repair.

On the Camp land both levee and protection (see Pl. III, fig. 2 and fig. 13A) are in bad condition. The guard has been riddled by the waves, which work under, through, and over it, and are rapidly washing away the levee. The slopes are steep and irregular and covered with pokeberry and other weeds.

At times considerable seepage was noticed through the levee between sluices 2 and 3 and contiguous to the only area of three-square sedge on the marsh.

On the Lupton land both levee and protection (see Pl. III, fig. 2) are in fair condition. Erosion by the river is prevented by a $3\frac{1}{2}$ to 4 foot pile of cordwood, laid butt ends to the river and weighted with stone; the outer face, battering about $4\frac{1}{2}$ inches to the foot, is supported by a 12-inch longitudinal log or mudsill. On portions of the levee there is a fair stand of grass.

It is stated by old bankmen that the brush facing makes a good protection; that because of its yielding nature it breaks up waves and swells and escapes injury better than a more solid bulkhead, and has the added advantage of being easily and cheaply repaired.

[Bull. 240]

SLUICES.

Five sluices vent the interior waters. The size, length, grade, and tributary drainage area of these sluices are shown in the following table:

Size, length, grade, and tributary drainage area of sluices at Dorchester, N. J.

Sluice.	Clear opening.	Length.	Elevation river end.		Elevation land end.		Tributary drainage area.
			Crown.	Floor.	Crown.	Floor.	
	<i>Sq. ft.</i>	<i>Feet.</i>	<i>Foot.</i>	<i>Feet.</i>	<i>Foot.</i>	<i>Feet.</i>	<i>Acres.</i>
1.....	2.57	41.4	—0.03	—1.05	0.05	—0.97	46.8
2.....	8.33	48.5	.53	—1.03	—35	—1.91	2,014.0
3.....	2.61	32.6	.36	— .68	.31	— .73	28.0
4.....	4.29	38.6	.05	— .96	—04	—1.05	91.2
5.....	5.56	46.2	— .17	—1.86	.13	—1.56	.....

The foundation of sluice 1 consists of 4 lines of Jersey-pine sheet piling 4 feet long and 2 inches thick approximately trisecting the length of the sluice. (See fig. 13F.) The foundations of the other sluices are believed to be similar.

Generally the sides are 3-inch hard pine and top and bottom 2-inch unmatched Jersey pine spiked to the side pieces.

The gates vary from 1½ to 3 inches in thickness of single unmatched plank and are held in place by two ½-inch chains, playing over wooden blocking 6 inches to 14 inches in height, set up on the roof of the sluice at its extreme outer end. (See Pl. III, fig. 2.) The chains are fastened to the top edge of the gate and to the roof of the sluice by one-half-inch iron staples 6 inches in length. It is stated that gates hung in this manner are not so liable to become obstructed as are some other styles on account of the wide opening along the upper edge when the sluice is in operation.

Sluice 2 is the only one which is badly out of level, the land end being about 10½ inches lower than the river end, and laterally the easterly side is about 3 inches lower than the westerly. None of the sluices are doing the work they should. The gates, to insure closing, are heavily weighted, which gives low coefficients of discharge, and their poor mechanical construction is responsible for large leakage from the river. The average head under which they operated was found to be about two-thirds of the maximum head.

The table following shows the average length of time sluices play, average discharge to river and coefficient of discharge, leakage from river, and leakage divided by discharge, expressed in percentages.

[Bull. 240]



FIG. 1.—MAIN DITCH LEADING TO SLUICE 1, MARSH LANDS OF HOWARD COMPTON, DORCHESTER, N. J., NOVEMBER 2, 1909.



FIG. 2.—CLEARING AND BURNING BRUSH AND STUMPS IN CEDAR SWAMP, MARSH LANDS OF THE MAURICETOWN BANKING CO., MAURICETOWN, N. J., DECEMBER 18, 1909.

Leakage and discharge from sluices.

Number of sluice.	Average length of time sluice plays.	Average discharge to river.	Average coefficient of discharge.	Approximate leakage from river between closing and opening.	Leakage divided by discharge.
	<i>Hrs. min.</i>	<i>Cu. ft.</i>		<i>Cu. ft.</i>	<i>Per cent.</i>
1.....	2 04	18,431	0.36	15,650	85
2.....	3 32	74,048	.39	33,580	45
3.....	1 24	8,400	.43	6,740	80
4.....	49	(¹)	(¹)	(¹)	.....
5.....	34	(¹)	(¹)	8,960	.....

¹ Not taken.

DITCHES.

Interior drainage is effected by about 2,423 rods of open ditches, varying in width from 2 to 24 feet and in depth from 1 foot to 3.5 feet. On the Compton land the ditches are generally of trapezoidal cross section; the sides are neatly trimmed, and the bottoms and sides are free from obstructing vegetable growths.

The main ditch (see Pl. VIII, fig. 1) leading to sluice 1, which takes the drainage from some 47 acres of land on the south side of Beaver Brook, is 19 feet wide at the top, 10 feet at the bottom, and about 3.5 feet deep. The bottom is little above the floor of the sluice and would probably average about 0.75 of a foot below datum.

The lateral ditches divide the lands into irregular quadrilaterals, averaging about $1\frac{1}{2}$ acres each. These ditches average about 5 feet wide, and their bottoms are from 0.5 of a foot below datum in the ditches near the river to 1.2 feet above mean low water in the ditch next the woodland. There are about 2,000 lineal feet of underdrains of wooden construction. Beaver Brook, draining 2,014 acres, flows by winding course and between slightly raised banks through the land of Compton and Camp and is discharged by sluice 2 into the river. From the railroad to the river this brook averages about 18 feet wide and 4 feet deep at the center. The bed is rough and unclean and from 1 to 3 feet above the floor of sluice 2. The brook water at the sluice is ordinarily lowered about 2.85 feet during the period of sluice action. At the railroad culvert, half a mile away, the fall is usually not more than 1 inch.

North of Beaver Brook the Compton land is somewhat lower and the ditches are shallower and subdivide the lands into lots of about 2 acres each. The drainage from this land is received into Beaver Brook through a small sluice 12 inches by 14 inches, situated about 300 feet northeasterly from sluice 2.

The ditches on the Camp, Grassman, Blisard, and Boggs lands are in poor condition. Not only are they badly choked with wild

[Bull. 240]

oats and other grasses, but are much too shallow to properly drain the land. Their bottoms would probably average at least a foot above the floor of sluice 3, to which they drain. Their average width is about 4 feet.

The main ditch on the westerly side of Camp's land is about 6 feet in width and 2 feet in depth; its storage capacity in the vicinity of the sluice is entirely inadequate, and two artificial barriers greatly diminish its usefulness even as a conducting channel.

The lateral ditches subdivide the Camp lands into 3 fields of about 4 acres each, Grassman's land into 6 fields of about 2 acres each, and Blisard's into 4 fields of about 1½ acres each. Bogg's area of 4 acres is undivided.

The Lupton farm is the lowest of the entire tract. It is a self-contained area of about 91 acres, free from all upland drainage and subdivided by ditches into fields, averaging about 5 acres in area each.

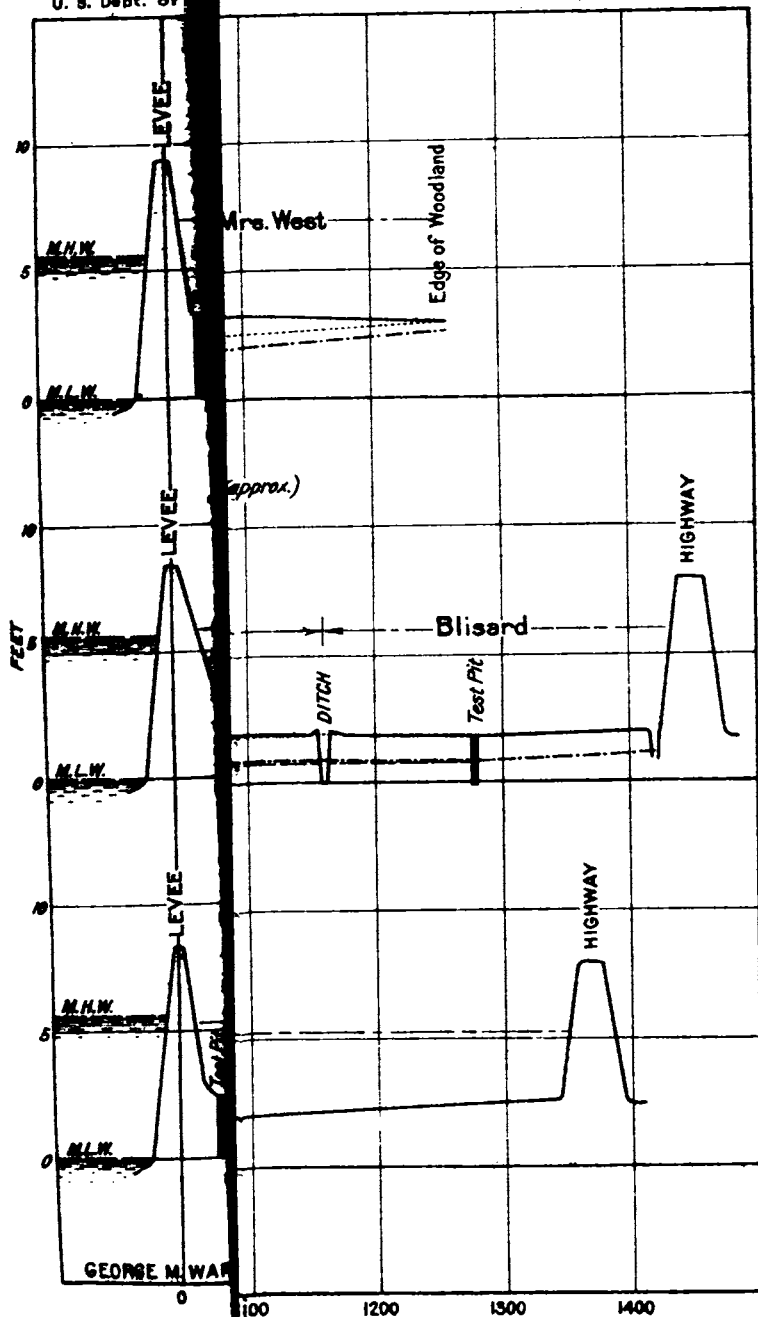
The main ditch leading to sluice 5 is from 11 to 24 feet in width and from 2 to 3 feet in depth; its bottom is from 1 to 1.5 feet below datum. In general the bottoms of all the ditches on this farm are from 0.5 of a foot to 1 foot below mean low water and are free from vegetable growths and serious obstructions. The laterals average 8 feet in width. The ditch water seldom rises more than 5 to 6 inches above mean low water, though sluices 4 and 5 play but for short periods and very frequently not at all. The difference in elevation of the water in the various ditches is shown by the table below:

Ordinary elevation of ditch water at opening and closing of sluices, and entire fall.

Number of sluice.	Owner of land.	Ordinary elevation ditch water.		Fall.
		When gates open.	When gates close.	
		<i>Feet.</i>	<i>Foot.</i>	<i>Feet.</i>
1.....	Compton.....	1.55	0.15	1.40
2.....	Camp.....	3.00	.15	2.85
3.....	do.....	1.10	.10	1.00
4,5.....	Lupton.....	.13	.06	.07

The areas of the different marshes, length and storage capacity (between M. L. W. and elevation of lowest part of tract being considered) of ditches, and ratio of superficial area of ditches to marsh, are noted in the table following.

[Bull. 240]



Ditch data, etc., for marsh lands near Dorchester, N. J.

Owner.	Area of marsh.	Length of ditches.		Storage capacity.		Ratio of ditch and marsh areas.
		Total.	Per acre.	Total.	Per acre.	
	<i>Acres.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Cu. ft.</i>	<i>Cu. ft.</i>	
Compton south of brook.....	22.6	8,754	387	88,970	3,937	4.5 : 100
Compton north of brook.....	26.4	6,385	242	26,426	1,001	1.8 : 100
Blisard.....	5.4	2,095	388	10,662	1,975	3.1 : 100
Grassman.....	12.1	4,614	381	21,561	1,782	3.0 : 100
Camp.....	12.4	2,900	234	16,995	1,371	2.4 : 100
Lupton.....	91.2	15,230	167	108,747	1,192	3.0 : 100

RAINFALL AND GROUND WATER.

The month of October, 1909, was exceptionally cool and dry throughout New Jersey, the rainfall being generally less than for any October in the past 25 years except in 1892. Judging by the recorded rainfall at three places in the vicinity, it is probable that the precipitation at Dorchester was about 1.5 inches for the month, nearly all of which came in three rains, approximating one-half inch each on the 12th, 15th, and 24th. Little rain fell in November until the 8th.

Seventeen test pits for purposes of observation on the ground water were dug. Their position is shown on the plan (see fig. 12). Four were in a north and south line (M-N) near the eastern side of the Lupton farm. Seven were in a nearly parallel line (O-P) on Camp, Grassman, and Blisard lands; and six were southerly of Beaver Brook on lands of Compton and Mrs. West (Q-R).

The positions of the ground water on November 4, 8, and 25 are shown in figure 14. On November 8 it was the lowest observed for a period of nearly one and one-half months. During the night of November 8, about 0.22 of an inch of rain fell, raising the water table about 0.18 of a foot in land of Camp, Grassman, and Blisard, but only 0.06 of a foot in Compton's land.

On the 23d and 24th of November about 2.2 inches of rain fell, raising the ground water about a foot at most of the test pits. While this storm caused the ground water to rise to the surface and completely saturate the marsh of Camp, Grassman, and Blisard, the lands of Compton and Lupton were firm under the foot and about 5 inches above the water table.

[Bull. 240]

Positions of ground water on November 8 and 25, the lowest and highest observed.

Profile.	Date.	Ground water.	
		Approximate elevation above M. L. W.	Approximate distance below surface of ground.
	1909.	<i>Feet.</i>	<i>Inches.</i>
M-N.....	Nov. 8	0.12	17
O-P.....	Nov. 8	.68	13
Q-R.....	Nov. 8	.82	22½
M-N.....	Nov. 25	1.11	5
O-P.....	Nov. 25	1.75	0
Q-R.....	Nov. 25	2.27	5

The distance from the surface of the marsh to the ground water, taking the average of all gaugings made at the several test pits from November 4 to December 6, was as follows:

	Feet.
Upon land of Compton.....	1.30
Upon land of West.....	1.22
Upon land of Lupton.....	1.14
Upon land of Grassman.....	.88
Upon land of Camp.....	.82
Upon land of Blisard.....	.75

From that which has preceded, it is clear:

(1) That the deeper, cleaner character and greater proportional storage capacity of the ditches on Compton's marsh, notwithstanding their interception of considerable ground water near the southeasterly corner of the tract, made possible, at the end of one and one-third months during which about 1.5 inches of rain fell, an average depth of soil above the water table of 22½ inches.

(2) That the deeper, cleaner character of the ditches on Lupton's marsh, notwithstanding the low elevation of the land and comparatively small storage capacity of the ditches themselves, made possible an average depth of soil above the water table of 17 inches.

(3) That the shallow, choked ditches on the marsh of Camp, Grassman, and Blisard, notwithstanding fair elevation of the tracts and slight drainage from the uplands, could not make possible a greater average depth of soil above the water table than 13 inches.

The marsh of Mr. Boggs is unimproved and the water stood practically at the surface of the ground at all times. The single test pit near the center of Mrs. West's lot showed the ground water with very slight variations at elevation 1.95. Just east of this test pit at the edge of the woods the water table varied little from 5 inches below the surface of the ground.

[Bull. 240]

It is obvious that a run of low tides produces a corresponding lowering of the water table and that a series of high tides, by increasing the leakage and seepage, produces a corresponding rise. In passing from the former conditions of the tide to the latter, the interior ground water very frequently was found to be rising near the levee while still falling in the remote parts.

At test pits considerably removed from the ditches it was found that a rise or fall of the ground water might follow the tides which produced the movement by from one to three days. Under the influence of a low run of tides and favorable weather the ground water may fall from 1 to 3 inches per day adjacent to the levee, $\frac{1}{4}$ to 1 inch near the center of the marsh, and from 0 to 1 inch at the more remote parts.

It is very probable from the studies made that in the long run the water table is very close to a mean between the surface of the ditch water at the opening and at the closing of a sluice.

CROPS AND THEIR VALUE.

The principal crops are corn, hay, strawberries, and potatoes. In 1909 16.4 acres of Compton land produced 2,235 bushels of corn in the ear, an average of 136 bushels per acre. These fields varied from 2 to 3 feet above datum. The best yield was 265 bushels from an area of 1.1 acres, averaging 3 feet above datum, which is at the rate of 241 bushels per acre. The poorest yield was 300 bushels from 3.9 acres near the southeast corner of the tract, where, from the inflow of upland ground water, the marsh had until recently been too soft to permit of working with horses. (See Pl. VI, fig. 2, and Pl. VII, fig. 1.)

Twenty-four acres of grass land yielded about 48 tons of timothy, red clover, and herd's grass, or an average of 2 tons per acre. This land varied from 1.6 to 4 feet above mean low water. The best yield is stated to have been in excess of 4 tons of timothy and red clover from a field which was found to contain 1.2 acres and its elevation to be about 3 feet above datum.

Three and five-tenths acres in potatoes yielded 300 bushels, which was stated by the foreman to have been about one-half an ordinary crop.

In 1907 an area of 0.55 of an acre 3 feet above datum yielded 150 crates of 32 quarts each Shropshire strawberries, which sold for \$2 per crate; \$1.40 must be deducted for crate, picking, freight, and commissions, leaving a profit of over \$163 per acre, less the cost of raising. In the same year 9 acres, set out in 1905 with Gandy Prize strawberry plants, cleared over \$1,600, or about \$180 per acre. In 1906 4 acres yielded 527 crates of Gandy Prize strawberries, which cleared over \$600, or about \$150 per acre. The last two parcels of land were from 2.5 to 4 feet above datum.

The Camp land, 12.4 acres, is largely covered with weeds and three-square sedge. The middle lot produced a small quantity of inferior hay, probably not exceeding \$25 in value.

The Grassman land, 12.1 acres, probably did not yield on the average more than a ton of inferior hay to the acre, worth from \$5 to \$8 per ton; the easterly lots are covered with weeds and tussocks.

The Blisard land, 5.4 acres, is estimated to yield about 3 tons of herd's grass, worth \$8 per ton, and to furnish about \$30 worth of pasturage per year. The two easterly lots are covered with weeds and tussocks.

The Boggs land, 4 acres, is covered with cat-tails, weeds and brush; it is producing nothing of value.

The land of Mrs. West is producing about 3 tons of rough hay and tussocks, worth perhaps \$6.50 per ton.

Mr. Lupton estimated the 1909 yield of his cornfield at 1,000 bushels; it contained 9 acres and its elevation varied from 1.3 to 3.8 feet above datum. Four and four-tenths acres of strawberries (see Pl. V, fig. 2), about 2.2 feet above datum, yielded 170 crates which brought \$467.50, but this is probably much below the ordinary crop. It is conservatively estimated that the remainder of the Lupton farm, 77.6 acres, produced an average of 2 tons of hay to the acre. Inside the levee, fields ranging from 1.5 to 2.4 feet above datum are said to have yielded 3 to 4 tons of timothy and red clover to the acre. When visited late in October there was still a fine growth of red clover. Four lots near the center of the farm contain 12.7 acres ranging from 0.9 to 1.2 feet above datum. The rough grass upon this area was sold standing for \$30.

Summarized, the value of the 1909 crops at market quotations would be as follows:

*Value of 1909 crops at market quotations from 172.5 acres of marsh lands at
Dorchester, N. J.*

Compton, 49 acres:

Corn, 2,235 bushels, at \$0.35 per bushel---	\$732.25	
Hay, 48 tons, at \$16 per ton-----	768.00	
Potatoes, 300 bushels, at \$0.70 per bushel--	210.00	
Pasturage -----	50.00	
Miscellaneous-----	50.00	
		\$1,860.25

Revenue per acre, \$37.96.

Camp, 12.4 acres:

Hay-----	25.00	
		25.00

Revenue per acre, \$2.02.

Grassman, 12.1 acres:

Hay, 12 tons, at \$6.50 per ton-----	78.00	
		78.00

Revenue per acre \$6.45.

[Bull. 240]

Blissard, 5.4 acres:

Hay, 3 tons, at \$8 per ton.....	\$24.00	
Pasturage	30.00	
		\$54.00

Revenue per acre, \$10.

West, 2.4 acres:

Hay, 3 tons, at \$6.50 per ton.....	19.50	
		19.50

Revenue per acre, \$8.13.

Lupton, 91.2 acres:

Corn, 1,000 bushels, at \$0.35 per bushel...	350.00	
Hay, 155 tons, at \$14 per ton.....	2,170.00	
Strawberries, 170 crates, at \$2.75 per crate..	467.50	
Miscellaneous.....	100.00	
		3,087.50

Revenue per acre, \$33.85.

Total.....		5,124.25

VALUE OF LANDS.

Unembanked these marshes had merely a nominal value. The gunning and trapping privileges might have created a value of \$5 per acre; agriculturally, they were worthless. After embanking in 1808, transfers were made at \$34 per acre. At the present time the assessed valuations range from \$10 to \$50 per acre, according to elevation and the amount of improvement. Upon this basis the value of these lands is as follows:

Value of marsh lands near Dorchester, N. J.

High marsh, 50 acres, at \$50 per acre.....	\$2,500
Low marsh, 90 acres, at \$20 per acre.....	1,800
Low marsh, 36.5 acres, at \$10 per acre.....	365
Total.....	4,665

Property transfers and the testimony of competent appraisers would indicate that market values are about \$10 per acre more than those above stated. This would make the fair market value of these marshes, exclusive of protected woodlands, \$6,430.

The woodland is assessed for \$3 to \$5 per acre, but some of the best groves of cedar are worth \$400 or \$500 per acre.

The cost of effecting this reclamation is given below in some detail, so that the cost of the different classes of work can be compared.

Estimated cost.

Embankment:

River embankment, 6,250 lineal feet, at \$0.80 per foot	\$5,000.00
Return bank (Compton's), 565 lineal feet, at \$0.50 per foot.....	282.50
Return bank (Lupton's), 1,450 lineal feet, at \$0.25 per foot.....	362.50
	\$5,645.00

Shore protection:

Brush, 2,100 linear feet, at \$0.32 per foot	\$672.00	
Cordwood, 1,300 linear feet, at \$0.90 per foot		1,170.00
Plank, 850 linear feet, at \$0.40 per foot	340.00	
		\$2,182.00
Ditches, 2,423 linear rods, at \$0.60 per rod	1,453.80	
		1,453.80

Sluices:

No. 1 (actual cost)	63.32	
No. 2	140.00	
No. 3	60.00	
No. 4	90.00	
No. 5	110.00	
		463.32
Underdrains, 2,500 linear feet, at \$0.05 per foot		125.00
Allowance for contingencies, 5 per cent		493.45
Total		10,362.57

SUMMARY.

As a result of the study of this reclamation, deductions may be made as follows:

(1) The soil will produce good yields of corn, hay, strawberries, and vegetables. Still better results would be obtained by the use of lime to correct the acidity of the soil and by improving the drainage conditions. Corn averages about 130 bushels and hay about 2 tons per acre.

(2) The marsh will not sustain any considerable weight without large settlement and displacement.

(3) Those tracts which have the deepest, cleanest, and most capacious ditches are the best drained and are making the best agricultural and financial showing.

(4) The sluices have coefficients of discharge varying from 0.36 to 0.43. From 45 to 85 per cent of the water discharged is leakage through the sluices from the river.

(5) Those tracts having less than 1 foot of soil above the water table generally are producing little of value.

(6) The height of the water table is about a mean between the heights of the ditch water before and after the sluices play.

(7) On the basis of the marsh thus far utilized, this reclamation has cost about \$59 per acre. The estimated cost is \$10,362.57, and the yearly income from the lands about \$5,124.25. The fair market value of the 176.5 acres of marsh land to-day is \$6,430. The levee, including sluices, cost about \$6,370 per mile.

[Bull. 240]

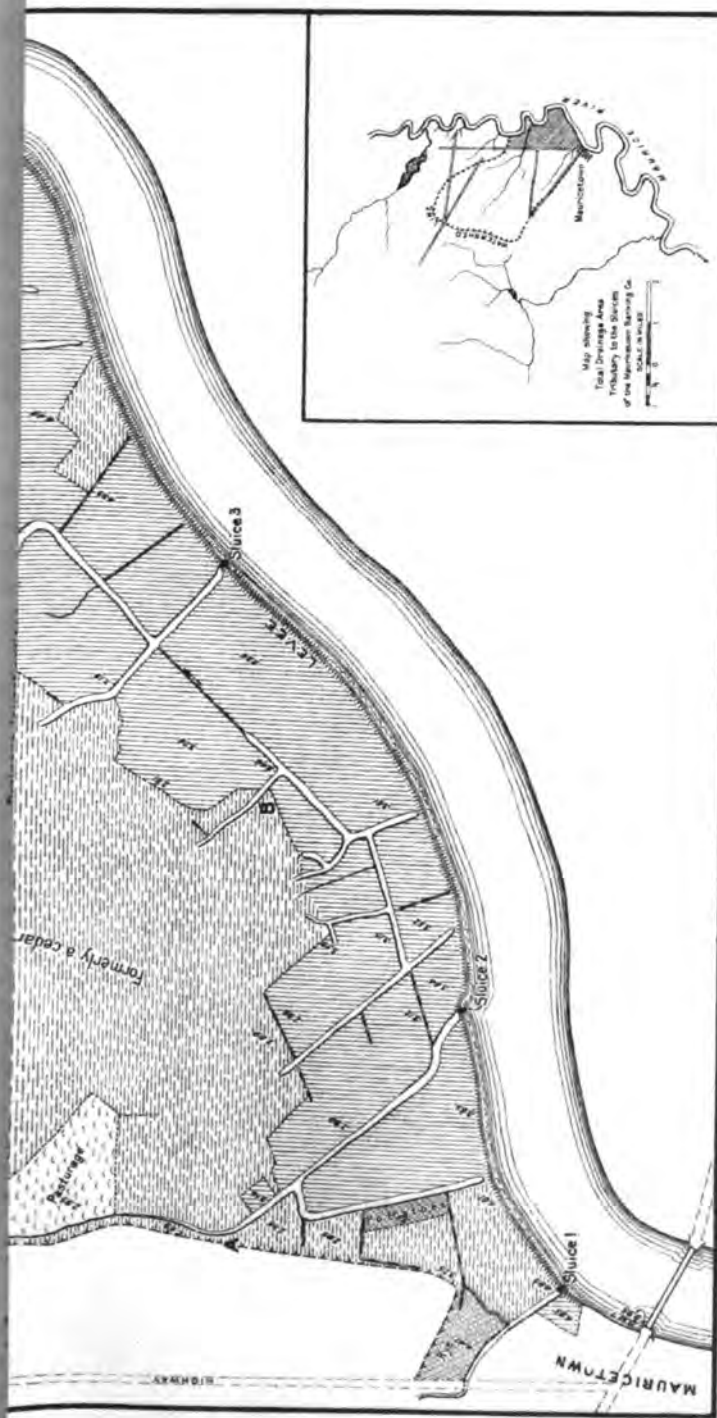


Fig 15.-Map of Mauricetown Banking Co.'s land, Mauricetown, Cumberland County, N. J.

THE MORRIS PETERS CO., WASH. DC

MARSH LAND NEAR MAURICETOWN, CUMBERLAND COUNTY, N. J.**HISTORY AND DESCRIPTION.**

The lands of this company are situated on the westerly side of the Maurice River, northerly from Mauricetown, Commercial Township, Cumberland County, N. J. (See fig. 15.)

They were first embanked about 100 years ago, but some 32 years ago, after the levee had become breached in a number of places, were practically abandoned until April, 1906. At the latter date embanking was again undertaken. A 1-cubic-yard orange-peel dredge placed about two-thirds of the material over the whole length of the levee, about 3 miles. The work was finished with a three-fourths-yard dredge of the same type.

The contributing drainage area contains about 3,635 acres, of which 459 acres constitute the marsh proper. The drainage from about 2,000 acres, collected in Steep Run, so called, is discharged through sluices 8 and 9 into the river. The drainage from 822 acres, collected by a brook just northerly of the village of Mauricetown, is discharged by sluice 1.

The remainder of the drainage area, 813 acres, furnishes the discharge for seven sluices; of these, sluice 7 is the only one which receives directly any considerable amount of upland drainage. Collectively, 5 sluices receive, through crooked and obstructed natural watercourses, the drainage from an old cedar swamp of about 170 acres. (See Pl. VIII, fig. 2.)

Immediately within the levee the marsh is generally from 3.5 to 4 feet above datum. The lowest area is adjacent to the bluff, where the ground ranges from 2 to 3 feet above datum.

The bluff marking the western limit of the marsh is 10 to 15 feet in height, and beyond the drainage area rises to heights of 50 feet or more above mean low water. The rise and fall of the tide is about 5.2 feet, and all levels are referred to the same datum as used on the Dorchester work.

SOIL AND SUBSOIL.

Beneath a thin layer of vegetable mold the soil is a plastic silty clay, generally grayish in color, and often mottled. Both the soil and soil water have a decided acid reaction. The deposit of new soil between 1877 and 1906, a period of 29 years, during which the tide was free to flood the marsh, is plainly observable along the sides of newly dug ditches. Its thickness ranges from 6 inches to 30 inches, and would probably average about 2 feet. Along the sides of ditches which had been opened a considerable length of time there was a fringe of tussocks and grasses growing from the cleavage

[Bull. 240]

line between the top of the marsh of 1877 and the bottom of the superimposed layer.

The downstream side of points of land projecting toward the river are higher and the deposit of new mud is thicker than on the upstream side. Beneath the decomposing vegetable matter marking the top of the marsh of 1877, the deposit of silty clay continues to a greater or less depth. A number of soundings, near the levee, were made into it a distance of 8 or 10 feet, but adjacent to the bluff it is much thinner.

Of the inherent fertility, the apparently inexhaustible supply of plant food in this soil, there can be little question. The oxidation and conversion into humus of its organic matter, the improvement of its structural condition, is the most that is necessary to render these lands extremely productive, and this result can be obtained by thorough drainage and tillage. A sample of this soil, No. 23016, which was recently examined by the Bureau of Soils had a total salt content of 350 parts in 100,000, mainly sulphates and chlorids. Tests by the Veitch method showed that 19,600 pounds of lime would be required to fully neutralize the acidity in 1 acre of soil to a depth of 1 foot. Proper drainage and aeration of the land would, of course, greatly reduce the lime requirement.

LEVEE.

The levee was built by dredge operating from the river side. A typical section is shown in figure 16 A, and cross sections at sluices 1 and 7 are shown in figure 16 B and C.

The channel cut by the dredge is about 31 feet wide and 4.5 to 5 feet in depth, and was made in the foreshore at that point, which is about half-tide level. There is a 9-foot berm between the channel and the levee. The levee is about 28 feet wide at the base, 5 feet at the top, and 5 feet high. The top is generally about 9 feet above mean low water; this is about $3\frac{1}{2}$ feet above mean high water and $1\frac{1}{2}$ feet above extreme high water.

The top and slopes of the levee are rough and irregular and covered with a thick growth of weeds. No attempt has been made to dress the slopes and secure a stand of grass, but the material is as it was deposited from the buckets.

The bank protection which covers about two-thirds of the $3\frac{1}{2}$ miles of levee, consists of a double row of 4-inch oak piles, spaced about $2\frac{1}{2}$ feet longitudinally and $1\frac{1}{2}$ feet transversely, the intervening space being filled with brush.

The piles are from 8 to 13 feet in length and were driven by a gang of three men. Two men with linemen's climbing irons would put their weight to a pile while the third, by a rotary motion, quickly

[Bull. 240]

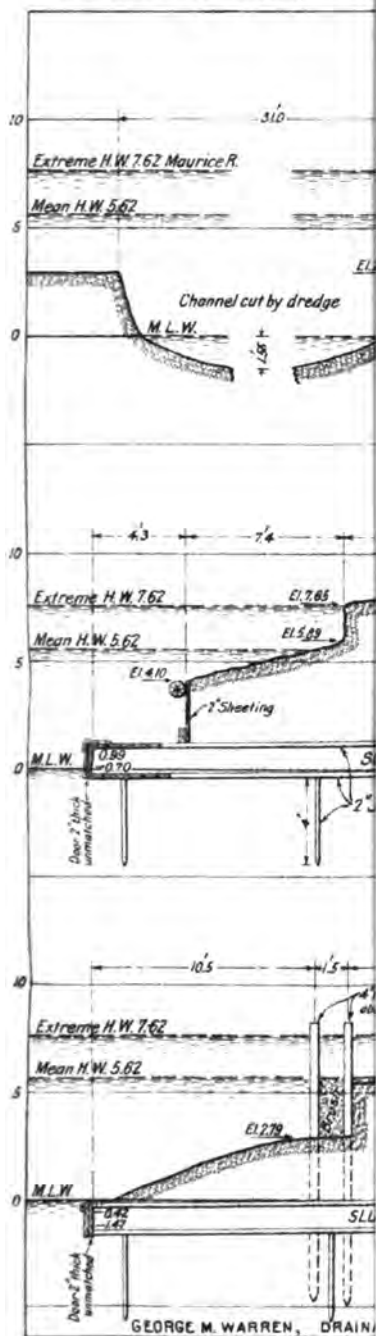


Fig. 16-Sections

worked it downward. It is stated that these piles cost about 5 cents each delivered on the work, and that three men have put down as many as 700 in a day.

The protection is insufficient in extent and lacking in strength. In places the waves are working under the brush, and at other points over it. The destructive effects to the levee at and above mean high-water level are clearly seen in figure 15, A, B, and C. At still other points the entire protection is practically destroyed. It is stated that there were twenty-five breaches in the old levee which required piling in order to close them.

SLUICES.

Ten sluices vent the interior waters. The size, length, grade, and approximate tributary drainage area of these sluices are shown in the following table:

Size, length, grade, and approximate tributary drainage area of 10 sluices at Mauricetown, N. J.

Sluice.	Clear opening.	Length.	Elevation river end.		Elevation land end.		Approximate drainage area.
			Crown.	Floor.	Crown.	Floor.	
	<i>Sq. ft.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Acres.</i>
1.....	2.97	39.8	0.99	-0.20	1.36	-0.17	822
2.....	2.05	37.4	.78	-.25	.82	-.21	130
3.....	2.06	45.0	.42	-.60	.27	-.75	110
4.....	2.02	39.1	.49	-.51	.53	-.47	45
5.....	3.06	41.0	.53	-.49	.16	-.86	65
6.....	1.21	39.0	.57	-.48	.58	-.47	80
7.....	2.07	42.0	-.42	-1.47	.06	-.99	250
8.....	4.45	31.8	1.23	-.07	.97	-.33	2,000
9.....	6.32	39.8	1.70		1.44	-.26	
10.....	2.11	41.2	.91	-.11	.60	-.42	133

The foundation of each sluice consists of five rows of sheet piling 2 inches thick and 4 feet long. About 18 inches from both ends of the sluice and parallel with the levee, 6-foot rows of piling are driven; the distance between these two lines is approximately quadrised by the other three rows. The tops, bottoms, and doors are 2-inch Jersey pine, costing \$20 per thousand. The sides are Georgia hard pine about 3 inches in thickness, costing \$30 per thousand.

The sluices were built complete at the edge of the hard land, floated to the several locations, and at low tide set upon the foundations previously prepared. It is to be regretted that they were not placed at a lower grade; this circumstance will become more apparent with the inevitable shrinkage and settlement of the marsh. For various reasons few of these sluices are doing the work they should. The ditches at the sluice entrances are too often narrow, shallow, or obstructed, and the small submergence of the gates, com-

bined with their weight, gives low coefficients of discharge. (See Pl. IX.)

The time of play, discharge to river, average coefficient of discharge, elevation of ditch water at opening and closing of gates, and fall in feet, on the dates and for the sluices given, appear in the following table:

Sluice data for the marsh lands near Mauricetown, N. J.

Date.	Number of sluice.	Time of play.		Discharge to river.	Average coefficient of discharge.	Elevation of ditch water.		Fall.
						When gate opened.	When gate closed.	
1909.		Hrs.	Min.	Cu. ft.		Feet.	Feet.	Feet.
Dec. 7.....	1	2	07	4,648	0.20	2.07	1.01	1.06
Dec. 8.....	2	2	14	11,175	.32	.80	.40	.40
Dec. 9.....	3	2	17	6,905	.20	.29	— .34	.53
Dec. 11.....	5	3	39	11,563	.17	1.15	— .47	1.62
Dec. 15.....	7	2	50	66,504	.46	.96	.05	.91
Do.....	8	4	46	62,977	.45	2.66	.45	2.21
Do.....	9	4	46	67,782	.45	2.66	.45	2.21

The leakage of the majority of these sluices is believed not to be excessive. Sluice 7, at half tide on December 14, was leaking at the rate of 1.27 second-feet, and it is known that there is a large leakage through sluice 9. On December 15, two days after a rainfall of between 2 and 3 inches, a weir was set in Steep Run just westerly of the highway. The drainage area tributary at that point was 1,943 acres. During a period of eight hours the flow over this weir was about 100,000 cubic feet. The subsequent discharge from sluices 8 and 9 was 130,759 cubic feet. The difference in these volumes is 30,759 cubic feet, and largely represents the leakage through the two sluices from the river. It amounts to over 23 per cent of the discharge.

DITCHES.

The interior drainage is largely through natural sloughs or water-courses, which are of all widths up to 40 or 50 feet. They are rough and crooked and the flat sloping sides have favored a rank growth of vegetation. (See Pl. X, fig. 1.)

Such well-aligned ditches (see Pl. X, fig. 2) as have been dug are inadequate for the proper drainage of the land. There are about $3\frac{1}{4}$ miles of these ditches, 4 to 5 feet wide at top, 2 to 3 feet wide at bottom, and about $2\frac{1}{2}$ feet deep. Many are badly choked with wild oats and other grasses. Observations on the ditch water at five different points on the marsh, designated on the plan (see fig. 15) by the letters A, B, C, D, E, showed the ordinary drop during the period of sluice play to be about as follows:

[Bull. 240]



FIG. 1.—SLUICES 8 AND 9, SHOWING FORMATION OF ICE BELOW ORDINARY HIGH WATER MARK.



FIG. 2.—SLUICE 8, SHOWING GATE SLIGHTLY OPEN, HOW THE WEIGHT OF THE GATE RETARDS THE DISCHARGE AND THE LIABILITY TO INTERFERENCE FROM ICE.

OUTER END OF SLUICES AT LOW TIDE IN MAURICE RIVER,
MARSH LANDS OF THE MAURICETOWN BANKING CO., MAU-
RICETOWN, N. J., DECEMBER 20, 1909.



FIG. 1.—MAIN DITCH LEADING TO SLUICE 4.
[Example of a choked ditch.]

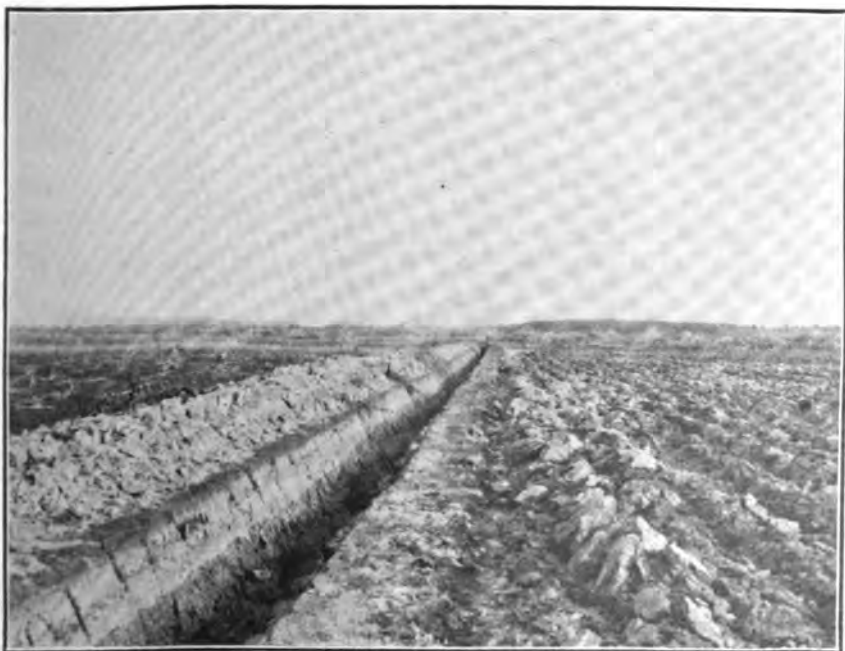


FIG. 2.—LATERAL DITCH NEAR SLUICE 3.
[Example of a clear ditch.]

DITCHES IN MARSH LANDS OF THE MAURICETOWN BANKING CO.,
MAURICETOWN, N. J., DECEMBER 18, 1909.

Ditch-water elevations.

Point.	Control- ling sluice.	Ditch-water elevation lowered—	
		From—	To—
A.....	2	<i>Feet.</i> 0.85	<i>Feet.</i> 0.56
B.....	3	1.37	1.37
C.....	7	1.72	1.72
D.....	10	1.43	1.40
E.....	10	3.08	3.06

It should be stated that point C was in a small ditch, slightly up the slope of the bluff, and that, while the surface of the water was practically the same at all times, there was a distinct and constant flow toward the main ditch leading to sluice 7.

From these figures it will be seen that the movement of the ditch water is very sluggish, and it is probable that the effect of the sluice discharge is not felt at some of these, and other points in obstructed ditches, until several hours after the gates have closed.

On December 13 a rainfall of between 2 and 3 inches raised the water a foot or more in most of the ditches. The elevations next morning, December 14, and four days later, December 18, were as follows:

Ditch-water elevation due to a 2 to 3 inch rainfall.

Date.	A.	B.	C.	D.	E.
1909.	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>
Dec. 14.....	1.77	2.00	2.04	2.75	3.21
Dec. 18.....	.97	1.64	1.78	1.50	3.03
Drop in 4 days.....	.80	.36	.26	1.25	.18

CROPS.

The principal efforts at tillage and crop production have thus far been confined to a strip of land, 600 to 800 feet in width, contiguous to the levee. In 1908 numerous attempts to raise corn proved failures. There was some growth along the edges of the ditches, but a few feet therefrom toward the centers of the fields corn would not grow, and the crop was worthless. The attempts at growing hay were almost as discouraging. The manager of the company reports that about 7 tons of timothy was the total product from upward of 15 acres.

During the year 1909 the yield of corn has been much better, and some spots have shown a very gratifying production. One man obtained 1,700 bushels in the ear from 30 acres; another, 160 bushels from 5 acres; another, 30 bushels from 3 acres. The best average yield was obtained from the field to the south of point D and lying

in part on the southerly side of Steep Run, where 6.8 acres yielded 700 bushels of corn in the ear, or at the rate of about 103 bushels per acre. A near-by field in strawberries yielded well. Wheat, buckwheat, rye, tomatoes, potatoes, cabbages, melons, and celery were other crops grown with varying degrees of success.

With continued development of the ditches and thorough tillage, the next few years will, beyond question, bring these lands to a high state of productiveness.

VALUE OF LANDS.

Unembanked these lands had a nominal value of \$2.50 per acre. The assessments for construction purposes were \$30 per acre on land near the levee, \$10 per acre on land near the bluff, and \$20 per acre on the intermediate areas. Present values may best be judged by recent transfers. Five and thirty-five hundredths acres near sluice 5 sold for \$55 per acre; two lots containing 2.8 and 4.25 acres, near sluice 4, sold for \$70 per acre in March, 1909; 6½ acres on the northerly side of the cedar swamp (see Pl. VIII, fig. 2) sold for \$32 per acre. Taking the whole tract of 459 acres, the present market value is about \$50 per acre.

ACTUAL COST.

The actual cost of this reclamation as furnished by Mr. E. L. Gandy, manager of the company, is as follows:

COST OF RECLAMATION.

Levee, 16,434 linear feet	\$9,701.08
Sluice 1	\$36.30
Sluice 2	31.52
Sluice 3	34.92
Sluice 4	33.18
Sluice 5	38.46
Sluice 6	55.72
Sluice 7	33.66
Sluice 8	33.00
Sluice 9	56.40
Sluice 10	34.48
	387.64
Levee protection, about 10,000 linear feet	1,400.00
Dredging Steep Run (25 feet wide), about 2,200 linear feet	475.00
Interior ditches	200.00
Salaries of commissioners, surveying, and staking lots	380.40
Fee of attorney	70.00
Incidental expenses	200.00
Total	12,814.12

To this should be added about \$600 for ditches which have been dug by individual owners.

[Bull. 240]

SUMMARY.

(1) The inherent fertility of the soil is beyond question. The crops have been all that could reasonably be expected in view of the newness of the enterprise and the crude and unweathered condition of the soil. Satisfactory yields can not be expected upon newly reclaimed lands in less than three years.

(2) The levee should be trimmed and seeded and the protection raised and strengthened.

(3) The sluices are high and have low coefficients of discharge. The combined area of sluice openings is 28.32 square feet.

(4) The ditch system must be further developed. Many existing channels must be deepened and freed of the impeding vegetation.

(5) The deposit of new mud in 29 years averages about 2 feet in depth. The thickest deposit is on the downstream side of projecting points.

(6) This reclamation has cost \$29.29 per acre and raised the land values from \$2.50 to an average of \$50 per acre. The actual cost, including \$600 expended on ditches by individuals, has been \$13,414.12. The levee, including sluices and protection, has cost about \$3,700 per mile.

BENCH MARKS.

The bench marks listed below have been used in making the surveys outlined, and may prove useful to engineers who may make other surveys in these localities:

List of bench marks.

No.	Elevation.	Description.
1	Feet. 12 114	Delaware City, Del., intersection of Battery Lane and Maple Boulevard, Fort Dupont, top of granite monument.
2	10 448	Delaware City, Del., Battery Gibson, Fort Dupont, rear of emplacement No. 1, concrete manhole in roadway, top of northeasterly corner.
3	1 44	Delaware City, Del., marsh of the Arthur Colburn estate, land end of sluice, southerly flume, top of 4-inch timber side, southwesterly corner.
4	11 39	Delaware City, Del., St. Georges Marsh, range light at St. Georges Creek, steel column marked "A IIII," top of northerly anchor bolt.
5	4 99	Dorchester, N. J., Howard Compton's marsh, large maple tree 25 feet westerly of tool house, westerly root, 20 inches from trunk of tree, 12 inches above ground, top of spike.
6	8 11	Mauricetown Station, N. J., West Jersey & Seashore R. R. track, center of highway crossing, top of westerly rail.
7	9 96	Mauricetown, N. J., highway bridge over Maurice River, westerly abutment, top of bridge seat, northeasterly corner.

GENERAL SUMMARY AND DISCUSSION.

The principal points established or elucidated by these investigations may be summarized as follows:

SLUICES.

(1) A sluice will play longer for a given height of interior water the less the range of tide.

[Bull. 240]

(2) The length of time a sluice will play is governed almost exclusively by the behavior of the tide and by the relative elevations of the outer and inner waters. On the ebb tide the gate will open when the water without passes the level of that within, and will remain open until the succeeding flood tide rises to the level of the interior water.

(3) The coefficient of discharge of sluices having unweighted wooden flap gates in complete submergence is 0.64. Heavily weighted and poorly constructed gates may cause the coefficient to drop to as low as 0.10 or even less. Light gates with long radius of swing, good mechanical construction, and complete submergence are all favorable to a high coefficient of discharge.

(4) Sluice leakage was found to exist to an unexpected extent. The smallest leakage measured was 23 per cent and the largest 97 per cent of all the water discharged.

(5) The practice is general of making sluices too small and setting them too high.

(6) The relative merits of the so-called "high sluice" and "low sluice" have been discussed far and wide. The advantage is distinctly with the latter. Only in case of an exceptionally high marsh and large tidal range should the top of a sluice be placed above ordinary low-water mark. The advantages of the low sluice are:

(a) It will discharge more water.

(b) Its life, if of wooden construction, is immeasurably increased by reason of being always submerged and not exposed alternately to the action of air and water.

(c) Its effectiveness will not be diminished by any ordinary settlement or subsidence of the marsh.

(d) There is less liability of obstruction and clogging of the gates from floating sticks, reeds, or other débris which, on the flood tide, has a set toward shore.

(e) It is less liable to interference from sportsmen or persons mischievously or maliciously inclined.

(f) It is less liable to injury or interference in its workings from the action of ice.

(g) The outfall channel is not more liable to become silted than in the case of a "high sluice." In either case silting does not usually occur in the immediate vicinity of the sluice, but at a point some distance therefrom where the velocity of flow has been reduced by a commingling with the quieter waters outside.

The advantages of the high sluice are:

(a) It is less costly to construct.

(b) Inspection and repairs are more easily and cheaply made.

[Bull. 240]

LEVEES.

The best protection which a levee can have, all things considered, is one that nature itself may supply, i. e., a high, wide foreshore. Few levees are built to a safe height, nor do they receive the inspection and care which their importance demands. Including sluices and protection, the Colburn levee has cost about \$6,900 per mile; the St. Georges, \$14,300; the Dorchester, \$6,370; and the Mauricetown, \$3,700.

DITCHES.

While the ditch system and its maintenance is one of the most important factors in marsh reclamation, it is also one of the most neglected. Sluices and levees may be in perfect order, but if the ditches are inadequate through faulty design, or by reason of accumulated deposit and impeding vegetation, the land will remain undrained.

There should be no "seepage ditch" along the inside toe of the levee as it weakens the embankment to that extent and serves as a playground for muskrats, snakes, and fiddler crabs. If interception of seepage through the levee is necessary, it should be done by underdraining. In actual practice few ditches in our reclaimed marshes have a water gradient of less than 7 inches per mile, and in very many it runs as high as 16 to 24 inches. In the reclamation of low, flat marsh lands, there are several practical advantages in making the bottoms of ditches deep and level, viz:

- (1) Storage capacity is increased.
- (2) The friction head is reduced.
- (3) Vegetation does not so readily take root and grows less rank by reason of the bottom being always well submerged.
- (4) Since velocity is dependent upon inclination of the water surface and not of ditch bottom, no advantage is gained by giving slopes to the bottoms of the ditches.

SOIL.

Marshes composed of a deep soil which contains sufficient clay to render it when moist somewhat slippery under the foot are most likely to prove agriculturally profitable, to be subject to only moderate settlement and subsidence, and to be best adapted to the building and sustaining of levees and sluices, or to the digging of ditches.

The marsh soils generally show an acid reaction, due to the decomposition of vegetable matter, and require lime as a corrective. The beneficial effects of lime do not continue as long as on upland soils, for it unites with the chlorin forming chlorid of lime which is soluble in water. Hence applications of lime may on some soils be needed every three or four years. The presence of marl, shells, or other calcareous matter is a favorable sign.

GROUND WATER.

The height of the ground water in the long run will be about a mean between the elevations of the ditch water just before and just after the sluice has played. The height of the ground water is practically unaffected by the oscillations of the tide for a single day. From one to three days must elapse before a low run of tides will have noticeably lowered the water table. In seasons of very small rainfall the water table may be lowered by evaporation considerably below mean low water outside.

VEGETATION AND RELATION TO WATER TABLE.

Upon salt marshes proper, depending upon the height to which they have been built up, are found various sedges, joint grass, salt grass, and black grass. On brackish marshes are found three-square sedge, snip-snap, cat-tails, cord grass, wild oats, and red fescue. On reclaimed marshes where the ditch water rises to such a height as to frequently submerge and keep the lands constantly saturated, reeds, flags, and cat-tails will abound. Land which is occasionally submerged and but a few inches above the water table is in a favorable condition for a profuse growth of three-square sedge.

Little of value is obtained from land less than 1 foot above the water table. At slightly higher elevation, 1 to $1\frac{1}{2}$ feet above the water table, June grass and other natural grasses come in, and with white clover or fescue afford excellent pasturage. There should be not less than $1\frac{1}{2}$ to 2 feet of soil above the ground water for good timothy and corn and $3\frac{1}{2}$ to 4 feet for wheat. If sluices and ditches can maintain the water table within 6 inches above mean low water outside, and this usually should be possible, we may conclude that land situated $1\frac{1}{2}$ to 2 feet above mean low tide would make good pasturage; 2 to $2\frac{1}{2}$ feet above, good hay and corn fields; and 4 to $4\frac{1}{2}$ feet above, good wheat fields. Conservative forecasts on the crop production of such lands would be 2 tons of hay, 65 bushels of shelled corn, and 20 to 25 bushels of wheat to the acre. The botany of tidal marshes has been studied by the Connecticut State Experiment Station, which has also reported complete chemical analyses showing the forage value of the principal marsh grasses.¹

TREATMENT OF LAND AND CROPS GROWN.

Draining marsh land should be done gradually, as otherwise the mechanical condition of the soil may be injuriously affected, its capillary power destroyed, and decomposition of the organic matter retarded. Where fresh water is available and can be promptly re-

¹ Connecticut State Station Rpt. 1889, p. 233.

moved, much of the saline matter can be washed from the soil. The usual method of subduing a rank sod is by burning, and is to be recommended, despite criticisms which have been made. If the burning does not extend deeper than 1 foot, comparatively little available plant food is destroyed and the ashes and charred matter improve the texture of the soil, correct acidity, and hasten nitrification. Every facility should be offered for air, rain, sunlight, and frost to enter and act upon the soil. Many marsh soils, in common with clay soils generally, bake when exposed to sun and drought. Plowing should be done in the fall or winter, and when the land is neither very wet nor very dry, as at such times a baked or lumpy surface will result, and proper preparation of the land will be rendered difficult, if not impossible. The land should be plowed when gentle rains have brought it to its most friable condition. The furrow-slice should be shallow the first year and increase in depth in subsequent years.

Corn is a favorite crop on newly reclaimed marshes, as it withstands considerable acidity. Red top, bent grass, meadow grass, and alsike clover grow well on damp, sour land; and timothy, rye, oats, buckwheat, potatoes, tomatoes, strawberries, celery, melons, and rice have all shown adaptability to marsh soils. Asparagus, onions, beets, and sorghum are crops that resist considerable salt.

FINANCIAL.

Unreclaimed, the marsh lands have a value of from \$1 to \$20 per acre, depending upon their location, elevation, and capability of growing salt hay. In general, the values are greater in the more thickly populated North Atlantic States than in the sparsely settled South Atlantic States. Reclaimed, the marsh lands are worth from \$20 to \$100 or more per acre, varying with the elevation of the land, the character of the soil, and the thoroughness of the development. Probably \$50 to \$60 per acre would be a fair average value at the present time.

The acre cost of a projected reclamation will of course vary widely with the extent of the land to be protected, the amount of upland drainage, and the length and height of the levee. Under average conditions it may run from \$50 to \$60 per acre.

SANITARY.

Marshes which are daily submerged by the tide or are so little above high tide as to be frequently covered through moon, wind, or storm influences are not considered prejudicial to health nor dangerous as mosquito-breeding territory. When the marsh becomes so high or its contour is such that flooding is infrequent the deleterious effects become manifest in malaria, chills, fevers, the mosquito pest,

and in certain localities, anthrax. Reclamation of land of this character and its utilization for agricultural purposes has seldom failed to abate the harmful influences and to destroy the mosquito nuisance.

REASONS FOR POOR PROGRESS AND CAUSES OF FAILURE.

Why has not greater progress in marsh reclamation been made and what are the causes of numerous failures where it has been tried?

A Massachusetts commission which investigated the matter reported as follows:

We are fully convinced that the chief obstacles hereto in the way of extensive reclamation on our New England coast have been—

- (1) The real value and profit of such improvement is not fully realized or understood.
- (2) The lack of practical experience in the art and proper method of reclaiming and subsequent treatment.
- (3) The necessity of united and harmonious action on the part of all the owners.
- (4) The absence of a plain and practical diking law, easily understood and simply applied, by which the best interests of all the owners are duly protected and promoted.
- (5) Want of sufficient capital that can be spared for the purpose by some of the owners of the marshes.

To the above may be added as the principal causes of failure:

- (a) Lack of cooperation among landowners.
- (b) Ignorance or disregard of the fact that many marshes, unless renewed by annual deposition of the tide or by allowing them to remain "out" for a term of years, will settle and subside to such an extent that drainage by pumping is the only possible method of relief.
- (c) Levees of insufficient height, and poorly constructed, protected, and maintained.
- (d) Sluices of insufficient size and of so poor mechanical construction that leakage to the land becomes a preponderate proportion of the discharge.
- (e) Ditches so silted and choked with vegetation that adequate drainage of the land is impossible.

IMPORTANT QUESTIONS TO BE DECIDED BEFORE RECLAIMING.

In considering a proposed reclamation, the all-important questions to be decided are:

- (1) What is the character of the soil, especially its fertility and depth?
- (2) What is the elevation of the land with respect to low tide, and the range of the tide?
- (3) What is the area and slope of the land?
- (4) How is the land situated with reference to shelter from storm tides?

- (5) Is the shore line advancing or receding?
- (6) What is the amount and character of the upland drainage?
- (7) Can intersecting streams be diverted?
- (8) What is the market for the products of the land?

Especial emphasis should be placed on the importance of carefully considered plans and thorough construction in the matter of levees, sluices, ditches, and pumping plants, as much money has been squandered in the past through hasty, ill-advised, and poorly constructed works.

THE DESIGN AND CONSTRUCTION OF DRAINAGE WORKS.

LEVEES.

With due allowance for existing physical conditions, levees should be located well back from the shore line. There is usually along tidal shores a fairly well-defined zone where the marsh has been built highest and where the deposit of new material is thickest and firmest. This should generally be the site of the levee, having in mind also the great value of a wide foreshore for the protection it affords to the levee.

The foreshore should not be less than 100 feet wide and preferably much more, and its rapid building up by tidal deposit should be assisted, when necessary, by the building of groynes or by the spread of vegetation. Instances are numerous where the foreshore is so high that ordinary high tide does not reach the levee at all. Such levees, provided no holes or depressions containing stagnant water are left on either side, are practically exempt from the operation of burrowing animals and the expense of artificial protection is avoided.

Where the sweep of currents and waves comes against a levee, artificial protection is indispensable. All the systems in common use have serious defects. Brush and wood are light, fragile, and short lived; riprap is often expensive, nor does it wholly prevent the burrowing of animals and the washing away of the fine material beneath it; paving is also expensive and unless the blocks are of large size and suitably backed is unequal to the requirements.

In this extremity it is believed that concrete blocks about 3 feet square and 5 inches thick covering the slope from the toe to above ordinary high water would make an ideal protection. Such blocks would weigh between 500 and 600 pounds, could be made at the most favorable location, and after the newly made levee had settled and solidified could be placed on the slope from a scow. This protection would circumvent all the evils which have been mentioned, would intercept considerable seepage, and its cost would be moderate. The top of the levee should be from $1\frac{1}{2}$ to 4 feet, depending upon exposure

[Bull. 240]

to severe storm tides or the height of freshets, above the highest known high water. Only in exceptional cases should the top width be made less than 5 feet.

The slopes will vary somewhat with the material, the exposure, and the method of protection. In no case should the inner slope be steeper than will take a good stand of grass and one that can be mowed over with a machine; such slope is probably about 2 horizontal to 1 vertical. The outer slope, unless protected, should be made very flat, for the certain effect of high waves and heavy swells is to batter down a steep bank and cause it to assume the slope and conditions of a natural beach. Waves can be "tired out," but the power of their sweep against a near-vertical face is tremendous. It has invariably been found that a slope is ultimately established up which the waves climb, come to rest through loss of inertia by friction and gravity, and recede with diminished velocity and lessened destructive capacity. This natural slope in a silt-clay mud exposed to moderate wave action is about 3 to 1. With an increased percentage of sand and stronger waves this slope may become 4 or 5 to 1, and pure sand may be laid by severe storms as flat as 6 to 1, or even 10 to 1.

With the improvements which have been made in dredging machinery, dredges afford the only practicable method of levee construction in tidal marshes, excepting the work be of very limited extent and the conditions unusual. Some form of floating dredge is best suited to the work, and the boom should be of such length that a berm of not less than 10 feet can be left along the outer toe.

No specific directions can be given as to the proper allowances to be made for the combined effects of waste, shrinkage of the material in a levee, and settlement beneath the base. The allowance should vary with the character of the material, the method of construction, and the nature of the marsh, but will seldom amount to less than 40 per cent of the material as measured in excavation, and may amount to 80 per cent or more. It is probable that 15 to 20 per cent should be added to the height for shrinkage in the levee if made of clay-silt, and 25 to 30 per cent if composed of muck.

The site should be cleared of all vegetation, stumps, logs, or anything of a perishable nature, and longitudinally furrowed or ditched to secure an intimate bond with the subsoil. If the base can be deepened (which is usually not possible) to a firm, impervious stratum, the stability and worth of the levee are greatly increased. A line of sheet piling or a thin concrete core wall is of great service in cutting off seepage and preventing the operations of burrowing animals.

After the levee has been built and sufficiently dried out and weathered, the slopes should be trimmed and seeded. A grass suited to the latitude and which forms a thick, tough sod should be used. There

are numerous soil-binding grasses but Bermuda grass and couch grass are two of the best, the former being used in the South and the latter in the North. Redtop, white clover, and blue grass are also extensively used. Beach or marram grass is the most used of the sand-binding grasses.

DITCHES AND SLUICES.

There is probably very little tidal marsh in the United States so high or so favorably situated that successful gravity drainage ultimately will not call into requisition every artifice of the engineer in reducing the ditch water to the lowest possible level. It is necessary that storm water and seepage should be intercepted by the ditches and delivered promptly to the sluices, and that there should be adequate storage capacity to hold the undischarged drainage at times of excessive precipitation or intermittent sluice action by reason of continued high tides.

To accomplish these ends there must be large storage facilities as near the sluice as possible, and the lateral ditches, especially those far from the sluice, should be designed as carriers rather than storage ditches. This arrangement places the accumulated drainage where it is discharged quickly; the head necessary to move water to the sluice is reduced to a minimum and the discharge head of the sluice correspondingly increased. The small lateral ditches then become real drains and continue their flow toward the reservoir or storage basin for a long time after the gates have closed.

All ditches should be designed to reduce the friction head to a minimum. They should be on direct lines, free from obstructions and vegetation. The quotient arising from dividing the cross sectional area of flow by the wetted perimeter or rubbed surface should be as near a maximum as possible. This condition is geometrically complied with when the form is semicircular and the flow line on the diameter. However, in practice such form would be impracticable and rectangular or trapezoidal sections are necessary. The most efficient width is twice the depth, but since velocities vary not directly but approximately as the square root of the depths, the efficiency is not materially lessened if the width is made three or four times the depth.

From a consideration of numerous marshes and a study of rainfall statistics covering both the Atlantic and Pacific coasts, it would seem that ditches and sluices capable of caring for the run-off of a 3-inch rainfall in 24 hours over the entire drainage area would be fulfilling the conditions of an adequate yet not too costly design. With such a rainfall, actual measurements of run-off, which are confirmed by the known gravitational space of marsh soils, show that provision must be made for the removal of three-fourths of an inch per day over the

entire area. This run-off amounts to 2,722 cubic feet per acre per day, but in view of the occasional failure of sluices to play, it is a reasonable and necessary assumption that storage should be provided in the ditches for at least all of this amount. It will also be assumed that the ditch water should not rise higher than 1 foot above mean low water and that at the end of sluice play it will be lowered to within 1 inch of the outside water.

On these premises the ditch area for each acre of land will be 3,000 square feet, or, in other words, about 7 per cent of the land must be given up to ditches. Under an average head of 1 inch, each square foot of sluice opening will discharge 1.5 second-feet, and in one and one-half hours, the period of time a sluice would play with the assumed height of ditch water and a tidal range of 7 feet, would discharge 8,100 cubic feet per operation, or 16,200 cubic feet per day. Since each acre yields 2,722 cubic feet per day, it is seen that each square foot of sluice opening would care for but 6 acres. This would lead to sluices of extraordinary size, and it is highly probable that if built little advantage would be gained for the reason that the high tides which usually accompany a storm make sluice action very uncertain, if indeed it be not entirely eliminated. Since the drainage water is stored in the ditches no harm can be done the land if two or three days, say five operations of the sluice, are required to discharge it, and therefore 1 square foot of sluice opening would protect 15 acres of land.

The table (see fig. 17) has been prepared along the lines above indicated.

In view of the fact that slopes of $\frac{1}{2}$ to 1, or as usually dug by dredge, will, in a silt-clay soil, soon flatten below the flow line to about 2 to 1, reducing the capacity and efficiency of the ditch, it is recommended that the bottom as excavated be made about 9 feet wider than the tabular widths. It will generally be found preferable in large reclamations to use several small sluices rather than one large sluice.

Sluices should be built in the most substantial and workmanlike manner. In important works and where suitable foundations can be secured, mass concrete has many advantages. Reinforced concrete, because of its lightness and ability to withstand tensional and torsional strains, is especially to be recommended. If timber is used it should be antiseptically treated, preferably with creosote (dead oil of coal tar). Wood impregnated with zinc chlorid, corrosive sublimate, or copper sulphate will prove less satisfactory on account of the solubility of these compounds in water.

All hardware should be noncorrosive, preferably of bronze, brass, copper, or galvanized iron.

[Bull. 240]

5

Land Drained in Acres							
	2			9		10	
	3-05			1-20		1-15	
	Clear Opening of Sluice in Sq.Ft.	Bottom Width of Main Ditch in Feet	Clear Opening of Sluice	Clear Opening of Sluice in Sq.Ft.	Bottom Width of Main Ditch in Feet	Clear Opening of Sluice in Sq.Ft.	Bottom Width of Main Ditch in Feet
25	.9	1	1	1.9	1	2.1	1
50	1.7	1	2	3.8	1	4.1	1
75	2.5	1	3	5.7	1	6.1	1
100	3.3	1	4	7.6	2	8.1	2
200	6.6	2	8	15.2	4	16.2	5
300	9.9	3	12	22.7	6	24.3	7
400	13.1	4	16	30.3	8	32.3	9
500	16.4	5	20	37.8	10	40.4	10
600	19.7	5	25	45.4	12	48.5	12
700	22.9	6	29	53.0	13	56.5	14
800	26.2	7	33	60.5	15	64.6	16
900	29.5	8	37	68.1	17	72.7	18
1000	32.7	9	41	75.6	19	80.7	20
1200	39.3	10	50	90.8	22	96.9	23
1400	45.8	12	58	105.9	25	113.0	27
1600	52.4	13	66	121.0	29	129.2	30
1800	58.9	15	75	136.1	32	145.3	34
2000	65.4	16	83	151.2	35	161.4	37
2500	81.8	20	104	189.0	43	201.8	46
3000	98.1	24	125	226.8	51	242.1	55
3500	114.5	27	146	264.6	60	282.5	64
4000	130.8	31	166	302.4	68	322.8	72

Fig. 11.—Showing the effect of drainage on marsh lands.

The gate and its seat demand special attention. The link-hinge allows the gate to adjust itself to the seat, which should have a rubber or other resilient lining or cushion. To protect the gate and seat from the gnawing of animals or the depredations of passers-by, it is recommended that it be set within a chamber or large manhole near the center line of the levee and both the outer and inner ends of the sluice covered with suitable metallic bar screens. This position and protection of the gate would also insure its exemption from obstruction and interference by floating débris and ice.

To obviate cofferdam work with the attendant expense when renewals or repairs on the gate are made, it is suggested that each end of the sluice be fitted with two or more permanent vertical grooves or guides, so that stop planks may be tightly placed over the ends, and the imprisoned water inside the sluice pumped out through the chamber or manhole, which should be surmounted with a suitable wooden or iron cover equipped with padlock.

Not less than two "cut-off" lines of strong tongued and grooved sheet piling should be driven under the sluice and carried well into the levee on both sides to prevent seepage or "blow outs" under or along the sides. The weakest point in a levee is apt to be at the sluice, but if the sheet piling is driven deeply into the mud or to an impervious stratum, little apprehension need be felt.

For the purpose of counterbalancing heavy gates that they may swing under slight pressure, several devices have been employed, but there is probably none in use which is not open to more or less objection. Complete submergence of the gates greatly lessens the need of any counterbalancing mechanism. Gates of the "barn door" or "canal lock" pattern have been extensively used abroad and to some extent in this country. They are best adapted to tidal streams draining large areas and where it might be desirable to pass small boats. The closing of these gates by the rising tide is liable to be accompanied by so much shock as to damage the gate or fastenings. They are believed to be growing in disfavor in this country and unsuited to the conditions of our present comparatively small reclamations.

DRAINAGE BY PUMPING.

GENERAL OBSERVATIONS.

In many localities the small tidal range and naturally low elevation of the marsh and at other places the large subsidence of the land render gravity drainage impossible and the water must be removed by pumping. It is not the purpose here to give explicit information regarding the design of pumping plants, for each reclamation requires special study and treatment.

[Bull. 240]

The questions of rainfall, evaporation, seepage, use to which the land is to be put, fuel supply, and capacity and type of machinery which shall properly balance operating expenses and interest and sinking fund requirements are matters which should receive the consideration of engineers experienced in the design and installation of pumping machinery. There are, however, certain general observations more or less applicable to all projects of this character.

The plant should be located near the natural drainage outlet, upon a substantial foundation, and where fuel may be landed cheaply. The machinery should be suitably housed, preferably in a fireproof building, and should be devoid of any unnecessarily complicated parts.

The head pumped against should be as small as practicable, and this can be accomplished by the use of a check valve in the discharge pipe, by laying the discharge pipe so that siphon action will take place therein, or by pumping through a sluice and not over the top of the levee. If 7 per cent of the marsh area is in ditches, as previously recommended, it will seldom be found that pumps capable of removing 900 cubic feet per acre per working day of eight hours (this is one-fourth of an inch in depth) are inadequate for the complete drainage of cultivated lands.

Many contend for continuous pumping. We believe this is inadvisable under ordinary circumstances. A plant intended for continuous running at times of large precipitation is without reserve capacity for emergencies, and the strain on machinery and men can not be ignored. In large works where the machinery is in duplicate and reserve crews available, the advantage of diminishing the size of plant and lengthening the hours of pumping is increased.

PUMPS.

Various styles of pump have been used at different times both here and abroad. Some form of centrifugal pump is probably best adapted to drainage work. Essentially, this pump consists of a shell containing a revolving runner or propeller, water entering the runner in the center and delivering by centrifugal force at its periphery into the receiving-pump shell. It is very simple, the revolving runner and shaft being the only working parts, and the discharge is continuous. The centrifugal pump is compactly built, does not require heavy foundations, may be belt driven or direct connected, and its cost is moderate.

The submerged type of centrifugal pump has a vertical shaft, the impeller being below the surface of the water to be raised. There is no suction pipe to cause friction and it is always primed. Against it are the difficulties of inspection and repair, and it must be driven

[Bull. 240]

with a twisted belt or by bevel gears and jack shaft. Belt drive is unsatisfactory and uneconomical.

The more common type, the horizontal centrifugal, consisting of a rotating vertical impeller on a horizontal shaft, is placed above the water to be raised. For low or moderate lifts of large quantities of water, and where the head is changing, both of these types are very satisfactory. The efficiency will range from 30 per cent in the smaller sizes to 50 or 60 per cent in the medium, and may reach 75 per cent or more in the larger sizes, which are specially designed. The pump should be set near the water to be raised and the suction pipe should be absolutely air tight, with few elbows, and laid so as to avoid air pockets. Before starting, the pump must be completely filled with water or primed. The small sizes can be primed with a hose or by pouring water into the opening at the top of the shell or with a hand primer. In larger sizes than 8-inch it is desirable to prime with a steam ejector, and for this purpose either the discharge pipe must have a check valve or the suction pipe a foot valve. To prevent damage to the pump in freezing weather, it should be drained after using unless properly housed. In the table below are given the size, capacity, and horsepower for ordinary centrifugal pumps with medium length of suction and discharge pipe and based on a velocity of 10 feet per second in the discharge pipe and efficiencies ranging from 30 to 60 per cent:

Data of small centrifugal pumps.

Diameter in inches.		Capacity in gallons per minute.	Horse- power required for each foot of lift.
Discharge opening.	Suction opening.		
1½	2	55	0.05
2	3	98	.08
2½	3½	153	.13
3	4	220	.18
4	5	391	.25
5	6	612	.38
6	8	882	.50
8	10	1,567	.78
10	12	2,448	1.22
12	15	3,525	1.62
15	18	5,508	2.75
18	20	7,931	3.60
20	22	9,792	4.45
24	24	14,100	5.88

A type of pump used in the Southern States consists of a vertical centrifugal pump within a wooden casing. There is no suction or discharge pipe, but the movement of the impeller causes the water to enter the casing through openings near the bottom and, rising with slight friction, to escape through large openings at the desired height into the outfall canal. Pulley, shaft, bearings, and impeller are the only metal parts, and it is therefore a low-cost pump. It is well

adapted to large quantities of water and low lifts, but lacks the durability of all-metal pumps.

The rotary pump has been used to some extent and is more efficient than the centrifugal, but it is heavy and being geared directly to the engine shaft requires foundations that permit of no settlement.

POWER.

The power to be used must depend upon local conditions; steam, oil, gasoline, gas producer, alcohol, electricity, and wind have been used.

The cost of pumping by windmills is very low, but the uncertain character of this power and the small size and duty of the mills found in the United States eliminate this source in all large or important plants. As an auxiliary it may be made very useful.

Pumping by electricity has in numerous cases proven advantageous. The efficiency, cleanliness, noiselessness, and simplicity of electric pumping, together with the small foundations and compact plant, make this method very attractive. Where electricity must be purchased the cost of pumping is likely to be high.

Alcohol engines have not been developed as yet to the point where they are successfully competing with those of other types, but with the lapse of time there is good reason to believe the competition will be stronger and more successful. The source of the fuel is inexhaustible, and its storage, handling, and use in internal combustion engines is not dangerous or unclean. There is no tendency for the interior of the engine to become sooty, and the odor of the exhaust is not offensive. Alcohol engines develop more power than gasoline or oil, but this increase is at the expense of greater consumption of fuel.

Gas-producer plants are unsuccessful for intermittent work and for sizes under 25 horsepower.

Gasoline and oil engines have long since passed the experimental stage. The advantages over steam are a saving in the first cost through absence of chimney, boiler house, coal shed, and large engine room, less attendance required, quick starting and stopping, and general adaptability to intermittent service.

Gasoline must be stored in metal tanks beneath ground to prevent loss by evaporation, and it is highly inflammable and explosive. Gasoline plants are generally less efficient than either steam or electric plants and the depreciation is higher. The fuel cost at 15 cents per gallon is about 1.7 cents per horsepower per hour. This is higher than in steam or gas-producer plants, but less than in alcohol.

Oil engines using crude or fuel oil, though costly, are splendidly adapted to small or medium-sized drainage operations. The fuel is

safe and economical, and no licensed attendant is required in operating the plant. If the engines are properly installed and handled, the exhaust is not objectionable, nor does the cylinder become sooty. The beginning and end of the run should be made on kerosene. At 4 cents per gallon the fuel cost is about 0.7 cent per horsepower per hour.

Steam is an old and dependable power. In very large reclamations it continues to have the preference. Perhaps the most economical plan, where it is necessary to maintain a number of isolated pumping units, is to generate electricity at a central power house and install electric pumps at the several substations. Small steam plants, however, are very wasteful of fuel and ill adapted to the intermittent character of drainage pumping. The large initial cost in foundations, settings, and appurtenances, the high grade of mechanical ability demanded of the pumping engineer, and the constant and close attention necessary in steam plants render their operation unsatisfactory and uneconomical for ordinary drainage work. Where well-designed plants have been installed artificial drainage has proven less expensive than might be supposed, the annual operating expenses on large areas in England being surprisingly low.

SUPPLEMENTAL INVESTIGATIONS.

MARSH LANDS AT GREEN HARBOR, MARSHFIELD, PLYMOUTH COUNTY, MASS.

HISTORY AND DESCRIPTION.

The largest and best-known reclaimed salt marshes on the New England coast are situated at Marshfield, Plymouth County, Mass., about 30 miles southeast of Boston and 10 miles north from Plymouth.

The history of this reclamation is unique, and no description should omit the salient facts covering a period of more than 100 years. The reclaimed marsh comprises an area of 1,334 acres situated in the southeast part of the town of Marshfield, and formerly drained by a small tidal stream known as Green Harbor River. This river, the reclaimed marsh, adjacent uplands, and coast lines are shown in figure 18.

In 1794 the mouth of the river was about five-eighths of a mile south of the present outlet, but not long previous to May, 1806, a violent storm closed the former mouth with sand and converted the marshes into a lake. For a period of four or five years following the latter date, the old outlet remained sealed and the agricultural value of the marsh was temporarily destroyed. In the latter part

[Bull. 240]

of 1810 or early in 1811 another violent storm opened a new channel through the beach at substantially the location of the present mouth, though there is evidence to show that the breach had artificial assistance. In 1812 it was said that this channel at high tide would float a 100-ton vessel.

In June, 1826, the inhabitants of the town petitioned the legislature for an act or law to preserve and secure from damage the whole of Marshfield Beach, alleging that the mouth of the river had of late years been in a shifting and uncertain state, being at one time choked by a sand bar, and at another time so open that not only was it difficult to cut the salt hay on the marshes but that storm tides took the greater portion of the stacks of hay off the staddles and carried them on to the uplands and into the adjacent swamps.

In February, 1827, legislative authority was granted the people to build and keep in repair a sea wall, palisades or hedge fences, but whatever work was done under the act is not now certain.

About 1870, when the reclamation of the marshes was being considered, certain investigations relative to the harbor were made under the direction of the United States Coast Survey, and in the report, which was prepared, is found the following statement:

As a small local harbor it also has some character. Once within the mouth of the river, a small vessel would find good anchorage, sufficient depth of water and complete shelter. The entrance, however, is shoaler than the river within, and really can not be called navigable at low water. As a harbor of refuge it will probably never be of use except by the local fishing boats and small pleasure yachts of the immediate neighborhood.

Up to this time there had never been a way of crossing Green Harbor River except by boat. From the village of Green Harbor on the south side to the village of Brant Rock on the north side was about 7 miles by road, while in a direct line across the river it was about three-fourths of a mile. Better facilities were needed. Two methods were projected and earnestly advocated. One was to build a bridge a short distance above the mouth of the river; the other to build a dike and road in connection therewith at a point farther up the river.

On February 19, 1870, the legislature passed a law authorizing the county commissioners of Plymouth County to construct a bridge with a draw across Green Harbor River at a point not less than 2,000 feet above the mouth.

On May 17, 1871, the legislature passed a law authorizing the proprietors of Green Harbor marsh to erect a dam and dikes at or near Turkey Point, so-called, with one or more sluiceways and gates for the purpose of draining the marsh, improving the same, and preventing flowage from the sea. The act also provided for the organization of the marsh owners as "proprietors of general fields," and for the

[Bull. 240]

appointment of a commission to execute the work, which commission was authorized to contract with the county commissioners of Plymouth County for the erection of a highway bridge and dam without a draw. The act further provided—

should shoaling take place above the level of mean low water in the channel of Green Harbor River, and its approaches below the dam and dike in consequence of the construction of said dam and dike, said shoaling shall be removed by the proprietors of Green Harbor marsh under the direction and to the acceptance of the board of harbor commissioners. And if the proprietors of said marsh shall fail to remove said obstructions in six months after due notice from said commission, then said commission shall cause the obstruction to be removed at the expense of said proprietors.

The bill, without any conditions or stipulations as to shoaling, was unanimously reported by the joint committee on agriculture and also by the joint committee on harbors and met little opposition in either branch of the legislature, but the petitioners for the bill were induced and agreed that the fourth section—that relating to shoaling—might be added.

Pursuant to the provisions of the act, commissioners were appointed by the superior court at its June term, 1871. This commission was headed by Clemens Herschel, civil and hydraulic engineer, now of New York, who during the year 1870 had made surveys and investigations for the interested marsh owners. Mr. Herschel's report to the marsh owners was dated January 28, 1871. It recommended a dike having a top width of 4 feet, inside slope $1\frac{1}{2}$ to 1, outside slopes varying from $1\frac{1}{2}$ to 1 to 3 to 1 at the bottom, and a height of $8\frac{1}{4}$ feet above the level of the marsh, or $2\frac{1}{2}$ feet above the storm tide which destroyed Minots Ledge lighthouse in 1851. The material was to be deposited in horizontal layers, each rolled and rammed. The sluice was to be of timber construction and have two flumes, each 4 feet square. The total estimated cost was \$14,536.50. The report states that "the marshes are all high marshes and are on a plane of about $8\frac{3}{4}$ feet above mean low water."

During the summer of 1871 the commissioners endeavored to negotiate with the county commissioners of Plymouth County to secure their cooperation in the building of a dike which should have a roadway on its top or along its shelter, but were unsuccessful, and finally decided to proceed independently.

In June, 1872, the commissioners, having received bids which were unsatisfactory, resolved to do the work by day labor, though subsequently several contracts were made for parts of the work.

On November 1, 1872, in making the final closure in the current of the river, there was a "blow-out" beneath the 70-foot timber apron, which had been laid and weighted with stone and gravel. On a low ebb tide the imprisoned water in the marshes cut away 14 feet in

depth of mud beneath the apron and canted the pile foundation downstream. This unfortunate, but not rare, occurrence added greatly to the cost and delayed the completion of the dike until July 1, 1873. The total actual cost was \$32,261.68.

Following the building of the dike came certain changes in the harbor. While it is of course impossible to determine to just what extent the dike is responsible for these changes, since the history of the river shows that changes were taking place many years before the marshes were reclaimed, yet the evidence is conclusive that with the upper reaches of the river cut off there was a diminished tidal scour which facilitated the deposition in the harbor below the dike of the shifting sands brought in by the sea. These changes have undoubtedly been an injury to the fishing interests of Green Harbor, and the dike itself has been a disappointment to the interests which in 1870 had petitioned for a bridge. With the lapse of time much feeling and bitterness has arisen between the two factions, composed respectively of those in favor of the dike and of those who opposed it and desired its removal. Five attempts have been made to blow up the sluice or dike.

In 1875 petitions were presented to the Massachusetts harbor commissioners alleging that shoaling had taken place and asking for relief. The board, with its engineers, visited the harbor, and in its tenth annual report said:

Shoaling has undoubtedly taken place both in the channel and its approaches above mean low water. Natural causes have contributed to this shoaling to some extent, and it would not be practicable to separate with precision the results of natural causes from the results of the dike, but it is clear that what has occurred must be mainly attributed to the dike.

After further surveys, which confirmed the board's opinion as to the responsibility of the dike, an order was issued directing the removal of the accumulation, but nothing was done.

On May 11, 1877, the legislature passed an act authorizing the supreme judicial court sitting as a court of equity to hear and determine the rights of all parties under the original act of 1871 and authorizing the attorney general, under certain conditions, to compel any and all parties liable to remove shoaling or other obstruction, and on May 9, 1878, appropriated \$2,000 to enforce the provisions of the original act.

In 1879 the dike was widened by the town at an expense of about \$3,000 to carry the road from Green Harbor to Brant Rock. This road is now a county road.

On May 7, 1881, the act of 1870, authorizing a bridge over Green Harbor River, was repealed. On May 22, 1888, an act was passed authorizing the county commissioners of Plymouth County, whenever a majority of the legal voters of Marshfield present and voting

should request them by a vote so to do, to construct a bridge with a draw not less than 2,000 feet above the mouth of the river.

June 5, 1896, an act was passed requiring an examination by competent engineers representing a joint board, consisting of the harbor and land commissioners and the State board of health, into the condition of Green Harbor, the marshes, and dike, and the feasibility of the removal of the dike, and \$12,000 was appropriated for the investigation. Very careful surveys and investigations were made under the direction of Messrs. F. W. Hodgdon and X. H. Goodnough, chief engineers, respectively, of the Massachusetts Board of Harbor and Land Commissioners and the State board of health. The expense of the work was \$9,645.62. The findings of the joint board were that the dike should not be removed; that the increased volume of the ebb tide due to the subsidence of the marsh would create a tidal scour greater than any formerly known and cause the washing away and destruction of considerable property, including 25 cottages and a hotel; that submergence of the marsh by salt water would destroy the existing vegetation and convert the land into foul mud flats to the detriment of the health and attractiveness of the neighborhood; that the damage to vested property rights would be far greater than the benefit to the harbor; and that in dollars and cents the dredging of an anchorage basin with channel thereto with two jetties and a training wall, all at an estimated cost of \$67,000, would be less costly than the removal of the dike, estimated to cost \$27,200, plus \$40,000 for necessary jetties and training wall, plus \$12,000 for land, cottages, and hotel likely to be washed away, a total of \$79,200, exclusive of damage to the reclaimed marsh, which at the assessed valuation would probably amount to about \$29,000.

On May 26, 1898, the legislature passed an act authorizing the harbor and land commissioners to expend a sum not exceeding \$67,000 for anchorage basin, channel, jetties, and training wall in accordance with the report of the joint board, and on May 29, 1899, \$37,000 additional was appropriated. The stone jetties, extending from the shore into the sea on each side of the entrance channel to a point where there was a depth of 6 feet at mean low water, were commenced late in 1898 and completed in September, 1899, and a timber training wall was built across the mouth of Cut River to deflect the ebb current from this branch and keep its flow in line with the current from the main harbor. During 1900 a channel 60 feet wide on the bottom and 5 feet deep at mean low water, with an anchorage basin 300 feet square at its inner end just inside the Narrows, was dredged, 92,000 cubic yards of material being excavated and deposited at sea. Observations in 1901, 1902, and 1904 showed that shoaling within the channel and anchorage basin was still in progress; in 1901

there was a depth of 2 feet in the channel at mean low water, and in 1902 it had been reduced to about 1 foot.

On June 2, 1904, \$10,000 was appropriated for further dredging at the discretion of the harbor and land commissioners, but it was decided inadvisable to do any more dredging until the southwesterly jetty had been built up to a sufficient height (this jetty was built upon soft sand and had settled considerably) to prevent the sand from being driven by wind and wave over the jetty and into the channel.

On June 4, 1908, the legislature passed an act authorizing the board of harbor and land commissioners and the State board of health, acting jointly, to examine the harbor, dike, and marshes to determine the feasibility of restoring the harbor to its conditions prior to the construction of the dike by the removal of the dike in whole or in part or by placing therein sufficient tide gates or otherwise. As before, the investigation was conducted by Mr. Hodgdon and Mr. Goodnough; the expense was \$1,227.34. The joint board in its findings, as did the previous joint board, believed it inexpedient to remove the dike and further said:

The experiment of reclaiming the marshes above the present dike has been costly to the Commonwealth, of slight benefit to the marsh owners who built the dike, and a source of undoubted injury to this small harbor. The relief, however, from this injury can not, in our opinion, be obtained by removing the dike, because the level of the meadows as they now exist above the dike is so low that, if the dike were removed, a tidal scour would be established in Green Harbor capable of destroying much valuable property and creating a serious nuisance to the whole neighborhood.

The engineers developed two plans to secure the ends sought. Plan 1 was for the control of the dike by the State, the building therein of six masonry sluices with operating gates, utilizing the storage capacity of the river and main tributaries above the dike up to grade 5 or possibly to grade 6 in winter, and permitting the escape of this impounded water on the ebb tide in such quantities and at such times that its scouring action would remove existing deposits and prevent further accumulations. With a capitalization of \$25,000 for superintendence and maintenance of sluices this plan was estimated to cost \$82,200.

Plan 2 did not disturb the dike but provided for the dredging of a channel 100 feet wide on the bottom, 7 feet deep at mean low water from the sea to the Narrows, the excavation of the whole area of the harbor from the Narrows to the dike to a depth of 5 feet at mean low water, and reconstruction of the southwesterly jetty together with pile and timber fence. This plan was estimated to cost \$158,900. The joint board made no recommendation as to the expediency of the necessary expenditure in connection with either plan. The total

[Bull. 240]

expenditures to date, November 30, 1910, by the State amount to \$76,333.26, which includes construction and investigational work.

Green Harbor River has a total drainage area of about 7.5 square miles, while the tributary drainage area at the dike is 6.9 square miles. The upland watershed is covered with scattered farms and woodland. The reclaimed marsh comprises 1,334 acres below the level of ordinary high tide and a total of 1,696 acres below the level of the very high tides reached several times in the course of a year. In a direction perpendicular to the coast line the marshes are about $2\frac{1}{2}$ miles in length and parallel the sea for about $1\frac{1}{2}$ miles. They are separated from the sea by a narrow strip of land from 600 to 3,000 feet in width, consisting partly of two upland areas, the sites of the villages of Brant Rock and Abington Village, and partly of shingly, sandy beaches and sand dunes. Both of these villages are summer resorts and have few permanent residents. South of the river are the villages of Duxbury Beach and Green Harbor, the former a summer resort and the latter a small all-the-year village inhabited principally by fishermen. The permanent population of the region about Green Harbor is small, probably not far from 200, while in summer the temporary residents number several thousand. Near the center of the reclaimed marsh is the farm formerly owned by Daniel Webster and near by the burial place of the Great Expounder.

TIDES.

The mean range of the tide is about 9.4 feet, and the high tides which may be expected several times a year reach 3.6 feet higher, or to about elevation 13. The great storm tides, April, 1851, when Minots Ledge lighthouse was destroyed, and November, 1898, when the steamer *Portland* with all on board were lost, probably reached to about elevation 14.5. It is known that the latter storm overtopped a portion of the dike and scoured a 50-foot breach down to the level of the marsh, and also broke through the sand dunes separating the marsh from the sea at several points, carrying sand, gravel, and débris on to the meadow. The hardest storms come from the northeast, but without any considerable shoaling at the harbor entrance, because of the protection afforded by Bluefish Rock and the adjacent headland, a natural riprap of bowlders. South of the entrance stretches a sandy beach 6 miles in length to Gurnet Point. The harbor opening widely to the south and southeast is the natural receptacle for the sand caught up by the wind and wave of southeasterly storms along this 6-mile stretch of beach. Glimpses of the contest between these two forces, the wind, wave, and flood tide on the one side, and the varying ebb tide on the other, together with man's efforts to establish equilibrium between them, have already been given.

DRAINAGE CONDITIONS.

Drainage has been secured mainly by the natural river with its tributary creeks. Considerable ditching has been done, but it has not been systematic nor general, nor have the ditches been well maintained. At the dike the river is about 500 feet in width; at Wharf Creek, 2,200 feet above the dike, the river is 350 feet in width; near Bass Creek, about 1 mile from the dike, it is 125 feet in width; above this it narrows gradually until at the highway and railway bridges it is a very narrow stream, and the flow ordinarily feeble. Through the greater body of the marsh the bed of the river and of Wharf and Bass Creeks are below the level of mean low water. At the highway bridge the bottom is about 4 feet above mean low water. The surface of the water in the river is practically level for a distance of over 3 miles from the dike, but above that point the gradient rises quite rapidly. From the investigations made during the summer and fall of 1908 it appears that the interior water was generally between elevations 3.75 and 4, substantially the same as in 1897. Below the dike the conditions were very different, for where in 1897 the surface of the water was held by sand bars or shoals at elevation 3.5 at low tide, in 1908 it averaged about elevation 1.6, or nearly 2 feet lower. These figures demonstrate one or both of two conditions. Either the leakage of the sluice to the land has increased tremendously since 1897 or else the sluice opening is too small for the tributary drainage area. There is evidence that both conditions obtain. Below the dike the discharge from the sluice is apparently maintaining a basin or channel which, starting with a depth of about 4 feet below mean low water near the gates, gradually shoals in a distance of 650 feet downstream to about 1 foot below mean low water.

SOIL.

The reclaimed marsh is not now receiving, nor has it received for many years in the past, any considerable amount of deposit either from the uplands or the sea. The top 6 to 12 inches is generally turf, beneath which is a layer of muck or peat from 1 to 3 feet in thickness, the peat predominating in the upper part of the marsh where poor drainage has retarded decomposition. Near the larger creeks and adjacent to the sand dunes on the narrow barrier toward the sea there is a considerable percentage of sand. Beneath the 2 to 4 feet of soil, which is largely of vegetable origin, is a stratum of blue silt clay from 3 to 6 feet in thickness overlaying a firm sand bottom. The average depth to the sand bottom is about 8 feet, but at several places is from 20 to 25 feet. As would be expected in a soft, spongy, muck or peat soil, there has been a considerable and rapid shrinkage or subsidence of the marsh following reclamation, and the large amount of

[Bull. 240]

investigational work which has been done on the Green Harbor marshes affords reliable figures as to the amount of this settlement.

Mr. Herschel states in his report of 1871 that the marshes are "on a plane of about $8\frac{3}{4}$ feet above mean low water." This is well confirmed by the testimony of old residents who say that the marsh was formerly about at the level of ordinary high water but was submerged a foot or more by spring tides, and also by levels taken in 1897 by the engineers of the joint board. They found the unreclaimed marsh just below the dike to have an average elevation of about 9.1 feet in 1897. The interior lands at the latter date were generally between elevations 7 and 7.5. It is apparent, therefore, that in a period of 24 years the subsidence has amounted on the average to about 20 inches, or at the rate of about 0.8 inch per year. In 1908 further leveling showed that the subsidence in 11 years had amounted to from 0.2 to 0.4 foot, or at the rate of about one-third of an inch per year. In 35 years following the completion of the dike the average settlement over the marsh has, therefore, been just about 2 feet. It is well known that certain areas have settled much more than this and others considerably less. The shrinkage of the soil is of course mainly due to the decomposition of the vegetable matter therein. The small roots and fibers contained in samples of the soil from the reclaimed marsh were generally much discolored and decomposed, while in samples from below the dike they were bright and in a state of vigorous growth. Tests made in 1897 by the State's engineer indicated that flooding the shrunken soil would not cause the surface of the meadows to rise appreciably. Chemical examinations also showed that the water entering the marsh at the upper end contained only about 3 parts of chlorin per 100,000; that the water of the sea contained about 1,740 parts per 100,000, and that from samples collected near the bottom of the river and main creeks the latter was generally about 70 per cent sea water. Much of the turf and muck soil had a specific gravity less than that of water.

DIKE AND SLUICE.

The dike is situated about 3,600 feet from the present mouth of the river at a place where the uplands approaching on both sides narrow the stream to about 500 feet in width. The top of the dike is about 22 feet wide and 1,600 feet long, and its average elevation 14.6 feet above mean low water. It is stated that a line of sheet piling was driven across the river and surrounded by a filling of stones, gravel, and marsh soil, built out from the upland on each side. The outer slope averages about $2\frac{1}{2}$ to 1 with a facing of large and small boulders roughly placed. The sluice is 65 feet long by 9.3 feet wide, outside dimensions. It has two flumes, each 4 feet high and 3.5 feet

[Bull. 240]

wide inside, although the clear opening is reduced by the thickness of the 4-inch upright timbers spaced about 4 feet apart along the inner sides and which sustain the side walls and partition. The top is 6-inch plank. The floor of the sluice is about 1.6 feet above mean low water and is practically level. Each flume has two automatic tide gates, one on the outer end of the sluice and one within but near the inner end. It is said that at the inner end of the sluice there were formerly two gates to be operated by hand and intended to control the level of the interior water, but these have disappeared, leaving only the decaying framing timbers. (See Pl. XI, fig. 1.) The sluice is in poor repair, and is leaking very badly. Observations made by the engineers of the joint board of 1896 showed that the leakage amounted to about 150,000 cubic feet at each tide, and it is stated to have increased since that time. The actual cost of dike and sluice in 1872 was as follows:

Cost of dike and sluice.

Land, gravel, and stone.....	\$2,435.20
Lumber and plies.....	2,842.46
Bolts, rods, spikes, etc.....	570.41
Labor.....	3,941.79
Pile driving.....	3,047.70
Gravel filling (two contracts).....	12,049.01
Sluices and tide gates.....	1,520.64
Sundry expenses.....	960.84
Interest account.....	1,131.71
Legal expenses.....	582.00
Salary of commissioners and collector's fees.....	2,579.92
Total.....	32,261.68

There was received for interest on deposits and petty sales, \$170.89. In 1879, \$3,000 was expended in widening the dike and making a road along the top.

CROPS.

The uses to which the reclaimed marsh was being put in 1897 and 1908 were, approximately, as follows:

Crop acreage for marsh lands at Green Harbor, Mass.

	1897	1908
	<i>Acres.</i>	<i>Acres.</i>
Hay and pasture land.....	630	750
Cranberry bogs.....	25	100
Reservoir for flooding bog.....	16	
Truck and seeded areas.....	2	47
Unimproved and partially wooded.....	660	430

In October, 1910, the cranberry bogs were estimated at 125 acres, and the average yield was about 60 barrels per acre. The berries were

[Bull. 240]

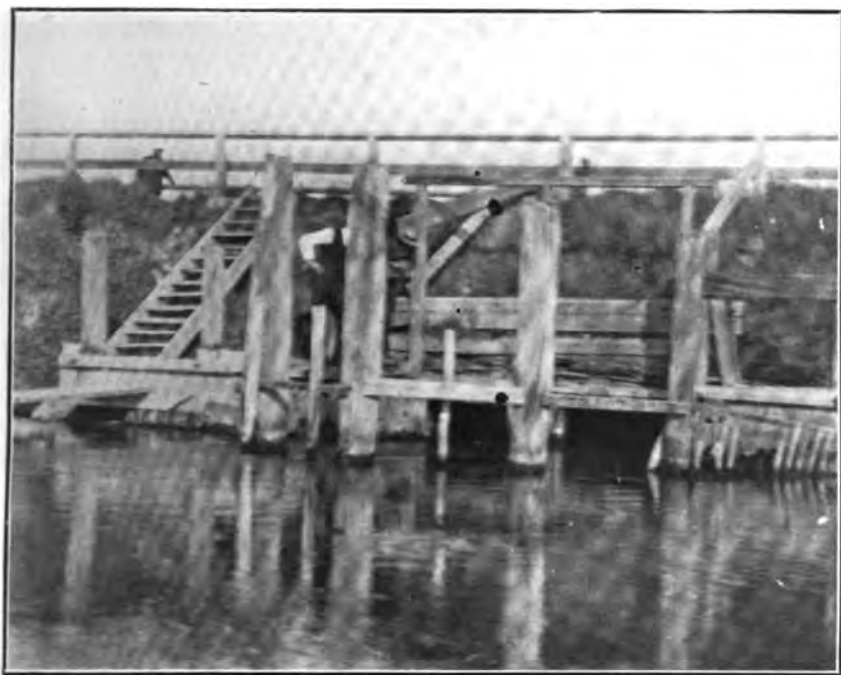


FIG. 1.—DIKE AND LAND END OF SLUICE AT LOW TIDE.



FIG. 2.—JAPANESE MILLET GROWN ON LAND ABOUT 7 FEET ABOVE MEAN LOW WATER.
MARSH LANDS AT GREEN HARBOR, MASS., SEPTEMBER 9, 1910.

large and of excellent quality and for a series of years should net a yearly profit of not less than \$135 per acre. Timothy, redtop, Japanese millet (see Pl. XI, fig. 2), corn, onions, squashes, and rhubarb have all yielded splendidly the present season without fertilizer of any kind. Oats, rye, asparagus, and strawberries have been raised with pronounced success.

In 1909 Dr. Stephen Henry tried the following experiment upon a 2-acre piece of marsh. The land was divided into 4 plats of one-half acre each. The first plat was given 200 pounds of ground bone; the second plat, 100 pounds of sulphate of potash; the third plat, 200 pounds of ground bone and 100 pounds of sulphate of potash; the fourth plat had nothing. On June 10 the four plats were planted to corn and harvested in the middle of October. There was no apparent difference in the yield of the four plats. In reseeding a field Dr. Henry breaks the land and puts on 6 or 8 casks of stone lime, placed in heaps at convenient distances, per acre. The lime is then slaked and spread with a shovel. This application is good for three years. The first and second years the yield of timothy and redtop is a strong 2 tons per acre, but the timothy gradually runs out and the third year the yield is not quite as good. A measured acre has produced 6,800 pounds of hay in a season, and another acre 34 bushels of rye and 5,454 pounds of straw. Dr. Wm. P. Brooks, director of the experiment station at Amherst, Mass., states in a recent publication:¹ "The best redtop that the author has ever seen in any part of Massachusetts was produced on the reclaimed salt marshes in the town of Marshfield."

FINANCIAL.

From such information as is available it appears that prior to reclamation the salt marsh was assessed for about \$12 or \$13 per acre. In 1888 1,054 acres were assessed for \$24,635, the valuations ranging from \$13 to \$32 per acre, but averaging \$23.37. In 1895 1,031 acres were assessed for \$22,335, an average of \$22.63 per acre, and in 1908 1,000 acres were assessed for about \$30,000, an average of \$30 per acre. The market value of the improved areas at the present time is from \$80 to \$100 per acre, and the cranberry bogs would probably run up to several hundred dollars per acre. Reliable statistics as to the revenues from the fishing interests of the harbor are not at hand, but it is estimated that during the 1909 season at least \$15,000 worth of lobsters were caught, besides a considerable quantity of fish.

CONCLUSION.

The reclamation at Green Harbor is one of great natural opportunity. There are few localities where 1,600 feet of dike will pro-

¹ Report of the Massachusetts State Board of Agriculture for 1905, p. 863. [Bull. 240]

tect 1,334 acres of rich marsh or, taking in all the area to the level of the higher tides, nearly 1,700 acres, and where the upland drainage is so small. Beyond all question the dike is a legal structure, and the controversy and bitterness which have continued through the years since its construction are much to be regretted. Reclaiming should add and doubtless has added to the healthfulness and attractiveness of the locality and there can be no question but that the agricultural and financial success of the undertaking would have been very much greater than it has, had the marsh owners been allowed to remain in peaceable possession of their property. There should be a new sluice of larger capacity and set lower, and the land should be ditched in a systematic way. With these improvements well maintained, good management, and a better feeling in the community there is every reason to believe that thorough gravity drainage may be secured and a new era be opened up in the history of the Green Harbor reclamation.

DIKED LANDS AT WELLFLEET, BARNSTABLE COUNTY, MASS.

GEOGRAPHY.

The town of Wellfleet is situated on Cape Cod, 106 miles by rail from Boston and 14 miles from Provincetown, at the extreme end of the cape. The town has an area of 20.8 square miles. On the west it has Cape Cod Bay, while the Atlantic Ocean beats against its eastern boundary, the approximate distance between the two shores being at this point about 5 miles. The outer coast is stern and unbroken, but on the bay side is a beautiful land-locked harbor. Along the ocean shore is a chain of a half dozen or more fresh-water ponds and from one of these, Herring Pond, in the northeasterly part of the town, flows Herring River, the largest in the town, which, flowing in a southwesterly direction, empties into Wellfleet Harbor.

The town has a population of about 1,000, largely engaged in fishing or allied industries, especially the culture and catching of oysters. The agriculture of the community has declined, due in part to the drift of the people to the cities and in part to the sandy, unproductive, almost barren character of much of the upland. The locality has great scenic attractions, however, which, combined with the invigorating breezes that blow across this narrow neck of land and the fine boating and bathing in the harbor, bring here a considerable and increasing number of summer residents. Its growth as a summer resort has been slower than might be expected, however, because myriads of mosquitoes, propagated in the stagnant waters of the Herring River and other marshes, have infested the whole locality and constituted a serious drawback to any development.

[Bull. 240]

HISTORY.

Through the efforts of public-spirited citizens a campaign was inaugurated, which had three principal objects in view: (1) The extermination of the mosquito pest; (2) the drainage of the marshes that the agricultural resources of the community might be increased; and (3) the transformation of the foul, unsightly marshes and swamps into healthy and attractive areas.

On February 1, 1904, the town appropriated \$1,000 to drain the marsh and oil the stagnant pools, and one year later voted \$1,000 more to continue the work. In September, 1905, the late Henry Clay Weeks, of New York, then secretary of the American Mosquito Extermination Society, visited Wellfleet, addressed the citizens and, in a report dated September 15, 1905, advised the diking of Herring River near its mouth and the ditching and draining of the inclosed marsh, thereby removing the conditions favorable to the propagation of the mosquito.

At a special town meeting held November 3, 1905, the services of Whitman and Howard, civil engineers of Boston, were authorized in investigating the feasibility and cost of diking Herring River. In their report dated February 5, 1906, the project is commended and plans and estimates are given for a dike 935 feet long at a point a little less than 1 mile above Wellfleet Harbor. The estimated cost of the dike was \$15,944.75. On January 23, 1906, a petition and bill were presented to the legislature asking authority to build the dike, to borrow therefor, and for a State appropriation. The appropriation was denied, but the remainder of the bill was passed.

Some of the citizens were apprehensive that the dike would cut off the food supply delivered by the river to the shellfish in the bay, and others that the harbor would be injured by shoaling. In these connections the statements of Dr. G. W. Field, chairman of the Massachusetts Fish and Game Commission, and of Messrs. Whitman and Howard, are of more than passing interest.

Dr. Field's statement is as follows:

The department of fisheries and game of Massachusetts strongly advocate the diking of the lands surrounding Herring River in the town of Wellfleet, for the reason that it has been the invariable experience in other places that the shellfish in bays into which runs the water from properly cultivated lands grow more rapidly than is the case where the water comes from barren lands, on the one extreme, or carries sewage pollution, on the other. The reason has been found to be that water from cultivated land carries with it a larger proportion of substances which serve as food for the microscopic plants and animals upon which such valuable shellfish as the oyster, quahog, and clam depend for food. Therefore, the increase of such soluble substances in the waters of Herring River must increase the amount of shellfish food in Wellfleet Harbor and thus cause a more rapid growth and a large yield per acre of all the valuable shellfish. To a considerable degree, also, it will attract larger numbers of young

[Bull. 240]

herring, porgies, smelts, and other surface-feeding fish, which at some period of their lives depend directly or indirectly upon these microscopic plants for food. These small, surface-feeding fish when abundant attract the rapacious species, e. g., mackerel, bluefish, squiteague, pollock, and others. Thus, by increasing the productiveness of both land and water, the good effects will be extended to practically every inhabitant of the town.

Concerning the after effect of the dike on the harbor, Messrs. Whitman and Howard in a report dated December 1, 1906, state:

We do not think the building of the dike and cutting off the relatively small portion of salt water which now ebbs and flows above the dike location will reduce the velocity of the current so that there will be any visible detrimental effect in keeping clear the channels below.

The area of creek and flats above the proposed dike is about 80 acres, and this area will hold at mean high tide about 12,000,000 cubic feet of water. A rough computation shows that this amount is about 15 per cent of the amount of water contained in the flats and creek above a line drawn northeasterly from the point of Great Island, i. e., the whole of Herring River to its mouth. Another calculation shows that this 12,000,000 cubic feet of water is but about 2 per cent of the water contained in the basin and estuaries above or northerly from a line drawn from the point of Great Island to Indian Neck. This line from Great Island to Indian Neck is about the northerly end of the Wellfleet Harbor channel proper, and all the waters above this line are conducive to the keeping open of the channel or to moving the sands which tend to fill up the channel, as the case may be.

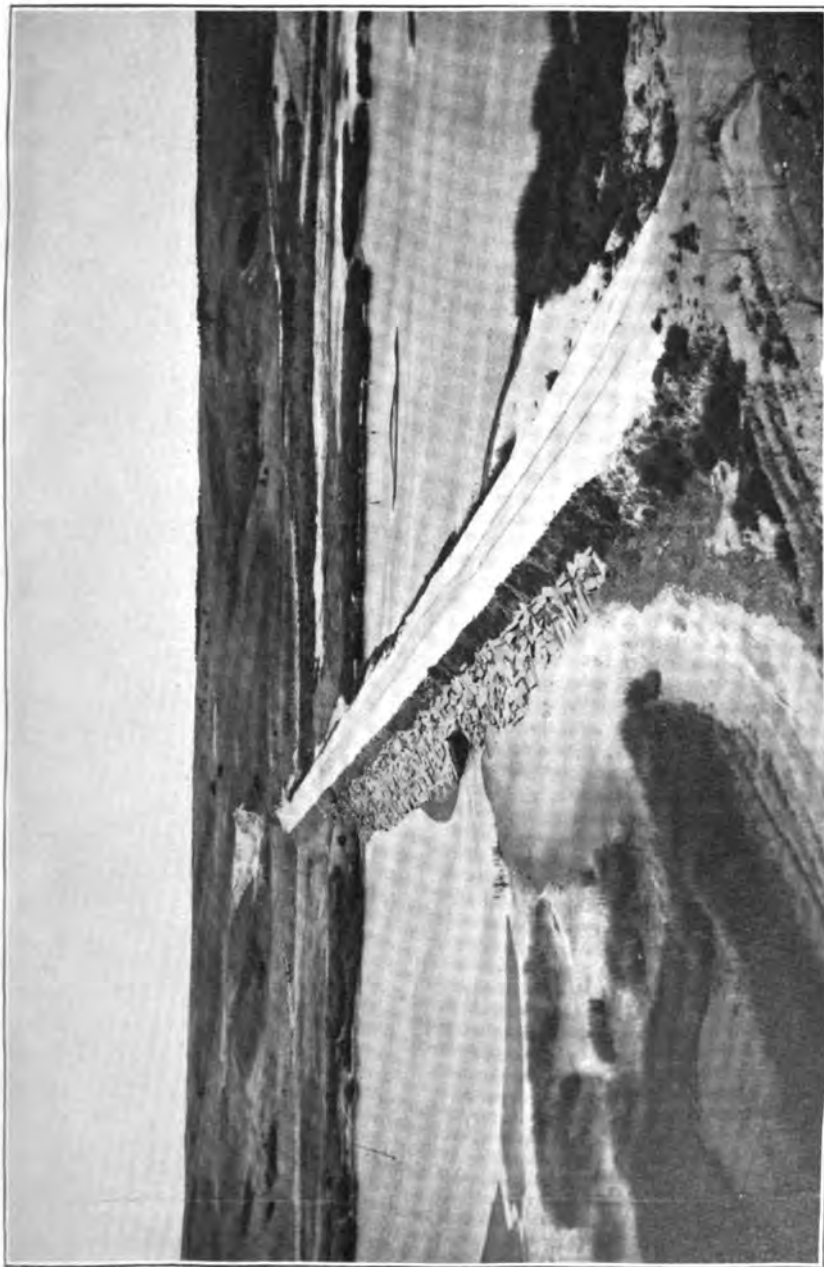
At spring tides this proportion would be slightly augmented, but we do not think it would be material in any case.

In February, 1907, Dr. Elwood Mead, of the United States Department of Agriculture, visited Wellfleet, looked over the ground, examined the plans, and in a subsequent report gave the project his hearty support. The legislature was again petitioned for an appropriation, this time for \$10,000. A bill granting \$10,000, an equal amount to be raised by the town, was passed. In order, however, to meet objections which had been raised as to the constitutionality of the act and the legality of certain acts at town meeting, a new bill amending the bill of the previous year was presented in the legislature of 1908. This became a law without opposition. A special town meeting on March 28, 1908, accepted the amendatory act, and the town's appropriation of \$10,000 was finally deposited with the State treasurer. On January 10, 1908, a hearing was given by the War Department, but no opposition to the project developed. By the act the construction of the dike was placed in charge of the State board of harbor and land commissioners. The lowest bid for the work was \$16,250. Construction was begun in August, 1908, and completed late in 1909. The land, sand, and gravel necessary were given by the town free of cost.

DESCRIPTION.

Herring River has a drainage area above the dike of about 5,800 acres, or 9 square miles, of which 1,100 acres, including water sur-

[Bull. 240]



GENERAL VIEW OF DIKE AT LOW TIDE, SHOWING METHOD OF PROTECTION, DIKED LANDS AT WELFLEET, MASS., SEPTEMBER 22, 1910.

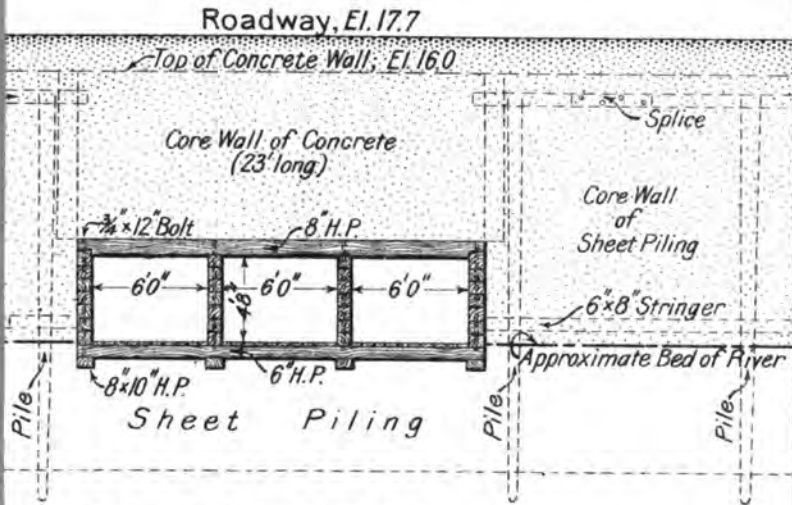
[High tide comes about 1 foot below top of facing.]



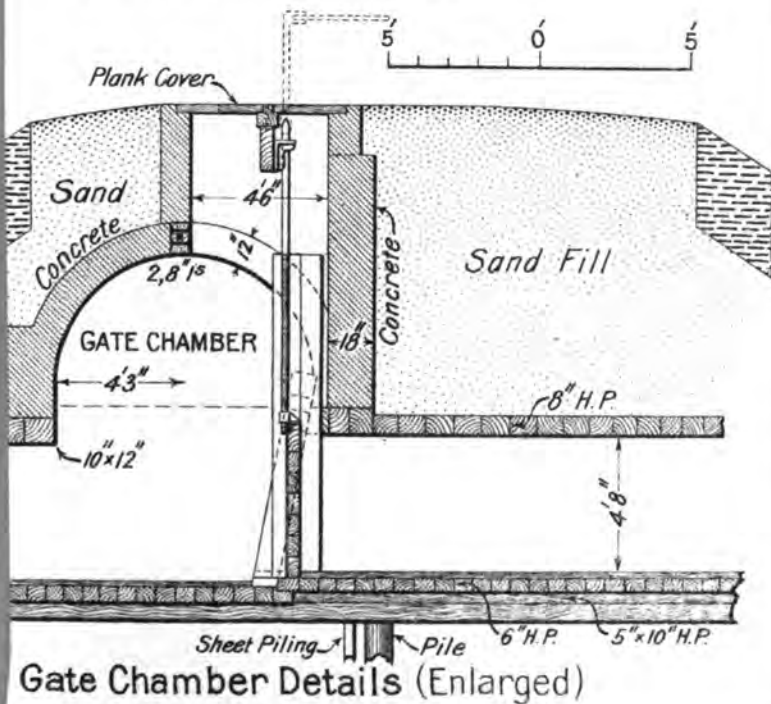
FIG. 1.—OUTER END OF SLUICE AT LOW TIDE, SHOWING GRANITE QUARRY GROUT FACING.



FIG. 2.—DIKING OPERATIONS, SHOWING METHOD OF PLACING MATERIAL.
DIKED LANDS AT WELLFLEET, MASS., SEPTEMBER 22, 1910.



Cross Section of Sluice



THE MORRIS PETERS CO., WASHINGTON, D. C.

faces, are marsh. The marsh land lies in narrow strips of perhaps 1,000 feet in width along the river and the three principal tidal creeks which meander through them. The adjacent uplands consist of steep, sandy, almost bare hills, sometimes rolling, which, long since deforested, have been deprived of their fertility through long-continued erosion by wind and water. The marsh generally is close to mean high water level, though some of the distant parts appear to be as much as 1 foot or more below.

Inside the dike is a natural basin which, with creeks running into it, has an area of about 80 acres, and through which the tide formerly ebbed and flowed for upward of a mile above the present dike. Above this the marshes were considered as brackish or fresh and not salt.

The river at the dike is about 500 feet wide, and its sandy bottom is from 1 to 2 feet above mean low water in the harbor. At low tide on September 22, 1910, when it was said that about an average low tide prevailed, there were 10 inches of water on the floor of the sluice. (See Pl. XIII, fig. 1.) The mean tidal range at Wellfleet is 10.7 feet, the spring range 12.3 feet, and the neap range 9 feet.

DIKE AND SLUICE.

The dike (see Pls. XII and XIII, figs. 1 and 2 and fig. 19) is a sand embankment about 900 feet long and 22 feet wide on top, and has side slopes of $1\frac{1}{2}$ to 1. The crown of the roadway along the top is at grade 17.7 feet above mean low water, or about 7 feet above ordinary high tide. The maximum bottom width is about 68 feet. The filling was obtained from pits in the hills at each end of the dike, and was hauled in automatic side dumping cars of about 3 cubic yards capacity. The 20-inch gauge track was laid so that the cars ran out from the pit by gravity; the empty cars were pushed back on the level track along the dike by two men and drawn up the grade to the pit by a rope and hoisting engine. On September 22, 1910, the writer visited diking operations at South Wellfleet, where the same track, cars, and methods of placing the material were being employed, except that the cars were returned to the pit entirely by hand. The sand was being placed at a labor cost of about 8 cents per cubic yard, the haul being about 450 feet. (See Pl. XIII, fig. 2.)

Along the center line of the dike from end to end 4-inch splined spruce sheeting was driven about 6 feet into the river bed, the top of the sheeting extending nearly to the top of the dike. The upstream slope of the dike is protected by a layer of marsh mud and sods 3 feet in thickness, while the downstream slope, up to 1 foot above mean high water, has a heavy 18-inch granite quarry grout facing backed by a 6-inch layer of granite chips. (See Pl. XIII,

fig. 1.) Some of the blocks in this facing weigh upward of 3 tons, and the whole construction appears to be very safe and durable. Above the heavy facing the protection is the same as on the upstream slope. The top of the dike is surfaced with a mixture of fine sand and clay silt, and is sufficiently compact to make a fair roadway for light teaming.

The sluice is about 52 feet long, 20.7 feet wide, and the floor 2 feet above mean low water outside. It has three flumes, each 6 feet wide and 4 feet 8 inches high inside. The top and sides are longleaf Georgia pine, 8 inches in thickness. The floor consists of four 8-inch by 10-inch hard pine longitudinal mud sills, covered with 6-inch by 6-inch hard pine crosspieces, close laid, which in turn are covered with a 2-inch hard-pine flooring laid lengthwise of the sluice. Above and just in front of the gates, and resting on 10-inch by 12-inch hard-pine timbers in the roof, is a concrete arched gate chamber, with a manhole $4\frac{1}{2}$ feet square extending to the top of the dike, where there is plank cover set flush with the roadway. The arch is 12 inches thick, semicircular, and has a span of 8 feet 6 inches. The gates are 5 feet 1 inch wide, 6 feet 5 inches long, and $3\frac{3}{4}$ inches thick, of longleaf pine and bolted with Tobin bronze bolts. Two of the gates are of the swing type, each hung with three heavy patented cast-iron link hinges with bronze pins, and counterweighted by a system of weights and pulleys. The third gate, intended for use in emergencies, or for allowing the passage of fish, is an ordinary wooden sluice gate, raised and lowered vertically by a Tobin bronze screw operated by a crank at the top of the dike. The leakage past the gates is very small. The three gates, including hardware and frames (except the frame of the fixed gate), were furnished by an East Boston foundry for the sum of \$682.80.

The wing bulkheads (see Pl. XIII, fig. 1) are of spruce, 4 inches thick, with hard-pine splines.

The method of making the closure in the river, several of the attempts being not wholly successful, is thus described by Mr. F. W. Hodgdon, chief engineer of the Massachusetts harbor and land commissioners, under whose direction the work was done:

The closure was made at low tide during a course of neap tides. After building out from both ends until a gap of about 100 feet remained, the sheeting across the gap was driven and cut off as soon as driven at about 18 inches above the river bottom at the level of one of the stringers used as a frame for guiding it. The pieces sawed off were saved to be replaced and spiked in place when the closure was made. Then the river bottom on both sides was protected with sand bags. The frame for guiding the sheeting was then strengthened by additional piles and stringers and was braced by wire guy ropes from the heads of the piles to other piles and heaps of quarry grout placed about 100 feet above and below the center of the dike.

[Bull. 240]

At low tide on the day selected the pieces of the sheeting which had been cut off and saved were replaced and spiked in position, closing the gap before the tide rose against it. Two gangs of four men each were employed and finished just as the tide rose against the sheeting.

The placing of the sand was at once begun, but it was nearly two weeks before the embankment was filled across the gap. The sand filling below high-tide level was either dumped into the water or was covered by the tide soon after it was deposited, and very little attempt was made to ram or otherwise compact it. It was mostly dumped from a trestle at about the level of the top of the dike from automatic side dumping cars which carried about 3 cubic yards each.

The cost of the dike and sluice to date, November 30, 1910, is as follows:

Cost of dike and sluice at Wellfleet, Mass.

Embankment (contract price)-----	\$16, 250. 00
Gates and frames-----	682. 80
Riprap (additional outside contract)-----	505. 14
Plans, engineering, and maintenance-----	2, 530. 05
Repairs on leak-----	580. 87
Total -----	20, 548. 86

In addition the town has expended \$547.70 in building two small dikes at other points where very high tides entered the marsh. These dikes are about 300 feet long, 8 feet wide on top, have steep slopes and no artificial protection, since the foreshore is so high that only spring tides reach them at all.

DITCHES.

Very little ditching has yet been done more than to open up small ditches for the removal of surface water and the abatement of conditions favorable to mosquito propagation. During 1910 the town spent \$3,000 for this work. In a small way, the soil has demonstrated its capability of producing quite a variety of agricultural products.

THE MARSH LANDS OF NOVA SCOTIA AND NEW BRUNSWICK.

GEOGRAPHY AND EXTENT.

Nova Scotia, New Brunswick, and Prince Edward Island constitute what are known as the maritime provinces of Canada.

Nova Scotia, the most easterly, is a jagged oblong peninsula about 360 miles in length from Glace Bay, on the island of Cape Breton in the northeast, to Cape Sable, at the southwest extremity. It has an average width of 60 miles, an area of 21,428 square miles, and a population of 459,574—about 22 to the square mile. The surface is traversed by several well-defined ranges of moderate elevation. The North and South Mountains parallel the Bay of Fundy shore and

[Bull. 240]

inclose the beautiful Annapolis Basin, River, and Valley, where De Monts in 1604 founded the first settlement by Europeans north of the Gulf of Mexico. This section is famous for its apple orchards. The Cobequid Mountains, traversing Colchester and Cumberland Counties at the head of the bay, have extensive mineral deposits.

The rivers are not of any great navigable length and are conspicuous mainly because of the extensive marshes through which they flow. The principal streams entering the Bay of Fundy are the Annapolis, with Annapolis, Granville, Bridgetown, and Laurencetown on or near it; the Canard, Cornwallis, and Gaspereau, with Wolfville and Grand Pre near their mouths; the Avon, with Windsor at its mouth; the Shubenacadie, with Maitland as a port; the Salmon, with Truro at its mouth; and the Herbert, Maccan, Nappan, La Planche, and Misseguash, with the thriving city of Amherst not far from their outlets, the latter river constituting the boundary line between Nova Scotia and New Brunswick. Along the lower reaches of these and other smaller streams are extensive areas of marsh land, the aggregate of which is only very approximately known, but is probably more than 120 square miles. Away from the shores the land is rocky and was formerly heavily wooded, but lumbering operations have been extensive and reforestation has been neglected.

While agriculture, lumbering, mining, and fishing are the principal industries, the steel plants at Sydney, Londonderry, and New Glasgow and the manufacturing establishments at Yarmouth, Windsor, Truro, Amherst, and Dartmouth have contributed much to the prosperity of the people, who are characterized by piety, patriotism, honesty, and respect for the law.

Nova Scotia is joined to the Province of New Brunswick by the Isthmus of Chignecto, which at its narrowest place between Cumberland Basin and the waters of Northumberland Strait is only 15 miles wide.

New Brunswick is in form an irregular square and contains 27,985 square miles and a population of 331,120—about 12 to the square mile. For the most part it has navigable waters on three sides.

The principal rivers emptying into the Bay of Fundy are the Aulac, the Tantramar, with Sackville near its mouth; the Memramcook, with Dorchester near it; the Peticodiac, with Moncton about 20 miles above its mouth; and the St. John, with the thriving maritime city of St. John at its outlet. The Province is more heavily timbered than Nova Scotia, spruce, hemlock, and tamarack forests stretching for many miles.

The diked marsh lands are the most fertile in the Province.

The two Provinces are divided by the Bay of Fundy, the "Back-water of the Atlantic," a long trumpet-shaped body of water, possessing probably the most remarkable tides in the world.

[Bull. 240]

The bay has a length, including Chignecto Bay and Cumberland Basin up to Amherst or through Minas Channel and Basin, of about 150 miles, while its width diminishes from about 50 miles opposite the international boundary to about 30 miles where the Cobequid Mountains cleave the waters and form the two converging arms, that of Chignecto Bay and Cumberland Basin on the north and that of Minas Basin and Cobequid Bay on the east.

The bay lies in a northeasterly and southwesterly direction, between walls increasing in height toward its head, and the two tapering arms serve to lengthen and intensify its trumpetlike character.

CLIMATE.

Rainfall data are not readily obtainable in the different sections of Nova Scotia and New Brunswick. It appears, however, that the mean annual rainfall at Truro is about 43 inches; at Moncton, 45 inches; at St. John, 47 inches; and at Charlottetown, Prince Edward Island, 41.5 inches. The distribution through the several months of the year, as shown by records kept for a long series of years at St. John, is as follows: January, 5.55; February, 3.93; March, 3.80; April, 2.50; May, 3.66; June, 2.72; July, 3.29; August, 4.64; September, 3.08; October, 4.13; November, 4.71; and December, 5.16 inches.

Midwinter, therefore, would seem to have the greatest precipitation, closely followed by the late fall. From the temperature records kept at St. John it appears that the mean annual temperature is about 41° F., ranging from a maximum of 89° to a minimum of 21° below zero.

Prof. W. F. Ganong, of Smith College, Northampton, Mass., from the records of the meteorological office at Ottawa, is authority for the following table on temperatures at St. John:

Average monthly and annual mean temperatures at St. John, New Brunswick.

	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.
Mean highest....	28.2	27.6	34.3	46.4	57.2	64.4	68.8	68.8	63.3	51.8	43.3	32.4	48.9
Mean lowest.....	9.0	9.7	18.3	30.8	40.4	48.3	53.2	53.7	47.8	37.6	28.9	15.1	32.7
Mean temperature.....	18.6	18.7	26.3	38.6	48.8	56.3	61.0	61.3	55.6	44.7	36.1	23.7	40.8
Mean daily range.....	19.2	17.9	16.0	15.6	16.8	16.1	15.6	15.1	15.5	14.2	14.4	17.3	16.2
Absolute highest.....	50.0	49.0	52.0	71.7	75.0	88.9	88.9	85.0	85.0	72.4	61.0	54.5	88.9
Absolute lowest.....	-21.0	-15.0	-10.0	12.0	27.0	35.0	41.0	43.0	32.5	21.4	-1.5	-19.5	-21.0

The prevailing winds are southwesterly. Like the tides, every southerly wind takes the course of the bay, is condensed and concentrated and exercises a marked effect on the vegetation, on and adjacent to the marshes, where trees or bushes are bent to the northeast and show a marked development of branches on that side.

TIDES.

Although the apparent width of the Bay of Fundy at its mouth is about 50 miles, its actual deep-water passage is reduced by Grand Manan Island and contiguous shoals to about 24 miles, of which 20 miles has an average depth of about 600 feet.

The tidal wave progressing across from the South Atlantic and pressing against the submerged border of the continent, undergoes a lateral compression in the mouth of the bay and creates through the passage a 3-mile-per-hour current, which continues up the rough, uneven grade of about 4 feet per mile of the floor of the bay with varying velocities into all the indentations and rivers. Through Parrsboro Passage the tides rush with a velocity of 10 miles per hour. Wherever projecting headlands or concealed submarine ledges hinder the progress of this tremendous current, powerful erosion is going on, and the swirling waters catching up the detritus deposit the same as their velocity is checked in the ascent of the rivers or by overspreading the marshes. All are agreed that the Bay of Fundy marshes have been built up in this way from the red Permocarbo-niferous sandstone forming the sides and bottom of the channels, and not from material brought down by the rivers, which are generally small and have wooded or swampy watersheds and carry little in suspension above the reach of the tides.

The following table gives the mean, spring, and neap ranges of the tide at several places, but it should be stated that in some cases they are theoretical rather than actual, for the reason that sand bars "pond" in the low water and prevent its falling to true low-tide level in the bay.

Range of tides at different points on the Bay of Fundy.

Place.	Range of tide in feet.		
	Mean.	Spring.	Neap.
Annapolis, Annapolis Basin, Nova Scotia.....	25.1	28.7	21.2
Horton Bluff, Minas Basin, Nova Scotia.....	42.0	48.0	35.5
Noel Bay, Minas Basin, Nova Scotia.....	44.2	50.5	37.4
Sackville, Cumberland Basin, New Brunswick.....	39.6	45.2	33.5
Moncton, Petitcodiac River, New Brunswick.....	41.2	47.0	34.9
St. John, New Brunswick.....	20.9	23.8	17.6

On October 5, 1869, occurred the famous Saxby tide, the highest ever recorded in the Bay of Fundy, the tide rising in different parts of the bay from 4 to 8 feet above high-water springs and submerging the marsh lands generally. High-water spring tides run about 6 feet above high-water neaps; low-water springs fall about 5 feet below low-water neaps.

[Bull. 240]

Levels taken by the engineers of the projected Chignecto Ship Railway, probably in 1893, show: (1) That mean sea level at the head of the Bay of Fundy and in the Gulf of St. Lawrence is practically the same; (2) that at ordinary high water the waters of the former are 18 feet above and at ordinary low water are 18 feet below mean sea level; (3) that the Saxby tide rose more than 29 feet above mean sea level, and (4) that extreme low tides may fall nearly 24 feet below mean sea level.

In the Petitcodiac River at Moncton, New Brunswick, the rise of the tide is so rapid that it comes in as a nearly perpendicular wall of water from 1 to 6 feet in height, and is known as the "bore." The bore is the broken water at the front edge of a long water slope, which advances up the river and travels about $8\frac{1}{2}$ miles per hour. The arrival is the first indication of the rising tide, which breaks into a bore about 8 miles below Moncton and continues up the river for

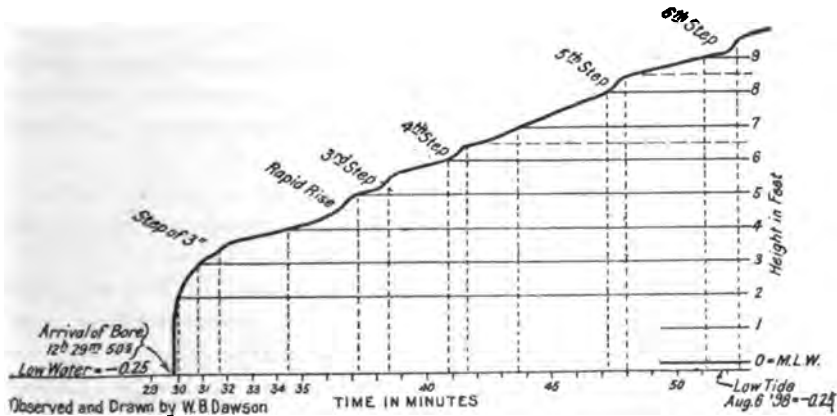


FIG. 20.—Diagram showing form of bore, Petitcodiac River, Moncton, N. B.

21 miles, or about 33 miles from the bay. The form of the bore is shown by figure 20.

Levels show that high tide, and, consequently, the marsh, is higher near the tide heads of these rivers than at their mouths, due to the tendency of the waters to pile up from the inertia of their rush. The phenomenon of two distinct columns of water flowing in opposite directions in the same channel at the same time can be observed. The greater weight of sea water by 1.6 pounds per cubic foot, or $2\frac{1}{2}$ per cent, causes the flood tide to be forced in a wedge-shaped column under the descending fresh water, stirring up and placing in suspension a large amount of sediment, which the ebb tide removes. The amount of mud carried by the tides is astonishing, especially on the first of the flood and the last of the ebb. The greatest quantity is

[Bull. 240]

found in the rivers emptying out at low tide, when it may amount to as much as 4 per cent by volume; at flood tide it seldom reaches 2 per cent.

The deposit from a single tide may range from a mere film on the higher parts of a marsh to several inches in the depressions, and old lake bottoms have been filled 1 foot in the course of five or six days, though ordinarily the rate is much less.

SOIL.

The soil of the marshes is a very fine, reddish sand and silt with from 5 to 10 per cent of clay and a somewhat less percentage of organic matter. When saturated it weighs about 101 pounds per cubic foot and contains 41 pounds of water, or about 66 per cent of its volume is interstitial space. Very little grit can be detected by the fingers or teeth.

The depth of marsh mud is believed to be very great. A boring at Aulac showed a depth of 80 feet overlying a 29-foot stratum of peat. This, together with other evidences, such as buried forests, stumps, and the presence of certain species of shells, indicate that the whole region is much depressed from the position it occupied in later post-glacial periods.

Borings at the wharves in Amherst, Nova Scotia, show depths of 10 to 25 feet of marsh mud, followed by sand, gravel, sometimes blue clay and peat, and an unknown depth of boulder clay.

At Moncton, New Brunswick, a boring showed 12 feet of marsh mud, followed by 228 feet, mainly of red clay, before striking ledge.

The following mechanical and chemical analyses have been furnished by courtesy of Prof. W. F. Ganong, of Smith College, Northampton, Mass.:

[Bull. 240]

Mechanical and chemical analyses of tide marsh soils from the Bay of Fundy.

Analyst.	Constituents.	Samples.					
		I. Timothymarsh unplowed for 40 years.	II. Low marsh with poor vegetation.	III. Brought in fresh by tide.	IV. Blue mud from 18 inches under surface.	V. From 30 inches below surface under canal above Point de Bute, Nova Scotia.	VI. From river Habitatant, Nova Scotia.
Mechanical analysis by Prof. G. E. Stone. ¹	Water.....	Per cent. 2.000	Per cent. 2.600	Per cent. 1.800	Per cent. 3.100	Per cent.	Per cent. 3.400
	Organic matter.....	6.505	10.920	6.200	7.360	.....	3.200
	Gravel, 2-1 millimeters diameter.....	.025	.000	1.125	.125	.....	.125
	Coarsesand, 1-0.5 millimeters.....	.275	.400	3.100	.325	.....	.260
	Medium sand, 0.5-0.25 millimeter.....	4.125	.285	2.025	2.400	.....	1.485
	Fine sand, 0.25-0.1 millimeter.....	9.360	1.900	4.225	6.210	.....	4.060
	Very finesand, 0.1-0.05 millimeter.....	22.185	1.300	45.275	33.885	.....	40.010
	Silt, 0.05-0.01 millimeter.....	36.165	50.110	14.125	20.375	.....	26.800
	Fine silt, 0.01-0.005 millimeter.....	10.390	17.735	12.400	10.865	.....	8.710
	Clay, 0.005-0.001 millimeter.....	8.585	10.530	9.660	15.200	.....	5.825
	Total.....	99.815	95.780	99.935	99.905	.....	99.875
	Organic and volatile matter.....	6.54	10.60	6.02	6.77	3.10	4.14
Chemical analysis by Prof. F. T. Shutt. ²	Clay and sand.....	75.29	73.18	75.83	76.01	84.48	75.59
	Oxide of iron and alumina.....	14.72	12.64	13.79	14.01	9.87	11.71
	Lime.....	.239	.234	.652	.409	.268	1.40
	Magnesia.....	.513	.397	.283	.183	.154	.48
	Potash.....	.817	.852	.902	.996	.646	.25
	Phosphoric acid.....	.136	.124	.146	.094	.110	.15
	Soluble silica.....	.091	.059	.063	.056	.063	.....
	Carbonic acid, etc., undetermined.....	1.654	1.914	2.314	1.472	1.289	.....
	Total.....	100.0	100.0	100.0	100.0	100.0	.....
	Nitrogen.....	.182	.338	.122	.106	.062	.128
	Available potash.....	.0068	.034	.0748	.0073	.030	.06
	Available phosphoric acid.....	.026	.016	.0466	.0436	.0354	.05
	Available lime.....	.0026	.0449	.397	.0792	.108	.....
	Reaction.....	Acid.	Acid.	(*)	Acid.	Acid.	.....
	Common salt.....	.037	1.048	4.16	.939	.217	.86

¹ Professor of botany, Massachusetts Agricultural College, Amherst, Mass.² Obviously a considerable error; cause unknown.³ Chief chemist, Experimental Farms, Ottawa.⁴ Neutral or slightly alkaline.

As will be seen from the table and the records of test borings, the Bay of Fundy soils are remarkable for their fineness, homogeneity, and depth, and it is undoubtedly due to these qualities that the lands remain unimpaired after the croppings of two centuries. The soluble minerals tend to diffuse evenly throughout the marsh, and as the ground water is practically motionless little or none of the valuable soluble mineral matter is lost, as is the case in well-drained upland soils, but by evaporation from the surface, the transpiration of plants, and the natural processes of diffusion, an upward movement is created from below which ever supplies to the marsh vegetation the elements required for its growth. Experiment and experience both show that

[Bull. 240]

a 1-foot layer of mud will not maintain fertility for so long a time as a 6-foot layer.

Because of the fine texture of the soil, it readily holds and delivers moisture to the plant, but aeration is difficult, and hence it follows that the soil is much better adapted to grasses and grains which have superficial or slender roots, than to truck crops or any woody growths which are thick rooted and require more air.

Although the deposits as laid down by the tide are of a red color, there are areas of greater or less extent where the mud is blue and unproductive. These areas are low and poorly drained, and the soil, subjected to long-continued fresh-water saturation, has undergone chemical changes, which are described by Dawson in his *Acadian Geology* as follows:

The red marsh derives its color from the peroxid of iron. In the gray or blue marsh the iron exists in the form of a sulphuret, as may easily be proved by exposing a piece of it to a red heat, when a strong sulphurous odor is exhaled, and the red color is restored. The change is produced by the action of the animal and vegetable matters present in the mud. These in their decay have a strong affinity for oxygen, by virtue of which they decompose the sulphuric acid present in the sea water in the forms of sulphate of magnesia and sulphate of lime. The sulphur thus liberated enters into combination with hydrogen obtained from the organic matter or from water, and the product is sulphureted hydrogen, the gas which gives to the mud its unpleasant smell. This gas dissolves in the water which permeates the mud, enters into combination with the oxid of iron, producing a sulphuret of iron, which, with the remains of the organic matter, serves to color the marsh blue or gray. The sulphuret of iron remains unchanged while submerged or water soaked, but when exposed to the atmosphere the oxygen of the air acts upon it and it passes into sulphate of iron or green vitriol—a substance poisonous to most cultivated crops, and which when dried or exposed to the action of alkaline substances deposits the hydrated brown oxid of iron. Hence the bad effects of disturbing blue marsh, and hence also the rusty color of the water coming from it. The remedies for this condition of the soil are draining and liming. Draining admits air and removes the saline water; lime decomposes the sulphate of iron and produces sulphate of lime and oxid of iron, both of which are useful substances to the farmer.

Marsh mud has been extensively used on poor upland soils, and its use is said to serve a better purpose than the common commercial fertilizers, because it does not act as a quick stimulant, leaving the soil poorer, but seems permanently to enrich the land.

Mr. Gustavus Bishop, of Greenwich, Nova Scotia, relates that old apple trees which had been bearing only every other year and a poor quality of fruit were made to bear annually more and better apples by simply spreading several loads of marsh mud around them.

DIKES.

The dikes go back to the Acadian French in the middle of the seventeenth century, who not long after the first occupation of the

[Bull. 240]

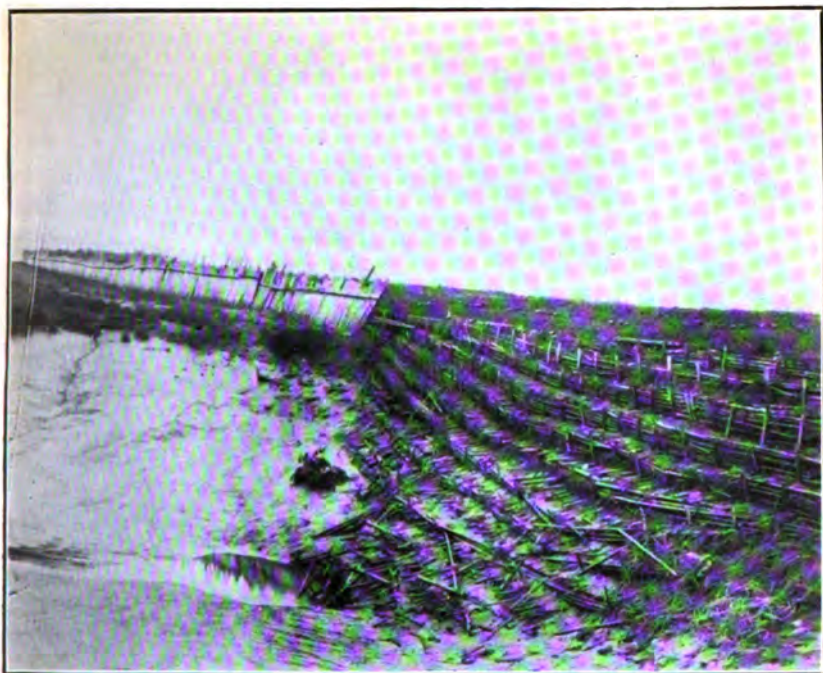


FIG. 1.—WATER SIDE, SHOWING METHOD OF PICKET AND HEADING BRUSH PROTECTION, AND ON THE LEFT, PLANK PROTECTION FOR "RUNNING DIKE."

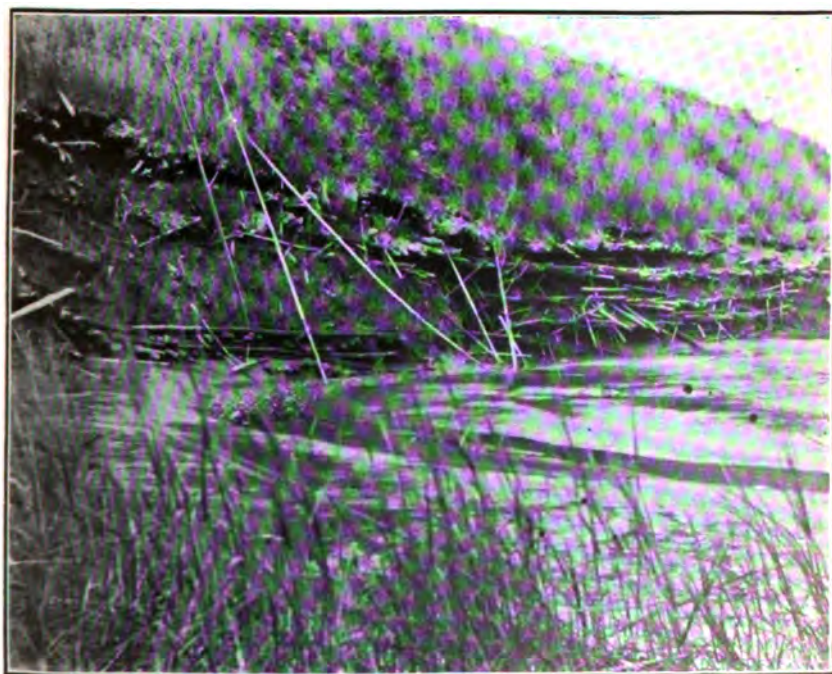
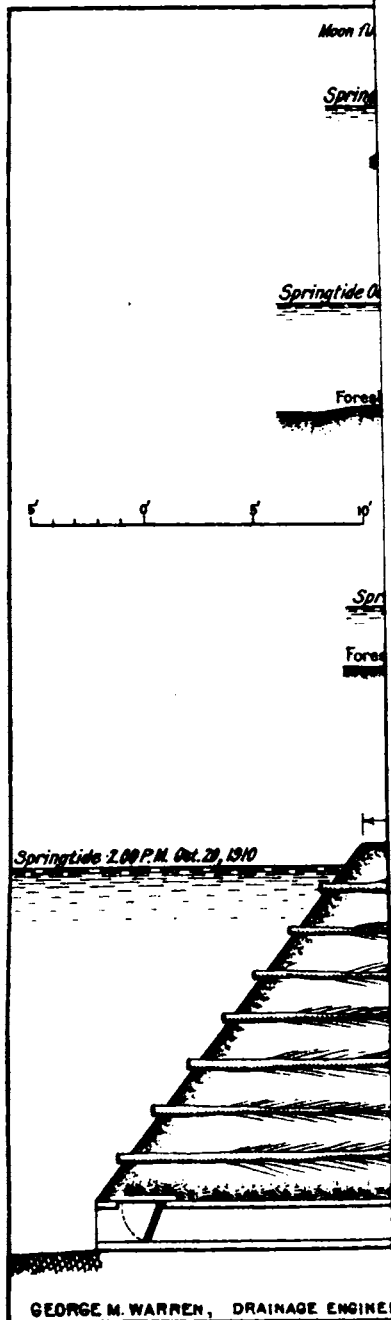


FIG. 2.—LAND SIDE, SHOWING LAYERS OF BRUSH AND ORDINARY HEIGHT OF INTERIOR WATER.

ABOIDEAU, DISCHARGE CREEK, GRAND PRE, NOVA SCOTIA, TOP 16½ FEET, BASE 55 FEET, HEIGHT 45 FEET. SLUICE BEGINNING TO PLAY, OCTOBER 22, 1910.



country began to throw out embankments and wrest the marshes from the sea. Their English successors have steadily extended the work and to-day the serpentine embankments following up both sides of the tidal streams or the "aboideaux"¹ boldly projected across the rivers can be seen throughout the Bay of Fundy marshes.

Since the marshes generally have been built up to about ordinary high-water mark, the dikes, or the "running dike," as termed in Nova Scotia, are usually no higher than those in the North Atlantic States—from 4 to 10 feet.

Three cross sections of dikes are shown in figure 21—A, B, and C, and the approximate cross section of a medium height aboideau in figure 21—D. The purpose of the brush is partially to afford a footing for teams, and it is used in alternate layers, great care being taken that none shall extend completely through the aboideau, as this allows water to seep through and create leaks.

The highest aboideau in the maritime provinces is across Discharge Creek, near Grand Pre, Nova Scotia. The water side and the land side of this aboideau are shown in Plate XIV, figures 1 and 2. Figure 1 clearly shows the method of picket and heading-brush protection, and beyond is seen the plank protection for the "running dike." This aboideau was built in 1871, costing \$5,000. It is 16½ feet wide on top, about 55 feet in thickness at the bottom, and 45 feet high, a mass wholly of mud and brush.

The art of combining and placing these two materials in a manner to exclude water and to close the deep, swift tidal streams is not easily acquired, and there are few men in the Provinces who can do the work successfully. However, when well done, the work lasts for generations with only moderate expenditure for repairs. In places the "running dike" is sometimes protected by a low palisade and in exceptionally exposed locations, though not often, by riprap.

The methods of construction are essentially primitive. Material is taken from both sides of the dike, and, while formerly deposited by hand or wheelbarrow, it is said that scoops and teams have grown in favor, especially where the work is of considerable magnitude. The dikes are built to no established heights, grades, or widths, and are so little above the level of spring tides as to be occasionally overtopped.

The average dike contains from 35 to 45 cubic yards of material per rod, and a quarter of a century ago with labor commanding about one-half the price paid to-day could be built for about 15 cents per cubic yard. Labor now is \$1.50 for 10 hours, and it is probable that

¹A word introduced by the Acadians from Saintonge, France, where it is still used in the form "aboteau." While originally it may have referred to the sluice or water box, the term as now used in the Provinces refers to the entire structure, dike and sluice, which extends across and closes a tidal stream or channel.

[Bull. 240]

dikes cost 25 to 30 cents per cubic yard in place. The plank protection costs about \$7.50 per rod. So far as known no dikes have been built in the Provinces by dredge.

SLUICES.

There is no observable rule as to the grade or size of sluices. They are set at such elevation as the topographical conditions of the marsh demand and are made of such size as meets the ideas of the builder unaided, usually, by engineering advice.

They are very small, but the conditions under which they operate do not require large sluices, and furnish no criterion for practice in the United States. Both marshes and sluices are so high that even spring tides in the average case will fall below the level of the interior water in 1 or 2 hours, permitting the sluice to play 8 to 10 hours, and it is probable that in many instances neap tides do not reach sufficiently high to close the gates at all.

The Wickwire dike at Wolfville, Nova Scotia, has roughly 133 acres of drainage area for each square foot of sluice opening; the Wellington aboideau at Lower Canard, Nova Scotia, has 350 acres for each square foot, and the Aulac aboideau at Aulac Station, New Brunswick, has 282 acres for each square foot.

The sluices are generally made of native spruce, birch frequently being used in the gates. In many of the later constructions, gates, seats, and frames of bronze are being used, and are said to give excellent satisfaction, as they can not be gnawed, are very durable, and the carefully ground seats permit little leakage.

Arthur A. Hicks, of Upper Sackville, New Brunswick, has built a number of sluices equipped with a very simple and effective device for preventing sluice leakage. (See Pl. XV, fig. 1.) Mr. Hicks takes a strip of horseshoe iron about one-fourth inch thick and 1½ inches wide and draws down one edge so that the iron has a wedge-shaped cross section with a base of one-fourth of an inch and an altitude of 1½ inches. The strip is then fashioned into a square or rectangular shape of such size that when the one-fourth-inch base is placed on the inside face of the gate the sharp edge of the wedge will coincide with the center line of the top, bottom, and side timbers of the sluice at the face against which the gate closes. At frequent intervals five-eighth-inch bolts are welded and riveted to the base, the free end of the bolt having a thread, washer, and nut. The bolts extend completely through the gate, and the nuts on the outer face draw the quarter-inch base tightly against or into the inner face. A V-shaped groove is then burned or chiseled in the end of the sluice along the lines which the wedge edge has scarred—that is, along the center line of top, bottom, and sides. The heavy strap hinges have an

[Bull. 240]



FIG. 1.—SLUICE UNDER CONSTRUCTION AND DEVICE BY ARTHUR A. HICKS, UPPER SACKVILLE, NEW BRUNSWICK, FOR SEALING THE SEAT AND PREVENTING LEAKAGE.
[Iron for a larger gate leans against sluice, and a diking spade rests on top.]

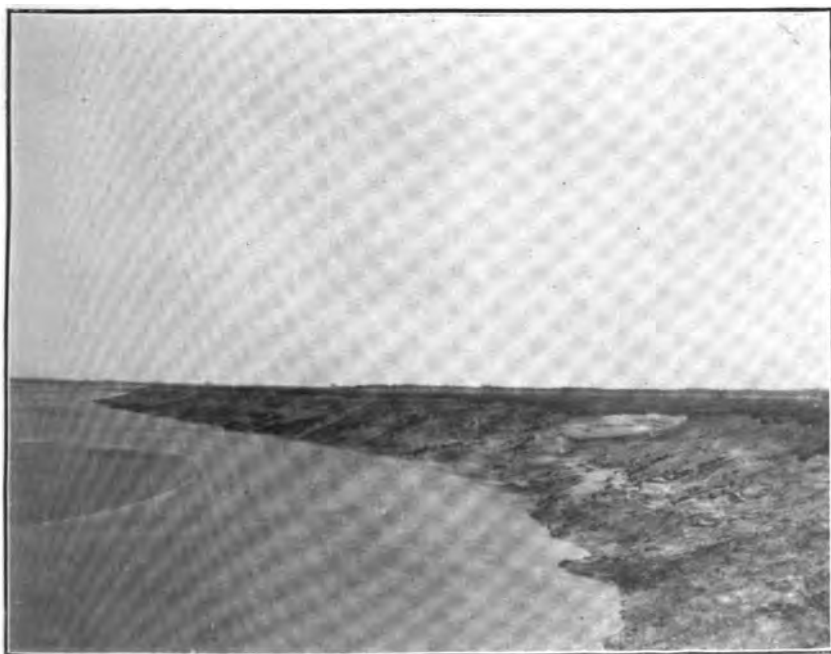


FIG. 2.—TANTRAMAR RIVER, NEW BRUNSWICK, AT HALF TIDE. SHOWING FORESHORE.
"RUNNING DIKE," AND HAY BARN IN THE DISTANCE.
[Seventy years ago forded at low tide and now crossed by bridge of 3 spans of 125 feet each,
October 31, 1910.]

elongated eye, permitting the gate to adjust itself to its seat. These gates are said to form a most effectual seal, and cut off practically all leakage.

Gates are generally placed from 2 to 5 feet from the outer end to prevent injury or interference from ice, and the top and sides of the flume at this point recessed or enlarged, affording a clear, unobstructed waterway when the gate is opened to the horizontal position. In some cases two separate and independent gates, one in front of the other, are placed in the same flume.

Notwithstanding the high pressure to which many of the sluice gates are subjected, it is generally to be observed that, as regards leakage, the sluices of the maritime Provinces are much more effective than are ours on the reclaimed salt marshes of the United States. Moreover, any considerable leakage there, where the waters are so heavily charged with sediment, would quickly silt up and destroy the interior drainage channels, and for this reason sluices must be made tight.

DITCHES.

One looks almost in vain for examples of deep systematic ditching for the removal of fresh water from the reclaimed marshes. The tides are below the level of the lands so much of the time and sluices play for such long periods that a fair degree of drainage becomes a simple problem and is readily secured through the natural depressions, sloughs, and water courses.

The lands are often gridironed by small ditches 12 to 15 inches deep and from 40 to 60 feet apart, and at other places the land has been plowed so as to raise slightly the centers of contiguous fields, leaving a dead furrow between. The object sought in both instances is to prevent surface water from standing on the land, rather than secure deep effective land drainage. Much greater success would be attained, beyond doubt, by more careful attention to the ditching.

Prof. W. W. Andrews of Mount Allison College, Sackville, New Brunswick, who is an owner and experimenter in the diked lands, says in a letter dated November 30, 1910:

I have found that the great evil in these lands is the lack of adequate drainage. All the poor land I have found is sour and contains considerable quantities of ferrous salts, especially the sulphate and silicate. Underdraining seems to be more effective than the ordinary open drain for well-understood reasons. I have used lime at the rate of 3 to 6 casks per acre to correct acidity, and have used basic slag phosphate and potassium chlorid, but no nitrate, as fertilizers. These have been thoroughly adequate.

BOGS AND WARPING.

Emptying into Cumberland Basin at the head of the bay and near the boundary line between Nova Scotia and New Brunswick are

[Bull. 240]

several tidal rivers, already mentioned, extending back into the country from 10 to 20 miles. Above the reach of the tide, the marsh merges into extensive areas of fresh-water bog, from 1 to 7 feet in depth, and literally afloat.

The formation of these bogs will readily be understood if the previous discussions of tidal hydraulics and deposits are recalled. The marsh builds fastest and highest along the banks of a river. At tide head, where the ascending salt water may be said to meet the descending fresh water, there is always a tendency for a river to dam itself, and such would be the case except for the scouring action of fresh water as the tide ebbs. Moreover, the gradual subsidence of the whole marsh country, together with the building of successive tide heads through eons of time, has assisted in the creation of large depressed areas adjacent to the uplands, at the heads of rivers, and even between rivers in the same watershed.

These depressed areas, through accumulation of rain water and drainage from the uplands, become the sites of shallow lakes, which develop a fresh-water vegetation, consisting mainly of sedges, which overspread the surface and give rise to the formation of true bog. As the age of the bog increases, various mosses, such as *Sphagnum* and other forms of vegetation, come in until there is formed a floating mat from 1 to 4 feet thick, often sufficiently firm to sustain the weight of a man. In still older bog the decomposition of this vegetable mass has produced sufficient soil so that coarse grasses and heath bushes take root, and even larches upward of 20 to 30 feet in height are found.

Beneath the bog formation everywhere is found the true tidal mud, blue near the top and red below, and sloping gradually downward from tide head to the remote upper parts of the marsh. Bogs are, of course, due to poor drainage, and moreover they have a constant tendency to extend seaward, and thus encroach upon and injure reclaimed areas near the rivers and toward the bay.

The French in all their reclamation work had merely diked where the land had already been made up by tidal deposit, and it remained for one, Toler Thompson, a farmer of Upper Sackville, who, after long study of the tides and bog levels, about 1815, began to build a canal from the Tantrammar River to Rush Lake, a distance of 2½ miles, for the purpose of draining off the fresh water and allowing the tide to enter and, by deposit, to build up the bog. His experiment was entirely successful, a large area of fine English marsh being made up, but the canal was aboideaued, and in the course of years the lands deteriorated.

The effects of Thompson's experiment were far-reaching, however, and the system he inaugurated, which in the Provinces is called

[Bull. 240]

"tiding" or "flooding," and is substantially the English "warping," has been steadily employed since and has resulted in the creation of thousands of acres of extraordinarily fine land.

When the fresh water is removed from a bog the vegetation shrinks to a small fraction of its original bulk, and most of it is instantly killed by the salt water, probably due to the plasmolysis of the root hairs and possibly to some poisonous action of the salt itself. The tides are allowed to flood the bog until the deposit of new mud becomes firm and of sufficient depth so that deep plowing will not turn up the bog vegetation. It is said that some of the most productive lands around Sackville are old lake or river bottoms which have been filled to a depth of 20 and even 30 feet. The tides are then diked out, the land is ditched, and small sluices are placed in the lateral ditches, for it is the opinion and belief of experienced marsh men about the great Amherst-Sackville marshes and bogs that the main streams or canals should not be aboideaued, but every facility afforded the tides to flood the rivers so that an adequate tidal scour may be created to prevent silting or damming up of the outfalls, with consequent interference with drainage and deterioration of the lands.

In this contention the Bay of Fundy marshmen point to the well-established principle in river and harbor work throughout the world, that of concentrating the flow and securing free rush of the tide up and of the freshet down.

The effects of aboideauing these swift tidal streams are shown in the cases of the Aulac and the Tantramar Rivers. In 1827 the Aulac was aboideaued 4 miles from its mouth, and again in 1840 about 2 miles below. In 1863 an aboideau having four openings, each 4 feet square, was built at a cost of \$27,500, and since then a new sluice having four openings, each $3\frac{1}{2}$ feet square, has been put in, over which cross a highway and the tracks of the Intercolonial Railway. This river has grown steadily smaller; the upper reaches, practically abandoned, have reverted to lake, bog, or poorly drained marsh, and even the adjacent uplands have depreciated.

On the other hand, the Tantramar was never aboideaued, and has not only kept its own channel scoured out, but has greatly increased its size (see Pl. XV, fig. 2) and thousands of acres of worthless bog and lake have been made into productive land with corresponding benefit to contiguous upland farms. The largest and most systematic attempt at bog reclamation has been on the Miseguash River, the boundary between Nova Scotia and New Brunswick, and having a lake, bog, and marsh area aggregating 8,300 acres. The Miseguash Marsh Co., composed of Boston and Dominion capitalists, acquired control of about 7,000 acres of this land, and on July 1, 1897, commenced the dredging of a canal from Mount Whatley,

[Bull. 240]

about 3 miles above the mouth of the river, to Hacquatack Lake, a distance of 6 miles. This canal was 30 feet wide, 15 feet deep, and had a uniform grade of 2 feet to the mile. From the levels of this company, taking the surface of the marsh at the mouth of the river as a datum, it appears that the surface of the bog, 10 miles above, is 3 feet above datum, and the bottom of the lakes and bog from 3 to 6 feet below datum, over which, when the fresh water was drawn off, spring tides would place from 7 to 10 feet of salt water.

The effect of this canal was to cause a rapid enlargement of the river below and enlargement of the canal itself, commencing at its outlet and working back. Where at its mouth the canal was originally 30 to 36 feet wide, in a few years it had become 100 feet wide. The drainage area above, estimated at 40 square miles, is bringing down a large amount of fresh water, so that the deposit of tidal mud over the land has not been up to the present all that might be desired. The company has recently (February, 1911) fitted up a power-driven machine for opening up the channels and assisting the processes of nature. This machine consists of a skeleton drum, 9 feet long and 2 feet in diameter, carrying about 40 knives. Power is furnished by a 20-horsepower gasoline engine and is transmitted by sprocket wheels and a chain drive. The whole is mounted on a scow, the drum being attached by pivoted arms so that it can be raised or lowered as required. The machine is said to have cost \$1,000 and to be very effective in freeing the channels of sedges and salt grasses. The machine is shown in Plate XVI, figure 1, and a view of the extensive hay fields of the Misseguash marsh appears on the same plate as figure 2.

The entire cost of the reclamation to the stockholders to the present time is but \$14 per acre.

During and after the deposit of tidal mud a new and varied vegetation springs up on the reclaimed bogs. At first the sedges come in, followed by samphire, but as drainage becomes more perfect and the soil becomes freshened these inferior forms are replaced by others, such as fox grass, broad leaf, and brown top, which in turn go down as an optimum is approached favorable to couch and timothy, which come in naturally and spontaneously in from three to five years. Timothy stands as the last of the succession, and under favorable drainage conditions holds its own indefinitely against all competition, weeds or any woody growths being unable to gain a foothold. When drainage becomes defective brown top comes in, and that in turn gives way to broad leaf.

CROPS AND THEIR VALUE.

The principal crop is hay. The soil, the climate, the incompleteness of the drainage attained, and the economic conditions all favor

[Bull. 240]



FIG. 1.—POWER-DRIVEN MACHINE FOR FREEING CHANNELS OF SEDGES AND SALT GRASSES, MISSEGUASH MARSH, NEW BRUNSWICK.

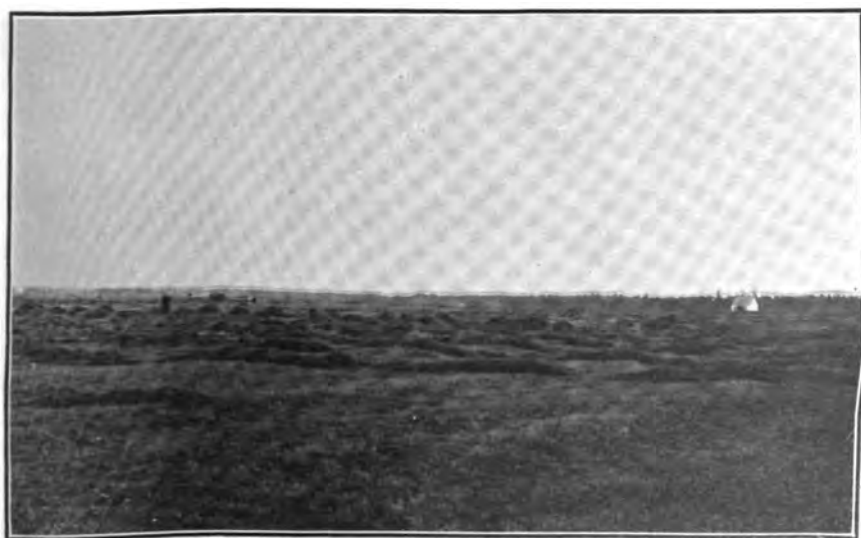


FIG. 2.—HAYING ON WARPED FRESH-WATER BOGS, UPPER REACHES OF MISSEGUASH RIVER, NEW BRUNSWICK.

the grasses as the most advantageous crop that can be raised, and although good root crops can be grown, as is evidenced by the experimental plats of turnips and celery on the Misseguash, conditions do not seem to warrant efforts in that direction.

Timothy, red, white, mammoth, and alsike clover, blue grass, and couch grow luxuriantly, and for a long series of years will probably average $1\frac{1}{2}$ to 2 tons per acre. Three tons per acre are common, and 4 tons per acre are occasionally produced. On the other hand, if the drainage becomes impaired, coarser grasses come in, and the quality and value of the yield, if not the quantity, are diminished. The year 1910 was one of enormous yield of hay. On November 1 good timothy was selling in the Nova Scotia markets for \$8 to \$11 per ton, but the price generally is \$10 to \$12, with extremes depending upon yield and demand of \$8 and \$14. On the above date the market price at Charlottetown, Prince Edward Island, was \$8 to \$8.50; at Bangor, Me., \$15; and at Boston, Mass., \$23 per ton.

Broad leaf, which grows on newly diked lands before the salt has been washed out and on the poorly drained blue marshes, has considerable feeding value for horned cattle, but is not considered suitable for horses.

No attempt is made to secure more than one crop per season. The best farmers break the marsh once in six or seven years, put in oats, from which they get an average yield of 30 to 40 bushels, worth about 45 cents per bushel, and immediately reseed with timothy and clover. Other farmers do not plow oftener than every 10 or 15 years, and many tracts are known to have been cropped for generations without renovation of any kind, and without once failing to yield good crops of the best English grasses.

The hay is cut between the middle and the latter part of July, and about September 10 thousands of cattle are turned onto the marshes to feed and fatten until early November or until killed off to replenish the beef supply. Grazing is especially prominent on the marshes of the Annapolis Valley, and in the southerly portion of the Nova Scotia Peninsula where the beef supply is quite largely native, and where the market is less accessible for shipments from the western Provinces. Statistics of the Canadian Provinces show that according to acreage under cultivation the number of cattle killed in Nova Scotia is very high, while the export of hay, which is the principal product of the marshes, is very low; herein is one of the factors accounting for the high value of marsh lands and for the prominent place which they hold in the agricultural life of the community.

For the "open" or grazing season of about six weeks the rental charge varies from 75 cents to \$2 per acre, with a usual allotment of 3 acres for every cow, ox, or steer, and 1 to 2 acres for yearlings.

LAND VALUES.

The value of the marsh lands, like the uplands, varies greatly with their condition and situation. Good English marsh in the Annapolis Valley is assessed for \$60 to \$80 per acre, but its market value is from \$80 to \$150 per acre. On the Grand Pre values run from \$100 to \$200 per acre, and it is vouched for that transfers of particularly favorable parcels on the Canard River diked lands have been made at \$400 per acre. On the Amherst-Sackville marshes the values will run from \$80 to \$150, but nearness to villages and good drainage may here, as elsewhere, send its value up to \$180 or \$200 per acre.

Prof. Andrews, of Sackville, New Brunswick, referring to crop yields in his letter of November 30, 1910, says:

Land which three years ago I bought at the rate of \$15 per acre yielded me a crop of hay which was sold standing at a rate which paid me 5 per cent on a valuation of \$180 per acre, and the man who bought the hay estimates that he paid considerably less than \$4 a ton, so great was the yield.

Upland farms, including buildings, if not far removed from villages and in fair condition, are worth \$75 per acre for general farming purposes. Away from the towns values may drop to \$30 or \$40, and on the other hand, deep, loamy tracts well situated for orcharding are worth upward of \$300 per acre.

The value of the broad-leaf marshes drops to one-half or one-third of the English marshes, and the unreclaimed bog lands have merely a nominal value of 50 cents to \$1 an acre.

" MARSH ACT."

In 1900 the Nova Scotia Legislature enacted very complete and comprehensive drainage laws, known as the "Marsh act."

These laws effectively provide for the organization of "a majority in interest of the proprietors," for the appointment and remuneration of commissioners, clerk, collector, overseers, and auditor, methods of procedure, execution of the work, adjustment of claims and damages, apportionment of cost, issuance of debentures and the complete administration of the affairs of the "body."

The chartered banks of Canada can not by law take mortgages on real estate, but it is said that through loan and trust companies and from individuals there is no difficulty in borrowing money on the marsh lands to the extent of 50 per cent on a fair valuation.

CONCLUSION.

The reclaimed marsh lands around the Bay of Fundy are very extensive, very valuable, an important agricultural asset, and are closely interwoven with the industrial and economic life of the people. Not

only farmers, but merchants and professional men who are looking for good, sound 8 and 10 per cent investments believe and invest in these reclaimed marsh lands.

The leading social club of the thriving city of Amherst is named the Marshlands Club.

We may well ask why Nova Scotia and New Brunswick, with a less inviting climate, sparse population, inferior transportation facilities, and poorer markets, have made such pronounced success in marsh-reclamation work, while the great bulk of our marshes, even within an hour's ride of such populous and wealthy cities as Boston, New York, and Philadelphia, are still in their natural state, or where reclaimed the successes have been few or indifferent. Unquestionably the fundamental reason lies in the great nature-bestowed gift of a large range of tide, which has built the marshes high and permits the sluices to play long periods of time, thus securing adequate drainage easily, cheaply, and certainly. There are, of course, other reasons of historical, physical, and economic nature which have contributed, but they are relatively insignificant and are more than offset by our own economic needs and by American energy, enterprise, and resourcefulness.

[Bull. 240]



U. S. DEPARTMENT OF AGRICULTURE.

OFFICE OF EXPERIMENT STATIONS—BULLETIN 241.

A. C. TRUE, Director.

LEGISLATION

RELATING TO

FARMERS' INSTITUTES IN THE UNITED STATES.

BY

JOHN HAMILTON,

FARMERS' INSTITUTE SPECIALIST.

[Revised April 1, 1911.]



WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1911.

OFFICE OF EXPERIMENT STATIONS.

A. C. TRUE, Ph. D., Director.

E. W. ALLEN, Ph. D., Assistant Director and Editor of Experiment Station Record.

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J. M. STEDMAN, Assistant Farmers' Institute Specialist.

[Bull. 241]

(2)

LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
Washington, D. C., May 22, 1911.

SIR: I have the honor to transmit herewith and to recommend for publication as a bulletin of this office a compilation of laws relating to farmers' institutes in the United States, prepared by John Hamilton, farmers' institute specialist of this office, revised to April 1, 1911.

Respectfully,

A. C. TRUE,
Director.

HON. JAMES WILSON, .
Secretary of Agriculture.

[Bull. 241]

(3)

CONTENTS.

	Page.
Introduction.....	7
State legislation.....	7
Alabama.....	7
Alaska.....	8
Arizona.....	8
Arkansas.....	9
California.....	9
Colorado.....	9
Connecticut.....	10
Delaware.....	10
Florida.....	11
Georgia.....	11
Hawaii.....	12
Idaho.....	12
Illinois.....	12
Indiana.....	16
Iowa.....	17
Kansas.....	18
Kentucky.....	20
Louisiana.....	21
Maine.....	22
Maryland.....	23
Massachusetts.....	24
Michigan.....	24
Minnesota.....	26
Mississippi.....	27
Missouri.....	27
Montana.....	28
Nebraska.....	28
Nevada.....	28
New Hampshire.....	29
New Jersey.....	29
New Mexico.....	29
New York.....	29
North Carolina.....	31
North Dakota.....	31
Ohio.....	32
Oklahoma.....	33
Oregon.....	35
Pennsylvania.....	36
Porto Rico.....	36
Rhode Island.....	36

State legislation—Continued.

	Page.
South Carolina.....	36
South Dakota.....	37
Tennessee.....	38
Texas.....	38
Utah.....	38
Vermont.....	39
Virginia.....	42
Washington.....	44
West Virginia.....	44
Wisconsin.....	46
Wyoming.....	46
Federal legislation.....	47
[Bull. 241]	

LEGISLATION RELATING TO FARMERS' INSTITUTES.

INTRODUCTION.

In order that legislation by the several States relating to the organization of farmers' institutes might be generally accessible to institute directors and workers, copies of the laws under which the institutes were organized were secured by this office in 1903 and were arranged and published as Bulletin No. 135 of the Office of Experiment Stations.

A revision of this bulletin was made August 1, 1905, embodying such modifications of the laws as had occurred since August 1, 1903. Since the date of this revision the institute laws in most of the States have been so modified by subsequent enactment as to make a second revision necessary. Copies of the old laws were accordingly sent to the several State directors of farmers' institutes with the request that where changes have occurred copies of the new laws be forwarded to this office to be inserted in the revised bulletin. The present revision includes legislation in force April 1, 1911.

An examination of the institute laws of the several States reveals the fact that while they differ in their form and requirements as well as in the authority which they confer and the amount of money which they appropriate, yet they are one in their purpose to aid farming people by affording them opportunity to secure the latest and most reliable information relating to agriculture and to receive definite instructions through a living teacher as to the application of these truths in their every-day practice.

STATE LEGISLATION.

ALABAMA.

The appropriation for farmers' institutes in Alabama is made to the department of agriculture and industries of the State, to be expended under the direction of the commissioner, and is as follows:

ARTICLE 6.—FARMERS' INSTITUTES AND AGRICULTURAL FAIRS.

(416.) **FARMERS' INSTITUTES.**—The commissioner is authorized and directed to adopt annually such measures as may be necessary to successfully conduct, in

[Bull. 241]

different sections of the State, farmers' institutes, consisting of lectures on subjects related to agriculture by persons of scientific attainments, and by practical and successful farmers, with discussions relating thereto, and of such exhibitions as may prove instructive and of practical value to the farmers of the vicinity where such institutes are held, a report of which, with a detailed statement of the money expended in that connection, must be embodied in his annual report.

(417.) **EXPENSES OF INSTITUTES.**—The commissioner is authorized to pay the necessary expenses incurred in conducting such farmers' institutes, including the expense of employing lecturers when necessary, and for distributing the reports thereof; and for this purpose there is annually appropriated, out of the funds of the department of agriculture and industries, three thousand dollars, or so much thereof as may be necessary to be paid for the monthly estimate and allowance for expenses of the department.

Approved February 28, 1889.

In addition to the State appropriation, the Alabama Polytechnic Institute appropriates annually the sum of \$600 for institute purposes, besides giving the service of members of the college and experiment station staff to the equivalent of about \$600 additional.

The legislature of 1911 made a continuous appropriation of \$27,000 annually to the Alabama Polytechnic Institute for conducting extension work. An additional sum of \$25,000 annually was appropriated by the legislature of 1911 to a board consisting of the commissioner of agriculture, the director of the Agricultural Experiment Station, the dean of the school of agriculture at the Agricultural College, and two members to be elected by the three named, for carrying on farm demonstration work, to be expended in cooperation with field demonstrations conducted in the State by the United States Department of Agriculture.

ALASKA.

Farmers' institutes have not yet been established in Alaska.

ARIZONA.

The Legislative Assembly of Arizona in 1909 provided for farmers' institutes by a paragraph in the appropriation to the University of Arizona as follows:

AN ACT Providing for the maintenance and continuation of agricultural and horticultural experiments and demonstrations by the University of Arizona Agricultural Experiment Station at the date orchards near Tempe and Yuma, Arizona; for dry-farming investigations in the northeastern and southeastern parts, respectively, of Arizona; for printing experiment station publications; and for continuation of farmers' institute lectures and short courses of instruction. * * *

SECTION 1. That the sum of thirteen thousand one hundred dollars is hereby appropriated to pay for the following required expenditures, for the use and benefit of the University of Arizona Agricultural Experiment Station. * * *

SEC. 4. For the continuation and maintenance of farmers' institutes and short courses of instruction throughout the Territory, two thousand five hundred dollars.

Approved March, 1909.

[Bull. 241]

ARKANSAS.

Arkansas has no farmers' institute legislation except that an appropriation of \$8,000 for the biennial period 1910-11 was made by the legislature to the agricultural experiment station of the University of Arkansas for the purpose of holding farmers' institutes throughout the State.

CALIFORNIA.

AN ACT Authorizing the regents of the State university to hold farmers' institutes, making an appropriation therefor, and prescribing the duties of the controller and treasurer in relation thereto.

The people of the State of California, represented in senate and assembly, do enact as follows:

SECTION 1. The regents of the University of California are hereby authorized to hold institutes for the instruction of citizens of this State in the various branches of agriculture. Such institutes shall be held at such times and at such places as said regents may direct. The said regents shall make such rules and regulations as they may deem proper for organizing and conducting such institutes, and may employ an agent or agents to perform such work in connection therewith as they deem best. The course of instruction at such institutes shall be so arranged as to present to those in attendance the results of the most recent investigations in theoretical and practical agriculture.

* * * * *

SEC. 4. This act shall be in effect from and after its passage.

Approved March 18, 1905.

The legislature for the biennium of 1910-11 has appropriated \$20,000 to the University of California for institute work.

COLORADO.

[Extract from senate bill No. 172, appropriating money for the benefit of the Colorado College and Station.]

SECTION 5. It shall be the duty of the State board of agriculture, through its officers and those of the State agricultural college, to organize and conduct a farmers' institute annually in each agricultural county of the State, to instruct stockmen and farmers and those interested in agriculture and horticulture and kindred industries. * * *

Approved ———, 1905.

[Extract from senate bill No. 82, making an appropriation for the State agricultural college and experiment station, to be expended under the direction of the State board of agriculture, for payments on land and water rights; the erection of buildings and equipment; making experimental investigations for farmers' institutes, and other extension work.]

SECTION 5. For the purpose of holding farmers' institutes and extending the work of instruction in agriculture to the farmers, horticulturists, and stock growers of the State, to employ instructors, teachers, and lecturers for this work, there is hereby authorized the expenditure of ten thousand dollars from the amount herein appropriated.

Approved ———, 1909.

101517°—Bull. 241—11—2

CONNECTICUT.

Connecticut has no special law regulating the holding of farmers' institutes. The State board of agriculture, the Connecticut Dairymen's Association, and the pomological society are all carrying on institute work in the State. These different organizations all draw money from the State for the benefit of agriculture in general; the dairymen's association for the dairying interests, the pomological society for the interests of fruit growing. The methods used by these different organizations for carrying out their work and disseminating useful information are entirely in their own discretion. Each however, has an institute committee appointed to have charge of institute work.

Where the citizens in any locality desire an institute, any one of these associations will furnish speakers free of expense. These different organizations have all held institutes during the past several years. Annual meetings are held in the winter by each of these organizations.

The Connecticut State Board of Agriculture requires "that localities applying for institutes shall furnish a suitable hall, local transportation for speakers and visitors, music if desired, and entertainment by collation or otherwise, unless there are convenient hotel accommodations." "The board pays for printing, traveling expenses, and services of the speakers." The authority under which the board acts in institute matters is through an act creating the State board of agriculture, which authorizes the secretary "to disseminate agricultural information by lectures or otherwise."

DELAWARE.

AN ACT Providing for farmers' institutes.

Be it enacted by the senate and house of representatives of the State of Delaware in general assembly met:

SECTION 1. That hereafter a farmers' institute shall be held annually in each county of this State. The meetings for organizing these institutes, respectively, shall be called as hereafter provided; afterwards they shall be held at such times and places as the members thereof may, either in general meeting or by their executive committee, determine. The objects of these institutes shall be the discussion, orally or by written essays or papers, of agricultural and kindred matters, and for the dissemination of agricultural knowledge among the farmers of this State.

SEC. 2. The first meeting for the purpose of organizing shall be held in the county courthouse of each county, respectively, on the third Saturday of May, A. D. eighteen hundred and eighty-nine, at two o'clock afternoon; and each of the clerks of the peace of the several counties shall give notice in two newspapers in his county by two insertions at least one week apart, and the last one not more than one week prior thereto, of such meetings for organization. He shall also attend and call the meeting to order and preside until a president be chosen. The expense of notices so published shall be paid by the respective counties on bills approved by the clerk of the peace ordering them.

[Bull. 241]

The notice shall be in this form:

NOTICE.—The farmers of ——— County are hereby invited to meet in the county courthouse on Saturday, the 18th day of May, 1889, at 2 o'clock afternoon, for the purpose of organizing a farmers' institute in pursuance of an act of the general assembly passed for that purpose.

May —, 1889.

_____,
Clerk of the Peace.

SEC. 3. The officers of the farmers' institutes herein provided for shall be a president, vice president, secretary, treasurer, and executive committee of not less than five nor more than nine members, and such other and additional officers as may be provided for by the by-laws or resolution of the institutes, respectively. None of the officers shall receive any compensation or emolument whatever. They shall hold their offices for one year and until their successors be chosen.

(This section was amended at the 1903 session of the legislature by adding thereto the following proviso):

“*Provided*, That the State board of agriculture may appoint a director of farmers' institutes for the State, to cooperate with the farmers' institutes of the several counties. The compensation of the said director shall be fixed by the State board of agriculture, which said compensation shall not exceed the sum of one hundred dollars per annum, and which said compensation shall be paid from the funds appropriated by the State to the said State board of agriculture.”

SEC. 4. For the purpose of defraying the incidental expenses of holding the institutes herein provided for the sum of six hundred dollars annually is hereby appropriated, to wit, two hundred dollars to the institute of each county, respectively, to be paid to the respective treasurers thereof on the certificate of the president and secretary that he is duly authorized to receive the same.

SEC. 5. Each institute shall be the judge of the qualifications and regulate the admission of its own members, and may also make and alter rules for the regulation of its own proceedings. The failure to hold an institute as herein contemplated in any one year shall forfeit its appropriation for that year.

Passed at Dover, March 29, 1889.

Under an act of the legislature the law which created the State board of agriculture was amended by adding to its powers and duties the following: “To devise and execute measures necessary for the agricultural development of the State.” Under this authority, in addition to the \$600 specifically appropriated for institutes, an additional amount may be granted by the State board for this purpose.

FLORIDA.

The Legislature of Florida at its session of 1910 appropriated the sum of \$15,000 for the years 1910 and 1911 for carrying on farmers' institutes. The manner of conducting the work is determined by the board of control. The director of the experiment station has been designated as the executive officer in charge of institute work.

GEORGIA.

No special appropriation for farmers' institutes as such has been made by the Legislature of Georgia. The act of 1910, under which

[Bull. 241]

institutes are conducted, provides \$60,000 for maintenance of the State college of agriculture, of which \$10,000 shall be used for extension teaching.

HAWAII.

There are no laws in this Territory relating to farmers' institutes.

IDAHO.

Farmers' institutes in Idaho are under the direction of the board of regents of the university and are supported out of an appropriation made for agricultural college extension. The director of the agricultural experiment station has been placed in charge of the work as executive officer of the board.

ILLINOIS.

AN ACT Creating the Illinois Farmers' Institute.

[Approved June 24, 1895. Amended and approved May 11, 1901. Amended and approved May 15, 1903. Amended and approved June 10, 1909.]

SECTION 1. *Be it enacted by the people of the State of Illinois, represented in the general assembly:* That to assist and encourage useful education among the farmers, and for developing the agricultural resources of the State, that an organization under the name and style of "Illinois Farmers' Institute" is hereby created and declared a public corporation of the State.

SEC. 2. It shall consist of three delegates from each county of the State, elected annually at the farmers' institutes for said county by the members thereof.

SEC. 3. The affairs of the Illinois Farmers' Institute shall be managed by a board of directors, consisting of:

1. State superintendent of public instruction.
2. Professor of agriculture of the State of Illinois.
3. President of the State board of agriculture.
4. President of the State horticultural society.

5. President of the State dairymen's association, and one member from each congressional district of the State, to be selected by the delegates from the district present at the annual meeting of this organization: *Provided*, That the members first selected from the congressional districts of even numbers shall serve for one year, and the members first selected from the congressional district of odd numbers shall serve for two years, and that the members selected thereafter to fill the expired terms of office shall serve for the period of two years.

SEC. 4. (As amended and approved June 10, 1909.) The board of directors of the Illinois Farmers' Institute shall have sole care and disposal of all sums that may be appropriated by the State to sustain the organization, and shall expend the same in such manner as in their judgment will best promote the interests in useful education among the farmers and develop the agricultural resources of the State. The Illinois Farmers' Institute shall make annual report to the governor of its transactions, which report shall include papers pertaining to its work and addresses made at the annual meeting of the organization, and a classified statement of all money received and of all expenditures made, and fifty thousand copies of such report shall be printed and bound in cloth on or before September first of each fiscal year, three-fourths for the use of

[Bull. 241]

the Illinois Farmers' Institute, and the remainder to the secretary of state for distribution. It shall make no appropriation without funds in hand to meet the same, and the State of Illinois shall in no event be held liable or responsible for debt, obligation, or contract made by the Illinois Farmers' Institute or its board of directors.

SEC. 5. There shall be held annually, under the direction of the board of directors, between October first and March first, following of each year, a public meeting of the delegates from county farmers' institutes and of farmers of this State at such time and place as may be determined by the board of directors, of not less than three days' duration, which meeting shall be held for the purpose of developing the greater interest in the cultivation of crops, in the care and breeding of domestic animals, in dairy husbandry, in horticulture, in farm drainage, in improved highways and general farm management through and by means of liberal discussions of these and kindred subjects, and any citizen may take part in these meetings, but only duly elected and accredited delegates from county farmers' institutes shall be permitted to vote in the election of the board of directors.

SEC. 6. (As amended and approved May fifteenth, nineteen hundred and three.) The members of each new board of directors shall enter upon their duties the second Tuesday after their election, and hold their offices for one or two years, as provided in section three, or until their successors are elected and enter upon their duties. The board of directors shall have power to fill vacancies in the board. It shall organize by the election of a president, vice president, treasurer, and secretary, who shall hold their offices for one year, their term of office to begin July first following their election. It shall employ such superintendents, speakers, and clerks as may be deemed proper for organizing and conducting the work of the Illinois Farmers' Institute, and provide for their compensation by the rules of the board of directors. The secretary and treasurer may be other than members of the board of directors. The salary of the secretary shall be two thousand dollars a year, payable in monthly installments.

The auditor of public accounts is hereby authorized to draw his warrants on the State treasurer monthly for the salary of the secretary of the Illinois Farmers' Institute, as herein provided, payable out of any fund in his hands not otherwise appropriated.

SEC. 7. Rooms in the capitol building shall be assigned to the officers of this organization by the proper authority, which shall then be under the control of the board of directors.

SEC. 8. The board of directors may make and enforce such rules and by-laws, not in conflict with the laws of this State, as will render its work most useful and efficient.

SEC. 9. For the purpose mentioned in the preceding sections, said board of directors may use such sums as it may deem proper and necessary, not exceeding the amount appropriated therefor by the general assembly from the general fund, for that purpose: *Provided further*, That the—

1. State superintendent of public instruction.
2. Professor of agriculture of the University of Illinois.
3. President of the State board of agriculture.
4. President of the State horticultural society.
5. President of the State dairymen's association.

And the present congressional representatives of the Illinois Farmers' Institute Association shall constitute the first board of directors of this organization, who shall have charge of the affairs of the same until their successors have been duly elected and enter upon their duties as provided in this act.

[Bull. 241]

A BILL For an act making an appropriation for the Illinois Farmers' Institute and county farmers' institutes. (Approved June 11, 1909.)

SECTION 1. *Be it enacted by the people of the State of Illinois, represented in the general assembly:* That there be and hereby is appropriated to the Illinois Farmers' Institute the following sums, to wit: For clerk hire, janitor service, postage, expressage, office, library, furniture, incidental office expenses, etc., two thousand five hundred dollars per annum, for the fiscal years beginning July first, nineteen hundred and nine and nineteen hundred and ten. The secretary of state shall provide all needful books, papers, stationery, and printing required on requisition by the secretary of the Illinois Farmers' Institute.

SEC. 2. For the salary of a superintendent, one thousand five hundred dollars per annum; for assistants to the superintendent, one thousand dollars per annum; for the fiscal years beginning July first, nineteen hundred and nine and nineteen hundred and ten.

SEC. 3. For the per diem and necessary expenses of expert judges, instructors, and speakers furnished by the board of directors for county institutes, farmers' study clubs, farmer boys' organization, home makers' clubs, etc., and for use of the board in furnishing to the daily and weekly newspapers of the State reports of the most approved and successful farm practice and experiment station results; the latest teachings of agricultural science and the educational ideas that are receiving the attention of scientists and foremost farmers, the sum of three thousand dollars per annum, for the fiscal years beginning July first, nineteen hundred and nine and nineteen hundred and ten.

SEC. 4. For the actual expenses of the members of the board of directors and officers of the Illinois Farmers' Institute, in the performance of their duties as such members and officers; for the expense of the district conferences, the expenses of the State institute meeting, and for the incidental expenses in promoting the development of the farmers' institute work throughout the State, five thousand dollars per annum; for the fiscal years beginning July first, nineteen hundred and nine and nineteen hundred and ten.

SEC. 5. For the purpose of holding one or more farmers' institute meetings in each county in the State, the sum of seventy-five dollars per annum for the fiscal years beginning July first, nineteen hundred and nine and nineteen hundred and ten, said sum to be paid to the treasurer of each county farmers' institute when such institute shall file with the secretary of the Illinois Farmers' Institute a sworn statement, which shall show that said county farmers' institute has held one or more duly advertised public sessions annually, in accordance with such rules as may be prescribed by the board of directors of the Illinois Farmers' Institute: *Provided*, That if necessary expenses of a county farmers' institute shall not equal the sum of seventy-five dollars, as aforesaid, then warrant shall only be drawn for the sum expended.

SEC. 6. That on the order of the president, approved by the director of the congressional district, the secretary of the Illinois Farmers' Institute shall draw his warrant on the treasurer of the Illinois Farmers' Institute in favor of the treasurer of the county farmers' institute for the sum herein appropriated, seventy-five dollars, or so much thereof as may be received for its use and benefit, as aforesaid, and it shall be the duty of the treasurer of the Illinois Farmers' Institute to pay over to the treasurer of the said county farmers' institute the said sum, and make annual report to the governor, as provided by law.

SEC. 7. No officer nor officers of a county farmers' institute shall be entitled, as such officer or officers, to receive any moneyed compensation for any service rendered the same.

[Bull. 241]

Sec. 8. The State auditor is hereby authorized and instructed to draw his warrant for the sum herewith specified and deliver the same to the treasurer of the Illinois Farmers' Institute upon his presenting voucher for same, signed by the president and secretary of said Illinois Farmers' Institute, and the State treasurer shall pay the same out of any money in the State treasury not otherwise appropriated.

**RULES PRESCRIBED BY THE BOARD OF DIRECTORS FOR THE MANAGEMENT OF
COUNTY FARMERS' INSTITUTES.**

RULE 1. The director of each district consisting of more than one county shall, at the request of the executive committee or the superintendent of institutes, call a conference of delegates from the several counties of his district at some convenient point, consisting of the following:

(a) One officer (or person selected by the officers) of each county farmers' institute.

(b) One officer (or person selected by the officers) of the department of household science of each county farmers' institute. (In counties in which the department is not organized, the officers of the county farmers' institute may appoint a delegate to represent the women of the county with the express understanding that said delegate shall, prior to the time for holding the county farmers' institute, make faithful effort to organize such department.)

(c) The county superintendent of schools for each county in the district.

The purpose of these conferences is to arrange the times and places for holding the next county institutes and to cooperate in securing speakers.

All necessary expenses of the three said delegates in attending the district conference shall be paid by the Illinois Farmers' Institute upon itemized bills approved by the director of the district.

NOTE 1. Rule 1 does not prohibit the attendance at the conference of more than three delegates. Indeed the number who may attend is unlimited, but the expenses of three only can be allowed from the State institute funds.

NOTE 2. Delegates from independent institutes are invited to come to the conference at their own expense. Their requests for speakers, however, will receive the same attention by the superintendent of institutes as those coming from the regular county organizations. The purpose of the conferences is to help everybody who will assist in the dissemination of agricultural information.

RULE 2. The director's approval shall be required in fixing the dates of the institutes in his district.

RULE 3. The secretary of each county institute shall submit the completed institute program to the district director for his approval before having it printed and distributed, and this shall be done at least 20 days prior to the time for holding the institute.

RULE 4. As soon as practicable after printing the programs the secretary of each institute shall send two or more copies to each of the following: The district director; Secretary H. A. McKeene, Springfield, Ill.; each of the speakers whose names appear upon the program.

RULE 5. The date or place for holding an institute shall not be changed from that determined upon at the district conference without the approval of the district director and the superintendent of institutes.

RULE 6. No part of the State fund shall be expended for music, recitations, amusements of any kind, or for premiums.

[Bull. 241]

INDIANA.

HOUSE BILL No. 274.

A BILL For an act for the improvement and advancement of agriculture, domestic science, and rural life, by the dissemination of information relative to agriculture, domestic science, and rural life among the people of the State.

SECTION 1. *Be it enacted by the General Assembly of the State of Indiana,* That in order to promote the improvement and advancement of agriculture, domestic science, and rural life among the people of the several counties of the State of Indiana, and aid in the diffusion among the people of the several counties of the State of Indiana, useful and practical information on subjects connected with agriculture, domestic science and rural betterment, the following sums of money are hereby appropriated to Purdue University, out of any moneys in the general fund of the State treasury not otherwise appropriated, ten thousand dollars for the fiscal year ending September thirtieth, nineteen hundred and eleven, and thirty thousand dollars annually thereafter, said sums to be paid quarterly to the treasurer of Purdue University.

SEC. 2. The sum of ten thousand dollars available during the current year and the thirty thousand dollars annually appropriated thereafter in section one of this act shall be expended by the school of agriculture and the agricultural experiment station of said university in securing the necessary office force, extension workers, lecturers, and equipment, and in defraying any other expenses in the study of rural conditions and in promoting and aiding in the organization and holding in various parts of the State farmers' short courses, farmers' institutes, farmers' conferences, contests, lectures and demonstration work of various types, and any other forms of agricultural extension, instruction, and demonstration agreed upon by the authorities of Purdue University as being necessary to accomplish the purpose of this act.

SEC. 3. The work proposed by this act shall be carried out by the said Purdue University through the extension department of the school of agriculture and agricultural experiment station under such rules, regulations, and methods as may be prescribed, and along lines to be determined by the following officers: The board of trustees, the president of the university, the dean of the school of agriculture, the director of the agricultural experiment station, the superintendent of agricultural extension of Purdue University, and the advisory committee, as provided for in section three of chapter one hundred and sixty-seven, laws of nineteen hundred and nine.

SEC. 4. For the purpose of defraying the local expenses of meetings held and other work done under the provisions of section two and in accordance with the rules and regulations provided for in this act, such as hall rents, printing, advertising, prizes for contests, and other local expenses, the county farmers' institute chairman is hereby authorized to file with the county auditor an itemized list of expenses of such meeting or meetings and other work done, and the county auditor shall, after such claims have been approved by the county commissioners, draw a warrant or warrants on the county treasurer, who shall pay same: *Provided*, That in no instance shall the aggregate of such items exceed an amount equal to twenty-five cents for each square mile of territory in said county.

SEC. 5. That there may be funds in the county treasury available for the payment of such warrants as are herein provided for, the county council shall appropriate annually an amount equal to twenty-five cents for each square mile of territory in said county.

[Bull. 241]

SEC. 6. An act entitled "An act to encourage the study of agriculture, horticulture, economic entomology, and agricultural chemistry, providing for the county institutes, prescribing the duties of the trustees and faculty of Purdue University in connection therewith, and making an appropriation therefor," approved March ninth, eighteen hundred and eighty-nine; an act to amend section three of "An act to encourage the study of agriculture, horticulture, economic entomology, and agricultural chemistry, providing for county institutes, prescribing the duties of trustees and faculty of Purdue University in connection therewith and making appropriations therefor, approved March ninth, eighteen hundred and eighty-nine, approved March fourth, nineteen hundred and one; and an act entitled "An act for the encouragement of farmers' institutes, and authorizing the county auditor to draw warrants under certain conditions," approved March eighth, nineteen hundred and seven, are hereby repealed.

SEC. 7. Whereas an emergency exists for the immediate taking effect of this act, the same shall be in effect from and after its passage.

Approved February 27, 1911.

IOWA.

AN ACT To repeal the law as it appears in section sixteen hundred and seventy-five (1675) of the supplement to the code, nineteen hundred and seven, relative to farmers' institutes and enact a substitute therefor.

Be it enacted by the General Assembly of the State of Iowa:

SECTION 1. That the law as it appears in section sixteen hundred and seventy-five of the supplement to the code, nineteen hundred and seven, be, and the same is hereby, repealed and the following enacted in lieu thereof:

When forty or more farmers of a county organize a farmers' institute, with a president, secretary, treasurer, and an executive committee of not less than three outside of such officers, and hold an institute, remaining in session not less than two days in each year, which institute may be adjourned from time to time and from place to place in said county, the secretary of the State board of agriculture, upon the filing with him a report of such institute and an itemized statement under oath showing that the same has been organized and held and for what purposes the money expended has been used, shall certify the same to the auditor of State, which State auditor shall remit to the county treasurer of each county his warrant for the amount so expended, not to exceed seventy-five dollars, and there is hereby appropriated, out of the moneys in the State treasury not otherwise appropriated, a sum not to exceed seventy-five dollars annually for such institute work in each county. No officer of any such farmers' institute shall receive, directly or indirectly, any compensation from said fund for said services as such officer. The report provided for in this section shall be filed with the secretary of the State board of agriculture on or before the first day of June of each year. When any institute fails to report on or before the first day of June, that institute shall not receive State aid for that year.

All counties not holding a regular farmers' institute, and where a short course is held, the money appropriated for such farmers' institute as provided in section sixteen hundred and seventy-five of the supplement to the code nineteen hundred and seven shall apply and be payable to said short course upon proof of such organization and such short course having been held being filed with the State board of agriculture by the officers of said short course.

SECTION 1679. * * * The director (of the experiment station) shall have advisory power to cooperate with the farmers' institute organizations of the several counties of the State for the purpose of arranging dates and providing

speakers or lecturers with a view to economy of time and travel in attending institutes, such institutes to be held as nearly as practicable in circuits and at such dates as will enable the speakers to attend two or more such institutes each week.

The annual convention is provided for under section 1657-D, at which each farmers' institute organization under provision sixteen hundred and seventy-five of the code is entitled to represent a membership, provided the State farmers' institute has been organized at least one year and has reported to the State secretary of agriculture not later than November first, through its president and secretary or executive committee, that an institute was held according to law, the date thereof, and the names and post-office addresses of its officers. That they shall also furnish said secretary of agriculture with a copy of each program hereafter held and one or more papers read before such institute if papers are read. In connection with the annual convention, either preceding or following the date on which the officers are elected, the board may hold a State farmers' institute for the discussion of practical and scientific topics relating to the various branches of agriculture, the substance of which shall be published in the annual report of the board.

Approved April 21, 1909.

KANSAS.

CHAPTER 103. SESSION LAWS OF 1909.

AN ACT Relating to farmers' institutes, and repealing chapter 238 of session laws of 1903.

Be it enacted by the Legislature of the State of Kansas:

SECTION 1. Whenever any county farmers' institute association in this State shall have elected a president, vice president, secretary-treasurer, and adopted a constitution and by-laws for its government, it shall be the duty of the county commissioners of such county to appropriate annually the sum of fifty dollars, or so much thereof as may be necessary, to defray the legitimate expense of a two days' institute at such place in the county as may be designated by the executive committee of the institute association: *Provided*, That this act shall not apply to institute associations that have not been in successful operation at least one year: *Provided further*, That no county institute shall be granted any sum in excess of one dollar for each resident farmer who is a bona fide member of said institute at the time the request is made, the total amount granted not to exceed fifty dollars in any one year.

SEC. 2. Whenever, in any county, a local institute shall be organized by or with the approval of the State farmers' institute department of the Kansas State Agricultural College, and shall have elected a president, vice president, and secretary-treasurer, and adopted a constitution and by-laws for its government, it shall be the duty of the county commissioners of such county to appropriate annually the sum of fifteen dollars, or so much thereof as may be necessary, to defray the legitimate expenses of a one-day institute: *Provided*, That this act shall not apply to institute associations that have not been in successful operation at least one year: *Provided further*, That not more than six such local institute associations in any county shall receive such aid in any one year: *Provided further*, That no local institute shall be granted any sum in excess of one dollar for each resident farmer who is a bona fide member of said institute at the time the request is made, and the total amount for such institute not to exceed fifteen dollars in any one year.

SEC. 3. Each and every institute association to receive said appropriation shall submit with each request for aid a certificate from the State department

[Bull. 241]

of farmers' institutes of the Kansas State Agricultural College certifying that the said institute is legally organized and has held its annual meeting as above provided.

SEC. 4. Chapter 238 of the session laws of nineteen hundred and three is hereby repealed.

SEC. 5. This act shall be in force from and after its publication in the statute book.

Approved, March 4, 1900.

Demonstration Farm Law.

CHAPTER 223. SESSION LAWS OF 1900.

AN ACT To authorize the board of county commissioners of any county in which an agricultural demonstration farm has been or shall hereafter be located by the board of regents of the State agricultural college to lease or donate a tract of land for such purpose and to appropriate money and contract for the maintenance of the same.

Be it enacted by the Legislature of the State of Kansas:

SECTION 1. The board of county commissioners of any county in this State in which an agricultural demonstration farm has been or shall be hereafter located, with the consent of such board of county commissioners, by the board of regents of the State agricultural college is hereby authorized to lease or donate to the board of regents of said college any portion of lands owned by said county, not exceeding forty acres in extent, suitable for use in demonstrating the value of crops and methods in farming, gardening, horticulture, and forestry, and to contract for the carrying on of such demonstration work under the plans, direction, and supervision of representatives of the board of regents of said college.

SEC. 2. All work upon such demonstration farms shall be planned and supervised by representatives of the board of regents of said agricultural college, and they may furnish such seeds and plants at reasonable cost on board the cars at Manhattan, Kans., as will not interfere with experimental work done at the college.

SEC. 3. County commissioners may furnish sufficient help and proper teams, tools, and materials, other than seeds, to do the work planned by the representatives of the board of regents, and are hereby authorized to pay out of the general fund the cost of such expense and work, including traveling expenses of supervisor. The total cost to any county not to exceed fifteen hundred dollars for the first year nor five hundred dollars in any other year thereafter.

SEC. 4. All crops grown upon such demonstration farm to be the property of the county in which it is located, and any surplus shall be sold to the citizens thereof when desired for seed or propagation, or used for public institutions; the receipts from such sales to be credited to the farm.

SEC. 5. That it may be known what is planted, methods used and results, each plat or planting shall be plainly and legibly marked for information of visitors to the farm and the representatives of the board of regents of said college. The superintendents of said farms shall furnish data for a brief printed summary, giving the results in amounts and values at usual market prices, to the county clerk by December 1 of each year, who shall have same printed and give, through the county treasurer, a copy of the same to each taxpayer with his tax receipt, and to others on request, and to publish same in the official paper of the county.

[Bull. 241]

SEC. 6. This act shall take effect and be in force from and after its publication in the official State paper.

Approved, March 2, 1909.

Published in official State paper March 5, 1909.

KENTUCKY.

AN ACT Creating a State board of agriculture, forestry, and immigration, specifying the duties thereof, and appropriating money therefor.

SECTION 5. It shall be the duty of the commissioner of agriculture, labor, and statistics, with the approval of said board, to see that a farmers' and industrial institute, of at least two days' duration, is held in each county of the State annually. The institute shall be advertised at least one month before convening, and an effort shall be made to interest and instruct the farmers in the most profitable and approved methods in agriculture and horticulture, and awaken an interest in the industrial development of the State generally. This institute shall be used as a means of gathering the people together, of ascertaining their names and post offices, learning their needs, and giving them information in agriculture and other industrial lines, and of distributing literature upon these subjects. The county institute shall select one or more crop reporters from each magisterial district in the county, to serve for one year without pay, whose duty shall be to report to the commissioner of agriculture, labor, and statistics monthly the acreage and condition of crops and such other information as he, under the law, may ask them.

Each county institute shall elect one or more delegates to the State institute, as provided for in the next section of this act.

SEC. 6. Said commissioner shall cause to be held at Frankfort, or some convenient place, as said board may agree upon, between the first day of January and the first day of March of each year, a State industrial institute for the farmers and others interested in the industrial development of the State, of at least three days' duration, at which only county delegates shall be entitled to vote, each county having one vote. Said commissioner shall be furnished the name and post-office address of each county delegate by the secretary of the county institute, and each delegate shall be notified of the time and place of holding the State institute at least ten days before same shall convene.

SEC. 7. The first State institute shall be held in nineteen hundred and seven, at which two citizens shall be elected from the appellate court districts by delegates of these respective districts as members of the State board of agriculture, forestry, and immigration for a period of four years, to fill the vacancies occurring by the expiration of the term of office of the two members appointed by the governor to serve until March first, nineteen hundred and seven, and each year thereafter the delegates to the State institute from the respective appellate districts shall elect a member of the board for a term of four years to fill the vacancy which shall occur the first of March of the same year. The governor shall appoint a member to fill any vacancies that may occur at any time, but said member shall only serve until the next State institute, when the delegates from that district shall elect as before to fill out the unexpired term.

The governor, for just cause and for the good of agriculture and other interests of the State, may remove any member of the board, but he must state his reasons therefor in writing, and it must be approved by a majority of the board.

Approved, March 21, 1906.

[Bull. 241]

For carrying out all the purposes of the board, including farmers' institutes, the sum of \$20,000 per annum, in addition to the amount already appropriated for the benefit of the bureau of agriculture, labor, and statistics, was appropriated by the above act.

LOUISIANA.

ABSTRACT FROM CONSTITUTION OF LOUISIANA OF 1898.

ART. 306. The Louisiana State Board of Agriculture and Immigration shall have the control and direction of all State agricultural organizations and State farmers' institutes, and shall adopt the needful measures for the securement of proper immigration.

ACT No. 162 of 1908.

AN ACT To authorize the commissioner of agriculture and immigration of this State to employ a farmers' institute conductor, to provide for the payment of his salary, his expenses and the expenses incurred in conducting said farmers' institutes; and to hold institutes for the instruction of the citizens of the State in the various branches of agriculture; to designate the time and place where institutes are to be held; to make such rules and regulations as he may deem proper for the guidance of institute conductor, and for organizing and conducting such institutes; to employ lecturers to perform such work in connection therewith as the commissioner may direct; to provide the course of instruction at such institutes.

SECTION 1. *Be it enacted by the General Assembly of the State of Louisiana,* That the commissioner of agriculture and immigration is hereby authorized to appoint a farmers' institute conductor and fix his salary, and he shall hold office at the pleasure of the commissioner, and shall devote his time exclusively to the work, as said commissioner may direct.

SEC. 2. *Be it further enacted, etc.,* Such institutes shall be held yearly at such time and at such places as said commissioner of agriculture may direct. The said commissioner shall make such rules and regulations as he may deem proper for organizing and conducting such institutes, and may call on the president of the Louisiana State University and Agricultural and Mechanical College to furnish one or more lecturers from the faculty or student body, whose travelling expenses shall be paid going to or returning from the institute work. The said commissioner may also employ one or more lecturers, male or female, at nominal salaries and traveling expense while so employed, to perform such duties in connection with institute work as he may deem best, provided he has the approval of the Louisiana State Board of Agriculture and Immigration. The course of instruction at such institutes shall be so arranged so as to present to those in attendance the results of the most recent investigations in practical and scientific agriculture.

SEC. 3. *Be it further enacted, etc.,* That the amounts for salaries, conducting institutes, publishing proceedings, printing, advertising, etc., shall be paid out of the funds appropriated and set aside annually for farmers' institute work, on the warrant of the commissioner, signed by the secretary of the State board of agriculture and immigration. But in no year shall the aggregate sum expended by the commissioner for salaries and conducting said institutes exceed the sum appropriated for that purpose.

SEC. 4. *Be it further enacted, etc.,* That this act shall take effect from and after its promulgation, and that all laws or parts of laws in conflict with its provisions are hereby repealed.

[Bull. 241]

The Legislature of Louisiana has discontinued the appropriation to the Louisiana State Board of Agriculture for farmers' institutes and has included in the appropriation for the experiment station an item for farmers' institute work, the amount to be expended for institutes being left to the discretion of the officers of the experiment station.

MAINE.

CHAPTER 60. REVISED STATUTES.

SEC. 2. The commissioner of agriculture shall hold or cause to be held two farmers' institutes in each county annually and as many more as the appropriation therefor will allow. The work of said institutes shall be devoted to the presentation and discussion of questions bearing upon agriculture and the agricultural interests of the State; and for this purpose said commissioner may employ speakers who are qualified and versed in the subjects assigned them; and he shall semiannually publish in the leading agricultural paper of the State a list of available speakers and their subjects, from which lists selection may be made for said institute purposes. He may also appoint and employ assistants, experts, lecturers, a stenographer, and other aids needed in conducting such institute work, and shall fix the compensation of such employees. He may hold such institutes independently or in connection with other organizations devoted to agricultural interests and as far as possible and for the best agricultural interests of the State, aid and encourage agricultural societies and associations in the State, and shall collect and preserve in his office for public inspection all valuable data relating to the practical work of such societies and associations.

SEC. 3. (As amended by P. L. 1909, c. 98.) He shall, in connection with and with the aid of the State dairymen's association, annually hold a State dairymen's conference for the exhibit of dairy products and appliances, wherein prizes for high merit and quality in butter and cheese may be offered, and may employ experts and lecturers to enhance dairy interests, but the expenses of the same shall not exceed the sum of seven hundred dollars annually.

SEC. 4. An appropriation of three thousand dollars annually shall be made for said institute work and for all other purposes set out in the two preceding sections.

SEC. 5. The commissioner of agriculture shall aid and assist societies and associations organized and established for the advancement of pomology, horticulture, and dairy work, also societies devoted to the interests of the pure breeding of stock of all kinds.

SEC. 6. He shall apportion annually the stipend due from the State to the said agricultural societies, including the State pomological society; he shall issue blanks to the proper officers of said societies for such returns as may be deemed necessary for a full and complete knowledge of the work of said societies for each year, and shall certify to the governor and council the amount of bounty due such society, and shall designate to the treasurer of State to whom such moneys shall be paid, but said societies shall not be entitled to such bounty unless they shall make such returns.

SEC. 7. He shall annually make a report to the governor and council, on or before the first day of January of each year, of the work of the department of agriculture in detail, combining in the same a report of the State pomological society, State dairymen's association, and the State of Maine cattle

[Bull. 241]

commission, and all other matters relating to the promotion of agriculture; and for the purpose of making his said report, said society, association, and commission shall furnish said commissioner with all necessary data therefor on or before the first day of December of each year. He shall further report all farmers' institutes held and the work therein done, and all public lectures carried on under his authority, and such part of said reports as is of public interest shall be printed for free distribution; for the purpose of making up his report as herein provided, said commissioner shall attend the various agricultural exhibitions in the State and report upon the quality and character of the work of the same.

MARYLAND.

CHAPTER 102.

AN ACT To provide for the formation of farmers' institutes in the State of Maryland, and to appropriate a sum of money therefor.

Be it enacted by the General Assembly of Maryland:

SECTION 1. That a department of farmers' institutes shall be established for the State of Maryland; that the purpose of these institutes shall be to bring before the farmers of the State such information as will effectually remedy many of the existing evils now prevalent in every department of agriculture as now pursued in Maryland, and that at said institutes men competent to instruct shall be present, and such topics shall be discussed as pertain to the principal agricultural interests of the several sections.

SEC. 2. *And be it enacted,* That one such institute shall be held in each year in each county of the State, and an additional one in each county if deemed necessary and desirable.

SEC. 3. *And be it enacted,* That said institute shall be under the direction of a director to be appointed by the trustees of the Maryland Agricultural College, who shall be a person well versed in the profession of agriculture and of practical experience, whose title shall be director of farmers' institutes, whose salary shall be fixed by said board of trustees and paid out of the appropriation hereinafter provided, and whose duties shall be defined by said board; that the said institutes shall be a department of said college similar to the experiment station; that all expenses of said institutes shall be paid out of said appropriation, and that said board of trustees be, and hereby is, invested with all powers necessary to carry into effect the provisions of this act, but no expense shall be incurred beyond the amount appropriated.

SEC. 4.¹ *And be it enacted,* That the sum of three thousand dollars per annum be, and the same hereby is, appropriated for the formation and support of farmers' institutes in this State, and that the comptroller be, and he is hereby, authorized to issue his warrant annually upon the treasurer of the State for the said sum of money, out of any fund not otherwise appropriated; that the said sum of money shall be payable to the order of the Maryland Agricultural College on or after the first day of October of each fiscal year, and that the first yearly payment shall be made during the fiscal year ending September thirtieth, eighteen hundred and ninety-six.

SEC. 5. *And be it enacted,* That accurate accounts of the expenditures of the money received under this act be kept by the registrar of the Maryland Agricultural College, separate from the general college accounts, and that an itemized and detailed report of such expenditure be made annually and published

¹ By the act of 1904 the sum of \$8,000 is annually appropriated, being \$3,000 more than the original appropriation.

[Bull. 241]

in such manner as the board of trustees of the Maryland Agricultural College shall direct.

SEC. 6. *And be it enacted*, That this act shall take effect from the date of its passage.

Approved, March 27, 1896.

MASSACHUSETTS.

The farmers' institutes of Massachusetts are held under a general law establishing the board of agriculture, which authorizes it to "disseminate useful information in agriculture by lectures or otherwise."

An appropriation of \$4,000 was made by the last legislature for the purposes indicated in the above extract from the law. This included farmers' institutes, the cost of issuing crop reports, nature leaflets, and bulletins.

RULES.

Rule 15 of the State board of agriculture requires that "each agricultural society receiving the bounty of the Commonwealth shall hold within its limits not less than three farmers' institutes each calendar year, and the board shall render all the assistance in its power to make these institutes interesting and profitable. The secretary of the board shall provide lecturers for farmers' institutes, so far as the appropriation for the object will allow and a wise expenditure of the money warrant, but he shall not be authorized to pay more than one lecturer for each institute. The secretary of each society shall be required to certify to the holding of each institute, on blanks furnished by the secretary of the board."

MICHIGAN.

ACT 137, PUBLIC ACTS, 1899.

AN ACT to authorize the State board of agriculture to hold institutes and to establish and maintain courses of reading and lectures for the instruction of citizens of this State in the various branches of agriculture, mechanic arts, domestic economy, and the sciences relating thereto, and making an appropriation therefor for the fiscal years ending June thirty, nineteen hundred, and June thirty, nineteen hundred one, and to provide a tax to meet the same.

The people of the State of Michigan enact:

SECTION 1. That the State board of agriculture is hereby authorized to hold institutes and to establish and maintain courses of reading and lectures for the instruction of citizens of this State in the various branches of agriculture, mechanic arts, domestic economy, and the sciences relating thereto. The said board shall formulate such rules and regulations as it shall deem proper to carry on the work contemplated in this act, and may employ such agent or agents to perform such duties in connection therewith as it shall deem best.

SEC. 2. In each county where an institute society shall be organized and maintained under the provisions of this act, the State board of agriculture shall annually hold at least one institute of at least two days in length. When twenty or more persons, residents of any county in this State, shall organize themselves into a society, to be called the ——— County Farmers' Institute Society, for the purpose of carrying out the objects of this act, and in accord-

[Bull. 241]

ance with rules and regulations furnished by the State board of agriculture, such society shall be deemed an institute society in the meaning of this act: *Provided*, That not more than one such institute society in any county shall be authorized by this act. The State board of agriculture shall hold one-day institutes in such counties of the State as it may deem expedient, *but not to exceed four annually in any one county*. The State board of agriculture may also hold, at such places and times as it may determine, special institutes at which the primary object shall be to furnish a school of instruction in the lines specified in section one of this act.

SEC. 3. For the purposes mentioned in the preceding section, the State board of agriculture may use such sum as it shall deem proper, not exceeding the sum of five thousand five hundred dollars, in the year ending June thirty, nineteen hundred, and five thousand five hundred dollars in the year ending June thirty, nineteen hundred one: *Provided*, That two hundred dollars of this appropriation shall be available before June thirty, eighteen hundred ninety-nine.

SEC. 4. The several sums appropriated by the provisions of this act shall be paid out of the general fund in the State treasury to the treasurer of the State board of agriculture, at such times and in such amounts as the general accounting laws of the State prescribe, and the disbursing officer shall render his accounts to the auditor-general thereunder.

SEC. 5. The auditor-general shall incorporate in the State tax for the year eighteen hundred ninety-nine the sum of five thousand five hundred dollars, and for the year nineteen hundred the sum of five thousand five hundred dollars, which, when collected, shall be credited to the general fund to reimburse the same for the moneys hereby appropriated.

SEC. 6. The State board of agriculture is further authorized to publish an annual report, to be known as the "Farmers' Institute Bulletin," of not to exceed two hundred fifty pages, which shall contain, besides statistical reports of the work done and expenditures incurred under this act, such addresses and discussions occurring at the meetings held under this act as the board of agriculture shall deem of sufficient interest to warrant publication. The board of State auditors is hereby directed to print said report and to cause it to be bound in substantial binding, in the same manner as other reports are printed and bound, and in number sufficient to furnish one to each member of each county farmers' institute society organized under this act, and not to exceed one thousand five hundred in addition for general distribution by the board of agriculture. The secretary of the State is hereby directed to ship by freight to the secretary of each regularly organized county farmers' institute society a sufficient number of copies of said report to supply one to each member of such county societies.

SEC. 7. The board of agriculture, the board of State auditors, and the secretary of State are hereby authorized and directed to publish, print, bind, and distribute a similar report for the year ending June thirtieth, eighteen hundred ninety-nine, as provided in section four, for future reports under this act.

This act is ordered to take immediate effect.

Approved June 21, 1899.

ACT 232, PUBLIC ACTS, 1901.

SEC. 3. The State board of agriculture is hereby authorized to hold institutes and to establish and maintain courses of reading and lectures for instruction in the various branches of agriculture, mechanic arts, domestic economy, and the related sciences, which courses of reading, instruction, and lectures shall be conducted, governed, and controlled by act number one hundred thirty-seven of

the public acts of eighteen hundred ninety-nine providing for the same: *Providing*, That not less than seven thousand five hundred dollars shall be expended annually for the purposes provided in said act; but the number of one-day institutes shall be determined by said State board of agriculture.

Approved June 6, 1901.

MINNESOTA.

REVISED LAWS OF 1905.

1452. BOARD OF ADMINISTRATION—SUPERINTENDENT. The board of administration of farmers' institutes shall consist of six members, three of whom shall be regents of the university, selected by and holding office at the pleasure of the board of regents, and the remaining three, at the time of their taking office, shall be the presidents, respectively, of the State agricultural society, the State dairy association, and the State horticultural society; and they shall serve for three years, and until their successors qualify. When the term of any of the last three members mentioned expires, he shall be succeeded on the board by the person then president of the organization through which he became a member. The board shall elect from among its number a president and a secretary, and from outside its number a superintendent, whose term of office shall be two years, but who may be removed at the pleasure of the board. He shall receive a salary of fifteen hundred dollars per year and his expenses necessarily incurred in the performance of his duties. (1903, c. 221, secs. 4, 5, 6, 9.)

1453. DUTIES OF THE BOARD. The board shall arrange the institute circuits to be held annually, determine when and where the institutes shall be held, audit the accounts of the superintendent at the close of each fiscal year, such auditing to be final, and file them with the State auditor, and publish annually a handbook of practical agriculture entitled, "Farmers' Institute Annual," for free distribution among the farmers of the State. The expense of the publication shall be met from the appropriation hereinafter made. (1903, c. 221, secs. 7, 10, 11.)

1454. INSTITUTES, THEIR CHARACTER AND OBJECT. The dissemination of practical knowledge concerning agriculture, horticulture, and stock and dairy farming shall be the sole objects of the institutes. They shall be held at times and places most convenient to the farmers, and each meeting shall occupy from one to three days, with sessions mornings, afternoons, and, when practicable, evenings. All sessions shall be free and public, and shall consist of practical lectures on subjects pertaining to farm and home, with addresses, discussions, and illustrations of methods adapted to our agriculture. (1903, c. 221, sec. 12.)

1455. SUPERINTENDENT'S DUTIES. The superintendent shall assist the board in arranging institute circuits, superintend the several institutes, engage instructors therefor, examine all bills for expenses and services payable out of appropriations for such purposes, and at the end of each fiscal year make a detailed report to the board of all institutes held under his direction, including therein the items of such expenses and services. (1903, c. 221, secs. 7, 8.)

1456. STANDING APPROPRIATION. The sum of eighteen thousand dollars is hereby annually appropriated for the purposes of such institutes. No warrant shall be issued for such purpose unless the claim be approved by the superintendent and by the president of the board. The average cost of the institutes for the necessary travelling expenses and board of the instructors, and their compensation, shall not exceed one hundred and fifty dollars, the expenses incurred in preliminary work not included. No money shall be spent for hall rent, fuel, lights, local advertising, or for the compensation of instructors other than those regularly employed. Expenses as allowed in this chapter for carrying on the institute work of the board, when made prior to August

[Bull. 241]

first in any calendar year when the legislative appropriation for said year has been exhausted, may be paid from an appropriation already made and to become due on said August first, and shall not be construed as creating a deficiency. (1903. c. 221, secs. 1-3, 9.)

MISSISSIPPI.

CHAPTER 42. HOUSE BILL No. 508.

AN ACT To make an appropriation to defray the expenses of the department of farmers' institute and agricultural extension in the Mississippi Agricultural and Mechanical College.

SECTION 1. *Be it enacted by the Legislature of the State of Mississippi*, That the sum of five thousand dollars for the year nineteen hundred and eight, and the sum of five thousand dollars for the year nineteen hundred and nine, or so much thereof as may be necessary, out of any money in the State treasury not otherwise appropriated, be, and the same is hereby, appropriated for the support of farmers' institutes and agricultural extension in the Mississippi Agricultural and Mechanical College.

SEC. 2. That accurate accounts of the expenditures of the money received under this act shall be kept by the treasurer of the Mississippi Agricultural and Mechanical College, separate from the general college accounts, and that an itemized and detailed report of such expenditures be made annually and published in such manner as the board of trustees of the Mississippi Agricultural and Mechanical College shall direct.

How drawn and expended.

SEC. 3. The money hereby appropriated shall be drawn and expended under the direction of the board of trustees of the Mississippi Agricultural and Mechanical College for the purposes above named and no other, and in the same manner as other appropriations for the said college.

SEC. 4. That this act shall take effect and be in force from and after its passage.

Approved, March 17, 1908.

The appropriation of \$5,000 for the years 1908 and 1909 has been continued for 1910 and 1911.

MISSOURI.

REVISED LAWS OF MISSOURI RELATING TO AGRICULTURE AND HORTICULTURE.

SECTION 602. EXTENSION COURSE IN AGRICULTURE—WHEN HELD—HOW CONDUCTED. Whenever fifty or more resident farmers of any county in this State, through the county court of such county, shall petition the State board of agriculture to hold at the county seat of such county, or such other place as may be designated by the county court, an extension course in agriculture, not to exceed ten days in length, during which time there shall be given lectures, demonstrations, and practical instruction in stock breeding and feeding, stock judging, crop growing, seed selection, seed testing, fertilizers and soil improvement, dairying, poultry raising, road making, and any other subject of interest and profit to farmers, it shall be the duty of the State board of agriculture to employ and send competent men to conduct a course of instruction in such of the above subjects as may be of the most benefit to the community where the meeting is held: *Provided*, That the petitioners shall furnish the State board of agriculture with a hall suitable for holding the meeting free of expense: *Provided further*, That the number of days duration of the meeting and the dates for holding it shall be agreed upon by the county court and the State board of agriculture. (Laws 1909, p. 119.)

[Bull. 2411]

MONTANA.

AN ACT Entitled "An act to amend an act providing for farmers' institutes, and making an appropriation therefor," approved March 14, 1901.

Be it enacted by the Legislative Assembly of the State of Montana:

SECTION 1. That section 1 of said act be, and the same is hereby, amended so as to read as follows:

"SECTION 1. The board of administration of the farmers' institutes, as provided for in this act, shall consist as follows:

"The governor of the State and the director of the Montana Experiment Station, both of whom shall be ex officio members, and the presidents of the following-named organizations:

"The Montana Registered Cattle Breeders' Association, the Montana Wool-growers' Association, the Montana Live Stock Association, the Montana Horticultural Society, the Montana State Board of Horticulture, the Montana Agricultural Association, and the Montana Dairyman's Association, when these last two shall have been duly organized. Members of such board of administration shall be designated the 'directors of the Montana farmers' institutes,' and shall be authorized to hold institutes for the instruction of the citizens of this State in the various branches of agriculture, and shall prescribe such rules and regulations as they may deem best for organizing and conducting the same. Such institutes shall be held at least once in each county in each year, and at such times and places as the directors may designate; provided the requirements of the board of administration have been complied with, such as county institutes or local organizations providing a suitable hall, lighting and heating the same, and bearing necessary advertising expense. The directors may employ an agent or agents to perform such work in organizing or conducting such institutes as they may deem best. A course of instruction at such institutes shall be so arranged as to present to those in attendance the results of the most recent investigations in theoretical and practical agriculture."

Approved February 11, 1909.

The appropriations for expenses of farmers' institutes for the years 1911 and 1912 are \$10,000 for each year.

NEBRASKA.

There is no State law under which the farmers' institutes are held in Nebraska. The institutes were started through the cooperation of the several State societies interested in agriculture with the University of Nebraska. The legislature, however, has appropriated \$35,000 to the university for the biennial period of 1911 and 1912. The university employs a superintendent of farmers' institutes who has charge of the field work.

Except at entirely new points the hotel bills of the speakers are paid by the local organization which cooperates with the university. The local organization also bears the expenses of hall rent, heating, lighting, and local advertising.

NEVADA.

There are no laws in Nevada with respect to the organization and conducting of farmers' institutes. The institutes are held under the direction of the experiment station staff.

[Bull. 241]

NEW HAMPSHIRE.**PUBLIC STATUTES OF NEW HAMPSHIRE. CHAPTER 12.**

SEC. 9. The secretary shall keep a record of all the proceedings of the board, which shall be open at all times to public inspection. He shall aid the board by obtaining all the information he can concerning the adaptation of the soils and climate of the State to the raising of grasses, grains, vegetables, fruits, and other products; the best methods for their cultivation; the production and rearing of domestic animals; the machinery and implements best adapted to the requirements of farmers and horticulturists, and all other subjects that will increase the prosperity and profit of agricultural and horticultural pursuits in the State. *He shall make arrangements for, give public notice of, and, if possible, personally attend the farmers' meetings authorized by the board, and report to the board all the important information there obtained.* He shall perform such other duties as may be assigned to him by the board.

NEW JERSEY.

The farmers' institutes in New Jersey are organized and conducted under authority granted to the State board of agriculture by the legislature. The section of the act is as follows:

Be it enacted, etc., That in order to collect and disseminate reliable and useful information and to encourage a higher standard in the agriculture and horticulture of the State the executive committee are hereby authorized to cause to be made experimental and practical tests of specific remedies or cures of diseases of domestic animals and poultry and to employ suitable persons to lecture before the State board of agriculture, at its annual or other meetings, and in the counties of the State as far as the sum herein appropriated will allow.

The executive committee of the State board of agriculture has delegated the management and conduct of the institutes to the secretary of the board.

There is also a provision in the general statutes relating to the State agricultural college, which directs "that the board of trustees shall cause to be delivered annually in each county in this State one or more public lectures upon the subject of agriculture free of charge."

NEW MEXICO.

In New Mexico the farmers' institute work has been performed by the agricultural college and experiment station. There has been no legislation providing for the organization of institutes, and no appropriation was made by the Territorial legislature of 1909 for institute purposes.

NEW YORK.

Section 2 of article 2 of the agricultural law of the State of New York defines the duties of the commissioner of agriculture as follows:

The commissioner of agriculture shall be the chief of the department. The commissioner of agriculture shall be appointed by the governor, by and with the advice and consent of the senate. His term of office shall be three years.

[Bull. 241]

* * * He may appoint a *director of farmers' institutes* and such clerks and assistant commissioners and employ such clerks, chemists, agents, and counsel as he may deem necessary for the proper enforcement of such laws and the proper administration of the department, who shall receive such compensation as may be fixed by him and their necessary expenses. The compensation of his clerks, assistants, and other persons employed by him and such necessary expenses shall be paid on his certificate by the treasurer on the warrant of the comptroller. All other charges, accounts, and expenses of the department authorized by law shall be paid by the treasurer on the warrant of the comptroller, after they have been audited and allowed by the comptroller. The trustees of public buildings shall furnish suitable rooms for the use of the department in the capitol.

Section 31 of article 3 of the agricultural law reads as follows:

Care and feed of cows, and care and keeping of the produce from such cows.

No person shall keep cows, for the production of milk for market or for sale or exchange, or for manufacturing the milk or cream from the same into any article of food, in a crowded or unhealthy condition or in unhealthful or insanitary surroundings, and no person shall keep such cows or the product therefrom in such condition or surroundings or in such places as shall cause or tend to cause the produce from such cows to be in an unclean, unhealthful, or diseased condition, if the produce from such cows is to be sold, offered, or exposed for sale upon the markets for consumption or to be manufactured into any food product, nor shall such cows or the produce therefrom be handled or cared for by any person suffering with or affected by an infectious or contagious disease, nor shall any such cows be fed on any substance that is in a state of putrefaction or fermentation, or upon any food that is unhealthful or that produces or may produce impure, unhealthful, diseased, or unwholesome milk. But this section shall not be construed to prohibit the feeding of ensilage. The commissioner of agriculture is hereby empowered to *give such instruction and impart such information* as in his judgment may be deemed best to produce a full observance of the provisions of this section.

Section 98 of article 5 of the agricultural law contains the following:

The chief veterinarian shall, under the direction of the commissioner of agriculture, have general charge of the enforcement of the provisions of this article, and shall collect and *disseminate through farmers' institutes* or otherwise, as the commissioner may direct, *information and statistics in relation* to the diseases of domestic animals, the proper care and sanitation of stables and other buildings used for the stabling of farm animals for the purpose of preventing the existence and spread of infectious and contagious diseases, the method of feeding, the methods of improving the breed or milking qualities of cattle, and such other matters as the commissioner may direct.

The appropriation bill for the fiscal year beginning on the 1st day of October, 1910, contains a clause which reads as follows:

For maintenance and extension of farmers' institutes held under the auspices of the commissioner of agriculture, including inspections of, and recommendations concerning farms connected with State institutions as provided in the agricultural law, twenty-five thousand dollars, or so much thereof as may be necessary, to be paid upon the order of the commissioner of agriculture, and certified in sums as needed, and for which vouchers for expenditures duly audited and verified by him shall be rendered.

[Bull. 241]

NORTH CAROLINA.

The Legislature of North Carolina, by an act which went into effect March 9, 1901, makes it the duty of the commissioner of agriculture, by and with the consent and advice of the board of agriculture, to hold "farmers' institutes in the several counties of the State as frequently as may be deemed advisable in order to instruct the people in improved methods in farming, in the beneficial use of fertilizers and composts, and to ascertain the wants and necessities of the various farming communities; and may collect the papers and addresses made at these institutes and publish the same in pamphlet form annually for distribution among the farmers of the State. He may secure such assistants as may be necessary or beneficial in holding such institutes."

NORTH DAKOTA.

Sections 1, 3, and 5 of the following act, creating a State farmers' institute board of directors and regulating the holding of such institutes, constitute portions of a law that went into effect July 1, 1901.

Sections 2 and 4 are amendments to the foregoing act and were approved March 15, 1905.

SECTION 1. There is hereby established a farmers' institute board composed of the president of the board of trustees of the North Dakota Agricultural College, the commissioner of agriculture and labor, the director of the experiment station, the professor of agriculture, and the professor of dairying of the North Dakota Agricultural College.

SEC. 2. (ORGANIZATION OF BOARD.) The State farmers' institute board of directors shall have power to organize by electing one of its members to act as president and one to act as secretary, and it is hereby made its duty to employ a director of farmers' institutes and such other institute lecturers as may be deemed necessary; to authorize the holding of not less than 50 institutes each year, the same to be of such a nature as to instruct the farmers of the State in maintaining the fertility of the soil, the improvement of cereal crops grown in the State, principles of breeding as applied to domestic animals, the making and handling of dairy products, the destruction of noxious weeds and injurious insects, forestry, and growing of fruits, feeding and management of live stock, and in general such instruction as will tend to promote the prosperity, home life, and comfort of the farming population.

SEC. 3. No member of this board shall receive any compensation for his services, but shall be allowed his actual and necessary traveling expenses when engaged upon business connected with the proper discharge of his duties under this act.

SEC. 4. (APPROPRIATION FOR INSTITUTES.) There is hereby appropriated, out of any money in the State treasury not otherwise appropriated, the sum of six thousand dollars annually for carrying out the purposes of this act. All charges, accounts, and expenses authorized by this act shall be paid by the treasurer of the State, upon the approval of the State board of audit, when certified by the president and secretary of the board of directors.

SEC. 5. All acts and parts of acts in conflict with the provisions of this act are hereby repealed.

[Bull. 241]

OHIO.

LAW GOVERNING FARMERS' INSTITUTE SOCIETIES IN OHIO.

[Passed April 26, 1890, and amended April 27, 1896, and March 31, 1906.]

Be it enacted by the General Assembly of the State of Ohio:

SECTION 1. That when twenty or more persons, residents of any county in the State, organize themselves into a farmers' institute society, for the purpose of teaching better methods of farming, stock raising, fruit culture, and all branches of business connected with the industry of agriculture, and adopt a constitution and by-laws agreeable to rules and regulations furnished by the State board of agriculture; and when such society shall have elected proper officers and performed such other acts as may be required by the rules of the State board of agriculture, such society shall be deemed a body corporate.

SEC. 2. Not to exceed four farmers' institute societies organized under the provisions of this act shall hold annual meetings under the auspices of the State board of agriculture in any one county in the State, and the State board of agriculture shall have power to determine the number and name the times and places for holding such institute meetings.

SEC. 3. When a society organized under the provisions of this act shall have held an annual farmers' institute meeting in accordance with the rules of the State board of agriculture, the secretary of said board shall issue certificates, one to the president of the farmers' institute society and one to the president of the State board of agriculture, setting forth these facts, and on the presentation of these certificates to the county auditor, he shall each year draw orders on the treasurer of the county as follows: One in favor of the president of the State board of agriculture for the sum of one hundred and twenty-five dollars, and one in favor of the president of each farmers' institute society in the county, holding meetings under the auspices and by the direction of the State board of agriculture, for a sum not to exceed thirty-one dollars and twenty-five cents, for the payment of necessary local expenses, and the treasurer of the county shall pay the same from the county fund: *Provided*, That in no county shall the total annual sum exceed two hundred and fifty dollars: *And provided further*, That the payment to any institute society shall not exceed the expense, as per detailed statement, provided in section four of this act.

SEC. 4. With each certificate of the secretary of the State board of agriculture to the county auditor, which certificate shall indicate the number of societies organized in the county and holding meetings by direction of the State board of agriculture, and before the auditor issues his order upon the treasurer, there shall be filed with the auditor a detailed statement of the expenses of the institute for the current year, no part of which shall be for salaries of officers of the institute society; but this provision shall not apply to the order in favor of the president of the State board of agriculture, which board shall issue statement as required in section six of this act.

SEC. 5. At the annual farmers' institute meetings, held under the provisions of this act and under the auspices of the State board of agriculture, the said board shall furnish lecturers or speakers whose compensation and expenses shall be paid by the board.

SEC. 6. At the close of each season's institute work, the State board of agriculture shall publish in pamphlet or book form such lectures and papers delivered at the several institute meetings as may seem of general interest and importance to the farmers, stock breeders, and horticulturists of the State, copies of which shall be furnished the secretary of each institute society, and the balance issued to be for general distribution; the cost of preparing the

[Bull. 241]

matter and the distribution of the pamphlet or book to be paid by the State board of agriculture. Said board shall also publish in such pamphlet or book a detailed statement of its receipts under the provisions of this act, and the disbursements on account of institute work.

Sec. 7. Said original act entitled "An act to provide for the organization and support of farmers' institutes," passed April twenty-sixth, eighteen hundred and ninety, is hereby repealed, and this act shall take effect and be in force from and after its passage.

OKLAHOMA.

COUNTY FARMERS' INSTITUTES.

AN ACT For the encouragement of farmers' institutes and authorizing the county clerks to draw warrants under certain conditions.

Be it enacted by the people of the State of Oklahoma:

SECTION 1. That in order to promote the extension of farmers' institute work, to encourage its better organization, and to increase the moneys expended for such work, the president of any farmers' county institute held under the regulations adopted by the State board of agriculture in any county in the State of Oklahoma shall be entitled to draw from the county treasury of such county a sum of money not exceeding two hundred dollars, to be paid on a warrant drawn by the county clerk, which said warrant shall be issued to such county president upon full compliance with the terms of this act.

Sec. 2. The president of any farmers' county institute making application for a warrant, as provided for in section 1 of this act, shall file with the county clerk, at the time of making such application, a verified statement as follows, to wit: A true and correct statement of the total paid membership in such county, which statement shall contain the names of the members paid, and no name shall be listed unless the person so listed shall have paid a membership fee of at least fifty cents, such statement shall also show the total amount of such membership fees collected in such county, a true and correct itemized statement of expense of such county institute, the receipted vouchers showing payment in full of all expenses so itemized being attached to such report.

Sec. 3. Any county in the State of Oklahoma where auxiliary organizations to county farmers' institutes have been, or hereafter may be, organized under regulations adopted by the State board of agriculture, such auxiliary organizations to be known as poultry associations, dairymen's associations, or women's auxiliary organizations for county institute work, and such auxiliary organizations are maintained separate and distinct from the organizations of such county institutes of such county and work under separate program, such auxiliary organizations charge and collect an annual membership fee of not less than twenty-five cents, and the president of such auxiliary organization makes a verified report to the president of the county institute in all particulars as required of the president of the county institute in section 2 of this act, then such auxiliary organizations shall be considered a part of such county institute, and the report of such auxiliary organization shall be combined with the report of such county institute by adding similar items, and the totals of such additions shall be considered as the totals of the county institutes.

Sec. 4. The county clerk shall draw a warrant on the county treasurer payable to the order of the president of the county institute for the sum represented by subtracting the total receipts of membership dues from the total expenses of conducting such institute, as shown by the county president's itemized report and receipted vouchers filed with the report of such president: *Provided*, That no warrant shall be drawn for a sum in excess of the total

[Bull. 241]

receipts of membership dues: *And, provided further.* That such warrants shall be drawn but once during any calendar year.

SEC. 5. The term expenses as used in section two of this act shall be construed to include any prize or prizes offered by such county institute or auxiliary organizations to stimulate competition in experimental work in agriculture, poultry breeding, dairy or domestic science research; rewards offered for results of extraordinary excellence in agriculture, poultry breeding, dairy or domestic science domain; or the necessary cost of cooperative work of an educational character along the lines of agricultural, horticultural, poultry breeding, dairy or domestic science development: *Provided.* That the scheme or plan of such special work provided for in this section shall have been adopted by the county institute and that competition shall be open to every eligible person of that particular class residing in such county. In adopting any such scheme or plan of special work, every member of such county institute or auxiliary organization not in arrears for payment of annual membership dues shall be entitled to one vote, and a plurality of all votes cast shall determine the adoption of any proposed scheme.

SEC. 6. Any president of the county institute who shall knowingly file a false report, or any officer of the county institute or auxiliary organization whose duty it shall be to keep a record of the attendance or render an accounting for moneys received or expended who shall knowingly make or submit a false report, or any officer of such county institute or auxiliary organization who shall expend any of the receipts of such county institute or auxiliary organization in any other manner than that shown by such verified report and by the receipted vouchers filed therewith, or any person who shall sign a fraudulent voucher showing moneys expended which were not so expended shall be deemed guilty of a misdemeanor and shall upon conviction be fined in any sum not exceeding fifty dollars.

SEC. 7. This act is supplemental to the act approved March third, nineteen hundred and eight, providing for the organization of the board of agriculture, and so forth, in force March third, nineteen hundred and eight, and repeals none of the provisions of said act.

Approved March twenty-second, nineteen hundred and nine.

REGULATIONS FOR CONDUCT OF INSTITUTE WORK.

In view of the provisions in recent institute act for effecting and promoting permanent local organizations, and for meeting the expenses of the local associations, and in accordance with the provisions of the original act creating the farmers' institute system in Oklahoma, the State board of agriculture announces the following general policy and plan of conducting the work under the existing laws:

1. The State board of agriculture will, as heretofore, select a superintendent of institutes and such additional and suitable persons as shall be necessary to conduct the institute work under the provisions of the laws governing institutes, and the rules and regulations of the board.

2. The State superintendent of farmers' institutes, under authority from the board, will, with the advice of the county officers, arrange the schedule of meetings, reserving the right to fix the time and place of same and assign the State speakers.

3. The State board of agriculture will use the State appropriation to pay for the services and traveling expenses of the superintendent and of State speakers, the general supervision of the work, and for such further improvement and extension of the farmers' institute work as the funds will permit.

[Bull. 241]

4. The local expenses of farmers' institutes, such as hall rent, extra speakers, postage, printing, stationery, advertising, etc., will be met from the fund derived from membership dues supplemented from the appropriation from the county treasury, as provided for in the institute act of 1906.

5. The State board of agriculture authorizes and directs the county institute organization and auxiliary associations, acting together upon the request of the State superintendent of farmers' institutes, to advise said officers as to the time, places, and subjects desired for meetings to be held in the county the ensuing year.

6. The State board authorizes and directs the county institute association, including auxiliary organizations (where they exist or may be formed) to arrange for, and duly advertise the meeting or meetings announced in the schedule of farmers' institutes, and properly conduct the same under such regulations as may be prescribed by said board, and promptly make official report of each meeting held to the State superintendent.

7. The State board of agriculture announces that the nature of the institute work permits the discussion of a wide range of subjects bearing upon agriculture, horticulture, animal husbandry, dairying, truck farming, gardening, the home, the school, the highway, rural improvement, relation of town and country, and the development of the agricultural resources of the locality; but it also recognizes that the above-named subjects can be presented without in any way involving political, sectarian or factional or personal discussion.

The board, therefore, rules that all subjects of a purely factional, political, personal, religious, sectarian, social or temperance nature should be excluded from the programs of the county farmers' meetings. All heated partisan or personal discussion at the meeting, upon any subject, is strictly prohibited. Speakers are instructed to urge, and presiding officers authorized and directed to secure the enforcement of above ruling. The discussion of public institutions, of farm and other organizations or of business enterprises, either for the purpose of advertisement, attack or defense, is not germane to the farmers' institute work and should, therefore, not be permitted.

8. The State board of agriculture directs that every meeting to which a speaker is assigned at State expense, or for which county funds will be expended, shall be open to the general public without restriction and without the payment of an admission fee.

OREGON.

The act providing for the holding of agricultural institutes and appropriating money for their maintenance is as follows:

SECTION 1. The board of regents of the State agricultural college is hereby authorized to hold institutes for the instruction of citizens of this State in the various branches of agriculture. Such institutes shall be held at such times and at such places as said board may direct. The said board shall make such rules and regulations as it may deem proper for organizing and conducting such institutes, and shall employ an agent or agents to perform such work in connection therewith as they may deem best. The course of instruction at such institutes shall be so arranged as to present to those in attendance results of the most recent investigations in theoretical and practical agriculture.

SEC. 2. For the purpose mentioned in the preceding section, the said board may use such sum as it may deem proper, not exceeding the sum of two thousand five hundred dollars in any one year, from the general fund, and such amount is hereby annually appropriated for that purpose.

Approved, ———, 1905.

[Bull. 241]

PENNSYLVANIA.

The farmers' institutes in Pennsylvania were established under the act of assembly of March 13, 1895, section 3 of which is as follows:

There shall be one deputy secretary, who shall be appointed by the governor for a term of four years, at a salary of three thousand dollars a year, who shall also be director of institutes.

The same act, section 5, provides—

That it shall be the duty of the superintendent of institutes to arrange them in such manner as to time and places of holding the same as to secure the greatest economy and efficiency of service, and to this end he shall, in each county where such institutes are to be held, confer and advise with the local member of the State board of agriculture, together with representatives duly appointed by each county agricultural, horticultural, and other like organizations with reference to the appointment of speakers and other local arrangements.

The institutes are supported by biennial appropriations by the legislature made to the department of agriculture. The appropriation for the biennium (1910-11) is \$45,000 for institute purposes.

PORTO RICO.

There has been no legislation in Porto Rico respecting farmers' institutes. The special agent in charge of the agricultural experiment station reports that an agricultural society has been organized and that \$1,000 was appropriated for institute purposes last year.

RHODE ISLAND.

Farmers' institutes in Rhode Island are conducted under authority granted by the general assembly in an act passed May 19, 1892, section 4 of which is as follows:

The board shall hold one agricultural institute in each county annually, either independently or in connection with any society or association, or other organization devoted to the same general objects, and may hold as many more as it shall deem expedient, and shall, as far as practicable, encourage State and local associations and societies in the interests of agriculture.

The arranging for the holding of institutes is committed by the State board of agriculture to its secretary, and the expenses are paid by the board out of the annual appropriation of \$20,000 appropriated for the purpose of carrying out the several provisions of the act by which the board is constituted.

SOUTH CAROLINA.

There is no specific law in this State for the holding of farmers' institutes. Institutes, however, are held under authority granted by the board of trustees of Clemson Agricultural College.

[Bull. 241]

There is organized in the college a division of extension work and farmers' institutes, with a principal and two assistants. The arranging for the institutes is left entirely in the hands of the superintendent of this division.

SOUTH DAKOTA.

AN ACT To establish and maintain farmers' institutes in the State of South Dakota.

Be it enacted by the legislature of the State of South Dakota:

SECTION 1. That there is hereby created a State farmers' institute board, to be composed of the president of the agricultural college and the two members of the State board of regents who are at the time acting on the committee for the agricultural college. The term of office as members of such institute board shall terminate with the expiration of their term of office, as above mentioned.

SEC. 2. The State farmers' institute board shall have authority to hold institutes of not to exceed three days, at such times and places within the State as in their judgment the needs of the people demand, which shall be free to the public, and shall consist of practical and instructive lectures, addresses, discussions, illustrations, and demonstrations on the subject of agriculture in all its branches, and such other matters as are of interest to the farming people of the State.

SEC. 3. The necessary and actual expenses incurred in the arranging for and conduct of such institutes, including such machinery, models, maps, charts, and other apparatus as shall be needed for the proper presentation of the various subjects, shall be paid out of the appropriation hereinafter provided, in the manner provided by law for the payment of other State expenses: *Provided*, That there shall be no expenditure for hall rent, fuel, lights, local advertising, or local speakers, in connection with the holding of such institutes, except when deemed necessary by the institute board.

SEC. 4. The said board shall have authority to engage such instructors as are needed for the proper presentation of the various subjects at such institutes, each of whom shall be a specialist on the subject he is to present, and to allow them a reasonable compensation for their services, together with their necessary and actual expenses while so employed.

SEC. 5. The said board shall have authority to do such advertising and publish such matters for free distribution as they may deem advisable for the best interests of the farmers of the State.

SEC. 6. For the purpose of carrying out the provisions of the above act, there is hereby appropriated, out of any money in the State treasury not otherwise appropriated, the sum of five thousand dollars annually.

Approved March 3, 1905.

The above appropriation of \$5,000 has been increased by act of legislature of 1910 to \$13,000 per year for the two years 1910 and 1911.

AN ACT Empowering, authorizing and directing the payment of the expenses of holding and maintaining farmers' institutes in counties where the same shall be held.

Be it enacted by the legislature of the State of South Dakota:

1. That in all counties in the State of South Dakota wherein there is held what is commonly termed a farmers' institute, consisting of a program for education and instruction upon matters relating to agriculture, horticulture, and the breeding and raising of stock, which said institute shall be held at least annually, and where there shall be an organization of agriculturists and per-

[Bull. 241]

sons interested in agriculture, horticulture, and stock breeding, and shall maintain an organization for holding such educational institute, and have regular officers elected, consisting of a board of five directors, and from this board shall be selected a president, vice president, secretary, and treasurer; then, and in such case, the county commissioners of the said county wherein such institute is held and such organization exists, shall pay out of the general fund of said county the necessary expenditures for maintaining such institute and rendering of such program of instructions as hereinafter provided.

2. That whenever the conditions exist as provided in section one, and such institute is maintained and such organization exists, the county commissioners, upon having filed with them vouchers showing the expenditure which shall have been made in and about the holding of said institute, which shall be for the employing of lecturers and necessary expenses connected with holding such institute, which said vouchers shall be subscribed by the president and secretary, and sworn to by either the president or secretary as being true and correct expenditures made therefor, the county commissioners shall then pay said expenditures in and for such county in a sum not exceeding two hundred dollars.

3. Whereas, there is no law relating to the payment of expenses of farmers' institutes, an emergency is hereby declared to exist, and this act shall take effect and be in force on and after its passage and approval.

Approved, March 3, 1905.

TENNESSEE.

Tennessee has no special law governing farmers' institutes. The legislature makes an appropriation to the department of agriculture to be used by the commissioner for institute purposes. The commissioner selects the lecturers, arranges the programs, and decides the places and times for holding the institutes.

TEXAS.

Under an act of legislature establishing the Texas department of agriculture approved April 4, 1907, subdivision 3 of section 11, is the following provision for regulating farmers' institute work—

He (the commissioner of agriculture) shall cause to be held farmers' institutes at such times and places throughout the State as will best promote the advancement of agricultural knowledge and improvement of agricultural methods and practices. He shall publish such papers and addresses read or delivered at these institutes as he shall deem to be of value to the farmers' interests.

The thirty-first legislature appropriated \$5,000 for the year ended August 31, 1910, and \$5,000 for the year ending August 31, 1911 "for conducting institute work" by the department.

UTAH.

AN ACT Providing for the holding of farmers' and domestic science schools, in the counties of the State and repealing sections 2095, 2096, 2097, and 2098, compiled laws of Utah, 1907.

SECTION 1. The agricultural college of Utah is hereby authorized and required to hold meetings, institutes, one or two week schools, exhibitions, and demonstrations for the instruction of the citizens of Utah in the various branches of agriculture and domestic science. At least one meeting, institute, or school shall

[Bull. 241]

be held in each county each year, at such time and place and under such regulations as the agricultural college may direct.

SEC. 2. The agricultural college may employ such agents as may be deemed necessary to assist the faculty in carrying out the provisions of this act; and the course of instruction at the meetings, institutes and schools herein provided for shall present the results of the most recent investigations in theoretical and practical agriculture and domestic science, especially as adapted to Utah conditions.

SEC. 3. It shall be the duty of those conducting institutes in any county or precinct in this State, under the provisions of this act, to encourage and assist in the organization of local agricultural societies, and to encourage legitimate industrial enterprises.

SEC. 4. At the close of each year's institute work, the agricultural college shall cause to be published in book or pamphlet form, for free distribution to the farmers of the State, an annual report of the institute work, which report shall contain the leading papers and discussions presented at the institute meetings of the State.

SEC. 5. For the purposes mentioned in this act, the agricultural college may use such sum as is deemed proper, not exceeding the sum of ten thousand dollars in any one year, and such amount is hereby annually appropriated for that purpose out of any moneys in the State treasury not otherwise appropriated.

SEC. 6. Sections 2095, 2096, 2097, and 2098, Compiled Laws of Utah, 1907, are hereby repealed.

Approved, February 26, 1909.

VERMONT.

NUMBER 11.

AN ACT Abolishing the board of agriculture and creating a board of agriculture and forestry.

It is hereby enacted by the General Assembly of the State of Vermont:

SECTION 1. The State board of agriculture and forestry is hereby created, consisting of the governor, the director of the Vermont Agricultural Experiment Station, and two citizens of the State, known to be interested in the advancement of agriculture and forestry, who shall be appointed by the governor. The term of office of such appointees shall, except as herein otherwise provided, be four years, beginning on the first day of December, nineteen hundred and eight. The first appointments under this act shall be made on or before January first, nineteen hundred and nine, and shall be one for the term of four years and one for the term of two years. Appointments to fill vacancies shall be for the unexpired term, and succeeding appointments for full terms shall be for four years. Each appointee shall continue in office until his successor is appointed. The members of the board shall receive no compensation for services, but shall be paid their actual necessary expenses incurred in the performance of the services required of them by law.

SEC. 2. The board shall appoint, to hold office during its pleasure, a State forester, who shall be a professionally trained forester. His compensation shall be fixed by the board and shall not exceed two thousand five hundred dollars annually, and actual necessary expenses incurred in the performance of his official duties. He shall, under the general supervision of the board, have direction of all forest interests and all matters pertaining to forestry in the State. He shall be, ex officio, State fire warden. He shall, by complaint to the proper prosecuting officer, cause the prosecution of all persons violating any provisions of the penal laws of the State relating to forests and forest fires,

[Bull. 241]

and shall cause suits to be instituted by the attorney general in behalf of the State against all persons trespassing upon or injuring any State forest property. He shall manage the State forest reserves. He shall collect data and make expert studies relative to State forest conditions, and conduct experimental investigations pertinent to forestry, which, subject to the approval of the board, may be made in cooperation with the Vermont Agricultural Experiment Station and with the United States Forest Service: *Provided, however, That said experiment station bear its proportional share of the total expense involved in such studies and investigations.* He shall be ex officio forester in charge of the nursery for forest seedlings. He shall make a full report of his work and the matters in his charge biennially to the general assembly. He may, so far as his other duties permit, prepare bulletins, deliver addresses, lectures, and demonstrations in forestry and personally advise owners of forest lands in this State relative to the management of the same: *Provided, however, That all necessary expenses incident thereto are met by those requesting such services.*

SEC. 3. The governor is hereby authorized, upon recommendation of the board, to accept gifts of land to the State, the same to be held, protected, and administered as a State forest reserve. The board may in its discretion purchase lands in the name of the State to be held as State forest reserves. All proceeds from the sales of timber or other products from said lands shall be paid to the State treasurer, and be used at the discretion of the board in the furtherance of the forestry interests of the State. All lands held as State forest reserves shall be appraised and set to the State in the grand list of the town where located, and the State shall pay taxes thereon. At each quadrennial appraisal of real estate the State forester shall be notified by the listers of the appraisal of all lands in the State forest reserve. The State forester may appeal from such appraisal to the county court, which shall, in open court or by commission, hear the State forester and local representatives of the town, and by its order fix the appraisal of such lands, which appraisal shall be certified by the clerk of the county court to the town clerk and shall stand as the appraisal for the quadrennial period. Such appeal shall be taken to the term of the county court of the county where the lands are situate next following the filing of the appraisal of the listers, and notice thereof shall be given to one of the selectmen of the town by the State forester at least twelve days before the sitting of the court.

SEC. 4. The State forester may, at the discretion of the board, use such proportion of the sum hereinafter appropriated as seems reasonable for the further development of the nursery for forest seedlings, and for the purpose of supplying such seedlings for the planting of State forest reserves and of private lands, as provided in section three hundred and sixty-five of the public statutes.

SEC. 5. All the authority and duties now devolving upon the forestry commissioner shall hereafter devolve upon and be exercised by the State forester, and the words "State forester" are hereby substituted for the words "forestry commissioner" or "commissioner" wherever they appear in chapter twenty-four of the public statutes. The State forester may, in his discretion, exercise all the authority of the fire warden in any town or gore in the State, and may do each and every act which the fire warden for such town or gore might do under the provisions of chapter twenty-four of the public statutes, and every person and town shall be governed and bound by his acts as if the same were performed by the fire warden. But the foregoing provision shall not affect the authority of the local fire warden.

* * * * *

SEC. 7. Said commissioner shall promote agricultural interests and education throughout the State by means of institutes, farmers' meetings, lectures, essays, bulletins, crop reports, nature leaflets, and such other means as he may deem

[Bull. 241]

advisable, and may employ special assistants, lecturers, essayists, and experts in conducting meetings, in the preparation of bulletins and crop reports, and in the proper discharge of his duties. The educational work herein provided shall include, among other topics, forestry, tree planting, roads and road making. Lectures and essays shall be given and institutes and meetings held at such places and times as to the commissioner shall seem advisable. The commissioner may, in his discretion and at the expense of the State, attend conventions, meetings, or institutes relating to agriculture held in other States or countries, the annual expenditure therefor not to exceed one hundred dollars.

SEC. 8. Said commissioner may use such means as in his judgment are necessary to exterminate or prevent the introduction of the San Jose scale, the gipsy moth, the brown-tail moth, and any other threatening and unusual insect pest found to be injuring vegetable growth. The auditor of accounts shall, upon the requisition of said commissioner, approved by the governor, draw all orders necessary to carry out the provisions of this section.

SEC. 9. Said commissioner shall annually, on or before the first day of October, prepare a detailed report of his work, together with such suggestions in regard to the duties of his office and the advancement of the agricultural interests of the State as may seem pertinent. He may include and publish in such annual reports such addresses, lectures, and essays delivered under the provisions of this act as he may deem advisable, and may reprint therein bulletins, crop reports, and leaflets. He may, in his discretion, include in such annual report an abstract of the proceedings of such agricultural clubs or other organizations or institutions for the furtherance of agricultural education and interests as to him shall seem advisable. There shall be published with such annual report the report of the State forester, of the annual meetings of the State horticultural society, of the Vermont Dairymen's Association, of the Maple Sugar Makers' Association, and of the State fair commission.

SEC. 10. Said commissioner may collect authentic statistical information, as full as practicable, relating to agriculture and agricultural products, farms and farm property, unoccupied farms and waste lands, and such information, under a separate head, may form a part of his annual report. He may also, with the approval of the governor, publish information in separate form, showing by description and illustration the resources and attractions of Vermont and the advantages the State offers to capitalists, tourists, summer visitors, and farmers, and shall distribute and advertise the same in such manner as in his judgment will be most effective in developing the resources and advertising the advantages of the State.

* * * * *

SEC. 12. Sections 283, 330, 331, 332, 333, and 6165 of the public statutes and all acts and parts of acts inconsistent with this act are hereby repealed.

SEC. 13. This act shall take effect from its passage.

Approved, December 18, 1908.

NUMBER 16.

AN ACT To amend sections six and eleven of number eleven of the acts of 1908, entitled "An act to abolish the board of agriculture and creating a board of agriculture and forestry."

It is hereby enacted by the General Assembly of the State of Vermont:

SECTION 1. Section six of number eleven of the acts of nineteen hundred and eight is hereby amended so as to read as follows:

"SEC. 6. The governor, with the advice and consent of the senate, shall appoint a commissioner of agriculture, who shall hold office during the pleasure of the governor. Said board shall fix the salary of said commissioner, who

[Bull. 241]

shall receive his necessary clerk hire and expenses incurred in the discharge of the duties of his office."

SEC. 2. Section eleven, as amended, of said last-named act, is hereby amended so as to read as follows:

"SEC. 11. The sum of ten thousand dollars is hereby appropriated to carry out the provisions of this act between December first, nineteen hundred and ten, and June thirtieth, nineteen hundred and eleven; and thereafter for like purposes the sum of twenty thousand dollars is hereby annually appropriated. The said board shall apportion the aforesaid appropriations between agriculture and forestry as in its judgment shall best subserve the interest of the State."

SEC. 3. This act shall take effect December first, nineteen hundred and ten. Approved November 11, 1910.

VIRGINIA.

CHAPTER 351.

AN ACT To constitute a united agricultural board to coordinate the Virginia College of Agriculture and Polytechnic Institute and the Virginia Agriculture Experiment Station, the commissioner and State board of agriculture, and the State board of education, in cooperation with the United States Department of Agriculture for the betterment of agricultural, experimental, and demonstration work, and generally to advance the agricultural interest of this State, and to authorize boards of supervisors to appropriate county funds for experimental and demonstration work in their respective counties.

Whereas experiments heretofore conducted have demonstrated that in order successfully to encourage the adoption of improved methods of agriculture in Virginia, applicable to every section, crop, and interest, it is necessary that experiment stations shall be located in the different agricultural districts of the State, which should ascertain by careful scientific experiments the best methods of crop rotation, fertilizing, culture, control of insect pests, and diseases, et cetera, of the crops most commonly grown, or which may be profitably grown in the respective districts, and that the facts so ascertained shall be carried by the teacher, institute lecturer, and demonstrator to the people; and

Whereas it is necessary to the fullest success of this plan that the said Virginia College of Agriculture and Polytechnic Institute, and the Virginia Agricultural Experiment Station, the commissioner and State board of agriculture, and the State board of education should unite their agencies in harmonious and determined efforts to advance by the methods above set forth, and in every other legitimate and practical way, the great agricultural interests of the State; and in order to coordinate harmoniously the efforts of these various State agencies in hearty cooperation with the United States Department of Agriculture which has been so successfully conducting its operations along these lines in Virginia: Therefore,

1. *Be it enacted by the General Assembly of Virginia*, That a board to be known as the united agricultural board be, and the same is hereby, established, to be composed of the governor; the State superintendent of public instruction, representing the State board of education; the commissioner of agriculture; and two members of the State board of agriculture, to be selected by that board; the president of the Virginia College of Agriculture and Polytechnic Institute; the director of the Virginia Agricultural Experiment Station; and one member of the board of visitors of those institutions, to be selected by the said board; the supervisor of the district experiment stations; the general director of demonstration work of the United States Department of Agriculture; and the Virginia director of demonstration work of the United States

[Bull. 241]

Department of Agriculture. The members of said board shall hold office during the term of incumbency of the several offices which render them ex officio members of this board, except that the State board of agriculture and the board of visitors of the Virginia College of Agriculture and Polytechnic Institute and Virginia Agricultural Experiment Station shall have power to elect a successor to its members of the board for two-year periods, beginning March first, nineteen hundred and ten, or in the interim whenever its member of the board is incapacitated from serving on said board by death, resignation, or otherwise. It is further provided, also, that the officials of the United States Department of Agriculture, herein designated as members of the board, shall continue in office so long as that department cooperates in the work for which the united agricultural board is established.

The officers of the board shall be the governor as chairman, and a secretary, to be elected by the board.

2. The members of the united agricultural board shall not be entitled to any compensation, but the Virginia members shall be reimbursed for their actual and necessary traveling expenses and hotel bills while engaged in the discharge of their duties, to be paid out of the funds hereinafter mentioned, allotted respectively to the State agencies entitled to membership on the board.

3. The united agricultural board shall, under such rules and regulations as it may prescribe, assign to the Virginia College of Agriculture and Polytechnic Institute the adult demonstration work and movable schools and other like agencies when established; to the Virginia Agricultural Experiment Station, under like rules and regulations, the establishment and direction of the local or district experiment stations; to the State board of education, under like rules and regulations, the experimental and demonstration work in connection with the public schools of the State; and to the commissioner and State board of agriculture, under like rules and regulations, the direction and management of the farmers' institutes to be held in the different sections of this State; and the said united agricultural board may adopt such other methods and agencies, not herein specifically enumerated, as shall tend to further the interests of agriculture, and assign to the various agencies represented on the united board such duties as may seem best.

4. For the purpose of carrying this bill into effect, in addition to the money allotted by the United States Department of Agriculture and the general education board, acting through the United States general director of demonstration work, and from other sources, the State board of education is hereby directed to appropriate and set apart out of the common school fund the sum of five thousand dollars annually; the sum of five thousand dollars shall be paid annually to the commissioner of agriculture; the sum of five thousand dollars shall be paid annually to the Virginia College of Agriculture and Polytechnic Institute; the sum of five thousand dollars shall be paid annually to the Virginia Agricultural Experiment Station, out of any fund in the treasury of the State not otherwise appropriated; said several sums of money to be paid by warrants authorized by the united agricultural board, signed by its secretary and countersigned by the chairman; provided, that all moneys appropriated under this act shall be used for the purposes of this act. But nothing in this act shall apply to any funds except those mentioned in this act. And the moneys allotted to the commissioner of agriculture shall be used for farmers' institutes; the moneys allotted to the Virginia College of Agriculture and Polytechnic Institute shall be used for adult demonstration work, movable schools, et cetera; and the money allotted to the Virginia Agricultural Experiment Station shall be used for experimental work at the local or district experiment station, established or to be established, and for no other pur-

pose; and the money appropriated by the State board of education shall be used for experiments and demonstration in connection with the schools of the State. An itemized statement, with all vouchers, shall be reported to the governor, and included in his annual report.

5. If it shall appear to the board that any of the work required by this act, or which shall be prescribed by the board, is not being faithfully and efficiently performed by the agency to which it is assigned, the board shall at once inquire into the matter and has the power to take action assigning said work to some other agency, or in any other way that may seem best for the faithful and efficient performance of said work. The moneys provided and appropriated under this act shall not be available prior to the twenty-eighth day of February, nineteen hundred and eleven.

6. The board may determine its own by-laws and rules of procedure, except that a meeting may be called at any time by the chairman on ten days' notice, and the secretary shall issue calls for a meeting of the members of the board, giving ten days' notice, upon request in writing of not less than five members, and it shall require a majority vote of the entire membership to pass any question or resolution coming before it. In case of a tie vote the governor shall be entitled to cast an additional deciding vote.

7. The boards of supervisors of the several counties of the State are hereby authorized and empowered to appropriate out of county funds for experimental and demonstration work in their respective counties such sums as the said boards shall deem proper, not to exceed twenty dollars for each one thousand inhabitants.

8. But nothing in this act shall apply to the Virginia Truck Experiment Station.

Approved, March 17, 1910.

WASHINGTON.

Section 192 of the session law of 1897 of the State of Washington, in defining the objects and purposes of the Washington Agricultural College and School of Science, declares that "one of the objects of said college shall be to hold farmers' institutes at such times and places and under such regulations as the board of regents may determine."

The Legislature of the State of Washington in 1909 appropriated \$17,500 to the State college of Washington for two years ending June 30, 1911, for extension work in agriculture.

WEST VIRGINIA.

The law under which farmers' institutes are held in West Virginia is that which established the State board of agriculture and prescribes its duties. The parts of the act relating to farmers' institutes are sections 5, 6, 7, 8, and 9, which are as follows:

SEC. 5. It shall be the duty of said board to look after and devise means of advancing the agricultural interests of the State; to promote and encourage as far as practicable the holding of farmers' institutes, the organization of agricultural and horticultural societies and other associations in the interest of agriculture in the several counties of the State.

It shall have charge of the preparation of manuscript, the printing, publishing, and distribution, by mail and otherwise, of such documents and reading matter

[Bull. 241]

as they may deem best for the agricultural interests of the State. And said board shall include in its publication the methods of farming in use, the variety of stock and crops grown, the special capacities and aptitude of the soils to the various products of the latitude and climate, the needs of the farmers, and such other matters as will convey a proper idea of the agricultural resources of the State to practical men. They shall have authority to request of any State official, or any official in any county, city, or town, any and all statistical and other information the board may desire. It is hereby made the duty of all State and county officers to assist in every way possible, and cooperate with the board, upon their request, to the end that the welfare and interest of agriculture may be promoted. It shall hold farmers' institutes for the instruction of the farmers of the State in the various branches of agriculture.

Such institutes shall be held at such times and places, in each year, as said board may direct. The said board shall make such orders and regulations as it may deem proper for organizing and conducting such institutes, and may employ an agent or agents to perform such work in connection therewith as they may deem best.

The course of instruction of such institutes shall be so arranged as to present to those in attendance the results of the most recent investigations in theoretical and practical farming.

SEC. 6. It shall be the duty of the secretary to attend all meetings of the board, keep a careful record of all their proceedings, in proper books, provided by the board, and keep on file all papers relating to the office.

To issue, under direction of the board, a monthly, a bimonthly, or quarterly publication, containing crop reports, agricultural statistics, and such other matter as the board may determine. He shall, before the assembling of each regular session of the legislature, compile a report giving a general review of agriculture, horticulture, and industrial resources of the State, with brief notices of each county, and the character of the public roads in the several counties, and how and by whom operated and kept in repair; the character of labor generally employed in the cultivation of the soil, and the prices paid therefor, and a report of the various institutes held during each year, and such other information as he is required to gather; and he shall have a sufficient number printed for the use of the legislature and for general distribution, and perform such other duties as the board may prescribe.

SEC. 7. The board shall report all its proceedings biennially to the governor, showing in detail the manner of its execution of the provisions of this act, which, together with the publication and report named in section six, and such incidental printing as may be necessary shall be printed by the public printer and paid for same as other public printing.

SEC. 8. The secretary shall have a permanent office at the capitol, under the control and supervision of the board, which shall be supplied and maintained at the expense of the State.

SEC. 9. A sum not exceeding three thousand dollars is hereby annually appropriated out of any funds in the treasury not otherwise appropriated for the support and maintenance of the board, including per diem of members, salary of secretary, necessary expenses of the board and secretary while attending meetings, and all other incidental expenses connected with and growing out of this department of the State government, which shall be paid on the order of the board, signed by the president and secretary.

While the law specifies that \$3,000 be appropriated for the department, the appropriation bill which is passed at each regular session of the legislature provides the funds for the work of the board

and takes precedence over all former bills. The annual appropriation at present is \$15,000, including the salaries, of which from \$8,000 to \$10,000 is set aside for institute work each year.

WISCONSIN.

WISCONSIN FARMERS' INSTITUTE LAW. CHAPTER 318. LAWS OF 1907.

AN ACT To amend section 1494b of the statutes of 1898, relating to farmers' institutes.

The people of the State of Wisconsin, represented in senate and assembly, do enact as follows:

SECTION 1. Section 1494b, statutes of eighteen hundred and ninety-eight, is amended as follows:

Section 1494b. The board of regents of the State university * * * shall hold at such time and places as they * * * may determine institutes for the instruction of the citizens of this State in the various branches of agriculture; the instruction given thereat shall be such as to present the results of the most recent investigations and experiments in theoretical and practical agriculture. They may make such rules and regulations as may be deemed proper for organizing and conducting such institutes and may employ an agent or agents to perform such work in connection therewith as they may direct. There shall not be used in any one year more than * * * twenty thousand dollars in paying the expense of, and such as are incident to, such institutes, which sum shall be payable from the general fund.

SEC. 2. This act shall take effect and be in force from and after its passage and publication.

Approved, June 31, 1907.

WYOMING.

CHAPTER 77. HOUSE BILL NO. 113, FARMERS' INSTITUTES.

AN ACT Authorizing the board of county commissioners of the several counties in the State to appropriate one hundred dollars per annum to defray the expense of holding farmers' institutes, under the supervision and with the cooperation of the University of Wyoming.

Be it enacted by the Legislature of the State of Wyoming:

SECTION 1. That the board of county commissioners of any county in Wyoming is hereby authorized, when they deem the same for the best interests of their county, to defray the local expense of holding a farmers' institute, under the supervision and with the cooperation of the University of Wyoming.

SEC. 2. No money shall be paid out of such appropriation for the services of any officers or local committees, in connection with any farmers' institute, or to any person or persons under pay by the University of Wyoming.

SEC. 3. Before any farmers' institute can take advantage of this appropriation, it shall be duly organized with a president, a secretary-treasurer, an executive board, consisting of not less than three members, and a signed membership of not less than thirty actual farmers; and no money shall be paid for the expense of any institute not held in cooperation with the said University of Wyoming.

SEC. 4. The money paid out under this act shall be upon warrants of the county authorizing the payment; such warrants to be drawn in favor of the treasurer of the institute, and upon a certificate of such local expense, which may include such expense as hall rent, advertising, hotel bills of speakers, and the expense of procuring speakers from a distance, who are not on the regular

[Bull. 241]

university institute staff; and such certificate to be signed and sworn to by said treasurer in the ordinary form of accounts against counties.

Sec. 5. This act shall take effect and be in force from and after its passage.
Approved, February 20, 1907.

FEDERAL LEGISLATION.

Direct Federal aid to farmers' institutes began with the act making appropriations for the Department of Agriculture for the fiscal year ended June 30, 1904, which provided "that five thousand dollars [of the sum appropriated for the Office of Experiment Stations] shall be used by the Secretary of Agriculture to investigate and report upon the organization and progress of farmers' institutes in the several States and Territories and upon similar organizations in foreign countries, with special suggestions of plans and methods for making such organizations more effective for the dissemination of the results of the work of the Department of Agriculture and the agricultural experiment stations and of improved methods of agricultural practice." Similar provisions have been continued in subsequent appropriation acts.

The appropriation act for the Department of Agriculture for the fiscal year ending June 30, 1912, contains the following clause providing for aid to farmers' institutes and agricultural schools:

To enable the Secretary of Agriculture to investigate and report upon the organization and progress of farmers' institutes and agricultural schools in the several States and Territories, and upon similar organizations in foreign countries, with special suggestions of plans and methods for making such organizations more effective for the dissemination of the results of the work of the Department of Agriculture and the agricultural experiment stations, and of improved methods of agricultural practice * * * \$10,000.

[Bull. 241]

O

U. S. DEPARTMENT OF AGRICULTURE.

OFFICE OF EXPERIMENT STATIONS—BULLETIN 242.

A. C. TRUE, Director.

COUNTY SCHOOLS OF AGRICULTURE AND
DOMESTIC ECONOMY IN WISCONSIN.

BY

A. A. JOHNSON,

*Principal La Crosse County School of Agriculture and
Domestic Economy.*WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1911.

LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
Washington, D. C., June 30, 1911.

SIR: I have the honor to transmit herewith a report by A. A. Johnson, principal of the La Crosse County School of Agriculture and Domestic Economy, on County Schools of Agriculture and Domestic Economy in Wisconsin. This report deals with the origin, equipment, organization, and work of these schools and also contains statistical data concerning their students, graduates, and income, and a reprint of the law providing for their establishment. A brief report under the same title was published in the annual report of this office for 1904 and has been in constant demand since that time. In order to supply more accurate information concerning these schools at the present time this fuller report has been secured and is recommended for publication as a bulletin of this office.

Respectfully,

A. C. TRUE, *Director.*

Hon. JAMES WILSON,
Secretary of Agriculture.

[Bull. 242]

(3)

CONTENTS.

	Page.
Introduction.....	5
Origin of the county schools of agriculture and domestic economy in Wisconsin.....	6
The Wisconsin type of school.....	6
Governing bodies.....	7
Points in common for all of the schools.....	8
Some ways in which these schools help the farmers.....	8
Marathon County School.....	8
Dunn County School.....	10
Winnebago County School.....	12
Marinette County School.....	14
La Crosse County School.....	16
Milwaukee County School.....	19
Statistical data.....	19
Secondary Agricultural Association.....	21
Legislation.....	22

ILLUSTRATIONS.

PLATES.	Page.
PLATE I. Fig. 1.—Cooking laboratory, Marathon County School, Wausau. Fig. 2.—Marathon County students removing stumps with dynamite.....	8
II. Fig. 1.—Students of the Dunn County School constructing a concrete silo. Fig. 2.—Students of Dunn County School raising the form for a concrete silo.....	10
III. Fig. 1.—Main building, Winnebago County School, Winneconne. Fig. 2.—Main building, Marinette School.....	12
IV. Fig. 1.—Main building, La Crosse County School, Onalaska. Fig. 2.—Machine sewing, La Crosse County School.....	16
V. Fig. 1.—Carpenter shop, La Crosse County School. Fig. 2.—Forge shop, La Crosse County School.....	16

TEXT FIGURE.

Fig. 1. Map showing location of county schools of agriculture and domestic economy in Wisconsin.....	7
[Bull. 242]	(4)

SECONDARY AGRICULTURAL EDUCATION IN WISCONSIN.

INTRODUCTION.

Probably no movement in education has received as much attention in the past few years as has that which pertains to the practical phases of farming and home making. The importance of this movement can easily be seen when consideration is given to the decreasing fertility of agricultural lands in the United States during the last 20 years and the relative decrease in farming population. From recent investigations it was found that probably 60,000,000 people live in cities and 31,000,000 remain on the farm, when only a few years ago the bulk of the population resided in the farming districts.

Formerly when free land was abundant and the soil fertile, little difficulty was experienced in the growing of crops. At that time, also, practically all the food and much of the clothing used by the farmer and his family were produced in the home, the homes themselves being built from trees in the neighboring forests. Now these conditions have changed materially. Most of the industries have been taken away from the farms and are now found in factories throughout the United States. And while these changes show advancement and this advancement is to be welcomed, at the same time it has taken away from the home a kind of training which is essential to the full development of the individual for successful home building. The realization of the educational loss occasioned by the transfer of these domestic industries to factories in cities and the growing need of something to take their place in the educational system, has brought about the establishment of practical schools of agriculture and domestic economy.

In many of the States throughout the Union thoughtful educators have come to realize the importance of developing the rural phases of industrial education. With this object in view many States have established and others are considering the establishment of secondary schools of agriculture and domestic economy. Of the more firmly established schools of this nature may be mentioned the congressional district agricultural schools of Georgia and Alabama, the judicial district agricultural schools of Oklahoma, the four district agricultural schools of Arkansas, the agricultural high schools of California, Minnesota, and New York, and the county agricultural schools of Wisconsin and Michigan. All these schools have one common object, that of dignifying farm labor and teaching boys and girls the industries which are now so rapidly vanishing in the rural homes of America.

ORIGIN OF THE COUNTY SCHOOLS OF AGRICULTURE AND DOMESTIC ECONOMY IN WISCONSIN.

Wisconsin was the first State in the Union to organize a county school of agriculture and domestic economy. The early history of secondary agricultural education in this State dates back to the winter of 1899, when the State legislature appointed Dr. L. D. Harvey, then State superintendent of public instruction, a commissioner, "to investigate and report upon the methods of procedure in this and other States and countries, in manual training and in the theories and arts of agriculture in the public schools." After a thorough investigation, a report was submitted to the governor of Wisconsin on January 1, 1901. This report covered the work done in secondary agricultural education in the various States of the Union, also different countries in Europe. At the conclusion of this report, Dr. Harvey recommended that, through legislative enactment, authority be given to county boards of supervisors to establish and maintain schools, to be known as county schools for instruction in agriculture and domestic economy, and that State aid be given to these schools when organized and established on a basis to be approved by State authority. He also recommended a course of study that he considered most suitable for these schools. Previous to the submitting of this report Dr. Harvey and ex-Governor Hoard gave several talks at farmers' institutes which resulted in creating a favorable impression for this kind of education in the State.

The legislature of 1901 passed a law embodying the recommendations of Dr. Harvey and permitting the establishment of two schools. This law has since been amended to permit the establishment of 10 schools and in its amended form is given on pages 22-24. In accordance with the amended law five schools have been established in the following places: Wausau, Marathon County; Menomonie, Dunn County; Winneconne, Winnebago County; Marinette, Marinette County; and Onalaska, La Crosse County. The supervisors of Milwaukee and Racine counties have voted to establish schools (fig. 1)

THE WISCONSIN TYPE OF SCHOOL.

Secondary agricultural education in Wisconsin is largely adapted to the conditions found in the counties where such schools are located. Special efforts are made to furnish additional opportunities for schooling to the 94 out of every 100 rural and urban school children who would otherwise finish their education with the common schools. These county schools are, strictly speaking, agricultural trade schools and have for their sole object the educating of the farmers' boys and girls who do not wish to take up an extensive college course, but who are anxious to get that form of training which will be most

useful to them when they take charge of the home farm or the farm home. The school is made the educational center of the community, and the farmers are free to call upon it for assistance in any line of work pertaining to farming and home making.

Unlike the congressional and judicial districts, the county is a taxable unit. These county schools are given their financial support by the county and the State, thus creating more local interest than



FIG. 1.—Map showing location of county schools of agriculture and domestic economy in Wisconsin.

do schools supported entirely by the State. Being of the trade-school type, these schools do not prepare students for the State university or the college of agriculture.

GOVERNING BODIES.

According to law, the governing bodies of these schools consist of three members, who form the county school board, two of them being elected by the county board of supervisors for a period of three

years. The county superintendent of schools is ex officio secretary of the school board. No member of the county board of supervisors is eligible for membership. These county school boards have charge and control of all matters relating to the organization, equipment, and arrangement of their respective schools, subject to the approval of the State superintendent of public instruction and the dean of the college of agriculture.

POINTS IN COMMON FOR ALL OF THE SCHOOLS.

The county agricultural schools of Wisconsin are coeducational. The course of study covers a period of two years of eight months each.

Each school receives support from the State amounting to \$4,000 a year.

All schools require for entrance that students shall have completed work equal to the eighth grade.

All schools admit students from outside of their respective counties. Institutes of various kinds are conducted at each of these schools.

SOME WAYS IN WHICH THESE SCHOOLS HELP THE FARMERS.

Prepare plans for farm buildings.

Make suggestions for remodeling old buildings.

Build forms for and supervise the construction of cement silos, watering troughs, and similar structures.

Test all kinds of dairy products.

Assist in the selecting of farm animals.

Plan drainage systems.

Test farm seeds for germination.

Test cattle for tuberculosis.

Test soils.

Recommend systems of rotation.

MARATHON COUNTY SCHOOL OF AGRICULTURE AND DOMESTIC ECONOMY.

Faculty: J. Frank Kadonsky, B. S., principal, agriculture (University of Wisconsin); Emma Connley, domestic economy (University of West Virginia); Ferdinand Schumacher, manual training (Northwestern College).

The school is located in the central part of the State, at Wausau, on the Wisconsin River, and was opened to students October 6, 1902. This county was once a dense forest, but has now been transformed into a fertile farming district. Health conditions are excellent.

The main building is a three-story brick structure 42 by 95 feet. The basement floor contains a carpenter shop, a laboratory, and a

[Bull. 242]



FIG. 1.—COOKING LABORATORY, MARATHON COUNTY SCHOOL, WAUSAU.



FIG. 2.—MARATHON COUNTY STUDENTS REMOVING STUMPS WITH DYNAMITE.

sewing room. On the second floor are located the assembly room, the kitchen (Pl. I, fig. 1), a recitation room, and the office. The third floor is used by the county training school for teachers. In addition to this building the school has an annex which contains a boiler room, a blacksmith shop, a creamery, and a greenhouse. A barn 30 by 40 feet was built by the students and is used for the housing of farm animals kept on the school farm.

The school has a small farm of 7 acres, which is utilized for demonstration work in the various phases of agriculture and horticulture (Pl. I, fig. 2).

Extension work is being done in the form of organizing agricultural clubs and conducting agricultural contests in the rural schools throughout the county.

Besides the regular course of two years, the school has a short course for more mature students.

AGRICULTURAL COURSE.

FIRST YEAR.

Fall term.	Winter term.	Spring term.
Plant culture.	Plant culture.	Farm crops.
Dairy cattle.	Farm crops.	Horses.
Manual training.	Dairying.	Manual training.
Drawing.	Farm poultry.	English.
English.	Manual training.	Bookkeeping.
Arithmetic.	Arithmetic.	
Music.	Drawing.	
	Literary society.	

SECOND YEAR.

Soil physics.	Soil fertility.	Fruit growing.
Stock feeding.	Forestry management.	Garden making.
Stock breeding.	Dairying.	Stock farming.
Manual training.	Manual training.	Manual training.
English.	English.	English.
Chemistry.	History.	History.
Parliamentary law.	Lecture course.	
Agricultural club.		

DOMESTIC SCIENCE COURSE.

FIRST YEAR.

Cooking.	Cooking.	Cooking.
Sewing.	Sewing.	Sewing.
Physiology.	Home economics.	Home economics.
English.	English.	English.
Arithmetic.	Arithmetic.	Bookkeeping.
General agriculture.	General agriculture.	General agriculture.
Music.	Drawing.	
	Literary society.	

SECOND YEAR.

Cooking.	Cooking.	Cooking.
Sewing.	Sewing.	Sewing.
Laundering.	Chemistry of foods.	Nursing.
English.	English.	English.
Chemistry.	History.	History.
General agriculture.	General agriculture.	General agriculture.
Parliamentary law.	Lecture course.	
Home economy club.		

DUNN COUNTY SCHOOL OF AGRICULTURE AND DOMESTIC ECONOMY.

Faculty: F. R. Crane, M. S., principal, field agriculture and horticulture (University of Illinois); L. H. Roehl, agricultural engineering (Stout Institute); Nellie Fitzgerald, domestic science (Stout Institute); G. A. Gilbert, B. S., animal and dairy husbandry (Michigan Agricultural College); Edith Lavake, academic department (Platteville Normal).

The Dunn County School of Agriculture and Domestic Economy is one of the two pioneer county agricultural schools of Wisconsin, and was opened to students in the fall of 1902. It is located in the heart of the city of Menomonie, in the northwestern part of the State. This school has become an important factor in the agricultural development of that section. Dr. L. D. Harvey and the late Hon. J. H. Stout, two of Wisconsin's most noted educators, have been mainly instrumental in the development of this institution. By their constant help, educationally and financially, this school has reached a prominent position in the State.

The Dunn County School has four buildings: The main building, the mechanical engineering building, the horticultural building, and the dairy building. The last three buildings are more or less connected, and are used entirely to demonstrate the practical phases of the instruction given. In them are found the carpenter shop, machine rooms, blacksmith shop, and laboratories for agronomy and horticulture. The dairy is run on a commercial basis, the students doing most of the work. This permits the learning of sanitary methods of handling milk and other dairy products. The school maintains a herd of 12 cows, which is used for exercises in live-stock judging as well as for dairy production.

The Dunn County School was the first in the Wisconsin system to lay stress on the practical and extension side of the instruction given. The faculty is made up of specialists, each one having charge of a department in the school and conducting instructional work among the farmers of the rural communities. The most notable feature of this extension work is that of building solid concrete silos (Pl. II). The forms for erecting the silos are loaned to the farmers at a very



FIG. 1.—STUDENTS OF THE DUNN COUNTY SCHOOL CONSTRUCTING A CONCRETE SILO.



FIG. 2.—STUDENTS OF THE DUNN COUNTY SCHOOL RAISING THE FORM FOR A CONCRETE SILO.

small cost. Twenty-four silos of solid concrete were erected in various parts of Dunn County during the year 1909 under the supervision of the school.

COURSE OF STUDY.

Junior year.

FIRST QUARTER.

Men.	Men and women.	Women.
Natural science.	English.	Cooking.
Dairy husbandry.	Mathematics.	Sewing.
Types of farm animals.		Food study.
Stock judging.		Household chemistry.
Wood shop.		Floriculture.
Concrete construction.		

SECOND QUARTER.

Natural science.	English.	Food study.
Stock judging.	Mathematics.	Cooking.
Dairy husbandry.	Bookkeeping.	Sewing.
Wood shop.		Darning and patching.
Types of farm animals.		
Mathematics (A).		

THIRD QUARTER.

Dairy husbandry.	English.	Food study.
Natural science.	Poultry.	Cooking.
Veterinary science.	Library reading.	Sewing.
Mathematics.	Physiology.	Wood shop.
Types of farm animals.		Millinery.
Stock judging.		
Wood shop.		

FOURTH QUARTER

Veterinary science.	English.	Cooking.
Blacksmith shop.	Poultry.	Sewing.
Mathematics (B).	Natural science.	Food study.
	Library reading.	Needlework.

Senior year.

FIRST QUARTER.

Comparative agriculture.	English.	Cooking.
Feeds and feeding.	Building.	Sewing.
Natural science.	Floriculture.	Household physics.
Stock judging.	Themes.	Millinery.
Mathematics		

SECOND QUARTER.

Building plans.	English.	Cooking.
Principles of breeding.		Sewing.
Natural science.		Laundrying.
Blacksmith shop.		Art needlework.
Power machinery.		Household management.
Stock judging.		Household bacteriology.
Dairy husbandry.		

[Bull. 242]

THIRD QUARTER.

Animal husbandry.	English.	Cooking.
Horticulture.	Natural science.	Sewing.
Spraying.	United States history.	Home nursing.
Blacksmith shop.	Themes.	Art needlework.
		Textiles.
		Food adulteration.

FOURTH QUARTER.

Stock judging.	English.	Cooking.
Animal husbandry.	Civics.	Sewing.
Dairy husbandry.	Landscape gardening.	House decoration.
Surveying.		
Field machinery.		

**THE WINNEBAGO COUNTY SCHOOL OF AGRICULTURE AND
DOMESTIC ECONOMY.**

Faculty: John M. Humphreys, B. S. A., principal, agriculture (University of Wisconsin); George R. Holton, manual training (Stout Institute); Frances R. Heller, domestic economy (Stout Institute); Lucinda C. Hotchkiss, academic subjects.

The Winnebago County School of Agriculture and Domestic Economy is located in the village of Winneconne, which is very near the geographical center of the county. This section is one of the oldest-settled portions of the State and its farming lands are as valuable as the best in the State. The Fox and Wolf Rivers furnish ample, though sluggish, drainage. Health conditions are excellent. The school was first opened to students in November, 1907.

The main building is constructed of brick and is a 30-room building, having all the laboratories necessary to do good work, recitation rooms, assembly hall, library, blacksmith and carpenter shops, plant house, kitchen, and sewing rooms. It is devoted entirely to the agricultural school and was erected at a cost of \$38,000 (Pl. III, fig. 1). A stable and live-stock judging pavilion is located near the main building, and serves as a laboratory for the study of the various types of farm animals. Its cost was \$1,200. There are 11 acres of farm land for demonstration work in connection with the school. One of the projects that is being developed there is the growing of shrubbery, which is eventually distributed to the rural schools of the county.

The course of study in the Winnebago School differs from those in the other schools in that it includes a preparatory year for students who are not far enough advanced to enter the regular work of the school.

{Bull. 242}



FIG. 1.—MAIN BUILDING, WINNEBAGO COUNTY SCHOOL, WINNECONNE.



FIG. 2.—MAIN BUILDING, MARINETTE SCHOOL.

ELEMENTARY COURSE OF ONE YEAR.

First semester:

Literature (5).
 Composition (5).
 American history (5).
 Arithmetic (5).
 Manual training—Men (5).
 Domestic science—Women (5).
 Spelling (3).
 Penmanship (2).

Second semester:

Commercial geography (5).
 Business composition (5).
 Civics (5).
 Farm arithmetic (5).
 Manual training (5).
 Domestic science (5).
 Spelling (3).
 Penmanship (2).

INDUSTRIAL COURSE OF TWO YEARS.

Junior year.

FIRST QUARTER.

Men.	Men and women.	Women.
Rudiments of veterinary science (5).	Horticulture (3 and 2d).	Cooking (3d).
Drafting (3d).	Farm arithmetic.	Sewing (2d).
Carpentering (3d).	Spelling (5).	Physiology (3).
	Penmanship (2).	

SECOND QUARTER.

Agronomy (2d).	Dairying (3d and 2d).	Cooking (3d).
Drafting (2d).	Farm arithmetic (5).	Sewing (2d).
Carpentry (4d).	Spelling (3).	Hygiene (3).
	Penmanship (2).	

THIRD QUARTER.

Dairying (3 and 2d).	Agronomy (3 and 2d).	Cooking (3d).
Farm mechanics (2d).	Business composition (5).	Sewing (2d).
Carpentry (4d).	Spelling (3).	Home nursing (3).
	Penmanship (2).	

FOURTH QUARTER.

Types of farm animals (5).	Chemistry (3 and 2d).	Cooking (3d).
Farm building (4d).	Business composition (5).	Sewing (2d).
Carpentry (2d).	Spelling (3).	Elective (3).
	Penmanship (2).	

Senior year.

FIRST QUARTER.

Feeds and feeding (5).	Bacteriology (3 and 2d).	Cooking (2d).
Cement work (3d).	Bookkeeping (5).	Sewing (3d).
Carpentry (3d).	Spelling (3).	Elective (3d).
	Penmanship (2).	

SECOND QUARTER.

Stock judging (3 and 2d).	Soils (3 and 2d).	Cooking (2d).
Blacksmithing (3d).	Bookkeeping (5).	Sewing (3d).
Carpentry (3d).	Spelling (3).	Food chemistry (3).
	Penmanship (2).	

THIRD QUARTER.

Stock judging (2d).	Soils (3d).	Cooking (2d).
Principles of breeding (3).	Trees and shrubs (2d).	Sewing (3d).
Blacksmithing (2d).	Commercial law (5).	Home management (3).
Farm mechanics (2d).		

FOURTH QUARTER.

Farm management (3).	Plant enemies (3).	Cooking and serving (2d).
Drainage (2d).	Horticulture (3d).	Sewing and millinery (3d).
Cabinet making (5d).	Thesis (2).	Laundrying (3)

TWO YEAR SHORT COURSE FOR MEN.**FIRST YEAR.****First half:**

Agronomy (3 and 2d).
 Dairying (3 and 2d).
 Drafting (2d)
 Farm arithmetic (5).
 Spelling.
 Penmanship.
 Carpentry (4d).

Second half:

Agronomy (3 and 2d).
 Dairying (3 and 2d).
 Farm mechanics (2d).
 Business composition (5).
 Spelling.
 Penmanship.
 Carpentry (4d).

SECOND YEAR.**First half:**

Soils (3 and 2d).
 Stock judging (3 and 2d).
 Blacksmithing (3d).
 Carpentry (3d).
 Bookkeeping (5).

Second half:

Soils (3).
 Trees and shrubs (2d).
 Judging (2d).
 Principles of breeding.
 Farm mechanics (3d).
 Commercial law (5).

NOTE.—Figures in parenthesis indicate the number of periods per week. Those marked "d" are double periods.

MARINETTE COUNTY SCHOOL OF AGRICULTURE AND DOMESTIC ECONOMY.

Faculty: L. R. Davis, B. S., principal, agriculture (University of Wisconsin); W. E. Morton, agricultural engineering (Oshkosh State Normal); Mildred McComb, academic subjects (Oshkosh State Normal); Mary Delziel, domestic economy (University of Chicago).

The Agricultural School of Marinette County is located in the city of Marinette on the Menominee River in the southeastern part of the county. This territory is in a transitory stage, the lumbering industry giving way to agricultural pursuits. The school is combined with the county training school for teachers, and together they are known as the Stephenson Training School, having been named in honor of United States Senator Isaac Stephenson of Wisconsin.

The building is an imposing structure of red brick with Bedford stone trimmings (Pl. III, fig. 2). It has two floors and a basement, and contains 24 rooms. The classrooms are supplied with the

[Bull. 242]

necessary books and apparatus for doing the most effective work, while the equipment in the laboratory and workshops is the latest and best. A beautiful school park is maintained which adds much to the appearance of the building.

Connected with the school is an experimental farm of 7 acres which is divided into plats and is used for demonstration purposes.

Literary and social entertainments are given throughout the year and tend to break the monotony of general school work.

COURSE OF STUDY.

FIRST TERM.

Men.	Men and women.	Women.
Types of animals (1).	Bacteriology (5).	Cooking (2).
Stock judging (1).	Spelling (5).	Sewing (3).
Horticulture (5).	Writing (5).	Textiles.
Mechanical drawing (2).		Food study.
Dairying (3).	English (5).	Personal hygiene.

SECOND TERM.

Types of animals (1).	Writing (5).	Cooking (2).
Stock judging (1).	Spelling (5).	Sewing (3).
Horticulture (5).	Arithmetic (5).	Physiology (5).
Dairying (3).		Laundering (1).
Cement work (2).		Food study (5).
Farm machinery (5).		Reading (5).

THIRD TERM.

Types of animals (1).	Spelling (5).	Cooking (2).
Stock judging (1).	Writing (5).	Sewing (3).
Horticulture (2).	English (5).	Food study (5).
Dairying (3).	Gardening (3).	Physiology (5).

Senior year.

FIRST TERM.

Animal breeding (1).	Spelling (5).	Cooking (2).
Stock judging (2).	Writing (5).	Sewing (3).
Veterinary science (3).	Chemistry (5).	Home economics (5).
Blacksmithing (5).	Business forms (5).	Dietetics (5).

SECOND TERM.

Animal breeding (1).	Writing (5).	Cooking (2).
Stock judging (2).	Spelling (5).	Sewing (3).
Feeds and feeding (3).		Physiology (5).
Agronomy (5).		Laundering (1).
Blacksmithing (2½).		Food study.
Mechanical drawing (1).		History (5).
Shopwork, ropework, and soldering (1½).		
Bookkeeping and rural accounts (5).		

[Bull. 242]

THIRD TERM.

Animal breeding (1).	Spelling (5).	Cooking (2).
Poultry (2).	Writing (5).	Sewing (3).
Soil physics (5).	Civil government (5).	Home economics (5).
Farm management (3).		Dietetics (5).
Mechanical drawing (2).		
Shopwork (3).		

SHORT COURSE.**JUNIOR YEAR.**

Types of animals (1).	Writing (5).	Cooking (2).
Stock judging (1).	Spelling (5).	Sewing (3).
Horticulture (5).	Arithmetic (5).	Physiology (5).
Dairying (3).		Laundrying (1).
Cement (3).		Food study (5).
Farm machinery (5).		Reading (5).

SENIOR YEAR.

Animal breeding (1).	Writing (5).	Cooking (2).
Stock judging (2).	Spelling (5).	Sewing (3).
Feeds and feeding (3).		Physiology (5).
Agronomy (5).		Laundrying (1).
Blacksmithing (2½).		Food study (5).
Mechanical drawing (1).		Reading (5).
Shopwork, ropework, and soldering (1½).		History (5).
Bookkeeping and rural ac- counts (5).		

NOTE.—Figures indicate number of periods per week.

LA CROSSE COUNTY SCHOOL OF AGRICULTURE AND DOMESTIC ECONOMY.

Faculty: A. A. Johnson, B. S., principal, agronomy (University of Wisconsin); Lucile W. Reynolds, domestic science (Stout Institute); P. L. Johnsrud, animal and dairy husbandry (University of Minnesota); Ethel R. Burnham, B. A., academic subjects (University of Wisconsin); W. E. Spreiter, agricultural engineering (University of Minnesota); Sarah Sutherland, B. S., domestic art (University of Wisconsin); E. E. Harris, laboratory assistant in horticulture; O. C. Hansen in charge of the dairy and tuberculin testing work.

The school is located in Onalaska, 4 miles from the city of La Crosse. It is situated in a large grove of oak trees, elevated enough to command a magnificent view of the Black and Mississippi Rivers and the Minnesota bluffs. Three railroads and one electric-car line make the city very accessible at all times.

The people of La Crosse County provided their school with a \$55,000 building, embodying all ideas of modern school architecture. The

[Bull. 242]



FIG. 1.--MAIN BUILDING, LA CROSSE COUNTY SCHOOL, ONALASKA.



FIG. 2.—MACHINE SEWING, LA CROSSE COUNTY SCHOOL.



FIG. 1.—CARPENTER SHOP, LA CROSSE COUNTY SCHOOL.



FIG. 2.—FORGE SHOP, LA CROSSE COUNTY SCHOOL.

building is constructed of vitrified brick and resembles in architectural design the English-Renaissance style (Pl. IV, fig. 1).

On October 9, 1909, the school was opened to students for the first time, and within two months it was crowded to its capacity, there being over 150 students enrolled.

The institution has well-equipped laboratories, the larger ones being the forge room, the carpenter shop, and the domestic science kitchen. The forge room contains 28 complete blacksmith outfits; the carpenter shop has 30 benches with all the necessary tools; and the kitchen, which is arranged to accommodate a class of 20 girls, is amply provided with modern apparatus. Besides the above-mentioned rooms there are the following laboratories: Chemistry and soils, dairy, two sewing rooms (Pl. IV, fig. 2), laundry, mechanical-drawing room, machine room, and conservatory, all of which are well equipped (Pl. V).

A demonstration farm of 30 acres lies within a stone's throw of the building. It is used for demonstration rather than experimental purposes.

A 2-acre athletic field is located in a natural amphitheater to the rear of the building. To the right is a double tennis court and an out-of-door basket-ball ground.

A band of 20 pieces and a military company of 65 boys equipped with rifles are features that tend to create much interest in school affairs. Besides the above may be mentioned the social, literary, and athletic organizations.

The financial support given to the school by the county since its beginning is *prima facie* evidence of the high esteem in which the school is held. This past year an increased appropriation of \$4,000 was added to the general fund for running expenses.

AGRICULTURAL COURSE.

Junior year.

FALL TERM.

Dairy husbandry (5).	Breeds of farm animals (5).
English (5).	Stock judging (5).
Farm arithmetic (5).	Physics (5).
Carpenter work (10).	Military drill (3).
	Physical training (2).

WINTER TERM.

Dairy sanitation and testing cattle for tuberculosis (5).	Physical training (2).
English (5).	Breeds of farm animals (5).
Farm arithmetic (5).	Stock judging (5).
Carpenter work (10).	Physics (5).
	Military drill (3)

[Bull. 242]

SPRING TERM.

Farm botany (5).	English (5).
Drainage and road construction (5).	Civics (5).
Farm machinery, including gas engines and steam traction engines (10).	Poultry, with the use of incubators (5).
	Military drill (3).
	Physical training (2).

*Senior year.***FALL TERM.**

Soil physics (5).	English (5).
Forge work (10).	Military drill (3).
Animal breeding (5).	Physical training (2).
Chemistry (5).	

WINTER TERM.

Soil physics (5).	Chemistry (5).
Forge work,	Mechanical drawing (5).
Soldering,	Blue-print making (5).
Pipe fitting,	English (3).
Babbitting,	Military drill (3).
Belt lacing,	Physical training (2).
Rope splicing,	

SPRING TERM.

Orcharding and spraying (5).	Farm management (5).
Feeding farm animals (5).	Concrete construction (5).
Field crops (5).	Military drill (3).
Birds and insects (5).	Physical training (2).

DOMESTIC SCIENCE COURSE.*Junior year.***FALL TERM.**

Cooking (10).	English (5).
Sewing (10).	Home arithmetic (5).
Food study (5).	Physical culture (5).

WINTER TERM.

Cooking (10).	English (5).
Sewing (10).	Home arithmetic (5).
Food study (5).	Physical training (5).

SPRING TERM.

Cooking (10).	Hat trimming (3).
Sewing (10).	Floriculture and vegetable gardening (5).
English (5).	Physical culture (5).
Laundering (2).	

[Bull. 242]

*Senior year.***FALL TERM.**

Cooking (10).
Sewing (10).
English (5).

Household management (5).
Physical culture (5).

WINTER TERM.

Cooking (10).
Sewing (10).
English (5).

Care of the sick and emergencies (5).
Physical culture (5).

SPRING TERM.

Cooking (10).
Sewing (10).
Woodwork (5).

Household art (5).
Physical culture (5).

NOTE.—Figures indicate the number of recitation periods per week.

MILWAUKEE COUNTY SCHOOL OF AGRICULTURE AND DOMESTIC ECONOMY.

From present indications Milwaukee County will probably have one of the largest and best-equipped schools of agriculture and domestic economy in the country. The county has purchased 400 acres of land, costing \$110,000, for a school site and farm.

Plans have also been completed for the erection of buildings costing approximately \$200,000, work to begin in the fall of 1911.

Milwaukee County has a somewhat different problem to solve than the other schools of this kind in the State. The main object will be to relieve the congested conditions of the city of Milwaukee by encouraging residents to study some form of farming, probably gardening, on their city property, thus creating in them a desire for out-of-door life and stimulating them to extend their farming interests to larger fields of labor.

STATISTICAL DATA.

Statistics of the counties having agricultural schools.

County.	Area in square miles.	Population, 1910.	Assessed valuation, 1910.	Estimated value of agricultural school buildings.	Cost of maintenance of schools for 1909-10.
Marathon.....	1,532	55,054	\$48,676,639	\$20,000	\$5,933.95
Dunn.....	844	25,260	23,197,434	30,000	10,425.70
Winnebago.....	472	62,116	69,786,562	40,000	7,044.56
Marquette.....	1,396	33,812	27,666,322	20,000	7,158.00
La Crosse.....	475	43,996	42,233,185	60,000	14,281.02
Milwaukee.....	228	433,187	540,484,848	.....	.....
Racine.....	323	57,424	69,292,905	.....	.....

[Bull. 242]

Appropriations for county schools of agriculture and domestic economy.

Purpose.	Marathon County School.			Dunn County School.			Winnebago County School.		
	County.	State.	Total.	County.	State.	Total.	County.	State.	Total.
(1) Maintenance since organization:									
1902-3.....	\$2,000	\$4,000	\$6,000	\$8,535	\$4,000	\$12,535			
1903-4.....	2,000	4,000	6,000	2,500	4,000	6,500			
1904-5.....	2,000	4,000	6,000	4,000	4,000	8,000			
1905-6.....	2,000	4,000	6,000	4,000	4,000	8,000			
1906-7.....	2,000	4,000	6,000	2,000	4,000	6,000			
1907-8.....	2,000	4,000	6,000	2,750	4,000	6,750	\$2,000	\$4,000	\$6,000
1908-9.....	2,000	4,000	6,000	4,500	4,000	8,500	2,100	4,000	6,100
1909-10.....	2,000	4,000	6,000	6,150	4,000	10,150	2,800	4,000	6,800
1910-11.....	2,000	4,000	6,000	6,200	4,000	10,200	4,500	4,000	8,500
Total.....	18,000	36,000	54,000	40,635	36,000	76,635	11,400	16,000	27,400
(2) Buildings.....	20,000		20,000	20,000		20,000	40,000		40,000
Total.....	38,000	30,000	74,000	60,635	36,000	106,635	51,400	16,000	67,400

Purpose.	Marquette County School.			La Crosse County School.			Milwaukee County School.		
	County.	State.	Total.	County.	State.	Total.	County.	State.	Total.
(1) Maintenance since organization:									
1907-8.....	\$3,195	\$4,000	\$7,195						
1908-9.....	2,000	4,000	6,000						
1909-10.....	2,250	4,000	6,250	\$9,000	\$4,000	\$13,000			
1910-11.....	2,500	4,000	6,500	13,000	4,000	17,000			
Total.....	9,945	16,000	25,945	22,000	8,000	30,000			
(2) Buildings.....	20,000		20,000	60,000		60,000			
Total.....	29,945	16,000	45,945	82,000	8,000	90,000			

¹ Including a deficit from two previous years.

² Including \$10,000 from private sources.

³ Half the amount appropriated for the two schools forming the Stephenson Training School.

Enrollment in county schools of agriculture and domestic economy.

Year.	Marathon County School.			Dunn County School.			Winnebago County School.		
	Boys.	Girls.	Total.	Boys.	Girls.	Total.	Boys.	Girls.	Total.
1902-3.....	18	57	75	137	126	263			
1903-4.....	19	34	53	45	34	79			
1904-5.....	24	31	55	46	27	73			
1905-6.....	23	38	61	27	38	65			
1906-7.....	19	37	56	37	39	76			
1907-8.....	29	34	63	37	27	64	39	19	58
1908-9.....	34	37	71	144	135	279	35	27	62
1909-10.....	17	32	49	47	46	93	42	36	78
1910-11.....	17	34	51	152	132	284	50	18	68
Total.....	200	334	534	372	304	676	166	100	266

¹ Estimated.

[Bull. 242]

Enrollment in county schools of agriculture and domestic economy—Continued.

Year.	Marinette County School.			La Crosse County School.			Milwaukee County School.		
	Boys.	Girls.	Total.	Boys.	Girls.	Total.	Boys.	Girls.	Total.
1907-8.....	13	17	30						
1908-9.....	32	43	75						
1909-10.....	16	25	41	87	70	157			
1910-11.....	11	31	42	88	65	153			
Total.....	72	116	188	175	135	310			

Graduates¹ from county schools of agriculture and domestic economy.

Year.	Marathon County School.			Dunn County School.			Winnebago County School.		
	Boys.	Girls.	Total.	Boys.	Girls.	Total.	Boys.	Girls.	Total.
1902-3.....									
1903-4.....	1	1	2	15	6	21			
1904-5.....	2	6	8	13	6	19			
1905-6.....	5	5	10	8	7	15			
1906-7.....	7	7	14	9	9	18			
1907-8.....	1	8	9	16	6	22			
1908-9.....	6	7	13	13	6	19	13	11	24
1909-10.....	3	5	8	13	8	21	8	8	16
1910-11.....	1	8	9	9	10	19	7	8	15
Total ²	26	47	73	96	58	154	28	27	55

Year.	Marinette County School.			La Crosse County School.			Milwaukee County School.		
	Boys.	Girls.	Total.	Boys.	Girls.	Total.	Boys.	Girls.	Total.
1907-8.....									
1908-9.....	4	7	11						
1909-10.....	6	5	11						
1910-11.....	2	6	8	31	32	63			
Total ³	12	18	30	31	32	63			

¹ All schools but the La Crosse County School give short courses, and the short-course graduates are included in the graduates given.

² Estimated.

³ About 90 per cent of the graduates return to some form of practical work, as the farm, home, or shop.

SECONDARY AGRICULTURAL ASSOCIATION.

Faculties of each of the county agricultural schools are members of the National Secondary Agricultural Educational Association, which had its origin in the State of Wisconsin some years ago. This association, while still young, has a membership composed of educators from many States.

At the last meeting held at Winneconne, Wis., Principal A. A. Johnson, of the La Crosse County School of Agriculture and Domestic Economy, was elected president for the ensuing year.

[Bull. 242]

LEGISLATION.

The law providing for the establishment and maintenance of the schools is in its amended form as follows:

HOW ORGANIZED. (Chap. 313, laws of 1909, amending chap. 288, laws of 1901.) SECTION 553c. 1. The county board of any county is hereby authorized to appropriate money for the organization, equipment, and maintenance of a county school of agriculture and domestic economy. The county boards of two or more counties may unite in establishing such a school and may appropriate money for its organization, equipment, and maintenance.

2. Immediately after the county board or county boards shall vote to establish a county school of agriculture and domestic economy, the county clerk or clerks of such county or counties, shall notify the dean of the college of agriculture of such vote for the establishment of such school.

3. The dean of the college of agriculture, the State superintendent of public instruction, and the president of the board of agriculture, acting as a committee for such purpose, shall decide upon and notify the county board or boards as to the proper location for such county school of agriculture and domestic economy and the county school of agriculture and domestic economy shall be located at such place as is determined upon by such committee.

SECTION 553l. 1. Any school established under the provisions of this act, whose course of study and qualifications of whose teachers have been approved by the State superintendent and the dean of the college of agriculture may, upon application, be placed upon an approved list of county schools of agriculture and domestic economy. A school once entered upon such list may remain listed and be entitled to State aid so long as the scope and character of its work are maintained in such manner as to meet the approval of the State superintendent; provided that he shall not place upon said list more than ten schools.

2. On the first day of July in each year the secretary of each county school board maintaining a school on the approved list, shall report to the State superintendent, setting forth the facts relating to the cost of maintaining the school, the character of the work done, the number of and names of teachers employed, and such other matters as may be required by the county board or the State superintendent. Upon the receipt of such report, if it shall appear that the school has been maintained in a satisfactory manner for a period of not less than eight months during the year closing on the thirtieth day of the preceding June, the said superintendent shall make a certificate to that effect and file it with the secretary of state.

3. Upon receiving such certificate, the secretary of state shall draw his warrant, payable to the treasurer of the county maintaining such school, for a sum equal to two-thirds the amount actually expended for maintaining such school during the year; provided, that the total amounts so apportioned shall not exceed four thousand dollars to any one school in any one year; when more than one county has contributed to the support of the school, the secretary of state shall draw his warrant payable to the treasurer of each county for such portion of the State aid as the amount contributed by his county is part of the total amount contributed by all the counties for the support of the school for the preceding year. The secretary of state shall annually include and apportion in the State tax such sum as shall have been so paid.

SEC. 2. (Chapter 288, laws of 1901). A board to be known as the county school board is hereby created, which shall have charge and control of all matters pertaining to the organization, equipment, and maintenance of such school, except as otherwise provided by law. Said board shall consist of three members, one of whom shall be the county superintendent of schools of the county or district in which the school is located. The other members of the board shall be elected by the county board for the

term of three years from the date of their election, but no member of the county board shall be eligible. Vacancies existing in the board from whatever cause, except in the case of the county superintendent, shall be filled by appointment made by the chairman of the county board, if the county board is not in session when such vacancy occurs. If the county board is in session, vacancies shall be filled by election by said board for the unexpired term. Appointments made by the chairman of the county board, as hereinbefore specified, shall be for the term elapsed until the next regular meeting of the county board. Each person appointed or created a member of the county school board, shall within ten days after the notice of such appointment, take and subscribe an oath, to support the Constitution of the United States and the constitution of Wisconsin, and honestly and faithfully, and impartially to discharge his duties as a member of said board to the best of his ability, which oath shall be filed in the office of the county clerk. He shall also, within the same time, file a bond in such sum as may be fixed by the county board, which bond shall be filed in the office of the county clerk. Within fifteen days after the appointment of said board, the members thereof shall meet and organize by electing one of their number as president. The county superintendent of schools shall be ex officio secretary of the said board. The said board shall prescribe the duties of the several officers, except as fixed by law.

SEC. 3. Whenever two or more counties unite in establishing such a school, the provisions of section 2 of this act shall apply to the organization of the county school board, and to filling vacancies therein, provided that the county superintendent of the county in which the school is located shall be a member of the board and ex officio secretary, and two members shall also be elected from each county by the county board thereof. But no member of the county board shall be eligible.

SEC. 4. Whenever two or more counties unite in establishing and maintaining such school, the county school board provided for in such cases shall determine the amount of money necessary for the equipment and maintenance of the school for the second year, and annually each year thereafter; they shall apportion the amount to be raised by taxation among the counties in proportion to the assessed valuation of each county as last fixed by the State board of assessment, and shall report to the county clerk of each county the apportionment so made on or before the first Monday of November in each year. The amount so apportioned to each county shall be levied in the county tax for the ensuing year for the support of the school.

SEC. 5. The county treasurer shall be ex officio treasurer of said board; all moneys appropriated and expended under the provisions of this act shall be expended by the county board, and shall be paid by the county treasurer or treasurers on orders issued by said board, and all moneys received by said board shall be paid to the county treasurer for the fund of the county school board.

SEC. 6. In all county schools of agriculture and domestic economy organized under the provisions of this act, instruction shall be given in the elements of agriculture, including instruction concerning the soil, the plant life, and the animal life of the farm; a system of farm accounts shall also be taught; instruction shall also be given in manual training and domestic economy, and such other subjects as may be prescribed.

SEC. 7. Each school shall have connected with it a tract of land suitable for purposes of experiment and demonstration, and not less than three acres in area.

SEC. 8. The schools organized under the provisions of this act shall be free to inhabitants of the county or counties contributing to their support, who shall be qualified to pursue the course of study, provided they shall have at least the qualifications required for completion of the course of study for common schools. Whenever students of advanced age desire admission to the school during the winter months in sufficient number to warrant the organization of special classes for their instruction, such classes shall be organized and continued for such time as their attendance may make necessary.

[Bull. 242]

Sec. 9. The State superintendent shall give such information and assistance and establish such requirements as may seem necessary for the proper organization and maintenance of such schools. With the advice of the dean of the college of agriculture of the State university, he shall prescribe the courses of study to be pursued, and determine the qualifications required of teachers employed in such schools. He shall have the general supervision of all schools established under this act; shall from time to time inspect the same, make such recommendations relating to their management as he may deem necessary, and make such report thereon as shall give full information concerning their number, character, and efficiency.

[Bull. 242]

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U. S. DEPARTMENT OF AGRICULTURE.

OFFICE OF EXPERIMENT STATIONS—BULLETIN 243.

A. C. TRUE, Director.

LAND DRAINAGE BY MEANS
OF PUMPS.

BY

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Drainage Engineer, Drainage Investigations.

PREPARED UNDER THE DIRECTION OF

C. G. ELLIOTT,

Chief of Drainage Investigations.

WASHINGTON:
GOVERNMENT PRINTING OFFICE,
1911,

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(2)

[Bull. 243]

LETTER OF TRANSMITTAL

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
Washington, D. C., January 27, 1911.

SIR: I have the honor to transmit herewith a manuscript on Land Drainage by Means of Pumps, by S. M. Woodward, professor of hydraulics, Iowa State University. This bulletin is based upon information obtained from numerous sources, among which are: Inspections of and reports upon the drainage pumping districts in Illinois, made by John T. Stewart in 1904, by G. A. Griffin in 1908, and by S. M. Woodward in 1910, all of whom have been connected with the staff of this office; data and descriptions furnished by various landowners and district officials, especially by Mr. Jacob A. Harman, of Peoria, Ill., whose long and intimate detailed acquaintance with drainage work and conditions on the Illinois River has especially qualified him to furnish extensive and exact information relating to that region, and various publications of this office.

This subject has come to be one of great importance in the development of large tracts of overflow and swamp lands and one upon which heretofore there has been little published information. I therefore recommend that this manuscript be published as Bulletin No. 243 of this office.

Very respectfully,

A. C. TRUE,
Director.

Hon. JAMES WILSON,
Secretary of Agriculture.

(3)

[Bull. 243]

CONTENTS.

	Page.
Introduction.....	7
Effectiveness of drainage reclamation.....	8
Drainage pumping in northern Europe.....	10
Past experience in the United States.....	11
Pumping in the upper Mississippi Valley.....	12
Size of pumping districts.....	13
Levees.....	13
Interior drainage ditches.....	16
Gravity sluiceways.....	20
Necessary capacity of pumping machinery.....	21
Location of pumping plant.....	29
Types of pumping machinery.....	30
Kind of pump.....	31
Sources of power.....	32
Kind of engine.....	33
Auxiliaries.....	33
Calculation of the size of pumping plant.....	33
Buildings and foundations.....	36
Arrangement of suction and discharge piping.....	36
Cost of pumping.....	40
Relative benefits of drainage by pumping.....	42
Summary.....	43

ILLUSTRATIONS.

PLATES.

	Page.
PLATE I. Fig. 1.—Crop of 1910, Coal Creek drainage and levee district. Fig. 2.—Hood Basin, Coal Creek drainage and levee district.....	12
II. Fig. 1.—Main ditch, Coal Creek drainage and levee district. Fig. 2.—Branch A, Coal Creek drainage and levee district.....	20
III. Fig. 1.—Pumping plant, Coal Creek drainage and levee district. Fig. 2.—Ends of outlet pipes, Coal Creek drainage and levee district.....	36
IV. Fig. 1.—Pumping plant, Louisa-Des Moines drainage district. Fig. 2.—Engine room, Louisa-Des Moines drainage district.....	40
V. Fig. 1.—Rear of pumping plant, Louisa-Des Moines drainage district. Fig. 2.—Suction bay, Louisa-Des Moines drainage district.....	40

TEXT FIGURES.

FIG. 1. Map of Coal Creek drainage and levee district, Illinois.....	17
2. Sketch plan of pumping plant, Coal Creek drainage and levee district, Illinois.....	36
3. Plan and elevation of pumping plant, Louisa-Des Moines drainage district No. 4, Iowa.....	39

[Bull. 243]

(6)

LAND DRAINAGE BY MEANS OF PUMPS.

INTRODUCTION.

The drainage of low-lying lands by the use of pumping machinery to lift the drainage water over levees into adjacent streams or other drainage channels is a recent development in this country. Along the banks of many of our larger interior rivers considerable areas of bottom land are subject to overflow from the adjacent streams during the high water occurring usually with great regularity throughout the spring and early summer months. Such lands in their native state do not become dry enough to be subject to ordinary cultural operations until well toward the middle of the summer, and hence can not generally be used for growing ordinary crops. They can, therefore, in this natural condition be used for nothing but pasture and have accordingly but little agricultural value.

Similarly, extensive marshy areas along our coasts may be for a part of the time above water level, but are subject to overflow at high tide, especially during spring tides and when the river channels which form their natural drainage outlets are in flood. All such low lands are, in general, formed by alluvial deposit and possess a high degree of fertility when relieved of their excess of water and changed from their original saturated condition to a degree of moisture content suitable for ordinary dry-land crops.

As a physical proposition it is possible to reclaim all such areas for agriculture by first constructing levees to keep them from being overflowed, and then, where necessary, by installing pumping plants to pump out from the interior of the district the excess rainfall and such water as may seep through or under the levees in injurious amounts. But as such work is expensive both for the first construction and for its subsequent maintenance and operation, the really difficult and fundamental question for the landowner is, whether the value of the land, after its reclamation, will be sufficient to justify the expenditures necessary to carry out the work.

So long as there exists in a locality any unoccupied or unutilized higher land suitable for agriculture there is little demand for the use of lands lying so low as to require drainage by pumps. But the present high price of agricultural land justifies a heavy expenditure

for the conversion to a productive state of areas formerly considered almost valueless, especially in those regions where agricultural land values are particularly high, either on account of unusually favorable natural conditions or the proximity of large centers of population.

EFFECTIVENESS OF DRAINAGE RECLAMATION.

Some areas are so favorably situated that, when once protected by levees from inundation, satisfactory interior drainage without the use of pumps may be secured by a natural or gravity flow of their drainage waters, either through sluice gates or through ditches or natural streams other than those producing the overflow. Examples of such lands are many tidal marshes and the vast areas in Arkansas, Mississippi, and northern Louisiana, where the land, protected from the Mississippi River by great levees, has good gravity drainage outlets through other streams.

But most overflowed lands are not so fortunately located. Ordinarily, in addition to a protective levee system a pumping plant is required for lifting the interior drainage water out over the levee. In fact, numerous cases may be found in which, when the levee system was first constructed, reliance was placed solely upon gravity outlets for disposing of the interior drainage water, but subsequent experience showed that by this means alone satisfactory reclamation of the land could not be secured; hence, a supplementary pumping plant, not contemplated in the original plans, was later installed.

The two characteristics which any agricultural drainage project must possess for its perfect success are, first, effectiveness, and, second, profitableness. If an elaborate plan for drainage improvement, when actually carried out, fails to drain the land sufficiently to secure a satisfactory cultivable condition the project is a failure. In fact, it is even worse than a failure, for not only may it mean an actual financial loss to its owners, but as an example may discourage others from undertaking other meritorious projects. So vital is it to secure adequate drainage, if any work at all is undertaken, it would seem that everyone connected with such work would appreciate its importance. Yet almost innumerable instances can be found where drainage improvements have been planned and constructed on a scale entirely too small to secure efficient results, and where those responsible for carrying out the work should have known in advance that the benefits resulting from their misdirected efforts would not be commensurate with the expenditures incurred.

It is characteristic of almost all artificial drainage improvement that, if a certain amount of work is needed, the actual construction of a part only of the whole work will not produce a correspondingly

[Bull. 248]

proportionate benefit. That is, if only one-half of the needed work is carried out much less than one-half of the full benefit will be obtained. It is, perhaps, approximately true that the carrying out of three-fourths of the needed work would yield one-fourth of the total benefit. The last one-fourth of the work produces perhaps three-fourths of the benefit. It is on account of this relation that the original planning of all drainage work on a sufficiently comprehensive and adequate scale is so important.

Naturally those who have had no experience in constructing drainage improvements can have little comprehension of the innumerable difficulties and obstacles that may arise in the construction of extensive work and in its operation after completion; and, too often, when they have the responsible charge of such work, they are prone to refuse to accept the advice of others who have had extended experience. There are still intricate problems and baffling uncertainties, numerous enough, in securing drainage in difficult situations, but there would seem to be no excuse nowadays for undertaking important work in violation of fundamental principles of drainage science well known to every experienced worker in this field of engineering.

It is not alone sufficient, however, that the drainage work as constructed shall secure the desired benefit. The work must be done economically and in such a way as to secure the greatest profit to the landowner. Several quite different plans for the drainage of a given district might secure equally well the desired improvement. In such a case that plan should be chosen which will prove cheapest in the long run, and to determine the best and cheapest plan is the special province of the engineer. The engineer has been defined as a person who can do with one dollar what anyone else can with two. One of the first steps taken in beginning a large drainage project should be to secure the services of a competent and experienced engineer. Such a man is needed to make the necessary surveys and plans for the work; to make inspections and estimates during construction; and, when a pumping plant is a part of the work, to test the completed plant to see that it complies with the specifications and meets the guaranties of capacity and efficiency. He is needed also to advise as to the most economical and efficient operation of the plant after its completion and as to its management, maintenance, and care.

Drainage by means of pumps has been carried on in European countries for the last 100 years and has been rapidly increasing in this country during the last 25 years. Through this extensive experience, including numerous failures, a considerable amount of knowledge is now available on the subject of the proper arrangement and the requisite capacity of pumping plants. It is the object of this

bulletin to discuss the various questions arising in connection with the reclamation of agricultural land by means of pumps in order that the conclusions drawn from experience may be available to all landowners, district officers, and drainage engineers who are interested in this kind of drainage.

DRAINAGE PUMPING IN NORTHERN EUROPE.

Draining with the aid of pumps or what may be termed "lift drainage" is required for large areas of productive agricultural land in Europe. Notable examples of successful work of this character are found in Holland, eastern England, and in Ireland, while large marsh areas in both northern and southern Italy depend upon pumps for adequate drainage. The development of mechanical means of removing water from the land has in most instances been forced upon landowners when gravity drainage failed to give sufficient relief, and for that reason the movement was slow, particularly in the early history of such drainage. The pumps which were first used were the well-known scoop wheel and the Archimedean screws, which were driven by windmills.

The Zuidplas polder of Holland, containing 10,363 acres, lies 22 feet below the level of the River Yssel, into which it is drained. In 1825 the basin was drained by dividing it by a canal into two parts and raising the water into the river by two lifts, the first or lower lift being accomplished by 15 windmills driving 8 Archimedean screws and 7 scoop wheels. For the upper lift there were 15 windmills driving 10 screws and 5 wheels. These were later supplanted by two pairs of pumping stations, each having scoop wheels and centrifugal pumps, all driven by steam, by which means the drainage of the entire tract is now accomplished.

The great Haarlem Lake of Holland is often referred to as the most remarkable pumping drainage project known. The total area of the tract, which is now surrounded by a canal 37 miles long, is 41,648 acres, 3,011 of which are occupied by roads and main waterways. The water in this lake, which originally was 15 feet deep, was removed by pumps in 1852, 39 months having been occupied in removing the water. It is kept drained by three immense pumping plants of 350 horsepower each, located at opposite sides and at one end of the great basin. The combined capacity of the three plants is nearly 2,000 tons of water per minute raised to a height of approximately 15 feet. The area which was formerly a lake is now traversed by well-improved highways and is occupied by about 20,000 people.

The drainage of large portions of the fenlands in eastern England was originally accomplished by means of scoop wheels operated by

[Bull. 243]

windmills. It was not an uncommon occurrence for the districts to be inundated, because of the failure of the pumps to operate when required to remove the water. Losses from this cause became so great that the several plants were gradually equipped with steam power, which rendered the drainage of the land much more certain than under the old system.

Mr. W. H. Wheeler, in his "History of the Fens of South Lincolnshire," states that the entire fens known by that name cover about 363,000 acres, of which about 85,000 acres are from 6 to 12 feet below high-water level, and that 124,600 acres of this area are drained by steam power. The pump originally used was the large scoop wheel which is still operated in many of the plants, but the centrifugal pump is gradually being introduced as being better suited to the conditions which now prevail. The same author in his book entitled "The Drainage of Fens and Low Lands," enumerates 13 distinct districts having areas varying from 800 acres to 35,000 acres which are now drained by steam plants which operate either the improved scoop wheel or the more modern centrifugal pump.

From available data it appears that not less than 203,000 acres of lowland in eastern England depend upon pumps for their drainage. The efficiency of these plants has from time to time been greatly increased until it is now estimated that the average cost of pumping in eastern England is 2 cents per acre for each foot the water is raised.

The conditions which are found in Europe are in many respects different from those we are required to meet in this country. The history of drainage by pumping, however, during the last 100 years shows a gratifying and substantial development of mechanical devices and the utilization of power for draining, and establishes beyond question the practicability of this kind of reclamation. The experience and practice of northern Europe are exceedingly valuable to those who contemplate the design and construction of works of this class, a study of which should prevent us from falling into certain errors which have at times been expensive and discouraging to European enterprise in land development.

PAST EXPERIENCE IN THE UNITED STATES.

In this country, among the plantations in the lowlands along the Gulf of Mexico, pumping has been in vogue for a long time, especially for the drainage of lands devoted to the cultivation of sugar cane. More recently pumping has been extensively introduced in the bottom lands lying along the Illinois River and the adjacent portions of the Mississippi. Along the Illinois, though pumping was first tried about 20 years ago, little had been accomplished previous to 1900. Since 1905, however, numerous large plants have been con-

structed, and in the spring of 1910 ten separate plants were in operation pumping the drainage water from a total area of about 85,000 acres. These plants have a combined capacity of about 2,000 horsepower and represent an investment for machinery alone of some \$150,000. There are under construction three additional plants to provide for about 33,000 acres more of land.

Along the Mississippi River, between Muscatine, Iowa, and Hannibal, Mo., there are in operation or nearing completion six large pumping plants planned to be able to pump the drainage water from 150,000 acres. In Illinois, along the Illinois River, the greater part of the bottom land has already been thus reclaimed. In other States the movement is just beginning, and it is now evident, from the numerous inquiries for information, that there exists at the present time a very active and widespread interest in this whole question.

The experience of those who undertake projects for pumping drainage water, without previous experience in similar work or full and accurate knowledge of what has been accomplished elsewhere, shows that invariably they greatly underestimate the magnitude and difficulties of the work contemplated. In this regard their experience is identical with that of those who have been pioneers in other forms of agricultural drainage work. As a consequence the first pumping plants were entirely inadequate in capacity, inefficient in operation, and largely a waste of the money invested in them. In numerous cases they have been added to or entirely replaced by the building of new plants. Some of the recent large plants, however, with their ample and economical machinery, are models of convenient arrangement, permanence, and durability.

In the upper Mississippi Valley the various conditions prevailing, such as intensity and distribution of rainfall, length of growing season, and kinds of crops raised, differ widely from those obtaining near the Gulf of Mexico in Louisiana, leading to correspondingly wide variations in recent drainage practice. The former situation will here be taken up in detail and the planning of districts, the requisite sizes and kinds of machinery, the first cost, and the cost of maintenance will be discussed. The situation in Louisiana is dealt with in a previous publication of the office.¹

PUMPING IN THE UPPER MISSISSIPPI VALLEY.

In Illinois and the adjacent States, the bottom lands which have been reclaimed by pumping are in the heart of the corn belt and possess a heavy, rich black soil, mixed in places with a varying amount of sand. They are adjacent to thickly populated lands, the best of which is worth \$150 per acre, and in some cases lies within a few



FIG. 1.—CROP OF 1910, COAL CREEK DRAINAGE AND LEVEE DISTRICT.

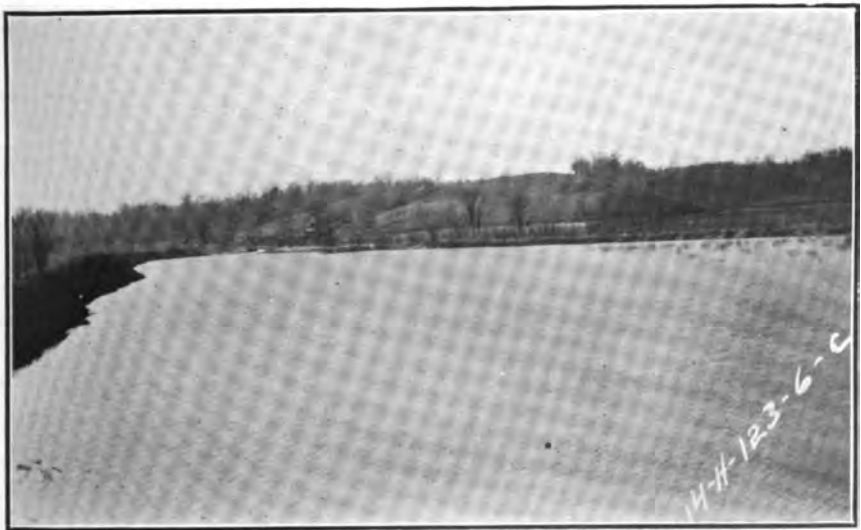


FIG. 2.—HOOD BASIN, COAL CREEK DRAINAGE AND LEVEE DISTRICT.

miles of large towns. This proximity to some of the most fertile and highest-priced agricultural lands in the United States has led to an earlier activity in drainage reclamation than has existed in most other portions of our country. The results of adequate protection and drainage are shown by figure 1 of Plate I, a view of part of a tract of reclaimed land on the Illinois River.

SIZE OF PUMPING DISTRICTS.

In order that the building of a levee around a tract of overflowed land and the installation and operation of a pumping plant may be carried out economically at a moderate cost per acre of land reclaimed, it is necessary to have a considerable area included in a single project. Hence, ordinarily, the land does not belong to a single owner, but rather to a number of individuals. In order that all the interested landowners may work harmoniously together it is necessary, first, that an incorporated drainage district be formed according to the method provided by the specific laws of the particular State relating to this subject. The officers of the district so formed may then proceed to carry out the necessary successive steps in the inauguration of the construction work.

Pumping districts of as small an area as 8,000 acres may profitably be formed in favorable locations; but, in general, the expense per acre is less, as the district is larger, up to a certain limit beyond which there is no further advantage from increased size. According to experience, about 10,000 acres of reclaimed land seems to be a very satisfactory size for such a district.

The boundaries of a district are determined by the natural surface conditions. A district will naturally include all the land on one side of the river between the channel and the bluff and extending up and down the valley from one tributary to the next of any size entering the river on the same side. Hence, a district may be but 1 or 2 miles wide, the part width of the river valley, but will ordinarily be much longer up and down the valley.

LEVEES.

The protective levee begins at the bluff at one end of the district, follows along the bank of the entering tributary to its junction with the river, thence along the river bank to the other tributary, and up that again to the bluff. Thus, ordinarily, the levee extends continuously around three sides of the district. The correct location of the levee to secure a good foundation and to leave sufficient floodway for the river, and its proper construction of sufficient strength to resist erosion, undermining, and overtopping, are engineering ques-

[Bull. 243]

tions of vital importance to the welfare of the district. It was the unfortunate experience of nearly every one of the early levee districts on the Illinois River that, as first constructed, the levees were entirely inadequate in size and strength, with the result that they were broken by floods, their interiors were inundated, and years elapsed before the districts recovered from the injury.

The height of the levees varies all the way from zero, at their ends against the high ground, to 20 feet in places, but they are in general between 8 and 12 feet high. The dimensions which a levee must have in order that it may be strong enough and be durable depend upon the kind of material used in its construction, the method of construction, and the nature of its exposure to the action of waves and currents. A tenacious clayey soil or gumbo will in general make the best levee. Experience shows that the least dimensions which a finished and compacted levee should have are a width on top of 6 feet, a slope on the river side of 3 horizontal to 1 vertical, and a slope on the land side of 2 to 1.¹ Where the location is such that the water remains against the outer side of the levee for only short periods of time, and where the material is good, the total slope of 5 to 1 might be divided equally between the two sides. If the material used is very sandy, or if the bank is to run any risk of being exposed to a strong current or any wave action, flatter slopes must be used. On account of the difficulty of maintaining a levee in good condition, a topic discussed more fully later in this bulletin, it is in many locations absolutely essential, and is always desirable, not to have the slope on either side of the levee steeper than 3 to 1. The crown of the levee should be at least 3 feet above the highest expected high water.

Levees are built with dipper dredges, with drag-bucket machines,² and with scrapers. If the material is put up wet there will be very little subsequent settlement, but if scrapers are used the original height of the levee must be increased by at least 10 per cent to allow for the settling during the first year or more. In any case, the material used to form the levee must all be taken from the river side of the embankment and a clean berm, at least 10 feet wide, must be left between the toe of the slope and the nearest point of the borrow pit. The latter must be kept shallow on the side near the levee, with a slope not steeper than the levee slope, so as not to undermine the embankment, and in no case must the excavation cross the imaginary

¹ This statement applies particularly to the larger rivers, such as the Illinois, where the flood waters frequently remain against the levees for some length of time. On creeks and smaller streams, where the water will only stand against the levee for short periods of time and where the material is good, steeper slopes may often be used and top widths even as small as 3 feet are sometimes admissible.

[Bull. 243]

line formed by extending the line of the outer slope of the levee down below the surface of the ground.

Before constructing the levee the entire area to be occupied by it should be cleared of all vegetation and all stumps and roots should be grubbed to a depth of 3 feet. The entire surface should then be plowed with a large dead furrow in the center. This treatment for the foundation may suffice if the material is firm and dense, the levee only moderately high, and the water not constantly against the levee. But where any unusual dangers exist there should be dug under the center of the levee a continuous muck ditch 2 to 4 feet wide and 3 or 4 feet deep, or deeper if needed, to cut off any possible seepage through the surface soil. The muck ditch should be filled with the best material obtainable, preferably a clayey mixture, well compacted. No vegetable matter should be permitted in any of the material used to form the levee. Insufficient care in preparing the foundation for levees has been the most frequent cause of subsequent disasters.

The care of levees subsequent to their completion is an important matter too often neglected. The slopes should be smoothed and as soon as practicable a good growth of grass should be secured. For this purpose bluegrass, Bermuda grass, redtop, timothy, and clover are all used. A good growth of sod will hold the soil in place and prevent erosion. A mowing machine can be used on a 3 to 1 slope, but scarcely on a steeper slope. On a steeper slope, too, beating rains are likely slowly to wash out the soil and thus gradually reduce the height of the cross section. All weeds and brush on a levee should be cut at least twice during the growing season, as they are particularly harmful, loosening and disintegrating the soil by their roots. Sometimes the top of a levee is used as a road, but this practice is not to be commended, for the wagon wheels cut off the corner of the top and the ruts likely to be formed grow rapidly to such dimensions as seriously to affect the height and efficiency of the levee. The proper place for a road along a levee is on the level ground just inside its inner toe. Burrowing animals of numerous sorts are a constant menace to the integrity of a levee, and they should be assiduously hunted and driven away. Frequently levees are pastured. This has the advantage of keeping down the vegetation, keeping the soil compacted, and driving away burrowing animals. The slight damage to a levee which may result from using it as a pasture is easily observed and repaired and is probably counterbalanced by the good results of the practice.

Constant attention and expense, the latter not large, are required for the proper maintenance of a levee. In the long run it will be found infinitely more profitable to incur this small regular expense

rather than to invite disaster during some period of unusually high water by permitting the levee to deteriorate to the danger point. Proper maintenance will be found the best economy in the end.

The strip of land occupied by the levee should not be located too close to the natural banks of the stream whose waters are to be diked off. Consideration must be given to the question of leaving outside the levee a sufficiently wide flood channel. The conclusion reached in any particular case will depend upon the conditions existing upon the opposite banks of the stream, and no definite rules can be stated. If the banks of the stream are subject to cutting or eaving, the question of the future permanence of the levee enters. A strip of timber should be left outside the borrow pit to form a protection for the levee during high water against erosion by too strong a current, and against destructive wave action during high winds. Where practicable, bars across the borrow pit should be left at intervals so as to prevent too strong a current near the levee. No sharp corners should be made in the line of the levee's location.

For a more complete discussion of levee construction, methods of protecting inadequate work in emergencies, and the repair of levees after they have been overtopped and broken, the reader should consult a previous publication of the office.¹

INTERIOR DRAINAGE DITCHES.

An excessive and injurious amount of drainage water may accumulate within the district from three sources: (1) Rainfall; (2) run-off from higher lands draining naturally into the district; and (3) seepage under the levees when the river level is higher than the surface of the land inside the levee. This water must be collected in ditches and led to some suitable point near the levee where the pumps may lift it over the levee and discharge it into the river. The amount of rainfall to be removed by pumping depends upon the amount and distribution of the seasonal precipitation.

The run-off from the bluff lands will depend upon the topography of the adjacent higher lands and the natural watershed boundaries, and the task of disposing of it is often one of the most serious problems to be solved in the planning of a district. The amount of water thus entering the district should be reduced as much as possible by proper location of the levee and by a diversion ditch wherever the latter is feasible. The only district known of where this has been tried on an extensive scale in this country until the last year is Coal Creek drainage and levee district near Beardstown, Ill., a map of which is given as figure 1. A large diversion ditch and levee has been constructed along the base of the bluff for a distance of about

¹ U. S. Dept. Agr., Office Expt. Stas. Bul. 158, Separate 9.

[Bull. 243]

4 miles, from the point where Coal Creek debouches from the hills, to the lower end of the district. The levee is on the lower side of the ditch; that is, toward the district. Not only is the flow of Coal Creek received by this diversion ditch, but several smaller streams also flow



FIG. 1.—Map of Coal Creek drainage and levee district, Illinois.

into it. The first diversion ditch, made several years ago, although sufficiently large at first, became too small by being filled with sediment brought down from the hills during floods, so that the various streams overtopped the levee and flowed into the district. In 1909 another ditch and levee were completed, but these differ from the

[Bull. 243]

previous construction by being so located as to include a settling reservoir opposite the mouth of each stream. It is expected that these reservoirs will receive the sand and sediment brought down from the hills and thus prevent the ditch from becoming clogged. The reservoirs are planned to be of sufficient size so that they will not become filled with sediment for many years. Two of them are 5 and 20 acres in extent, respectively, while two are of 6 acres each and three are of 4 acres each. Figure 2 of Plate I is a view looking west-northwest across Hood Basin, the largest of the reservoirs. Across the basin may be seen a part of the embankment of the original diversion ditch which failed. The hills in the background show the nature of the country drained by Coal Creek. Two years' experience with the last ditch indicates that it will prove quite satisfactory, though it is to be remarked that the seasons of 1909 and 1910 were not wet enough to afford a crucial test of the system. Recently the Crane Creek drainage and levee district has constructed a somewhat similar diversion ditch. In England and Holland diversion ditches to prevent drainage water from flowing from higher lands onto lower areas, to the damage of the latter, have been in systematic use for a long time.

If the levees are properly constructed, as heretofore explained, the amount of seepage water passing under them is ordinarily so small as to be negligible, but if the soil or the subsoil of the district be very sandy, or if the levees have been carelessly constructed upon an improper foundation, the seepage may accumulate in sufficient quantity to be troublesome. Ordinarily, if land near the levee is injured by seepage, the difficulty may be corrected by laying a line of tile parallel to the levee and 50 to 100 feet from the toe of the slope.

The determination of the proper size and arrangement of the interior drainage ditches for a pumping district is not fundamentally different from the planning of a gravity ditch system for an ordinary district. The same hydraulic principles apply to the one as to the other, but in some details essential modifications are necessary. Ordinarily river-bottom land has a somewhat uneven surface, varying in elevation by several feet, and lies in long ridges and depressions, the latter bearing local names as lakes, sloughs, or creeks. The ridges may be quite sandy while the lakes contain a heavy black soil. To fit all the land for cultivation the drainage system should be planned to keep the ordinary ground-water level at least 3 feet below the surface of the ground in the lowest spots that are to be cultivated. This is necessary, not only for the purpose of providing room for the root systems of growing crops, but also as a margin of safety by furnishing a reservoir capacity in the drained soil for

the temporary storage of water after an unusually heavy period of rain.

In some localities there are sloughs so low that to drain them would require undue expense. In such a case it is better to reserve these areas for use as reservoirs in connection with the ditch system, with the expectation that they will fill with water during heavy rains and store it until it is gradually removed by the operation of the pumps. This tends to reduce the maximum capacity required of the pumping plant of the district concerned. Some districts on the Mississippi River have as much as 7 per cent of their total area occupied by such storage basins, but other districts have none at all, and such storage areas do not seem to be essential in regions where the natural condition of the ground surface is not favorable for their use.

The main ditch and its branches should traverse the lowest areas in the district, following the land subdivisional lines where practicable. This will secure surface drainage in the lowest areas, where it is most needed, and also prove cheapest because the amount of excavation will be a minimum. Cutting ditches through the ridges should be avoided as much as possible, especially where these are sandy, on account of the great difficulty of making and maintaining a ditch in sandy soil owing to the trouble caused by the caving banks. At times the previously existing natural drainage channels, when suitably cleaned, may be made to form a considerable part of the ditch system.

Often the district, as a whole, may have very little surface slope and it becomes necessary to dig the main ditch with a bottom without grade. To compute its carrying capacity, then, it must be assumed that the pumping plant when in operation at full capacity will lower the water level at the pump by amount equal possibly to 3 feet or more. A comparison of this level with the permissible water-surface level at the upper end of the ditch will give a surface slope for computing the velocity in the ditch. This surface slope will not often need to be less than 3 inches to the mile. From the velocity of the water as computed and the available cross section of the ditch at the lowered water level the carrying capacity of the ditch is determined.

The greatest amount of sediment is likely to be washed into the main ditches during a heavy storm when the ditches are bank full. It should be noticed that at such a time there is an important difference between the condition of these ditches and that existing in main ditches of gravity-drainage systems. In the latter, when more than normally full, the velocity is a maximum and hence there is the least possible tendency toward the deposition of sediment in the ditches.

But in a pumping district, on the contrary, when the main ditches are unusually full, the velocity will be low and hence sediment may be easily deposited. In general, the velocity in these ditches will always be so low that they are not self-cleaning. On this account, as well as on account of the drawing down of the level in the ditches by the pumps, such ditches should be of unusually generous dimensions. The engineer will wisely give particular attention to the designing of the ditches to insure ample depth and breadth to provide the requisite capacity. In general, it is probable that the main ditches should be dug from 8 to 10 feet deep. Figure 1 of Plate II is a view of the main ditch, Coal Creek drainage and levee district, Illinois, which was constructed in 1909 with a dipper dredge having side spuds. The view was taken before the ditch was completed at the lower end. The water level as shown is about 4 feet below the ground surface and about 4 feet above the normal level after the ditch was completed. Figure 2 of Plate II is a view looking up Branch A of east lateral, from near the outlet of tile drain No. 7.

Experience shows that to put bottom land into perfect agricultural condition some tile drainage is usually necessary. Where this has once been demonstrated the landowner, who has already been put to considerable expense for the main drainage of the district, is not content to have his land in anything but the most fertile condition and hence is usually quite willing to go to the comparatively small additional expense involved in the necessary tiling. Parallel lines of 5-inch or 6-inch tile are laid at such distances apart as the elevation, slope, and nature of the soil require. Where the lines are long, larger sizes are used in the lower portions. The distances between parallel lines found necessary by trial is usually between 10 and 30 rods, and their minimum depth below the surface should not be less than 30 inches.

On account of the surface erosion and consequent sedimentation in the main ditches, small open-surface field ditches or laterals emptying into the main ditches are highly objectionable unless for some distance back from the junction they are dug as deep as the bottom of the main ditch. The difficulty could be avoided by the use of some sort of permanent and stable masonry inlet; otherwise, small ditches should be replaced by tile.

GRAVITY SLUICWAYS.

In the case of districts where the river falls low enough during the latter part of the summer to afford an outlet for gravity drainage, sluiceways, so arranged that they may be opened when desired, should be built under the levee near the pumping plant. The sluices

[Bull. 243]

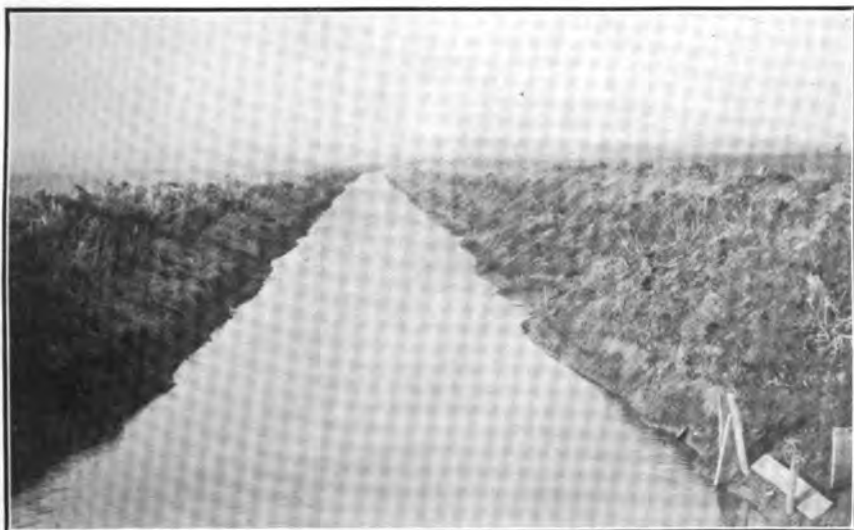


FIG. 1.—MAIN DITCH, COAL CREEK DRAINAGE AND LEVEE DISTRICT.



FIG. 2.—BRANCH A, COAL CREEK DRAINAGE AND LEVEE DISTRICT.

should be composed of one or more parallel pipes laid nearly level and provided with suitable valves. The length of the pipes will naturally be 100 feet or more. Metal, concrete, or vitrified sewer pipe may be used in their construction. Both ends should be protected with strong concrete bulkheads, and cut-off walls should be placed around the pipes at intervals along their length to prevent seepage along their exterior surface. Cracking and failure of these end bulkheads, one of the commonest accidents in drainage districts, show that they must be made with special care, amply deep, and of liberal dimensions. If the outer end of the sluiceway is not below low-water line of the river, the bottom of the channel, through which the water will flow beyond the end of the pipe, should be protected from washing out by riprap, paving, or a concrete floor carried to a safe distance. Where feasible, this protection should extend below low-water line.

The sluiceway should be sufficient in size to discharge in 24 hours such an amount of water as would cover the whole drainage area one-fourth inch deep. In making this calculation the velocity of the water through the sluiceway should not be assumed to be greater than 5 feet per second. The sluiceway openings should be low enough so that their highest point will be at about the line at which it is desired to maintain the water level within the district. Their interior surfaces should be as smooth as possible in order to reduce the friction which retards the flowing water. If the entrance to the pipes is made well rounded, their maximum discharging capacity will be considerably increased. Automatic outward-opening flap valves may be put on the outer end of the pipes, but in important cases there should be also a place where the pipe may be closed by stop planks or by a gate valve if the automatic valve should get out of order.¹

NECESSARY CAPACITY OF PUMPING MACHINERY.

Before discussing in detail the conditions determining the size needed for a pumping plant it will be illuminating to describe the general method of operation of such a plant in the latitude of Illinois. In the late summer and fall, since the precipitation is slight and is more than balanced by evaporation, the pumps are not run. During the winter storms are more frequent and evaporation is small, so that gradually the ground becomes completely saturated and the ditches full. Some districts pump occasionally throughout the whole winter; others start the pumps at some date in the spring and operate them continuously night and day for several days to

¹ U. S. Dept. Agr., Office Expt. Stas. Bul. 158, Separate 9.

[Bull. 243]

remove the large accumulation of water stored up during the winter months. Gradually the water level in the ditches is lowered, and when the desired minimum is reached the machinery is stopped during the night. The water will rise in the ditches perhaps 2 or 3 feet during the night. When the pumps start up in the morning the water level at the pumping plant quickly drops a foot or more and then less slowly for the rest of the day. At points some distance away the effect of starting the pump is less quickly seen in the morning, but the lowering of the water is gradual throughout the day. After a few days of such operation the supply of water diminishes and the pumps are not run the whole day.

Later, since it is troublesome to start up a big plant for only a few hours of operation, the speed of the engine and pump is reduced to diminish its discharge, or, if there is more than one pump in the plant, only one may be run. At last, days are skipped and pumping ceases entirely. After every rain of any importance, the pumps are started and a similar cycle of operations transpires, extending over a longer or shorter period, according to the amount of water to be removed. In some districts pumping for the season ends in June, and drainage is by gravity for the remainder of the summer. In others no gravity drainage is available, and the pumps must be run later in the season. Thus it is clear that, though the pumps must constantly be in readiness for use, their operation is very intermittent. The total time of running in a whole year never exceeds 60 to 90 days of 24 hours each. In some seasons it is not more than 15 to 20 such days.

The size of pumping plant required for any particular district depends upon a variety of conditions, among which are the size and slope of the drainage district and of any other area from which drainage water is received; the amount of storage capacity available in ditches and reservoirs; the system of interior drains used and the method of construction adopted for the levee; the nature of the soil and subsoil; the method of operation of the pumping plant; the kind of crops raised and the degree of drainage required; and the amount and distribution of the rainfall throughout the year.

In the vicinity of Illinois the weight to be given to some of these factors is very small, and in the present state of our knowledge no definite allowance can be made for them. Yet, notwithstanding our ignorance concerning some of them, it may be profitable to discuss briefly the nature of the effect of each. This is a field in which much careful study is still needed and must be carried out to secure the complete knowledge necessary for the most satisfactory design and management of the pumping machinery of drainage districts.

Along the Illinois and upper Mississippi Rivers the majority of pumping plants already installed have been planned to have a

maximum pumping capacity sufficient to remove in 24 hours one-fourth inch in depth of water over the entire district. This is equivalent to 6.74 cubic feet per second per square mile of drainage area, or 0.0105 cubic feet per second per acre.

It is doubtful whether any change should be made in the one-quarter inch coefficient solely on account of change in the size of the district; however, where some portions of the district are materially higher than others, the coefficient might be increased to prevent danger to the lower portions from the run-off from the higher areas. Where drainage from higher land flows into the district a larger run-off coefficient must be used for the higher area. The proper amount depends upon the nature of the country. For rolling pasture land free from undergrowth, or for cultivated corn land, probably an increase of 50 per cent in the coefficient, or a total of three-eighths inch, for such upland areas is none too great. Where feasible, the drainage from such higher areas should be diverted around the district instead of being brought to the pumping plant, as previously explained on page 18.

With a considerable reservoir storage area within the district, the size of the pumping plant may be materially reduced. If the storage area equals 5 per cent of the total area, a 2-inch rainfall, all running into the reservoir, would raise its level only 40 inches. Therefore, if a rise of 3 feet in the reservoir can be permitted it would seem that the capacity of the pumping plant could certainly be reduced by one-third and possibly to one-half of what would otherwise be required.

If tile drainage at a depth of 3 feet or more is extensively used, the demand upon the pumping plant will be somewhat reduced, for the tiled land will act like a reservoir in storing a large amount of water and will deliver it only slowly to the ditches. On the other hand, an extensive system of shallow open field ditches will deliver the rainfall rapidly and may thus damage any especially low areas unless the capacity of the pumping plant is increased. If the levees have been properly constructed, as previously described, the amount of seepage through them can never be sufficient to affect the pumping plant. Cases have been known, however, of levees so poorly built that the quantity of water coming through them was sufficient not only to endanger the stability and safety of the levees themselves, but also to increase appreciably the amount of water to be pumped.

If the soil is very stiff and tenacious the surface run-off after a heavy summer shower will be greater than from a porous open soil. During a time of flood in the river, a sandy subsoil may develop springs and boils, not only in the bottoms of the ditches, but sometimes even in the fields. The quantity of water that may be received

in this way is very uncertain but it is not probable that it is often sufficient in amount to affect the pumping plant.

A pumping plant that is designed to operate night and day may, of course, be smaller than one intended to operate only in the daytime. Practically all plants are expected to run nights occasionally, when needed. Pumping plants are operated chiefly during the months from March to June. One of the times of longest continuous operation during the whole year is always at the beginning of pumping in the spring, because if there has been no pumping during the fall and winter the rains and snows will have completely saturated the ground and filled the ditches. Hence, those districts which have had the longest experience in pumping are unanimously of the opinion that even though at that time there is no danger of immediate damage to crops, still it is best to pump occasionally during the winter so as to maintain the ground water constantly at a low level, and thus secure the great advantage of early drying of the soil in the spring and the opportunity for early cultivation and planting. Moreover, the lower the normal ground-water level is kept below the surface, the less will be the flooding effect of a severe storm.

It should be clear from the foregoing discussion that a district which gives especial care and attention to its pumping, running throughout the winter as needed and frequently during the growing season, so as to maintain a minimum ground-water level while there is any danger from the occurrence of heavy and sudden rains, will require a smaller pumping plant than would otherwise be needed.

From a surface covered with a growing hay or grain crop the run-off is less rapid than from land in corn. For corn and hay the ground water must be kept at a lower level than is necessary for grain. Corn is considered the most profitable crop in the region under consideration, and where the soil can be kept sufficiently dry it is raised as frequently as is consistent with a proper crop rotation necessary for maintaining the fertility of the soil. Much land can be observed, however, which is not sufficiently drained for the most successful raising of corn and which therefore is devoted to wheat and oats instead.

The amount and distribution of the rainfall are the chief factors determining the size of pumping plant required in a given location, and we shall proceed to a detailed discussion of all the evidence that it has been possible to gather bearing upon this point. From a consideration of all the data, the conclusion seems justified that in the present state of our knowledge the run-off coefficient of one-fourth inch in depth over the whole drainage district in 24 hours is the cor-

[Bull. 243]

rect one to use in designing pumping plants on the Illinois and upper Mississippi Rivers. Direct observations on numerous plants in actual operation for a series of years will be needed to settle the question finally.

In the region referred to, though some pumping on an inadequate scale has been carried on for more than 10 years, all the older plants until recently had troubles with their ditches and levees which prevented their pumping experience from furnishing conclusive data, and from no plant has it been possible to obtain definite records going back more than two years. Now, though there are nearly a dozen large plants in operating condition, it is still surprising to learn that some of these neglect to keep even the simplest, most fundamental records, such as would determine whether the plant is operating economically or wastefully—records which would be of great use to others as well as to the district immediately concerned.

As indirect evidence it may be stated that for many years in central Illinois the one-fourth inch coefficient has been used in designing ditches for the drainage by gravity of flat lands and has been found adequate and satisfactory. For a much longer time in Holland and in the fens of England the coefficient of one-fourth inch or a little more has been the basis used in the designing of pumping plants. Although their total annual rainfall is about the same as in Illinois, their climate is otherwise quite different. In England and Holland there are many more rainy days, so that the rainfall is much more evenly distributed than in this country. In these countries, too, there is much less sunshine and hot weather in summer and therefore less rapid evaporation. On the other hand, they do not have such violent and excessive rains falling during brief periods as we have.

From two districts on the Illinois River valuable data were obtained. During the history of its pumping, extending over nearly 20 years, the Pekin-La Marsh levee and drainage district, near Pekin, has used in succession four different sources of power, including two sizes of steam engine, a producer gas plant, and electricity. It has also used at least four different sizes of centrifugal pump. In March, 1908, the producer gas pumping plant was tested by men connected with the faculty of the University of Illinois and the 26-inch centrifugal pump was found to be discharging 28.7 cubic feet per second. Although the nominal rated capacity of the pump is about 37 cubic feet per second, from all that can be learned it seems probable that the average discharge of the pump, when run by the producer gas engine, could not have exceeded 30 cubic feet per second. Since the drainage area of the district is about 3,000 acres, this is equivalent to 1 cubic foot per second for 100 acres of land, or a capacity sufficient to remove 0.24-inch depth in 24 hours. In 1909 this plant started March 10 and operated intermittently, as required, until

July 25, during which time it kept the district satisfactorily dry. A rough daily memorandum kept by the engineer in charge shows a total operation during this period of 1,098 hours, equivalent to 45.7 24-hour days. The total depth of water removed was 45.7 times 0.24, equal to 11 inches.

During this period the most severe test of the capacity of the plant was 4 days' steady operation, July 7-10, followed by 7 hours on July 11, or a continuous run of 103 hours. This was necessitated by a heavy rain on July 5, 6, and 7, the representative character of which will be discussed later. In October the district began pumping by electricity, and, to June 20, 1910, had run a total of 1,365 hours, equivalent to 56.9 days. It is quite certain that, as operated by the present electric motor, the pump has a higher speed and a greater discharge than when operated by the producer gas engine. But in default of precise information, if we assume the same discharge as before, the total water removed between October 15, 1909, and June 20, 1910, was equivalent to 13.6 inches in depth over the whole district. During all this period the electric pump was never run more than, and very seldom as much as, 12 hours in one day. As will be shown later, the year 1909, although not an extreme one, was rather wetter than the average, while 1910 has been remarkably dry. The Pekin-La Marsh district is generally considered to be the best and most completely drained district on the Illinois River, and is in an entirely satisfactory condition so far as drainage is concerned.

The Coal Creek levee and drainage district, near Beardstown, Ill., has been practicing pumping for a number of years, though not with entire success previous to 1909. The equipment includes one 24-inch centrifugal pump with a nominal rated capacity of 33.5 cubic feet per second and two 15-inch pumps rated at 15.5 cubic feet per second each, or a total capacity of 64.5 cubic feet per second. The area of the district is 6,700 acres, hence the nominal capacity of the pumping plant equals $\frac{64.5 \times 60 \times 24}{6,700} = 0.23$ inch in depth in 24 hours. The three pumps are run by one Corliss condensing engine which has been in operation about 10 years.

Since July, 1909, accurate and detailed daily records have been kept of the operation of this plant by its owners. Between July 1, 1909, and July 1, 1910, the only times when it was necessary to run all three pumps continuously night and day were once in July, 1909, and twice in May, 1910. The rainfall is measured at the pumping plant by means of a Weather Bureau pattern rain gauge. On July 7, 8, and 9, 1909, the total rainfall was 2.8 inches, causing all the pumps to be run continuously for 57 hours, after which one of the smaller pumps was stopped and the other two were operated during the third night. No more night running was required by this storm.

[Bull. 243]

May, 1910, was a particularly wet month at this station, the total precipitation having been recorded as 6.8 inches, though there were no single remarkably heavy showers. On the first two days of the month 1.4 inches fell; on the 7th, 1.4 inches; on the 11th, 1.2 inches; from the 15th to the 17th, 0.8 inch. To meet this steady wet period all three pumps were run continuously for 72 hours from the 13th to the 15th and again for 42 hours on the 18th and 19th. The large pump was run every day during the month and during over two-thirds of the nights. At least one of the small pumps was run nearly every day and nearly as many nights as the large pump. The total operation of all three pumps, taking due account of the different sizes, was equivalent to operating all the pumps together for about 70 per cent of the time during the whole month. The elastic arrangement of the pumps in this station illustrates very well the advantage of having separate units in such a pumping station.

The pumps are frequently run at a decreased speed when the quantity of water to be lifted diminishes. Taking this into consideration, as well as the fact that as practically operated all such pumps when actually measured almost invariably show a capacity considerably below their nominal capacity, it seems probable that the pumps do not exceed 80 per cent of their theoretical discharge. With this conclusion the owners of the Coal Creek plant agree. Using, therefore, 12.5 cubic feet per second as the discharge of each of the smaller pumps and 25 cubic feet per second as the discharge of the large pump, the total amount of water removed from the district, according to the records kept at the plant, between July 1, 1909, and July 1, 1910, was equivalent to 24.3 inches in depth over the whole district, though in the first part of the season of 1909 some land was under water and much was too wet for satisfactory cultivation, this stored-up excess of water was removed and the whole district was maintained in proper condition. On account of the wet condition at the beginning of the season, the amount of water removed was greater than would have been necessary if the pumps had previously been operated satisfactorily. There are no data for determining how much the total depth removed (24 inches) would have been reduced by normal operating conditions. The greatest amount removed during any one month of the year was 3.7 inches in May, 1910, when the rainfall was 6.8 inches. The owners of the plant are convinced that its capacity is ample for the drainage of the district.

It remains to show how nearly representative were the rainfall conditions during 1909 and 1910, for which the pumping data obtained at the Pekin-La Marsh and Coal Creek pumping plants have been discussed above. A United States Weather Bureau station is located at Peoria, on the Illinois River. The following table gives

[Bull. 243]

for the last 10 years the annual rainfall for each month in which the precipitation exceeded 3 inches.

Annual and monthly rainfall, in inches, for all months exceeding 3 inches, at Peoria, Ill., from January 1, 1900, to July 1, 1910.

Year.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual. ¹
1900.....		5.6			5.6								32.7
1901.....			4.3			4.3	3.1						25.0
1902.....					3.0	9.6	7.3	7.4	6.8	3.8			49.2
1903.....			3.7	5.2	4.2		4.9	7.2	5.8				36.8
1904.....			4.4	3.5	4.1			4.1	6.7				32.5
1905.....				4.0	4.5	5.1	4.2						32.4
1906.....						3.2			4.9				29.0
1907.....	5.4				4.0	4.0	4.9	6.6					34.9
1908.....		4.0		4.1	7.8	4.1	3.9						34.0
1909.....		3.7		7.2	3.7	3.6	4.6		3.7	3.0	5.5		42.1
1910.....				3.6	4.5								

¹ Average annual rainfall, 35.3 inches.

The greatest annual rainfall was 49 inches in 1902. The only other year in which 40 inches was exceeded was 1909. The only months in which the precipitation exceeded 6 inches were: June, July, August, and September, 1902; August, 1903; September, 1904; August, 1907; May, 1908; and April, 1909. From this it is evident that a pumping plant to be satisfactory must be able to handle a monthly rainfall of 6 or 7 inches, and that this will be sufficient.

From the daily rainfall records a list was made of all the storms occurring at Peoria between January 1, 1902, and July 1, 1910, lasting one or more days, during which the total rainfall for the whole storm was 2 inches or more, but leaving out of the calculation all days on which the precipitation was less than one-fourth inch. There were 28 such storms, in 10 of which the total precipitation exceeded 3 inches, and in 4 of the latter the precipitation exceeded 4 inches. Hence a pumping plant should be able to handle a downfall in one storm of at least 4 inches. One of the above-mentioned four storms was long drawn out, covering six days in January, 1907. Probably much of the precipitation was in the form of snow, and it does not require further consideration as affecting drainage. The other three heavy storms were as follows:

Three storm periods during period January 1, 1902, to July 1, 1910, with precipitation of over 4 inches.

Date.	Precipitation.	Date.	Precipitation.	Date.	Precipitation.
	<i>Inches.</i>		<i>Inches.</i>		<i>Inches.</i>
June 25, 1902.....	0.8	July 16, 1902.....	0.3	July 5, 1909.....	1.4
26, 1902.....		17, 1902.....	1.3	6, 1909.....	2.4
27, 1902.....	.4	18, 1902.....	1.6	7, 1909.....	.8
28, 1902.....	2.5	19, 1902.....	1.3		
29, 1902.....	.7			Total.....	4.1
Total.....	4.4	Total.....	4.5		

The Pekin-La Marsh pumping plant, located about 10 miles from the Peoria Weather Bureau station, handled satisfactorily the storm of July, 1909. As this rain was not a sudden shower but a slow, steady rain extending over much of the State, we seem justified in assuming that the Peoria record represents the actual rain at Pekin. Just 11 days before this rain another rainfall of over 1 inch had occurred. It seems fair to conclude that the Pekin plant is able to take care of a 4-inch storm. The only other storm which was plainly and definitely more dangerous than the one just discussed is the one of July, 1902. Preceding the latter by just a week there had been a rain of 2 inches. No other equally severe storm has occurred in 10 years and it does not seem justifiable to make special provision for such a rare occurrence. On several occasions the rainfall on a single day has exceeded the greatest given above, 2.5 inches, but on the whole these other storms have not been so violent as the ones already described. On no occasion has a single day's rainfall exceeded 3 inches.

To see how well the rainfall record at one station might represent the whole region, the record of Peoria was compared with that at other stations, as shown in the following table:

Comparison of records of the Weather Bureau stations at Peoria, Havana, and Griggsville, Ill.

	Peoria.	Havana.	Griggsville.
Average annual rainfall.....Inches.....	35.3	35.5	36.2
Number of months when rainfall exceeded 6 inches between Jan. 1, 1902, and July 1, 1910.....	9	.....	7
Number of storms equaling 2 inches.....	28	.....	27
Number of storms equaling 3 inches.....	10	.....	11
Number of storms equaling 4 inches.....	4	.....	3

In many cases the individual heavy storms were entirely distinct at the two places, but over a long period the total number and intensity of the various storms are about the same.

To sum up: Since the Pekin plant handled successfully a storm of over 4 inches in July, 1909; also a rainfall for the month of April, 1909, of 7.2 inches; and since the Coal Creek plant handled satisfactorily a rainfall of 6.1 inches for July, 1909, and 6.8 inches for May, 1910, all the experience so far available seems to show that for this region a pumping capacity sufficient to remove one-fourth inch in depth in 24 hours is sufficient.

LOCATION OF PUMPING PLANT.

The pumping plant should be so located that the drainage water may be brought to it with the least expenditure for interior ditches. Where convenient there is some apparent advantage in locating the

plant on an arm of the river of ample capacity rather than on the main river channel. The location should be so chosen as to be most easily accessible for the delivery of fuel and for convenience of attendance. In the Pekin-La Marsh district the pumping plant is at the upper end of the district so as to be close to the town of Pekin.

TYPES OF PUMPING MACHINERY.

Since pumps are to be depended upon to remove promptly surplus water, whose presence may endanger a whole crop, it is of the utmost importance that the pumping plant be able to work with certainty and reliability whenever needed.

The annual cost of a pumping plant is made up of three main items: (1) The charge for interest on the original cost of the plant and for depreciation; (2) the cost of fuel; and (3) the cost of labor. Certain general principles concerning the mutual relations of these different items must be understood before taking up the comparison of the different types of machinery available for pumping.

The interest upon the original cost of the plant goes on every year whether the plant is operated much or little. Depreciation also takes place whether the plant is operated or not, and for such installations as are under discussion it probably does not depend much upon the length of time the plants are in operation each year. What amount to allow for depreciation is a difficult matter to decide. The length of time before such machinery will wear out depends chiefly upon the original quality of the installation and the care that is taken of it afterwards. We can not, in general, assume that such machinery will last more than 20 or 25 years. Much of it will be discarded sooner, either because it is outgrown or worn out. With proper care it is probable that such machinery may be made to endure twice as long as it will last if it is carelessly treated. It is customary to include with depreciation an item for repairs. This should be very small during the first few years of the life of a well-constructed plant, but will grow larger as the plant becomes older.

The cost of fuel per year depends to a considerable extent upon the kind of machinery used and also upon the amount of time the plant is run. Whenever a steam plant starts there is a certain consumption of fuel in preparation before starting, and likewise a similar loss after stopping. Hence, since the operation of a pumping plant is very intermittent, the fuel consumption is not strictly proportionate to the time run. The amount of fuel used also depends largely upon the skill of the fireman. An unskillful man may easily use 25 per cent more fuel than is really necessary. Different types of equipment require different amounts of fuel to produce the same result; that is, some types are more economical of fuel than others. The cost

of the labor at the pumping plant depends upon the class employed and the length of time it is required.

In general, in a given location, that type of pumping plant will be best which requires the least annual cost, including all the elements enumerated above. To a certain extent, variations in these different elements tend to offset each other. For example, a highly efficient plant from the point of view of fuel economy is complicated and expensive, and hence will have a relatively high charge for interest and depreciation. Likewise, it will require skillful and high-priced attendance, but may, on the other hand, in a large plant, require fewer men. If cheap labor is employed, the coal and repair bills will be increased and the deterioration of the plant will be more rapid. The advantage of fuel economy is relatively more important in locations where fuel is especially high and in a large plant than in a small one, but in any plant it diminishes in importance as the time of running per year decreases or becomes much interrupted.

The above principles have long been regarded as fundamental in the science of mechanical engineering design. Applying them to drainage pumping, since the work will usually be confined to a small portion of the year, since the labor available will be cheap and unskilled, and the other conditions not favorable for careful preservative care of the plant, the fundamental requirements in a drainage pumping plant are reliability and simplicity.

KIND OF PUMP.

The centrifugal pump is the kind most often used for drainage. It is simple, has no valves, and can be obtained in all sizes. Its disadvantages are that it must be primed in starting, it can operate satisfactorily under a particular set of conditions only within a narrow range of speed, and its efficiency when operating under practical conditions is not high. In order to work economically, the speed must be varied as the head under which it operates changes. The size of a centrifugal pump is usually given as the diameter of the suction or discharge opening—that is, a 24-inch pump is one having suction and discharge pipes 24 inches in diameter. Most large pumps are made with a horizontal shaft and are called horizontal pumps. When larger than 24 inches, they frequently have a double suction—that is, water entering at the center on both sides of the impeller. This has the advantage of balancing the side thrust on the impeller and shaft. Without this arrangement some automatic balancing device must be used in connection with the impeller and a collar thrust bearing on the shaft.

The capacity of a pump is usually reckoned by assuming the water to have a velocity of 10 feet a second through the suction and dis-

charge openings of the pump. While it is possible to obtain this discharge by using sufficient power and speed, as the pumps are usually operated in practice the discharge is considerably—often 20 per cent—less than the theoretical rating. In this respect a centrifugal pump differs greatly from engines and boilers. An engine or boiler from any reputable maker can, in an emergency, be made to do 25 per cent more than its rated output—that is, it is said to have an overload capacity of 25 per cent. On the contrary, the rated capacity of a centrifugal pump is just about the limit to which it can be pushed and it has no overload capacity, but usually operates at a lower figure.

Rotary displacement pumps and plunger pumps have been occasionally used for pumping drainage water, but are not well adapted to this use. They may have a very high mechanical efficiency, but their cost more than offsets this advantage. Scoop wheels have been extensively used in England and Holland, and to some extent in this country in Louisiana. They may be made to have a higher efficiency than centrifugal pumps, especially for very low lifts, but they are not so well adapted for a location where the head is subject to wide fluctuations. A full description of the construction and operation of these scoop wheels may be found in a book by W. H. Wheeler.¹ Another publication² describes a recent large and successful installation in Holland and gives the results of tests.

SOURCES OF POWER.

Steam is the source of power best for general use. In Illinois soft coal is abundant and cheap for fuel, though in some places crude oil or natural gas may be found more available. A suction gas producer with a gas engine has been tried, but such a plant requires hard coal or coke for fuel, which greatly increases the expense. Furthermore, such a type of plant is not adapted to intermittent working. Electricity is by far the most convenient source of power where it is available, but in general it will be considerably more expensive than using coal to produce steam. Its convenience may perhaps offset its cost, especially for a small plant.

Return tubular, marine, locomotive type, and water-tube boilers have all been used. For a small plant the locomotive type or the simple return tubular boiler is simplest and cheapest. For plants of over 200 horsepower water-tube boilers have decided advantages, though they may cost somewhat more than the simpler fire-tube boilers. The boilers of all large plants should be kept constantly insured by some reliable boiler-insurance company.

¹ *The Drainage of Fens and Low Lands by Gravitation and Steam Power.* London and New York, 1888.

² *Engin. News*, 63 (1910), No. 20, p. 581.

[Bull. 248]

KIND OF ENGINE.

Either vertical or horizontal engines may be used. When possible, it is best to have the pump directly connected to the engine. This is usually not feasible for a pump smaller than the 24-inch size, because such a pump would require too high a speed of the engine. In this case the pump must be driven by a belt or a rope. The engine should be condensing and, if large, should be compound. A high-speed automatic engine is more difficult to operate with inexperienced labor than a slow-speed engine, but it has the advantage of being smaller and lighter for the same power than the slow-speed engine of the Corliss or some similar type. In general, however, the high-speed engine is not as economical of steam as the slow-speed type. The engine should be provided with a governor able to keep it from racing if the entire load is suddenly removed. The engine should be adjustable for a considerable range of speed, should be able to carry a considerable overload, and should work as economically as possible through a wide range of load. As will be explained more fully below, it is especially desirable that an engine for this work should be capable of very flexible operation.

AUXILIARIES.

The plant will require the usual auxiliaries. A surface condenser will furnish pure feed water, but some form of jet condenser is simpler and cheaper. For priming the pumps a steam ejector is the simplest arrangement, though an air pump may be used. Separators and traps, filters, and heaters should be used as needed for safe and economical operation. Piping and boilers should be well covered to reduce as much as possible the amount of radiation and condensation of steam.

In large plants boilers, engines, and pumps should all be divided into two or more equal-sized units, so arranged that they can, when necessary, be operated independently, and the auxiliaries should be installed in duplicate.

CALCULATION OF THE SIZE OF PUMPING PLANT.

To illustrate the method of determining the size of machinery to be installed in a pumping plant, the calculation will be made for a district of 10,000 acres. To remove a depth of water of one-fourth inch over the whole district in 24 hours will require a capacity of 105 cubic feet per second. For such a district it will be best to use two separate pumps, which should be identical in size. A 30-inch pump will be rated at about 49 cubic feet per second; a 32-inch pump at about 56 cubic feet per second; and a 36-inch pump at about

[Bull. 243]

71 cubic feet per second. In this case it would be best to use two 32-inch pumps, which would seem to have a slight margin of excess capacity. However, since pumps of this style so frequently fail to have the capacity assumed, they should be taken only under the guaranty of the manufacturer, and subject to a thorough test after they are installed. The pumps will need to be run at about 200 revolutions per minute and hence may be directly connected to two separate engines.

Assume that the difference between the river-surface level outside the district and the desired ground-water level within the district will vary from a possible maximum of 20 feet during spring floods to nothing in the late summer. The machinery must have sufficient power to pump against the highest head, although much of the time it will run against a lower head. This is a disadvantage so far as the efficiency of the machinery is concerned, because every engine runs most efficiently at about its rated capacity, and if it is either overloaded or underloaded its efficiency is reduced. The actual head against which the pumps must force the water, sometimes called the dynamic head or the hydraulic head, is always greater than the difference in water level as described above, which is called the static head. This increase is due to the friction of the water in the suction and discharge pipes and the so-called velocity head—that is, the head necessary to start the water into motion in the pipes. The friction in pipes carrying water at a high velocity is greatly affected by the kind of pipe used and the smoothness of the interior surface, and hence can not be predicted with certainty. For a velocity of 8 feet a second, the friction in 200 feet of 48-inch pipe would probably amount to 2 feet of head, and in a 24-inch pipe to at least 6 feet of head. A bend of 90° adds probably a foot to the friction head. The velocity head amounts to about 1 foot, and if the water passes around a sharp edge in entering the suction pipe there is probably a loss of another foot of head. To be safe, then, we should assume the addition of at least 6 feet to the static head to give the head on the pump. Another small amount might be added to the lift, on account of the lowering of the water level in the supply ditch when the pumps are being operated. But it is probably better to ignore this last addition and assume that during the short time when the river is at maximum flood stage the water level in the district will not be pumped down quite to its normal level rather than to provide extra capacity for the very short and infrequent periods of maximum river floods.

With a total head of 26 feet the hydraulic horsepower is calculated by multiplying together the lift—26 feet—the number of cubic feet of water per second—105—the weight of 1 cubic foot of water—

[Bull. 243]

62.5 pounds—and dividing by 550. In this case the result is 310. The power required of the engine will be greater than this amount, depending upon the efficiency of the pumps, which for these conditions should be at least 60 or 70 per cent. For this case probably manufacturers would be willing to guarantee an efficiency under test of 70 per cent. Accordingly the maximum brake horsepower required of the engines would be 440. Engines suitable for this work should be able to carry continuously an overload of 25 per cent without an increase of speed and without a great loss in steam economy; hence, if 440 horsepower puts this overload on the engines, their normal rating would be 350 brake horsepower. They should develop this power at the speed at which the pump has the best efficiency for a static lift of 15 feet or a dynamic lift of 21 feet. When the pumps operate at the maximum lift, their speed should be increased in order to maintain the discharge and the efficiency of the pumps, and the engines should be adjustable and so constructed as to run safely at the higher speed. Since increasing the speed of itself increases the power developed by the engines, this gives a margin of safety in the capacity of the engines. If two separate engines and pumps are used, each engine should have a brake horsepower of 175. Its indicated horsepower will be from 10 to 20 per cent greater. An engine should run fairly economically down to three-fourths of its rating. These units, then, would be economical of fuel down to a static lift of 10 feet. But when the lift falls below 5 or 6 feet, the steam used by the engines will be much increased in proportion to the useful work actually performed in lifting the water. This disadvantage is not very important, however, because the amount of water to be lifted under such conditions is small.

The boiler capacity required would depend upon the particular engines used, upon the number and kind of auxiliaries, and upon the quality of coal to be used. For a plant of this kind, however, the nominal boiler horsepower should be at least as large as the rated engine horsepower. The boilers must have a capacity amply sufficient to supply safely all the steam needed by the engines when operating at their maximum overload. This may be secured by additional boilers or by forcing the boilers when necessary through appliances for producing an artificial draft. In general, large engines of the best types require less steam per horsepower than smaller ones. In a very large plant the nominal boiler horsepower may be less than the engine horsepower.

In designing such a plant all the elements must be carefully calculated to secure in each the necessary maximum capacity. It is especially needful that the auxiliaries be large enough. A deficiency in some single comparatively slight but essential element may hinder

the operation of the whole plant. Durability and reliability in workmanship and materials may be secured to some extent by specifying that the boiler shall be capable of operating at a higher pressure than its regular working pressure, and that the engines shall be able to run with higher steam pressures and at higher speeds than the normal. Descriptions of a large number of pumping plants and the results of tests are given in detail in a bulletin of the office.¹

BUILDINGS AND FOUNDATIONS.

The pumping plant should be inclosed in a substantial and durable building. The foundations of the building, and especially of the machinery, should be prepared with great care. Usually the soil conditions are not good, so that piling must be driven under all the foundations for the machinery. The piling must be made ample to secure firm and rigid support for all the machinery so that there may be no subsequent settlement.

ARRANGEMENT OF SUCTION AND DISCHARGE PIPING.

Proper arrangement of the suction and discharge pipes is very important for the economical and reliable operation of the plant. A

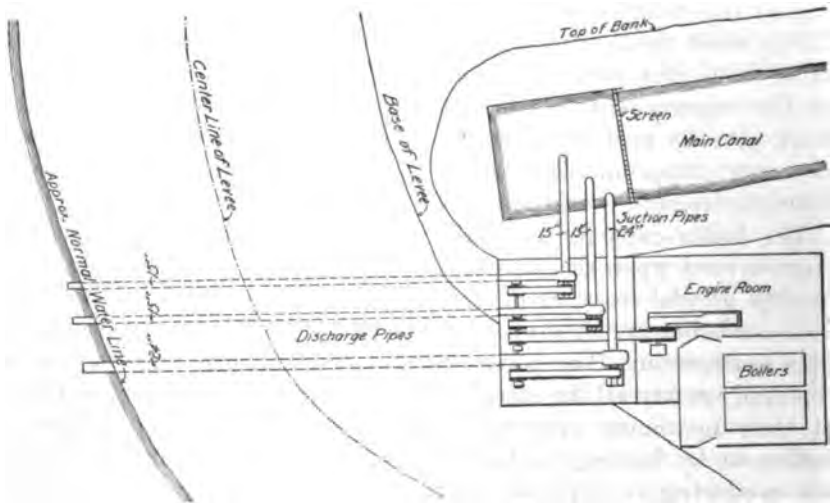


FIG. 2.—Sketch plan of pumping plant, Coal Creek drainage and levee district, Illinois.

sketch plan of the Coal Creek drainage and levee district pumping plant, showing the general arrangement of the pumps and pipes with regard to the main ditch and the levee, is given as figure 2. The pipes should be as direct and straight as possible. All bends should be of long radius and the interior of the pipe should be as smooth as

¹ U. S. Dept. Agr., Office Expt. Stas. Bul. 183.



FIG. 1.—PUMPING PLANT, COAL CREEK DRAINAGE AND LEVEE DISTRICT.

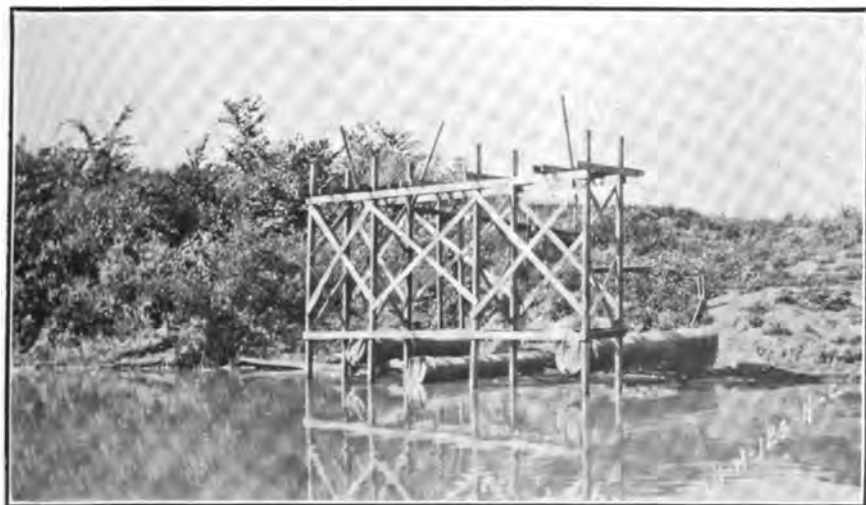


FIG. 2.—ENDS OF OUTLET PIPES, COAL CREEK DRAINAGE AND LEVEE DISTRICT.

practicable in order that the lost work due to friction may be small. Since the head consumed in overcoming friction varies as the square of the velocity, the larger the piping the less the friction loss. Where the piping is long this is the more important. The piping should be made large enough to reduce the velocity in the pipe down to as near 5 feet per second as practicable. All changes in size and direction of the piping should be gradual, and at no point should the water be permitted to flow around a sharp corner.

The suction pit should be carried to a greater depth than the main canal, even though this results in some danger of excessive seepage and of the opening of springs or boils through the lower layers of soil from the river when the suction pit is close to the river bank. This has been a frequent source of difficulty in pumping plants, and on this account the pipes to and from the pumps should be made longer than would otherwise be necessary. In the smaller plants the lower part of the suction pipe is usually vertical or nearly vertical, and has above the vertical portion a right-angle turn connecting to a horizontal piece of pipe leading to the pump. Such an arrangement is illustrated by figure 1 of Plate III, a rear view of the pumping plant of the Coal Creek drainage and levee district showing the suction pipes and the suction bay. Where this arrangement is used the edge of the lower end of the pipe is made in a horizontal plane. This end should also be expanded so as to provide for a gradual contraction of the stream of entering water. The curvature of the expanded end may be relatively abrupt, but should be smooth so that the water may not flow swiftly past any sharp edge or angle. In general, in contracting a stream there is no loss of head, even if the reductions in cross section are comparatively sudden, so long as the surfaces are smooth and curved without any sharp angles. On the other hand, in expanding the cross section of a stream so as to reduce its velocity, the changes must be very gradual or there will be loss of energy due to the impact of the rapidly moving stream striking against the more slowly moving mass of water.

The horizontal edge of the entrance to the suction pipe must be at least as low as the lowest level to which the water is to be reduced in the main ditch, and below this edge there should be a clear distance to the bottom of the suction pit equal to one or one and a half times the diameter of the suction pipe. It would be better if the end of the pipe were a foot lower than the level mentioned above. If the entrance to the suction pipe is expanded to such a degree that the velocity of the incoming water past the edge of the pipe is not more than 2 feet per second, the water level can be drawn down to the end of the suction pipe without trouble from sucking air. Without such expansion, while the level of the water is still a consider-

able distance above the end of the pipe, much air will be drawn into the pump, with a consequent waste of power and danger of stopping the pump. Neglect to provide ample water way around the entrance to the suction pipe has been a source of much annoyance to pumping plants.

Though a suction pipe with a vertical portion at its lower end is probably most easily given a rigid support in the suction pit, a better arrangement for a large plant would be to place the suction pipe on a uniform slope from the pump to its open lower end in the suction pit. This slope should be flat enough so that the pipe can be supported rigidly. The suction pit should be of concrete throughout, reenforced where necessary, shaped so as to form a suitable gradually curved entrance to the suction pipe, and provided at its outer end with a steel screen and with vertical ways for inserting stop planks. The gate openings and the screen openings should be of such size that the velocity through them under normal conditions would not be more than 1 foot per second. In order that the suction lift may be kept low, the pump should be set as low as is consistent with securing good foundations, ease of installation, and safety after installation. The suction pipe must be perfectly airtight and strong enough not to collapse under the greatest suction that will be put upon it.

The discharge pipe should be gradually expanded immediately after leaving the pump so as to reduce the velocity to as near 5 feet per second as seems practicable. If the velocity is not lowered to this amount the outlet should be expanded an equivalent amount. Practice is not uniform as to the best method of preventing water from flowing back through the pipes into the district from the river when the pumps are not operating. Some prefer to carry the discharge pipe through the levee above high-water line and then down, with its end opening below low water, so as to secure a water seal. This is necessary in order that the pipe may act like a siphon and that hence the head on the pump may be only the difference in level between the water in the canal and the water in the river. In this case the pipe must have an opening of ample size at the highest point for use in priming the pump. This is opened to prevent water flowing back by siphon action when the pump is stopped. Others prefer to carry the discharge pipe from the pump through the levee on a level. This necessitates the installation of a gate valve in the pipe next the pump. If the pipe is not over 2 feet in diameter a flap valve may be used on its outer end, but such a valve is never entirely reliable and certain in its operation. A gate valve, if such is used, must be of a slow-closing type, as it is very dangerous to the plant to close such a large valve quickly. The outlet end of the discharge

[Bull. 243]

pipe must have an adequate masonry protection against river wash and against undercutting by the pump discharge.

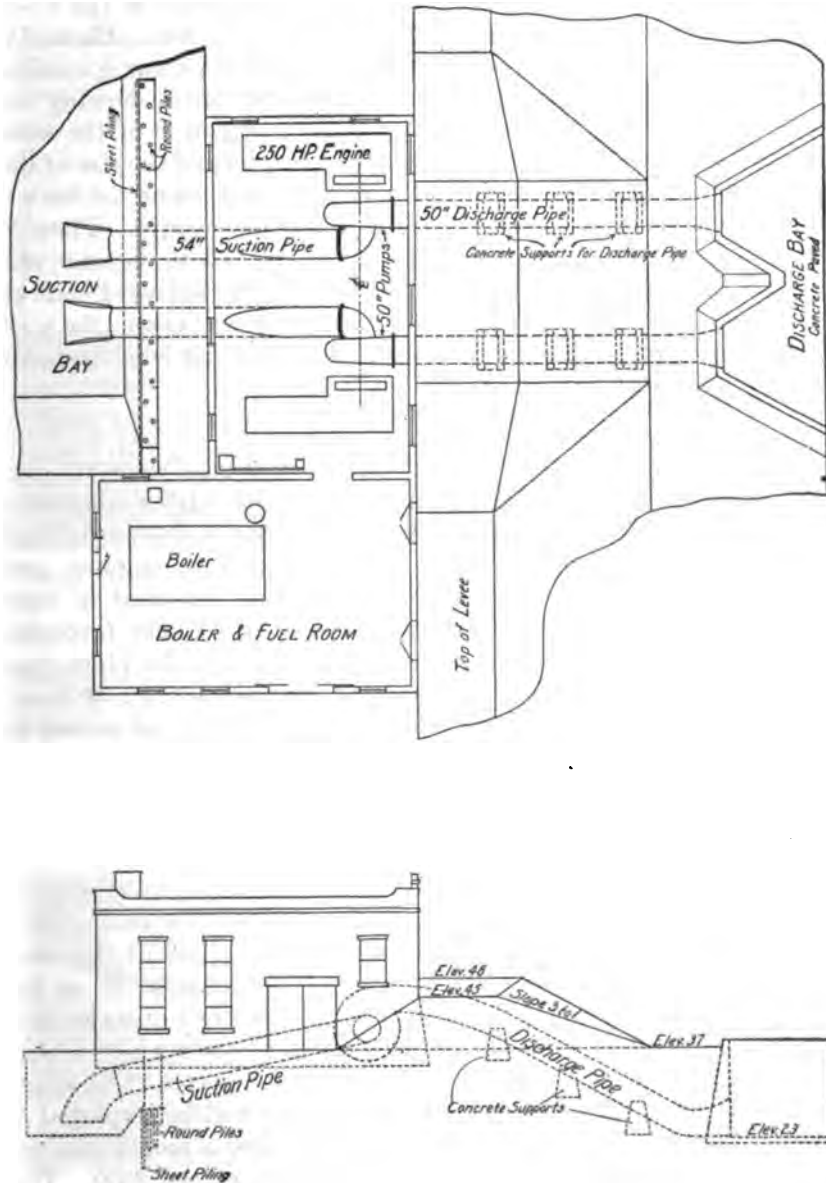


FIG. 3.—Plan and elevation of pumping plant, Louisa-Des Moines drainage district No. 4, Iowa.

The Louisa-Des Moines drainage district No. 4, in Louisa and Des Moines Counties, Iowa, has a well-arranged pumping plant of large size. Figure 3 gives the plan and elevation, showing well the [Bull. 248]

arrangement of suction and discharge pipes. Figure 2 of Plate III shows the flap valves on the outer ends of the discharge pipes of the Coal Creek district. The pipes are above low water in the river and so are exposed, as shown, whenever the river is low. Plates IV and V are views of the Louisa-Des Moines district pumping station. Figure 1 of Plate IV is a view from outside the levee, showing the front of the building and the discharge bay. Figure 2 of the same plate is a view of the engine-room giving a good idea of the size of the 50-inch centrifugal pumps, each of which is direct-connected with a tandem compound condensing engine of 250 horsepower. Plate V shows in figure 1 the rear of the building, with the levee beyond, and in figure 2 a near view of suction bay showing the enlarged ends of the suction pipes. When the latter photograph was taken, the wall about the bay had not been completed. The building is of fireproof construction.

COST OF PUMPING.

The cost of installing a pumping plant will depend upon its size, location, the kinds of machines adopted, and the market conditions at the time, so that it is impossible to determine a definite normal price; probably the entire plant, including pumps, engines, and boilers, can be installed and a suitable building provided in most places for not over \$90 per nominal horsepower. Under favorable circumstances the cost may be materially lower. For the plant used as an illustration, above 1 horsepower was required for each 30 acres. Hence, the cost of the pumping plant complete should not exceed \$3 per acre. With interest at 6 per cent and an allowance of 4 per cent for depreciation, the total fixed charges would amount to 10 per cent per annum or 30 cents per acre of land per year. This charge is, of course, constant every year, whether the plant runs much or little, or not at all.

The annual cost of operation will depend upon how much water the pump raises during the year. Continuing the use of the same illustration as before, with liberal assumptions so as to be on the safe side, to remove during the year a depth of 1.5 feet of water over the district of 10,000 acres against an average static head of 16 feet will probably require 1,700 tons of coal which, at a cost of \$2.50 per ton, would amount to \$4,250. One man might well be employed to take care of the plant throughout the year at \$100 a month; the expenditure for all other labor probably need not exceed \$800. This would make a total of \$2,000 per year for labor. The total cost of operation, then, might approximate \$6,250, or about 60 cents per acre, which with the charge for interest and depreciation would make the total annual charge 90 cents per acre. This is a liberal estimate and in dry years would be much reduced.

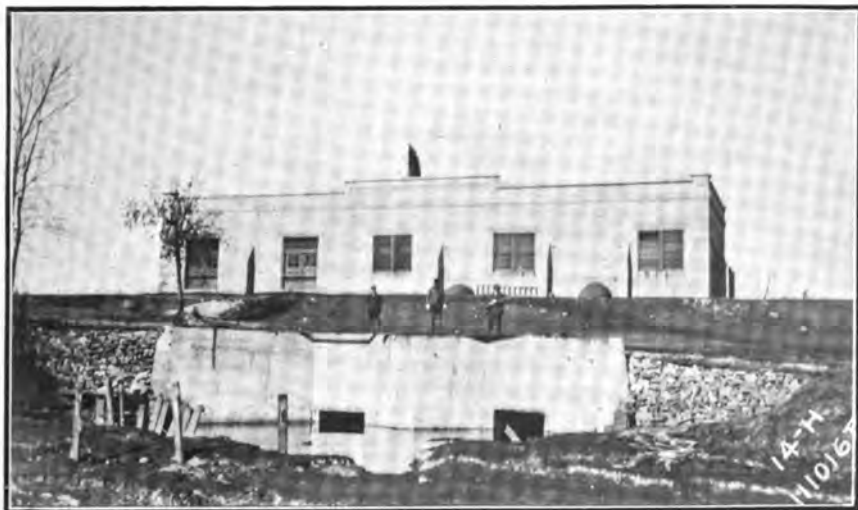


FIG. 1.—PUMPING PLANT AND DISCHARGE BAY, LOUISA-DES MOINES DRAINAGE DISTRICT.

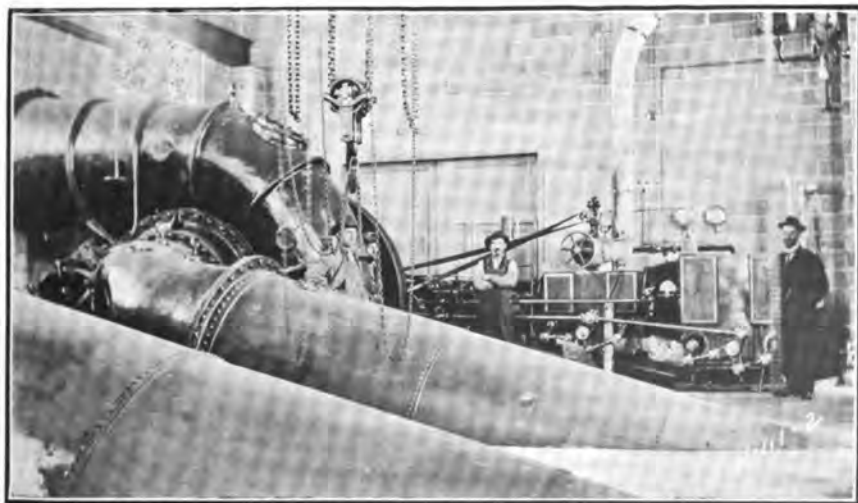


FIG. 2.—ENGINE ROOM, LOUISA-DES MOINES DRAINAGE DISTRICT.



FIG. 1.—REAR OF PUMPING PLANT, LOUISA-DES MOINES DRAINAGE DISTRICT.



FIG. 2.—SUCTION BAY, LOUISA-DES MOINES DRAINAGE DISTRICT.

Careful management will do much to reduce the operating expense. Without expert supervision the cost of running when left to ignorant workmen may greatly exceed the estimate given above. To discover possible sources of waste, a complete daily record of the operation of the plant should be maintained. From such data it may be possible to study out improved methods of operation or ways of securing greater economy. Without such a record it is impossible for anyone to tell in what particulars the operation of the plant may be susceptible of improvement. Such a record should show the time of starting and stopping the pumps each day, the height of the water level within and without the district, the speed of the pumps or engines, and the amount of fuel consumed. It should set forth all happenings of importance in the operation of the plant, and may be kept in a form similar to the following:

Form for daily pumping records.

Date.....

Hour.	Ditch gauge.	River gauge.	Lift.	Speed of pump.	Steam pressure.	Rainfall.	Remarks.
	<i>Feet.</i>	<i>Feet.</i>	<i>Feet.</i>	<i>R. P. M.</i>	<i>Pounds.</i>	<i>Inches.</i>	

One page should be used for each day. The gauges should be read before the pumps are started, again as soon as the ditch level has reached a fairly steady state, perhaps one-half hour after starting the pumps, and at several additional times during the day. If more than one pump is in operation the speed of each should be recorded. All additional matters should be recorded in the Remarks column. The amount of fuel consumed each day should be determined, if feasible, and recorded. An accurate rainfall record should be kept at every pumping plant.

The expenses of operating a pumping plant should be divided under the following headings: Fuel; labor; supplies, such as lubricating oil, waste, etc.; repairs; and superintendence. These expenses should be totaled for each month and for the whole season.

The engineer in charge of the plans for a pumping district should do the utmost to impress upon the district authorities the relative importance of the fixed interest and depreciation charges, the neces-

sity of proper attention to the care and maintenance of the plant, especially during the part of the year when it is not in operation, and the need of proper records and attention for the economical operation of the plant. The keeping of proper records for a pumping plant is as important as bookkeeping for a merchant. In default of previous knowledge, people must be taught these things. They may find experience a dear teacher.

RELATIVE BENEFITS OF DRAINAGE BY PUMPING.

Experience on the Illinois River shows that the first cost of the general district drainage improvements, including levees, ditches, and pumping plant, has varied between \$15 and \$30 an acre. As all the cheapest projects have now been developed, however, there is a growing tendency to undertake the reclamation of more expensive districts in which the cost may exceed by \$10 or \$20 per acre the amount just stated. The cost of clearing the land and field drainage may be between \$5 and \$20 an acre. Hence, in places the total cost for putting the land into profitable productive condition may be as high as \$50 per acre. Such land is then worth from \$100 to \$125 per acre, according to the present value of the contiguous uplands.

The best way for one unfamiliar with the conditions existing in pumping districts to become informed on the subject is to visit and inspect thoroughly one or more such districts. The following list contains most of those with much experience in pumping. Following the name of the district is given its size, the date when pumping was first begun, and the name and address of some one of its officers who can give information concerning it.

Pekin-La Marsh district; 2,800 acres; about 1890; C. L. Velde, Pekin, Ill.

Rhodes district; 3,000 acres; 1900; Judge Williams, Havana, Ill.

Langellier district; 2,200 acres; 1907; A. L. Langellier, Havana, Ill.

Coal Creek district; 6,700 acres; 1898; Jesse Lowe, Beardstown, Ill.

Meredosia district; 3,500 acres; 1904; John Rogge, Meredosia, Ill.

Magee Creek district; 12,000 acres; January, 1909; ———.

Big Swan district; 12,000 acres; 1908; Charles Condit, Winchester, Ill.

Hillview district; 12,400 acres; January, 1909; Louis Lowenstein, Hillview, Ill.

Fairbanks district, near Hillview; 12,000 acres; 1910; W. A. Hubbard, Carrollton, Ill.

Nutwood district; 10,800 acres; February 1, 1910; Steven M. Reddish, Jerseyville, Ill.

Bay Island district; 22,000 acres; March, 1910; M. F. Prouty, New Boston, Ill.

[Bull. 243]

Louisa-Des Moines district, No. 4; 17,000 acres; May, 1909; ———, Oakville, Iowa.

South River district; 12,000 acres; 1910; ———, Hannibal, Mo.

SUMMARY.

The reclamation for agricultural purposes of river bottom lands lying so low that they are subject to serious injury by overflow has been proved by experience in Europe and in this country to be feasible and profitable when carried out by means of a system of protective levees supplemented by interior drainage ditches and a pumping plant to remove excessive precipitation which may fall within the district.

Numerous tracts in units of from 5,000 to 20,000 acres have been thus reclaimed along the Illinois River and on both sides of the Mississippi in the States of Illinois, Iowa, and Missouri. In some districts the cost of the general drainage improvements, including levees, ditches, and pumping plant, has been as high as \$30 per acre. This method of reclamation may be expected to be extended constantly to new localities as agricultural land becomes more valuable.

The design and construction of the levees, ditches, and pumping plant require a considerable degree of engineering ability. Poor design may result either in a system so inadequate for its purpose as to yield a benefit to the land insufficient to make the undertaking profitable, or it may lead to an expenditure for construction greatly in excess of the amount that could have been made to suffice. In general, the inexperienced tend to underestimate greatly the extent and expense of the work required in such reclamation.

The levees must originally be made of such height and thickness as to afford ample strength and they must also be given careful subsequent attention to secure proper maintenance. The internal drainage ditches should be deep enough to keep the ground water level at least 3 feet below the surface and their capacity should be sufficient to discharge heavy rains freely to the pumping station. Streams entering the district from higher ground should be diverted around the levees where such a plan is feasible.

The pumping plant should have a capacity sufficient to remove as a minimum amount in 24 hours a quantity of water sufficient to cover the entire district to a depth of one-fourth inch. The capacity should be greater in situations of heavy rainfall and where the run-off of rolling land is received in the district.

The pumping machinery should be so arranged as to reduce to a minimum the work of disposing of the surplus water, and it should be chosen with especial regard to economy and efficiency in opera-

tion. Where large fluctuations in the river level are to be expected, the machinery must be sufficiently large to operate at the maximum head, and at the same time must be as efficient as practicable for more moderate heads.

The operation and supervision of the pumping machinery must be given careful attention with a view to securing the greatest economy in operation and careful preservation throughout the year. This requires the use of reliable skilled attendants. Full records of the operation of the pumping plant should be maintained, as well as detailed classification of expenditures, so that those in charge can determine at all times whether the operation of the plant is the most economical that may be possible in securing the results desired from the plant.

Where practicable, gravity outlet sluiceways should be installed in connection with a pumping plant for use during times of low water outside of the drainage district.

When properly designed and operated drainage pumping plants prove highly profitable for the reclamation of wet lands in regions where agricultural land is sufficiently valuable.

[Bull. 243]



U. S. DEPARTMENT OF AGRICULTURE.

OFFICE OF EXPERIMENT STATIONS—BULLETIN 244.

A. C. TRUE, Director.

REPORT
ON THE
BELZONI DRAINAGE DISTRICT IN
WASHINGTON COUNTY,
MISSISSIPPI.

BY

H. A. KIPP,
Drainage Engineer.

PREPARED UNDER THE DIRECTION OF

C. G. ELLIOTT,
Chief of Drainage Investigations.



WASHINGTON
GOVERNMENT PRINTING OFFICE
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[Bull. 244]

(2)

LETTER OF TRANSMITTAL

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
Washington, D. C., August 1, 1911.

SIR: I have the honor to transmit herewith a report prepared by H. A. Kipp, drainage engineer, under the direction of C. G. Elliott, chief of drainage investigations, accompanied by maps and diagrams. It presents a plan of drainage for a tract of 100,000 acres of wet lowlands in the Yazoo Delta lying in the eastern part of Washington County, Miss., known as the Belzoni drainage district. The report gives the results of an extensive field survey, supplemented by special investigations of run-off and high-water stages in the vicinity of the district, made by engineers of drainage investigations in 1910-11. Plans for the improvement of the district, together with a discussion of the difficulty of completely reclaiming these lowlands are given, together with an estimate of the probable cost of the drainage work.

The plans recommended in the report, while referring particularly to the Belzoni drainage district, are representative in a general way of the methods of overcoming the difficulties which may be encountered in the reclamation of many similar areas in the Yazoo Delta. Land-owners within this great valley of 4,000,000 acres of rich alluvial soil are becoming more and more interested in the improvement and agricultural development of the land, 70 per cent of which is still covered with a dense growth of timber and heavy underbrush. Other drainage districts are being organized, and being assured that this report contains much that will be of vital interest to those who contemplate such undertakings in the lower Mississippi Valley, its publication as Bulletin 244 of this office is recommended.

Respectfully,

A. C. TRUE, *Director.*

HON. JAMES WILSON,
Secretary of Agriculture.

CONTENTS.

	Page.
Introduction.....	9
Location and description.....	10
Natural drainage and outlets.....	11
Soils and crops.....	13
The survey.....	14
Rainfall and run-off.....	15
Rainfall at Greenville, Miss.....	19
Rainfall at Yazoo City, Miss.....	19
Storms recorded at Yazoo City.....	20
Storms recorded at Greenville.....	21
Plan for drainage.....	22
Map.....	26
Profiles.....	26
Hydrographs.....	27
Drainage unit No. 1.....	28
Drainage unit No. 2.....	28
Estimate of cost for unit No. 2.....	30
Drainage unit No. 3.....	31
Estimate of cost for unit No. 3.....	32
Drainage unit No. 4.....	32
Drainage unit No. 5.....	32
Estimate of cost for unit No. 5.....	34
Drainage unit No. 6.....	35
Estimate of cost for unit No. 6.....	37
Drainage unit No. 7.....	38
Estimate of cost for unit No. 7.....	39
Drainage unit No. 8.....	40
Estimate of cost for unit No. 8.....	41
Bridges.....	41
Summary.....	42
Method of construction.....	44
Beneficial results.....	45
Appendix.....	46
Acreage which may be flooded during periods of extreme and average high water.....	46
Division of the district by drainage units into cultivated, timber and deadened timber lands, and sloughs, bayous, and lakes.....	46
Division of the district by sections into cultivated, timber and deadened timber lands, and sloughs, bayous, and lakes.....	47
Bench marks.....	50

ILLUSTRATIONS.

	Page.
FIG. 1. Rainfall and run-off, Hopson Bayou drainage district, during April, 1911.	17
2. Curve showing run-off to be provided for by drainage ditches of the Belzoni drainage district	18
3. Map of Belzoni drainage district, showing drainage units and proposed improvements.....	26
4. Profiles of general surface, Belzoni drainage district.....	26
5. Hydrographs for years 1907-1910, inclusive, Belzoni drainage district..	28
6. Table of ditch sizes and excavation proposed for the Belzoni drainage district.....	28

(7)

[Bull. 244]

REPORT ON THE BELZONI DRAINAGE DISTRICT, MISSISSIPPI.

INTRODUCTION.

The Belzoni drainage district, embracing that part of Washington County, Miss., east of the Big Sunflower River, was organized under a special act passed by the legislature in the year 1909. The bill provided for the cooperation of the Belzoni Drainage Commission with the United States Government in the making of the necessary surveys and plans for the drainage of the district. Accordingly, in June, 1910, Mr. S. Castleman, of Belzoni, one of the newly elected drainage commissioners, requested the Secretary of Agriculture to have the necessary drainage survey made by engineers of this department. The matter was referred to C. G. Elliott, chief of drainage investigations of the Office of Experiment Stations.

This district is representative of a number of similar tracts in the Yazoo Delta, which are subject to periodic overflow from the larger streams, or which are too wet for cultivation on account of the lack of drainage, and it was therefore considered a profitable field for investigation by this office. S. H. McCrory, drainage engineer of drainage investigations, spent two days in early September, 1910, making a preliminary examination of the territory. He arranged with the board of commissioners that the survey would be made and a report with plans, estimates, and maps would be prepared by this office for the drainage of the district, provided that the commissioners would furnish \$2,000 toward the cost thereof. This agreement was approved by the chief of drainage investigations.

On October 6, a few days prior to the beginning of the survey, Chancellor E. N. Thomas, presiding in the Washington County Chancery Court at Greenville, held the law creating the Belzoni drainage district to be unconstitutional. The case was promptly appealed to the Supreme Court, which, on December 20, rendered a decision upholding the findings of the lower court and abolishing the Belzoni drainage district. The \$2,000 fund having been furnished by the Board of Drainage Commissioners and about half spent by that time, it was deemed advisable not to stop the field work and it was carried through to completion without delay. The report, plans, estimates,

and maps have since been made and copies forwarded to the commissioners in accordance with the original agreement, and in all probability the district will proceed under the general drainage law of the State or under a revised special act.

LOCATION AND DESCRIPTION.

The district lies in Washington County wholly within the Yazoo Delta, about 130 miles south of Memphis, Tenn., 60 miles north of Vicksburg, Miss., and 30 miles east of the Mississippi River. The Big Sunflower and Yazoo Rivers form the west and east boundaries of the district, respectively, while the Washington County line forms the boundary on the north and south. The Choctaw boundary and the Yazoo County line clip the northeast and southeast corners of the district diagonally. The width, north and south, is 12 miles, and the length, east and west, varies between 11 and 19 miles. The average length is about 13 miles and the area is approximately 103,000 acres. Belzoni, the principal town of the district, is midway between the north and south boundaries on the Yazoo River. It is on the Yazoo Delta branch of the Yazoo & Mississippi Valley Railroad and at the south end of the Itta Bena branch of the Southern Railway. The former road extends northwest and south from Belzoni; the latter, north. A right of way through the timber has been cleared for an extension of the Southern Railway to the southwest from Belzoni, and some grading has been done, but this work has been abandoned and the road may not be completed for some time. Isola, the second largest town in the district, is on the Yazoo & Mississippi Valley Railroad near the north boundary and midway between the two rivers. There are also several smaller settlements within or near the boundaries of the district, such as Duke, Perkins, Jaketown, Belgrade, Silver City, Murphy, and Callao.

Most of the area is very flat and approximately 74 per cent of the district is covered with heavy timber and underbrush. About 21 per cent of the area is under cultivation, 2 per cent is deadened timber land, and the remaining 3 per cent is occupied by deep sloughs, bayous, and lakes which can not be reclaimed. Some of these are apparently old river channels, while others are but shallow depressions connected by swales so shallow that they can scarcely be followed, except by noting the character of vegetation rather than by any apparent depth of channel. They are very winding, branching out and reuniting to form a veritable network of obstructed water-courses. The banks of the two rivers and of the larger lakes and deeper bayous have an elevation several feet higher than the general level of the area, having been built up by the deposit of sediment after overflows.

[Bull. 244]

There are but few roads crossing the district. These are very poor and during the wet seasons some of them become impassable. Teams get mired in the soft mud and much time and energy is wasted by drivers picking out new trails through the woods when the roads are in such bad condition. Cotton is hauled from the Sunflower River to Isola and Belzoni when the roads permit, but most commerce along that stream is carried on by steamboat. The lumber business is quite extensive, the Barr-Holliday, Interstate Cooperage, Castleman, Belzoni, and Belgrade companies all operating large plants within the district. This industry is second to that of raising and marketing cotton, but much of the cotton handled at Belzoni and Isola is grown outside the limits of the drainage district. Land under cultivation is valued at \$20 to \$50 per acre and timbered land at \$10 to \$20 per acre, depending upon the kind of timber and location of the land with reference to the towns.

NATURAL DRAINAGE AND OUTLETS.

The natural drainage of the entire Belzoni drainage district is very poor. All of the smaller existing channels are crooked, are more or less obstructed by fallen trees, logs, and a heavy growth of underbrush, lack good outlets, and are altogether entirely inadequate to remove the rainfall of this area. The interior of the district, being considerably lower than the land along the banks of the rivers and larger bayous, acts as a huge basin, holding much of the water which falls upon it, or which is backed in upon it from the rivers and remains there until taken up by the vegetation, or evaporated. Hence a large portion of the entire area remains saturated throughout the greater part of the year, and is entirely unfit for cultivation. The natural slope of the western four-fifths of the drainage district is toward the west and south. Jackson Bayou, Little Jackson Bayou, Cold Lake, and Buck Bayou form an indefinitely connected system of drainage with Ditchlow Bayou, which empties into the Sunflower River at Murphy. Beasley Bayou drains a part of Sunflower County and a part of the northwestern corner of the Belzoni district and has a good outlet into the Sunflower River near the Sunflower County line. The extreme southwestern portion of the district is partially drained by a system of sloughs and bayous which have outlet into the Sunflower River through a definite channel at the Sharkey County line. The eastern one-fifth part of the district is partially drained into the Yazoo River through a system of old channels composed of Sky Lake, Bear Creek, and Wasp Lake, and several smaller and independent bayous in the vicinity of Belzoni, having direct outlet into the river. Little Atchafalaya Bayou, which empties into the Yazoo River at the town of Belgrade, drains only a small tract of land in that vicinity, but the channel is very crooked, of varying depth, and

badly obstructed by underbrush and logs in some places, and is of little value. The overflow from Little Atchafalaya sometimes finds its way south from Belgrade into a great cypress pond in the southeastern corner of the district, and occasionally goes even farther westward to the head of Gooden Lake, about halfway to the Sunflower River, following a low, shallow, and ill-defined slough all the way.

Two of the above-named natural channels, Ditchlow Bayou and Wasp Lake, would form very good outlets for practically the entire drainage district, except for the high stage of water in the Sunflower and Yazoo Rivers during spring freshets. During such periods these two channels, together with Beasley Bayou, Little Atchafalaya Bayou, and several smaller bayous, act as intakes rather than outlets and permit the high water from the river to reach and flood the interior of the district. Sometimes when the water has been very high in both rivers at the same time, it has been observed that muddy water backing in from the Yazoo through Little Atchafalaya Bayou meets clear water backing in from the Sunflower through Ditchlow Bayou, the meeting point being at the head of Gooden Lake. During such periods the lowlands in the southeast corner of the district, a tract of about 6,000 acres in the northwest part of township 15 north, range 5 west, and an extensive area in the vicinity of Wasp Lake, become flooded to a depth of from 3 to 5 feet, while most of the remainder of the district is covered with water several inches deep.

Both the Yazoo and Sunflower are subject to backwater from the Mississippi River, and the duration of blocked outlets at the mouths of Wasp Lake and Ditchlow Bayou depends almost entirely upon the high stage of water in the Mississippi at Vicksburg. The Sunflower River and its watershed lie wholly within the flat Delta country. It has a deep and well-defined channel, caused by overflows of the Mississippi in former years, and it has a comparatively uniform flow throughout the year. But the Yazoo has its headwaters in the hilly country of northern Mississippi and is subject to erratic fluctuations. Some spring freshets coming down the crooked channel of this stream rise above the banks and cause flooding of the lowlands away from the river. Sometimes these flood waters find their way from the Yazoo across to Bacons Bayou in Leflore County and from there down into Sky Lake and Bear Creek, reentering the river through Wasp Lake. Some of the water goes even farther over into Jackson Bayou and Dawson Lake, and from there over into the Sunflower through Beasley Bayou and other channels in Sunflower County.

There is now a movement on foot in the Tallahatchie drainage district of northern Mississippi to divert the Coldwater River, one of the principal tributaries of the Yazoo River, into Horn Lake, thence

into the Mississippi, thus cutting off a great volume of water coming down from 1,000 square miles of hilly watershed and preventing it from ever reaching the Yazoo. When this plan is carried out, the flooding of Washington County, due to freshets coming down the Yazoo River, will cease, and there will then be only backwater from the Mississippi to contend with. It is also probable that the Mississippi River levee, which now ends at a point 14 miles above Vicksburg, will be extended southward to the mouth of the Yazoo, and when this takes place the effect of backwater will be entirely eliminated. With these two factors combined there should be no more backing of water onto the lowlands between the Yazoo and Sunflower in the Belzoni district, and there would then always be a free outlet at the mouths of Ditchlow Bayou and Wasp Lake.

SOILS AND CROPS.

The soils of this district are evidently the same as those found in the land between the Yazoo and Big Sunflower Rivers, which are described in the report on the Soil Survey of the Yazoo Area, Miss.¹ They were all formed by the deposit of sediment brought down by the Mississippi River and by the Yazoo and Big Sunflower Rivers. The coarser particles were dropped along the river banks, where the velocity was first checked, and the finer particles were carried farther and deposited in the quiet waters away from the watercourses. This is the cause of the banks being high, sandy, and comparatively well drained, while the ground back of these is low, fine grained, and usually wet. The soil is Yazoo sandy loam on the tops of the ridges, and from this it grades through Yazoo loam and Yazoo clay to Sharkey clay in the lowest parts. Judging from its drab color and the amount of underbrush in the timber, the predominating soil type is probably Yazoo clay.

The loams are friable and easy of cultivation save when too wet. The clays, however, must be worked while the degree of saturation remains within comparatively narrow limits, a condition which is seldom found in this region. If plowed when too wet, they resume their solid texture and the surface dries hard and compact; if plowed too dry, they are but broken into hard lumps and yield poor crops, but when the proper quantity of moisture is present these soils are easily worked and very productive. The sandy loam has been longest cultivated, both because it is above the more frequent inundations and is better drained, and because it is located along the watercourses that furnished the earliest means of communication. This soil and the loam yield good crops, the average of cotton being from $\frac{1}{2}$ to 1 bale per acre, and of corn probably between 25 and 30 bushels per

¹ U. S. Dept. Agr., Advance Sheets from Field Operations of the Bureau of Soils, 1901, pp. 359-388. [Bull. 244]

acre. Only a small percentage of the cultivated land is in corn, and small patches of peas, beans, cabbages, potatoes, and other truck are raised in the gardens about the cabins of the field hands. The clay soils are richer in plant food, due to the nature of the material left by the floods and to the larger proportion of humus from the covering forests. Very little of these is cultivated because they are wet too great a part of the year. They are practically all in timber, which consists principally of gum, several varieties of oak, some ash, elm, and hickory, with cypress along the lakes and bayous.

THE SURVEY.

The survey was begun October 10, 1910, at Belzoni. The field party consisted of H. A. Kipp, drainage engineer, in charge; C. W. Okey, A. G. Hall, and R. D. Marsden, assistant engineers; 3 rodmen, 5 axmen, a cook, and a teamster. Practically all of the field work was done from four camps, the first of which was located at Belzoni, the second at Murphy, the third at Callao, and the last at Isola. By using teams, railroads, and lumber trams, half of the territory was surveyed from the camp at Belzoni. Base levels fully checked were run from Belzoni to Silver City on the Yazoo & Mississippi Valley Railroad; from Belzoni to the north county line on the Southern Railway; and from Belzoni to the Big Sunflower River on the north line of township 15. The levels were tied to bench marks set by the United States Army engineers along the Big Sunflower River, and sea-level datum was thus obtained. Levels were run across the district on the east-and-west section lines, the ends being tied to a line of levels along the Sunflower and Yazoo Rivers at either end. Check levels were run from Belzoni to Dawson Lake along the Yazoo & Mississippi Valley Railroad and elsewhere as occasion required, so that all work was checked within the allowable error for good wye-level work. All of the larger watercourses and many of the smaller ones were meandered by the compass needle and stadia method, levels being carried with the meanders, and sufficient cross-sections taken to determine the size and capacity of the channels. Bench marks were set approximately at section corners, on the bayou crossings, and at many other points. Most of the bench marks were made by cutting a notch in the root of a tree and driving in a copper rivet, the elevation being taken on the top of the rivet. A list giving the numbers, descriptions, and elevations of nearly all of these benches will be found in the appendix of this report. It will be understood that the section lines were followed merely for convenience, and only approximately, a great many of the actual section corners not being found at all. Bench marks are described with reference to what seemed to be the locations of these section lines and corners. Considerable difficulty was experienced in running many of the cross levels and mean-

ders, due to the fact that the cane, vines, briars, and other tangled underbrush made progress very slow. At other times during the winter high water and ice on the sloughs and bayous in the woods caused great inconvenience. It was deemed advisable to include in the survey that part of Leflore and Yazoo Counties in townships 15 and 16 east of the organized district to the Yazoo River, and all cross-level lines were therefore carried through to the Yazoo River.

A base, or skeleton map, was prepared in camp, using the township plats of the United States General Land Office for a guide, and upon this map were platted all the data secured by the field party. Later the arrangement for the proposed drainage system was determined from this completed map. About 300 miles of levels and 200 miles of meanders with levels were run, requiring a total of 80 working days. Nearly 115,000 acres were covered, at a cost of about 4 cents per acre. The cost of the field and office work in connection with the project is as follows:

Field expenses paid by drainage investigations	\$2, 311
Field expenses paid by drainage district.....	2, 000
Total cost of field work.....	4, 311
Cost of preliminary examination.....	50
Cost of office work, including report and maps.....	1, 339
Total cost of project.....	5, 700

RAINFALL AND RUN-OFF.

From an examination of the rainfall records at Greenville and Yazoo City, the two Weather Bureau stations nearest to the Belzoni drainage district, for the years from 1897 to 1910, inclusive, it is found that the greatest precipitation occurs in the winter and spring, or from December to May, inclusive. Only very rarely less than 2 inches are recorded for any month during this period, the average being about 4.7 inches. The greatest monthly precipitation occurred at Yazoo City in May, 1909, when 19.2 inches were recorded. The greatest annual rainfall occurred in 1908, when 61.1 inches were recorded at Yazoo City and 59.4 inches at Greenville. The least annual rainfall occurred in 1904, when 37.3 inches were recorded at Yazoo City and 39.7 inches at Greenville.

The greatest amount of damage due to overflows and lack of drainage is done during the months of March, April, and May—the planting season. At present only the higher lands which can be drained without the expenditure of much money are under cultivation, but should any attempt be made to cultivate the lower lands without an extensive system of drainage it would doubtless be found to be very difficult and unprofitable. Cotton would have to be replanted several times in the spring, and the gathering of the crop, which often lasts well into the winter, would become almost impossible on account

of the December overflows. Many instances are on record when excessive rains occurred during December and January, as shown in the rainfall tables on page 20.

The run-off which will need to be provided for by the new drainage system depends upon the rainfall during the wet season, and more particularly upon the excessive storms of from 24 to 72 hours' duration. The records show that an average of six times a year storms of 2 inches or more precipitation occur. About half of them are recorded during the wet season, from December to May, when the ground is saturated and the effect of flooding is the worst. The other half occur during the dry season, when most of the rainfall is absorbed by the ground, taken up by the growing vegetation, or quickly evaporated, and no material damage is done. Measurements have been made by engineers of this office of flood discharges in certain completed drainage districts within the Delta in Coahoma County, in the upper part of the Sunflower River watershed. The surface conditions in this region, the Hopson Bayou and Fishing Bayou drainage districts, are identical with those of the Belzoni district, only a much greater proportion of the land in that area is under cultivation than is found in Washington County. Although almost three-fourths of the Belzoni district is now covered with timber, which naturally tends to hold back the water from draining quickly into the low sloughs and bayous, it must be considered that this land will eventually become cleared and cultivated, as in the above-named districts, and a more rapid run-off will then take place than at present.

The results of the observation on run-off in the Hopson Bayou drainage district during the month of April, 1911, when an unusually heavy precipitation occurred, show that nearly 1 inch depth of water covering the entire watershed above the gauging station was discharged in 24 hours, after a 12-hour storm, during which 7 inches of rainfall were recorded. No storms of like intensity have ever been recorded before or since that time, and it is not likely that such heavy precipitation in so short a time will occur again, excepting perhaps at very long intervals. After storms of over 2 inches and less than 3 inches, such as are tabulated below, it was found that the maximum run-off from this same area, and when the ground was thoroughly saturated by previous rains, varied between one-half and three-fourths of an inch per 24 hours.

The following diagram, figure 1, clearly illustrates the relation between the rainfall and run-off in the Hopson Bayou drainage district during the month of April, 1911. The vertical black lines indicate the amount of rainfall in inches for each day and the shaded areas indicate the amount of run-off in inches depth per 24 hours over the entire drainage area above the gaging station. Attention is called to the date, April 4, when 7.05 inches of rain fell. For that partic-

ular day the diagram shows a run-off of 0.95 of an inch. For each following day up to April 13 the run-off decreased steadily and was not affected by the light rains of April 8 and 11. By April 13 the run-off had lowered to 0.2 of an inch, only to climb again to 0.68 of an inch on April 19, after a 2-day's rainstorm, during which 2.88 inches of rain fell. From this day to the end of the month the run-off decreased steadily, not being affected by the light rains of April 24, 27, and 28, and lowering to less than 0.1 of an inch by the 1st of May. Previous to the time when the gagings for the above result

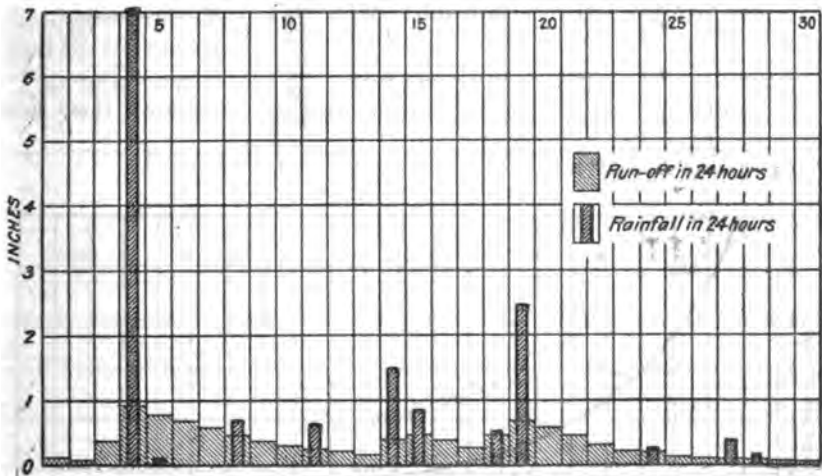


FIG. 1.—Rainfall and run-off, Hopson Bayou drainage district, during April, 1911.

were begun the ground was only slightly wet, owing to an unusually dry March, when only 2.89 inches rainfall were recorded. A large percentage of the heavy rain of April 4 must have been absorbed by the dry ground, causing a much lighter run-off than that which would have occurred had the ground been previously saturated. The diagram shows clearly that the relation of run-off to rainfall on April 4 is much out of proportion when compared to the corresponding relation on April 19, when the ground was thoroughly saturated and a 2.88-inch rain caused a 0.68-inch run-off.

In the following table the rainfall at Clarksdale (Hopson Bayou drainage district) during April, 1911, and the daily run-off coefficients are given:

Rainfall and run-off at Clarksdale (Hopson Bayou drainage district), during April, 1911.

Date.	Rain-fall.	Run-off.	Date.	Rain-fall.	Run-off.	Date.	Rain-fall.	Run-off.
	Inches.	Inch.		Inches.	Inch.		Inches.	Inches.
Apr. 1.....		0.045	Apr. 12.....		0.254	Apr. 23.....		0.279
2.....		.039	13.....		.210	24.....	0.22	.197
3.....		.318	14.....	1.52	.416	25.....		.130
4.....	7.05	.952	15.....	.86	.512	26.....		.086
5.....	.06	.707	16.....		.402	27.....	.39	.085
6.....		.700	17.....		.279	28.....	.16	.077
7.....		.593	18.....	.44	.416	29.....		.061
8.....	.68	.472	19.....	2.44	.682	30.....		.053
9.....		.376	20.....		.610	Total.....	14.43	10.500
10.....		.332	21.....		.488			
11.....	.64	.304	22.....		.365			

Per cent of run-off to rainfall, 72.7.

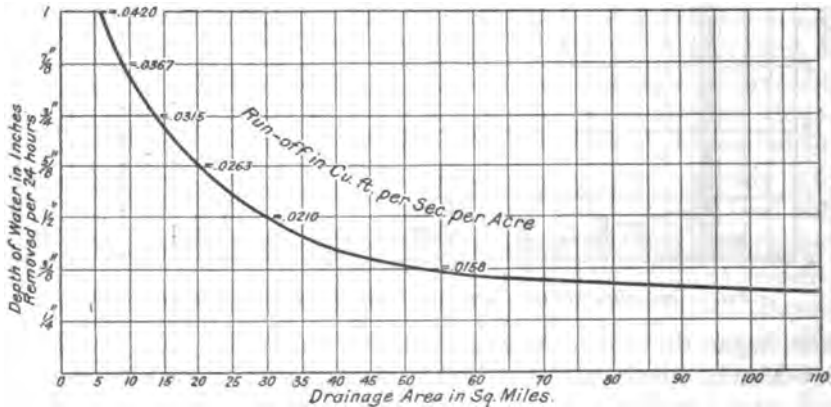


FIG. 2.—Curve showing run-off to be provided for by drainage ditches of the Belzoni drainage district.

The average total rainfall for the month of April for 7 years preceding 1911 was 4.89 inches, and for the month of March was 5.01 inches.

The results given in the table compare favorably with those obtained in other drainage districts where soil and surface conditions are similar to those of the Belzoni district, and where storms of like intensity occur with about the same frequency. The main point of difference between the Hopson Bayou district, upon which the above observations were made, and the Belzoni district is in the size of the drainage area. The former district contains only 14,800 acres, or about 23 square miles, while the latter contains over 100,000 acres, but it must be remembered that the Belzoni district is divided up into eight drainage units, varying in size from 3,343 acres to 26,627 acres. This fact again makes the conditions of the two districts similar, excepting in the case of the large main ditches, which will carry the water from

[Bull. 244]

more than one drainage unit. A table, based upon these combined observations, has been made and is represented by a curve, figure 2, which indicates the amount of water, expressed in inches of depth, over any size of watershed from 1 square mile to 110 square miles, which the ditch draining that watershed will be required to remove per 24 hours. It shows that the smallest ditches, which drain from 1 to 6 square miles of land, will be required to remove 1 inch of water over that area per 24 hours and that the largest ditch, which carries the drainage from 110 square miles, must remove 0.31 inch of water over that area per 24 hours, or 916 cubic feet per second. Intermediate ditches will carry proportional amounts, and are indicated by the curve.

The following tables give the monthly and annual rainfall from 1897-1911, inclusive, both at Greenville and Yazoo City, Miss.

Rainfall at Greenville and Yazoo City, Miss., 1897-1911.

GREENVILLE, MISS.

Years.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Year.
	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>
1897.....	4.50	4.21	11.37	1.97	1.51	1.09	4.43	2.72	0.02	1.75	3.67	9.12	46.36
1898.....	8.38	3.05	3.13	4.18	3.28	2.40	1.69	7.95	5.75	6.03	4.68	1.66	52.18
1899.....	5.38	4.53	5.44	2.24	4.67	1.41	2.11	.83	1.18	1.09	1.06	4.22	34.13
1900.....	1.93	5.06	5.74	6.09	3.94	9.51	6.20	1.00	2.75	4.88	3.38	3.46	54.84
1901.....	4.61	3.82	4.45	3.17	5.08	1.22	2.23	2.52	4.59	.85	3.69	4.92	41.75
1902.....	2.58	3.07	7.89	3.11	4.57	.97	2.13	1.31	5.46	2.48	6.64	4.96	45.17
1903.....	5.04	8.04	5.76	1.12	2.42	2.07	4.50	5.34	.38	.50	.27	4.21	39.65
1904.....	2.57	1.23	5.36	3.58	1.33	8.82	4.41	1.72	.04	.16	3.47	9.26	41.95
1905.....	7.88	4.26	5.11	8.04	6.45	5.91	5.29	9.31	2.44	2.41	3.49	6.15	66.65
1906.....	3.49	1.43	5.44	1.35	6.49	1.43	5.89	2.24	8.80	3.65	8.76	5.68	54.65
1907.....	2.03	3.66	6.14	5.29	7.55	1.58	2.27	.58	4.40	3.24	4.46	4.79	45.99
1908.....	4.93	11.28	4.76	4.13	5.63	4.54	4.61	7.12	2.06	.14	3.53	6.71	59.44
1909.....	1.31	6.29	5.03	6.56	8.69	4.00	3.00	.89	4.35	1.55	1.85	6.49	50.01
1910.....	6.58	4.48	.20	3.06	6.08	5.77	5.26	6.22	.02	4.46	.70	4.67	47.50
1911.....	3.48	5.67	3.21	8.14	1.21	3.52							
Average.....	4.31	4.67	5.27	4.19	4.63	3.62	3.85	3.55	3.01	2.37	3.54	5.45	48.59

YAZOO CITY, MISS.

1897.....	4.43	3.79	5.14	2.11	4.30	3.14	3.30	3.52	Trace	1.60	2.53	11.22	45.08
1898.....	7.92	2.12	3.97	3.00	1.84	6.64	7.74	5.57	7.92	2.95	4.18	2.08	56.53
1899.....	8.36	3.67	7.44	2.41	3.91	1.13	5.00	2.69	1.87	.77	1.18	4.75	43.18
1900.....	2.40	5.23	5.10	0.85	2.65	12.11	7.57	1.30	1.75	4.05	2.85	3.70	58.56
1901.....	6.75	3.97	4.55	4.02	6.08	3.31	2.40	6.75	3.55	1.00	2.20	7.85	52.43
1902.....	2.65	2.42	13.20	3.25	3.00	.27	3.54	6.20	5.05	1.60	3.99	4.07	48.64
1903.....	4.57	12.96	3.58	1.55	1.55	1.21	1.75	5.55	1.75	.55	Trace	2.61	37.63
1904.....	2.57	2.25	5.02	2.35	2.05	3.35	7.25	2.70	Trace	0	3.40	5.72	37.26
1905.....	4.60	7.74	5.60	7.28	3.86	5.77	3.80	4.00	1.07	4.40	4.71	4.60	57.43
1906.....	4.36	1.08	7.84	2.82	8.10	1.65	4.70	3.08	7.56	3.98	3.30	3.64	52.11
1907.....	3.76	3.68	1.49	5.08	6.18	2.66	4.37	5.88	4.22	1.76	4.51	3.76	47.35
1908.....	3.32	8.30	0.56	6.36	7.90	4.56	5.20	7.50	2.60	.02	2.52	6.24	61.08
1909.....	.66	8.91	6.07	6.26	19.24	4.38	1.39	3.18	3.74	.80	1.80	2.96	58.39
1910.....	5.54	5.84	.26	3.27	4.27	5.88	5.25	8.92	.44	6.46	3.08	3.88	53.09
1911.....	5.42	4.33	2.14	8.70	2.24	4.30							
Average.....	4.49	5.09	5.13	4.59	5.18	4.02	4.51	4.77	2.96	2.09	2.87	4.79	50.62

The larger storms occurring over a watershed are of more importance in the design of drainage improvements than average rainfall data. The following table, therefore, gives the amount of precipitation during such storms as occurred at Yazoo City during the years 1897-1911 and at Greenville, 1897-1908.

Storms recorded at Yazoo City and Greenville, Miss., 1897-1911.

YAZOO CITY.

Date.	Inches rain- fall.	Date.	Inches rain- fall.	Date.	Inches rain- fall.	Date.	Inches rain- fall.
1897.		1900.		1904.		1906.	
Dec. 2.....	0.20	June 19.....	0.54	July 4.....	1.00	Oct. 3.....	0.02
3.....	3.67	20.....	.30	5.....	.95	5.....	2.00
4.....	1.90	21.....	.40	12.....	2.00	6.....	.86
18.....	.90	22.....	.30	Dec. 24.....	1.10	Nov. 18.....	2.32
19.....	1.38	23.....	.40	25.....	T.	19.....	.22
20.....	.03	1901.		26.....	.05	20.....	T.
21.....	1.55	Jan. 10.....	.25	27.....	3.17	21.....	.70
22.....	.55	11.....	4.40				
		12.....	.85				
1898.		Mar. 3.....	2.00	1905.		1907.	
Jan. 13.....	.23	Apr. 17.....	1.25	Jan. 10.....	.75	Jan. 30.....	1.62
14.....	.55	18.....	1.70	11.....	T.	31.....	1.10
15.....	1.55	19.....	.45	12.....	1.50	Feb. 1.....	.22
19.....	2.04	May 25.....	2.20	Feb. 8.....	1.30	Aug. 21.....	2.52
20.....	1.33	June 6.....	.15	9.....	1.04	30.....	1.88
Apr. 23.....	2.20	7.....	2.10	19.....	1.20	Sept. 1.....	1.62
June 2.....	1.87	Aug. 13.....	1.65	20.....	1.50	9.....	1.54
3.....	.29	14.....	2.00	Mar. 9.....	2.30	10.....	.54
July 9.....	1.90	15.....	.80	Apr. 25.....	2.00		
10.....	1.35	16.....	.70	May 22.....	1.50	1908.	
Aug. 5.....	1.71	Sept. 13.....	2.30	23.....	.76	Feb. 9.....	1.10
6.....	.51	14.....	.20	June 26.....	.50	10.....	.40
10.....	2.55	15.....	.95	27.....	1.10	12.....	.08
Sept. 7.....	2.00	16.....	.10	28.....	1.12	13.....	2.30
8.....	.16	Dec. 9.....	2.30	Nov. 3.....	.20	14.....	.52
20.....	.68	28.....	1.30	4.....	.82	15.....	.20
21.....	1.95	29.....	1.35	5.....	1.20	Mar. 30.....	.60
				6.....	1.15	21.....	.06
1899.		1902.		Dec. 13.....	.12	22.....	1.20
Jan. 4.....	.11	Mar. 27.....	3.65	14.....	1.66	23.....	2.80
5.....	2.09	28.....	4.40	15.....	1.10	24.....	1.20
6.....	2.32	29.....	.95			Apr. 24.....	1.84
7.....	.34	Apr. 7.....	2.90	1906.		25.....	1.02
Mar. 12.....	.30	July 27.....	2.00	Jan. 3.....	2.20	May 5.....	3.30
13.....	1.30	30.....	.60	Mar. 19.....	3.80	14.....	1.04
14.....	2.08	Aug. 1.....	2.85	27.....	.18	15.....	.34
15.....	1.66	2.....	.20	28.....	1.55	16.....	.22
May 13.....	2.00	3.....	.25	29.....	1.36	17.....	.94
Mar. 1900.		20.....	2.80	30.....	.14	18.....	.82
Apr. 16.....	1.30	Nov. 25.....	2.00	May 4.....	1.00	19.....	1.34
17.....	2.70	Feb. 1903.		5.....	1.78	June 9.....	.10
May 31.....	.80	Mar. 3.....	2.40	6.....	.24	10.....	1.24
June 1.....	1.95	4.....	.25	7.....	1.58	11.....	1.28
2.....	1.90	7.....	4.35	July 28.....	.08	July 29.....	1.08
3.....	.20	8.....	.75	29.....	.18	30.....	.96
4.....	.90	11.....	1.10	30.....	2.16	Aug. 1.....	.10
5.....	T.	14.....	.45	Sept. 25.....	.22	2.....	1.62
6.....	.50	15.....	.07	26.....	.44	3.....	3.14
13.....	.05	16.....	2.10	27.....	.18	5.....	1.36
14.....	2.20	17.....	.35	28.....	4.80	Dec. 6.....	.66
16.....	.70	Aug. 20.....	2.10	29.....	.10	7.....	2.20
18.....	.73			30.....	.58	19.....	.20
				Oct. 1.....	.08	20.....	.50
				2.....	.70	21.....	.90
						22.....	.90

Storms recorded at Yazoo City and Greenville, Miss., 1897-1911—Continued.

YAZOO CITY—Continued.

Date.	Inches rain- fall.	Date.	Inches rain- fall.	Date.	Inches rain- fall.	Date.	Inches rain- fall.
1909.		1909.		1910.		1911.	
Feb. 9.....	2.01	May 18.....	0.16	Feb. 17.....	2.90	Feb. 9.....	1.86
10.....	.32	19.....	2.30				
13.....	.24	20.....	.40	Apr. 16.....	2.22	Mar. 26.....	1.08
14.....	.10	25.....	3.30	17.....	.35		
15.....	1.93	26.....	2.30	July 31.....	.25	Apr. 4.....	3.02
16.....	.15	27.....	2.04			8.....	.42
19.....	.92	28.....	3.60	Aug. 1.....	3.30	9.....	1.06
22.....	1.00	29.....	.24	5.....	2.22	11.....	1.08
23.....	.02	30.....	.10	7.....	1.76	12.....	.62
24.....	1.92	31.....	1.70	10.....	1.34	19.....	1.16
Mar. 12.....	.34	June 14.....	1.64	Oct. 6.....	.06	June 20.....	.52
13.....	1.70	15.....	.72	7.....	2.34	21.....	.87
14.....	1.40	Sept. 21.....	3.02	13.....	3.74	22.....	.17
15.....	.20					23.....	.07
Apr. 13.....	2.24	Jan. 1910.	1.48	Jan. 1911.	3.74	24.....	.36
		6.....	2.70	2.....	.78	25.....	1.86

GREENVILLE.

1897.		1900.		1902.		1905.	
July 19.....	2.04	May 16.....	1.61	Nov. 22.....	0.08	Jan. 29.....	2.54
		17.....	2.06	23.....	.02		
Oct. 31.....	1.53	30.....	.32	24.....	.30	Apr. 11.....	2.03
Nov. 1.....	1.90	31.....	.30	25.....	2.91	12.....	.37
				26.....	.03	25.....	2.00
Dec. 2.....	.16	June 1.....	.08				
3.....	2.24	2.....	.01	1903.		May 7.....	2.50
4.....	1.20	3.....	1.29	Jan. 1.....	.27	8.....	.32
		4.....	.90	2.....	1.98		
18.....	.71			3.....	.02	June 26.....	.46
19.....	1.70	26.....	2.07			27.....	1.60
20.....	.29	27.....	.54	Feb. 7.....	1.93	28.....	1.04
21.....	.56	July 31.....	3.10	8.....	.19		
22.....	1.23	Oct. 26.....	3.21	Mar. 8.....	.19	July 24.....	1.42
				9.....	1.00	25.....	1.10
1898.		Jan. 1901.	.54	10.....	1.56	Aug. 9.....	2.12
Jan. 19.....	1.89	11.....	2.28	11.....	.96		
20.....	1.03	12.....	.59	July 11.....	2.34	14.....	.98
22.....	.85			12.....	.24	15.....	1.72
23.....	.76	Mar. 9.....	1.09	13.....	.15	16.....	.14
		10.....	1.57			17.....	.56
Apr. 23.....	2.36	May 25.....	2.30	Aug. 9.....	.06	Aug. 18.....	.55
Aug. 9.....	1.51			10.....	1.33	19.....	1.59
10.....	1.38	Sept. 12.....	1.09	11.....	.31		
Sept. 20.....	.10	13.....	.46	12.....	.04	Dec. 13.....	.21
21.....	2.40	14.....	1.55	13.....	2.36	14.....	2.35
22.....	.30	15.....	.72	15.....	.35	15.....	1.23
30.....	1.43	17.....	.77				
Oct. 1.....	1.48	1902.		1904.		1906.	
2.....	.12	Mar. 27.....	.64	June 4.....	1.12	Mar. 19.....	2.30
Nov. 9.....	2.00	28.....	2.32	5.....	1.02		
10.....	.92	29.....	1.75	6.....	.11	27.....	.10
				7.....	.45	28.....	.58
1899.		May 30.....	2.15	9.....	1.02	29.....	1.32
Jan. 5.....	1.46	31.....	.15	10.....	1.84	30.....	.55
6.....	4.21			22.....	1.27	31.....	.04
Feb. 26.....	2.36	July 30.....	.33	23.....	.62		
		31.....	1.45	Dec. 24.....	2.27	May 3.....	.65
Mar. 13.....	.24	Aug. 1.....	.61	25.....	.06	4.....	1.13
14.....	3.09	2.....	.43	26.....	.99	5.....	1.42
15.....	1.10	Oct. 3.....	.12	27.....	5.06	6.....	1.08
May 11.....	1.21	4.....	1.96			7.....	1.13
12.....	.04	Nov. 4.....	.05	1905.		July 28.....	.31
13.....	2.06	5.....	2.31	Jan. 9.....	.33	29.....	1.99
				10.....	1.51	30.....	.04
				11.....	.19		
				12.....	1.77	Sept. 25.....	.92

Storms recorded at Yazoo City and Greenville, Miss., 1897-1911—Continued.

GREENVILLE—Continued.

Date.	Inches rain- fall.	Date.	Inches rain- fall.	Date.	Inches rain- fall.	Date.	Inches rain- fall.
1906.		1907.		1909.		1910.	
Sept. 26.....	1.03	May 8.....	1.59	Feb. 14.....	0.67	July 1.....	0.02
27.....	.52			15.....	2.09	2.....	.74
28.....	3.48	Sept. 9.....	2.47			3.....	.55
29.....	.17	10.....	.24	Apr. 13.....	2.11	4.....	1.75
30.....	.28					5.....	.56
Oct. 1.....	.26	Oct. 8.....	2.78	May 25.....	3.11	6.....	.24
2.....	.18			26.....	.48	7.....	.02
3.....	.03	1908.		27.....	.04	31.....	.05
5.....	.75	Jan. 11.....	1.38	28.....	.06		
6.....	1.04	12.....	.91	29.....	.T	Aug. 1.....	2.39
				30.....	.27		
Nov. 17.....	.05	Feb. 9.....	1.01	31.....	1.47		
18.....	3.36	10.....	.96			1911.	
19.....	.34	11.....	.T	Sept. 21.....	3.52	Jan. 1.....	1.48
20.....	.75	12.....	.43	22.....	.04	2.....	.97
21.....	4.16	13.....	3.14	23.....	.72	Feb. 9.....	1.83
22.....	.02	14.....	1.76			26.....	.14
		15.....	1.12	Jan. 1910.		27.....	2.60
Dec. 15.....	.11			5.....	1.08		
16.....	1.33	Mar. 22.....	.82	6.....	2.96	Mar. 26.....	1.90
17.....	1.69	23.....	2.63	7.....	.14		
		24.....	.60	18.....	.15	Apr. 4.....	2.27
1907.				19.....	.17	11.....	1.43
Jan. 30.....	.42	Aug. 1.....	.20	20.....	1.45	18.....	.06
31.....	.61	2.....	.63	21.....	.55	19.....	1.70
Feb. 1.....	1.38	3.....	.27				
2.....	.58	4.....	.T	May 20.....	.52	June 19.....	.64
		5.....	2.38	21.....	1.32	20.....	.11
28.....	.80	6.....	.05	22.....	.27	21.....	.70
Mar. 1.....	1.61	8.....	.T	23.....	.51	22.....	.17
2.....	.54	9.....	1.00	24.....	.05	23.....	.66
				25.....	.18	24.....	.05
Apr. 17.....	.73	Dec. 6.....	2.10	31.....	2.25		
18.....	1.34	7.....	1.58			25.....	1.13
				June 28.....	.05		
May 6.....	.11	20.....	.15				
7.....	.78	21.....	1.17	29.....	.71		
		22.....	.98	30.....	.06		

PLAN FOR DRAINAGE.

For convenience, and also in accordance with the Belzoni drainage law, the drainage district as originally organized has been divided into eight different units, each one of which may be treated as a separate problem, independent of all the others. The boundaries of these units are generally the natural divides between the various areas under consideration, but a few of them are arbitrarily located along convenient lines and may be shifted at will if found convenient to do so. They are shown upon the map by dashed and crossed lines and each unit is designated by number, from No. 1 to No. 8.

Two of these units, No. 1, lying to the north of Beasley Bayou in the northwest corner of the district, and No. 4, lying in the southeast corner of the district, can not be well drained through outlets within Washington County, and are therefore excluded from this discussion. Unit No. 1 slopes to the north and should properly be included in any scheme for drainage in the southwestern part of Sunflower County, and unit No. 4, which slopes to the south and drains partially

[Bull. 244]

into Silver Creek, should be included in any scheme for drainage in the northern part of Yazoo County. That part of Leflore County lying adjacent to the Choctaw boundary will receive some benefit from the drainage of unit No. 7, but can not be included for assessment under the present plan. Also that part of Sunflower County lying adjacent to unit No. 6, and particularly in the vicinity of Sky Lake, will receive a benefit from the drainage of that unit, but can not be included as a part of this scheme until the boundary of the original district is revised to include all lands out to the natural drainage boundaries and until the proper surveys are extended to cover that much more ground.

A system of ditches has been planned to relieve the remainder of the original district, including units Nos. 2, 3, 5, 6, 7, and 8, of its surplus water just the same as though there were permanent and free outlets for each unit at all times, but it should be understood at the outset that all the land will not receive complete drainage at all times. As stated in the discussion of natural drainage conditions, the free outlets depend upon the stages of the Yazoo and Sunflower Rivers, and upon these outlets depend the amount of land which will receive permanent and effective drainage. This amount has been roughly determined by drawing high-water contours in the several parts of the district and assuming that all land lying higher than that contour for each unit will receive permanent and effective drainage at all times, and the remainder of the land will receive drainage only at such times as the main outlets are free. The area of land covered by extreme high water is considerably larger than the area covered by ordinary floods, and since extreme high water is of considerably shorter duration than ordinary high water, the overflow land has been classified into two parts, i. e., that which is flooded by average high water and that which is flooded only by extreme high water.

The natural divide between the Sunflower and Yazoo Rivers runs almost due north and south and passes through a point 1 mile west of Belzoni. Therefore, all the lands lying to the west of this line are drained to the west and south and will have outlet in Ditchlow Bayou and two other bayous emptying into the Sunflower River, and all the remainder will be drained to the east and south into Wasp Lake and the Yazoo River. The rate of fall of most of the land varies between 1 and 2 feet per mile in the directions named, but there are a few places where the ground is perfectly level and others where there is a slope of 6 to 8 feet per mile. In designing the new drainage system the amount of water which each ditch will be required to carry was first estimated, and then the size of the ditch was computed such as to carry that amount of water.

[Bull. 244]

The well-known formula of Chezy for flow in open channels was used in these calculations, as follows:

$$V = c\sqrt{r s}.$$

In which V = velocity of flow in feet per second.

c = coefficient of flow depending upon the condition of the channel and determined by Kutter's formula in which the coefficient of roughness, " n ," = 0.025.

$$r = \text{hydraulic radius} = \frac{A}{p}$$

A = area of cross section of channel.

p = wetted perimeter.

s = slope, or fall of water surface per unit of length.

$$Q = A V.$$

In which Q = discharge of ditch in cubic feet per second.

It was found that in order to use dredge boats in the construction of the ditches many of them will have to be made considerably larger than necessary to carry the amount of water as computed by the above formula. The minimum dredge ditch has been fixed at a 14-foot bottom, 6 feet deep with side slopes of $\frac{1}{2}$ to 1, which is the smallest ditch that can be excavated with a machine having an 18-foot hull. All other dredge ditches have also been figured with side slopes of $\frac{1}{2}$ to 1.

Each drainage unit has been designed with one or more main or trunk line ditches with laterals spaced 1 mile apart, the laterals being of sufficient depth to allow good outlets for field sublaterals. At places where the old bayou and lake channels are of sufficient size and depth, they will be cleared of timber, cleaned out and used in connection with the new system of ditches, but in most cases the shallow sloughs have been avoided and the ditches follow the lines of greatest fall. The average depth of cut in most all the ditches will be greater than the required depth of flow because the bottom grade was made to pass at a certain depth below the lowest surface elevations along the line of each ditch. In some cases, however, it was impossible to establish the bottom grade that low, and it will be necessary to deposit the spoil banks along certain short stretches of some of the new ditches so as to form levees which will confine the waters within the new channels during periods of flood flow. In such cases it becomes necessary to put in sluice gates to conduct the drainage of the low land under the levee into the ditch.

The lateral ditches in most cases follow along section lines to avoid cutting up the land into irregular tracts, but there are a few placed where it was necessary to locate them in diagonal directions. All of the main ditches and 90 per cent of the laterals are designed to be constructed or improved by dredge, while the remainder, which are very short ones and drain only small areas, can best be done by hand

labor. One ditch has been planned to be excavated by dynamite blasting as an experiment. If it is found that small ditches can be economically excavated by this method it will be of great benefit in the construction of the field or sublaterals when the land is cleared. The hand-dug ditches, like the dredge ditches, are to be made with side slopes of $\frac{1}{2}$ to 1, and the one dynamite ditch has been figured with side slopes of 1 to 1.

Those parts of units No. 2 and No. 5 which lie below the 120-foot contour line will act as a storage reservoir during periods of high water and excessive rainfall, and will hold the water brought down from units Nos. 2, 5, and 6 until the Sunflower recedes and allows the water to escape. This reservoir contains 5,700 acres, and its average depth when water is standing at the 120-foot level is 2.5 feet. Its capacity at that depth is 620,730,000 cubic feet, which is equivalent to 3 inches of rainfall over the entire 56,100 acres of watershed which drain into this reservoir. That part of unit No. 3 which lies below the 119-foot contour will act in the same manner for that unit. The average depth when the water stands at that level is about 2 feet, giving this reservoir a capacity of 46,173,000 cubic feet, which is equivalent to 3.5 rainfall on the 3,340 acres of watershed draining into this unit. In unit No. 4 there are approximately 9,550 acres below the 120-foot contour on which the water averages 3.1 feet deep when standing at that level. The capacity of this reservoir is 519,900,000 cubic feet, which is equivalent to 9.1 inches rainfall on the 15,600 acres of watershed of that unit. Under the present plan, however, this reservoir is not available in connection with the reservoirs of units 2, 3, and 5 owing to the lack of suitable outlet south into Sharkey County. Unit No. 2 is protected from the overflow of this reservoir by a continuous embankment along the south side of ditch No. 17, which will keep the water which collects in unit No. 4 from entering at the head of Gooden Lake. In unit No. 7 there are approximately 4,780 acres which are below the 129-foot, or high water level, and when the water stands at this height the average depth is about 3.5 feet. This gives a reservoir capacity of 145,490,000 cubic feet, which is equivalent to 4 inches of rainfall over the 12,915 acres of watershed which drain into this unit.

The accompanying table (fig. 6, p. 28) shows all the necessary data for the construction of each ditch, including the drainage area for each ditch and each part thereof, the bottom width, the grade or slope of the bottom, the average depth of cut, the elevations of all grade points, and the yardage of material to be removed. It also shows which of the present channels are to be used in the new drainage system, and between which stations on the old channels excavation and other improvement is necessary. The required capacity and the estimated amount of water which each ditch of given size will actually carry

have not been recorded, but in each case there is a safe margin, and there will be no flooding except in the cases previously described.

MAP.

The accompanying map (fig. 3) is complete in detail, showing the proposed division of the Belzoni drainage district into 8 units and the new system of drainage ditches for each unit. Towns, railroads, tramroads, wagon roads, ferries, and bridges are shown and the approximate dividing lines between cleared and timber lands, and the probable area of overflowed lands during extreme and average high-water periods are indicated. Each main ditch is designated by letter and each lateral by number, and all are station numbered from the outlet upstream. The map also shows the location of all present sloughs, bayous, and lakes, and the bottom elevations thereof, and the surface elevations at intervals of 600 feet or less along all east and west section lines and at numerous other points. The locations, numbers, and elevations of bench marks at all section corners and the bottom elevations of all new ditches at grade points and at places where old channels are to be deepened are also shown.

PROFILES.

The accompanying profiles, figure 4, show the general surface elevations from east to west between the Yazoo and Sunflower Rivers on four different lines within the drainage district. The upper one is at the widest part of the district 3 miles south of the north line of Washington County and shows distinctly the dividing line between the east and west watersheds. It also shows the low area in unit No. 7 which is subject to overflow, the gradual slope of the land to the west from the east boundary of unit No. 6 to Ditch Main A, and the sudden rise from that point to the bank of the Sunflower River. The second profile shows the general elevation along the line between townships 15 and 16. Like the above profile, it shows the divide between units 5 and 8, the gradual slope to the west until Ditch Main A is reached, and again the sudden rise to the bank of the Sunflower. The third profile shows the general elevation 3 miles north of the south line of Washington County at the narrowest part of the district. It shows that the slope to the west begins immediately at the Yazoo River and continues to the low overflow parts of units 5 and 2 and again the sudden rise to the bank of the Sunflower. The bottom profile shows the general elevation extending from the Sunflower eastward along the Washington-Sharkey County line and further through Yazoo County to the Yazoo River. The very low ground in unit No. 4, which has no outlet within Washington County except through Little Atchafalaya Bayou and the low ground adja-

[Bull. 244]

have not been recorded, but in each

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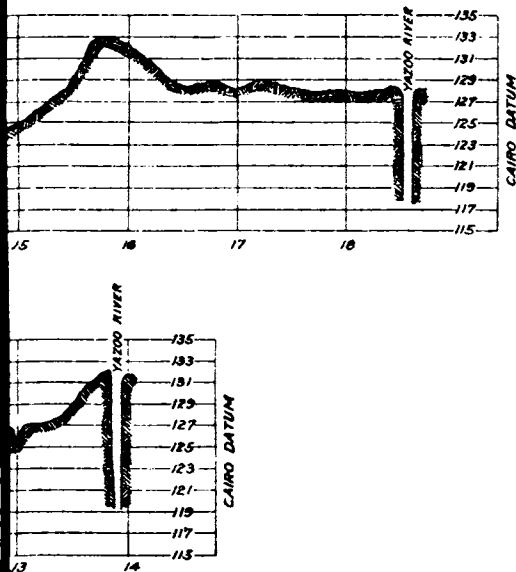


Fig.4.

U.S. DEPARTMENT OF AGRICULTURE OFFICE OF EXPERIMENT STATIONS
DRAINAGE INVESTIGATIONS

THE BELZONI DRAINAGE DISTRICT WASHINGTON COUNTY, MISS.

PROFILES

SHOWING GENERAL SURFACE ELEVATIONS
EAST AND WEST BETWEEN THE SUNFLOWER AND YAZOO RIVERS

SCALES
HORIZONTAL 1 MILE
VERTICAL 4 FEET
1911

cent to the Sunflower River in unit No. 3, are distinctly visible in this profile.

It is not considered necessary to include in this report the profiles upon which are based the estimates for earthwork. The surface elevations on the map show the lay of the ground along all east and west ditches, and the earthworks for diagonal and north and south ditches were approximated.

HYDROGRAPHS.

In order to determine approximately the length of time during which the low ground in the various parts of the district may be flooded by backwater from the rivers it was necessary to determine during which periods of the year the water surface in the Yazoo at the mouth of Wasp Lake and in the Sunflower at the mouth of Ditchlow Bayou remains too high to allow free outlet for drainage. There are no Government gauging stations on the Sunflower River, but on the Yazoo stations are maintained at Greenwood, Yazoo City, and Vicksburg. From the daily records kept by these stations a series of hydrographs, showing the daily stages of the Yazoo at each station over a period of eight years, were plotted. The slope of the water surface between Greenwood, Yazoo City, and Vicksburg under various conditions was determined and then the river heights at the mouth of Wasp Lake and at the mouth of the Sunflower River were interpolated. From a series of actual observations on the water surface at both high and low water at the mouth of Ditchlow Bayou and other points on the Sunflower in Washington County the relative height under various conditions of the water at this place above the mouth of the Sunflower was determined and also plotted on the hydrographs. The accompanying sheet, figure 5, shows the hydrographs thus constructed for the years 1907, 1908, 1909, and 1910. The periods during which there is no free outlet at the mouth of Wasp Lake are indicated by horizontal lines drawn at elevation 125 and showing by shaded areas how long and how much the water is higher than that elevation. For the periods of no free outlet at the mouth of Ditchlow Bayou the horizontal lines and shaded areas are drawn at elevation 115 in the same manner as above.

The hydrograph for 1907, a year of normal rainfall, shows that the Wasp Lake outlet was blocked three times for a total of 128 days and Ditchlow was blocked three times for a total of 105 days. In 1908, a year of excessive rainfall, Wasp Lake was blocked 61 days in one stretch and Ditchlow was blocked 133 days in one stretch. In 1909 Wasp Lake was blocked during two periods for a total of 101 days and Ditchlow was blocked during two periods for a total of 90 days. In 1910, a year of less than normal rainfall, neither the Yazoo nor the Sunflower rose sufficiently to block either Wasp Lake or

Ditchlow and there were free outlets throughout the year. The high water generally comes between January 1 and June 1 and is not dependent wholly upon the local rainfall, but upon the stage of the Mississippi at Vicksburg. This is shown very distinctly in the hydrograph for 1908, when the Mississippi remained high over a long period, holding up the Yazoo and Sunflower Rivers at these outlets while the Yazoo at Greenwood was falling rapidly.

In this connection it is the opinion of Asst. Engineer E. C. Toller, of the Mississippi River Commission, sustained by Capt. J. A. Woodruff, Corps of Engineers, United States Army, at Vicksburg, that the completion of the Mississippi River levee from Brunswick to Vicksburg would extend the natural high-water slope of the Big Sunflower and Yazoo Rivers about 26 miles downstream and would reduce the effect of the Mississippi River on the high water of these two rivers about 7.2 feet. The diagram of high and low water on the Yazoo and Sunflower Rivers on file in the office of the Mississippi River Commission confirms these conclusions. The hydrographs show that the greatest amount of blocking of the outlet at Ditchlow Bayou is only 7 feet, and since the records of the high-water slopes of these two rivers seem to indicate that this proposed extension of the Mississippi River levee would remove the effect of backwater of that river upon the Yazoo and Sunflower by 7.2 feet at Murphy and Belzoni, there will, after the completion of the levee, always be free outlet for drainage at Ditchlow Bayou.

DRAINAGE UNIT NO. 1.

Owing to conditions as previously stated no plans were made for draining the lands in unit No. 1. Attention is here called to figure 6, a table showing ditch sizes and excavations proposed and which will be discussed in detail under the various drainage units.

DRAINAGE UNIT NO. 2.

Ditch Main A, the trunk line for unit No. 2, is $11\frac{1}{2}$ miles long and extends from the mouth of Ditchlow Bayou generally northward along the lowest ground in this unit to the head of Martin Lake and drains a strip of country from $2\frac{1}{2}$ to 5 miles wide adjoining the Sunflower River. The first $1\frac{1}{2}$ miles of this main follows along Ditchlow Bayou, thence it runs diagonally across sections 24 and 19 about 1 mile to Blue Lake, thence due north 4 miles through very low land which is sometimes flooded to a depth of 3 feet or more to a shallow bayou 2 miles east of Callao. Following the northwesterly direction of this bayou the line of the ditch goes to the northwest corner of section 30, township 16 north, range 4 west, and from that point due north 1 mile to Martin Lake, follows Martin Lake 1 mile, and thence up through a slough almost to Beasley Bayou. Ditch No. 1 has outlet

[Bull. 244]

U. S. DEPARTMENT OF AGRICULTURE OFFICE OF EXPERIMENT STATIONS
DRAINAGE INVESTIGATIONS

into Main A in Martin Lake at the northwest corner of section 18, township 16 north, range 4 west, and extends $1\frac{1}{4}$ miles due east to the east boundary of unit No. 2. Ditch No. 2 has outlet into Main A at the northeast corner of section 24, township 16 north, range 5 west, and extends $2\frac{1}{2}$ miles due west, the last mile running parallel with and about one-fourth mile south of Beasley Bayou. Ditch No. 3 has outlet into Main A at the northwest corner of section 19, township 16 north, range 4 west, and extends $1\frac{1}{4}$ miles due east to the east boundary of unit No. 2. Ditch No. 5 has outlet into Main A at the northwest corner of section 30, township 16 north, range 4 west, and extends due east $1\frac{1}{4}$ miles to the east boundary of unit No. 2. Ditch No. 6 has outlet into Main A through a shallow bayou in the southwest part of section 30, township 16 north, range 4 west. It follows the bayou westward a distance of one-half mile, thence due west along the north line of section 36, township 16 north, range 5 west, to the edge of the high cultivated land bordering on the Sunflower River. Ditch No. 7 has its outlet into Main A near the south quarter corner of section 31, township 16 north, range 4 west, and extends $1\frac{1}{4}$ miles due west to the edge of cultivated land along the Sunflower River. Ditch No. 8 has outlet into Main A near the south quarter corner of section 6, township 15 north, range 4 west, and extends $1\frac{1}{4}$ miles due west to the edge of cultivated land along the Sunflower River.

Ditch Main B follows an old bayou which has outlet into the Sunflower through a deep gully at Callao, and is supplemented by one short lateral, No. 4, which extends from the main $1\frac{1}{4}$ miles west along the north line of section 26, township 16 north, range 5 west. These two ditches will give good drainage to 1,000 acres of land in that vicinity, extreme high water in the Sunflower River not blocking this outlet sufficiently to cause any damage.

Ditch No. 9 has outlet into Ditchlow Bayou three-fourths of a mile from its mouth into the Sunflower River. It extends up Cat Tail Bayou one-half mile to the fork of several branches, thence northward along the eastern branch a distance of about 2 miles, ending near the middle of section 12, township 15 north, range 5 west. Ditch No. 10 has outlet into ditch No. 9 near the north quarter corner of section 13, township 15 north, range 5 west, and extends 1 mile due west to the edge of cultivated ground along the Sunflower River. Ditch No. 11 has outlet into ditch No. 9 at the head of Cat Tail Bayou and extends northward along a shallow slough and into Eagle Lake to the north line of section 24, township 16 north, range 5 west, thence due west 1 mile farther to the edge of the high cultivated ground along the Sunflower River.

The headwaters of Beasley Bayou being diverted into Cold Lake and Martin Lake, this old channel will need no improvement and

will in its present condition remove all the water which falls upon its narrow watershed.

There are about 2,150 acres in the southeast part of this unit which lie below the 120-foot contour line and which may be subject to overflow to an average depth of 2.5 to 3 feet during periods of extreme high water. One thousand two hundred and twenty acres of this tract are below the 117-foot contour and are subject to overflow to a depth of a few inches to 1 foot during periods of average high water. The estimate for the work in this unit follows.

Estimate of cost for unit No. 2.

Main A. —Cleaning out Ditchlow Bayou, stations 0 to 89, 89 stations, 100 feet wide, at \$4.50 per station.....		\$400. 50
Clearing 150 feet right of way, stations 89 to 156, 67 stations, at \$9 per station.....		603. 00
Clearing 100 feet right of way, stations 156 to 493+30, 337.3 stations, at \$6 per station.....		2, 023. 80
Excavation by dredge, stations 89 to 493+30, 284,660 cubic yards, at 8 cents per cubic yard.....		22, 772. 80
Cleaning out Martin Lake, stations 590 to 625, 35 stations, 100 feet wide, at \$4.50 per station.....		157. 50
2 sluices at stations 211 and 237, at \$40 each.....		80. 00
Main B. —Clearing 100 feet right of way, stations 20 to 65, 45 stations, at \$6 per station.....		270. 00
Excavation by dredge, stations 13 to 65, 13,730 cubic yards, at 8 cents per cubic yard.....		1, 098. 40
No. 1. —Excavation by hand labor, stations 0 to 65, 6,040 cubic yards, at 25 cents per cubic yard.....		1, 510. 00
2.—Clearing 100 feet right of way, stations 0 to 75, 75 stations, at \$6 per station.....		450. 00
2.—Excavation by dredge, stations 0 to 132+00, 49,870 cubic yards, at 8 cents per cubic yard.....		3, 989. 60
3.—Excavation by hand labor, stations 0 to 65, 5,870 cubic yards, at 25 cents per cubic yard.....		1, 467. 50
4.—Excavation by hand labor, stations 0 to 62+50, 5,120 cubic yards, at 25 cents per cubic yard.....		1, 280. 00
5.—Clearing 100 feet right of way, stations 0 to 92+40, 92.4 stations, at \$6 per station.....		554. 40
5.—Excavation by dredge, stations 0 to 92+40, 35,590 cubic yards, at 8 cents per cubic yard.....		2, 847. 20
6.—Cleaning out old channel, stations 0 to 27+50, 27.5 stations, 50 feet wide, at \$2.25 per station.....		61. 90
6.—Excavation by hand labor, stations 27+50 to 65+00, 3,790 cubic yards, at 25 cents per cubic yard.....		947. 50
7.—Clearing 100 feet right of way, stations 0 to 92+40, 92.4 stations, at \$6 per station.....		554. 40
7.—Excavation by dredge, stations 0 to 92+40, 35,590 cubic yards, at 8 cents per cubic yard.....		2, 847. 20
8.—Clearing 100 feet right of way, stations 0 to 92+40, 92.4 stations, at \$6 per station.....		554. 40
8.—Excavation by dredge, stations 0 to 92+40, 38,360 cubic yards, at 8 cents per cubic yard.....		3, 068. 80

[Bull. 244]

No. 9.—Cleaning out Cat Tail Bayou, stations 0 to 10, 10 stations, 50 feet wide, at \$2.25 per station.....	\$22. 50
9.—Clearing 100 feet right of way, stations 10 to 112, 102 stations, at \$6 per station.....	612. 00
9.—Excavation by dredge, stations 10 to 112, 31,150 cubic yards, at 8 cents per cubic yard.....	2, 492. 00
9.—Excavation by hand labor, stations 112 to 140, 930 cubic yards, at 25 cents per cubic yard.....	232. 50
10.—Excavation by hand labor, stations 0 to 52+80, 6,350 cubic yards, at 25 cents per cubic yard.....	1, 587. 50
11.—Cleaning out Eagle Lake, stations 0 to 30, 30 stations, 50 feet wide, at \$2.25 per station.....	67. 50
11.—Excavation by hand labor, stations 0 to 82+80, 5,570 cubic yards, at 25 cents per cubic yard.....	1, 392. 50
Engineering and legal expenses, 10 per cent.....	5, 394. 50
Total.....	59, 339. 90
16,726 acres receive 100 per cent benefit at cost of \$3.34+ per acre.....	55, 912. 00
930 acres receive 67 per cent benefit at cost of \$2.24 per acre.....	2, 082. 20
1,220 acres receive 33 per cent benefit at cost of \$1.10+ per acre.....	1, 345. 70
Total.....	59, 339. 90
Average cost per acre in unit No. 2, \$3.14+.	

It is assumed that all the land lying above the 120-foot contour will receive a maximum or 100 per cent benefit because it will never be overflowed. That land which is flooded only during periods of extreme high water and lying between the 117-foot and 120-foot contours it is assumed will receive only two-thirds as much benefit as that receiving permanent drainage, while all the remainder of the overflow land which floods at ordinary high water will receive only one-third as much benefit as the former. This percentage of benefit is only a rough approximation, and it may be found that the actual proportion of benefits will vary somewhat from the ratio of 1, 2, and 3. This applies equally as well to units 3, 5, and 7, where the cost has been divided in a similar manner.

DRAINAGE UNIT NO. 3.

Ditch Main C follows along the south branch of Twin Lake Bayou, a distance of $1\frac{1}{2}$ miles from its mouth in the Sunflower River to the southeast corner of section 36, township 15 north, range 5 west, thence the ditch goes due east along the line between Washington and Sharkey Counties to the old Delta Southern Railway right-of-way clearing. One-quarter of a mile east of this point there is a sudden drop of the surface elevation into unit No. 4. All of the excavated material from this ditch should be deposited in a continuous bank on the south side to prevent any water from entering it from the Sharkey County side. Ditch No. 12 is another branch of Twin Lake Bayou,

[Bull. 244]

and needs only to be deepened a short distance from its outlet into Main C upstream.

The estimate for the cost of this unit follows:

Estimate of cost for unit No. 3.

Main C.—Cleaning out bayou, stations 0 to 89, 89 stations, 100 feet wide, at \$4.50 per station.....	\$400. 50
Clearing 100 feet right of way, stations 89 to 225, 136 stations, at \$6 per station.....	816. 00
Excavation by dredge, stations 27 to 225+00, 84,390 cubic yards, at 8 cents per cubic yard.....	6,751. 20
No. 12.—Cleaning out old channel, stations 0 to 65, 65 stations, 50 feet wide, at \$2.25 per station	146. 25
Excavation by dredge, stations 0 to 17, 1,300 cubic yards, at 8 cents per cubic yard.....	104. 00
Engineering and legal expenses, 10 per cent.....	821. 80
Total.....	9,039. 75
2,283 acres receive 100 per cent benefit at cost of \$3.02+ per acre.....	6,902. 90
1,060 acres receive 67 per cent benefit at cost of \$2.01+ per acre.....	2,136. 85
Total.....	9,039. 75
Average cost per acre in unit No. 3, \$2.75.	

In the above division of costs it is assumed that all land lying above the 119-foot contour will receive permanent drainage or 100 per cent benefit, and that the land lying below the 119-foot contour, which is flooded only during periods of extreme high water, will receive two-thirds or 67 per cent benefit.

DRAINAGE UNIT NO. 4.

Owing to conditions previously mentioned, no plans were made for draining the lands in unit No. 4.

DRAINAGE UNIT NO. 5.

Ditches Main D and Main E are the trunk lines of unit No. 5 and receive 90 per cent of the drainage from units Nos. 6 and 5, Main D being the only ditch passing through more than one unit. Main D has its outlet in Main A at Blue Lake, goes one-half mile east to Buck Bayou, thence follows Buck Bayou northward 1 mile, thence continues northward 2 miles farther through the same low area which is subject to overflow and described in unit No. 2, and enters the south end of Cold Lake in section 32, township 16 north, range 4 west. At the lower end of this main where it enters Buck Bayou on the north line of section 20 the spoil bank should be deposited on the south side only, in order to divert the water coming down Buck Bayou to follow the new ditch and prevent it from continuing southward down the old channel and spreading out upon the low ground in sections 19 and 20. Also from station 105 to station 200, where the ditch crosses

[Bull. 244]

the low area mentioned above, the spoil banks should be deposited as levees. The upper end of Main D will be described under unit No. 6.

Main E has its outlet into Main D in the center of section 8, township 15 north, range 4 west, extends 1 mile due east to the west end of Brushy Lake, thence two-thirds of a mile up Brushy Lake to the north $\frac{1}{4}$ corner of section 10, thence due east a distance of $5\frac{1}{2}$ miles to the east border of unit No. 5. From station 170 to 275 the spoil banks should be deposited as levees, except where the ditch crosses Buck Bayou on the north line of section 11 and the shallow swale on the north line of section 12. At these two points the north banks should be left open and all the excavated material deposited on the south side.

Ditch No. 13 has its outlet into the west end of Brushy Lake, follows an old slough northward a distance of 1 mile along the east edge of the lowland which is subject to overflow, and ends at the Interstate Cooperage tram at the north $\frac{1}{4}$ corner of section 4, township 15 north, range 4 west.

Ditch No. 14 has its outlet into Main E at the north $\frac{1}{4}$ corner of section 10, township 15 north, range 4 west, goes 1 mile due north to the Interstate Cooperage tram, thence due east a distance of $5\frac{1}{2}$ miles to the east boundary of unit No. 5. Where this ditch crosses Buck Bayou on the north line of section 2 the spoil bank should be left open on the north side and all the excavated material deposited on the south side. From station 150 to 200 the spoil banks should be deposited as levees except where the ditch crosses the shallow slough on the north line of sections 1 and 6. Here the excavated material should be deposited on the south side only.

Ditch No. 15 is 8 miles long. Its outlet is in Main D where that main turns up Buck Bayou from the north line of section 20, township 15 north, range 4 west. From this point it extends east 1 mile, thence diagonally across section 16 to the northwest corner of section 15, thence due east a distance of 6 miles to the east boundary of unit No. 5. From station 230 to 315 the spoil banks should be deposited as levees. In the northeast corner of section 16, township 15 north, range 4 west, where the ditch crosses a small bayou, the excavated material should be deposited on the south side only.

Ditch No. 16 follows along Ditchlow Bayou and Gooden Lake from the point where Main A leaves Ditchlow to the bridge over the east end of Gooden Lake, and there will be no excavation between these two points. From the bridge the ditch extends in a northeasterly direction across sections 21 and 22 a distance of 1 mile, thence follows a bayou eastward along the Belgrade Lumber Co. tram a distance of $3\frac{1}{2}$ miles to the east boundary of the unit..

[Bull. 244]

Ditch No. 17 has its outlet into the east end of Gooden Lake and extends due east a distance of $5\frac{1}{2}$ miles along the south boundary of unit No. 5. From station 0 to 35 all the excavated material should be deposited on the south side of the ditch, forming a levee to prevent water from unit No. 4 from entering the ditch. From station 165 to 260 the spoil banks should be deposited as levees on both sides.

Ditch No. 18 follows along Buck Bayou from its outlet into Ditchlow Bayou one-half mile, thence turns and extends due east about 2 miles. This ditch should be constructed by dynamite blasting as an experiment as previously stated.

The mouth of Little Atchafalaya Bayou should be closed by a dam to prevent the Yazoo from backing up into the low country in the vicinity of Belgrade during flood periods. Ditches Nos. 15, 16, and 17 will provide outlet for that area which now drains into Little Atchafalaya when that stream has free outlet into the Yazoo. This dam should be constructed at the bridge which now crosses the bayou near its mouth. Drainage unit No. 4 will be greatly benefited by this improvement, but until additional ditches are constructed with outlets into Silver Creek in Yazoo County or Sharkey County this area can not be entirely reclaimed. The estimate for the cost of the work in unit No. 5 follows.

Estimate of cost for unit No. 5.

Main D.—Clearing 150 feet right of way, stations 0 to 30, 30 stations, at \$9 per station.....	\$270. 00
Cleaning out Buck Bayou, stations 30 to 89, 59 stations, 100 feet wide, at \$6 per station.....	354. 00
Clearing 100 feet right of way, stations 89 to 220.40, 131.4 stations, at \$6 per station.....	788. 40
Cleaning out Cold Lake, stations 220.40 to 247.50, 27.1 stations, 100 feet wide, at \$4.50 per station.....	122. 00
Excavation by dredge, stations 0 to 220.40, 134,610 cubic yards, at 8 cents per cubic yard.....	10,768. 80
3 sluices at stations 117, 143, and 170, at \$40 each.....	120. 00
Main E.—Clearing 100 feet right of way, stations 0 to 62 and 99 to 295, and 375 to 399, 282 stations, at \$6 per station.....	1,692. 00
Cleaning out Brushy Lake, stations 62 to 99, 37 stations, 100 feet wide, at \$4.50 per station.....	166. 50
Excavation by dredge, stations 0 to 399, 172,270 cubic yards, at 8 cents per cubic yard.....	13,781. 60
4 sluices at stations 25, 100, 215, and 242, at \$40 each.....	160. 00
No. 13.—Cleaning out bayou, stations 0 to 50, 50 stations, 100 feet wide, at \$4.50 per station.....	225. 00
13.—Clearing 100 feet right of way, stations 50 to 83, 33 stations, at \$6 per station.....	198. 00
13.—Excavation by dredge, stations 0 to 83, 18,560 cubic yards, at 8 cents per cubic yard.....	1,484. 80
14.—Clearing 100 feet right of way, stations 0 to 252, 252 stations, at \$6 per station.....	1,512. 00
14.—Excavation by dredge, stations 0 to 337.90, 133,780 cubic yards, at 8 cents per cubic yard.....	10,702. 40

No. 14.—1 sluice at station 180, at \$40.....	\$40. 00
15.—Clearing 100 feet right of way, stations 0 to 340, 340 stations, at \$6 per station.....	2, 040. 00
15.—Excavation by dredge, stations 0 to 395, 215,635 cubic yards, at 8 cents per cubic yard.....	17, 250. 80
15.—Excavation by hand labor, stations 395 to 426.70, 1,860 cubic yards, at 25 cents per cubic yard.....	465. 00
15.—2 sluices at stations 240 and 276, at \$40 each.....	80. 00
16.—Cleaning out Ditchlow & Gooden Lake, stations 0 to 100, 100 stations, 100 feet wide, at \$4.50 per station.....	450. 00
16.—Clearing 100 feet right of way, stations 208 to 271, 63 stations, at \$6 per station.....	378. 00
16.—Cleaning out bayou, stations 271 to 465, 194 stations, 100 feet wide, at \$4.50 per station.....	873. 00
16.—Excavation by dredge, stations 208 to 465, 65,620 cubic yards, at 8 cents per cubic yard.....	5, 249. 60
17.—Clearing 100 feet right of way, stations 0 to 270, 270 stations, at \$6 per station.....	1, 620. 00
17.—Excavation by dredge, stations 0 to 280.70, 48,270 cubic yards, at 8 cents per cubic yard.....	3, 861. 60
18.—Cleaning out Buck Bayou, stations 0 to 22, 22 stations, 50 feet wide, at \$2.25 per station.....	49. 50
18.—Excavation by dynamite blasting, stations 22 to 107.20, 9,590 cubic yards, at 12 cents per cubic yard.....	1, 150. 80
Closing outlet of Little Atchafalaya Bayou, 4,000 cubic yards, at 15 cents per cubic yard.....	600. 00
Engineering and legal expenses, 10 per cent.....	7, 645. 40
Total.....	84, 099. 20
23,077 acres receive 100 per cent benefit at cost of \$3.40+ per acre.....	77, 938. 00
1,920 acres receive 67 per cent benefit at cost of \$2.27+ per acre.....	4, 344. 00
1,630 acres receive 33 per cent benefit at cost of \$1.12+ per acre.....	1, 817. 20
Total.....	84, 099. 20
Average cost per acre in unit No. 5, \$3.16+.	

The division of costs according to benefits in unit No. 5 is assumed to be the same as in unit No. 2.

DRAINAGE UNIT NO. 6.

Cold Lake, Little Jackson Bayou, designated as Main D, Main F, and No. 23, respectively, are the main drains for unit No. 6 and will, with but little improvement, be sufficient main channels to carry all the waters of that unit in addition to a considerable drainage area to the north in Sunflower County. Main D follows Cold Lake from the south boundary of unit No. 6 to the head of the lake, thence northeasterly along a shallow bayou to Dawson Lake. There will be no excavation necessary except from station 535 to 590 and at Dawson Lake, on the county line, where a dam should be constructed across the mouth of the bayou. This dam will prevent the water of Dawson Lake from coming down through Main D and inundating

the low area in the northwest part of unit No. 6 during flood periods. Main F has its outlet into Cold Lake, follows along Little Jackson Bayou to its junction with Jackson Bayou, thence takes the east or upstream fork of Jackson Bayou around its winding course to the county line. There will be no excavation necessary except from station 135 to 155, but there are a number of drifts and other obstructions along the upper reaches of the channel which will need to be removed. This main will also carry the overflow waters from Dawson Lake and the low area west of Sky Lake which come down through ditch No. 25.

Ditch No. 19 is a very short one, having its outlet into No. 20 through a small bayou in the north part of section 9, township 16 north, range 4 west. It follows this bayou from the outlet northward to the section line, thence extends westward one-fourth of a mile to the section corner.

Ditch No. 20 has outlet into Main D and follows a winding bayou through sections 17, 16, and 9, township 16 north, range 4 west, to the north line of section 9, thence goes due east a distance of 1 mile to the Yazoo & Mississippi Valley Railroad, one-half mile south of Isola. That part of the ditch which follows the bayou needs no further improvement than the cleaning out of the trees and brushwood.

Ditch No. 21 has outlet into No. 20 on the north line of section 16 and extends due east a distance of 2 miles to the Yazoo & Mississippi Valley Railroad. No. 22 has outlet into Main D at the basin of Cold Lake in section 20, township 16 north, range 4 west, extends northeast to the northwest corner of section 21, thence due east a distance of 3 miles.

Ditch No. 23 is that part of Jackson Bayou from the junction of Little Jackson Bayou northward to Dawson Lake. The channel is of sufficient size and depth to carry all the water coming into it and will need no improvement. The direction of flow is now to the north, but with the opening of Little Jackson Bayou, giving free outlet to the southward, the direction of flow will be reversed.

Ditch No. 24 has outlet into Jackson Bayou at the northeast corner of section 12, township 16 north, range 4 west, and extends $1\frac{1}{2}$ miles due west. Ditch No. 25 has outlet into Jackson Bayou in section 5, township 16 north, range 3 west, and follows an old bayou 1 mile northward to a point near the county line. There will be no excavation necessary, and only the trees and brush will need to be cleaned out of the channel to make it provide for a large quantity of water coming down from Sunflower County in the vicinity of Sky Lake. Ditch No. 26 is a short lateral having outlet into Jackson Bayou through a small slough in the northeast part of section 8, township 16 north, range 3 west. It follows this slough 1,100 feet, thence

turns due east 1 mile along the north line of section 9. Ditch No. 27 is also a short lateral, having outlet into Jackson Bayou on the north line of section 17 and extending three-fourths mile due east. No. 28 has outlet into Jackson Bayou on the north line of section 24, township 16 north, range 4 west, and extends due east a distance of 3 miles.

Ditch No. 29 has outlet into Jackson Bayou through a slough at southwest corner of section 24, township 16 north, range 4 west. It follows this slough, which needs to be deepened slightly, a distance of 1 mile eastward, thence due east along the north line of sections 30, 29, and 28, a distance of 2½ miles. Ditch No. 30 has outlet into No. 29 and follows a bayou in section 20, township 16 north, range 3 west, a distance of about 1 mile in a northeasterly direction to the Yazoo and Mississippi Valley Railroad track.

Ditch No. 31 is 7 miles long, extending from its outlet into Jackson Bayou, near the northeast corner of section 32, township 16 north, range 4 west, to that corner, thence due east to the Yazoo & Mississippi Valley Railroad at the east boundary of unit 6. The spoil banks should be deposited only on the south side of the ditch where it crosses the bayous on the north line of sections 34 and 35, township 16 north, range 4 west, and at the north line of section 31, township 16 north, range 3 west.

The estimate for the cost of unit No. 6 follows:

Estimate of cost for unit No. 6.

Main D.—Cold Lake stations 247+50 to 500, no improvements necessary.	
Cleaning out bayou, stations 500 to 610, 110 stations, 100 feet wide, at \$4.50 per station.....	\$495.00
Excavation by dredge, stations 535 to 590, 7,000 cubic yards, at 8 cents per cubic yard.....	567.20
Closing head of ditch at Dawson Lake, 2,000 cubic yards, at 15 cents per cubic yard.....	390.00
No. 19.—Cleaning out slough, stations 0 to 16, 16 stations, 50 feet wide, at \$2.25 per station.....	36.00
19.—Excavation by hand labor, stations 16 to 33, 1,170 cubic yards, at 25 cents per cubic yard.....	292.50
20.—Clearing 100 feet right of way, stations 0 to 13, 13 stations, at \$1 per station.....	13.00
20.—Cleaning out bayou, stations 13 to 137, 124 stations 50 feet wide, at \$2.25 per station.....	279.00
20.—Excavation by dredge, stations 0 to 13, 4,900 cubic yards, at 8 cents per cubic yard.....	392.00
20.—Excavation by hand labor, stations 137 to 187+00, 4,460 cubic yards, at 25 cents per cubic yard.....	1,115.00
21.—Clearing 100 feet right of way, stations 0 to 90, 90 stations, at \$6 per station.....	540.00
21.—Excavation by dredge, stations 0 to 115, 46,820 cubic yards, at 8 cents per cubic yard.....	3,745.60

[Bull. 244]

No. 22.—Clearing 100 feet right of way, stations 40 to 80 and 95 to 185+40, 130.4 stations, at \$6 per station.....	\$782. 40
22.—Excavation by dredge, stations 0 to 185+40, 80,010 cubic yards, at 8 cents per cubic yard.....	6, 400. 80
Main F.—Cleaning out Jackson Bayou, stations 90 to 210, 120 stations 100 feet wide at \$4.50 per station.....	540. 00
Cleaning out Jackson Bayou, stations 272+50 to 537, 264.5 stations 100 feet wide, at \$4.50 per station.....	1, 190. 25
Excavation by dredge, stations 135 to 255, 39,860 cubic yards, at 8 cents per cubic yard.....	3, 188. 80
No. 23.—Jackson Bayou, no improvements necessary.	
24.—Excavation by hand labor, stations 3 to 80, 6,550 cubic yards, at 25 cents per cubic yard.....	1, 637. 50
25.—Cleaning out old channel, stations 0 to 45, 45 stations 50 feet wide, at \$2.25 per station.....	101. 25
26.—Cleaning out old channel, stations 0 to 11, 11 stations 100 feet wide, at \$4.50 per station.....	49. 50
26.—Clearing 100 feet right of way, stations 11 to 55, 44 stations, at \$6 per station.....	264. 00
26.—Excavation by dredge, stations 11 to 73+70, 27,030 cubic yards, at 8 cents per cubic yard.....	2, 162. 40
27.—Excavation by hand labor, stations 0 to 48+40, 4,370 cubic yards, at 25 cents per cubic yard.....	1, 092. 50
28.—Clearing 100 feet right of way, stations 108 to 155, 47 stations, at \$6 per station.....	282. 00
28.—Excavation by dredge, stations 0 to 162+00, 60,930 cubic yards, at 8 cents per cubic yard.....	4, 874. 40
29.—Cleaning out old channel, stations 0 to 58, 58 stations 100 feet wide, at \$4.50 per station.....	261. 00
29.—Clearing 100 feet right of way, stations 89 to 104, and 130 to 180, 65 stations, at \$6 per station.....	390. 00
29.—Excavation by dredge, stations 0 to 178+80, 43,620 cubic yards, at 8 cents per cubic yard.....	3, 489. 60
30.—Cleaning out old channel, stations 0 to 45, 45 stations 50 feet wide, at \$2.25 per station.....	101. 25
31.—Clearing 100 feet right of way, stations 0 to 322, 322 stations, at \$6 per station.....	1, 932. 00
31.—Excavation by dredge, stations 0 to 361+00, 157,540 cubic yards, at 8 cents per cubic yard.....	12, 603. 20
Engineering and legal expenses 10 per cent.....	4, 920. 80
Total.....	54, 128. 95
23,059 acres benefited at an average cost of \$2.35 per acre.	

DRAINAGE UNIT NO. 7.

Quite a large portion of unit No. 7 is subject to overflow from the Yazoo River and backwater up Wasp Lake. The surface conditions are too irregular to permit the drawing of contour lines to show the area flooded during periods of extreme and average high water, but an estimate has been made of the area covered during such times. A more detailed survey will be necessary to determine exactly what portions of unit No. 7 are subject to flooding and

[Bull. 244]

therefore to a reduced rate of assessment. It is here assumed that all land lying above an elevation of 130 feet will receive 100 per cent benefit while that lying below 130 feet and above the 127-foot elevation will receive 67 per cent benefit, and the remainder, which lies below 127 feet, will receive 33 per cent benefit.

Ditch Main G follows Wasp Lake from its mouth in the Yazoo River at the southeast corner of section 29, township 16 north, range 2 west, a distance of $6\frac{1}{2}$ miles, thence up Sky Lake Bayou to the Southern Railway trestle over Sky Lake at Perkins, thence up Sky Lake until it reaches open water in section 3, township 16 north, range 3 west. Wasp Lake is a wide, open body of water which was probably at one time the channel of the Yazoo River and will require no improvement, but the connection with Sky Lake from stations 345 to 436 will need to be dredged out. Also a 100-foot strip of that part of Sky Lake from Perkins to open water will have to be cleared of timber and brush to permit a free flow to the east and south.

Ditch No. 32 is a short lateral having outlet into Wasp Lake at the north line of section 14, township 16 north, range 3 west, and extending due west $1\frac{1}{4}$ miles to the northwest corner of section 15. Ditch No. 33 has its outlet into Wasp Lake at the north line of section 29, township 16 north, range 3 west, and extends $1\frac{1}{2}$ miles due west to the northwest corner of section 22.

Ditch No. 34 has its outlet into Wasp Lake at the east line of section 23, township 16 north, range 3 west, and extends $1\frac{1}{2}$ miles due north. No. 35 has its outlet into Wasp Lake at the east line of section 24, township 16 north, range 3 west, and extends $1\frac{1}{2}$ miles due north, ending in a small lake at the northeast corner of section 13. Ditch No. 36 has its outlet into Wasp Lake at the southeast corner of section 19, township 16 north, range 2 west, and extends 2 miles due north, ending one-fourth of a mile south of Bear Creek. Ditch No. 37 has its outlet into Wasp Lake at its mouth, near the southeast corner of section 29, township 16 north, range 2 west, and extends due north $1\frac{1}{4}$ miles to the east quarter corner of section 20.

It is possible that the locations of ditches Nos. 34, 35, 36, and 37 can be improved upon by running additional levels in that area. In this survey only east and west section lines were leveled, and perhaps some of the existing channels between the Yazoo River and Wasp Lake will serve as north and south drains. The estimate for the cost of unit No. 7 follows:

Estimate of cost for unit No. 7.

Main G.—Stations 0 to 345 is Wasp Lake, no improvements necessary.

Clearing out Sky Lake Bayou and Sky Lake, stations 345 to 525, 180 stations, 100 feet wide, at \$4.50 per station.....	\$810. 00
Excavation by dredge, stations 360 to 435, 21,860 cubic yards, at 8 cents per cubic yard.....	1, 748. 80

[Bull. 244]

No. 32.—Clearing 100 feet right of way, stations 50 to 67, 17 stations, at \$6 per station.....	\$102. 00
32.—Excavation by dredge, stations 0 to 66+80, 20,390 cubic yards, at 8 cents per cubic yard.....	1, 631. 20
33.—Clearing 100 feet right of way, stations 24 to 64 and 76 to 86, 50 stations, at \$6 per station.....	300. 00
33.—Excavation by dredge, stations 0 to 85+80, 40,930 cubic yards, at 8 cents per cubic yard.....	3, 274. 40
34.—Excavation by hand labor, stations 0 to 75, 6,360 cubic yards, at 25 cents per cubic yard.....	1, 590. 00
35.—Clearing 100 feet right of way, stations 5 to 65, 60 stations, at \$6 per station.....	360. 00
35.—Excavation by dredge, stations 0 to 82+80, 40,170 cubic yards, at 8 cents per cubic yard.....	3, 213. 60
36.—Clearing 100 feet right of way, stations 15 to 115, 100 stations, at \$6 per station.....	600. 00
36.—Excavation by dredge, stations 0 to 115, 47,760 cubic yards, at 8 cents per cubic yard.....	3, 820. 00
37.—Clearing 100 feet right of way, stations 0 to 74+40, 74.4 stations, at \$6 per station.....	446. 40
37.—Excavation by dredge, stations 0 to 74+40, 48,440 cubic yards, at 8 cents per cubic yard.....	3, 875. 20
Engineering and legal expenses, 10 per cent.....	2, 177. 15
Total.....	23, 948. 75
8,135 acres receive 100 per cent benefit at cost of \$2.32+per acre.....	18, 882. 50
1,780 acres receive 67 per cent benefit at cost of \$1.55+per acre.....	2, 768. 25
3,000 acres receive 33 per cent benefit at cost of \$0.76+per acre.....	2, 298. 00
Total.....	23, 948. 75
Average cost per acre for unit No. 7 is \$1.85.	

DRAINAGE UNIT NO. 8.

Drainage unit No. 8 is the smallest in the district and embraces the town of Belzoni and vicinity and a narrow strip of land south to Belgrade adjacent to the Yazoo River. There are no large ditches in this unit, and use is made of the existing bayous for outlets into the Yazoo. There may be occasional flooding of a very small portion of this unit, but this has not taken place in many years, and the whole of unit No. 8 may be considered as having a permanent free outlet.

Ditch Main H is the principal drain. Its outlet is the Yazoo through a bayou, whose mouth is 1 mile east of Belzoni. It follows this bayou, which needs to be deepened slightly, in a northeasterly direction a distance of $1\frac{1}{2}$ miles, thence turns and extends due north $1\frac{1}{2}$ miles to the north quarter corner of section 25, township 16 north, range 3 west, thence $1\frac{1}{2}$ miles west to the northwest corner of section 26.

Ditch No. 38 is a short lateral having outlet into Main H at the north quarter of section 36, township 16 north, range 3 west, and extending $1\frac{1}{2}$ miles due east.

Ditch Main I is an old bayou having outlet into the Yazoo just east of Belzoni and extending northward along the Southern Railway a

distance of $2\frac{1}{2}$ miles. It needs no excavation, but will have to be cleared of the trees and brush to make it properly carry the water from its watershed.

Ditch Main J is Burton Bayou, having outlet into the Yazoo just south of Belzoni and extending in a northwesterly direction a distance of 1 mile. Only the upper end of this ditch need be deepened and cleared of the timber and brush.

The estimate for the cost of unit No. 8 follows:

Estimate of cost for unit No. 8.

Main II.—Cleaning out old channel, stations 0 to 75, 75 stations, 100 feet wide, at \$4.50 per station.....	\$337. 50
Clearing 100 feet right of way, stations 135 to 205, 70 stations, at \$6 per station.....	420. 00
Excavation by dredge, stations 43 to 236, 70,480 cubic yards, at 8 cents per cubic yard.....	5, 638. 40
No. 38.—Clearing 100 feet right of way, stations 0 to 45, 45 stations, at \$6 per station.....	270. 00
38.—Excavation by dredge, stations 0 to 76+90, 29,620 cubic yards, at 8 cents per cubic yard.....	2, 369. 60
Main I.—Cleaning out old channel, stations 0 to 120, 120 stations, 100 feet wide, at \$3 per station.....	360. 00
J.—Stations 0 to 35 is Burton Bayou, no improvement necessary.	
Excavation by hand labor, stations 35 to 55, 590 cubic yards, at 25 cents per cubic yard.....	147. 50
Engineering and legal expenses, 10 per cent.....	954. 30
Total.....	10, 497. 30
8,172 acres benefited 100 per cent at average cost of \$1.30 per acre.	

BRIDGES.

The proposed improvements necessitate the building of new or the replacing of old bridges, as follows.

Removing and replacing part of bridge at mouth of Ditchlow Bayou.....	\$50
New highway bridge over Main A at station 415, 22 feet long, at \$5 per foot.....	110
Removing and replacing 2 bridges over Cold Lake in sections 8 and 20, at \$50 each.....	100
New highway bridge over Main E at stations 346+70, 22 feet long, at \$5 per foot.....	110
New highway bridge over ditch No. 14 at stations 285+10, 22 feet long, at \$5 per foot.....	110
Removing and replacing part of bridge at head of Gooden Lake, ditch No. 16....	50
New highway bridge over ditch No. 16 at station 270, 22 feet long, at \$5 per foot..	110
New highway bridge over ditch No. 15 at station 382, 22 feet long, at \$5 per foot..	110
3 new highway bridges over Little Jackson Bayou and branch bayou near fork at station 162+50 and 272+50, one 24 feet and two 22 feet, at \$5 per foot.....	340
New railroad bridge over ditch No. 28 at station 42, 25 feet long, at \$30 per foot..	750
New railroad bridge over ditch No. 29 at station 126, 25 feet long, at \$30 per foot..	750
New highway bridge over ditch No. 32 on north line of section 15, 22 feet long, at \$5 per foot.....	110
New railroad bridge over ditch No. 32 on north line of section 14, 25 feet long, at \$30 per foot.....	750

[Bull. 244]

New highway bridge over ditch No. 33 on north line of section 22, 22 feet long, at \$5 per foot.....	\$110
New highway bridge over ditch No. 33 on north line of section 23, 22 feet long, at \$5 per foot.....	110
New railroad bridge over ditch No. 33 on north line of section 23, 25 feet long, at \$30 per foot.....	750
New highway bridge over Main H in sections 36, at stations 66, 22 feet long, at \$5 per foot.....	110
Total.....	4,530

The above estimates for bridges are not included in the cost of reclamation, for the reason that all the highway bridges are county bridges and the cost thereof should be borne by the county and the railroad bridges should be built and paid for by the railroads.

SUMMARY.

The necessary construction work of the project is herewith summarized and the total estimated cost given.

Drainage unit No. 2.....	\$59,339.90
Drainage unit No. 3.....	9,039.75
Drainage unit No. 5.....	84,099.20
Drainage unit No. 6.....	54,128.95
Drainage unit No. 7.....	23,948.75
Drainage unit No. 8.....	10,497.30
	241,053.85

90,158 acres in entire district actually benefited. Average cost per acre, \$2.67+.

In the case of all dredge ditches the excavated material should be deposited not nearer than 8 feet from the edge of the ditch, and the work should be so finished that the margins will be clear cut, the slope of the sides uniform, and the bottom of an even grade. Excepting in cases where the excavated material is to be deposited as levees on both sides of the ditch, there should be a sufficient number of openings or breaks left in the spoil banks to allow the entrance of field laterals. These openings should not be less than 4 feet wide at the bottom and should occur at intervals of not more than one-fourth mile apart and at all places where there are natural depressions or creeks which may become channels for lateral or field drainage.

Where the excavated material is deposited as levee along low ground to confine heavy flows within the banks of the ditch, the same care should be taken with the work as noted above. The base of the levee should first be cleared of all vegetable growth and stumps, so as to permit the new material placed in the levee to unite with the ground underneath and thus prevent seepage. The material taken from a minimum dredge ditch will be sufficient to make a levee 4 feet high, with side slopes of 2 to 1, which will be all-sufficient for the purpose for which they are intended

[Bull. 244]

In order to provide for the removal of drainage water from the lowland back of the levee into the ditch, sluice gates must be constructed under the levee embankment at intervals of about one-half mile. These sluices will permit the escape of surface water falling upon the lowland except during such times when the large ditch is flowing full or nearly so, when the gates will be automatically closed. The gates being closed will prevent water of the main ditch from backing in upon the low ground back of the levee, and it is not likely that the water in the ditch will remain so high as to keep the gates closed long enough to do any material damage, except in the case of the extremely low ground previously described as reservoirs.

The sluices should be made of 24-inch iron or corrugated-metal pipe, or of vitrified sewer pipe with cemented joints, and fitted with a flap gate suspended on suitable hinges at the outer end. The pipe should be at least 25 feet long, so that when in position under the embankment it will project well out from the toe of the slope at either end, and both ends should be held firmly in position by a heading of stone or concrete. The outer end of the pipe should be protected by a grating of heavy rods to prevent driftwood from becoming lodged under the gate, and the other end should be provided with a sliding valve which can be opened or closed by hand in case the outer valve fails to work properly. Such sluices can be purchased ready-made from either one of several firms which make a specialty of valves, traps, sluices, etc., at a cost of about \$35 or \$40 each. The exact location of the sluices has not been determined, a more detailed survey for interior drainage being necessary to establish their positions, but the table of ditch sizes gives the number required and their approximate locations. They should be placed in position and firmly tamped before the excavation is begun, so that the levee will not be disturbed after it is once finished.

It should be distinctly understood that the earthwork computations in the case of all north-and-south ditches and diagonal ditches are only approximations, due to the absence of levels along those lines, and that an actual location survey may disclose quite a variation in the true yardage required. The above estimates are, however, sufficiently accurate for the determination of the cost of drainage. The drainage law under which the district proceeds, whether it be a special act or the general drainage law, will provide for the equitable assessment of the various parts of the district to pay for the cost of the improvements, and in the foregoing estimates the ratio of 33 per cent—67 per cent in the case of overflowed lands—is merely assumed for convenience in determining the probable cost. There will be a certain benefit to railroads and county roads within the district, and when assessments are levied against the railroads and county for such improvements the cost per acre for the land improved may be

reduced as much as 5 per cent. Sometimes the engineering and legal expenses exceed 10 per cent of the cost of construction, due to organized opposition to the drainage district and other unforeseen contingencies, and therefore a more exact unit cost per acre can not be determined until the details of assessment are worked out. As shown above, the cost will probably vary between \$1 and \$3 per acre, depending upon the locality, and the average cost over the entire area will be about \$2.50 per acre.

The above cost estimates do not, of course, include interior or detailed drainage, which will have to be constructed by the land-owners themselves. The plan outlined herein will provide good drainage outlets for all lands except in the cases previously described, unless the Mississippi River levee is extended to the vicinity of Vicksburg and the Coldwater River in the northern part of the State is diverted and prevented from augmenting the floods coming down the Yazoo River. The starting and completion of the Mississippi River Levee work will depend upon the cooperation of the railroad and landed interests behind the levee with the Mississippi River Commission. All are agreed as to the desirability of having the work done, but when they will agree as to the proper proportion of the cost to be borne by each, and when the necessary funds will become available, are matters of great uncertainty. The proposed Government improvement of the upper Sunflower River for navigation purposes will not effect the drainage in Washington County. Another alternative which would protect the low overflowed lands in units Nos. 2 and 5 at all times would be to install a large concrete multiple sluice gate and pumping plant at the mouth of Ditchlow Bayou. The sluice gate would permit the escape of all drainage water during such times when there is free outlet and prevent back-water from the Sunflower coming in upon the lowlands of the interior during periods of high water. The pumping plant, which would require a maximum capacity of 400,000 gallons a minute, would then have to be put into operation and kept running until the Sunflower receded sufficiently to permit the opening of the sluices. Such a plant would cost a great deal more money than the land at present could afford to pay, especially because the overflowed or reservoir land would have to bear the burden of the expense, and if at some future date it is found that such extensive plans are practical the sluice and pump can be installed without any rearrangement of the drainage system herein outlined.

METHOD OF CONSTRUCTION.

Floating dipper dredges should be used in the construction of all ditches except the very short ones, as indicated in the estimates. They will be required to work upstream in most cases on account

[Bull. 244]

of the arrangement of the system, but it is not anticipated that there will be any difficulty due to lack of water to float the machines. The minimum size of dredge ditch has been fixed at 14-foot bottom, 20-foot top, and 6 feet deep. This will permit the operation of an 18-foot hull boat, the smallest upon which the heavy type of machinery necessary in rough timber work can be mounted. The short small ditches can best be done by hand labor, as it is almost impossible to use teams and scrapers in the rough wooded country characteristic of this district.

In the case of ditch No. 18, where dynamite blasting has been recommended, it is thought that an experiment of this kind might prove to be quite profitable. Dynamite ditches have been made up to 18 feet top width and up to 6 feet deep, but it is not certain that successful blasting of this kind can be done in the close alluvial soil of the Delta. The cost of such excavation is considerably less than excavation by hand or by team and scraper, and if it is found that the proper-strength dynamite placed at certain depths and distances apart will make the proper ditches, this method can well be used in the construction of the interior drainage.

The method of advertising for bids and letting contracts will be well explained in the drainage law, and a discussion of that phase of the work will not be given here.

BENEFICIAL RESULTS.

There is a certain intrinsic value to all the lands within the district which can not be realized until a system of thorough drainage has been installed. Nor is there any doubt as to the productiveness of the soil of the Delta when well drained and that the land is capable of producing a large revenue to the State when improved. When properly utilized it would doubtless increase from its present almost worthless condition to compare most favorably with the best agricultural lands in the South. Furthermore, the health of the community will be greatly improved, due to the removal of malarial conditions, as has been the case in similar areas in the South where extensive drainage works have been carried out. Also under present conditions it is impossible to construct and maintain in passable condition during wet seasons any roads traversing the district. The construction of good roads depends upon good drainage, and upon good roads crops can be hauled to market at greatly reduced cost. Other benefits will result from the drainage of the land which, combined with those already named, will be so great as compared to the cost of the work that there is no doubt as to its feasibility.

[Bull. 244]

APPENDIX.

Acreege which may be flooded during periods of extreme and average high water.

Drainage unit.	Total area.	Area receiving complete drainage.	Areas subject to overflow.					
			Maximum.			Average.		
			Area.	Depth.	Time.	Area.	Depth.	Time.
	<i>Acres.</i>	<i>Acres.</i>	<i>Acres.</i>	<i>Fect.</i>	<i>Weeks.</i>	<i>Acres.</i>	<i>Fect.</i>	
No. 1.....	4,748							
No. 2.....	18,876	16,726	2,150	2.5	8	1,220	0.5	2 weeks to 6 months.
No. 3.....	3,343	2,283	1,060	2.0	8			
No. 4.....	5,586							
No. 5.....	26,627	23,077	3,550	2.5	8	1,630	.5	2 weeks to 6 months.
No. 6.....	23,059	23,059						
No. 7.....	12,915	8,135	4,780	5.0	2	3,000	3.0	0 to 15 weeks.
No. 8.....	8,172	8,172						
Total.....	103,326	78,752	11,540			5,850		

Division of the district by drainage units into cultivated, timber, and deadened timber lands, and sloughs, bayous, and lakes.

Unit.	Area in acres.	Cultivated.		Timber.		Deadened timber.		Sloughs, bayous, and lakes.	
		Acres.	Per cent of unit.	Acres.	Per cent of unit.	Acres.	Per cent of unit.	Acres.	Per cent of unit.
No. 1.....	4,748	21	0.5	4,643	97.5			84	2.0
No. 2.....	18,876	3,181	17.0	15,108	80.0	100	0.5	487	2.5
No. 3.....	3,343	105	3.0	3,166	95.0			72	2.0
No. 4.....	5,586	8		5,541	99.0			37	1.0
No. 5.....	26,627	3,094	11.0	23,014	87.0	100	.5	419	1.5
No. 6.....	23,059	7,780	34.0	13,095	57.0	1,480	6.0	704	3.0
No. 7.....	12,915	3,187	25.0	8,455	65.0	250	2.0	1,023	8.0
No. 8.....	8,172	4,247	52.0	3,778	46.0			129	2.0
Entire district.....	103,326	21,641	21.0	76,800	74.0	1,930	2.0	2,955	3.0
Units Nos. 2, 3, 5, 6, 7, and 8 combined.....	92,992	21,612	23.0	66,616	72.0	1,930	2.0	2,834	3.0

Division of the district by sections into cultivated, timber and deadened timber lands, and sloughs, bayous, and lakes.

Location.	Drainage unit.	Section.	Area.				
			Cultivated.	Timber and deadened timber.	Cleared.	Water.	Total.
			Acres.	Acres.	Acres.	Acres.	Acres.
T. 16 N., R. 5 W.	1	1		467			467
Do.	2	1	40	54		6	100
Do.	1	2		566		4	570
Do.	1	3		556		14	570
Do.	1	4	10	425		5	440
Do.	1	5	1	149			150
Do.	1	8		36		1	37
Do.	1	9		421		50	471
Do.	2	9		160		10	170
Do.	1	10		635		5	640
Do.	1	11		580		5	585
Do.	2	11		55			55
Do.	1	12		40			40
Do.	2	12	140	407		50	597
Do.	2	13	60	557		22	639
Do.	1	14	166	166			166
Do.	2	14	189	241		44	474
Do.	1	15	292	292			292
Do.	2	15	132	176		40	348
Do.	1	16		10			10
Do.	2	16	55	524		23	602
Do.	2	17		106			106
Do.	2	21	88	50			138
Do.	2	22	210	390			600
Do.	2	23	14	624		2	640
Do.	2	24		630		10	640
Do.	2	25	43	592		7	642
Do.	2	26	216	90		5	311
Do.	2	27	24				24
Do.	2	35	155				220
Do.	2	36	50	590			640
T. 16 N., R. 4 W.	6	1		317	300	20	637
Do.	6	2	445	135	25	30	635
Do.	6	3	562			70	632
Do.	6	4	471	95		70	636
Do.	6	5	156	125		27	308
Do.	1	5		115			115
Do.	2	5		192		18	210
Do.	2	6	40	327		30	397
Do.	1	6	10	185			195
Do.	2	7	60	532		5	597
Do.	2	8	32	148			180
Do.	6	8	305	120		35	460
Do.	6	9	340	235		65	640
Do.	6	10	309	320		10	639
Do.	6	11	363	248		30	641
Do.	6	12	74	375	160	30	639
Do.	6	13	565	60		15	640
Do.	6	14	54	586			640
Do.	6	15	200	441			641
Do.	6	16	45	585		10	640
Do.	6	17	48	393		40	481
Do.	2	17		100			160
Do.	2	18		581		15	596
Do.	2	19		599			599
Do.	2	20	335				335
Do.	6	20	74	192		40	306
Do.	6	21	140	475		25	640
Do.	6	22	180	458		2	640
Do.	6	23	80	550		10	640
Do.	6	24	120	501		20	641
Do.	6	25	210	425		5	640
Do.	6	26	50	580		10	640
Do.	6	27	40	574		25	639
Do.	6	28		623		18	641
Do.	6	29	100	110		10	220
Do.	2	29		422			422
Do.	2	30		591		5	596
Do.	2	31		584		12	596
Do.	5	32	115	516		10	641
Do.	5	33		640			640
Do.	5	34		636		4	640
Do.	5	35		629		10	639
Do.	5	36		640			640
T. 16 N., R. 3 W.	7	1	190	375		60	625
Do.	7	2	271	338		30	639

[Bull. 244]

Division of the district by sections into cultivated, timber and deadened timber lands, and sloughs, bayous, and lakes—Continued.

Location.	Drainage unit.	Section.	Area.				
			Culti- vated.	Timber and deadened timber.	Cleared.	Water.	Total.
			Acres.	Acres.	Acres.	Acres.	Acres.
T. 16 N., R. 3 W.	7	3	362	100		175	637
Do.	7	4				103	103
Do.	6	4	112	424			536
Do.	6	5	513		110	10	633
Do.	6	6	170	370		22	562
Do.	6	7	140	267	150	3	560
Do.	6	8	406	140	60	30	636
Do.	6	9	65	424	65	3	557
Do.	7	9		40	40		80
Do.	7	10	220	284	130	2	636
Do.	7	11	345	180	40	70	635
Do.	7	12	40	524		80	644
Do.	7	13	40	595		5	640
Do.	7	14	90	452		95	637
Do.	7	15	250	388			638
Do.	7	16		120	40		160
Do.	6	16	40	378	60		478
Do.	6	17	474	160		1	635
Do.	6	18	550			10	560
Do.	6	19	312	240		8	560
Do.	6	20	160	475			635
Do.	6	21	40	439			479
Do.	7	21		80			80
Do.	8	21	10	70			80
Do.	7	22	80	240			320
Do.	8	22	186	132		2	320
Do.	7	23	273	12		35	320
Do.	8	23	100	217			317
Do.	7	24	60	323		100	483
Do.	8	24	15	145			160
Do.	8	25	305	336			641
Do.	8	26	459	175		4	638
Do.	8	27	330	305		4	639
Do.	8	28		160			160
Do.	6	28	260	77	140		477
Do.	6	29	110	487	40		637
Do.	6	30	180	378			558
Do.	5	31		556			556
Do.	5	32		459			639
Do.	5	33	627				627
Do.	8	33	11				11
Do.	8	34	284	355			639
Do.	8	35	439	194		7	640
Do.	8	36	280	345		15	640
T. 16 N., R. 2 W.	7	6		190			190
Do.	7	7	120	421		70	611
Do.	7	8		215		14	229
Do.	7	16		215			215
Do.	7	17	36	600			636
Do.	7	18	150	457		5	612
Do.	7	19	100	412		100	612
Do.	7	20	100	533		7	640
Do.	7	21		628			628
Do.	7	22		22			22
Do.	7	28		303			303
Do.	7	29	440	125		70	635
Do.	8	29	7			3	10
Do.	7	30	20	283		2	305
Do.	8	30	80	222		2	304
Do.	8	31	274	135		25	434
Do.	8	32	241	45		30	316
Do.	8	33		67		3	70
T. 15 N., R. 2 W.	8	6	25				25
T. 15 N., R. 3 W.	8	1	182	290		20	492
Do.	8	2	186	190		4	380
Do.	8	3	277	264		5	546
Do.	5	4	140	524			664
Do.	5	5	210	458			668
Do.	5	6		589			589
Do.	5	7		639			634
Do.	5	8	320	314			639
Do.	5	9	40	589			629
Do.	8	9		5			5
Do.	8	10	227	82		5	314

[Ball. 244]

Division of the district by sections into cultivated, timber and deadened timber lands, and sloughs, bayous, and lakes—Continued.

Location.	Drainage unit.	Section.	Area.				
			Culti- vated.	Timber and deadened timber.	Cleared.	Water.	Total.
			<i>Acres.</i>	<i>Acres.</i>	<i>Acres.</i>	<i>Acres.</i>	<i>Acres.</i>
T. 15 N., R. 3 W.	8	15	133	3			136
Do.	8	16	207	30			237
Do.	5	16	294	46		18	358
Do.	5	17	565	60		12	637
Do.	5	18	60	570		6	636
Do.	5	19		636		3	639
Do.	5	20	60	550		24	634
Do.	5	21	273			12	265
Do.	8	21	18				18
Do.	4	23	8				8
Do.	4	29		363		15	378
Do.	4	30		640			640
Do.	4	31		346			346
T. 15 N., R. 4 W.	5	1		661		2	663
Do.	5	2		663		5	668
Do.	5	3		670		2	672
Do.	5	4		668		10	678
Do.	5	5		665		3	668
Do.	2	6		660		3	663
Do.	2	7		607		15	622
Do.	5	8		609		20	629
Do.	5	9		617		25	642
Do.	5	10		613		25	638
Do.	5	11		606		25	631
Do.	5	12		628			628
Do.	5	13		621		10	631
Do.	5	14	40	582		10	632
Do.	5	15		637		2	639
Do.	5	16	40	588		10	638
Do.	5	17		585		45	630
Do.	2	18		508	100	15	623
Do.	2	19		86		2	88
Do.	5	19		414	100	20	534
Do.	5	20		626		8	634
Do.	5	21	100	492		4	596
Do.	5	21		40		1	41
Do.	5	22		182		10	192
Do.	5	22		445			445
Do.	5	23		623			623
Do.	5	23		6		4	10
Do.	5	24		630		2	632
Do.	4	25		632			632
Do.	4	26		634			634
Do.	4	27		624		12	636
Do.	4	28		200			200
Do.	5	28	50	144		32	226
Do.	3	28		210			210
Do.	5	29		486		20	506
Do.	3	29		130			130
Do.	5	30		337		25	362
Do.	3	30		265			265
Do.	3	31		625		5	630
Do.	3	32		637			637
Do.	3	33		439			439
Do.	4	33		200			200
Do.	4	34		629		10	639
Do.	4	35		637			637
Do.	4	36		636			636
T. 15 N., R. 5 W.	2	1		638			638
Do.	2	2	130	145			275
Do.	2	11	167	273			440
Do.	2	12		620		6	626
Do.	2	13		600		58	628
Do.	2	14	150	350			500
Do.	2	15	3				3
Do.	2	22	170				170
Do.	2	23	120			26	641
Do.	2	24		574		30	604
Do.	5	24		25			25
Do.	2	25	198	50		50	298
Do.	3	25		222		10	232
Do.	5	25		100			100

[Bull. 244]

Division of the district by sections into cultivated, timber and deadened timber lands, and sloughs, bayous, and lakes—Continued.

Location.	Drainage unit.	Section.	Area.				
			Cultivated.	Timber and deadened timber.	Cleared.	Water.	Total.
			Acres.	Acres.	Acres.	Acres.	Acres.
T. 15 N., R. 5 W	2	26	304	25		8	337
Do.	2	27	26				26
Do.	3	34		48		2	50
Do.	3	35	105	30		10	145
Do.	2	35	30				30
Do.	3	36		560		46	606
Do.	2	36		30			30
Total			21,641	76,800	1,930	2,955	103,326
Per cent of total acreage.			21	74	2	3	100

BENCH MARKS.

Bench mark No.	Elevation in feet.	Description.
H-1	123.86	NW. cor. sec. 18, T. 15, R. 3, 30 ft. N. of concrete monument at corner; on base 30-in. white oak.
H-2	123.91	NW. cor. sec. 13, T. 15, R. 4; copper rivet in base 18-in. oak witness tree.
H-3	120.90	NE. cor. sec. 26, T. 16, R. 3; copper rivet in base 30-in. oak, 500 ft. E. of corner.
H-4	126.74	NE. cor. sec. 25, T. 16, R. 3; copper rivet in base 24-in. white oak about 600 ft. E. of sec. cor.
H-5	126.76	N. line sec. 30, T. 16, R. 2, on E. edge of bayou, about 1,700 ft. E. from NW. cor. sec. 30; copper nail in root 50-in. gum.
H-6	110.89	NE. cor. sec. 30, T. 16, R. 2, on W. bank Wasp Lake; 15-in. pecan, near ferry at corner.
H-7	122.17	NW. cor. sec. 29, T. 16, R. 2, on E. bank Wasp Lake; copper rivet in base 36-in. hickory, 380 ft. E. of corner.
H-8	127.64	N. line sec. 28, T. 16, R. 2, about 1,400 ft. E. from W. cor.; copper rivet in base 30-in. oak.
H-9	131.07	N. line sec. 28, T. 16, R. 2, top W. bank Yazoo River; copper rivet in base 24-in. oak, probably 150 ft. S. of sec. line.
H-10	134.49	NW. cor. sec. 27, T. 16, R. 3; copper rivet in base double maple, about 450 ft. E. and 100 ft. N. from sec. cor.
H-11	131.95	NW. cor. sec. 28, T. 16, R. 3; copper rivet in base 24-in. oak about 450 ft. E. from sec. cor.
H-12	132.36	N. line sec. 29, T. 16, R. 3, on Yazoo & Mississippi Valley Railroad at Alexander's saw-mill; railroad spike in 24 tel. pole south of mill.
H-13	132.63	NW. cor. sec. 29, T. 16, R. 3; copper rivet in base oak witness tree.
H-14	133.31	NW. cor. sec. 30, T. 16, R. 3, on N. bank bayou, 200 ft. N. of highway, on sycamore.
H-15	130.26	NW. cor. sec. 25, T. 16, R. 4; copper rivet in base double oak witness tree.
H-16	128.30	NW. cor. sec. 26, T. 16, R. 4, on S. side bayou at foot-log crossing, on base elm about 500 ft. W. from corner.
H-17	129.95	NW. cor. sec. 27, T. 16, R. 4; copper rivet in base 48-in. gum about 300 ft. E. from corner.
H-18	129.36	N. line sec. 28, T. 16, R. 4, on E. bank Cold Lake; copper rivet in base of tree.
H-19	124.35	N. line sec. 33, T. 15, R. 3, on W. side Yazoo & Mississippi Valley Railroad; copper rivet in base 20-in. gum.
H-20	124.11	NW. cor. sec. 33, T. 15, R. 3; copper rivet in base 18-in. elm.
H-21	122.18	NW. cor. sec. 32, T. 15, R. 3, at N. and S. fence about 300 ft. E. of cor.; copper rivet in base 36-in. oak.
H-22	120.54	NW. cor. sec. 31, T. 15, R. 3; copper rivet in base witness tree.
H-23	126.06	NE. cor. sec. 12, T. 16, R. 3, on W. bank Sky Lake Bayou; copper rivet in base 24-in. oak.
H-24	130.67	N. cor. sec. 7, T. 16, R. 2; copper rivet in base 36-in. oak witness tree.
H-25	117.10	Sec. 8, T. 16, R. 2, 100 ft. N. of Bear Creek, about 1,000 ft. W. from SW. cor. sec. 9, about 640 ft. W. of H-26; copper rivet in base 36-in. cypress.
H-26	123.34	Sec. 8, T. 16, R. 2, on E. bank Bear Creek opposite cabin on W. bank; copper rivet in base 24-in. oak about 400 ft. W. of SW. cor. 9-16-2.
H-27	130.15	SE. cor. sec. 9, T. 16, R. 2; copper rivet in base 24-in. gum about 400 ft. W. of sec. cor.
H-28	132.04	SE. cor. sec. 10, T. 16, R. 2; copper rivet in base gum tree.
H-29	121.08	S. line sec. 11, T. 16, R. 2, on W. bank Yazoo River; copper rivet in base 24-in. oak half-way down bank.
H-30	130.67	Sec. 2, T. 16, R. 2, on W. bank Yazoo River, about 1,300 ft. N. from S. line of sec., N. edge of timber; copper rivet in base 30-in. pecan.
H-31	135.85	Sec. 3, T. 16, R. 2, on S. side Bacon Bayou, about 2,000 ft. E. of W. sec. line; copper rivet in base 30-in. oak.
H-32	136.38	Sec. 4, T. 16, R. 2, on S. side Bacon Bayou, near mouth of Caney Bayou; copper rivet in base of holly N.W. of highway bridge.
H-33	137.20	Sec. 5, T. 16, R. 2, on S. side Bacon Bayou, about 2,300 ft. W. of E. sec. line.
H-34	125.95	Sec. 5, T. 16, R. 2, on N. bank Bear Creek, about 2,000 ft. E. of W. sec. line; copper rivet in base 24-in. oak.
H-35	119.72	Sec. 2, T. 16, R. 3, on N. side Sky Lake, about 1,500 ft. W. of E. sec. line and about 600 ft. W. of mouth of ravine; copper rivet in 24-in. oak.

[Bull. 244]

Bench marks—Continued.

Bench mark No.	Elevation in feet.	Description.
H-36	124.09	NW. cor. sec. 11, T. 15, R. 4; copper rivet in base 18-in. black oak.
H-37	121.80	N. line sec. 15, T. 15, R. 4, on E. bank of bayou, about 150 ft. E. of $\frac{1}{2}$ cor., on 20-in. oak.
H-38	123.37	NW. cor. sec. 15, T. 15, R. 4; copper rivet in base 24-in. oak, about 500 ft. E. of sec. cor.
H-40	122.07	NW. cor. sec. 16, T. 15, R. 4; base 24-in. elm 200 ft. E. and 180 ft. N. from corner.
H-41	116.52	N. line 17-15-4, about 3,400 ft. W. of NE. sec. cor.
H-42	118.34	NW. cor. sec. 36, T. 15, R. 4; copper rivet in base white oak.
H-43	116.42	NW. cor. sec. 35, T. 15, R. 4; copper rivet in base 10-in. hickory.
H-44	114.63	N. line sec. 34, T. 15, R. 4, on E. bank of shallow bayou; copper rivet in base thorn tree about 200 ft. W. of $\frac{1}{2}$ cor.
H-45	133.47	NW. cor. sec. 18, T. 16, R. 3, at church and schoolhouse N. of Bellewood; copper rivet in base of oak bearing sign "Belzoni—7 mi."
H-46	127.57	NW. cor. sec. 26, T. 15, R. 5, on E. bank Big Sunflower River, N. side Ditchlow Bayou; copper rivet in base large elm top of river bank.
H-47	125.30	Sec. 25, T. 15, R. 5, S. bank Ditchlow Bayou, W. side branch bayou, near highway bridge; in base sycamore about 1,200 ft. S. and 400 ft. E. from NW. sec. cor.
H-50	121.05	NW. cor. sec. 31, T. 15, R. 4; copper rivet in base 24-in. gum.
H-51	121.07	NE. cor. sec. 31, T. 15, R. 4; copper rivet in base 18-in. oak probably 100 ft. E. of corner.
H-52	122.16	NE. cor. sec. 32, T. 15, R. 4; copper rivet in base 18-in. elm.
H-53	126.26	NE. cor. sec. 33, T. 15, R. 4; nail in base 12-in. oak.
H-54	110.32	Sec. 36, T. 15, R. 5, at junction of lakes, about 1,800 ft. SE. from NW. sec. cor., on cottonwood.
H-55	121.12	N. line sec. 13, T. 15, R. 5, on W. side bayou, about 800 ft. E. of NW. cor. sec.; copper rivet in base 16-in. oak.
H-56	120.15	NW. cor. sec. 18, T. 15, R. 4; copper rivet in base 18-in. hickory.
H-57	109.13	Sec. 30, T. 15, R. 4, on S. side Ditchlow Bayou, at mouth Buck Bayou; on oak tree.
H-58	127.72	West bank Big Sunflower River at Callao, at mouth of bayou; copper rivet in post at NW. cor. of bridge.
H-59	128.24	NW. cor. sec. 26, T. 16, R. 5, on E. bank Big Sunflower River; copper rivet in base 48-in. oak, 800 ft. S. 57° W. from sec. cor.
H-60	124.56	E. line sec. 21, T. 16, R. 5, on E. bank Big Sunflower River, about 1,700 ft. N. from SE. cor. sec.; copper rivet in base 24-in. leaning sycamore.
H-61	126.06	NE. cor. sec. 26, T. 16, R. 5; copper rivet in base 36-in. oak witness tree.
H-62	122.32	N. line sec. 25, T. 16, R. 5, about 850 ft. W. of NE. cor. sec.; copper rivet in base ash tree.
H-63	122.57	NW. cor. sec. 30, T. 16, R. 4, about 50 ft. N. and 500 ft. W. from sec. cor.; copper rivet in base hard maple.
H-64	125.62	NE. cor. sec. 30, T. 16, R. 4, about 225 ft. E. of sec. cor.; copper rivet in base 24-in. oak.
H-65	129.93	Sec. 21, T. 16, R. 4, on E. bank Cold Lake at mouth Little Jackson Bayou, in front of house; base 36-in. oak, about 1,450 ft. N. of S. line of sec.
H-66	125.83	NE. cor. sec. 16, T. 16, R. 5; copper rivet in base 30-in. oak witness tree.
H-67	127.60	NE. cor. sec. 15, T. 16, R. 5; copper rivet in base 40-in. gum.
H-68	130.05	NE. cor. sec. 14, T. 16, R. 5; copper rivet in base double oak on E. side private road.
H-70	126.11	N. line sec. 13, T. 16, R. 5, on W. bank Martin Lake; copper rivet in base of dead oak.
H-71	127.66	NE. cor. sec. 13, T. 16, R. 5, on E. bank Martin Lake; copper rivet in base of tree.
H-72	131.50	NE. cor. sec. 2, T. 16, R. 4, at fence N. & S.; copper rivet in base of 30-in. dead oak.
H-73	123.80	NE. cor. sec. 1, T. 16, R. 4, on E. bank Beaver Dam Bayou; on base of oak tree, about 350 ft. W. of sec. cor.
H-74	130.83	NW. cor. sec. 14, T. 16, R. 4; copper rivet in base 12-in. hickory—"road W. and N."
H-75	129.32	NW. cor. sec. 15, T. 16, R. 4; copper rivet in base elm witness tree.
H-76	131.23	NW. cor. sec. 16, T. 16, R. 4; copper rivet in base 20-in. oak, 250 ft. W. of cor.
H-77	129.24	NW. cor. sec. 17, T. 16, R. 4; copper rivet in 36-in. oak.
M-1	134.50	Belzoni, S. side Main St., 10 ft. E. of Delta Southern Railroad track, top of railroad rail set in ground.
M-4	131.84	NE. cor. sec. 34, T. 16, R. 3, 2 nails in N. side tel. pole, E. side Delta Southern Railroad track.
M-6	134.80	NW. cor. sec. 26, T. 16, R. 3, 2 nails in N. side tel. pole, E. side Delta Southern Railroad track.
M-8	136.90	N. line sec. 23, T. 16, R. 3, at fence E. side of Delta Southern Railroad, 25 ft. S. of abandoned store; 2 nails in W. side 20-in. white oak.
M-13	127.83	$\frac{1}{4}$ mi. S. of Belzoni station, Yazoo & Mississippi Valley Railroad; copper rivet in NE. root of 16-in. elm, 80 ft. W. of track, at Sta. 83+50.
M-17	132.00	Belgrade, 60 ft. S. of tram road, 15 ft. E. of Yazoo & Mississippi Valley Railroad; copper rivet in W. side of post "R. W."
M-21	133.32	Silver City, 100 ft. S. of Yazoo & Mississippi Valley Railroad station; copper rivet in E. side milepost "M-163; No. 301."
M-24	133.04	N. line sec. 14, T. 16, R. 3; cu. rivet E. and middle bent 16-ft. trestle Delta Southern Railroad track.
M-26	137.54	Jaketown, E. side of Delta Southern Railroad and E. side of road; copper rivet in N. gatepost near crossing of highway and railroad.
M-28	131.42	SE. cor. sec. 2, T. 16, R. 3; cu. rivet W. side 14-inch elm, 60 ft. E. of Delta Southern Railroad.
M-31	132.13	Duke, S. bank of Bear Creek, 100 ft. E. of Delta Southern Railroad; 2 copper rivets in S. root of 14-in. oak.
M-33	129.58	Duke, 2,000 ft. N. of Bear Creek, 60 ft. W. of Yazoo & Mississippi Valley Railroad; copper rivet in N. side of 14-in. red oak.
M-34	127.64	Belzoni, at N. $\frac{1}{2}$ cor. sec. 2, T. 15, R. 3, on W. bank of creek; copper rivet in N. side 24-in. willow.
M-35	129.12	NE. cor. sec. 2, T. 15, R. 3; copper rivet in N. 14-inch gum with old "X".
M-36	118.60	N. line sec. 1, T. 15, R. 3, on W. bank of bayou about 2,000 ft. E. of NW. sec. cor.; copper rivet in NE. side 15-in. cypress.
M-37	130.27	N. line sec. 1, T. 15, R. 3, at edge of woods near E. $\frac{1}{2}$ cor.; copper rivet in S. side 24-in. gum.

Bench marks—Continued.

Bench mark No.	Elevation in feet.	Description.
M-38	121.98	N. line sec. 6, T. 15, R. 2, W. bank of Yazoo River; copper rivet in S. side 16-in. tree about 8 ft. below top of bank.
M-40	132.01	Alexander's sawmill, 125 ft. N. of road, 60 ft. W. of Yazoo & Mississippi Valley Railroad; copper rivet in E. side 12-in. elm.
M-43	130.57	Near N. line sec. 19, T. 16, R. 3; nail in tel. pole E. side Yazoo & Mississippi Valley Railroad track.
M-44	128.22	Bellewood, 100 ft. W. of Yazoo & Mississippi Valley Railroad, 100 ft. S. of highway, on S. side of bayou; copper rivet in NE. side 18-in. oak.
M-46	130.39	Isola, on S. bank of Jackson Bayou, 500 ft. N. of Yazoo & Mississippi Valley Railroad station, 70 ft. E. of track; copper rivet in NW. side of 24-in. willow oak.
M-47	126.37	Dawson Lake, S. bank, 60 ft. E. of Yazoo & Mississippi Valley Railroad; copper rivet in W. side of 12-in. black oak.
M-48	133.93	N. line sec. 3, T. 16, R. 4, N. line Washington Co.; nail in W. side post "M-148, J-79," Yazoo & Mississippi Valley Railroad.
M-49	134.07	Near Isola, N. line sec. 10, T. 16, R. 4, 60 ft. W. of Yazoo & Mississippi Valley Railroad; copper rivet in NE. root of 14-in. gum.
M-51	136.38	NE. cor. sec. 14, T. 16, R. 4; cu. rivet top post "LD-150.56" Yazoo & Mississippi Valley Railroad.
M-52	126.09	S. line sec. 35, T. 15, R. 3, at W. bank of Yazoo River; nail through copper washer in S. side 54-in. oak on township line.
M-53	127.53	S. line sec. 33, T. 15, R. 3, about 100 ft. W. and 40 ft. S. from $\frac{1}{2}$ cor.; nail through copper washer in N. side 20-in. black oak.
M-54	124.94	S. line sec. 33, T. 15, R. 3, 1,250 ft. E. of W. sec. cor. (not marked).
M-55	123.48	SW. cor. sec. 33, T. 15, R. 3; nail through copper washer in S. side 16-in. hickory, 10 ft. N. of 6-in. oak at corner.
M-56	124.10	S. line sec. 32, T. 15, R. 3; nail in S. side 3-ft. willow oak, about 200 ft. W. of $\frac{1}{2}$ cor.
M-57	122.89	SW. cor. sec. 32, T. 15, R. 3; nail through copper washer, in S. side 16-in. oak, about 80 ft. W. of corner.
M-59	120.43	SW. cor. sec. 31, T. 15, R. 3; copper rivet in S. root 40-in. bur oak, 40 ft. W. of concrete monument at sec. cor.
M-65	117.92	S. line sec. 36, T. 15, R. 4; copper rivet in S. side 16-in. post oak about 300 ft. W. of $\frac{1}{2}$ cor.
M-66	118.02	SW. cor. sec. 36, T. 15, R. 4; copper rivet in S. side 18-in. hickory, about 150 ft. W. of corner.
M-67	129.92	NW. cor. sec. 1, T. 16, R. 3; copper rivet in N. side 24-in. post oak near sec. cor.
M-68	139.03	Near NW. cor. sec. 2, T. 16, R. 3, at turn of road to N., about 700 ft. W. sec. cor.; nail through copper washer, W. side of big post in N. and S. fence, near S. fence E. and W. N. $\frac{1}{2}$ cor. sec. 3, T. 16, R. 3; copper rivet in S. root 40-in. red oak, 15 ft. W. of cor.
M-69	135.63	NW. cor. sec. 3, T. 16, R. 3, E. side Sky Lake; copper rivet in 10-in. leaning ironwood (20-in. cypress scribed), 130 ft. E. of open water, on county line.
M-71	131.99	NW. cor. sec. 4, T. 16, R. 3; copper rivet in W. side 20-in. gum witness tree, 25 ft. S. of cor.
M-72	131.89	NW. cor. sec. 5, T. 16, R. 3; copper rivet in S. side 24-in. oak, 6 ft. S. of county-line fence, about 40 ft. east of cor.
M-73	130.76	N. line sec. 6, T. 16, R. 3, 1,500 ft. W. of E. cor.; copper rivet in NW. root 36-in. water oak, about on county line.
M-74	119.08	Brushy Lake at E. end of open water, N. bank of Buck Bayou, near N. $\frac{1}{2}$ line of sec. 10, T. 15, R. 4; copper rivet in S. side 3-ft. gum.
M-75	127.50	Sec. 26, T. 16, R. 4, about 1,000 ft. NW. from center of sec.; copper rivet in S. side 20-in. red oak in middle of bayou.
M-76	117.64	SW. cor. sec. 35, T. 15, R. 4; copper rivet in N. root 16-in. oak, about 100 ft. W. of cor.
M-77	119.01	SW. cor. sec. 34, T. 15, R. 4; copper rivet in NE. root 40-in. white oak, 30 ft. SW. from sec. cor. as marked by blazed trees.
M-78	122.85	SW. cor. sec. 33, T. 15, R. 4; copper rivet in SE. root 24-in. red elm, about 600 ft. E. of cor.
M-79	134.59	NW. cor. sec. 16, T. 16, R. 3; copper rivet in 10-in. leaning gum, about 50 ft. W. and 800 ft. N. of cor.
M-80	130.69	NE. cor. sec. 18, T. 16, R. 3, at E. edge of woods, about 600 ft. N. of Jackson Bayou and 800 ft. W. of sec. line; copper rivet in N. side 10-in. persimmon tree at fence.
M-81	119.89	SW. cor. sec. 35, T. 15, R. 5; copper rivet in W. root 24-in. bitter pecan at township-line fence, on W. side woods road, 45 ft. E. of cor.
M-82	119.49	SW. cor. sec. 36, T. 15, R. 5; copper rivet in SE. root 12-in. hackberry scribed "Sharkey Co.," 20 ft. SE. of pipe marking cor.
M-83	118.38	SW. cor. sec. 31, T. 15, R. 4, 868 ft. S. from pipe marking SE. cor. sec. 36, T. 15, R. 5; copper rivet in NE. root 30-in. ash on range line.
M-84	120.25	SW. cor. sec. 32, T. 15, R. 4; copper rivet in NW. root 20-in. white oak, about 50 ft. E. of cor.
M-85	115.93	Sec. 36, T. 15, R. 5; copper rivet in N. side 10-in. hackberry, on E. bank of lake and N. bank of bayou, $\frac{1}{2}$ mile N. of SW. cor. sec. 36.
M-86	121.27	S. line sec. 34, T. 15, R. 5, top of E. bank Big Sunflower River; copper rivet in NE. root 4-ft. forked sycamore, 75 ft. N. of county line.
M-87	124.43	N. bank Ditchlow Bayou, E. bank of Cat Tail Bayou at mouth; copper cartridge shell in N. root 30-in. hackberry on S. side road.
K-1	131.72	NE. cor. sec. 3, T. 15, R. 3, 20 ft. S. of churchyard; copper rivet in SE. root of 42-in. oak.
K-2	132.80	NE. cor. sec. 4, T. 15, R. 3, in front of negro cabin; copper rivet in root 24-in. gum, 10 ft. S. of tram road.
K-2 $\frac{1}{2}$	131.20	NE. cor. sec. 5, T. 15, R. 3; copper rivet in root 36-in. black gum, at east edge of road, inside fence, 480 ft. N. of corner.
K-4	126.82	NE. cor. sec. 6, T. 15, R. 3, near shanty and small clearing N. of tramroad, on 15-in. sycamore 15 ft. S. of tram.
K-4 $\frac{1}{2}$	125.44	NE. cor. sec. 1, T. 15, R. 4; copper rivet in 20-in. water oak, 15 ft. N. of tramroad.
K-5	124.59	N. line sec. 1, T. 15, R. 4, 20 ft. W. of W. end of trestle, 870 ft. W. of NE. cor. sec. 1.

[Bull. 244]

Bench marks—Continued.

Bench mark No.	Elevation in feet.	Description.
K-6	124.79	NE. cor. sec. 2, T. 15, R. 4, at abandoned tramroad spur to NW.; copper rivet in root 30-in. gum 15 ft. S. of tram, 60 ft. E. of cor.
K-7	128.00	N. 1/4 cor. sec. 2, T. 15, R. 4; copper rivet in root 20-in. red oak 30 ft. N. of tramroad.
K-8	124.19	NE. cor. sec. 3, T. 15, R. 4; copper rivet in root 30-in. red oak 8 ft. S. of tramroad about 540 ft. W. of sec. cor.
K-9	124.42	NE. cor. sec. 4, T. 15, R. 4, at "Y" of tramroad, about 800 ft. E. of sec. cor.; copper rivet in 20-in. oak 100 ft. W. of switch.
K-10	122.30	NE. cor. sec. 5, T. 15, R. 4, at Interstate Cooperage Co. camp; copper rivet in root of 18-in. black oak 20 ft. N. of tramroad.
K-11	130.44	N. line sec. 10, T. 15, R. 3, W. of Yazoo & Mississippi Valley Railroad, in front of white cabin; copper rivet in root 24-in. black oak in hog lot.
K-12	128.08	NE. cor. sec. 9, T. 15, R. 3, 100 ft. E. of cabin, 50 ft. S. of road; copper rivet in root of 18-in. elm.
K-13	129.17	NE. cor. sec. 8, T. 15, R. 3, at intersection of roads north and south and east and west; on 10-in. elm 12 ft. N. of house SE. of cor.
K-14	129.62	NE. cor. sec. 7, T. 15, R. 3, at edge of timber, N. side road; copper rivet in root 15-in. sweet gum.
K-15	121.30	NE. cor. sec. 6, T. 15, R. 4; copper rivet in root of 15-in. white oak.
K-16	121.60	NW. cor. sec. 6, T. 15, R. 4, at N. side right-of-way clearing for tramroad, W. edge shallow slough; copper rivet in root 24-in. elm (250 ft. N. 40° E. from K-17).
K-17	121.76	NE. cor. sec. 1, T. 15, R. 5, at W. edge shallow slough; copper rivet in root 12-in. oak (250 ft. S. 40° W. from K-16).
K-18	126.49	N. line sec. 16, T. 15 N., R. 3, W. edge Yazoo & Mississippi Valley Railroad right of way, at bridge LD 159-05; copper rivet in 20-in. oak.
K-19	126.93	NE. cor. sec. 16, T. 15, R. 3, 10 ft. NW. from concrete corner monument; copper rivet in root of 30-in. water oak.
K-20	131.67	N. line sec. 15, T. 15, R. 3, on W. bank Yazoo River on 8-in. gum.
K-21	129.52	NE. cor. sec. 17, T. 15, R. 3; copper rivet in root 40-in. hollow gum, 100 ft. E. of cor.
K-22	127.64	N. line sec. 17, T. 15, R. 3, at NW. cor. large field; copper rivet in root of 24-in. cottonwood, about 1,000 ft. E. of NW. cor. sec.
K-23	125.99	NE. cor. sec. 18, T. 15, R. 3; copper rivet in 40-in. elm.
K-24	132.76	Belzoni, at Yazoo River bridge, top of iron rail 20 ft. S. of W. end of bridge.
K-25	128.65	Belzoni, at head of Main St. on N. bank Yazoo River; 2 nails in 12 in. by 12 in. signpost.
K-26	126.02	Sec. 10, T. 15, R. 3, near middle of sec., N. bank Yazoo River and S. bank of creek; copper rivet in root 40-in. willow oak.
K-27	120.53	W. bank Yazoo River, N. bank Little Atchafalaya Bayou, on N. side 36-in. cypress 150 ft. from river bank.
K-28	122.99	N. line sec. 20, T. 15, R. 3, at E. edge Little Atchafalaya Bayou; copper rivet in root of 32-in. elm on S. side Belgrade tramroad.
K-30a	125.32	NE. cor. sec. 2, T. 15, R. 5; copper rivet in root 24-in. white oak, about 800 ft. S. of sec. cor.
K-30b	135.59	NE. cor. sec. 10, T. 16, R. 3; copper rivet in root 24-in. oak witness tree 30 ft. SW. of sec. cor.
K-31a	128.79	N. line 2-15-5, Middle Callao, in front of house, top of E. bank Big Sunflower River; copper rivet in W. root 24-in. pecan.
K-31b	133.48	NW. cor. sec. 10, T. 16, R. 3, on E. side road to Belzoni; copper rivet in root 6-in. oak about 140 ft. E. of sec. cor.
K-32	131.19	N. line sec. 9, T. 16, R. 3, about 1,760 ft. E. of NW. sec. cor.; copper rivet in root 14-in. ash.
K-33	134.03	NE. cor. sec. 16, T. 16, R. 3; copper rivet in root 18-in. oak.
K-34	134.66	N. line sec. 16, T. 16, R. 3, about 1,100 ft. E. of NW. sec. cor., 600 ft. W. of Castleman's lumber yard; copper rivet in root 20-in. black gum.
K-35	124.95	NE. cor. sec. 8, T. 16, R. 5, on E. bank of bayou; copper rivet in root 20-in. white oak.
K-36	125.60	SW. 1/4 sec. 4, T. 16, R. 5, in road 50 ft. NW. from bayou, on 40-in. gum.
K-37	124.49	NW. 1/4 sec. 9, T. 16, R. 5, at end of bayou; 30-in. over cup oak.
K-38	127.95	NE. cor. sec. 9, T. 16, R. 5; copper rivet in root 4-ft. double gum.
K-39	127.66	NE. cor. sec. 10, T. 16, R. 5; copper rivet in root 40-in. gum 60 ft. S. of iron pipe at sec. cor.
K-40	127.53	NE. cor. sec. 11, T. 16, R. 5; copper rivet in root 40-in. gum, 45 ft. NE. of iron pipe at sec. cor.
K-41	136.40	NE. cor. sec. 10, T. 16, R. 4; top of 6-in. square iron post at sec. cor.
K-42	132.53	NE. cor. sec. 11, T. 16, R. 4; nail in 12-in. red oak 10 ft. S. iron pipe at sec. cor.
K-43	128.98	NE. cor. sec. 12, T. 16, R. 4; 18-in. gum in abandoned woods road.
K-44	129.98	NE. cor. sec. 7, T. 16, R. 3; copper rivet in root 24-in. gum, 180 ft. W. and 150 ft. S. of sec. cor.
K-45	131.82	NE. cor. sec. 8, T. 16, R. 3; copper rivet in 10-in. elm about 150 ft. S. of sec. cor.
K-46	131.89	NW. cor. sec. 10, T. 16, R. 4; top of iron post 6-in. square marking sec. cor.
K-47	127.93	NE. cor. sec. 8, T. 16, R. 4, in dry bayou; 12-in. elm.
K-48	124.49	N. line sec. 12-16-5, S. side Beasley Bayou, about 700 ft. W. of NE. sec. cor. on 12-in. black oak (not scribed).
K-49	129.41	NE. cor. sec. 7-16-4; 15-in. gum 25 ft. SW. of post at sec. cor.
O-1	129.97	NE. cor. sec. 35, T. 16, R. 3; copper rivet in base 30-in. sweet gum.
O-2	129.19	NE. cor. sec. 36, T. 16, R. 3; copper rivet in S. side 40-in. water oak.
O-3	134.46	NE. cor. sec. 31, T. 16, R. 2; copper rivet in base 18-in. sycamore, 200 ft. S. of cor.
O-4	133.15	NE. cor. sec. 32, T. 16, R. 2, on W. bank Yazoo River; copper rivet in quadruple pecan.
O-5	121.45	Sec. 32, T. 16, R. 2, on N. bank Yazoo River, about 700 ft. W. of center of sec.; copper rivet in base 30-in. pecan.
O-6	128.46	NW. cor. sec. 34, T. 16, R. 3; copper rivet in W. root 18-in. gum 40 ft. N. of bearing tree.
O-7	131.27	N. line sec. 33, T. 16, R. 3, on E. side Yazoo & Mississippi Valley Railroad; nail in tel. pole.
O-8	129.95	NW. cor. sec. 33, T. 16, R. 3; copper rivet in base 18-in. cottonwood.
O-9	129.45	N. line sec. 32, T. 16, R. 3, about 100 ft. W. of E. cor.; copper rivet in base 10-in. Jack oak.
O-10	127.66	NW. cor. sec. 32, T. 16, R. 3; copper rivet in base 36-in. gum, 730 ft. W. of sec. cor.

[Bull. 244]

Bench marks—Continued.

Bench mark No.	Elevation in feet.	Description.
O-11	125.63	NW. cor. sec. 31, T. 16, R. 3; copper rivet in base 12-in. oak, 90 ft. E. of sec. cor.
O-12	128.45	NW. cor. sec. 36, T. 16, R. 4; copper rivet in base 40-in. white oak, 120 ft. E. of sec. cor.
O-13	125.04	NW. cor. sec. 7, T. 15, R. 3; copper rivet in base 48-in. oak, 100 ft. N. of sec. cor.
O-14	123.44	NW. cor. sec. 12, T. 15, R. 4; copper rivet in base 24-in. oak 40 ft. W. of sec. cor.
O-15	120.32	N. line sec. 11, T. 15, R. 4, on W. bank of bayou, 840 ft. W. from NE. sec. cor.; copper rivet in base 36-in. cypress.
O-16	123.78	N. line sec. 24, T. 16, R. 3, 1,500 ft. E. of NW. sec. cor.; copper rivet in base 18-in. oak.
O-17	127.65	NE. cor. sec. 24, T. 16, R. 3, W. of houses; copper rivet in base 30-in. oak 380 ft. W. of sec. cor.
O-18	129.69	NE. cor. sec. 20, T. 16, R. 2; copper rivet in 36-in. water oak.
O-19	129.55	N. $\frac{1}{2}$ cor. sec. 21, T. 16, R. 2; copper rivet in base 48-in. gum 200 ft. W. of $\frac{1}{2}$ cor.
O-20	131.15	NE. cor. sec. 21, T. 16, R. 2, top of W. bank Yazoo River; copper rivet in base 24-in. gum.
O-21	127.64	NW. cor. sec. 20, T. 15, R. 3, on S. side tram road, 400 ft. E. of sec. cor.; copper rivet in base 18-in. willow oak.
O-22	129.21	NW. cor. sec. 19, T. 15, R. 3, 100 ft. S. of sec. cor., 50 ft. S. of tram road; copper rivet in base 30-in. white oak.
O-23	128.27	NW. cor. sec. 24, T. 15, R. 4, on N. side tram road; copper nail in base 24-in. white oak.
O-24	135.07	N. line sec. 22, T. 16, R. 3, 1,500 ft. E. of NW. sec. cor., 40 ft. S. of cabin in open field; copper rivet in base 30-in. oak.
O-25	133.40	N. line sec. 21, T. 16, R. 3, 2,000 ft. E. of NW. sec. cor.; copper nail in 18-in. white oak.
O-26	133.33	N. line sec. 20, T. 16, R. 3, 1,750 ft. E. of NW. sec. cor., 400 ft. W. of cabin; 24-in. oak on edge of clearing.
O-28	124.05	NW. cor. sec. 35, T. 16, R. 4; copper rivet in 30-in. oak, 300 ft. E. of cor.
O-29	123.12	N. line sec. 34, T. 16, R. 4, on W. side bayou, 3,000 ft. W. of NE. sec. cor.; copper rivet in S. side 30-in. gum.
O-30	127.61	NW. cor. sec. 34, T. 16, R. 4; copper rivet in base 40-in. gum, 20 ft. W. of cor.
O-31	125.39	N. line sec. 23, T. 15, R. 4, 1,800 ft. W. of NE. sec. cor., S. side tram road at trestle 200 ft. E. of turn to N.; copper rivet in N. side 20-in. elm.
O-32	128.26	NW. cor. sec. 23, T. 15, R. 4; copper rivet in base 12-in. jack oak witness tree.
O-33	126.32	NW. cor. sec. 22, T. 15, R. 4, on old Southern Railroad right of way; copper rivet in 36-in. gum 50 ft. SE. of sec. cor.
O-34	131.31	N. line sec. 28, T. 15, R. 3, on W. bank Yazoo River; nail in fence post.
O-35	126.44	N. line sec. 29, T. 15, R. 3, on E. side bayou 1,600 ft. W. of NE. sec. cor.; copper rivet in 24-in. black gum.
O-36	123.45	NW. cor. sec. 29, T. 15, R. 3; copper rivet in base 40-in. white oak 260 ft. E. of sec. cor. monument.
O-37	122.71	NW. cor. sec. 30, T. 15, R. 3; copper rivet in 36-in. pin oak, 30 ft. N. of sec. cor. monument.
O-38	125.43	NW. cor. sec. 33, T. 16, R. 4, at E. edge of clearing; copper rivet in base 10-in. gum 100 ft. NW. of sec. cor.
O-39	125.25	N. line sec. 32, T. 16, R. 4, on W. bank Cold Lake; on 30-in. sycamore in front of cabin.
O-40	131.45	N. line sec. 14, T. 16, R. 3, on W. bank Wasp Lake, 1,000 ft. E. of NW. sec. cor.; nail in root 12-in. oak.
O-41	127.96	NE. cor. sec. 14, T. 16, R. 3; copper rivet in S. side 24-in. black oak.
O-42	128.18	N. line sec. 13, T. 16, R. 3, on E. side of bayou 2,300 ft. E. of NW. sec. cor.; nail in base 12-in. oak.
O-43	127.75	NE. cor. sec. 13, T. 16, R. 3, on W. bank Cypress Lake, about 400 ft. W. of sec. cor.; copper rivet in base 24-in. tupelo gum.
O-44	128.15	NW. cor. sec. 18, T. 16, R. 2, on E. bank Cypress Lake, about 450 ft. E. of sec. cor.
O-45	132.05	NE. cor. sec. 18, T. 16, R. 2; copper rivet in S. side 20-in. elm bearing tree.
O-46	131.54	Sec. 16, T. 16, R. 2, about 700 ft. N. and 260 ft. E. from intersection of W. line sec. 8 with Choctaw Boundary (county line) at E. edge of clearing; copper rivet in base 14-in. white oak.
O-47	127.03	Sec. 16, T. 16, R. 2, on W. bank Yazoo River about 3,000 ft. W. and 1,000 ft. N. from SW. cor. sec. 15, T. 16, R. 2; copper rivet in base 36-in. white oak.
O-48	122.45	Sec. 12, T. 16, R. 3, near middle of sec., 300 ft. from N. bank Wasp Lake, on W. bank branch bayou; copper rivet in base 20-in. hickory.
O-49	127.70	NW. cor. sec. 11, T. 15, R. 4, about 200 ft. W. of small bayou; copper rivet in base 40-in. black oak, about 500 ft. W. of sec. cor.
O-50	124.44	NW. cor. sec. 10, T. 15, R. 4; copper rivet in base 24-in. sweet gum, 160 ft. N. and 40 ft. E. of sec. cor.
O-51	119.00	N. line sec. 9, T. 15, R. 4, on W. bank Buck Bayou, 2,260 ft. W. from NE. sec. cor.; copper rivet in base 16-in. hickory 70 ft. E. of tram road.
O-52	117.75	NW. cor. sec. 9, T. 15, R. 4; copper rivet in base 24-in. white oak at cor.
O-53	120.25	Sec. 4, T. 15, R. 4, in middle of Cold Lake Bayou about 1,400 ft. SE. from sec. cor.; copper rivet in 3-ft. cypress.
O-54	120.13	Sec. 8, T. 15, R. 4, on W. bank Buck Bayou, about 1,400 ft. NW. of center of sec.; 3-ft. cypress.
O-55	124.12	NW. cor. sec. 25, T. 15, R. 4, 60 ft. E. of sec. cor.
O-56	122.55	NW. cor. sec. 26, T. 15, R. 4; copper rivet in base 24-in. white oak 50 ft. W. of sec. cor.
O-57	132.27	NW. cor. sec. 24, T. 16, R. 4, at NW. cor. open timber; copper rivet in base 24-in. hickory, 60 ft. S. of sec. cor.
O-58	132.24	NW. cor. sec. 23, T. 16, R. 4, at E. edge clearing; copper rivet in base 18-in. oak, 120 ft. E. of sec. cor.
O-59	121.79	Murphy on E. bank Big Sunflower River, S. side of approach to ferry; copper rivet in 18-in. pecan.
O-60	125.65	Sec. 26, T. 15, R. 5, on N. bank Big Sunflower River, just outside cotton field, about 600 ft. SE. from center of sec.; copper rivet in base 36-in. water oak.
O-61	126.47	N. line sec. 35, T. 15, R. 5, top of E. bank Big Sunflower River, at fence line; copper rivet in base 30-in. black gum.

[Bull. 244]

Bench marks—Continued.

Bench mark No.	Elevation in feet.	Description.
O-62	126.64	Sec. 35, T. 15, R. 5, top of E. bank Big Sunflower River and N. bank bayou, about 500 ft. W. from E. $\frac{1}{2}$ cor.; copper rivet in base 30-in. black gum.
O-63	125.07	W. line sec. 35, T. 15, R. 5, top of S. bank Big Sunflower River; copper rivet in base 20-in. gum.
O-64	127.47	N. line sec. 22, T. 15, R. 5, top E. bank Big Sunflower River, at branch road E.; copper rivet in base 20-in. black oak.
O-65	127.86	N. line sec. 14, T. 15, R. 5, top E. bank Big Sunflower River, 500 ft. S. from sec. line; copper rivet in base 20-in. gum.
O-66	129.48	N. line sec. 11, T. 15, R. 5, on E. bank Big Sunflower River, at E. and W. fence; copper rivet in base 14-in. water oak.
O-67	123.86	NE. cor. sec. 26, T. 15, R. 5; copper rivet in base 12-in. hickory 60 ft. W. from iron pipe marking corner.
O-68	126.02	NW. cor. sec. 30, T. 15, R. 4; copper rivet in base 6-ft. gum at cor.
O-70	117.05	NE. cor. sec. 30, T. 15, R. 4; copper rivet in base 18-in. hackberry, 80 ft. E. from corner.
O-71	124.75	NE. cor. sec. 29, T. 15, R. 4, at SW. cor. cotton field; copper rivet base 40-in. gum, 40 ft. N. from cor.
O-72	116.72	N. line sec. 28, T. 15, R. 4, on bank of Gooden Lake, 3,160 ft. E. from NW. cor. sec. 28; copper rivet in base 20-in. oak, 30 ft. N. of line.
O-73	123.41	NE. cor. sec. 23, T. 15, R. 5; copper rivet in 2-ft. black oak, 60 ft. E. and 40 ft. S. from cor.
O-74	121.03	N. line sec. 24, T. 15, R. 5, at E. edge open brake, 1,070 ft. E. of NW. cor. sec.; copper rivet in base 3-ft. cypress.
O-75	119.65	NW. cor. sec. 19, T. 15, R. 4; copper rivet in base 16-in. oak, 140 ft. E. and 205 ft. N. of sec. cor.
O-76	125.14	NE. cor. sec. 11, T. 15, R. 5; copper rivet in base 24-in. oak, 40 ft. E. from cor.
O-77	118.01	NW. cor. sec. 7, T. 15, R. 4; copper rivet in base 18-in. white oak, 40 ft. E. from cor.
O-78	118.44	NE. cor. sec. 7, T. 15, R. 4; copper rivet in base 3-ft. oak, 30 ft. W. from cor.
O-79	118.06	N. line sec. 19, T. 15, R. 4, on E. bank Blue Lake; copper rivet in base 24-in. oak, 2,800 ft. E. of NW. cor. sec.
O-80	117.14	NE. cor. sec. 19, T. 15, R. 4, on E. bank bayou; copper rivet in base 18-in. oak.
O-81	121.81	NW. cor. sec. 21, T. 15, R. 4; copper rivet in base 18-in. oak, 25 ft. NE. from cor.
O-82	124.06	Sec. 9, T. 15, R. 4, about 700 ft. N. and 500 ft. W. from SE. cor. sec. in bottom of bayou; copper rivet in base 18-in. elm.
O-83A	123.68	NE. cor. sec. 36, T. 16, R. 5; copper rivet in base 4-ft. gum on range line, near cor.
O-83B	129.39	N. line sec. 21, T. 16, R. 5, on E. bank Big Sunflower River; copper rivet in base 12-in. oak at E. and W. fence, 50 ft. from top of bank.
O-84	130.09	Sec. 17, T. 16, R. 5, top of E. bank Big Sunflower River, about 1,800 ft. S. of N. line sec. 17; copper rivet in base 18-in. ash, E. side of road.
O-85	123.22	SW. cor. sec. 9, T. 16, R. 5, on E. bank Big Sunflower River, S. bank Beasley Bayou, about 800 ft. N. of sec. cor.; copper rivet in base 18-in. hickory, W. side road.
O-86	120.47	N. line sec. 31, T. 16, R. 4, on W. bank of bayou, 1,640 ft. E. from NW. cor. of sec.; copper rivet in base 30-in. oak.
O-87	122.02	NE. cor. sec. 31, T. 16, R. 4; copper rivet in base 2-ft. oak, 40 ft. E. of cor.
O-88	121.94	N. line Washington Co., E. bank Big Sunflower River, 1,060 ft. W. of NE. cor. sec. 4, T. 16, R. 5; copper rivet in base 18-in. sycamore.
O-89	127.73	N. line sec. 3, T. 16, R. 5, 1,600 ft. E. from NW. cor. sec., about 250 ft. E. of middle of bayou; copper rivet in base 3-ft. oak.
O-90	128.69	NE. cor. sec. 21, T. 16, R. 5; copper rivet in 2-ft. gum witness tree.
O-91	129.63	NE. cor. sec. 22, T. 16, R. 5; copper rivet in 30-in. cottonwood witness tree.
O-92	127.73	NE. cor. sec. 23, T. 16, R. 5; copper rivet in 18-in. gum, 100 ft. W. of cor.
O-93	127.16	NW. cor. sec. 19, T. 16, R. 4; copper rivet in 3-ft. gum.
O-94	129.38	NE. cor. sec. 19, T. 16, R. 4; copper rivet in 3-ft. black stump, 50 ft. S. and 40 ft. W. from cor.
O-95	125.11	N. line sec. 20, T. 16, R. 4, on W. bank Cold Lake, 400 ft. N. of wagon bridge; in 20-in. oak.
O-96	126.78	NE. cor. sec. 3, T. 16, R. 5; copper rivet in base 3-ft. elm, 100 ft. W. of cor.
O-97	125.84	NE. cor. sec. 2, T. 16, R. 5; copper rivet in base 2-ft. oak, 60 ft. W. of cor.
O-98	121.85	N. line sec. 17, T. 16, R. 4, on W. bank Cold Lake in small pig pen, 400 ft. N. of branch bayou; copper rivet in base 8-in. twin black oak.
O-99	129.90	N. line sec. 8, T. 16, R. 4, at E. end bridge over Cold Lake, 400 ft. S. of sec. line; copper rivet in base 3-ft. oak.
O-100	128.52	N. line sec. 3, T. 16, R. 4, on S. bank Dawson Lake, about 2,800 ft. W. from NE. cor. sec.; copper rivet in base 12-in. persimmon.
O-101	134.56	NE. cor. sec. 4, T. 16, R. 4, top W. bank of branch bayou; nail in base 2-ft. gum, 100 ft. W. of cor.
O-102	131.24	NW. cor. sec. 4, T. 16, R. 4, at line of fence to N.; copper rivet in base 14-in. white-oak witness tree.
O-103	127.28	NW. cor. sec. 5, T. 16, R. 4; copper rivet in base 4-ft. oak, 140 ft. W. of cor.
O-104	124.32	NW. cor. sec. 6, T. 16, R. 4; copper rivet in base 18-in. oak witness tree.
O-105	126.30	NW. cor. sec. 22, T. 16, R. 4; copper rivet in base 12-in. oak, 240 ft. S. and 260 ft. W. from cor.
O-106	128.20	NW. cor. sec. 21, T. 16, R. 4; copper rivet in base 18-in. black oak.
O-107	126.35	N. line sec. 9, T. 16, R. 4, 1,800 ft. W. of sec. cor.; copper rivet in base 18-in. oak.

U. S. DEPARTMENT OF AGRICULTURE.

OFFICE OF EXPERIMENT STATIONS—BULLETIN 245.

A. C. TRUE, Director.

COURSE IN THE USE AND PREPARATION
OF VEGETABLE FOODSFOR MOVABLE AND CORRESPONDENCE
SCHOOLS OF AGRICULTURE.

BY

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School of Household Arts, Columbia University.*WASHINGTON:
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OFFICE OF EXPERIMENT STATIONS.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
Washington, D. C., October 10, 1911.

SIR: I have the honor to transmit herewith and to recommend for publication as Bulletin 245 of this office a Course in the Use and Preparation of Vegetable Foods, prepared by Miss Anna Barrows, of the School of Household Arts of Columbia University, and director of the School of Domestic Science at Chautauqua, N. Y., and edited under the supervision of C. F. Langworthy, chief of nutrition investigations of this office. It has been the author's purpose to reduce the subject of the preparation of vegetable foods to such pedagogical form that the student may be brought to know in a comparatively brief period not only how food of this character should be prepared, but also be taught the relative value of different vegetable foods and the principles which underlie their rational use.

The series of courses of which this bulletin is one was originally intended for use exclusively in movable schools of agriculture. As extension teaching has developed it has become apparent that the courses ought, if possible, to be made available for a much larger body of students than can be reached by the short-course and movable-school method. In order to do this the form of the present bulletin has been modified from those that have preceded it in this series, with a view to adapting it to use in teaching by correspondence. The changes consist mainly in somewhat greater detail of explanation in the body of the text, the addition of a list of queries following each lecture, and the printing of the lectures separately in the bulletin so that they may be detached and given to the members of the class for reference in their reading and practice work.

Respectfully,

A. C. TRUE, *Director.*

HON. JAMES WILSON,
Secretary of Agriculture.

CONTENTS.

	Page.
Prefatory note.....	9
General suggestions to teachers.....	13
First lecture—Classification of plants.....	15
Introductory—Relation of economic botany to cookery.....	15
The structure of plants.....	17
Food plants and their composition.....	18
Experiment and practice work, first lecture.....	19
Composition of foods.....	19
Water and mineral matter.....	19
Fat.....	19
Protein.....	19
Starch.....	20
Sugar.....	20
Germination tests with seeds, etc.....	20
Review questions, first lecture.....	20
Second lecture—Leaves and stalks.....	21
Use of raw vegetables.....	21
Experiment and practice work, second lecture.....	24
Lettuce.....	25
Celery.....	25
Cabbage.....	25
Salads and salad dressings.....	25
Review questions, second lecture.....	26
Third lecture—Leaves and stalks—Continued	27
Wild plants used as potherbs.....	27
Cultivated potherbs or greens.....	28
Seaweeds.....	30
Experiment and practice work, third lecture.....	31
Preparation and cooking of potherbs and similar vegetables.....	31
Review questions, third lecture.....	32
Fourth lecture—Bulbs.....	33
The onion tribe.....	33
Experiment and practice work, fourth lecture.....	35
Preparation of onions.....	35
Methods of cooking.....	35
Securing onion flavor.....	36
Spanish onion.....	36
Onion and apple salad.....	36
Onion soup without meat.....	37
Fried onions.....	37
Stuffed onions.....	37
Onion custard.....	37
Onion soufflé.....	37
Review questions, fourth lecture.....	37

	Page.
Fifth lecture—Tubers and roots.....	39
White or Irish potatoes.....	39
Sweet potatoes.....	41
Jerusalem artichoke, yam, cassava, and other starch-bearing tubers and roots.....	41
Experiment and practice work, fifth lecture.....	43
Potatoes.....	43
Baked.....	43
Boiled.....	44
Steamed.....	44
Mashed.....	44
Cut and boiled.....	44
Soup.....	44
Salad.....	44
Experiments with starchy materials.....	44
Review questions, fifth lecture.....	44
Sixth lecture—Succulent roots.....	45
Beets.....	45
Turnips.....	45
Kohl-rabi.....	46
Radishes.....	46
Carrots.....	46
Parsnips.....	46
Celeriac.....	46
Salsify.....	47
Condimental roots.....	47
Experiment and practice work, sixth lecture.....	47
Parsnips, salsify, beet, and celeriac.....	47
Carrots.....	48
White sauce for vegetables.....	48
Review questions, sixth lecture.....	48
Seventh lecture—Flowers and fruits.....	49
Flowers and products made from them.....	49
Capers.....	49
Cauliflower.....	49
Globe artichoke.....	49
Honey.....	50
Colors and flavoring extracts.....	50
Fruits used as vegetables.....	51
Pumpkins and squash.....	51
Cucumbers and melons.....	51
Peppers.....	52
Okra.....	52
Eggplant.....	53
Tomato.....	53
Bananas.....	54
Experiment and practice work, seventh lecture.....	54
Review questions, seventh lecture.....	54
Eighth lecture—Seeds.....	55
Beans, peas, and lentils.....	56
Peanuts.....	58
Cottonseed.....	59

Eighth lecture—Seeds—Continued.	Page.
Cereal seeds as vegetables	59
Wheat, oats, and rice.....	59
Corn.....	59
Buckwheat.....	60
Experiments and practice work, eighth lecture.....	60
Comparison of fresh, dried, and canned legumes.....	60
Lima beans.....	61
Baked beans.....	61
Cowpeas	61
Review questions, eighth lecture.....	62
Ninth lecture—Fungi.....	63
Mushrooms, etc.....	63
Mildew, molds, and ferments.....	64
Yeast.....	65
Experiment and practice work, ninth lecture	65
Mushrooms.....	65
Mold and decay.....	65
Yeasts and fermentations.....	65
Review questions, ninth lecture.....	66
Tenth lecture—Condimental vegetable foods and food accessories.....	67
Condimental vegetables and prepared relishes.....	67
Flavoring materials.....	68
Herbs.....	68
Spices.....	68
Flavoring extracts.....	68
Beverages.....	69
Tea.....	69
Coffee.....	69
Chocolate and cocoa.....	69
Miscellaneous food accessories.....	69
Experiment and practice work, tenth lecture.....	69
Flavoring materials.....	69
Spices and herbs.....	70
Flavoring extracts.....	70
Beverages.....	70
Tea, coffee, cocoa, and chocolate.....	70
Review questions, tenth lecture.....	70
Eleventh lecture—Summary of cookery.....	71
Choosing, sorting, and cleaning vegetables.....	71
Combinations of vegetables.....	73
Utensils used in cooking vegetables.....	74
Cooking terms.....	74
Time of cooking.....	75
Ways of serving.....	75
Soups.....	75
Salads.....	75
Scallops.....	75
Fritters.....	75
Croquettes.....	76
Frying.....	76
Experiment and practice work, eleventh lecture.....	76
Review questions, eleventh lecture.....	76

	Page.
Twelfth lecture—Drying, evaporating, and salting vegetables	77
Drying and evaporating foods.....	77
Preserving by salting.....	78
Experiment and practice work, twelfth lecture.....	79
Drying vegetable substances.....	79
Restoring dried foods to their original conditions.....	79
Review questions, twelfth lecture.....	80
Thirteenth lecture—Preserving and canning vegetables.....	81
Preserving with sugar.....	81
Preserving by sterilization—Canning.....	83
Experiment and practice work, thirteenth lecture.....	84
Action of bacteria, molds, etc.....	84
Sugar.....	85
Canning.....	85
Review questions, thirteenth lecture.....	86
Fourteenth lecture—Pickling vegetables.....	87
Vinegar.....	87
Herb vinegars.....	87
Pickles and sauces.....	87
Care of pickled and canned goods.....	88
Experiment and practice work, fourteenth lecture.....	87
Simple pickles.....	87
Combination in pickling	89
Review questions, fourteenth lecture.....	90
Fifteenth lecture—Vegetables for the table: Marketing.....	91
Cultivating vegetables for the table.....	91
Weights and measures.....	92
Trade customs and market conditions.....	92
Growing vegetables for the home table.....	93
Experiment and practice work, fifteenth lecture.....	94
Review questions, fifteenth lecture.....	94
Appendix.....	95
References.....	95
List of apparatus and supplies required	97

PREFATORY NOTE.

The aim of this course is to make available to country people and others not able to attend fixed schools of home economics the main facts connected with the preparation and use of vegetable foods. The effort has been to arrange these facts in such pedagogic form that they may be studied successfully by persons having had little opportunity for instruction along scientific lines. On the other hand, a certain amount of practical acquaintance with domestic art is expected of those registering for study as well as a degree of scholastic acquirement equal to at least the completion of the eighth grade in school. The course is for adults and not for persons of immature age or inexperience.

In the movable-school course as originally contemplated the teacher was expected to be an expert, thoroughly familiar with the subject taught, and able to add to the information given in the printed lessons by drawing from his own resources. He was also expected to be able to conduct the reviews and the periodical and final examinations without the aid of a list of questions other than his own.

Inability to secure a sufficient number of experts of this character and the expense involved has led to the effort to adapt the movable-school courses to correspondence work, the instruction to be initiated and controlled by a central institution. Under the correspondence method the leader directly in charge of the local work may be a layman with perhaps only slight experience in teaching and limited information along scientific lines. The main business of this leader is to see that the work required of each student is performed as outlined in the printed course. He is also in charge of the apparatus and material for laboratory work and has oversight and direction of all the operations prescribed for performance by the students.

Experience has demonstrated that study by isolated individuals under the old correspondence method is impracticable except in instances too few to be regarded in a system that is to be effective in reaching the masses. The organization of students, therefore, into classes is essential in correspondence work. The leader preferably should be a resident of the neighborhood in which the class is organized. This class leader must be approved and appointed by the head

of the extension department, and when appointed becomes the official representative of that department and is held responsible for all apparatus, books, and material furnished to the class by the institution under whose auspices the correspondence course is conducted. He conducts the quiz on the previous day's lesson, using the printed questions; presents the lesson of the day by reading the printed outline before the class; assists the students in their reference work and oversees the practicums. He keeps a record of attendance, requires and receives the examination papers of the members, and submits them, together with his report upon the week's work, to the chief of the extension department at the central institution.

The correspondence course is intended to be organized and conducted under the oversight of the agricultural-extension department of the agricultural college or experiment station. In organizing the class a representative of this extension department should visit the community, select the leader, list the names of those who wish to join, assist in securing proper rooms in which the class exercises are to be conducted, and make out the order on the college or experiment station for the material needed in conducting the course.

Apparatus and supplies for the class are to be furnished by the extension department sufficient to provide each student with a complete set for his individual use during the course. Each student is to be charged in an itemized account with the apparatus and material committed to him, the money to be refunded at the close of the school period, less 10 per cent, and the cost of material consumed or broken.

The expenses connected with securing a hall, providing janitor service, water, light, heat, seating, and all incidentals are to be met by the locality in which the class is held. Each member is required to pay a registration fee, in addition to the fee for apparatus and supplies. This registration fee is to be an amount sufficient to meet the salary of the leader of the class, and such minor incidental expenses as may be necessary. At the close of each week an examination upon the lectures of the week is to be written up by each student upon blanks provided by the extension department, to be transmitted through the leader of the class to the chief of the extension department for inspection and rating. At the completion of the course an examination upon the entire course will be conducted by a representative of the extension department who visits the community and conducts the examination exercises. To all who complete the course and pass the examination satisfactorily a certificate of the fact is made out and given to the student by the institution under whose auspices the course is conducted. This certificate entitles the holder to credits for entrance in case he should desire to become a resident student.

The course is a "study course" and not a set of lectures to be received without subsequent effort on the part of the students. By it they are shown where to get information. They are then expected to look up the references for themselves and apply the teachings. The leader is to see that the study is performed by each student, that the references are consulted and tested by laboratory methods, and that the examination papers are made out and forwarded regularly to the extension department responsible for the course.

The bulletin is so printed and bound that the lectures may be detached and given to the students of the class as each is delivered, thus avoiding the necessity for taking notes, and providing also a reference list for reading and for laboratory use.

Classes in correspondence study can be organized with little effort and to a great advantage by granges, farm clubs, young peoples' institutes, county farmers' institutes, high schools in vacation periods, and by county fair associations.

Instructions giving detailed information respecting the use of this and the other courses in correspondence work have been prepared and can be had upon application to the farmers' institute division of the Office of Experiment Stations.

JOHN HAMILTON,
Farmers' Institute Specialist.

COURSE IN VEGETABLE FOODS FOR MOVABLE AND CORRESPONDENCE SCHOOLS.

GENERAL SUGGESTIONS TO TEACHERS.

It is desirable that the student should know in advance of entering the class something of the structure of plants and of the vital processes that go on within them. Some knowledge also of the chemical composition of food plants is necessary if the study is to be pursued to the best advantage, and he should have some information as to the functions of the digestive organs of the body and of the material needed for its sustenance and some understanding of the changes that food undergoes in its assimilation. It may be well for the teacher at the outset to utilize two or three of the lecture periods in giving information and in directing the reading along these lines.

It is not essential that the lessons be given in the precise order in which they are here presented. It may be found advisable to change the order to meet local conditions. In some instances also the practice exercises are more than can be accomplished in a single period. In such case they can be continued and completed later.

When the course is used in correspondence teaching and the leader is not a thoroughly trained expert the class will necessarily be dependent almost wholly upon the printed text, the reference readings, and the practice exercises for instruction. The leader, however, is expected to study the course in advance of the students and be able to answer such questions as the particular lesson being studied suggests.

The queries at the end of each exercise are intended to aid in fixing the leading points in the students' minds, and the weekly examinations, to be sent in to the correspondence department for criticism and correction, give opportunity for that department to keep informed as to the quality of the work. The majority of the questions have to do with facts brought out in the lessons, but some of them refer to matters which the student is expected to gather from the supplementary reading suggested. The final examination by a member of the extension department will determine the grade of each member of the class.

Each lesson is to be followed by reference reading by the students, and later by practice exercises or laboratory work. The books referred to in the lectures constitute the library of reference. Apparatus sufficient to furnish each student with a set for use in practice work is supplied at a nominal rental by the department conducting the course.

COURSE IN VEGETABLE FOODS.

FIRST LECTURE—CLASSIFICATION OF PLANTS.

INTRODUCTORY—RELATION OF ECONOMIC BOTANY TO COOKERY.

A great variety of food plants are included under the term "vegetables," and there are many matters connected with their growth, selection, and preparation as human foods that are important in a study of their economic value and use.

Their study may be conducted along a variety of lines, depending upon the use to which the information sought is intended to be applied. They may be studied with reference to—

- (1) Their discovery and improvement by man.
- (2) Their classification by botanists.
- (3) The parts of each plant desirable for food.
- (4) Their chemical composition and food value.
- (5) The commercial conditions of their transmission from producer to consumer.
- (6) The culinary processes through which they must pass before they can be properly utilized by the human body as food.

This course of study is more particularly along the line of the sixth item in this list—the culinary processes through which vegetables must pass before they can be properly utilized by the human body as food.

Few of the vegetables which are now man's main dependence were attractive in their original form, but most have been evolved through centuries of cultivation and experiment. (Reference No. 90, pp. 9–30.) Cookery as well as agriculture has served to increase the number of plants available for food. "The number of inhabitants that can be supported in a country depends as much upon the art of cookery as upon that of agriculture; both arts belong to civilization," said Count Rumford, a pioneer in scientific food study.

Primitive man gave little thought to agriculture, but took seeds, fruits, roots, leaves, and stalks, or fish and game, as nature provided them, thus satisfying his hunger and getting such variety as he could. In the division of labor between the sexes in early times the men were usually the hunters, and the women gathered, transported, and stored the simple forms of vegetable foods, including fruits and nuts, roots and seeds. (Reference No. 90, pp. 9–30, 67.)

The evolution of the use of plant products as food has been described as follows (Reference No. 90, p. 15) :

In her exploitation of the vegetable world, woman first appears as taking from the hands of nature those fruits and other parts of the plants that were ready for consumption without further preparation. On the next journey she ventured a step farther. With digging stick and carrying basket she went to search out roots and such other parts of plants as might be prepared for consumption by roasting or perhaps by boiling with hot stones. On her third journey she gathered seeds of all kinds, but especially the seeds of grasses, which at her hand were to undergo a multitude of transformations. Wherever tribes of mankind have gone women have found out by and by that great staple productions were to be their chief reliance. In Polynesia it is taro and bread-fruit. In Africa it is palm and tapioca, millet and yams. In Asia it is rice, in Europe the cereals, and in America corn and potatoes, and acorns or pignons in some places. The whole industrial life of women is built up around these staples. From the first journey on foot to procure the raw material until the food is served and eaten, there is a line of trades that are continuous and are born of the environment.

The occupations necessarily grouped around any vegetal industry are the gathering of the plant or the parts to be utilized, the transportation of the harvest from the field to the place of storage, the activities necessary to change a raw foodstuff into an elaborated product, and lastly, the cooking and serving of the meal. It may be stated with much certitude, though there are noteworthy exceptions, that all of these processes in savagery were the function of women, and in their performance she includes within herself a multitude of callings, some of which now belong largely to men.

To trace the common vegetables back to their sources from our times through past ages by aid of literature and history would be an interesting task.

The possibilities of the agriculturists and cooks of the future are seen when we learn that of the more than 100,000 species of flowering plants now known, only about 300 species are yet cultivated to any extent, and some of these have been used for thousands of years. (Reference No. 67, Vol. II, p. 3.) The enormous possibilities of securing new and valuable plants by crossing and breeding should also be remembered. Yet large markets offer hardly 50 varieties of vegetables, and most families use less than half this number.

There are many ways of classifying the plants which are useful to man (Reference Nos. 18, pp. 6, 7; 64, p. 120; 69, pp. 289-291; 91, p. 241); a simple plan is to divide them according to their uses into—

- (1) Those that yield food for man, or for those animals which in turn serve as food for man;
- (2) Those which furnish materials for clothing and shelter; and
- (3) Those which supply no material need, but add beauty to human surroundings.

For accurate designation of plants the Latin form of names are used, and some familiarity with these is necessary in studying this subject or even for reference to the dictionaries and encyclopædias.

[Vegetable Foods, Bul. 245.]

The majority of the plants mentioned in these lessons belong to the following families. Familiar examples are given after the name of each group. (Reference No. 67, Vol. II, p. 2.)

Chenopodiaceæ: Beets and spinach.

Compositæ or composite family: Jerusalem artichoke.

Cruciferæ or mustard family: Mustard and cabbage.

Cucurbitaceæ or gourd family: Squash and cucumber.

Gramineæ or grass family: Indian corn, rice, and wheat.

Leguminosæ or pulse family: Beans and peas.

Liliaceæ or lily family: Onions and leek.

Solanaceæ or nightshade family: Potato and tomato.

Umbelliferæ or parsley family: Carrot and parsnip.

THE STRUCTURE OF PLANTS.

Every plant may be considered a factory into which are carried substances from the air and the earth to be manufactured into other and very different products. In general, the processes which go on within the plants are those of upbuilding, the substances which enter being very simple and the majority of those which are produced being complex.¹

In accordance with the classification on page 16, some plants may be considered factories for the manufacture of food, others factories for the manufacture of textile fibers, while still others may be considered factories for the manufacture of fuel or building materials. Some serve several or all of these purposes. But whatever may be the use to which the plants are put, they all have certain characteristics in common which may be learned from any work on botany. (Reference Nos. 79; 81, pp. 50-53; 85, pp. 105, 144-153.)

In studying plants in general we learn that they have a framework of a substance which is known as cellulose and that this cellulose frequently surrounds other materials in the plant. It gives to some plant tissues such tenacity that they may be used for textiles. In those plants or parts of plants which are used for fuel, wood, for example, it is the chief source of heat. (Reference Nos. 65, pp. 20-30; 92.) It is, however, acted upon with difficulty by most chemical reagents and it can be digested in appreciable amounts by human beings only when it is very young. In approaching the study of food plants, therefore, we need to be made familiar not only with those plant materials which can be utilized for food but also with this other substance, cellulose, which is invariably present. (Reference No. 83, p. 94.)

¹ The general structure of the plant may be shown under the microscope, or when that is not available, by pictures or lantern slides. (Reference No. 67, Vol. II, pp. 11-21.)

14579°—Bull. 245—12—2

[Vegetable Foods, Bul. 245.]

FOOD PLANTS AND THEIR COMPOSITION.

Within the network of cellulose which is to be found in all plants most of the nutritious materials of the food plants are deposited. Since the cellulose is not digested except when very young, it is usually necessary to soften it in some way so as to prevent its interference with the digestion of other substances. This is usually done by heat, but to accomplish it water must be present. Sometimes there is sufficient water in the vegetable itself. The potato, for example, is three-fourths water; even when a potato is baked, therefore, its starch and other ingredients are heated in water. If the vegetable has been dried, it is necessary to soak it in water before cooking it.

Though the greater part of the cellulose of vegetable foods remains undigested, it plays an important part in the digestion of other nutrients. These other nutrients are gradually rendered soluble by the digestive juices and are absorbed. If it were not, therefore, for the presence of cellulose, the bulk of the food in the alimentary canal would become so small as to make its passage through the canal difficult. This is the reason why it is so frequently said that cellulose is useful chiefly to give bulk to the food.

Most foods include more or less refuse as well as the edible portion. Modern commercial enterprise separates much of the refuse before delivering foods to the consumer.¹ The edible portion consists of water and four types of nutrients. (Reference Nos. 7, pp. 11-14; 34, pp. 12-13, 17.)

Water.—This substance, essential to life, is present in almost all foods, but in varying proportions. Even the dry cereals and other seeds contain 10 per cent or more. Watery juice is often apparent to the sight or touch or will be yielded from many fresh vegetables by pressure. Dry seeds must be soaked or cooked in water before they are fit for food.

Mineral matter.—In most vegetables the percentage of ash is higher than in grains. When one notes the small bit of ash remaining after food is burned and considers that ash contains calcium, iron, potassium, sulphur, etc., one realizes how small an amount of each must be present. Still, these minute quantities, often, in all, barely 1 per cent of the total weight of the food, are essential to health. Such materials are considered much more efficacious when taken into the body in this form than in "spring medicines." (Reference Nos. 33 and 36.)

Fat.—Comparatively few common vegetables contain enough fat to have it show readily. Nuts, such as pecans and coconuts and seeds, such as cottonseed, peanuts (a beanlike seed commonly called

¹ In every lesson attention may be directed to the small percentage of each plant which is useful as food.

[Vegetable Foods, Bul. 245.]

a nut), sesame, mustard, and corn, and such fruits as the olive and avocado, or alligator pear, may yield a considerable amount. The lack of fats in most vegetables justifies the habit of using cream, butter, meat fats, or olive oil with them, as is generally done.

Protein.—Except in legumes there is too little protein, as the total nitrogenous material is called, in vegetables to be detected by simple experiments. From the point of view of dietetics this is not significant, for vegetables are commonly eaten with meat and milk products which supply protein and fat.

Carbohydrates.—As a class vegetables are rich in carbohydrates. Starch, cellulose, and sugar are usually all present. Though the amount of sugar is usually small it is apparent in the sweet taste of squash, young peas, and green corn. (Reference Nos. 34, p. 25; 81, pp. 53-57.)

EXPERIMENT AND PRACTICE WORK, FIRST LECTURE.

Materials needed.—Test tubes, paper, cheesecloth, wire strainer, filter paper, alcohol lamp or Bunsen burner; a few each of large seeds such as corn, squash, beans, peas, nuts; ripe olives; onions and other bulbs; potatoes, beets, carrots, and piece of squash; small quantities of iodine, ether, nitric acid.

Composition of Foods.

Water and mineral matter.—Weigh a small portion of a vegetable, slice thin or grate it, and spread on a shallow dish and set in the oven with the door open or on the back of the stove, or put the sections in the upper part of a double boiler and leave uncovered, or spread in the sunlight in a current of air. Weigh after 1 hour and again after 24 hours. Also soak dried fruit or vegetables, measuring and weighing before and after soaking and estimating percentage of water absorbed. Burn any vegetable substance on a clean surface which can be made very hot; the ash left after all charcoal disappears is the mineral matter. Small tin covers are convenient for this purpose.

Weigh a potato; bake it, and weigh again after baking; put in the oven and allow it to turn to charcoal, and weigh again; then burn the charcoal in a crucible and weigh the ash, and compare approximately with the original weight of the potato.

Fat.—Crush nuts or bruise ripe olives or mustard seeds on blotting paper.

Put some peanut butter in a piece of cheesecloth and leave in the oven or in a water bottle until the warm oil separates.

If an equal volume of ether is added to ground flaxseed or peanuts and allowed to stand a short time, 10 minutes or more, the fat is dissolved with the ether. It may then be filtered and the liquid left in a draft of air until the ether evaporates and the fat remains. Great care must be exercised in the use of ether, as it is very volatile and inflammable. Do not use it near a fire or lighted lamp.

Protein.—Heat split peas in the water in which they have soaked for 24 hours or more. Gather the white froth which rises and test that and some of the water with dilute nitric acid. Such substances become yellow when the nitric acid is added and the whole is heated. Treat some egg white or milk in the same way for comparison.

[Vegetable Foods, Bul. 245.]

A still simpler though less certain test for protein or albuminous substances is the unpleasant smell given off by all materials containing them when burned. Burned milk or eggs have a well-known odor, and plants or seeds, such as beans and peas, burn with much the same smell.

Starch.—From ground peas or beans or grated potato starch may be washed out as from flour, through a coarse cloth or fine wire strainer. This may be dried and compared with commercial starch or cooked and tested with iodine. (Reference Nos. 34, p. 25; 81, pp. 53–57.) See also experiments under Lesson 5, page 43. (Reference Nos. 71, pp. 54, 59, 62; 72, pp. 60–62, 236, 237.)

Sugar.—Evaporate water in which carrots, beets, or squash have been boiled. Test it by tasting when it becomes a thick sirup.

Evaporate further until it burns and compare the odor with the result from burning sugar.

Germination Tests with Seeds, etc.

(Reference No. 79, chap. 1.)

Have some squash seed soaked for 24 hours or longer. Plant some of them and examine one or more each succeeding lesson. Split open some of the soaked seeds and find the seed leaves and embryo plant. Soak other seeds and compare with the first ones after the leaves begin to unfurl.

Try similar experiments with other large seeds, like peas or kidney or Lima beans. (Reference No. 99.)

In the same manner experiment with sprouting potatoes or onions. These may be put in earth or in a glass of water or even wrapped in moist cloth or paper. Notice the changes from day to day and the gradual shrinking of tuber or bulb as the sprouts develop; estimate loss of substance. Keep some away from the light and others in bright sunshine.

Cut the green top from a carrot and put the cut surface in a glass of water and place in the sunlight and in a few days small leaves will appear.

Another interesting experiment is the extraction of chlorophyll. (Reference No. 80, p. 287.)

Chop raw spinach fine, press in a cloth, then heat the juice extracted. Dip or strain the extract from the water and combine with sugar to preserve it. The green coloring matter thus obtained may be reserved for tinting candles and ice cream. If cooked too long it loses its vivid green.

REVIEW QUESTIONS, FIRST LECTURE.

1. Give different methods of classifying plants.
2. Mention five of the principal plant families and some members of each.
3. Describe the structure of some typical plant.
4. What is cellulose? What of its food value?
5. What proportion of average plants is utilized for food? Give examples.
6. Report your personal observation and experiments in the germination of plants.
7. Describe the principal nutritive substances derived from plants.
8. How may the presence of each one of these substances be recognized?
9. Tell something of the source and changes produced by cultivation of three plant foods.
10. What part has women had in the development of such foods?

[Vegetable Foods, Bul. 245.]

COURSE IN VEGETABLE FOODS.

SECOND LECTURE—LEAVES AND STALKS.

USE OF RAW VEGETABLES.

It seems logical to begin our study with plants or parts of plants that may be eaten raw. Fresh, green vegetables are generally relished and form a part of the diet wherever they can be obtained, and many of those which are most prized are eaten without cooking, as they were by primitive man. Such vegetables may be called salad plants, though it is difficult to classify plants according to the uses to which they are put, for almost all are used for many different purposes. Lettuce, for example, a vegetable which in this country is most always eaten raw, in Europe is often cooked, and thus it becomes a potherb as well as a salad plant. Water cress, though often used as a salad, is sometimes used simply as a condiment. Peas, beans, potatoes, and vegetables such as spinach, which are most commonly served as a "vegetable," are often put into salads. In spite of these difficulties in the way of classification, we may include under salad plants those whose leaves and stems are usually eaten raw with a sour dressing, and define a salad as a dish consisting in whole or in part of vegetables, either raw or cooked, mixed with a sour dressing. Salad dressing usually contains a fat as well as an acid.

The use and cultivation of salad plants go far back into ancient history. These foods are valuable not only because their freshness and attractive appearance arouse an appetite for the more substantial materials served with them, but because in this shape we get all their mineral constituents, which are liable to be lost in part or perhaps rendered less useful by cooking. Hence the desire for such foods should be considered to represent a real need, and raw salad plants should be supplied freely in all dietaries. "Spring bitters," on which the housewives of earlier days set so much store, are more palatable when obtained from salads than from medicine bottles; and, setting aside any question of medicinal value and all that pertains to it, such plants without any doubt help to make the diet attractive and to give a relish to food, particularly in the spring, when one is weary of the limited variety of winter foods.

Housekeepers often claim to know and care little about salads, but those who dig wild Jerusalem artichokes in the spring or start the early peppergrass or radish to serve as relishes at the table are pro-

viding salads for their families; or again, those who prepare the cold vegetables left at noon, such as "greens," with a dressing even of salt and vinegar for supper, make salads. Fresh cucumbers with vinegar or other dressing are salads just as much as are the more elaborate dishes. The derivation of the word salad shows it to mean a food to be eaten with salt.

It would be better to keep near to this original meaning rather than to go to the extreme of some housekeepers who, in their search for novelties for their tables, build up salads from strange combinations in ornate forms.

The distinctive salad plants are very succulent; that is, they consist mainly of water. Hence, they are especially refreshing in warm weather. As a separate course they are a pleasant contrast to the heavier dishes of a formal meal. They also serve to prevent too great concentration of food, and thus aid in the digestive process. Upon the valuable saline properties of these raw plants we are just beginning to place a definite value, though evidently these were recognized by the instinct of the people of the far past. (Reference Nos. 33 and 36.)

Fat is a compact food and, weight for weight, is about two and a quarter times as valuable as protein or carbohydrate for fuel in the human body. (Reference No. 7, p. 12.) A tablespoonful of oil would go farther toward supplying energy for keeping the human machinery running than a large head of lettuce. Over all the world people have instinctively added a condensed dressing consisting mainly of oil, bacon fat, or cream to the salad plants bulky with cellular tissue and water, and have eaten such salads with meat and bread supplying protein and carbohydrate, and thus have secured a fairly balanced ration.

The use of salad plants and salads as decorations on the dining table deserves consideration. Beware of unattractive combinations of color, however, such as beet with tomato, etc. (Reference Nos. 84, ch. 28; 93.)

Modern study of bacteriology indicates that pagan and religious ceremonies of purification by fire and water had definite value for healthful life in this world. Water cleanses to some extent, but only through intense or long-continued heat is complete sterilization and freedom from bacteria and parasites secured. Therefore great care is needed in the selection and preparation of foods which are not to be subjected to heat. Cress, lettuce, and other salad plants, carelessly cultivated and handled in the market and half cleaned in the kitchen, may transmit disease, as may milk, raw oysters, and other animal foods. (Reference Nos. 28, pp. 1-13; 61, p. 115; 97, p. 284.)

The fashion of cutting across a head of lettuce or celery, though it may give each person a fair share of the choice and less tender por-

[Vegetable Foods, Bul. 245.]

tions, can not be recommended, because it is practically impossible to cleanse the axils of the leaves, the grooves where they join the stem. All such plants should be separated in their natural divisions and washed in more than one water, individual attention being given to hollows in stalks or leaves. Sand is unpleasant, but less harmful than other things that may be left behind after washing; its presence, however, justifies the suspicion that the washing was not thorough or carefully done. Vegetables such as spinach, which are difficult to free from grit, should be washed in a number of waters, and lifted out of the pan each time in loose handfuls before the water has been drained off. In this way the sand and grit has an opportunity to sink to the bottom of the pan and can be rinsed out. If the water is poured from the pan while the vegetables are in it, part of the sand at least is again distributed over the washed leaves.

Green vegetables should always be looked over carefully to make sure that any inferior portions, insects, or other things which are undesirable are removed. The quality of vegetables may be greatly injured by insect pests and plant diseases. If the plant suffers very severely from such enemies, it can not make normal growth, and so all or parts of it may be inferior. For instance, green peas or string beans from vines badly attacked by insects or by some fungus disease do not attain full perfection. Obviously, leaves used as greens are of inferior quality if worm-eaten. Insect pests and plant diseases can often be controlled by the use of insecticides and in similar ways. (Reference No. 55.) If such things are used there is all the more reason for washing vegetables thoroughly before preparing them for the table, to remove any hellebore, copper salts, or other substance used in treating the plant, which may adhere to it. Salt in the water will aid in drawing out parasites if they happen to be present. There is distinct advantage in washing all salad plants in running water, especially for the removal of insects from lettuce. After washing several times and removing imperfections, salad plants may be kept in a cool place like a cellar or refrigerator for some hours or even a day before using. After draining off the last water, wrap the leaves or stalks in a cloth or put in a clean paper bag; this is more effective than keeping them in water. (Reference No. 28, p. 39.)

During the cleaning process it is advisable to sort out the coarsest portions to add to soup materials; the next best may not be attractive to serve by themselves, but can be cut or shredded for combination with other materials, while the best of all—the heart of the cabbage, celery, or lettuce—should be served in the least elaborate way with salt or a simple dressing.

No plan for serving salads should be encouraged which leads to a waste of food material. If it is desired to use the outer portion of a cabbage for a salad bowl (Reference No. 70, p. 293), any adhering

dressing may afterwards be washed off and the cabbage used for a scallop or soup. The outer leaves of lettuce may be cooked for greens or soup.

Many materials may be combined with the cabbage, celery, and lettuce—raw apples, radishes, or even canned fruit, such as pears cut in slices or cubes. Lettuce is generally recognized in this country as the main dependence for salad by itself and in combination with other foods. There are many varieties, adapted to different conditions, but all may be classed under two general heads—the cabbage lettuce, where the heads are solid and compact, and the cos lettuce, where the leaves are long and loose and less delicate than those of the other type. Romaine is an example of cos lettuce. There are also varieties with blanched centers and curly varieties with dark-tinged leaves.

Chicory may be cultivated for salad, and is more desirable when blanched. Endive, which is very nearly related to chicory, is another useful salad plant. The corn salad or lamb's lettuce is a small plant often found in city markets. Sorrel, wild and cultivated, some young and tender seaweeds, and many mild-flavored plants or weeds may be used as raw salads. Others are better for partial cooking, even if served cold as salads. (Reference Nos. 18, p. 33; 73, p. 151.)

Celery in its wild state is an unpromising if not harmful vegetable; by cultivation, and especially by blanching its leafstalks, it has been made a popular salad plant, and has been thought to have certain medicinal virtues. The fibrous outer stalks and larger white leaves of a bunch of celery should be reserved for soup making. Some of the larger stalks, too stringy to serve whole, may be used in salads if cut in quarter-inch slices, or if too tough for that, may be cooked after cutting and added to soups or served with white sauce or toast. The tender inner stalks should be served plain to eat with salt. Sometimes the groove in the stalk is filled with prepared cheese. The center of the root is a delicate morsel. Leaves and root may be dried to flavor future soups. (Reference No. 20.)

EXPERIMENT AND PRACTICE WORK, SECOND LECTURE.

Materials needed.—Any available salad plants, such as chicory, chives, endive, escarole, mustard, parsley, peppergrass, radish, romaine, water cress, as many types as possible. If only lettuce or celery can be secured, have one root for each pupil. Cabbage, apples, cucumbers, etc., may also be used. For salad dressings provide olive oil, sour cream, peanut butter, eggs, bacon fat, lemon juice, vinegar, and other seasoning materials, according to the recipes to be chosen from those at the end of this section.

Excursion.—If feasible, visit markets, farms, or gardens, or gather wild plants. Learn to recognize different kinds and test their merits as raw foods, alone or with various dressings. At the same time secure other plants to illustrate this and the following lesson.

[Vegetable Foods, Bul. 245.]

Lettuce.

Weigh head of lettuce with the roots and all, if possible. Remove inedible portions and weigh again. Divide into lots, according to quality; weigh or estimate the percentage of refuse and relative values of each portion. (Reference Nos. 7, p. 11; 30.) Estimate cost per calorie. Pull apart and wash each section thoroughly, dry on a cloth without bruising, then arrange the lettuce in a salad bowl as nearly as possible as it grew, the larger perfect leaves outside and the tender ones in the center. Imperfect leaves when not decayed may be rolled or folded and cut in shreds or ribbons for other salads.

Celery.

In the same way clean, weigh, or estimate values of all parts of celery, including the root. Reserve for use in soup stock in some succeeding lesson (5 or 11) tough stalks and portions of the root and coarser white leaves. The tough outer fiber sometimes may be pulled or scraped off. For fringed celery see Reference Nos. 75, p. 120; 76, p. 35. Sort celery like lettuce, reserving tenderest portions to serve in simplest form. If there are enough of the tender white leaves, cut them for greens. The coarse, bright-green leaves have stronger flavor. Cut the coarser stalks across the grain in quarter-inch slices. A large stalk first may be cut in several strips. Let these stand in a French dressing for an hour or more, then combine with other material or fill into a hollowed apple or tomato to serve to each individual. Sections of cabbage or cucumber may be used in this way when celery is not available.

Cabbage.

Cut a portion of the stem from a cabbage, put the cabbage in a dish of water, and cover with a cloth. In 24 hours it will be much crisper, having absorbed water like any withered plant. Take a small light-weight cabbage, turn back the leaves, and compare with a head of lettuce. Compare with a cabbage of similar size, but weighing twice as much as the first. Cut a cabbage in quarters, take out the inner third of each section and serve as a salad. Sometimes the inner cabbage leaves are tender enough to serve whole like lettuce, but usually they should be shaved with a knife or vegetable cutter or chopped. The coarser outer cabbage leaves may be reserved for the succeeding lessons, for soup, or scalloped cabbage.

Salads and Salad Dressings.

(Reference Nos. 18, p. 23; 69, pp. 309-314; 73, pp. 100-103; 76, p. 350; 93.)

Various salad dressings may be made in this lesson and some reserved in glass jars for future lessons. The cooked dressings may be taken up later. In this lesson prepare the simplest types, like the following:

French dressing: To each tablespoonful of olive oil add a few grains of pepper and a little salt, blend thoroughly, and then add slowly one teaspoonful of lemon juice or vinegar. Cottonseed oil may be used in the same way.

Nut dressing: Dilute peanut or other nut butter with lemon juice and vinegar and a little water. Season with salt and pepper.

Cream dressing: Beat thick cream, sweet or sour, with an egg beater until stiff. Season with salt, pepper, and lemon juice or vinegar. Continue the beating while gradually adding the acid.

[Vegetable Foods, Bul. 245.]

REVIEW QUESTIONS, SECOND LECTURE.

1. Mention five plants commonly eaten raw.
2. What of the possible medicinal value of raw foods of this kind?
3. What food materials are most abundant in salad plants? What do they lack?
4. Mention special characteristics and describe the preparation of three of the most common salad plants.
5. Give reasons for special attention to cleansing such materials.
6. How may these leaves and stalks be kept in good condition for the table from one day to another?
7. Why are oils or other fats usually combined with such plant foods?
8. Give directions for dressing a salad with olive oil.
9. What are the usual ingredients in a cooked salad dressing? Give reason for the use of each.
10. Of what value are the decorative possibilities of a salad?
[Vegetable Foods, Bul. 245.]

COURSE IN VEGETABLE FOODS.

THIRD LECTURE—LEAVES AND STALKS—Continued.

Closely associated with the plants that are eaten raw are a host of leaves and stalks commonly cooked and served under the general name "potherbs" or "greens." This old term indicates the instinct of primitive people to seize upon the first green tips that appear in the spring for food. These must have been very welcome after the winter struggle for game, grains, roots, and nuts, if indeed the nomad tribes were fortunate enough to have so much. Notwithstanding the low fuel value of such foods the discerning housewife, even when dependent upon the high prices of city markets, recognizes the necessity of supplying her family bountifully with this type of food in the early spring. A wide variety of plants are usable in this way. Many wild ones are available, and some are cultivated especially for this purpose. Others are by-products; for example, the small beet plants which are thinned out in the home garden.

WILD PLANTS USED AS POTHERBS.

A double purpose may be accomplished in the country home by the use of such wild greens, namely, freeing the grounds from weeds and providing food. Among the wild plants which have been used in this way are the following:

The common dandelion is cut close to the ground before the flower bud has expanded. When it is desired to root out the plant from a lawn, the entire root must be dug up; if simply the top is cut off, the dandelion grows again and in a larger head. The slightly bitter flavor is not disagreeable. The roots furnish a bitter extract often used medicinally, particularly in the domestic medicine of early times. When cultivated, the dandelion is milder and more tender, and may be used as salad, as may the very young wild plant, or dandelions blanched by covering them for a few days. (Reference No. 10, p. 18.)

The milkweed, cut when less than 6 inches high before its leaves have fairly unfolded from the stalk, is considered almost equal to asparagus, and may be used to extend a scanty supply of the latter.

The sour sorrels, so abundant on poor soil, may be added to soups or salads, and the larger leaves of the cultivated imported varieties make excellent greens.

The chicory, which is a common weed in many places, furnishes excellent greens, much like the dandelion, only rather more bitter. They are better if blanched by covering the plant with an empty flower pot or in some similar way. A plant nearly related to chicory, carefully grown and blanched, is the "endive" of the market gardeners.

The cowslip or marsh marigold is sufficiently abundant in some regions to serve as a food plant, and is prepared like spinach or other greens.

Poke sprouts are a favorite potherb in some regions of the Southern States and are on sale in the spring in Washington, D. C., and other southern cities. The young shoots are cooked and served like asparagus.

Purslane is one of the most common weeds now, yet in remote ages it appears to have been cultivated as a potherb and to have been brought from the East to Europe as a salad plant. It is best when well developed, but just before it blossoms, and should be cut at the surface of the ground without the roots. But little time is required for cooking its succulent, red, branching stems, which provide after cooking a dish closely resembling beet greens in flavor.

Pigweed or goosefoot or lamb's-quarters, shepherd's-purse, and similar weeds are used in this fashion. Experiments with wild plants should not be tried unless one is sure that the plant is not poisonous.

CULTIVATED POTHERBS OR GREENS.

Of the plants cultivated especially for greens, asparagus, which Charles Lamb said "seems to inspire gentle thoughts," is a general favorite. This is a member of the lily family akin to the lily of the valley. Many an asparagus bed does good service unto the second and third generation of owners (one in England is known to be over 90 years old), and it is strange that any farm should lack this long-lived, easily cultivated delicacy. (Reference Nos. 18, pp. 17, 18; 75, p. 140.)

Spinach is a favorite form of greens and is seen in city markets most of the year. A French proverb calls it the "broom of the stomach," and it appears to be richer in iron than most common foods. (Reference No. 33.) The tenderest leaves may be served raw as a salad.

Beets are rarely raised especially for greens, but surplus plants are reserved for this purpose. These are often eaten when very small. The tops of the early bunch beets brought to the city markets may often be used as greens, even when the stalk and leaf are 6 or 8 inches long. Swiss chard is a variety of the beet plant with thick leaf stems and is raised especially for greens.

[Vegetable Foods, Bul. 245.]

Carrot tops are sometimes used as a potherb, but are too fibrous unless very young. It should be remembered that some of the same family (the Umbelliferæ) are poisonous. Turnip tops are also used in this fashion, and resemble kale. Alfalfa tops are said to make satisfactory greens. Pumpkin tops also are sometimes used in this way.

Hop sprouts are seen in the Belgian markets in March and April and are even canned and exported. Care is taken to cut the sprouts so as not to interfere with the later growth of the vines.

The Japanese use young shoots of burdock cooked. They are better if blanched with earth for a few days before cutting. Then they should be parboiled, drained, and cooked again until tender, and served warm or cold with a salad dressing. Udo is another Japanese salad plant which is being tried in this country. (Reference No. 44.)

Fennel is used as a culinary vegetable in Europe and occasionally in this country. The leafstalk is thick and swollen toward the root, and thus becomes united almost like a bulb. It is used as a salad or for greens; the finely divided leaves may be cooked like spinach, while the stalks may be cut in sections, cooked, and served with white sauce like celery.

American housewives realize less commonly than those of Europe that lettuce makes excellent "greens." This, as mentioned above, suggests a good way to use the tougher or outer leaves of the lettuce bought for salad and the surplus crop of the home garden. As is the case with all potherbs, lettuce should not be overcooked. (Reference No. 87, p. 29.)

The cabbage tribe, belonging to the Cruciferæ, supplies many types of vegetables used as potherbs, and is said to contain no harmful members. (Reference No. 86, p. 180.) The original wild type was the *Brassica oleracea*. The group of plants now include the white, red, or purple, and Savoy cabbages, coleworts, borecole or Scotch kale, cauliflower, broccoli, and others. Their growth is luxuriant and a variety of forms has been developed.

The swollen stem of the kohl-rabi is one type of development, and another is the stalk surrounded by buds known as Brussels sprouts. The cauliflower (Reference Nos. 18, pp. 15-16; 69, p. 301) usually considered the most digestible of the tribe, owes its delicacy to undeveloped flower buds; broccoli is similar in form but hardly equal in quality.

Collards or coleworts are also similar to cabbage, having long, loose leaves. (Reference No. 75, p. 116.) They grow where the weather is not cold enough for cabbages to head.

Kale consists of curly, open leaves not forming a compact head. The blanched shoots of sea kale are prepared like asparagus and the

[Vegetable Foods, Bul. 245.]

flower heads also are used. (Reference No. 18, pp. 16-17.) The sprouts from cabbage stalks left in the ground over winter may be used in the same way.

The Chinese cabbage, pak-tsai, is being tried in this country and gives promise of becoming adapted to our conditions and being a useful potherb.

Some of the cabbage tribe may be used raw when young and tender as salads, and have long been regarded as valuable preventives against scurvy.

Often when this type of plants is cooked an unpleasant odor and flavor is developed. This is obviated in large measure by cooking uncovered and in an abundance of water. (Reference No. 18, p. 13.) It is also important that such vegetables shall not be cooked too long. Once it was considered necessary to cook cabbage several hours, but a young cabbage may be made perfectly tender in 20 minutes and an older one will not take twice as long. The old idea that cabbage was indigestible was due to its being overcooked.

When cabbage or cauliflower begin to grow darker in color in cooking, changes caused by lack of ventilation and too long cooking are taking place. Such plants are therefore less satisfactory if prepared in the steam cooker than when cooked in an abundance of water.

Rhubarb is another plant in which the leafstalks are the useful portion, though it may from its use be classed as a fruit rather than as a vegetable. The various acids and other flavors it contains are acceptable in the early spring when it is at its best. Later in the season, when the stalks are tough and fibrous, the juice may be extracted for jelly making. Because it contains some oxalic acid the use of rhubarb is frequently forbidden to persons of gouty tendencies.

SEAWEEDS.

Several varieties of seaweeds are used as foods in different parts of the world, sometimes for flavor or supposed medicinal value and sometimes in place of gelatin.

Dulse is sometimes eaten raw as a salad and because of the iodine it contains has enjoyed much reputation as a medicinal plant. (Reference No. 86, p. 187.)

Irish moss or carrageen is a variety of dulse. Its greenish purple tint fades out as it dries on the beach. Though of slight food value, since more than half its substance is a kind of mucilage which the body does not assimilate, it has long been used like gelatin; its use for the stiffening of blanc mange, etc., was formerly more general than at present. (Reference No. 73, p. 164.) Iceland moss is a kind of lichen used to stiffen desserts, etc., and is supposed to have a soothing effect in cases of irritated throats.

[Vegetable Foods, Bul. 245.]

Agar, or Ceylon moss, a seaweed from the Indian Ocean, is much used as a culture medium in biological laboratories, and is also used by many cooks in place of gelatin of animal origin. (Reference No. 75, p. 222.)

EXPERIMENT AND PRACTICE WORK, THIRD LECTURE.

Materials needed.—Different greens according to season, such as spinach, cabbage, cauliflower, Brussels sprouts, canned asparagus; also butter, eggs, and salad dressing. A quart of Brussels sprouts and a peck of each of the green vegetables are convenient amounts.

Utensils.—Saucepans for boiling vegetables, pans for washing, knives, colander, chopping bowl, and chopping knife.

The first step in the preparation of all these plants is thorough cleansing, for though the boiling process might render invisible dirt harmless (Reference No. 28, p. 13), sand is particularly obnoxious in greens.

The best plan is to sort and trim off all old or imperfect portions, then wash leaf by leaf and float in several waters in order that all solid particles may settle to the bottom of the pan.

Preparation and Cooking of Potherbs and Similar Vegetables.

Exercise 1.—Let each pupil weigh, trim, and wash several roots of spinach; weigh refuse, estimate the percentage of loss. Cook in little salted water approximately 30 minutes, or till tender. Let this be done individually, and the amount of sand be noted. Drain, measure the leaves, and compare with original bulk. (Reference Nos. 18, p. 17-18; 70, pp. 299-300; 75, p. 140.)

Let each pupil prepare some one of the following and all results be compared:

(1) Cook spinach in its own juice, in covered saucepan.

(2) Cook in considerable water uncovered.

Serve 1 and 2 plain and compare their flavor.

(3) After cooking, drain, chop, rub through sieve, reheat, add a little cream or white sauce.

(4) Mold in cups, garnish with egg rubbed through strainer.

(5) Cream of spinach soup; prepare spinach as in exercise 3; then dilute to desired consistency with milk.

Exercise 2.—While the spinach is cooking each member of the class may be given a different kind of plant, if as many are obtainable.

The preliminary preparation should be similar to that of raw salad plants or spinach; remove all dirt, decayed portions, etc.

Sort out tougher portions and give them longer application of heat; when they are partially cooked, add the tender parts.

So far as possible cook most vegetables uncovered in sufficient boiling water to prevent all danger of burning. The water should bubble.

Exercise 3.—If possible provide one pupil with a few Brussels sprouts, one with cabbage, one with cauliflower, etc.; in this way small quantities will serve for the class and all varieties may be cooked at the same time.

Such plants should be soaked head down in cold salted water before cooking. (Reference No. 18, p. 9.)

Use center of cabbage for salad, outside for boiling. Serve boiled cabbage in the following ways:

(1) Plain with butter.

(2) With oil and vinegar.

(3) With white sauce.

(4) With white sauce and crumbs. (Reference No. 73, p. 150.)

[Vegetable Foods, Bul. 245.]

- (5) With white sauce, crumbs, and cheese.
- (6) With sausage. (Reference No. 18, p. 14.)
- (7) With potatoes (kolcannon). (Reference No. 18, p. 15.)
- (8) German cabbage. (Reference No. 73, p. 150.)

Exercise 4.—Supply each member of the class with a different “green” if possible.

The preliminary preparation should be similar to that for the raw salad plants. Even if all is to be cooked it is desirable to sort out the tougher parts and give them a blanching (Reference No. 18, pp. 10–11), or parboiling before combining with the tenderer portions.

Let each vegetable cook uncovered in sufficient boiling, salted water to prevent any danger of burning (with the exception of spinach in its own juices, which must be covered).

Adopt a small standard portion suitable for one serving per person—2 ounces or one-fourth cup is a fair average—estimate cost, including original cost, labor, and cost of additions. Compare with cost of canned vegetables.

Observe the constant tendency to add to such plants the protein, fat, etc., which they lack by combining with them milk, butter, eggs, and salad dressings.

When few fresh greens are available, use canned asparagus. Remove from can, taste of liquid, and reserve it if the flavor is good. The stalks may be reheated and served on toast. Or tips may be served for salad with French dressing, and the stalks used for cream of asparagus soup. (Reference No. 73, p. 77.) Split open stalks, add liquid from can if suitable, heat, rub all possible through coarse strainer, add milk, thicken and flavor.

In each case work out the cost of material in city and in country, and add the labor of preparation. Note the advantage in the country in the use of such by-products or weeds as thinned-out best greens or purslane.

Irish moss blanc mange may fitly form a part of this lesson. (Reference No. 73, p. 164.) The whole moss is preferable to the sea-moss farina.

Stewed pieplant or rhubarb will also illustrate use of leafstalks as food. (Reference No. 73, p. 15.)

This lesson may be carried out in the preparation of a luncheon or simple dinner with either of these menus:

No. 1.

Cream of asparagus soup.
Spinach and eggs.
Creamed cabbage with cheese.
Stewed rhubarb.

No. 2.

Cream of celery soup.
Asparagus on toast.
Kolcannon (potato and cabbage).
Blanc mange.

REVIEW QUESTIONS, THIRD LECTURE.

1. Explain the terms “greens,” “potherbs.”
2. How divide plants that part may be used for salads, part as greens, or in other ways?
3. Give general directions for choosing, cleaning, and cooking dandelion greens.
4. Give a list of wild plants in your vicinity suitable for this purpose. How many have you tried?
5. Explain the shrinkage common with such foods.
6. Why is fat meat often cooked with plants of this type?
7. Give general directions for cooking cabbage or cauliflower.
8. How many asparagus beds in your neighborhood? Give method of preparing canned asparagus.
9. What reasons for use of white sauce with cooked cabbage, celery, etc.?
10. Give directions for making white sauce.

[Vegetable Foods, Bul. 245.]

COURSE IN VEGETABLE FOODS.

FOURTH LECTURE—BULBS.

THE ONION TRIBE.

Next to leaves and stalks we may study bulbs, which may in a way be considered as a form between stems and roots.

Bulbs are a kind of bud, spheroidal in shape, and from the botanist's standpoint consist of a cluster of leaves, modified in form and tightly folded together, one over the other. Usually they form above or just below the top of the ground. In some cases the young bulb-lets appear in the axils of the leaves (tiger lily) or at the blossom, as in top onions.

Such bulbs are characteristic of the lily family, which includes some of the most ornamental plants of the flower garden—hyacinths, lilies, narcissus, and tulips, for example.

The American Indians used certain wild lilies as food, and the bulbs of some garden lilies are eaten in Japan and China and are also sold in Chinese shops in American cities. In American homes the lily bulb had some use in olden times for medicinal purposes.

From the culinary viewpoint, however, the *Allium* tribe of the lily family includes the most important of the bulbous plants, namely, the onion and some of its relatives.

The derivation of the word "onion" is significant, indicating the oneness of the bulb or close union of the underground stems. The onion appears to have been a native of Asia and to have been used by the human race from the most ancient times. It is mentioned in the Bible and in old Egyptian writings. (Reference Nos. 87, pp. 106-107; 100, pp. 223-226.)

No one seems ready to say what is the special virtue derived from plants of the onion race, but most dietitians agree that it is wise to serve them frequently either raw or cooked.

Onions owe their flavor to a volatile, oil-like compound containing sulphur, which has been carefully studied by chemists. They are very succulent, but nevertheless supply some nutritive material, chiefly carbohydrates, as is the case with most succulent vegetables.

There is a large variety of onions (*Allium cepa*) available, and all of them are useful in turn. Many varieties are grown by American farmers and gardeners, and the crop is a very important one and supplies the bulk of the onions found in our markets.

The tiny pearl and button onions are convenient for salads or pickles or for the hint of flavor wanted where a large onion would be far too much.

From the Bermudas and the South in the early spring come flat, crisp onions of a purplish tint which are appetizing either raw or cooked, and more agreeable in texture than the coarser varieties commonly raised for the winter market. The large Spanish onions are mild and tender, suitable for salad or cooking purposes. The white-skinned Egyptian onions are usually a satisfactory variety. There are many onions in the market which are strong in flavor and tough, and justify the prejudice which the indiscriminating have against all onions. In general, the greenish yellow and red types of onion, owing to their texture and flavor, are less satisfactory for cooking as a vegetable than those of lighter hue.

Garlic is of interest in the study of bulbs, even to those who may not like its flavor. Each bulbous root or stalk is a compound made up of several smaller bulblets, each of which is known as a clove of garlic, clove signifying the cleavage or splitting of the larger group. This plant, like other members of the onion race, has been used in cookery from the earliest times, and its use is especially common among the Latin races in southern Europe. Rightly used and in small quantities garlic is considered a desirable seasoning by most trained cooks. A salad may be flavored by rubbing the dish with the cut surface of a clove of garlic. The oil of garlic, which gives it its flavor (Reference No. 86, p. 183), is composed mainly of allyl sulphid, a substance common to all the onion family—asafetida, radishes, cress, mustard, etc.

The leek is another useful plant of the same race. The bulbous portion is much elongated, cylindrical rather than spherical, and the leaves are long and flat and sheathed over each other. In cultivation the lower part of the leafy part of the leek is blanched, like celery, for several inches. This plant also was known to the Egyptians, Greeks, and Romans, and is the national emblem of the Welsh.

To cook leeks remove the fine roots and green ends of the leaves and cut the white portion in 3-inch lengths. Wash and cook in boiling water until tender; that is, for 20 minutes or more. Serve on buttered toast like asparagus or with white sauce. The stocks, if too thick, may be split and flattened after cooking. The water in which leeks are cooked may be used in soups. Closely related species called wild leek or wild garlic grow in some parts of this country and are liable to flavor the milk and butter of cows that eat them in the pasture. Wild leek is sometimes used as a seasoning. The shallot is a cultivated plant similar to the leek, but with a tubular leaf.

Ordinary young onions are often sold under the name of “scullion” or “scallion,” which properly belongs to any thick-necked or un-

[Vegetable Foods, Bul. 245.]

developed bulb of the onion tribe which has not grown round, but more nearly resembles the leek in shape. In onion beds these are pulled out and marketed when young, or they may be grown from the bulbs of the previous year. The name is derived from Ascalon in Syria and belongs especially to the shallot, which is also known as cibol or eschalot by the French and which is a dwarf onion resembling the leek in that it has no distinct bulb and has tubelike leaves.

Chive is a perennial of this same race, the leaves of which have a delicate, appetizing flavor frequently relished by those who object to the stronger onion flavors. Chives are sometimes used as a border plant in flower gardens, having an attractive blue blossom. A clump of these tiny bulbs will grow for weeks in the house; if they are planted in a dish of mixed ferns the peculiar shade of green in their leaves will make an attractive combination with the other plants, and the fine stalks may be cut as needed to flavor salads and soups. The essential oil is so abundant that a very small quantity of the leaf suffices. Onion tops, like the stalks of wild leeks and chives, can also be used for flavoring, especially the sprouts that start when the bulbs have been kept in a warm room. The young spring onions are sometimes eaten like radishes as a relish, or cooked and served like asparagus, and are a favorite dish.

Rocambole somewhat resembles leek, and is also called sand leek.

EXPERIMENT AND PRACTICE WORK, FOURTH LECTURE.

Materials needed.—Butter or drippings, salt and pepper, milk, egg; one or two onions for each pupil, different varieties preferred; specimens of as many of the other members of the *Allium* tribe as possible.

Preparation of Onions.

To prepare onions, peel under water so that the volatile bodies which affect the eyes may remain in the water and be kept from scattering. Where the onions are especially strong or liable to prove indigestible to anyone, they may be put, after peeling, into boiling water, to each quart of which one-fourth teaspoon of bicarbonate of soda has been added. After letting them stand in this water half an hour, drain and boil in plenty of salted water from $\frac{1}{2}$ to 2 hours, according to the nature of the variety in hand, changing the water if desirable.

Often it is wise to take off one or two of the coarser layers next the outside skin and reserve them for flavoring soups, while a part of the tender succulent center may be reserved for a salad. This plan of selection corresponds to that already suggested for cabbage, celery, lettuce, etc.

Methods of Cooking.

The water in which onions are boiled will contain much flavor, and some of it may be reserved to flavor soups, either milk or stock.

Any strong variety of onion is much improved for the table in spite of loss of nutritive value if the water is changed several times during the cooking process. Milk may be used as the medium for final cooking.

[Vegetable Foods, Bul. 245.]

If onions are cooked uncovered, the odor apparent in the house is less intense, and, like cabbage and beans, they are commonly said to be more digestible when thus cooked. (Reference No. 18, p. 13.)

There is a culinary tradition that parsley eaten with onions not only sweetens the breath, but counteracts the tendency toward flatulence.

Securing Onion Flavor.

The simplest way to extract onion flavor for seasoning salads, etc., is to cut a slice from the root end of the bulb and press the cut surface firmly against a grater, turning gently until some drops of juice fall. Cut off another slice and press the fresh surface again if more flavor is required.

When the onion is old and has begun to sprout there is little juice to flow and more pressure must be used; the soft pulp which passes through the holes of the grater will serve instead of the juice. Sometimes with a fresh onion the grater is unnecessary, as sufficient juice will follow a few gashes from a knife.

Another way to secure onion flavor is to cook the chopped bulb in water, milk, or stock. Slices from which some of the juice has been extracted will again yield flavor if cooked in that way.

A third method is to extract the juice in fat, and for this purpose sliced onion is cooked in the fat until light golden brown, or sometimes until very brown, thus securing a combination of caramel from the browned sugar and the peculiar flavoring bodies of the onion, a flavor quite different from those obtained by either of the other methods. The scraps of onion may be strained out and the flavored fat added to sauce or soup, or they may all be used together.

Onion for forcemeat or stuffing may be prepared in any one of these ways, or chopped onion may be blanched or scalded in soda water and then added directly.

A little chopped or finely cut onion may be prepared without soiling the fingers by peeling the onion on a fork, cutting off the outer skin, cutting into one end in different directions, and then slicing off on a piece of clean paper as much as is needed.

Each pupil may boil two varieties of onion or an onion and a leek and note the time required and other points of difference in each. Save the water, note color, compare flavor.

Further exercises follow:

Spanish Onion.

Cut an onion in two, reserve small portion of center for salad, parboil remainder 10 minutes, save water. Cut onion small, put in saucepan with 1 tablespoon butter or dripping, a little salt and pepper, cover and cook slowly until tender.

Another method for preparing this dish is as follows: Cut, reserve center, cook in water until tender, combine with milk or white sauce.

Still another method for Spanish onion is: Cook as before in a little water, when soft rub onion with water through strainer, add milk, thicken and season. Try with further addition of (a) egg, (b) cheese. (Reference No. 73.)

Onion and Apple Salad.

Slice centers of Spanish onion very thin. Pile up slices and cut across to divide still finer. Combine with twice as much sliced apple. Leave red skins [Vegetable Foods, Bul. 245.]

on apple as garnish. Add French dressing and chopped parsley or pepper. Mayonnaise or cooked dressing may also be used.

Onion Soup Without Meat.

French families are fond of an onion soup which is very easily and quickly made and very palatable.

Peel a good-sized onion, cut in small pieces, and cook slowly and carefully until tender in a heaping tablespoonful of fat or of butter. Then move the saucepan to a hotter part of the stove and cook the onion until well browned, stirring all the time to prevent burning. Add a pint and a half of boiling water, or milk and water half-and-half. Season with salt and pepper, bring to a boil, and serve poured over a piece of toasted bread, or serve small cubes of bread fried in butter. If no milk is used, it is a common custom to serve some grated, mild-flavored cheese, such as Swiss cheese, with the soup, which may be added to it as desired.

Fried Onions.

Fried onions may be prepared in either of two ways: (1) Sauté sliced onion in olive oil, butter, or other fat until golden brown and tender; or (2) fry a few pieces at a time in deep fat, let them remain in the hot fat until they are crisp, like Saratoga potatoes, but do not let them become too brown. (Reference No. 70, p. 296.) Use to garnish meats or add to soups, or combine with potatoes, stewed beans, or other vegetables.

Stuffed Onions.

Parboil large onions, remove centers without breaking other layers, and stuff with seasoned crumbs or meat, and bake until tender.

Onion Custard.

Cook onions until tender; drain thoroughly. Pour over them a custard mixture made of one egg, one-half cup milk, salt and pepper to taste, for each half pint of onions. Bake gently and serve as a vegetable. In southern Europe this dish is popular cooked in a crust, like small custard pies.

Onion Soufflé.

Chop cooked onion fine or rub through a coarse strainer. Combine with equal quantity soft bread crumbs or half as many dry ones. Season with butter, salt, and pepper. For each half pint beat in one egg yolk and fold in one stiffly beaten white. Put in small dishes or in onion cases and bake gently until firm.

For making tests of the different food materials in onions, see Reference No. 79, pages 116-117.

REVIEW QUESTIONS, FOURTH LECTURE.

1. Describe a bulb. Give examples.
2. Tell something of the history of the onion.
3. Mention and tell characteristics of other members of the same family of plants.

[Vegetable Foods, Bul. 245.]

4. Give general directions for preparation for the table.
5. When the flavor is objectionable, how may it be reduced?
6. What portion of an onion would be most acceptable in a salad?
7. Describe several ways of extracting flavor from the onion for soups, salads, etc.
8. Suggest some method of warming over boiled onions left from one day's dinner, so that they may appear in different form.
9. Is the onion a desirable food?
10. Tell how to make an onion soup.

[Vegetable Foods, Bul. 245.]

COURSE IN VEGETABLE FOODS.

FIFTH LECTURE—TUBERS AND ROOTS.

During the favorable season some plants store material for future growth in enlarged roots or underground stems. From the botanical viewpoint it is important to distinguish between true roots, such as turnips and beets, and underground stems, such as onion bulbs or tubers, of which the common potato is a familiar type, but for the present purpose divisions which show their nutritive value are quite as important. Nearly all these roots and underground stems contain large quantities of water. Sometimes the plant has stored most of its food as insoluble starch, which appears in grains throughout the enlarged portion of the root or stem, as in potatoes and many tropical plants, such as cassava. Such tubers and roots may be roughly grouped as starch-bearing ones. On the other hand, some plants, such as the beet, store much of their food in the form of soluble carbohydrates (sugar in the case of the beet), which are dissolved in the water and give the root a more or less juicy character; these are classed as succulent roots. Such distinctions, though rather imperfect, will aid in understanding the nature and food value of the tubers and roots to be described in the following lecture. (Reference No. 79, pp. 41-46, 114-115.) Two distinct vegetables are commonly used in the United States under the name potato, i. e., the white or Irish potato and the sweet potato or yam of the Southern States.

WHITE OR IRISH POTATOES.

The prominence of the white or Irish potato in the daily diet of most Americans justifies special attention to it in these lessons. It has been called the king of vegetables. Though a native of America, it became so generally adopted in Ireland that it is now frequently termed the Irish potato.

Many incidents are told of the slow recognition it received as a valuable food, and its early history is connected with Sir Walter Raleigh, Sir Francis Drake, and other early visitors to the New World.

According to the historian of an early New England town:

Even potatoes could not be afforded for ordinary use for many years. During the Revolution a well-to-do family thought itself well off if it could have a barrel of potatoes for winter use. And these were kept for rare and special luxuries and a choice honor to a guest; but potatoes flourished so well in the new soil that early in 1790 they became a staple article of food.

One reason why the potato has become such a favorite vegetable is doubtless its lack of pronounced flavor. It harmonizes with foods having a more positive taste, and one does not tire of it as one would of the continuous use of turnip or squash. Then, too, it is easily grown, gives an abundant yield, and may be readily stored for winter use. Mankind almost universally uses starchy food, and this nutrient potatoes abundantly supply in palatable form.

Potatoes should weigh 60 pounds to the bushel, or 15 pounds to the peck. As three or four average potatoes will together weigh 1 pound, a peck should number from 40 to 60.

The oftener potatoes are handled in their transit from producer to consumer, the poorer their quality and the greater the percentage of refuse. When received from the market it is desirable to sort them carefully, that those of the same size may be cooked together—smooth, medium ones to be baked, large ones to be steamed in their skins, and imperfect and inferior ones to be pared before boiling. Any portions that are dark-colored or green should be removed, as they may impart a bad flavor to the rest. Sprouts should be broken from potatoes before cooking. (Reference No. 22, p. 19.)

When potatoes are old and wrinkled they are much improved by cutting off the ends or by partially or wholly paring and by soaking in cold water for several hours like dried beans, etc. In fact, inferior potatoes of any age are much improved by paring and soaking. Where potatoes are inexpensive or the parings can be fed to animals it is often a profitable custom to pare before cooking, since thus imperfections and strong-flavored portions are disposed of, leaving a nearly pure starch, comparable to arrowroot or tapioca and ready for the table as soon as cooked; this is true notwithstanding that careful investigations have proved that such cooking causes considerable loss of the nutrients in the potato. (Reference No. 32, pp. 25–31.)

When potatoes are the only vegetable attainable it might be wiser to cook them without paring, so that their mineral salts may be retained, but people who use salad plants and other vegetables freely are justified in considering chiefly convenience and palatability in the preparation of these tubers.

Often it is a convenience for the housekeeper who has several dishes to prepare at once just before dinner to have the potatoes pared earlier in the day.

Most good cooks believe that it is wiser to discard the water in which potatoes are boiled, as it is likely to be strong in flavor. (Reference Nos. 22, p. 19; 60, p. 229.) For general directions for cooking potatoes see Reference No. 18, pp. 27–29.

Potato flour may be found in large groceries and is used in cakes and for thickening purposes.

[Vegetable Foods, Bul. 245.]

SWEET POTATOES.

Sweet potatoes (Reference Nos. 18, pp. 29-30; 25, p. 39) are not strictly tubers, but tuberous roots. There are many varieties of the plant, with different shape and color. Northern markets prefer a dry, smooth, yellow type, while in the South the moist varieties showing more sugar when baked are the favorites. They may be kept in a dry place at a temperature of 50° to 65° F., and are sometimes canned and often dried like fruits for family use. A flour is also made from the sweet potato.

Because their sweetness is to some extent lost in water they are better steamed than boiled, and baking is a favorite method.

After steaming they may be sifted and used in puddings or pies like squash or added to breads.

In southern homes the sliced sweet potato (often first parboiled) has always been cooked with sugar, butter, and other seasoning. Such dishes, under a variety of names, are now general favorites.

When the tubers are baked the process should not be too rapid, but should continue for an hour or until the skin separates from the pulp, and in the case of the varieties moist when cooked, until the sirup condenses, and the pulp grows moist. The negroes in the Southern States bake them in the ashes in the fireplace, and as soon as one meal is over put in those needed for the next. (Reference No. 18, pp. 29-30.)

JERUSALEM ARTICHOKE, YAM, CASSAVA, AND OTHER STARCH-BEARING
TUBERS AND ROOTS.

(Reference Nos. 18, p. 30; 22, p. 28.)

The Jerusalem artichoke is a kind of sunflower which has a thickened rootstalk valuable for food. The carbohydrate material in the tuber is like gum rather than starch, which gives a peculiar texture after cooking. The tubers were more popular before potatoes came into general use. They are crisp in the spring before they begin to grow, and may be cooked like potatoes, or served raw as a salad like radishes, or pickled. They are common in many rural regions, are found in city markets, and are not expensive.

Yam (Reference No. 22, p. 32) is a name carelessly applied to some types of sweet potato. The true yams belong to the genus *Dioscorea* (Reference No. 48), and include many species abundant in the Tropics, but which may also be grown in temperate regions. Many are grown in the West Indies and Florida. They are rich in starch, though lacking the sugar of sweet potatoes, and the flavor is pleasant when they are boiled or cooked in other ways.

Many of these tubers are most satisfactory when baked, but, like the potato, they may be prepared in other ways.

[Vegetable Foods, Bul. 245.]

A new tuber which has received some attention from the Bureau of Plant Industry is the dasheen from tropical countries. (Reference No. 22, p. 31.) The plants resemble the caladium, which is such a popular ornamental plant, and the taro, which provides the "poi" of the Hawaiians, and which is a staple food in many tropical islands. The dasheens may be served like potatoes, boiled, fried, creamed, etc., but to many are, like potatoes, most acceptable when baked. They have a rough outer coating, which may be partially removed before cooking. If entirely pared there is a tendency to discolor, as with potatoes.

The yautia (Reference No. 22, p. 31) is a Porto Rican tuber very much like the dasheen, which may be used like potatoes. Stachys (Reference No. 22, p. 29) is a tuber introduced from Japan and has little practical value, as it is not marketed in any considerable quantity.

Cassava belongs to the spurge family (Reference Nos. 8; 22, p. 30), and forms roots rich in starch. There are two principal types of the plant, the bitter and the sweet manihot. The first is commonly grown in the Tropics and requires a longer season than the other, but produces a greater yield. The many varieties of the bitter cassava grown in Brazil contain in relatively large amounts the volatile poison found in this family of plants. This is dissipated by heat and the washing of the grated roots. The sweet manihot is cultivated in some of our Southern States, but mainly for starch to be used in textile and other industries. From both varieties tapioca of various forms is made, as is also the cassava bread which is so common in tropical countries, and which is found in many city shops under the name of cassava cakes.

Arrowroot (Reference No. 103) is the name of the fine starch obtained from various tropical roots, and is due to the fact that the pounded roots were applied to swellings from poisoned arrows. The best arrowroot comes from Bermuda and the West Indies. In Europe it is popularly supposed to be the most digestible form of starch, and is much used for infants and invalids, as well as in fine puddings and similar dishes. (Reference No. 60, p. 236.) In the United States cornstarch, the "corn flour" of English cooks, is more generally used.

Sago may be properly studied in connection with tapioca, arrowroot, and similar starches, as its use is very similar, but it is the product not of a root or tuber, but the pith of a palm tree. The trees are cut and split; then the starch is washed, dried, and granulated. Fifteen years are required to grow a palm yielding 500 pounds of sago. The tree must be cut before blossoming. If time permitted, it would be interesting to study other palms which yield food products, especially the "cabbage palm" and those producing coconuts.

[Vegetable Foods, Bul. 245.]

The principal food substance derived from all the underground stems enumerated is the starch which has been thus stored up for the next generation of the plant's life. Starches from different plants or plant parts differ in the form of the starch grain, so that starches of various kinds can be identified by the aid of the microscope. But from the culinary standpoint they are practically interchangeable, and one form of starch may be substituted for another in nearly all cases. Just as we may substitute the yam or a dish of rice for the potato as a vegetable, so we may use starch from the potato, or corn, or wheat, or rice for thickening gravies or making puddings, making slight changes in proportion, according to the expansive powers of each kind.

Starch cookery is a very important subject. That starch may be cooked it is essential that every starch grain be brought into contact with water of at least 140° to 178° F. (Reference No. 35, p. 25.)

Potato, arrowroot, and probably tapioca and sago starch pastes are not made more easily digestible by long-continued cooking. * * * However, in the case of starch still inclosed in cellulose cells, as in many starchy foods, the long-continued cooking may be necessary. (Reference No. 35, p. 41.)

The selection of potato starch instead of corn or wheat starch for thickening sauces in accordance with the custom of French cooks is rational, * * * since it does not require 40 minutes boiling for improvement in flavor as is the case with cornstarch. (Reference No. 35, p. 42.)

For further study of starch see Reference Nos. 14; 34, pp. 24-48; 85, pp. 109, 119, 146.

EXPERIMENT AND PRACTICE WORK, FIFTH LECTURE.

Materials needed.—A potato for each pupil; any other tubers available; rice, tapioca, cornstarch, rice flour, fruit juice or jelly, milk, butter, salad dressing; fancy cutters, slicers, and scoops, different styles of potato mashers and ricers. These for trial; a fork may be used to mash a small quantity.

Exercises.—Let each pupil prepare a potato; each in slightly different fashion according to the directions given below; weigh before and after cooking, weigh refuse, estimate percentage of loss and time and fuel required for cooking one potato. Are these factors proportionately increased for a larger quantity? Compare time required to pare potatoes before cooking and after. What advantages for either method?

Potatoes.

While the potatoes are cooking grate one raw potato, press out the water through a cloth or wire strainer into a glass measuring cup. Estimate percentage of water in the potato (reference No. 34, p. 14), then wash out the starch and cook it. (Reference No. 74, pp. 83-84.) Observe the nature of the material remaining in the strainer.

Among the methods of cooking potatoes which may be tried in this lesson are these:

Baked (1). Serve one at the right moment, leave another until the moisture condenses and the potato becomes soggy, with unpleasant odor and flavor.

Baked (2). Cut, skin in half lengthwise, mash and season contents and return to skin. Add beaten egg white to one half, bake and notice difference. How is this difference caused?

[Vegetable Foods, Bul. 245.]

Baked (3). Bake in dish, skin having been removed first; glaze occasionally with butter or meat fat.

Boiled. Cook one in skin, another without skin.

Steamed. Cook one in skin, another without skin.

Mashed. Boil one potato, mash, season with butter, salt, etc., add hot milk, measured, and note how much the potato will absorb.

Cut and boiled. Cut a potato in slices or cubes, add milk and seasoning as in previous recipe, and compare results. Add grated cheese to part.

Soup. Make soup from mashed potato in same fashion as with onion in previous lesson. Note lack of flavor—some addition of onion or celery indicated. Also note slight thickening needed in potato soup compared with onion soup.

Salad. Make salad with cooked potato and onion like apple and onion salad in Lesson 4.

Look up composition of potato. (Reference No. 30.) How does this explain the need for the addition of other materials?

For various dishes in which potatoes are an important ingredient see Reference Nos. 69, pp. 292-296; 72, pp. 59-67; 77, pp. 458-470.

Comparison of rice and potato. Weigh out $\frac{1}{2}$ pound rice and cook in 2 quarts of rapidly boiling salted water until tender, and drain. The water may be reserved for soup in next lesson. (Reference No. 18, p. 38.) Cook an equal money value of potatoes. Compare value of results, including cost of fuel and labor expended and considering refuse in potatoes, etc.

Experiments with Starchy Materials.

Let each pupil or each two take a different form of starchy substance, flake, pearl, granulated tapioca, cornstarch, rice flour, sago, starch from potato, etc.; cook with water until fairly transparent, salt slightly, and taste of each to learn to recognize characteristic flavor. Flavor with fruit-juice and sugar in similar proportions and taste again to see how uniformity in the dominant flavor disguises characteristics of the starches. Note possibility of substitutions in recipes. (Reference No. 34, pp. 24-28.)

REVIEW QUESTIONS, FIFTH LECTURE.

1. Show differences between bulbs and roots; roots and tubers.
2. What are the principal food substances derived from roots?
3. Where did the potato originate and when was it introduced into Europe?
4. What differences in the nature of the new and old potato? How do these influence methods of cooking each?
5. What is the weight of an average potato?
6. Give approximate chemical composition of the potato.
7. How may we find that the potato contains starch?
8. From potatoes as ordinarily purchased how select for baking, steaming, croquettes, etc.?
9. Describe general preparation and use of the sweet potato.
10. What other roots and tubers furnish valuable starch?

[Vegetable Foods, Bul. 245.]

COURSE IN VEGETABLE FOODS.

SIXTH LECTURE—SUCCULENT ROOTS.

The majority of these root vegetables are those where the main or taproot has become thick and fleshy. Cross sections of different specimens of such roots carefully examined, even without a microscope, will aid in understanding the effect of heat and moisture upon such foods. In older vegetables of this type woody fibers or cellulose will be found, which does not yield readily to the processes of cookery.

This class of plants has long been cultivated by mankind, and was used more generally before the introduction of the potato. Occasionally they are combined with potatoes.

BEETS.

The beet gives an excellent illustration of the difference between the young and old plant. The whole plant in an immature state may be cooked for greens (see Lecture 3), but by the time the beet is as large as an egg, the leafstalk is too fibrous to use. The bunches of beets from warmer climates found in northern markets in the spring usually have leaves that may be cooked and served for greens with the sliced roots, and these yield to the influence of heat and moisture in half an hour. Large winter beets which have been out of the ground for months have lost moisture and become woody, and may require four hours or more to make them eatable. Pickling in vinegar must often be resorted to before such beets are really tender. (Reference No. 73, p. 149.)

Beets contain a larger percentage of sugar than most vegetables, and should be baked or steamed to retain as much of this as possible. At all events, they should be cooked in the skins, and the tip of the root and a portion of the leaf stems should also be left on until after cooking. Even so, some color and sweetness are lost in the water in which they are cooked.

TURNIPS.

The turnip is cultivated in many varieties, but those used for human food fall into two main classes, those with white-fleshed roots and those yellowish in color, the latter are called rutabagas or "Swedish" turnips. (Reference No. 22, p. 39.)

KOHL-RABI.

The kohl-rabi, which belongs to the same family as the turnip and the cabbage and combines characteristics of both, has been described on page 29.

RADISHES.

Radishes, red or white, when a little too large to eat raw, may be cooked like turnips and served with a white sauce.

CARROTS.

The tribe of Umbelliferae furnishes many of the root vegetables. A characteristic is the much-divided leaf, so noticeable in the carrot, celery, parsley, and parsnip. Some of the herbs used chiefly for flavoring purposes also belong to this group. (See p. 68).

The carrot may have been a native of England, or, if not, was introduced at an early period. It is believed that originally the root was hard and fibrous, and that the fleshy outside has been developed by cultivation. As with other vegetables, there are many varieties, and some are so coarse in texture that those who have known no other type consider the carrot unfit for human food. Small or young carrots properly prepared are deservedly popular. Raw carrots often are eaten by children, and are advocated by those who believe in the use of raw foods. When grated, raw carrots may be used in soups without further cooking, or added to salads. The carrot contains so much sugar that its use for sugar making, in the same way as the beet, has been seriously considered.

PARSNIPS.

The parsnip is said to have been cultivated even before the Christian era. The woody fiber of these roots is softened by freezing without injury to other portions. Hence they are left in the ground until the frost comes or even through the winter. But the roots must be used before they begin to grow again or they lose their sweetness and get "rusty." The larger ones are likely to be less sweet and more woody. Small parsnips just from the ground in the spring will cook in less than a half hour. If steamed in their skins, they lose less sweetness than by boiling. They should be peeled after cooking, and served plain or with white sauce, or sautéed in butter or mashed and made into fritters. They may be made into a stew with potatoes, onions, and milk. (Reference Nos. 18, p. 31; 73, p. 156.)

CELERIAC.

This is a variety of celery (see p. 24). (Reference Nos. 18, pp. 32-33; 22, p. 35) sometimes known as German or "knob" celery or "turnip-rooted" celery, and resembles the turnip in shape and tex-

[Vegetable Foods, Bul. 245.]

ture, and may be cooked in like manner. Often if it is desired to retain all the flavor in the root, it is more satisfactory to steam than to boil it. Again, it may be pared before cooking, in which case the water should be saved to flavor soups, etc. Where time must be saved celeriac, like carrots, may be cut in cubes before cooking, then there will be still more loss of flavor, but the result may be more agreeable to some palates, and if the water is reserved for another purpose nothing is lost.

SALSIFY.

This vegetable, which on account of its flavor is sometimes called oyster plant, is available during the late fall and winter, and, like the parsnip, may be left in the ground during the winter. (Reference No. 22, p. 38.) The resemblance in flavor to the oyster is most apparent when the boiled vegetable is sautéed in butter or made into fritters. (Reference No. 18, p. 31.) The root turns dark quickly if the skin is removed before cooking, and after paring should be dropped at once into vinegar and water to prevent discoloration. After boiling for about 30 minutes, the salsify may be served with butter or white sauce, or mashed and made into fritters. (Reference No. 20.) It is also used made into a soup with milk.

CONDIMENTAL ROOTS.

Ginger and horseradish are other valuable roots, but are used not so much for food as for the flavor or relish they give to other things. (See Lectures 10 and 14.) (Reference No. 47.)

EXPERIMENT AND PRACTICE WORK, SIXTH LECTURE.

Materials needed.—Old and new root vegetables of any kind within reach, such as beets, carrots, parsnips, celeriac, or salsify; graters, cheesecloth, test tubes, saucepans, measuring cup, tablespoon, teaspoon, and knife; cup milk, butter, flour, salt, pepper.

Exercises.—Grate portions of each root available and note the proportion of water and the nature of the woody fiber. Compare results with those from the potato in the previous lesson. How about the proportion of starch? Taste the extracted water. Evaporate it and taste again.

Parsnip, Salsify, Beet, and Celeriac.

(1) Cook some parsnips, separating outer layer beforehand, and notice which part cooks sooner.

(2) Pare some before cooking, and cook others in the skin in separate kettles. Taste the water from each. Which has lost most sugar, presumably?

(3) Steam some parsnips of same size as those that were boiled. Compare time required for each process. Prepare salsify in same way. Use each for fritters or to sauté.

(4) Cook beets whole, in skins, and in smaller sections and note loss of juice and color.

(5) Try celeriac in the same ways.

[Vegetable Foods, Bul. 245.]

Carrots.

(Reference Nos. 22, p. 36; 32, pp. 16, 17.)

- (1) Cook one large old carrot whole in the skin.
- (2) Cook one large old carrot whole with skin scraped off.
- (3) Cook one large old carrot in slices.
- (4) Cook one large old carrot cut in cubes.

If necessary these may all be boiled in one kettle and thus variation in time of cooking shown; but the difference in loss of substance can be shown only by cooking each size by itself. Compare, if possible, with young carrots as to time of cooking, texture, and sweetness.

The carrots cooked as above may be served: (1) Plain with butter, (2) with cream or white sauce, (3) buttered and combined with half as many green peas, or (4) buttered and blended with a little chopped parsley or chives.

For further experiments grated carrot may be made into marmalade with sugar and lemon juice or added to a suet pudding. (Reference No. 69, p. 332.) Grated carrot or that which has been put through the meat chopper makes an effective garnish for salad and may be used without cooking. It may be added to soups with little more cooking than is needed to heat it through.

White Sauce for Vegetables.

If the white sauce has been studied in a previous lesson with cabbage, onions, or potatoes, here is a chance to review it or otherwise to take it up. (Reference No. 73, pp. 63-65.)

Follow directions given in reference, using 1 tablespoon butter, 1 tablespoon flour, and one-half cup milk. Make another sauce in the same fashion, but in place of half the milk use the water in which carrot, celeriac, etc., were boiled.

REVIEW QUESTIONS, SIXTH LECTURE.

1. Describe the structure of roots.
2. Tell of the methods of growth and preparation for the table of five common root vegetables.
3. Define succulence.
4. What are the principal food substances obtained from roots?
5. Suggest combinations of vegetables of this type with others of a different nature.
6. To increase the food value of this class of plants, what additions are desirable?
7. Mention some of the most helpful utensils for the preparation of these vegetables.
8. What are the advantages and disadvantages of paring before and after cooking?
9. Are there any vegetables of this class with which you are not familiar or have not learned to eat?
10. What substances extracted from roots have commercial value?

[Vegetable Foods, Bul. 245.]

COURSE IN VEGETABLE FOODS.

SEVENTH LECTURE—FLOWERS AND FRUITS.

FLOWERS AND PRODUCTS MADE FROM THEM.

Most flowers are too delicate in structure to be of much value as foods, yet some are cooked occasionally.

While flowers are attractive ornaments on or near the table, highly scented ones should not be allowed in the dining room, as their odors rarely combine well with the odors from cooked foods.

The fashion of serving salads in roses or molding blossoms in jellies can not be commended. Nasturtium flowers are occasionally used to garnish a salad, and since they have a flavor like water cress are sometimes eaten. The buds are occasionally pickled. Orange flowers are well-known ingredients of cakes, creams, and confectionery, being added for the flavor which they impart. Saffron and marigold petals once were considered important adjuncts in cookery, chiefly for the yellow color they imparted, and are often mentioned in old recipes for soups, etc. In southern Europe squash blossoms and the tiny squash to which the blossom is attached are dipped in batter and fried, and elder flowers also are used for fritters. Cooked squash flowers may be folded in an omelet. But such things have little food value in themselves.

Sometimes rose petals, violets, and mint leaves are candied, but are used more for garnishing than for food purposes. Rose petals in the Orient are used for making a very sweet preserve. Many other blossoms serve as food, chiefly in the Tropics, but need not be mentioned further.

Capers.

Capers are unexpanded flower buds of a tropical plant packed in vinegar. Cloves are also flower buds picked before expansion and dried.

Cauliflower.

As has been shown (see p. 29), the portion of the cauliflower that we eat is the flower head, and we discard root, stalk, and leaf, though the white midrib of the leaf may be cooked also. (Reference No. 18, p. 15.)

Globe Artichoke.

The French or globe artichoke is, next to the cauliflower, the most important example of the use as food of this portion of the plant.

It thrives in southern Europe and the southern and central United States, but is not hardy enough for cold climates. The base of the flower head and the scales are thick and fleshy and have a delicate flavor if used before fully opened. (Reference No. 49.) The simplest method of preparing them is the best. (Reference Nos. 18, pp. 19, 20; 75, pp. 99, 100.) Remove the stalk and under leaves and cut off tips of leaves. The flower heads may be eaten raw when very young, but commonly are soaked and parboiled in salted water until tender even when used as a salad. When done the leaves will separate readily. The "choke" is the fibrous center which should be scraped out with a spoon after cooking. The individual "leaves" are pulled off and eaten with a sauce or dressing. The bottoms or artichoke "buttons" may be dipped in batter and fried in deep fat or covered with force meat and then baked like stuffed tomatoes.

The cardoon is allied to the globe artichoke, but is little used in the United States.

Honey.

Honey (Reference Nos. 2; 41) may properly be classed among the food products derived from flowers. In ancient times, before cane sugar was manufactured, it was the principal sweet, and to-day it is still much prized. A study of its history and folklore is interesting.

The varying qualities of honey derived from different flowers are worthy of note. That obtained from white clover fields is of fine flavor and light color; raspberry plantations furnish a good quality, while buckwheat gives a dark color and a flavor which some do not relish; and certain wild plants, such as mountain laurel, may impart poisonous qualities to the honey made from them. Many races made fermented beverages from honey, mead for example. Recipes which have been handed down for generations are still used for honey cakes and cookies.

Certain medicinal virtues are attributed to honey, and it has been the basis of many remedies for coughs and colds because of its detergent and soothing properties.

Colors and Flavoring Extracts.

Flowers find a considerable use in cookery for coloring and flavoring purposes. Dried saffron flowers, as already mentioned, are employed for coloring foods yellow. Violets are used in a similar way for imparting a purple color, while a number of other colors are made from blossoms or leaves. Some highly prized flavoring extracts are made from flowers; for instance, rose extract, orange-flower water, and sirup of violets. Nasturtium flowers are used like tarragon for flavoring vinegar, and other similar uses might be cited.

[Vegetable Foods, Bul. 245.]

FRUITS USED AS VEGETABLES.

(Reference No. 21.)

The fruit of a plant, botanically, is that portion in which the seed is perfected. In popular language, the distinction between a fruit and a vegetable is not easily made, and on the border line are several important food plants which have been called vegetable fruits. Such are tomato, eggplant, peppers, melons, cucumbers, squash, etc.

The gourd family, or Cucurbitaceæ, includes many of the true fruits used as vegetables. This family furnishes the largest fruits of any known plant, some being over 8 feet around and weighing more than 200 pounds. The squash, both winter and summer varieties, the pumpkin, vegetable marrow, cucumber, and melons belong to this family, and each may be used in several ways. Some varieties were known in Egypt and Persia from the earliest times, and squashes or pumpkins, the "pompions" mentioned by some of the early writers in this country, were raised by the American Indians before the white men came.

The water in these fleshy seed receptacles may be shown by slicing and sprinkling with salt and leaving overnight. Then drain, weigh, and compare the result with original weight.

Pumpkins and Squash.

There is great variety in texture and flavor of the individual specimens of the same kind of either squashes or pumpkins, but careful cooking will modify these differences. The best are heavy in proportion to their size, having thick rather than thin flesh. Where the fibers are coarse, long cooking and straining will reduce them, and an excess of water may be evaporated. Where the shells are hard, bake or steam and then scrape out and mash the flesh.

The cooked, strained pulp of squash or pumpkin is sometimes combined with milk or stock for soups or with custard for pies, or is added to doughs like those of corn bread or muffins, or may be cooked with sugar and spices for marmalades. (Reference No. 75, p. 51.)

The summer squash is often not fully appreciated because often allowed to grow too large. Either variety, crookneck or turban, should be so tender that the seeds and skin are edible when cooked. Summer squashes may be cut in slices and fried, though they are most commonly boiled. When fully grown they may be used like winter squash, skin and seeds being removed. (Reference No. 18, p. 37.)

Cucumbers and Melons.

These fruits long have been popular with the human race as a means of supplying water in a clean and wholesome form, as well as for food. When stale, wilted, or overgrown, the cucumber may in-

[Vegetable Foods, Bul. 245.]

terfere with digestion, but a fresh, young specimen, thoroughly peeled and left in cold water (sometimes salted) before serving, loses its bitter juices and is a palatable and usually healthful relish.

The cucumber may be served as a salad by itself or to accompany fish or meats, or may be grated to add to rich sauces. It may be cut in strips, cooked, and served on toast like asparagus, and in other ways. The skin and seeds may be removed and the firm flesh used as a case for salads or, like pepper and tomato, it may be filled with forcemeat and baked. (Reference No. 16.)

Melons rank with fruits. The common varieties are almost never cooked but are eaten as they come from the garden. The use of melon rinds and melons in their unripe state will be considered under pickles. (See Lecture 14.)

Peppers.

The fleshy seed vessels of many peppers are used not only for their condimental value, but as a receptacle in which to serve other food. The southern green peppers, a variety which lacks the "hot" characteristic of common garden green peppers, may be found in the city markets most of the year at 2 cents to 5 cents each, and are used increasingly either stuffed and baked or as an ingredient of omelets, soups, and salads.

The stem and seeds of the green pepper are removed together by cutting around the stem, and this portion may be used for flavoring soups. The seeds themselves are likely to be hot, and are considered indigestible. The thick section to which the seeds adhere may be trimmed and cooked with the peppers.

If the peppers are small and fresh, they may be chopped or sliced thin and used raw in salads or as a garnish. Often they are better for parboiling. If put in a hot oven or on top of the stove for a few moments, the skins may be pulled off.

The canned sweet Spanish red peppers (pimmentoes, see p. 56) may be used in similar fashion, and may be obtained from any large grocery store at moderate prices. These peppers are valuable because they make tasteless foods savory and attractive. (Reference No. 18, p. 36.) Paprika is prepared from peppers of this mild type (see Lecture 10), red or cayenne pepper from "sharp" or "hot" varieties.

Okra.

This plant grows best in warm climates, though it may be grown as far north as New England. (Reference No. 13.) Dried and canned okra is obtainable in most markets, and the fresh pods are common in many large markets in regions where the plant is not raised.

The pod and seeds are used together, and usually are sliced cross-wise and cooked till tender. It may be used alone, but is more often added to watery soups, as its mucilaginous nature serves as thickening. (Reference No. 18, pp. 36, 42.)

Eggplant.

This plant has long been known, but is less generally used than many vegetables. It belongs to the same family as the potato and tomato—the nightshade family. As is the case with all succulent vegetables, its nutritive value is not high, but it is palatable and much liked by many. It may be cut in two, stuffed and baked, or in slices, crumbed and boiled or fried. (Reference No. 18, pp. 36, 37.)

Tomato.

Though probably a native of America and known in Europe since the sixteenth century, the tomato was slow in coming into favor, possibly because of supposed poisonous qualities. It has been generally used in this country for less than a hundred years, but its growth in popularity has been rapid.

To this vegetable fruit we owe much in cookery. Alone and in combination it provides soups, sauces, and salads, and many relishes which make many mild-flavored materials appetizing. The sour taste of the tomato is due chiefly to citric rather than oxalic acid. (Reference No. 60, p. 243.)

When tomatoes are served raw the skin is very commonly removed, and this is particularly desirable in the case of tomatoes which have tough skins. The peeling may be easily removed if the tomatoes are plunged into boiling water for less than a minute, then drained, and chilled over ice, if possible. They may be peeled when needed. Perfectly ripe tomatoes may be scraped with the back of a knife to loosen the skin, which then will peel easily, but this is less rapid than the scalding process. If cooked tomatoes are to be strained, it is unnecessary to peel them before stewing, as the skin will remain in the strainer with the seeds. Some persons believe that immersion in hot water injures the appearance and flavor of the tomato and peel them without this treatment. Many persons prefer to serve tomatoes unpeeled, particularly the hothouse tomatoes or other varieties with thin, tender skins. If this is done, the tomatoes should always be carefully washed in order that they may be free from any dirt accidentally present. The very small red tomatoes which grow in clusters and are known as cherry tomatoes, often found in large markets, are very attractive for salads, and the yellow plum tomatoes are perhaps always eaten without peeling.

[Vegetable Foods, Bul. 245.]

Bananas.

Like the tomato, the banana may be regarded as a kind of connecting link between vegetables and fruits. The under-ripe banana especially may be baked or fried like the potato or yam and served with meats. A satisfactory and simple way to cook bananas is to remove the skin, scrape off the rough outside, cut large ones in two across, dip in egg and crumbs, and fry brown in deep fat.

EXPERIMENT AND PRACTICE WORK, SEVENTH LECTURE.

Materials needed.—Three cans tomato, or fresh tomatoes; onion, green pepper, any other vegetable fruits in season; can opener or sardine scissors, strainer, masher, bread crumbs, butter, flour, seasoning.

Exercises.—Have canned tomato of two grades with marked difference in price. Weigh each can; weigh contents again after emptying.

Cook each grade separately 15 minutes and strain through medium wire strainer, weigh refuse from each lot, and compare results. Estimate relative values based on cost, quality, and quantity.

Open another can of tomato and drain in strainer without pressing through. Reserve liquid for soup, use solid portion for escalloped tomatoes. (Reference Nos. 18, p. 35; 73, pp. 162-163.)

Use the strained tomatoes in any of the following ways:

- (1) Tomato toast. (Reference No. 18, p. 35.)
- (2) Tomato jelly salad. (Reference No. 73, p. 109.)
- (3) Tomato soup. (Reference No. 18, p. 41.)

Several types of tomato soup may be made:

- (a) One part tomato, one part water, with flavor of herbs, and slight thickening with cornstarch.
- (b) One part tomato, two parts water, and a little beef extract.
- (c) One part tomato, two parts milk, and seasoning.
- (4) Tomato sauce. (Reference No. 73, p. 68.)
- (5) Spanish sauce. (Reference No. 73, p. 67.)
- (6) Cream of tomato. (Reference No. 73, p. 78.)

The following processes are also suitable for this lesson if the materials are obtainable:

Stuffed eggplant; summer squash sautéd (fried); winter squash, hard shell, steamed or baked; pumpkin or squash pie; stewed cucumbers on toast; cucumber and tomato salad; eggs poached in tomato sauce; stuffed peppers or tomatoes; squash biscuits (Reference No. 73, p. 31. See also p. 41).

REVIEW QUESTIONS, SEVENTH LECTURE.

1. What have you to say regarding the association of flowers with food?
2. Have you ever seen flowers used in a way that seemed unsuitable?
3. Tell something of the source and preparation of capers and cloves.
4. What product from flowers does the human race obtain through insects?
5. Describe a fruit.
6. Mention five so-called vegetables that are strictly fruits.
7. Mention several members of the gourd family that have been used from ancient times.
8. Tell something about the tomato plant, its family and characteristics.
9. Give a list of dishes where the tomato is useful.
10. Mention any other flowers and fruits used chiefly for condimental purposes.

[Vegetable Foods, Bul. 245.]

COURSE IN VEGETABLE FOODS.

EIGHTH LECTURE—SEEDS.

For the structure of seeds see Reference No. 80, pages 257, 275.

In the higher plants nature's most usual method for the perpetuation of the species is by means of the seed. Seeds contain the embryo from which the new plant develops and almost always a store of nutritive material for the growth of the new plant for a longer or shorter time after the seed has sprouted. The stored material varies in different plants; thus in such nuts as the walnut, oil is very abundant, while in the cereal grains it is chiefly starch which is stored. Seeds are usually protected by a hard outer covering like the bran layers and skin of wheat kernels, the skin of the peanut, or the shell of a nut. Frequently there is additional protection, as the husks on an ear of corn, the pod in which beans or peas grow, or the outer thick covering of a walnut.

Taken together, seeds constitute one of the most important food groups, as is evident when we consider that numbered among them are the cereal grains and beans, peas, and other legumes, as well as nuts and the oil-bearing seeds such as cottonseed and sesame seed.

Many seeds besides those used as foodstuffs are important; for instance, those prized for their aromatic flavors, such as allspice, cardamom, and caraway.

The cereal grains have been considered at length in an earlier bulletin of this series (Reference No. 34), and aromatic seeds in the chapter which deals with spices (p. 68). The pulse family, which includes a number of our most important vegetables, is considered in the following section.

The Leguminosæ or pulse family (Reference No. 5) includes some of our most important food plants. The bean, lentil, and pea have been recognized in all ages and in all lands as substitutes for both bread and meat, and for the human race come next to the grains in general use. A Hindu proverb indicates the nutritive value of this type of food thus: "Rice is good, but lentils are my life."

The principal objections to a more general use of this class of foods are that their flavor does not appeal at all, and that they have been found a cause of digestive disturbance under certain conditions.

So far as the natural flavor is concerned, it is often wise to remove a portion of it, even if this means also loss of substance, by occasionally changing the water in which the beans are soaking or in

the early stages of cooking. There might be far more use of added flavors than is customary. Mint, parsley, onion, etc., often are cooked with green peas and beans, and their use would seem more needed with the dry ones. Other herbs and sweet peppers or pimientos, either green or red, also may be used to give variety. The chef sometimes uses bay leaf, clove, and nutmeg, but these must be added sparingly. We have much to learn from the Mexicans in their use of beans in combination with meat. (Reference No. 29, pp. 24, 25.)

BEANS, PEAS, AND LENTILS.

Such beans (Reference No. 30, pp. 15, 16) as the navy bean and Lima bean contain relatively little fat. They do not grow rancid like grain products, but the older they are the harder to make them palatable and soft and the longer the processes of soaking and cooking.

The long soaking of leguminous seeds is an important factor in their cookery. It took a long time for the seed to ripen and dry in the pod on the vine and it loses rather than gains water in the store and house. Therefore it is reasonable that considerable time will be required to fill out the cells of such a dense substance with water. Where there is no danger of fermentation, beans, etc., may be profitably soaked for even 48 hours. Pick over, wash well, add nearly 1 quart of water for 1 cup of beans, and set in the refrigerator or other cold place. The water may be changed, if convenient, after 12 or 24 hours. This serves to remove any rank flavor. (Reference No. 74, pp. 87-89.) It is said that in eastern countries lentils are soaked a long time for this purpose.

After this complete filling of the tissues with water the time required for cooking will not be much longer than for shelled beans fresh from the garden. True, there has been some loss of substance, but a corresponding gain in palatability. Soft water is preferable to hard both for soaking and cooking. (Reference Nos. 62, pp. 119, 120; 65, pp. 7, 62; 82, p. 234.)

Since the proper preparation of legumes is a long process, it is well to cook enough to serve in two or more fashions. Thus the baked beans often are reheated or served cold, and the final remainder used in soup. So, too, the dry Limas or red kidney or any variety may first appear as plain buttered beans, a further portion, prepared at the same time, be reserved for salad or croquettes, and any still remaining be utilized as a soup. (Reference No. 103, pp. 213, 214.)

Lentils are not as generally used in this country as they deserve to be. They may be found in the markets of foreign sections of large cities and in the larger groceries. The price is about the same as that of dry beans and peas. There are many colors, as with beans.

[Vegetable Foods, Bul. 245.]

Esau's pottage is supposed to have been made from red lentils. Sometimes they are served like peas or with a seasoning of fried onion. Sometimes soup or purée is made from them.

Revalenta or ervalenta are forms of lentil flour. In some parts of Europe a kind of bread is made from ground lentils.

The use of bicarbonate of soda in the preparation of legumes is often decried, and it certainly should be employed with moderation, nevertheless it serves a useful purpose in making the skins more tender, and probably also forms new combinations with or neutralizes substances which tend to produce indigestion or flatulence. (Reference Nos. 5, pp. 23, 24, 31, 32; 103, pp. 217, 218.) The addition of the potato or onion to the pot of beans before baking is doubtless an instinctive attempt to supply flavor lacking in the bean. In the same way East Indian cooks have learned to season their beans with asafetida, which is also thought to prevent flatulence. These phases of vegetable cookery have not as yet been studied sufficiently to warrant positive assertions, but the instinct of primitive people is often verified by scientists.

The use of fresh, young peas and beans is extensive, the seeds being sometimes served alone, and often with the succulent pod containing them. The pods of peas are ordinarily discarded, but sometimes they are cooked for a while, and then the water in which they were boiled is used for cooking the peas themselves. There are also edible podded peas.

"String" or "snap" beans, if young and tender, may be cooked quickly. If old and well grown they need longer cooking than is often given them. If overgrown they will be improved by parboiling for a few minutes in water to which soda has been added, about one-fourth level teaspoon of soda for 2 quarts of water. They should then be drained and cooked in fresh water. A combination of string and shell beans is a pleasing change from either alone. String beans appear to be more readily digestible if cooked uncovered. (Reference No. 18.)

The large green pods of the red or cranberry beans remain tender until the seeds are nearly full grown, making them among the best types of string beans.

In the Southern States cowpeas or field peas have been grown for many years as a fertilizer and for food for animals and man. These have a distinctive, pleasant flavor, are used green and dry, and are cooked like other peas or beans. The young pods are excellent as "snap beans."

Chick-peas are used extensively in southern Europe, and may be found in the foreign markets in our large cities.

The Mexican frijole is another type of bean the use of which might well be extended.

[Vegetable Foods, Bul. 245.]

The people of the Far East have cultivated many varieties of legumes that are not so well known elsewhere as food for man, though much use is made of them in the United States, particularly as forage crops. The soy bean from China and Japan differs from other common varieties in containing considerable fat; it is used in making special types of so-called bean cheese or bean curd and for sauces of agreeable flavor. (Reference No. 5, p. 13.) The adsuki bean from the same countries is very prolific, and may be grown in this country. Its seeds are smaller than even the pea bean, but when prepared in the same fashions seem not unlike other legumes. These beans are often combined with rice by the Japanese.

Some experiments recently have been tried, using a flour made from soy beans in bread making with an equal proportion of wheat flour. Such bread, it is claimed, has an advantage, particularly for diabetics, in furnishing less starch and more protein than that made from wheat flour alone.

Condensed foods for explorers have been made consisting largely of legumes. The "erbwurst," or pea sausage, was very useful to the German Army in the Franco-Prussian War. Of this, Mrs. Abel says (Reference No. 5):

It was invented by a cook, and the German Government bought the secret of its preparation. It consists of pea and lentil flour well cooked, evaporated, and mixed with a proportion of bacon, the proper seasonings, and some preservative. Mixed with hot water, it made a very nutritious soup for the soldier. It was found by the German Army to be invaluable, if used only in emergencies, but its continuous use brought on digestive disturbances and the eater soon tired of its taste.

A flour of beans and peas may be obtained, but the soups resulting are not always as palatable as those properly made direct from the seeds themselves.

PEANUTS.

Peanuts assumed little commercial importance until after 1865. About this time their use became general all over the United States. (Reference No. 5, pp. 25-26, 35-36.) Even now their food value is not popularly appreciated, though the demand for peanut butter increases. In this form the peanut is available for use in sandwiches, salad dressings, and soups.

Some households find it wise to buy raw peanuts and roast them as needed. Overroasted peanuts are undesirable both as to flavor and digestibility. Raw peanuts are sometimes eaten, and are relished by many if well ripened and cured. They are often said to be difficult of digestion.

The peanut butter may be made as wanted at less cost and of superior quality to much that is sold in the markets by putting the

[Vegetable Foods, Bul. 245.]

roasted and shelled nuts through the meat chopper. The name is justified by the large amount of fat which the peanut contains, and which differentiates it from other legumes.

COTTONSEED.

Cottonseed meal is being experimented upon for human food. It has long been used for animals. The meal or flour remains after the oil has been extracted. Cottonseed oil is used in many ways like olive oil and similar oils, and in the manufacture of culinary fats.

CEREAL SEEDS AS VEGETABLES.

Wheat, Oats, and Rice.

The seeds of the common cereals are often used in preparing dishes served as vegetables, as, for instance, boiled rice, macaroni dishes, oatmeal fritters, farina cake, etc. (Reference No. 34, pp. 34-38.)

Cereals do not possess very distinctive flavors, so it is a common practice when using cereal products in this way, to season the dishes highly with cheese, with tomato, or with onion, or else to cook the dishes in ways which will give flavor, as for instance, by browning in fat. Rice cooked with tomatoes, macaroni with cheese, and noodles seasoned with fried onions, are familiar examples of well-seasoned cereal dishes made tasty by the use of seasoning, while rice croquettes, mock oysters (made of oatmeal), and farina fritters are examples of foods made savory by browning in deep fat.

Corn.

Corn is a native of the New World and had been cultivated for centuries before America was discovered. Originally a tropical plant, it had been developed and changed by selection and culture until it would mature a crop as far north as Montreal, a remarkable achievement for an uncivilized people.

Corn is commonly regarded as a distinctively American foodstuff, but it was long ago introduced into other countries and is now extensively used in the Mediterranean regions of Europe, in Africa, in Australia, and in China. In the United States it is—as it has been since Colonial times—a staple and very important foodstuff.

Corn serves in more forms as a vegetable food than perhaps any other grain. (Reference No. 23.) The Mexican uses the corn husk to wrap the combination of corn, meat, and seasoning known as tamales. The hulled corn or lye hominy is used not only as a breakfast cereal but also as a vegetable, and so is the cracked corn or hominy. (Reference No. 14.)

But the sweet or green corn is most used and is one of the most highly esteemed of American fresh vegetables. Enormous quantities

[Vegetable Foods, Bul. 245.]

are eaten fresh, and its canning is a great industry. The ears are roasted or boiled and served on the cobs; or the raw or boiled corn is cut from the cob and stewed or fried alone or in combination with beans, tomatoes, potatoes, etc., or served in soups or salads. (Reference No. 23, pp. 34-37.) Corn cut from the cob is sometimes used in making pickles or relishes. The very young cobs are also pickled (see p. 88).

Buckwheat.

Another seed of importance is the buckwheat, which in reality is not a wheat at all, but is a near relative of sorrel, dock, and bindweed. (Reference No. 54.) It has been used for centuries in most countries of the Old World where grains are cultivated. The pancake or griddlecake made from this flour is a distinctly American product. A sort of biscuit or shortcake or shortbread was a rather common dish in earlier times in the United States. In the Old World, notably in Russia, buckwheat is much used for making porridge. (Reference No. 34, p. 55.)

EXPERIMENTS AND PRACTICE WORK, EIGHTH LECTURE.

Materials needed.—Dry beans and peas of as many varieties as are obtainable, such as white pea, yellow eye, red kidney, black, Lima, green flageolet beans, whole, split yellow, split green peas, lentils, approximately one-half pound each: flour of beans, peas, and lentils: peanut butter; cans of green corn, peas, and of Lima or red kidney beans, or both; butter or other fat, milk, seasoning. For analysis of peas and beans see Reference No. 30, pages 65, 67.

COMPARISON OF FRESH, DRIED, AND CANNED LEGUMES.

When possible secure green peas or beans in the pod, measure and weigh (1) as purchased, (2) after preparation for cooking, (3) after cooking, and estimate percentage of loss and actual cost per person. Keep a record of the time required to string the beans or shell the peas.

Compare all results regarding cost with those from canned peas and beans, using care in separating the liquid from the latter.

Taste the water in which fresh green peas are boiled and note its sweetness; allow it to evaporate until just enough remains to serve with the peas. Taste the water from canned peas; if agreeable in flavor, do not throw it away. Note the difference in the water from string beans.

Lima Beans.

Weigh and measure the dried beans, wash, soak, and leave 24 hours; weigh again; if feasible, leave 12 to 24 hours longer and again weigh to see how much they swell after the first; measure and compare with original bulk. Compare also with contents of Lima beans. It is a good plan to count the number of beans in the can and compare with the cost of the same number of dry ones.

If Lima beans are not available, try the same experiment with any kind of beans available.

[Vegetable Foods, Bul. 245.]

Dry Lima beans may be cooked until the skins are tender. The beans are so large that it does not take long to slip off the skins by hand after parboiling. The skinned beans may then be cooked and served much like mashed potato, with addition of fat, salt and pepper, or may be used for croquettes or soup. Or some of the beans which retain their shape may be rinsed off and served with lettuce and dressing for a salad.

In connection with this use of Lima beans it is interesting to note another use of legumes in salad dressing. Peanut butter reduced with lemon juice or water and vinegar and seasoned makes an excellent salad dressing. Cottonseed oil, peanut oil, and a number of other seed oils, when rightly made and refined and fresh, are palatable in salads used in the same way as olive oil.

Baked Beans.

Baked beans are not easily managed in short experimental periods, but their study may be accomplished in lessons on successive days. Soak the beans 12 to 24 hours, and then parboil. Let them be well started in the baking process, and then transfer to a fireless cooker (Reference No. 34, p. 33), where they may remain till the next day. At the beginning of the next lesson put them in a hot oven and bake two or three hours more. By this plan a fairly good result will be obtained. (Reference No. 18, p. 26; 73, pp. 147, 148; 71, p. 67.)

Cowpeas.

The cowpea, or field pea, as it is sometimes called, is commonly grown in the Southern States. Cowpeas may be used in place of other legumes in practice work, if more convenient, or may be used in addition to them.

The cowpea requires a longer season to mature than the kidney bean and so is seldom found in northern markets, though it might well be generally introduced on account of its distinctive and agreeable flavor. The tender cowpea pods can be cooked like string beans, the underripe peas shelled and cooked like green peas or green beans, while the dry peas may be used in various ways for making soups, croquettes, fritters, and other dishes.

Baked cowpeas may be prepared according to the directions given above for baked beans, or the dry cowpeas may be covered with luke-warm water and parboiled slowly for several hours until a little soft, at one lesson; and then at the next period, transferred to the bean pot, seasoned with salt pork and other seasoning if desired and baked slowly for about 6 hours. (Reference No. 5, p. 11. For additional data, see U. S. Dept. Agr., O. E. S. Bul. 187, "Studies on the Digestibility and Nutritive Value of Legumes at the University of Tennessee, 1901-1905;" Tuskegee Norm. Ind. Inst. Expt. Sta. Bul. 5, "Cowpeas.")

To accompany this lesson one of these menus might be prepared:

1.	2.
Soup—Green split peas. (Reference No. 73, p. 178.)	Peanut soup. (Reference No. 73, p. 80.)
Baked beans. (Reference No. 73, p. 147.)	Spanish beans. (Reference No. 73, p. 148.)
Apple and onion salad with peanut-butter dressing.	Green pea timbales. (Reference No. 73, p. 156.)
	String bean salad.
	Peanut cookies. (Reference No. 73, p. 210.)

[Vegetable Foods, Bul. 245.]

3.

Cream of corn soup.
Succotash, or
Corn fritters, or
Hominy croquettes.
Baked Indian pudding, or
Cornstarch blanc mange.

REVIEW QUESTIONS, EIGHTH LECTURE.

1. Describe seeds of different types.
2. Why do seeds contain more concentrated nutritive material than other parts of plants?
3. What groups of seeds are most important for human food?
4. Describe two principal types of leguminous plants.
5. What is the main difference in composition between dry beans and fresh shelled beans?
6. Explain the addition of fat meat in baking beans.
7. What uses have been found for cotton seeds?
8. What can you say of buckwheat, its characteristics, growth, and uses?
9. Mention points in favor of and against grinding peas, beans, etc., into a flour before using them for soups.
10. Compare canned and dry beans as to cost, labor of preparation, and quality.

[Vegetable Foods, Bul. 245.]

COURSE IN VEGETABLE FOODS.

NINTH LECTURE—FUNGI.

There are many plants quite unlike those already studied, in that they contain no green coloring matter or chlorophyll and are flowerless. This class of plants is called by the Latin name fungus, and includes many curious specimens of varied sizes, forms, and colors.

A characteristic of this type of plant life is that it draws its subsistence not directly from the earth, but from other organic matter. (Reference No. 53.) There are thousands of species thriving either on the living tissues of their hosts or on the cast-off cellular matter of the latter. Some, like the molds, are very minute, while puffballs and toadstools have been found from 1 to 2 feet through.

MUSHROOMS, ETC.

Many of the larger types of fungi are popularly grouped together as mushrooms. (Reference No. 46.) Some of these are extremely poisonous; others are harmless, but of no particular culinary value, while there are many edible varieties much esteemed for their delicate and peculiar flavor. Every country dweller fond of mushrooms might well learn to recognize the common mushroom (*Agaricus campestris*), the shaggy mane (*Coprinus comatus*), the ink cap (*Coprinus atramentarius*), the parasol (*Lepiota procera*), the chanterelle (*Cantharellus cibarius*), morel (*Morchella esculenta*), the liver or beefsteak fungus (*Fistulina hepatica*), the fairy ring (*Marasmius oreades*), the giant puffball (*Lycoperdon giganteum*), and others. (Reference Nos. 50 and 95.)

Many of the edible mushrooms prove a cause of gastric disturbance, or irritating to the digestive tract, if used when past their prime. None of the common tests of silver spoon, etc., for poisonous varieties are safeguards, but if the fungi are gathered with due caution, to include only wholesome kinds, many a savory morsel may be enjoyed. Even around an old tree trunk in a large city more than one dish of ink caps has been secured.

Mushrooms should be gathered without the adhering earth, the stems broken rather than pulled, for once sand is scattered through the gills it is hard to remove. (Reference No. 1, p. 12.) First wash by floating in water, gills down. Young or button mushrooms need

not be peeled, but old ones should have the skin removed, pulling it from the circumference to the center.

The common market mushroom (*Agaricus campestris*), which is often found growing in old pastures, is the only kind commercially cultivated in this country. It grows 2 to 3 inches high, has a cap about as wide when fully expanded, which is a brownish white above and sometimes tinged with pink below. The color deepens as the mushroom grows older, but even when it is fully expanded and quite dark the flavor is good. It may be purchased canned, but is much better fresh, and may be grown for home use. (Reference Nos. 1, 12, 53, 95.) Dried mushrooms of various kinds may be bought in some of our large markets and in the small stores in the foreign quarters of our large cities. The fairy ring and parasol varieties may be easily dried and kept indefinitely at home. They should be freshened, like any dried vegetable, by soaking until they have regained their natural size.

Many recipes for cooking mushrooms call for the removal of the stems, but they may be used if not too woody. It is a good plan to slice them crosswise and cook for a few minutes previous to adding the caps, or the stems may be reserved for flavoring soups or sauces.

The food value of the mushroom is often rated higher than it deserves, partly because the analyses of the fresh and dry have been confused. (Reference No. 3.) The average composition of the fresh material is as follows: Water, 88 per cent; protein, 3.5 per cent; fat, 0.4 per cent; carbohydrate, 6.8 per cent. (Reference No. 57.)

These figures are comparable to those for milk as regards water and protein, but the fat is much less—more like that in skim milk—and the carbohydrate content is higher. The special value of the mushroom, however, is not as a source of nutrients, but as a flavoring for otherwise tasteless viands. (Reference No. 40, p. 365.)

The truffle, an underground fungus growth much esteemed for its flavor, has been called the “diamond of the kitchen” and a “sample of Paradise” by French epicures. (Reference No. 87, pp. 383–396.) It was known to the Greeks and Romans, but had its greatest vogue in Paris early in the nineteenth century. Dogs and pigs have been trained to hunt for truffles, and their presence is also indicated by insects which are attracted by their odor. The canned truffles available here seem to many not worth the price demanded for them.

MILDEW, MOLDS, AND FERMENTS.

These also are classed under fungi. Some of them are looked upon as enemies, yet many of the characteristic and delicious flavors in butter, cheese, fruit cakes, and pickles are due to the development of such fungi. (Reference No. 59, pp. 51–57.)

[Vegetable Foods, Bul. 245.]

YEAST.

Yeast is a microscopic plant of the fungus type. It will grow without light, but like any plant it must be kept moist and warm. It will grow in a wide range of temperatures from just above freezing point to over 120° F. (Reference No. 96, ch. 34.) Though formerly commonly prepared at home, yeast for bread making and similar purposes is now very commonly purchased ready prepared. (Reference Nos. 63, pp. 7-39; 71, pp. 79, 80, 82; 85, pp. 184-191; 97, pp. 161-163.)

In connection with bread making it is worthy of notice that most of the chemicals used to leaven quick breads are of vegetable origin, though not living organisms like yeast. Soda is commonly produced from ash of vegetable substances. Cream of tartar is a deposit from the juice of grapes formed on wine casks during fermentation. Occasionally it is found in the dregs of grape juice. Since this is an expensive article, other substances often are used in its place. (Reference Nos. 61, pp. 147-154; 62, pp. 23, 36-39; 65, pp. 89-92.)

EXPERIMENT AND PRACTICE WORK, NINTH LECTURE.

Materials needed.—The materials needed include mushrooms, fresh, dried, or canned, pieces of rotten or moldy apple or other fruit, and either yeast cakes or liquid yeast.

Mushrooms.

Prepare fresh, dried, or canned mushrooms with white sauce or use in soups.

Mold and Decay.

(1) Cut through the skin of some vegetable or fruit with a knife dipped into mold or decay from another fruit. Watch day by day for changes.

(2) Put a whole fruit or vegetable and a piece of bread in a sterile jar, cover, and set away.

(3) Scatter spores of mold in a jar and then put in the jar a bruised fruit or vegetable and piece of the same bread. Cover and leave for several days beside the other jar. (Reference Nos. 34, p. 60; 59; 62, pp. 73-75, 77, 78; 63, pp. 33-38, 109-116; 85, Ch. XVI.)

Yeasts and Fermentations.

(1) Experiment on the effect of temperature (from Reference No. 71, p. 79). Blend one yeast cake thoroughly in a pint of water to which has been added 1 tablespoon of sugar.

(a) Freeze a portion of the mixture, then allow to thaw at room temperature.

(b) Boil another portion and cool to room temperature.

(c) Take a third portion at room temperature

(d) Chill a fourth portion.

14579°—Bul. 245—12—5

[Vegetable Foods, Bul. 245.]

Fill bottles from each of the above and invert them on plates. Keep (a), (b), and (c) at 32° to 37° F. and (d) packed in ice during the remainder of the laboratory period. Explain results observed.

(2) Molasses and yeast. (Reference No. 59, exp. pp. 21-29.) For further experiments see Reference No. 59, pp. 30, 31, and Appendix, pp. 267-285.

Yeast muffins, etc., may be made in the usual way and also with the addition of strained pulp of fruit or vegetables, such as white or sweet potato, apples, squash, or pumpkin, and mashed parsnips. These may be used interchangeably. (Reference No. 73, p. 31.)

If there is time in connection with the lesson, breads should be made wholly or in part with flours made from bananas, chestnuts, potatoes, soy beans, or such other substances of like vegetable origin as can be secured.

Some writers on cookery consider such addition as adulterations of bread, but they deserve recognition for the variety thus afforded. (Reference Nos. 34, pp. 42-44; 72, pp. 125-129; 74, pp. 101-108.)

REVIEW QUESTIONS, NINTH LECTURE.

1. What are the characteristics of fungi?
2. Describe any mushrooms you know to be edible.
3. Can you describe any poisonous fungi?
4. How do mushrooms rank in nutritive value?
5. What effect have such fungi, as mold, etc., on foods?
6. What is the source of the various leavening agents used in breads, etc.?
7. Tell all you can of yeast, its nature, method of use, etc.
8. What vegetables are sometimes combined with flour for making bread?
9. How may we guard foods from ill effects of molds and ferments?
10. What forms of fungi commonly attack fabrics?

[Vegetable Foods, Bul. 245.]

COURSE IN VEGETABLE FOODS.

TENTH LECTURE—CONDIMENTAL VEGETABLE FOODS AND FOOD ACCESSORIES.

The value of appetizers or food accessories is generally recognized. (Reference No. 60, pp. 274-275.) The Germans class these with others under a convenient title "Genusmittel," or "means of enjoyment," "pleasure giving." The words condiment, herb, and spice are used somewhat indiscriminately, but together refer to various vegetable products used in small quantities to add flavor where it is lacking or to develop natural flavors in food. (Reference No. 74, p. 130.) The terms may include such vegetables as radishes and water cress, which are served in their natural state; flavoring materials, such as spices, savory herbs, and extracts used in general cookery; and prepared sauces, pickles, etc., in which some mild-tasting material usually serves to carry a combination of flavors. In whatever form they may finally appear, the majority of these flavors are due to the volatile oils or similar bodies developed in the plants from which they were obtained.

The actual quantity of these articles in any one dish is usually so small that their nutritive value can hardly be counted, but in the total estimate they are important, because they may make otherwise insipid or monotonous foods more palatable and so render them more digestible.

Beverages like tea and coffee, such materials as sugar and oil when used mainly for flavor, vinegar, and other food accessories, are also considered in this lecture.

CONDIMENTAL VEGETABLES AND PREPARED RELISHES.

Under this head may be included many vegetable products, such as peppers of various sorts, mustard, and horseradish (Reference No. 61, pp. 130-134), and a host of preparations or compounds designed to give zest or enjoyment to the act of eating and to aid digestion. Various pickled fruits and vegetables, the preparation and use of which is discussed in a later lecture (see p. 88), should be mentioned in this connection.

Some materials of East Indian origin, such as curry, chutney, cat-sup, and tamarinds, are well-known relishes. Tomato, apple pulp, etc., are likewise used as a medium for combining many spices and

condiments. Cassareep, made from the juice of manihot roots, the poisonous property of which has been rendered harmless by boiling, is a thick, black fluid used as the basis of some potent table sauces. Mushroom and walnut juices are used for the same purpose. Sassafras leaves, when young and tender, are used in some localities to thicken soups, etc., and, like okra, supply a mucilaginous material.

FLAVORING MATERIALS.

Herbs.

The herbs properly include the herbaceous or green portion of certain annuals, biennials, and perennials that are used green or dried and usually in a chopped or sifted form in sauces and stuffings. The word is also used to include the medicinal plants which once were grown or gathered and stored by every housemother. By the way of further distinction, the herbs used for flavoring were often called savory herbs, and those which were cooked for use alone were called potherbs (see p. 28). Among the herbs most used in the kitchen are marjoram, sage, summer savory, thyme, mint, parsley, dill, tarragon, and sweet basil. These are combined with meats or used in unsweetened dishes.

Spices.

Spices, with the exception of pepper, red pepper, and mustard, are associated mainly with sugar in common household use. Some spices, as nutmeg and mace, are used in meat dishes and with vegetables in continental cookery and much less commonly by American cooks. Cloves are also used in a limited way in meat cookery.

Other common species are allspice (pimento), cassia, cinnamon, ginger, mace, nutmeg; anise seed, bay leaves, carraway, cardamon, and coriander are less generally used. (Reference No. 102.)

Flavoring Extracts.

Vanilla is perhaps the most popular flavoring extract used in home cooking, and different qualities should be known; almond and lemon extracts, too, are common. Since true vanilla is the most expensive flavoring material, it is possible to reduce its use where economy must be practiced and to substitute other flavors and spices in small amounts. They are often used too freely, and the result is unpalatable. These three and rose and orange are made directly from the natural product, while other fruit extracts are usually made synthetically. (See also p. 50.) (Reference No. 61, pp. 143-146.)

Condimental foods are especially liable to adulteration and sophistication. There are usually several grades of the pure article and the teacher and housekeeper should know the difference. (Reference Nos. 51; 86, ch. 37.)

[Vegetable Foods, Bul. 245.]

BEVERAGES.

Tea.

Tea has been used as a beverage from remote ages by the Chinese, and is probably in more general use than any other hot beverage. (Reference No. 97, pp. 203-207.) Leaves of many other plants have been substituted for tea, particularly in times of scarcity. The maté or Paraguay tea is a common beverage of South America, made from the leaves of a species of holly. (Reference Nos. 24; 104.)

Coffee.

Coffee has been known in Arabia and Persia from ancient times. Its introduction into England was accomplished with difficulty. The United States consumes about half of the world's supply. The amount used is not far from 1 pound per person a month. (Reference No. 61, p. 31-41.)

Chocolate and Cocoa.

Chocolate and cocoa may be classed with other beverages, though they are foods in themselves, and, as usually served, are combined with a larger proportion of milk and sugar than are tea and coffee. These are products of an American plant apparently introduced into the Old World shortly after the discovery of this country. (Reference Nos. 61, pp. 41-46; 97, pp. 210-213; 101.)

MISCELLANEOUS FOOD ACCESSORIES.

Sugar and olive oil, peanut oil, cottonseed oil, and other vegetable oils are often thought of as accessories rather than as real foods in the United States, yet they have a high value as energy-yielding foods, and this fact should be appreciated. Sugar is, of course, used in large quantities and the use of vegetable oils, though fairly common at present, may well become more general. (Reference Nos. 23, p. 14; 42; 61, pp. 104-106.)

Vinegar, which is one of the oldest condiments, may be classed as a food accessory, and has little or no food value. It will be considered further on in relation to the preservation of food materials.

EXPERIMENT AND PRACTICE WORK, TENTH LECTURE.

Flavoring Materials.

Materials needed.—Samples of spices, herbs, etc., in different stages of preparation; 2 lemons, 2 oranges, 1 vanilla bean, a few lumps of sugar, some powdered sugar, alcohol, bottles; lemon extract.

[Vegetable Foods, Bul. 245.]

Spices and herbs.—Cover the labels on the spices and see how many the pupils can distinguish by sight and taste. Other tasting contests may be arranged. Cook whole spices in water or sugar sirup and taste each combination. Try similar tasting exercises with herbs, steeping in vinegar instead of boiling in sirup.

Flavoring extracts.—Wash and dry lemons and oranges. With lumps of sugar rub surface of one of each till sugar absorbs some of the yellow flavoring oil. Cut fine, thin strips of the yellow rind only, put in bottles, cover with alcohol, and leave for several days. The extract may, after a time, be drained off and the peel discarded.

Divide the vanilla bean and pound part of it in a small mortar with powdered sugar. Sift the sugar and keep it to sweeten and flavor. The particles of the bean removed may be steeped in milk for custards, etc. The other portion of the bean may be put in alcohol.

To test lemon extract add equal volume of water, if lemon oil is present the mixture will be cloudy.

Beverages.

Materials needed.—Any available samples of teas, coffees, cocoa, and chocolate; filter coffeepot.

Tea, coffee, cocoa, and chocolate:

1. Soak in cold water; notice color and flavor or lack of it. Bring to boiling point and again taste.

2. Pour rapidly boiling water over tea; infuse with tea ball. Let boiling water drip through coffee in a strainer or filter coffeepot.

3. Boil tea and compare color and strong flavor with that made properly as in experiment 2.

4. Boil coffee in uncovered saucepan. Note loss of aroma.

5. Any available "patent" coffeepots may be tested and the result compared with the right use of the simplest appliances.

6. Soak different grades of tea in water, unroll the leaves, noting size of leaf, proportion of stem, etc. (Reference No. 72, pp. 308-309.)

7. Test different samples of coffee for chicory and other adulterations. When mixed with cold water pure coffee floats on top, while adulterations, especially chicory, sink and give a brownish color to the surrounding water. (Reference No. 88, pp. 133, 134.)

8. Prepare cocoa and chocolate in different ways (Reference No. 72, pp. 308-310) and compare flavor, nutritive value, and cost of each.

REVIEW QUESTIONS, TENTH LECTURE.

1. What is the use of flavoring materials?
2. How does the cost of such articles compare with their actual nutritive value?
3. Give a simple classification of these substances.
4. What are some of the virtues of olive oil?
5. Have you learned to eat it and enjoy it?
6. What can you say of the food value of the three principal beverages commonly served hot?
7. What is the best method of making tea?
8. In its preparation what special points must be safeguarded?
9. What simple tests will indicate presence of adulteration in coffee?
10. Distinguish between chocolate and cocoa. Tell how to prepare each.

[Vegetable Foods, Bul. 245.]

COURSE IN VEGETABLE FOODS.

ELEVENTH LECTURE—SUMMARY OF COOKERY.

Having briefly studied some of the most important groups of vegetable foods, we are now better prepared to classify methods of cooking and see how they may be adapted to developing the best qualities of plant foods.

The chief objects of cooking vegetables are these: To sterilize any from doubtful sources; to soften or separate the woody fibers; to make the carbohydrates, etc., more accessible to the digestive juices; to modify and develop flavors; and to put in attractive form for the table.

The principal processes of cookery for vegetables are the same as for meats—baking, boiling, and frying, with their modifications; but these must be adapted to the nature of the specific vegetable. (Reference No. 74, pp. 22, 23, 90, 122.)

There are classifications of vegetables according to their botanical families and the parts of plants represented or according to their composition, as green or watery, starchy, nitrogenous, fatty, etc. In discussing the use of different varieties in the kitchen these groups are not always considered as they should be. Instead of studying the family and composition of the plant which would aid in showing the best way to prepare it, too often every type is treated in the same fashion.

For convenience of the cook, all vegetables may be classed as either the fresh, which are ready for cooking, or the dry, which must be thoroughly soaked before using, and the canned, which may be used by simply heating and seasoning, or in many other ways. Furthermore, with both fruits and dried vegetables, it should be considered whether they are strong in flavor, in which case they should be cooked in water first to remove some of their juices, or sweet or well-flavored, and to be prepared in such a way as to retain as much of their natural flavor as possible. Yet here the age and condition of each specimen must be considered, and the dividing lines between sweet and strong can not be made hard and fast; the young and perfect forms of the stronger types may be much sweeter and better flavored than old and imperfect samples of the sweet-flavored kinds. (Reference No. 70, p. 32.)

CHOOSING, SORTING, AND CLEANING VEGETABLES.

Careful choosing, sorting, and cleaning should precede any process of cookery. (Reference No. 28, pp. 24, 25.)

Medium-sized vegetables are always to be preferred to the over-large.

Plants grown slowly are liable to be tough and corky, while those having abundant moisture and sunlight are crisp, tender, and well flavored.

The shorter the time and journey between garden and table the better for green plants. It is wiser not to gather vegetables while they feel the effects of the midday sun, but rather to pick them after the dew has evaporated in the morning, or if that is not possible, in the cool of the late afternoon. (Reference No. 28, p. 33.)

Wilted vegetables can never be wholly satisfactory, but may be improved by careful washing and removal of inferior portions, and then soaking in cold water, or with salad plants by wrapping in a damp cloth. (Reference No. 28, p. 39.)

The soaking of vegetables in cold water to freshen them probably extracts some of the valuable saline matter. When they are blanched in hot water or parboiled still more mineral matter is lost. If boiled in considerable water of which no use is made, some of the soluble saline matter is wasted. This mineral matter is generally conceded to be valuable. Obviously it would be of special importance if the dietary were such that little was obtained from other sources, such as fresh fruits, salad plants, and other foods with a reasonably high ash content. It has already been indicated how the waste may sometimes be avoided by using the water for soup, scallops, etc.

Often it is convenient and wise to cook a double portion of a vegetable and serve part of it a second day in a different form. This should not be attempted in warm weather unless a refrigerator is available. Ordinarily a vegetable well salted while cooking and drained and cooled quickly will keep 24 or 48 hours in cool weather.

Enough potatoes may be cooked to serve as plain boiled or mashed to-day, while the firmer ones are reserved to broil or grill in slices, fry, or cream the next day. When gas is the fuel this is worth while, for it would take 30 minutes to boil fresh potatoes and only 10 minutes to reheat them. For use of fireless cookers with vegetables, see Reference No. 89.

Most vegetables are lacking in fat, so we contrive to add it in some form while preparing them for the table or to serve them with fat meats, etc. So far as the need of the human body goes, it makes little difference whether this fat is in cheap or expensive form, whether the vegetable is cooked with fat or dressed with cream or salad oil; one form may be more agreeable to some than another, or some fat may be less rapid in digestion, though that is a point on which little reliable information is available.

Beef suet, bacon fat, cream, butter, and olive and other vegetable oils all are used. There is little difference in expense between the

[Vegetable Foods, Bul. 245.]

best olive oil and thick cream. The oil keeps better, and hence always may be available. A taste for salad oils is desirable and should be acquired. (Reference No. 42.) Better results often are obtained by combining cream with vegetables than by using butter and milk costing quite as much.

Whenever a vegetable dish, other than beans, etc., is to be the principal part of a meal, it is easily possible, as well as reasonable, to increase its food value by the addition of milk, cheese, or eggs. Skim milk may be heated uncovered until considerable water has evaporated, then little or no thickening is needed. (Reference No. 74, pp. 42-54, 60-62.)

For cereals, rice, etc., which are used as vegetables, see Reference No. 34, pages 34-37.

Although almost any vegetable may appear as soup or purée, scalloped, in salad, or as the basis of croquettes, fritters, or soufflés, the simplest way of preparing each is usually the best to develop its natural advantages, and a fair sample of any vegetable is not improved by overmanipulation or additions that disguise its own flavor. Intricate dishes have their place for emergency or variety. If our supply of any given vegetable is limited, combinations with other materials are in order. When we have an abundance of one kind, and it must be our main dependence for weeks, the form of serving it must be varied or we grow tired of it.

Just as one kind of starch may be used in place of another, or as the flavor of different varieties of the same family of plants is similar, so the pulp and fiber of different plants may be used interchangeably. The same general formula will apply to all "cream" vegetable soups, and without searching for new recipes we may venture to combine two or more vegetables, as beans and squash or potato and turnip, in the same soup.

COMBINATIONS OF VEGETABLES.

There are many combinations of vegetables which have proved satisfactory, and no one need hesitate to experiment with others. In general it is safe to combine a starchy vegetable with a succulent one, or one lacking in flavor with another that will give relish.

Cooked celery is agreeable with creamed potato. It may be added to Brussels sprouts or cabbage.

Contrasts in color often add to the value of a compound by making it attractive to the eye, as in carrots and green peas. Since some combinations of color are not considered pleasing, on this basis it is well to beware of serving tomato and red beets together, etc.

Green corn with potatoes and onion, with the addition of milk, etc., makes as good a chowder as fish in the opinion of many.

[Vegetable Foods, Bul. 245.]

Potatoes boiled and cut in slices or cubes may be used to extend expensive, highly flavored vegetables in salads, etc.

Potatoes with onions or white turnips make a more agreeable soup for some palates than the stronger vegetables alone.

Carrots often are more palatable cut in dice and blended with green peas than served alone.

Large white beans may be served in a tomato sauce with onion and green or red sweet peppers or both.

Mint, parsley, sweet peppers, onions, etc., may be added in small portion to many vegetables to give a new flavor when the usual methods of serving have become monotonous.

UTENSILS USED IN COOKING VEGETABLES.

The following suggestions as to utensils may be of practical use: A small scrubbing brush is essential for washing all vegetables that have grown in the earth, and should be kept in a convenient place, and for this purpose only.

Knives of different types are desirable. A small, sharp point is needed for the removal of eyes from potatoes and small blemishes from any vegetables.

Fancy cutters are not essential, but convenient, especially when it is necessary to give variety to a monotonous diet.

A wire basket is convenient to hold greens, string beans, or even potatoes while cooking, as thus they are less likely to adhere to the bottom of the kettle, and often it is easier to remove the basket than to drain off the water.

Colanders, purée strainers, potato ricers, etc., all are helpful in washing and straining potatoes, squash, etc.

A potato masher of strong, continuous wire, the two ends inserted in a wooden handle, is inexpensive and fully as satisfactory as a more costly style. (Reference No. 68, p. 724.)

COOKING TERMS.

A few of the terms indicating the use of vegetables may be of service in studying books arranged by chefs and others.

À la—according to, or in the style of.

Au gratin—with browned crumbs, as of bread, sometimes with cheese.

Bouquet of herbs—a sprig each of several kinds, as marjoram, parsley, savory, thyme.

Creole or West Indian—with tomatoes, often also peppers, onions, and mushrooms.

Jardinière—mixed vegetables.

Macedoine—a medley or mixture of vegetables, often with meat.

Maigre—without meat, as vegetable soup.

[Vegetable Foods, Bul. 245.]

Printanière—a garnish of spring vegetables.

Purée—material mashed through a strainer.

Roux—flour browned in butter.

Soufflé—a puff, something inflated or swollen, as by beaten white of egg.

TIME OF COOKING.

While overdone vegetables are not desirable, underdone ones are often even less appetizing, therefore it is wise to start in season and stop the process as soon as the plant is tender, and then reheat quickly just before serving. Most time-tables in cookbooks do not take into consideration the variations in time required for the same kind of vegetables at different ages.

WAYS OF SERVING.

Soups.

This is one of the best ways to use left-over vegetables. A cupful of cooked cauliflower with some of the water in which it was cooked and equal amount of milk and a slight thickening of butter and flour will provide a cream of cauliflower soup. If the vegetable already has white sauce with it, reduce it with milk to right consistency, season and strain, and the soup is ready. (Reference No. 73, pp. 76-82.)

A purée is half way between a cream soup and mashed vegetables; it is sometimes a thick soup, but oftener strained vegetables made soft with milk or stock and butter, and served with meats. (Reference Nos. 18, pp. 25, 33; 70, p. 300; 75, p. 141; 98, p. 94.)

Salads.

The derivation of the word—something to be eaten with salt—shows its original simplicity. (Reference 71.) The young tips or tender leaves of certain plants are especially suited to this purpose. (See p. 21.)

Scallops.

These consist of cooked vegetables with cream sauce, seasoned, covered with buttered crumbs and browned in the oven. The proportion and thickness of sauce varies with the dryness of the vegetable, usually half as much sauce as vegetable, in the case of cabbage or onions.

Fritters.

Many vegetables, partially cooked, may be dipped in batter and fried in deep fat, thus giving variety and adding material of a different type from their constituents. (See Reference Nos. 69, pp. 106, 107; 70, pp. 348-357.) Among the vegetables best adapted to this process are cauliflower, celery, corn, okra, and salsify.

[Vegetable Foods, Bnl. 245.]

Croquettes.

These may be made from mashed vegetables held together with a small proportion of beaten egg or from chopped, cooked vegetables combined with a thick cream sauce. There is justification for the additional time required for this process when left overs can be thus used economically or when variety is needed.

Frying.

Parsley, "the crown of cookery," may be drained on towel, shaken to remove moisture, and fried 40 seconds in deep fat. (Reference No. 34, pp. 68, 73.)

From the potato cake or croquette it is but a short step to a potato crust for a meat pie (Reference No. 88, p. 46), or from the corn fritter to the tortilla and thus to doughs. (Reference No. 91, pp. 248-250.)

EXPERIMENTS AND PRACTICE WORK, ELEVENTH LECTURE.

Material needed.—Take vegetables not previously used in the practice lessons and prepare them in any of the standard forms.

Use any formula proved successful for some vegetable, and substitute another vegetable with due variation in other ingredients to adapt the formula to the composition of the substitute. For example, a cream soup may be made with any cooked and strained vegetable pulp, but if in one case it is potato with much starch and little flavor, little thickening and more seasoning will be needed; while another time, with celery or onion, more thickening and less added flavor will be required.

Exercise.—Make two green pea soups, using for one the dry split green peas at about 14 cents per quart, and for the other canned green peas at the same price per can. Count cost of materials, time, and fuel in each case.

For variations on these foundations, see Reference No. 78.

Verify and compare tables of weights and measures. (Reference No. 34, p. 33.) See also Reference No. 70, pp. 28, 54.

REVIEW QUESTIONS, ELEVENTH LECTURE.

1. Briefly describe the principal processes of cooking vegetables.
2. What general preparation would be common to all methods?
3. When may it be advisable to cook a double portion of any vegetable?
4. How shall we decide what materials to add to a vegetable in its preparation for the table?
5. What types of knives are most helpful in preparing vegetables? Describe different processes requiring different motions.
6. Some vegetables should be scraped, others pared. Give examples.
7. Describe several utensils helpful in preparation of vegetables.
8. Suggest combinations of vegetables and explain why they are acceptable.
9. Give general plan for making soups from one kind of vegetable. Mention combinations that might be used in the same way.
10. Describe process of making croquettes or some scalloped vegetable.

[Vegetable Foods, Bul. 245.]

COURSE IN VEGETABLE FOODS.

TWELFTH LECTURE—DRYING, EVAPORATING, AND SALTING VEGETABLES.

Most foods are best when fresh, but since they can not always be had in this condition, some means must be found for preserving them. Decay in fruit or vegetables with its accompanying changes of texture and flavor is caused by the development of bacteria, molds, and other low forms of life. The various methods of preserving are simply means of checking the growth of these microorganisms. The first step should be to protect the material from unnecessary contamination from them, but since they are everywhere present in the air, even the most scrupulous cleanliness is hardly sufficient alone.

Most of the microorganisms grow only in the presence of moisture, and this fact explains the method of preserving by means of drying. (Reference No. 59, pp. 141-148.)

DRYING AND EVAPORATING FOODS.

The drying of foods has been practiced by primitive people from the beginning of civilization and is only aiding nature's processes. The seeds dry as they ripen and berries dry on the bushes. The Indians preserved blueberries and other fruits in this way. Pumpkin was often dried in strips by our colonial grandmothers, and sections of apple were strung and hung where they would dry readily. The bulk and weight of such foods is much less than in their natural condition, hence less room is required for storage and much less labor is involved in their transportation from place to place.

Herbs and spices were gathered, dried, and used to aid in the preservation of other foods. There was a right time for gathering each plant, it was believed, and in this lore ancient housekeepers were far more interested than modern ones.

Dried lavender, sweet grass, clover, and rose petals have from time immemorial been used by housewives to give perfume in their linen chests.

Dates, figs, and raisins long have been considered important foods for the traveler and explorer, containing valuable food material in concentrated and convenient form.

Modern evaporated fruits and vegetables differ from dried, simply in that the process is shortened, and there is less opportunity for fermentation, darkening, or the accumulation of dirt. (Reference No. 59, pp. 141-148.)

Tomatoes may be cooked, strained, and evaporated to a thick paste, resembling beef extracts in texture. In this form they are found in Italian markets.

Dried mushrooms are another commodity found in the foreign shops, which we might well learn to use.

Dried fruits and vegetables are less expensive than canned, mainly because they have required less labor in preparation and transportation than the canned. (Reference No. 52.) Their value is not generally appreciated, partly because they are cheaper and partly because the older dried products were often damaged by dust and insects, and because sufficient attention is not given to freshening them. Some good modern methods of drying and marketing are perfectly sanitary, and so far as chemists are able to tell us, a dried plum, peach, or vegetable, properly soaked and cooked, is just as valuable a food as a fresh one similarly cooked.

A homemade drier is a desirable appliance for the possessor of a good vegetable garden. A simple form consists of trays in a holder; four strong, upright, wooden supports, connected by horizontal bars, will hold several trays at once. The trays are made like window-screen frames and may be covered with wire netting for some things, but cheesecloth is preferable. The supports should be tipped at the base with a large nail or piece of metal that they may safely rest on the back of the stove when sunlight is not available. Shelled beans and green peas may be dried in this fashion. Some find it an advantage to scald them in boiling water before drying. Sweet corn should be slightly cooked, cut from the cob, and spread in very thin layers on the cheesecloth. Corn on the cob may be dried after scalding.

Small quantities of vegetables may be evaporated on earthen plates set over a kettle of boiling water or in an afternoon oven. While drying, they may hang in cheesecloth bags at the top of a warm closet. When very thoroughly dried, put away in tin boxes or glass jars.

PRESERVING BY SALTING.

The addition of salt indicates a step forward in the art of preserving food. The salt of the sea and the smoke of the camp fire were ready at hand for the first man intelligent or observant enough to make use of them.

Salt hastens the drying process by drawing out water from the vegetable tissues, making them firmer; it is also injurious to bacterial life. Young cucumbers and other green vegetables often are packed in salt as they are gathered and then kept until a convenient time comes for their further preparation for pickles. Greens, string beans, and similar vegetables used to be packed in salt like young cucumbers. Thoroughly freshened in the winter, they afford an agreeable variety. Now canned vegetables are more convenient.

[Vegetable Foods, Bul. 245.]

Smoking is very commonly combined with drying and salting as a means of preserving foods, but almost exclusively with meats and fish. Dried smoked pears and other fruits are, however, not uncommon in some parts of Germany.

Sauerkraut, a German preparation of cabbage, is evidently the survival of an ancient way of preserving the vegetable. The process is somewhat akin to the ensiling of forage for animals. (Reference Nos. 59, p. 166; 103, pp. 213-216.) Firm cabbages are sliced and packed in salt, sometimes a few cloves, etc., are added, the mass is pressed down solidly under a weighted cover. After a time a partial fermentation takes place, the liquid is poured off and more salt and water added. The acid developed by the fermentation works upon the tough fibers, making them more tender. The sauerkraut is kept in a cool place and cooked as needed, like fresh cabbage. Dill pickles are made with cucumbers packed in a similar way, the cucumbers being flavored with dill. From similar methods our other types of pickles may have been evolved.

EXPERIMENTS AND PRACTICE WORK, TWELFTH LECTURE.

Drying Vegetable Substances.

Materials needed.—Frames covered with cheesecloth or white mosquito netting; these may be sections of boxes, even of heavy pasteboard.

Exercises.—The essentials in drying vegetables are cleanliness, heat, and circulation of air. The more rapid the process the less the danger of bacteria, ferments, and molds.

(1) Arrange part of the vegetables on the frame and expose in current of air, or place part in a very moderate oven with the door open, or in upper portion of an uncovered double boiler, and compare the results.

(2) Place pieces of different thickness side by side and dry under the same conditions. Cut a carrot in fancy shapes and dry for soup garnish.

(3) If possible, try (a) green or undeveloped tissues, (b) fully grown or ripe and overripe; compare results.

(4) Weigh and measure vegetables or fruits as purchased; weigh and measure after process of evaporation is completed.

(5) Dry parsley; note effect of too much heat in change of color. When dry, rub through strainer and use like fresh chopped parsley. Plunge in boiling water before drying and compare result with other not so treated.

(6) Try experiments with thick sections or with thin ones placed over each other, exposed to dust where process must be slow, without sun or heat, and note results. (Reference No. 71.)

(7) Test effect of alcohol, oil, vinegar, sugar, salt, and spice separately, and two or three together on similar sections of the same fruit or vegetable, raw and cooked.

(8) Test effect on similar sections from the same article, thus: (a) In refrigerator; (b) in sunlight; (c) in moderate oven; (d) in dusty room.

Restoring Dried Foods to their Original Conditions.

Reverse the experiments just described by the use of dry vegetables and fruits, such as evaporated apples, beans, cherries, peas, peaches, prunes, sweet [Vegetable Foods, Bul. 245.]

corn, and the dry Julienne (mixed vegetables) which comes prepared for soups. Weigh and measure these as purchased; weigh and measure after soaking. Make tea, unroll the leaves and note shape; make teas from herbs.

Nuts are a type of dry or condensed foods which may be studied in this connection.

Exercise.—Take 1 pound of mixed nuts in shells, or $\frac{1}{2}$ pound each of any available kinds. Weigh before and after shelling. Note composition of each type. (Reference Nos. 26; 30.) Suggest additions and combinations with other food materials to dilute the nuts and make a food which in composition might be similar to a meat and potato hash or legumes stewed with pork. (Reference No. 75, pp. 16, 18, 32, 33, 41, 42.)

REVIEW QUESTIONS, TWELFTH LECTURE.

1. What objects are sought in the preservation of vegetables?
2. Describe methods used before the process of canning was discovered.
3. Explain the effect of air and sunlight on canned foods.
4. Mention appliances helpful in any processes of preservation of vegetables.
5. Explain the action of salt, sugar, spice, oil, vinegar, alcohol on vegetable tissues.
6. Contrast processes of drying and canning, giving the relative merits of each.
7. How is the large percentage of water in vegetables shown in any method of preservation?
8. What is the relative proportion of nut meats to shell, both as to bulk and weight?
9. Mention points for and against buying shelled nuts or seeded raisins, etc.
10. Estimating cost of jars, fuel, etc., allowing a fair price for your own labor, what does it cost you per jar to can your own fruits and vegetables? How does this compare with drying?

[Vegetable Foods, Bul. 245.]

COURSE IN VEGETABLE FOODS.

THIRTEENTH LECTURE—PRESERVING AND CANNING VEGETABLES.

The home canning of fruits and vegetables is a matter of more importance to those who grow such products than to those who must buy them in any case. The cost of labor and fuel, added to the cost of the raw material, makes it wiser for many to buy the canned article. But there is no question that the surplus products of the home garden should be preserved in some form for future use. The publications cited in Reference Nos. 11 and 27 treat different phases of this subject fully and can be used as textbooks for this lesson. See also Reference No. 9.

The essential points in all canning are few—absolute cleanliness and sterilization and suitable containers, which means the destruction and exclusion of ferments, molds, and bacteria. (Reference Nos. 59, Ch. XII; 72, pp. 284–288; 74, pp. 34–38.)

Poisonous or doubtful preservatives never should be used. Long use has so accustomed us to the use of sugar, salt, vinegar, and spices that we forget that flavor is secondary to their preservative effect. (Reference Nos. 27, p. 8; 59, pp. 157–162.)

A practical point worth remembering is that 1 quart by measure means 1 pound in weight with many of the green vegetables and fruits. For serving or canning it is well to remember also that 1 quart of average substances as purchased will be required to fill a pint jar or dish, the shrinkage being due to loose measure, removal of uneatable portions, and condensation in cooking.

PRESERVING WITH SUGAR.

The earliest method of preserving fruit aside from drying appears to have been to coat it with honey and allow it to dry somewhat. From that may have been derived the plan of packing in jars and filling the spaces with strained honey. This might have been the result of observation of the way in which flowers, etc., accidentally coated with honey retained their original freshness. In any case it was unconscious application of the fact that bacteria and molds do not grow readily in the presence of concentrated sugar solutions. (Reference Nos. 59, pp. 162–165; 100.)

Preserving with sugar is, of course, more important for fruits than for vegetables, but is worth consideration here, partly because it

shows an important principle in the general science of food preservation, and partly because a few vegetables are sometimes put up in sugar.

Dates, figs, grapes, and other fruits rich in sugar have always been known to keep well when only partially dried, and others less sweet have been dried with the addition of a little sugar. The old-fashioned New England custom of drying wild raspberries with maple sugar is an illustration of the latter, and also of how necessity sometimes leads to the discovery of pleasant flavor combinations.

Although sugar is a good preservative against bacteria and molds, it is not so efficient against the yeasts which cause fermentation; hence the occasional "spoiling" of even fairly sweet fruit preserves and the need of keeping them in clean, tight jars.

If the products commonly classed as vegetables were preserved in sugar, their sweetness would spoil them for their ordinary uses in the bill of fare. Where fruits are scarce and expensive women have been ingenious in the use of vegetables in place of them. Thus the seed vessels of roses are sometimes made into preserves in northern Europe. Pumpkin, squash, carrot, even beet and cabbage are used in this way and flavored with lemon, ginger, etc. Certain kinds of tomatoes, also, such as the yellow plum variety, are frequently preserved in sugar, but they are so sweet in this form that they are used as a dessert rather than in the meat or salad course. Small quantities of sugar are sometimes used in canning such vegetables as green corn and peas.

Since sugar and other sweetening materials are of vegetable origin, they may be briefly mentioned here. (Reference Nos. 4, 6, 15, 104.) Honey already has been considered among the flowers (see p. 50). Maple sirup and sugar making were known to the Indians, who recognized a "sugar-making moon" in the spring. A study of the history of methods of condensing the sirup, from the primitive appliances of a century ago to the improved evaporations of the present, would be of interest and suggest possible advance in household methods of cookery.

Cane sugar is a popular and valuable food, and its use appears to be increasing everywhere. But there are limits to human capacity, and some physiologists believe that its consumption should not much exceed 1 pound per person per week. (Reference No. 4, p. 27.)

Granulated and other white sugars are the most important products of sugar cane, but brown sugars and molasses also play a useful part, not only in those sections of the Southern States where molasses is a large factor of the diet, but also in general cooking. The old-fashioned somewhat acid molasses was the result of evaporation in open kettles, a process rarely followed now.

[Vegetable Foods, Bul. 245.]

During the last half century there has been a marked increase in the production of sugar from special varieties of beets. So far as the chemist can discern, this sugar is identical with that made from sugar cane.

Regarding corn sirups, glucose, etc., see Reference Nos. 4, page 9; 23, pages 14, 15.

Sorghum sirup is less used since corn sirups have been manufactured.

The evaporation of water in which sweet vegetables like carrots, green peas, or squash have been boiled would yield a sweet sirup.

PRESERVING BY STERILIZATION—CANNING.

In ordinary sweet preserves the heat of cooking may increase their keeping qualities by killing some or all of the microorganisms present in the raw material. It has been shown that such sterilization is one of the reasons for cooking vegetables (see p. 71). It is the most important factor in canning vegetables, whether in the home or in the factory. (Reference No. 59, pp. 169-181.)

Prolonged or extreme heating tends to change the flavor and texture of foods, sometimes for the worse. The best method of canning, therefore, will be the one which kills the most of the undesirable microorganisms while it occasions the least injury to the material. Whatever method is used, the receptacles in which the food is put must be sterilized as carefully as the food and finally closed so tightly that no fresh organisms can find entrance.

The method known as intermittent or fractional sterilization usually answers all these conditions. Its success seems to depend on two facts, first, that more heat is required to kill some of the spores of the microorganisms than the organisms themselves, and second, that these spores become full-fledged organisms within a short period (say 24 hours) after they have been subjected to heat sufficient to kill the parent organisms. When this method is followed the vegetables are put in jars; the rubber rings and glass covers are laid on but not clamped; sterilized water is added, and the jars heated to the boiling point of water for about an hour; then the jar is fastened. This process is repeated with clasps up 24 hours later, and again the third day. (Reference Nos. 27, pp. 7, 15, 16, 19; 58.)

For a continuous process a longer time is required. String beans, etc., should steam 3 to 5 hours in the jars and be tested before being put away. To test them, unclamp the jar and lift by the cover; if the contents are not satisfactorily sterilized, the cover will come off.

Where the source of the vegetables is uncertain it is a safeguard to blanch or parboil them in well-salted water and drain thoroughly before packing them in the jars for either the fractional or the continuous process. A small quantity of cooking soda may be added

[Vegetable Foods, Bul. 245.]

to the water in which string beans are parboiled and which is not used in the canning process. As vegetables are salted before serving, from 1 teaspoon to 1 tablespoon of salt is frequently added to each jar.

The relative economy of the use of fresh vegetables and canned ones involves many problems, including convenience, value of time and labor, as well as variety and quality of the foods.

Compare canned green peas with fresh ones in the pods out of season and the advantage is with those from the can as to quality as well as cost. But canned or fresh at the lowest rates for either are expensive compared with the amount of nutriment obtainable for the same money from the dry green or split yellow peas.

To illustrate this matter in detail: A 15-cent (pint) can of Lima beans yielded 150 beans. The same number of dry beans at 9 cents per pound weighed $5\frac{1}{4}$ ounces, or one-third of a pound, and measured less than 1 cup. The dry beans would cost 3 or 4 cents; with a fair allowance for labor and fuel the total cost would be less than half that of the canned beans and the quality much better.

The larger the family the greater the gain in the use of the dried beans, for even at wholesale rates the cost of the cans would be greater than that of dry beans plus the labor and fuel required for the preparation of the latter.

Because this happens in one instance it does not follow that it will in others. Some of these questions, as that of canned beets versus fresh, etc., may be worked out in the practice period. In general it will prove that the fresh vegetable directly from the garden in its season is always superior to the canned, and that a dried fruit or vegetable properly soaked and cooked will rival all but the very highest grades of canned foods of the same kind.

"Canned vegetables are relatively free from adulterations by means of foreign substances. The different grades of products may with care be readily detected by the general appearance of the sample." (Reference No. 43, p. 48.)

To use canned vegetables, open an hour or more before using; empty the can as soon as opened and expose the contents to the air to freshen. To freshen quickly, drain the vegetables and rinse with cold water. Taste of the liquor in the can and use or discard as seems best; do not keep it long after opening.

EXPERIMENT AND PRACTICE WORK, THIRTEENTH LECTURE.

Action of Bacteria, Molda, etc.

(Reference No. 71, experiments 41, 42.)

Exercises.—Expose bread, cheese, fruit juices, cut raw and cooked vegetables, milk, etc., to dusty air, and leave for some time; note changes in each. Note the cloudy appearance of fruit sirup, indicating presence of bacteria. Scald the fruit, remove scum, and sirup will be seen to be clear again.

[Vegetable Foods, Bul. 245.]

Leave stewed fruit in glass jar uncovered. Note the difference in lower portions which do not come in contact with air. After a time, stir slightly so that part of top layer is distributed throughout the jar. Note the groups of bacteria, etc., forming where portions of the top layer remain.

Note the need of sterilization of jelly bags, jars, utensils, and the danger from sweeping, dust from open window, etc.

Sugar.

An entire lesson might be given to a study of sugar and the way it is affected by heat and moisture. (Reference No. 34, p. 69.)

Caramelization, etc.: Try experiments 41 and 42. (Reference No. 71, p. 48.)

With a sirup gauge, experiment with sirups of different densities. (Reference No. 11.)

Canning.

Materials needed.—Any vegetables available, including tomatoes, either fresh or canned; apple or green grape jelly, fresh mint, spinach extract for coloring (p. 20). Several types and sizes of jars.

Exercises.—(1) Can any available fresh vegetable. (Reference No. 11, p. 5.)

(2) When fresh tomatoes are not available, open a quart can, reheat and seal part in half-pint jar. This is a practical point for the small family where a larger can is too much to use at once. Another portion of the tomato may be strained and canned in a half-pint jar. The remainder, strained, may be evaporated to half its first bulk, seasoned with spices, salt, and vinegar, and put in bottles as catsup. Note whether varying the kind of spices and the proportion of vinegar affects the flavor materially. (Reference Nos. 11; 71, pp. 50, 51; 72, pp. 259-264.)

(3) Note results with different types of jars. Have different sorts of tops any special advantages? Why are good rubber rings essential?

Another lesson on this general subject might deal with the use of canned foods, as already indicated in Lecture 7 with the tomato (p. 53). Cream soups may be made from canned tomato, peas, asparagus, etc. Scalloped tomato and corn fritters are other dishes in which small quantities of canned vegetables may be utilized. For ways of avoiding waste in preparing vegetables for canning, etc., see Reference No. 27, page 15. This may suggest other possible combinations for soups, salads, etc., not already covered in other lessons.

Combinations of highly flavored fruits with others of different flavor, or sometimes of less distinctive taste, are by no means uncommon. Thus, housewives often combine raspberries and currants for jelly making or for canning. Another combination, which may prove useful if lessons are given at seasons when fresh berries and fruits can not readily be procured, is raisins, orange, and cranberry. The proportion is a matter of taste, so it is well for pupils to use different quantities and compare results.

In old domestic recipes, quinces are often combined with sweet apples which have little distinctive flavor or with pears of firm texture and also lacking in this quality. The relative proportions of the two fruits is a matter of preference, the greater the proportion of quinces, the higher the flavor.

Such preserves can be made by the student if time permits. Note the texture of the different fruits when cooked.

Experiment with vegetable pulp like sifted squash, pumpkin, sweet potato, or tomato as a basis for marmalade, with flavor supplied by spice or a small proportion of high-flavored fruit like apricot or quince.

[Vegetable Foods, Bul. 245.]

REVIEW QUESTIONS, THIRTEENTH LECTURE.

1. What kind of kettles would you choose for canning, and why?
2. What is the aim of this plan of preservation?
3. Has any case in your own experience shown the importance of sterilization?
4. Describe fractional sterilization.
5. Give an outline of the process of canning based on your own experience.
6. How would you estimate shrinkage between market and jars, including imperfect vegetables, necessary refuse, effect of cooking, etc.?
7. What fruits and vegetables do you can at home?
8. What do you find it wiser to buy, and why?
9. Give details of relative cost to you of buying tomatoes to can yourself or buying them already canned.
10. Does this lesson explain any failures that have troubled you?
[Vegetable Foods, Bul. 245.]

COURSE IN VEGETABLE FOODS.

FOURTEENTH LECTURE—PICKLING VEGETABLES.

VINEGAR.

Vinegar is another substance which acts as a food preservative. Its name means "sour wine," and at least when a domestic product it is usually made from cider or light wine, in which bacteria give rise to fermentation and the production of acetic acid. (Reference No. 60, p. 275.) This acid gives the vinegar its sour taste, and is very unfavorable to the growth of bacteria. When vinegar is used in pickle making, the hard fibers of undeveloped vegetables, vegetable skins, etc., are softened by it. Spices and salt have much the same effect as vinegar on bacteria, though in a different degree. These preservatives, of course, entirely change the flavor of food in which they are used, and usually set it among the condimental materials. (Reference Nos. 39, p. 29; 59, pp. 165-168; 61, pp. 140-142; 63, pp. 60-62, 68-74; 71, p. 48; 74, p. 33; 85, chs. 16, 17.)

HERB VINEGARS.

Herb vinegars are useful for the housekeeper's store closet, as by their means a new flavor is easily added to a salad sauce. These may be prepared either in Lesson 10 or here by steeping fresh or dried herbs in cold or hot vinegar. The more delicate flavors may be lost by heating, but the cold process is slower.

PICKLES AND SAUCES.

The word "pickle" is applied to the process of preserving foods, either with salt or vinegar, or both. Thus, meats are pickled in brine, either a saturated solution of salt and water or the water which the dry salt draws out of the foods themselves, which are often three-quarters or more water. When the term is applied to vegetable foods, it is commonly understood to mean preservation with vinegar, either with or without the addition of other materials, as salt, spices, or sugar. In some cases as in dill pickle making, the acid is supplied by the fermentation of the product itself and not by adding vinegar. The number and variety of fruits and vegetables used in pickle making is almost endless, cucumbers, tomatoes, onions, and green or unripe fruits being most common.

An old household name for pickles in which the flavor of vinegar predominates is "sour pickles." Those in which spices are particularly noticeable are frequently spoken of as "spiced pickles" or "spiced fruits," and those in which sugar predominates as "sweet pickles."

The transition is gradual from the acid fruits preserved with sugar and spice to the sweet pickles where somewhat tasteless vegetable tissue has been filled with vinegar instead of natural fruit acid and spiced and sweetened.

By using them for pickle making our thrifty foremothers contrived to make attractive most unpromising food materials as well as common fruits, etc., for instance, the rinds of the watermelon, the unripe windfalls from the fruit tree, martynias, cucumbers, ripe tomatoes, and the green tomatoes remaining when frost had killed the vines. Even young ears of corn 2 or 3 inches long are used for pickles. Though the kernels have already formed, the cobs are tender and will absorb the vinegar.

Some materials are more satisfactory for pickle making if first soaked in salt water to extract acrid flavors. Special treatment of this sort is required with such materials as green melons, but with the more common fruits and vegetables used in pickle making there seems to be little difference in results, whether they are soaked overnight in that fashion or whether they are parboiled in salt water. By either process some water is extracted from the tissues, which are then ready to fill out with the prepared vinegar.

Old recipes for pickle making sometimes call for ingredients not now recommended. The use of alum to insure crispness or a brass kettle to "green" the pickles can not be advised. In these days when fresh fruit from all over the world comes to our doors, are we justified in spending much time to provide many jars of highly seasoned condiments for ourselves or our neighbors? This is a question the housewife should consider.

When the materials used in pickle making are so finely divided that the resulting product is a more or less thick fluid, they are usually called "catsups" or "sauces."

Tomato is a favorite foundation, but many fruits may be cooked and strained for this purpose; decayed ones never should be used.

There are hosts of table sauces which, by their names, seem to be derived from the Orient. Consult a dictionary for the origin of some of these words: Catsup or ketchup, chili sauce, chowchow, chutney, etc., which are made in many ways from diverse materials.

CARE OF PICKLED AND CANNED GOODS.

Any canned foods or pickles should be well cared for. The stone jars with more or less tightly fitting covers used by our grandmothers

[Vegetable Foods, Bul. 245.]

may serve for very sweet or for highly seasoned material, but the glass or other jars with air-tight covers are more satisfactory for all purposes. Each household should have several sizes. Often a large jar is opened and not half its contents used. The remainder can be reheated and again canned in a smaller jar. All jars should be carefully labeled. When one lot of pickles has been used, the vinegar still may serve for partial preparation of another vegetable. The spiced sweet pickle vinegar is usable in several other ways; prunes or beets may be put into it or it may be used in mince pies or stiffened with gelatin to serve with meats.

EXPERIMENT AND PRACTICE WORK, FOURTEENTH LECTURE.

Materials needed.—The materials for this lesson will depend on season and locality. Cabbage and onions usually will be available if nothing else is at hand. Citron melon, watermelon rinds, and green tomatoes are excellent for such lessons.

Simple Pickles.

A simple type of pickling may be observed by grating horseradish or putting it through the food grinder and combining it with sufficient vinegar to moisten it.

Beets cooked in Lecture 8 (p. 47) might be kept in vinegar until this lesson. If the jars were not entirely closed, mold may have formed on the top and yet the beets below be in good condition. They now might be put in a spiced sweetened vinegar, scalded to sterilize them, and canned.

Combination in Pickling.

Almost any combination of onions, peppers, and tomatoes, ripe or green, will form an acceptable relish with vinegar and spices. The basis of the pickles may be of one kind or several, but in the latter case each should be parboiled separately, or some may be hard while others are overcooked.

Exercise.—Collect personal and family recipes for all types of pickles and refer to standard cookbooks dealing with the subject. With the aid of the blackboard, reduce these formulas to their lowest terms and arrange in tabular form.

It will surprise the pupils to see how many recipes for sweet pickles may be condensed to some such form as this: For 2 pounds of prepared vegetables or fruit, 1 pound of sugar (or less), one-half pint vinegar, 1 ounce mixed spice.

The usual sauce for mustard pickles is some variation of this formula: Mix one-fourth to one-half cup sugar with 1 ounce ground mustard and 2 tablespoonfuls flour. Stir into 1 pint hot vinegar and cook until thickened. Turmeric may be added to give color. Combine with 1 quart mixed vegetables parboiled. Note resemblance between salads with cooked dressing and mustard pickles.

Salad oil, such as olive oil, cottonseed oil, or peanut oil, in small proportion is often added to mixed pickles or poured over the top after they are put in jars to protect them from the air and prevent the growth of molds.

To show that the natural acid of some fruits may have the same antiseptic effect as vinegar, put cranberries or rhubarb in sterile jars; fill the jars with clear, freshly sterilized water and seal; time will show that the fruit keeps as well this way as if cooked.

[Vegetable Foods, Bul. 245.]

REVIEW QUESTIONS, FOURTEENTH LECTURE.

1. Define pickles.
2. What are the essential steps in the process of pickling?
3. Describe the making of sweet pickles.
4. Mention some names of products of this type which indicate a universal demand for such foods.
5. Is there any reason why pickles and relishes should be less important to us than to our grandmothers?
6. Why is vinegar useful as a preservative?
7. Are any fruits or vegetables ever pickled without vinegar?
8. What may be combined with vinegar to give it greater efficiency?
9. What need of caution in selecting utensils for pickle making.
10. Are exact recipes essential in the preparation of pickles?

[Vegetable Foods, Bul. 245.]

COURSE IN VEGETABLE FOODS.

FIFTEENTH LECTURE—VEGETABLES FOR THE TABLE: MARKETING.

Savages found their food where they could and pursued game from place to place. Nomadic tribes required a large area to sustain a small population. The fixed hearthstone and planting of seeds were higher steps on the ladder of civilization; grazing succeeded the chase as a method of supplying food, and grazing and crop raising combined are the foundations of agriculture. We do not yet know the possibilities of intensive farming in the development of the food supply. Moreover, the skilled efforts of the farmer must be supplemented by equal intelligence on the part of the cook who handles his products.

CULTIVATING VEGETABLES FOR THE TABLE.

There is an increasing attention given to the cultivation of vegetable foods, with the result that the quality is better and the texture less fibrous. Less attention evidently is being given in this country to production of cakes and pastries, and the per capita consumption of flour appears to be diminishing as coarser cereals, fruits, and vegetables are used more. Some time ago the editor of a hotel periodical gave a summary of many holiday menu cards to show that vegetable dishes were not given the attention or prominence they deserved; that chefs were inclined to ignore common and inexpensive foods; and that if care were taken to make such foods attractive the hotel and restaurant patrons would be educated to prefer them to the superfluity of meat dishes usually provided.

"The result of this, in these days of high prices for all foods, is that the cost of the meals as a whole would be lessened. * * * It is these dishes that are wanted to give variety to the bills of fare and do away with that 'sameness' in hotel cuisine noticeable throughout this most prolific land." This is quite as true of the home table.

Farmers are beginning to see more profit in the intensive cultivation of choice vegetables than in larger acreage of less profitable crops. Too often a type of plant is chosen for its shipping or keeping qualities rather than for flavor and texture. The improved quality of fruits and vegetables gained by improved methods in agriculture is often more than offset by carelessness in packing. Good varieties should be grown by the best methods and handled and shipped so that they reach the consumer in satisfactory condition.

What is needed is greater knowledge on the part of the producer of the relative values of different varieties of the same plant, while the consumers must be discriminating in the selection of the special article for a given purpose or know in what way the available material can best be utilized.

The housekeeper unfamiliar with the country garden hardly knows when a vegetable is at its best, and may buy them at abnormal prices out of season and rely on canned vegetables when "natives" are abundant. Easy transportation, cold storage, and cultivation under glass have changed the times and seasons to a great extent, and while this is often an advantage, still we do not have the same desire or appetite for foods attainable at any time as we do when their season is short. Producer and consumer should confer frequently to secure better food for all and better methods for its transportation and use.

Cold storage has advantages, but often is carried so far that there is distinct loss of quality or flavor or both. (Reference No. 28, p. 27.)

WEIGHTS AND MEASURES.

There is need everywhere of enforcing definite standards of measure and weight, especially in cities where the average portion sold is small; the arithmetic of the vegetable markets is confusing, and more uniform methods of measuring market produce should be adopted. For example, sometimes onions are sold by the quart, sometimes by the pound or by the bunch. Four or six or more may constitute a bunch of beets or young turnips, etc., with little regard to the size of the individual roots.

In many States a legal weight to the bushel has been established for the standard common vegetables; thus a bushel of potatoes should weigh 60 pounds; white beans, 60 pounds; carrots and parsnips, 50 pounds; turnips, 55 pounds; onions, 57 pounds, or about 2 pounds to the quart.

TRADE CUSTOMS AND MARKET CONDITIONS.

Certain trade customs tend to foster ignorance of the best season for each vegetable and the best way to use it. A premium has been placed on bulk rather than quality, size rather than flavor. Why should not summer squashes and cucumbers be sold by weight as well as winter squashes? Most of those in the markets now are overgrown. Asparagus 8 or 10 inches long is less desirable than if it had been cut a day earlier at half the length. The custom of keeping asparagus fresh in water increases its weight by absorption of water, but causes loss of nitrogenous and mineral matter. Celery should not have its roots spoiled by nails or its stalks bound with colored strings. (Reference No. 94, pp. 15, 16.)

[Vegetable Foods, Bul. 245.]

The medicinal qualities of vegetables need fuller investigation. Money spent for scientific research in establishing or refuting traditional and popular ideas about the effects of celery in rheumatism, onions for sleeplessness, etc., should give good returns. Probably in most cases green vegetables and salad plants would prove more useful than "spring medicine," in which so many have faith.

There are times when it is justifiable to pay a larger price for a food than its actual nutritive value seems to warrant because its attractive appearance and flavor will make palatable the more familiar and less costly foods.

The wise buyer knows the nature of each article so well that when strict economy is practiced decayed vegetables are discarded, while those only slightly withered but so unattractive as to be low priced are secured and promptly freshened. (Reference No. 75, p. 281.)

The prices of vegetables in city markets seem exorbitant to those who have never had to pay cash for such products, and then only is the home garden fully appreciated. (Reference Nos. 18; 45, pp. 201, 202.) Too often in the country the garden is neglected that "money crops" may have more attention because its economic value is not recognized. A garden plot intelligently arranged and its products properly prepared for the table, often yields more profit than any corresponding area on a farm.

At the present time the list of vegetables which may be grown is a long one and is being added to as new plants are found or new varieties produced. Some of the novel plants recently brought to this country for experiment by the Department of Agriculture are the "udo," a salad plant from Japan; Hungarian paprika; the dasheen; and the adsuki bean.

The future, judging from the recent past, will give increased facilities for the preservation and transportation of all types of vegetable products from every part of the world. Many plants now little known will be studied, improved, and made available. Fewer seeds and less cellulose or fiber will remain in many of the plants now in common use. There will very likely be greater concentration of the valuable constituents of such foods for convenience in transportation and preservation, but none of the improvements are likely to change the fact that the vegetables are at their best when the interval between their picking and their use is the shortest possible.

GROWING VEGETABLES FOR THE HOME TABLE.

Women should be encouraged to take more interest in the vegetable garden. Even the actual work there is less taxing than much that is done indoors, which gives less valuable return in health and comfort. (Reference No. 17.)

[Vegetable Foods, Bul. 245.]

Too many gardens are planted all at once. It is far better to leave open spaces and plant additional rows of lettuce, radishes, beans, and corn each week until after the middle of summer. Another important point is to prevent the maturing of any seeds if it is desired that plants continue to produce. Therefore cucumbers, summer squash, etc., must be kept closely cut, even when not needed for the home table.

EXPERIMENT AND PRACTICE WORK, FIFTEENTH LECTURE.

Materials needed.—Pencils and paper.

Exercise.—Plan menus for single meals or longer periods containing a wide variety of vegetable products and supplement any deficiencies of nutritive value by other additions. (Reference No. 56.)

Review any processes needing further attention.

Take this opportunity to test initiative of pupils in the preparation of any novel vegetable products available at the time.

REVIEW QUESTIONS, FIFTEENTH LECTURE.

1. Tell all you can of the weights and measures commonly used for the sale of vegetables.
2. Are there any improvements that you can suggest in market customs?
3. How many varieties of vegetables are attainable in your vicinity from garden or market?
4. Are there any vegetables available which are not used in your household, and why?
5. What means have you employed to make any vegetable more popular on your family table?
6. Mention cases in your experience when vegetables were unpalatable because of careless methods of cooking.
7. What of the relative economy of animal and vegetable foods for your household?
8. Plan a menu for one week including as little meat as you think would be reasonable.
9. Compare the energy required to care for a home vegetable garden with that used in making cake, pies, and puddings.
10. What have you to say regarding the rational use of meats, vegetables, and desserts in planning wholesome meals?

[Vegetable Foods, Bul. 245.]

APPENDIX.

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54. Buckwheat. New York (Cornell) Experiment Station Bul. 238.
55. Insect Pests of House and Garden. Cornell Reading-Course for Farmers' Wives, n. ser. 1. Bul. 2.
56. Human Nutrition. Cornell Reading-Course for Farmers' Wives, n. ser. 2. Bul. 6.
57. Composition of Mushrooms. Vermont Experiment Station Rpt. 1903
58. Canning Fruits and Vegetables. Preserving Fruit Juices. Oregon Experiment Station Bul. 87. Canning Mushrooms. Oregon Experiment Station Bul. 98.

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59. Bacteria, Yeasts, and Molds in the Home. H. W. Conn.
60. Food and the Principles of Dietetics. Robert Hutchison.
61. Food Materials and their Adulterations (Third Edition). Ellen H. Richards.
62. Chemistry of Cooking and Cleaning. Ellen H. Richards and S. Maria Elliott.
63. Household Bacteriology. S. Maria Elliott.
64. Food and Dietetics. Alice P. Norton.
65. Chemistry of the Household. Margaret E. Dodd.
66. The Book of Vegetables. Allen French.
67. Cyclopedia of American Agriculture. L. H. Bailey, Editor.
68. Encyclopedia of Practical Cookery. T. F. Garret, Editor.
69. Boston Cook Book. Mary J. Lincoln.
70. Boston Cooking School Cook Book. Fannie M. Farmer.
71. Selection and Preparation of Food. Isabel Bevier and Anna R. Van Meter.
72. Elements of the Theory and Practice of Cookery. Mary E. Williams and Katharine R. Fisher.
73. Home Science Cook-Book. Mary J. Lincoln and Anna Barrows.
74. Principles of Cookery. Anna Barrows.
75. Vegetable Cookery and Meat Substitutes. Sarah T. Rorer.
76. Practical Cooking and Serving. Janet M. Hill.
77. European and American Cookery. Gesline Lemcke.
78. How to Cook Vegetables. Olive Green.

79. Foundations of Botany. J. Y. Bergen.
80. The Teaching Botanist. William F. Ganong.
81. Botany. Charles E. Bessey.
82. Chemistry—Briefer Course. Ira Remsen.
83. Human Mechanism. T. Hough and W. T. Sedgwick.
84. The Spirit of Cookery. J. L. W. Thudichum.
85. Introduction to General Biology. W. T. Sedgwick and E. B. Wilson.
86. Food and Its Functions. James Knight.
87. The Pleasures of the Table. G. H. Elwanger.
88. Practical, Sanitary, and Economic Cookery. Mary H. Abel.
89. The Fireless Cook Book. Margaret J. Mitchell.
90. Woman's Share in Primitive Culture. O. T. Mason.
91. Home Economics. Maria Parloa.
92. Fuels of the Household. Marian White.
93. Salads and Sauces. Thomas J. Murrey.
94. Art of Cookery. Emma P. Ewing.
95. Mushrooms and Their Use. Charles H. Peck.
96. Chemistry of Plant and Animal Life. H. Snyder.
97. Human Foods and Their Nutritive Value. H. Snyder.
98. French Home Cooking. Berthe J. Low.
99. Outlines of Lessons in Botany. Newell.
100. Our Vlands. Buckland.
101. The Chocolate Plant. W. Baker & Co.
102. Spices and How to Know Them. W. M. Gibbs.
103. Chemistry of Cookery. W. M. Williams.
104. Encyclopedia Americana.

LIST OF APPARATUS AND SUPPLIES REQUIRED.

APPARATUS FOR GENERAL USE.

Stove. Scales. 12 glass jars, pints and half pints. 1 quart measure. 1 can opener. 1 potato slicer. 1 wire potato masher. 1 frying basket. 2 to 6 kettles or stewpans. 1 double boiler, 1 quart. 1 double boiler, 2 quart. 1 Dover egg beater. 1 wire egg beater. Food chopper. Vegetable cutters of different types. Chopping bowl and knife. Molds. Bean pot. Pudding dishes. Colander. Fruit funnel. Dish pan.	Garbage can. Box of labels. Roll of paper. Twine. Scissors. Dish towels. Cheesecloth. Paper towels. Alcohol or oil for stoves. Iodin. Ether. Nitric acid. Test tubes. Filter paper. Petrie dishes. Thermometer. Sirup gauge. Microscope. Blackboard and chalk. Charts. Thumb tacks.

APPARATUS FOR INDIVIDUAL USE OF PUPILS.

As many of each article as there are pupils in the class.

Measure cups.	Knife and fork.
Tin or agate pans.	Palette knife.
Tin or agate plates to cover pans.	Paring knife.
Earthen bowls, 1 quart each.	Saucepans.
Strainers to fit cup (fine).	Frying pans.
Strainers to fit bowl (coarser).	Graters.
Tablespoon.	Note books and pencils.
Teaspoons.	

SUPPLIES.

Whatever green vegetables are available, as mentioned in each lesson, or any canned vegetables that will aid in the lessons when fresh vegetables are not available. Also the following:

Dry beans and peas.	Rice.
Nuts.	Tapioca.
Peanut butter.	Cornstarch.
Potatoes.	Salt.
Squash seeds.	Pepper.
Olive oil, cottonseed oil, or other salad oil.	Spices, etc.
Vinegar.	Tea.
Flour.	Coffee.
Sugar.	Chocolate.
Butter.	Vanilla bean.
Cream.	Cream of tartar.
Milk.	Soda.
Eggs.	Soap.
	Sand soap.



U. S. DEPARTMENT OF AGRICULTURE.

OFFICE OF EXPERIMENT STATIONS—BULLETIN 246.

A. C. TRUE, Director.

A REPORT

UPON THE

BACK SWAMP AND JACOB SWAMP DRAINAGE
DISTRICT, ROBESON COUNTY,
NORTH CAROLINA.

BY

SAMUEL H. McCrORY,
Drainage Engineer,

ASSISTED BY

CARL W. MENGEL,
Assistant Drainage Engineer.

PREPARED UNDER THE DIRECTION OF

C. G. ELLIOTT,
Chief of Drainage Investigations.WASHINGTON
GOVERNMENT PRINTING OFFICE
1912

OFFICE OF EXPERIMENT STATIONS.

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E. W. ALLEN, Assistant Director.

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S. M. WOODWARD, A. E. MORGAN, C. F. BROWN, L. L. HIDINGER.

[Bull. 248]

(2)

LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
Washington, D. C., June 15, 1911.

SIR: I have the honor to transmit herewith a report upon the Back Swamp and Jacob Swamp drainage district, Robeson County, N. C., prepared by engineers of this office under the direction of C. G. Elliott, chief of drainage investigations.

This district embraces an area of about 33,000 acres of swamp land in eastern North Carolina, which, when drained, it is believed, will become good agricultural land. The report embodies the results of an examination made by this office with a view to ascertaining and recommending the best methods of accomplishing the reclamation of this land.

The drainage district has already been organized, and as the matters discussed will be of interest to a large number of people who will be affected by the improvements, and likewise serve as an example for the drainage of similar lands in the coastal region, the publication of the report as a bulletin of this office is recommended.

Respectfully,

A. C. TRUE,
Director.

Hon. JAMES WILSON,
Secretary of Agriculture.

[Bull. 246]

(3)

CONTENTS.

	Page.
Introduction.....	7
General description.....	8
Watersheds.....	8
Drainage channels.....	9
The Lumber River.....	10
Back Swamp.....	10
Jacob Swamp.....	11
Gum Branch and Cotton Mill Branch.....	11
Soil and crops.....	11
The survey.....	12
Rainfall and run-off.....	13
Rainfall.....	14
Heavy storms.....	14
Run-off.....	17
The plan recommended.....	18
Details of construction.....	18
Size of ditches.....	18
Berms and side slopes.....	19
Right of way.....	19
Unit prices for excavation.....	20
Maintenance.....	21
Bridges.....	21
Outlets for farm drainage.....	21
Drainage at Maxton.....	22
The improvements in detail.....	22
Back Swamp.....	22
Lateral A.....	24
Dees Branch.....	25
Cypress Branch.....	25
Turkey Branch.....	27
Little Back Swamp.....	27
Jacob Swamp.....	28
Little Jacob Swamp.....	30
South Fork, Panther Branch.....	30
Lateral X.....	31
Cotton Mill Branch.....	31
Gum Branch.....	32
Summary of estimates.....	32
Review and conclusion.....	33

APPENDIX I.

Monthly, annual, and normal precipitation, in inches and hundredths, at Lumberton, Robeson County, N. C.....	34
Monthly, annual, and normal precipitation, in inches and hundredths, at Fayetteville, Cumberland County, N. C.....	34

	Page.
Monthly, annual, and normal precipitation, in inches and hundredths, at Whiteville, Columbus County, N. C.....	35
Storm periods for the years 1896 to 1910, inclusive, as shown by the records of the U. S. Weather Bureau stations at Fair Bluff, Lumberton, Fayetteville, and Whiteville, N. C.....	35
APPENDIX II.	
List of bench marks set.....	41
APPENDIX III.	
Courses and distances of located lines.....	44
APPENDIX IV.	
General specifications for open ditches in Back Swamp and Jacob Swamp drainage district.....	46

ILLUSTRATIONS.

	Page.
FIG. 1. Watershed map of Back Swamp and Jacob Swamp drainage district....	9
2. Map of Back Swamp and Jacob Swamp drainage district. (Sheet 1, Back Swamp).....	12
3. Map of Back Swamp and Jacob Swamp drainage district. (Sheet 2, Back Swamp).....	12
4. Map of Back Swamp and Jacob Swamp drainage district. (Sheet 3, Jacob Swamp).....	12
5. Profiles of proposed ditches in Back Swamp and Jacob Swamp drainage district. (Sheet 1).....	12
6. Profiles of proposed ditches in Back Swamp and Jacob Swamp drainage district. (Sheet 2).....	12
7. Cross section of minimum dredged ditch, Back Swamp and Jacob Swamp drainage district.....	19

[Bull. 246]

THE BACK SWAMP AND JACOB SWAMP DRAINAGE DISTRICT, NORTH CAROLINA.

INTRODUCTION.

The need of drainage in the territory of the Back Swamp and Jacob Swamp drainage district, Robeson County, N. C., was brought to the attention of drainage investigations, Office of Experiment Stations, United States Department of Agriculture, in March, 1910, by Mr. Daniel B. McNeil, through Representative H. L. Godwin, who requested that an engineer from the office be sent to make an examination of the district and advise the interested landowners as to the possibilities of drainage. H. A. Kipp, drainage engineer, was detailed by the office to make a preliminary examination of the proposed district and to advise the interested parties as to the best plan to follow in the construction of a drainage system. On April 11 and 12, 1910, Mr. Kipp made an examination and found that all the land in the proposed district could be drained. The landowners had already started the formation of a drainage district, and they requested that the office make the necessary survey and prepare a plan for drainage. As the problems involved and the methods to be pursued in the draining of these lands are more or less typical of those of other swamp areas in the eastern part of the State, this request was granted. An agreement was made between the office and the interested landowners, under the terms of which the former agreed to make the survey and prepare a plan for draining the district, furnishing the services of engineers and rodmen, and the necessary equipment and subsistence for the entire party, the landowners to furnish the services of Mr. F. F. Wetmore, engineer for the drainage district, and all labor necessary in making the survey.

To expedite matters Mr. Wetmore made a preliminary survey of the district during the summer of 1910, and the organization of a drainage district was started under the State drainage law. The project was assigned to Samuel H. McCrory, drainage engineer, assisted by Carl W. Mengel, assistant drainage engineer, both of drainage investigations, Office of Experiment Stations. A field party was organized at Maxton, N. C., September 13, 1910, and the survey begun at the upper end of the district. It was completed December 9, 1910, and the party transferred to another project.

A description of the survey and the method of applying the data obtained therefrom are set forth in this report, which contains also detailed recommendations for draining the district and an estimate in detail of the cost of the proposed improvements. Accompanying the report and forming an essential part thereof are a general map (in three sheets), showing the physical features of the district and the proposed system of drainage, and two sheets showing in profile the several ditches and the natural ground surface along the lines upon which the ditches are located. Tables of rainfall data, a list of permanent bench marks set, descriptions of the located ditch lines, and specifications for the ditches are given as appendixes.

GENERAL DESCRIPTION.

Back and Jacob swamps are located on the south side of the Lumber River in Robeson County, N. C. Back Swamp heads about 1 mile southeast of Maxton, N. C., and runs to the southeast, paralleling the Lumber River to a point near Back Swamp Church, where it turns to the north and enters Lumber River. The watershed is about 17 miles long and varies in width from one-half to $2\frac{1}{2}$ miles and contains 21,550 acres, about one-third of which is under cultivation. Jacob Swamp heads in Back Swamp near Back Swamp Church and runs to the southeast, entering the Lumber River at a point $4\frac{1}{2}$ miles southeast of Lumberton, N. C. Its watershed has a length of $9\frac{1}{2}$ miles and varies in width from 1 to 4 miles. Its drainage area contains 9,980 acres, approximately one-fourth of which is cultivated land.

Gum and Cotton Mill branches are two small tributaries lying south of the Seaboard Air Line Railway, near Lumberton. They empty directly into the river and drain 1,320 acres, about 10 per cent of which is under cultivation.

The general location of the drainage district and of the several watersheds is shown in figure 1. The boundary of the district has been made to coincide with the outside watershed boundary lines of the several drainage areas. The district is crossed from north to south by the Atlantic Coast Line Railway and the Alma Lumber Co. and Beaufort Lumber Co. tramroads. There are no towns in the district, and it can be most conveniently reached by driving from Maxton, Pembroke, or Lumberton.

WATERSHEDS.

The secondary watersheds are very flat with general slopes toward the branches, while the whole watershed slopes to the east. In a few places ridges rise abruptly to a height of 15 or 20 feet above the general level, the largest of these being the ridge at Back Swamp

[Bull. 246]

Church and the ridge between Dees Branch and Cypress Branch above the Lowery Road. The natural drainage of nearly all the land in the district is poor. The land on the ridges that can be most easily drained has been cleared and is under cultivation. The lowland and that in the swamps is still in timber, although in places attempts have been made to clear this land and to farm it. The land will grow fine crops in dry years when conditions are favorable, but in wet years the crops are failures. The greater part of the timberland in the district has such poor drainage that until improved outlets are provided for the drainage it can not be cleared and cultivated successfully. The cultivated land has almost the same need

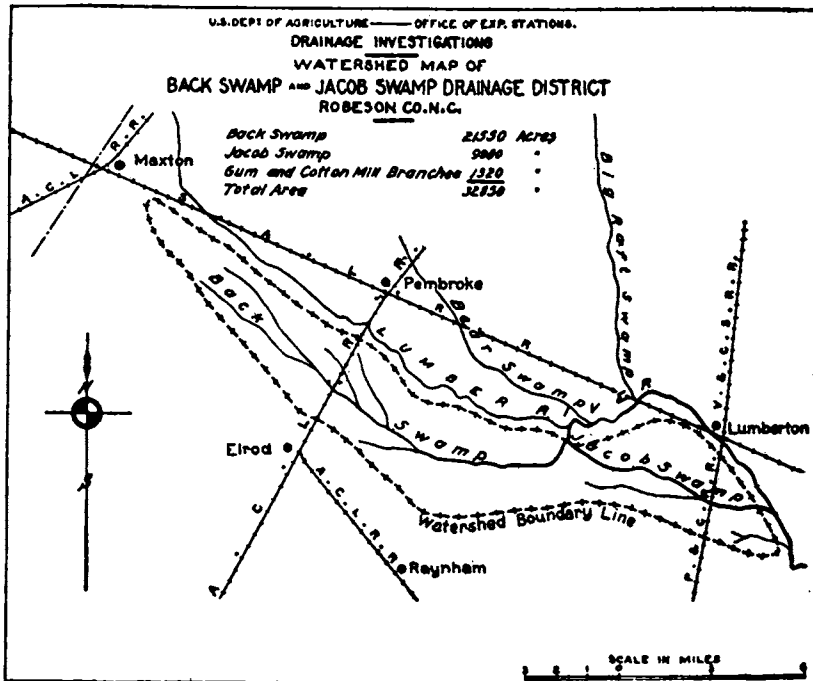


FIG. 1.—Watershed map of Back Swamp and Jacob Swamp drainage district.

for drainage as the unimproved. Attempts have been made to drain this land, but on account of the poor outlets for the field ditches it has not been possible to obtain the results desired; nearly every field in the district shows the need of better drainage.

DRAINAGE CHANNELS.

During the rainy season the entire district is wet. The flat character of the watershed makes the movement of the water to the present drainage channels extremely slow; over much of the district the water stands in the low places until it evaporates. The present

drainage channels, even if cleared, are entirely inadequate to remove the drainage from the district or give a satisfactory outlet for lateral or farm drainage.

The district is drained by four main watercourses—Back Swamp, Jacob Swamp, Gum Branch, and Cotton Mill Branch, which discharge into the Lumber River, the ultimate outlet for this region.

THE LUMBER RIVER.

The Lumber River is the outlet for the entire district. In Robeson County the river is very crooked, flowing through a wet gum and cypress swamp. The banks of the stream in the swamp are low, and at many places the river overflows its banks and runs through the swamp; a small rise in the river will flood the entire river swamp. The bottom of the channel is sandy. The water in the deepest part of the channel was from 8 to 10 feet deep at the time the survey was made. The river has a fall of 41 feet from a point near Mr. J. B. Sellers's residence to the mouth of Back Swamp and of 20 feet from the mouth of Back Swamp to the mouth of Jacob Swamp Ditch. Above the mouth of Back Swamp the Lumber River drains 575 square miles. The flood line of the 1908 flood, as nearly as can be determined from available data, was between 10 and 11 feet higher than the water level at the time the survey was made. With the river in its present condition, a limited amount of work at the mouths of the proposed ditches will afford them good outlet.

BACK SWAMP.

Back Swamp is the most important of the interior drainage outlets, draining about two-thirds of the entire district. Through the greater part of its course it is a broad, flat, swampy waterway with poorly defined banks, and covered with a heavy growth of timber and underbrush. The channel varies in width from 50 to 1,500 feet. The drainage from its watershed finds its way slowly through the tangled undergrowth in the swamp, and in only a few places is the channel at all defined. At the time the survey was made the swamp was dry, excepting the portion near the river. The present channel or "run" of the swamp affords no outlet for lateral drainage when there is water in it; for this reason it is impossible to cultivate much of the land in the district. Back Swamp receives the drainage from a number of tributary drains; these are very similar in character to the main stream, with wide, flat swamps and poorly defined banks, most of which are so shallow that they afford but indifferent outlet to lateral or farm drainage. All tributaries are heavily timbered and covered with dense undergrowth, but they are well located to serve as outlet drains if their channels were improved.

JACOB SWAMP.

Jacob Swamp is similar in character to Back Swamp, having a wide, flat, swampy drainage channel heavily timbered and varying in width from 150 to 800 feet and having well-defined but not steep banks. About a mile above the mouth of Jacob Swamp a low place is found on the south bank. During floods part of the water is diverted from Jacob Swamp and, passing through this low area, reaches Panther Branch and through it the river. Little Jacob Swamp enters Jacob Swamp from the south, and Panther Branch drains part of the watershed and really should be considered as part of the same stream. Panther Branch is a wide, flat swamp, with no defined channel and covered with a very heavy growth of timber and undergrowth.

GUM BRANCH AND COTTON MILL BRANCH.

Gum Branch and Cotton Mill Branch are small watercourses that drain directly into the river. Near the river they have well-defined channels that flatten out near the head. Both branches head in large swamps or brakes.

SOIL AND CROPS.

The district lies within the Atlantic Coastal Plain, and its soils are typical of this region, being loams varying greatly in character, color, and texture. The Bureau of Soils, United States Department of Agriculture, has made a survey of Robeson County and divides the soils of the district into nine different types. From the report ¹ on this survey the following quotations are made:

Norfolk sandy loam.—The surface soil of the Norfolk sandy loam consists of a gray, yellowish gray, or light-brown, medium to coarse sandy loam, about 8 to 12 inches deep. * * * This soil is cultivated with ease, and its position allows the use of modern machinery for practically all areas. Over the larger and more uniform areas the subsoil is a yellow, sticky, sandy clay, and in a few localities it is a yellow, sticky, sandy loam, especially sandy near the areas of Norfolk sand. * * * The Norfolk sandy loam is the best general farming soil in the county. It is well adapted to the production of cotton, peanuts, tobacco, Irish potatoes, sweet potatoes, corn; and cow-peas. The truck crops, such as watermelons, cantaloups, beans, English peas, tomatoes, sweet corn, and asparagus, do well on the lighter phase of this type.

Portsmouth sandy loam.—The soil of the Portsmouth sandy loam to a depth of 6 to 15 inches is a dark gray or black, medium to coarse sandy loam. The gray phase is usually under cultivation, while the heavy black phase, locally known as black land, occurs in the forested and poorly drained areas. * * * The subsoil is a light gray, sticky, sandy clay mottled with brown and sometimes red or yellow. Just south of Lumberton a yellowish mottled clay is found. * * * Much of the subsoil holds water well and acts like an impervious clay. * * * This soil when good drainage has been established is well suited to corn, oats, cotton, cabbage, onions, strawberries,

¹ Soil Survey of Robeson County, N. C., by W. Edward Hearn.

and garden vegetables. It ranks as one of the best corn soils in the county. * * * The soil is fairly easily tilled, and machinery can be used to good advantage.

Swamp.—The soil in the areas mapped as swamp vary in texture from a heavy loam to a coarse sand, and no textural or type classification could be made on account of the wet conditions. If drained much of the soil could be classed with types of the Portsmouth series.

Small areas of Norfolk fine sandy loam, Norfolk very fine sandy loam, Portsmouth loam, Portsmouth fine sandy loam, Norfolk sand, and Orangeburg fine sandy loam are found at various places in the district, but are of such small extent as to be unimportant. All the soils in the district are fertile, easily tilled, and if well drained would produce fine crops. The value of the improved lands ranges from \$25 to \$100 per acre and that of unimproved portions from \$10 to \$35.

The principal crop in the district is cotton, it being the crop that is sold, corn and hay being raised for home consumption. Formerly tobacco was grown extensively, but its low price has made the industry unprofitable, and at the time the survey was made but a small amount of tobacco was being grown in the district. A few fields of wheat and oats are grown. Irish and sweet potatoes are raised for early shipping and home consumption. Strawberries, watermelons, and vegetables do well in the district, as do also peaches, pears, figs, apples, mulberries, and grapes.

Much of the timber is being cut and used for lumber and crossties. Lumbering at the present time is an important industry in the district, and the lumber products are valuable.

THE SURVEY.

A field party was organized at Maxton, N. C., September 13, 1910, and the survey started on the following day, at the upper end of the district. The large branches were all meandered, using stadia and compass, sufficient topography being taken to enable the best ditch lines to be determined. The ditch lines were then located, all distances being measured with a steel tape, and pine stakes 1 by 2 by 24 inches long, with the station numbers marked on them with blue crayon, were set at 100-foot intervals and at all points where the ditches changed direction.

In locating the proposed ditch lines, letters were used to designate the different lines and make them easy to identify. The station numbers marked on the stakes of the located ditch lines are in every case preceded by the letter that designates the swamp or branch which the ditch follows. The ditch lines located and the letter designating each ditch line are as follows:

Back Swamp (L), Lateral A (A), Dees Branch (B), Cypress Branch (C), Turkey Branch (D), Jacob Swamp (E), Little Back Swamp (F),

[Bull. 246]

uran
1870
1871
1872
1873

FIG. 3.
Sheet NPL

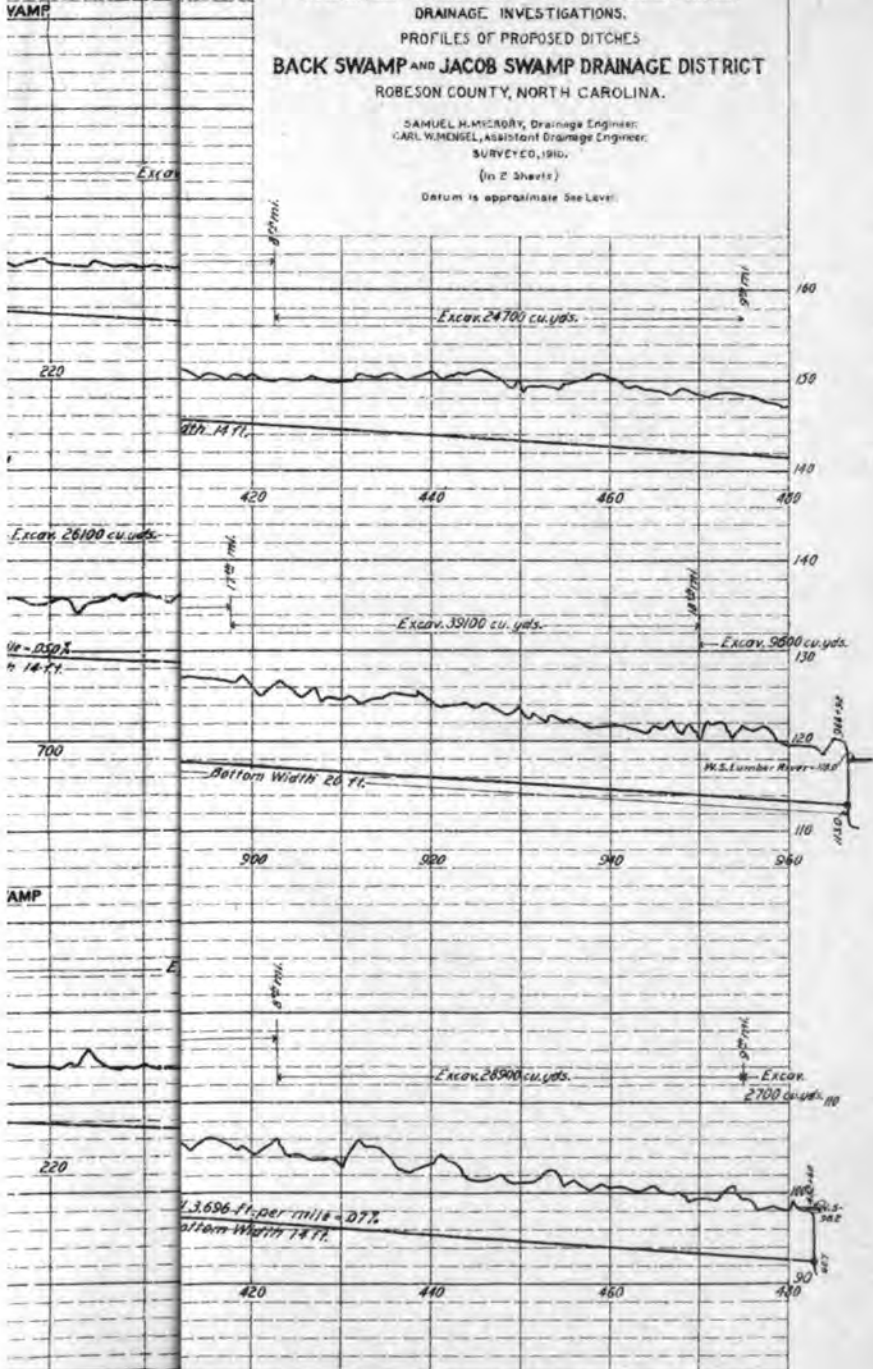
U.S. DEPARTMENT OF AGRICULTURE OFFICE OF EXPERIMENT STATIONS
DRAINAGE INVESTIGATIONS.
PROFILES OF PROPOSED DITCHES

BACK SWAMP AND JACOB SWAMP DRAINAGE DISTRICT
ROBESON COUNTY, NORTH CAROLINA.

SAMUEL H. MAYER, Drainage Engineer.
CARL W. MENDEL, Assistant Drainage Engineer.
SURVEYED, 1910.

(In 2 Sheets)

Datum is approximate Sea Level.



THE ENGINEER-PETERSEN, WASHINGTON, D. C.

Excor. 220

40

Excor

220

Excor. 23200 cu. yds

80

Little Jacob Swamp (G), Gum Branch (H), Cotton Mill Branch (K), South Fork Panther Branch (S), and Lateral X (X).

The trees on both sides of each line were well blazed, so that the line can be retraced even though the stakes be destroyed. All courses are magnetic bearings. Elevations were taken at each stake on all located ditch lines. Cross sections, consisting of a stadia and level traverse, were made at approximate 1-mile intervals and were tied to all ditch lines and other traverses that were crossed. All the important roads in the district were traversed. The elevation of the top of the rail in front of the Seaboard Air Line Railway depot at Maxton was obtained from the Dictionary of Altitudes, United States Geological Survey, the datum of which is approximately sea level. This was taken as a starting point and a base line of levels run around that part of the district surveyed from the first camp, and all level work was tied to this closed circuit. A similar plan was adopted for all the work. All level work was checked within the allowable error for good Y level work. On all level work bench marks were set at intervals of about 1 mile, each of these being numbered and marked with the number of the bench mark and initial of the person setting it. A list and description of all bench marks set are given as Appendix II. The watershed line and district boundary was located by running lines of levels across it at approximate half-mile intervals and sketching the watershed between these lines. The Lumber River was meandered from Barkers Bridge, above the mouth of Back Swamp, to McNeils Bridge, about 4 miles below the mouth of Back Swamp, and from the mouth of Jacob Swamp to a point about 1 mile below. The data obtained on the survey are set forth on the accompanying maps and profiles. (Figs. 2 to 6, inclusive.)

RAINFALL AND RUN-OFF.

Of the total precipitation that falls upon a given tract of land, a certain portion is taken up by vegetation, some is removed by evaporation, some sinks into the ground, and some finds its way over the surface into natural or artificial channels and thence into the larger streams. The water removed in the last-mentioned manner is known as run-off; a certain portion of the water that sinks into the ground later appears also as run-off. The rate of run-off, as the term is used in the following discussion, is the depth of water, in inches, over the entire watershed that passes off through surface channels in a period of 24 hours as a result of maximum precipitation. For convenience in making calculations the rate of run-off is also expressed in cubic feet per second. It is that part of the precipitation which appears as run-off that must be dealt with in reclaiming lands that under natural conditions are perpetual swamps or that are periodically damaged by the overflow of adjoining streams.

[Bull. 246]

The most important factors affecting the rate of run-off from a given watershed are: Precipitation; the size, shape, and topography of the watershed; the nature of the soil; the character of the vegetation; and the rate of evaporation. Of these the most important consideration is precipitation, and therefore before an intelligent decision can be arrived at as to the volume of water a proposed drainage system must be designed to handle a careful study of the precipitation in the region involved must be made. The maximum monthly and daily rainfall, the frequency, duration, and intensity of large rainstorms, as well as the time of the year in which they are most likely to occur, are matters of prime importance as bases for the design of drainage improvements. The stations of the United States Weather Bureau are now so well distributed over the country that records for a varying number of years past are usually available for almost any region for which such information is desired. These records are invaluable in the study of rainfall as applied to the question of drainage.

RAINFALL.

The rainfall records from four observation stations of the United States Weather Bureau near the district have been compiled for a period from September, 1896, to date. Unfortunately the record at Lumberton, the only station in the immediate vicinity of Back and Jacob Swamps, is incomplete. Fayetteville was chosen as the nearest station to the district where a full record could be obtained. The records of the stations at Fair Bluff and Whiteville are incomplete, but are presented as showing something of the way the rainfall is distributed in this region. Tables have been prepared from the Weather Bureau records showing the monthly and annual rainfall for the years from 1896 to 1910, inclusive, and the daily precipitation during all storm periods within this time, where the daily precipitation at any station exceeded 1 inch; these tables are attached to the report as Appendix I.

The annual rainfall at Lumberton varies from a minimum of 38.43 inches in 1909 to a maximum of 62.76 in 1901. The table of monthly and annual rainfall shows that February, June, July, and August have a normal precipitation exceeding 5 inches per month. The minimum monthly rainfall recorded was 0.28 inch in October, 1896, and the maximum monthly was 12.52 inches in May, 1901. The maximum recorded precipitation in 24 hours occurred September 14 and 15, 1904, when 5.87 inches fell.

HEAVY STORMS.

The following table has been prepared to show the frequency of heavy storms in the district and the seasons in which they are most likely to occur:

[Bull. 240]

Dates of excessive precipitation (2 inches or more in 24 hours) at Lumberton, Robeson County, N. C., 1897 to 1910, inclusive.

[From records of the U. S. Weather Bureau.]

Date.	Inches.	Date.	Inches.	Date.	Inches.	Date.	Inches.
1897.		1900.		1904.		1907.	
May 2	2.54	Apr. 21	2.35	June 30	2.91	June 11	3.90
June 5	2.00			Sept. 14	5.87	July 15	2.30
July 21	2.20	1901.		Oct. 21	2.86	Aug. 19	3.67
1898.		May 20	2.59			Sept. 29	2.76
July 31	2.95	May 22	4.12	1905.			
Sept. 8	2.06	July 18	2.22	May 11	2.72	1908.	
Nov. 17	2.11	Sept. 1	4.48			June 26	2.51
		Sept. 18	2.09	1906.		Aug. 19	3.03
1899.				Jan. 26	2.14	Sept. 6	2.22
June 11	2.12	1903.		Feb. 9	2.00	Oct. 23	2.20
July 18	2.60	Feb. 8	3.00	Feb. 13	2.64		
July 25	2.09	Feb. 28	2.01	June 14	3.06	1909.	
Oct. 31	4.06	Mar. 30	2.46			June 4	2.13
		June 19	2.43			Aug. 15	2.32
		July 14	2.33				
						1910.	
						June 6	2.16

1 5.87 inches of rain fell in 24 hours on Sept. 14 and 15, 1904.

An examination of the foregoing table shows that during these 14 years there were 4 days in which there was a precipitation of 4 inches or more and 9 days in which more than 3 inches fell in the 24 hours.

The periods of heavy precipitation in the foregoing table are divided among the months as follows:

Periods of heavy precipitation at Lumberton, Robeson County, N. C., 1897-1910, inclusive.

Months.	Periods.	Months.	Periods.	Months.	Periods.
January.....	0	May.....	4	September...	7
February.....	4	June.....	8	October.....	3
March.....	1	July.....	7	November.....	1
April.....	1	August.....	3	December.....	0

It is apparent from the above classification that the heavy or flood-causing storms are most likely to occur during the summer months, from June to September, inclusive.

There is but little available information as to when overflow conditions occur in the district, and the lack of these data make it difficult to determine just how great a precipitation in a given period is necessary to cause overflow conditions. In June, 1910, there was a rainy period that caused the Lumber River to reach a high stage and caused overflow in the district. The precipitation for this storm period is given in the following table:

Daily precipitation (in inches) at Fayetteville, Lumberton, and Whiteville, N. C., from June 5 to 17, 1910.

Stations.	June, 1910.														Total.	Average daily.
	5	6	7	8	9	10	11	12	13	14	15	16	17			
Fayetteville.....	0.15	1.70	0.02	.....	.....	0.31	1.54	0.02	1.58	0.10	1.30	0.26	0.02	7.00	0.54	
Lumberton.....	Tr.	2.18	.03	Tr.	Tr.	Tr.	1.67	.41	1.14	.15	.70	.42	.02	6.70	.51	
Whiteville.....	Tr.	2.10	.02	0.06	0.10	.14	1.07	.33	1.02	.27	.92	.23	.01	6.27	.48	

This storm caused high water over the entire district, and in the Lumber River the flood water is said to have reached a stage about 2 feet lower than that reached by the flood of 1908.

The records of the Weather Bureau show that two floods or freshets occurred in North Carolina during 1908. The first of these occurred in July and was caused by the storm period from the 28th to the 31st, inclusive. The largest flood occurred during the latter part of August, the river reaching its highest stage August 30, when the entire district was again flooded. The people living in the district stated that this latter overflow was the highest that they had ever seen. It was the opinion of some of the Croatan Indians that the river at this time was higher than it had been at any time in the past 100 years. The following table has been prepared showing the daily precipitation during the storm period that caused the floods of 1908:

Daily precipitation (in inches) at Fayetteville, Lumberton, and Whiteville, N. C., from July 28 to August 27, 1908.

Stations.	July.				August.							
	28	29	30	31	1	6	7	8	9	13	14	16
Fayetteville.....	0.87	0.03	0.35	1.34	0.09	0.66			1.09			0.96
Lumberton.....	1.12	.06	1.04	1.82	.09		0.40	Tr.	.53		Tr.	
Whiteville.....	1.50	.50	5.60	1.50		.17		0.37	.10	0.05		.66

Stations.	August.										Total.
	17	19	20	21	22	23	24	25	26	27	
Fayetteville.....	0.40	0.63	0.32	0.86	0.61		4.68	1.02	0.78	1.44	16.13
Lumberton.....	.30	3.03	.14	1.32	.67	0.27	.20	.20	.23	1.00	12.42
Whiteville.....		2.75	.05	.65	.10	.06	Tr.	1.00	2.00	.85	17.91

The rainfall records further show that in 1901 exceedingly heavy rains occurred at Lumberton, causing floods over the entire district; no information is available, however, as to the exact height reached by the water at this time. The maximum yearly and monthly precipitations recorded at Lumberton occurred during this year. The records of the Weather Bureau covering the period from 1882 to date show no storms exceeding in precipitation those of 1901 and 1908. C. F. von Herrman, section director in climate and crops, North Carolina section, September, 1901, states:

The average precipitation for the State from April 1 to September 30, 1901, was 15 inches in excess of the normal amount. During no other period since 1872 has such excessive rainfall been recorded in North Carolina.

In the past 14 years, as shown in the table on page 37, there have been 39 days when the precipitation at Lumberton has been 2 inches

[Bull. 246]

or more in 24 hours. On 9 days the precipitation has exceeded 3 inches in 24 hours, and on 4 days it has exceeded 4 inches in 24 hours. The storm period of 1908, which caused the highest floods on record, extended over a period of 31 days. The average daily precipitation during this period was, at Fayetteville, 0.52 inch; at Lumberton, 0.40 inch, and at Whiteville, 0.54 inch. Two short periods of very heavy precipitation occurred during this time. From July 28 to 31, inclusive, the daily average precipitation was Fayetteville, 0.65 inch; Lumberton, 1.02 inches; and Whiteville, 2.27 inches. Again, from August 19 to 27, inclusive, the average daily precipitation was Fayetteville, 1.15 inches; Lumberton, 0.78 inch, and Whiteville, 0.83 inch. A storm period with heavy precipitation occurred from May 19 to 23, 1901; the average daily precipitation for this period was Fayetteville, 1.09 inches; Lumberton, 1.87 inches. The storm period that caused the 1910 storm had an average daily precipitation of 0.51 inch for 13 days. The storms of 1901 and 1910 are the heaviest that have occurred in the last 14 years. Storms of such intensity as that of 1908 are not apt to occur often, and from all that can be learned no other storm in the past 50 years has caused such high water.

RUN-OFF.

It has been stated that the rate of run-off from a watershed is affected by the size, shape, and topography of the latter. In a large watershed, other things being equal, the run-off in 24 hours, per unit of area, will be less than that in a smaller one, for the reason that in the former the water falling near the outlet channel will tend to pass off before the arrival of that falling upon the more distant portions of the drainage area. For the same reason a fan-shaped watershed, whose outlet is at the apex, would have a greater rate of run-off per unit of area than would a long and narrow one of the same area and having similar topography; and obviously, a rough, precipitous area would concentrate the water falling upon it much more quickly than would a level watershed.

The watershed of Back Swamp is long and narrow; the surface is flat, with no steep slopes in any part of the area. The soil over the entire area is a very absorbent sandy loam. In the months when, as shown by the records, the precipitation is apt to be the heaviest and floods most harmful, vegetation is growing rapidly and requires a great deal of water. Evaporation is also the most rapid during the summer months.

Aside from the storms of 1901 and 1908, there are no storm periods that show an average daily precipitation in this region of more than 0.75 of an inch over a long period of time, and as the heaviest storms generally occur in the months from May to September, when condi-

tions are most favorable for the soil to absorb precipitation, and as the soil absorbs water readily and responds quickly to drainage, it was decided that ditches designed to remove a run-off of one-half inch of water in 24 hours from the entire watershed of Back Swamp and three-fourths of an inch of water in 24 hours from the watershed of Jacob Swamp, would afford good drainage. The higher rate of run-off assumed for Jacob Swamp is due to the fact that its area is less than half that of Back Swamp. The size of the upper portions of the main ditch and of the lateral ditches was determined by the requirements of the machinery to be used in their construction; all lateral ditches will remove a run-off of 1 inch or more of water in 24 hours from their watersheds. The ditches are planned to remove this amount of water when the depth of flow is but 5.5 feet, and will remove about 30 per cent more when running bank full.

THE PLAN RECOMMENDED.

The plan recommended for the improvement of the district includes:

- (1) The construction of ditches in the larger natural drainage channels.
- (2) The improvement of the Lumber River.

DETAILS OF CONSTRUCTION.

All the ditches in the district are located in the lowest parts of the swamps and branches, all of which are heavily timbered and during the greater part of the year wet. September and October of the year 1910 were the driest on record at Lumberton, and the greater part of the swamps was dry during these months, but with the usual amount of rain all the swamps and branches will be wet the greater part of the year.

In Appendix IV are given some specifications which cover the main points to be met with in ordinary ditch construction. These are general specifications for drainage ditches which have been altered to meet the conditions of the Back and Jacob Swamp project. It is assumed that more detailed specifications will be prepared before contracts are let. In the following paragraphs the main features of ditch construction are discussed in some detail.

SIZE OF DITCHES.

There are many different kinds of machines that are used for excavating drainage ditches in various sections of the country. It is probable, however, that the machine best adapted to the Back and Jacob Swamp work is some type of floating dipper dredge. The decision as to the type of machine to be used is usually left to the contractor for the work.

Experience has shown that the smallest ditch that can be built by a dipper dredge in a wooded country is one having a 14-foot bottom and side slopes suited to the material in which the ditch is excavated. A ditch with a 14-foot bottom and 1 to 1 side slopes and having a depth of about 6 feet is well adapted to the conditions existing in the district, and this size was therefore adopted as the minimum section for dredged ditches (fig. 7). Side slopes of 1 to 1 rather than one-half to 1, as is usual for dredged ditches, are specified on account of the sandy nature of the soil. It is true that a ditch of these dimensions is, in some cases, larger than the assumed rate of run-off would require. The cheapness of dredge work, however, as compared with handwork makes it much more economical to construct a ditch of sufficient size to float a dipper dredge in order

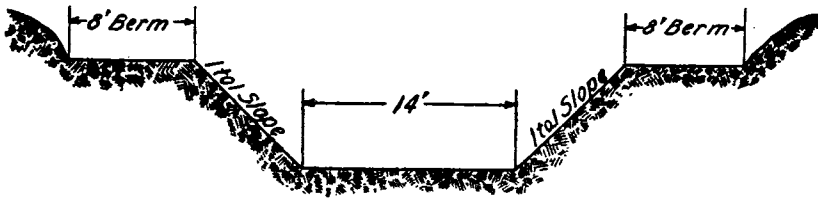


FIG. 7.—Cross section of minimum dredged ditch, Back Swamp and Jacob Swamp drainage district.

to obtain the advantage of the low price per yard made possible by the use of a dredge of this type.

BERMS AND SIDE SLOPES.

Clean berms should be left on all ditches. The small ditches that are to be dug by hand labor should have a berm 6 feet wide on each side. All ditches constructed with 14-foot bases or wider should have a berm 8 feet wide on each side. All ditches should have banks with side slopes of 1 to 1.

RIGHT OF WAY.

It will be necessary to clear a right of way for all the ditches. A right of way 80 feet wide will be necessary for all ditches with 14-foot bottoms and 90 feet wide for ditches with 16, 18, and 20 foot bottoms. The right of way should be cleared as rapidly as possible after the contract is let. When cleared, there will be afforded a much better outlet to flood water than now exists. The fear has been expressed by persons living in the district that the lands in the lower part of the district would be flooded if heavy rains occurred while the ditch was under construction. By clearing the right of way in advance of the dredge all danger of flooding before the ditch is

completed is avoided. The following statement shows the amount of right of way required for each ditch:

Acres of right of way required for each ditch.

Ditch.	Acres.	Ditch.	Acres.
Back Swamp.....	180	Jacob Swamp.....	87
Lateral A.....	3	Little Jacob Swamp.....	41
Dees Branch.....	48	South Fork Panther Branch.....	13
Cypress Branch.....	43	Lateral X.....	5
Turkey Branch.....	33	Cotton Mill Branch.....	14
Little Back Swamp.....	19	Gum Branch.....	23

The right of way required will be in the lowest part of the swamps and branches, and the price per acre should not be high. It is believed that \$10 per acre will be a fair price for the land taken for right of way.

UNIT PRICES FOR EXCAVATION.

It will be best to let the work in the district in such a manner that each dredge will have enough work to keep it busy for the time allowed in which to complete the work. The unit cost of excavation will depend to a large extent upon the amount of excavation that each machine will have. Three dredges should be able to complete the work in two years after the contract is let. If the work is let to different contractors, it could be advantageously divided in the following manner:

Contract No. 1, ditch in Back Swamp, lateral A, and section No. 1 of Cypress Branch, all of which can be excavated by one dredge without rebuilding. Total excavation, 509,900 cubic yards.

Contract No. 2, ditches in Dees Branch, section No. 2 of Cypress Branch, Turkey Branch, and Little Back Swamp. Total excavation, 342,200 cubic yards.

Contract No. 3, ditches in Jacob Swamp, Little Jacob Swamp, South Fork of Panther Branch, and lateral X of Jacob Swamp. Total excavation, 359,400 cubic yards.

The hand ditches in Gum and Cotton Mill Branches should be let as a separate contract.

The amount of excavation that will be necessary in the construction of each ditch has been computed, using the elevations taken at the stations and assuming that the ground surface at each station is level transversely to the ditch. The estimated amount of excavation in each mile section of the several ditches and the total excavation required for the construction of each ditch, as determined in this manner, is shown in the following pages. Parts of the ditches where the surface is quite uneven should be cross sectioned before the ditches are constructed and the yardage more accurately determined.

Work very similar in character to that in the district has been let recently for from 6 to 10 cents per cubic yard. The time that is allowed for the construction of the ditches will have a material effect on the unit prices. Assuming that the work will be let in sections, so that each dredge will have approximately two years' work, it is believed that the ditches which one dredge can construct in this time without rebuilding can be let for 8 cents per cubic yard, whereas those ditches where the dredge will have to be rebuilt at the completion of each ditch will cost approximately 9 cents per cubic yard. On all ditches that are to be constructed by hand labor the cost of excavation has been estimated at 20 cents per cubic yard. These prices include clearing the right of way.

MAINTENANCE.

After the ditches are completed they should be examined at least once each year, and all trees, logs, brush, snags, and other obstructions removed. If the ditches have become silted up at any place the silt should be removed. No fences, fish traps, or piling should be allowed in the channel. The inspection should be made before each rainy season. A small amount of work each year will keep the ditches in good order and make them permanent structures, but if dug and not taken care of they will deteriorate rapidly and will have to be rebuilt in a few years. The waste banks should be seeded to Bermuda or other grasses that will form a sod.

BRIDGES.

The State law requires that the drainage district construct all bridges on public highways made necessary by the construction of a ditch. It is recommended that steel bridges with concrete abutments be constructed wherever bridges are necessary. The first cost of such bridges will be greater than that for wooden bridges, but the cost of maintaining them will be much less. In making the estimate of cost, bridges have been allowed for at all public road crossings. It is assumed that in most cases a 32-foot steel bridge with concrete abutments will be suitable for ditches with 14-foot bases. On the lower part of Back Swamp the wider base will make longer bridges necessary, and the price has been increased accordingly. The estimated price is based on the cost of similar bridges in other parts of the country.

OUTLETS FOR FARM DRAINAGE.

The landowner in the district whose land has not a direct outlet into a ditch, and who, in order to obtain an outlet, must cross the land of another with whom he is unable to agree as to the terms or

[Bull. 246]

conditions on which he may acquire an outlet, is fully provided for under the State drainage law. That part of the law relating to this matter is here given in full.

[North Carolina Drainage Law. Chapter 442, Laws of 1906.]

SEC. 30. The owner of any land that has been assessed for the cost of the construction of any ditch, drain, or water course, as herein provided, shall have the right to use the ditch, drain, or water course as an outlet for lateral drains from said lands; and if said land is separated from the ditch, drain, or water courses by the land of another or others, and the owner thereof shall be unable to agree with said other or others as to the terms and conditions on which he may enter their lands and construct said drain or ditch, he may file his ancillary petition in such pending proceeding to the court, and the procedure shall be as now provided by law. When the ditch is constructed it shall become a part of the drainage system and shall be under the control of the board of drainage commissioners and be kept in repair by them as herein provided.

DRAINAGE AT MAXTON.

The attention of the chief of party was called to the possibility of draining part of the town of Maxton by extending the main ditch in Back Swamp. It will be possible to drain the eastern part lying south of the Seaboard Air Line Railway by extending the main ditch approximately $1\frac{1}{2}$ miles. It probably will be much cheaper and give better drainage to improve Shoe Heel Creek and use it as the outlet for this part of Maxton.

THE IMPROVEMENTS IN DETAIL.

BACK SWAMP.

The drainage area of Back Swamp and its tributaries contains 21,550 acres, all of which is included in the district. The district is to be drained by a main ditch, located in Back Swamp, and five lateral ditches located as shown on the accompanying map of the district. (See fig. 2, p. 12.)

The main ditch starts in the flat woods near the head of the watershed and continues to the southeast, following the course of the present drain to a point near Back Swamp Church, where it turns to the north and enters Lumber River, which is the outlet for the drainage of the district. The main ditch, from the starting point to the mouth of Little Back Swamp, is to have a 14-foot base. From the mouth of Little Back Swamp at station 760 to station 800 the base is to be 16 feet wide; from station 800 to station 850 the base is to be 18 feet wide; and from station 850 to the outlet at the Lumber River the bottom is to be 20 feet in width. The ditch will have an average depth of approximately 6.5 feet. A profile of the ditch accompanies this report. (See fig. 5, p. 12.) The main ditch is crossed by the Alma tramroad and the Atlantic Coast Line Railway; at the point where the

[Bull. 246]

Alma tram crosses, the ditch has a 14-foot bottom and is 6.7 feet deep. The Atlantic Coast Line Railway is crossed at station 506+15 and the ditch here has a 14-foot base and is 6.5 feet deep.

At the point where the Atlantic Coast Line Railway crosses the ditch the railroad at the present time has a 310-foot pile trestle. A clear span should be placed over the ditch; this span should be approximately 32 feet long and should be of steel. No piling or other obstructions should be permitted in the channel of the ditch. At the point where Jacob Swamp leaves Back Swamp the present bridge on the Harleesville road should be removed and the road made a solid embankment, the top being raised to an elevation of 127.5 feet above datum. It is estimated that approximately 1,000 cubic yards of excavation will be required to raise the present road grade to the desired elevation and put it in good condition. It is assumed that this will be done with teams at a cost of about 15 cents per yard. Seven highway bridges will be required on the ditch.

The capacity of the ditch has been computed, using the formula $v=c\sqrt{rs}$, where n in Kutter's formula is given a value of 0.025. The following table has been prepared showing the capacity of the ditch at various places.

Dimensions, fall, computed and required capacities of Back Swamp ditch, and area drained by it.

[Run-off, one-half inch in 24 hours. Depth of water, 5.5 feet. " n "=0.025.]

	Width of base in feet.	Side slope of banks.	Slope in feet per foot.	Fall in feet per mile.	Capacity in cubic feet per second.	Area drained in acres.	Required capacity in cubic feet per second.	Remarks.
Station 46+00.....	14	1-1	0.00077	4.07	Ditch will remove more than 1 inch in 24 hours.			
Station 57+00.....	14	1-1	.00278	14.67				
Station 100+00.....	14	1-1	.00278	14.67				
Station 140+00.....	14	1-1	.00100	5.28				
Station 600+00.....	14	1-1	.00049	3.168				
Station 679+00.....	14	1-1	.00050	2.64				
Station 782+00.....	16	1-1	.00065	3.43	431	1,609	350	To and including Turkey Branch.
Station 940+00.....	20	1-1	.00065	3.43	532	2,155	452	To and including Little Back Swamp. At Rockingham Road.

The ditch, if built as planned, will have a capacity approximately 30 per cent greater than computed when flowing bank full.

The Lumber River, as shown on the large map at the point where the Back Swamp ditch enters it, is not in very good order and is quite crooked. The fall in Lumber River is approximately 2 feet per mile, and by clearing the present channel and cutting off a few bends it will be possible to prevent any congestion in the river at the point where Back Swamp enters. The river was meandered for about 4 miles below the mouth of Back Swamp, but no improved channel

was located at the time the survey was made, as it was impossible to determine at that time what work would be needed. The approximate location that the improved channel should have is shown on the large map. (See fig. 4, p. 12) The cost of this improvement was estimated to be \$2,000.

A table has been prepared showing the excavation in each mile of ditch and the total excavation for the ditch. The quantities were computed for each 100-foot station, using center cuts, and assuming that the ground was flat, transversely to the ditch. As stated on page 20, the ditch should be cross sectioned before it is excavated and the amount of excavation accurately determined.

Excavation per mile section and total excavation in Back Swamp ditch.

	From station—	To station—	Cubic yards excavation.		From station—	To station—	Cubic yards excavation.
Mile 1.....	20+00	52+80	13,000	Mile 12.....	580+80	633+60	27,500
Mile 2.....	52+80	105+60	21,000	Mile 13.....	633+60	686+40	23,300
Mile 3.....	105+60	158+40	23,400	Mile 14.....	686+40	739+20	26,100
Mile 4.....	158+40	211+20	24,100	Mile 15.....	739+20	792+00	30,300
Mile 5.....	211+20	264+00	22,800	Mile 16.....	792+00	844+80	33,400
Mile 6.....	264+00	316+80	23,000	Mile 17.....	844+80	897+60	41,200
Mile 7.....	316+80	369+60	22,800	Mile 18.....	897+60	950+40	39,100
Mile 8.....	369+60	422+40	22,100	Mile 19.....	950+40	967+00	9,600
Mile 9.....	422+40	475+20	24,300				
Mile 10.....	475+20	528+00	28,800	Total.....			480,500
Mile 11.....	528+00	580+80	28,800				

Beginning at station 830, a proposed relocation is shown on the map. (See fig. 3, p. 12.) This location has the advantage of missing the large island and will save considerable excavation and give better drainage.

Estimate of cost.

480,000 cubic yards excavation, at 8 cents per yard.....	\$38,400
1,000 cubic yards excavation, at 15 cents per yard.....	150
5 steel highway bridges, 30 feet long, at \$500 each.....	2,500
2 steel highway bridges, 40 feet long, at \$700 each.....	1,400
180 acres right of way, at \$10 per acre.....	1,800
Improving Lumber River.....	2,000
10 per cent for engineering, legal, and incidental expenses.....	4,625
Total.....	50,875

LATERAL A.

This is a short lateral, 2,000 feet long, that drains a large and very wet bay or swamp on the north side of Back Swamp, just east of the Alma Tramroad. This lateral should be dug by the same dredge that constructs the ditch in Back Swamp. The lateral is so short that it can readily be dug upstream. It is to be a standard minimum ditch, having a 14-foot bottom, and depth as shown on the profile. (See fig. 6, p. 12.) Its construction will require the excavation of 8,300 cubic yards of earth.

[Bull. 246]

Estimate of cost.

8,300 cubic yards excavation, at 8 cents per yard.....	\$664
3 acres right of way, at \$10 per acre.....	30
10 per cent for engineering, legal, and incidental expenses.....	69
Total.....	763

DEES BRANCH.

Dees Branch is a branch about 5 miles long, lying north of Back Swamp, which it enters about one-half mile west of the Atlantic Coast Line Railway, as shown on the map. (See fig. 2, p. 12.) It drains approximately 2,260 acres. The branch has no channel, but is simply a flat swamp covered with undergrowth and large trees. An attempt has been made to drain the swamp and adjoining land above the Red Banks Road, but the ditch is small and shallow and has a very poor outlet, and results have not been all that was hoped for, although this ditch is said to have improved conditions greatly. As constructed, however, it is so located that it will be impossible to use it in constructing the new ditch. The proposed ditch is to have a 14-foot base and an average depth of 6 feet, as shown on the profile. (See fig. 6, p. 12.)

Excavation per mile section and total excavation in Dees Branch ditch.

	From station—	To station—	Cubic yards excavation.
Mile 1.....	0	52+80	24,600
Mile 2.....	52+80	105+60	24,200
Mile 3.....	105+60	158+40	22,900
Mile 4.....	158+40	211+20	22,200
Mile 5.....	211+20	261+00	22,500
Total.....			116,400

Estimate of cost.

116,400 cubic yards excavation, at 9 cents per cubic yard.....	\$10,476
Two 32-foot highway bridges, at \$500 each	1,000
48 acres right of way, at \$10 per acre.....	480
10 per cent for engineering, legal, and incidental expenses.....	1,196
Total.....	13,152

CYPRESS BRANCH.

Cypress Branch heads in the flat woods north of Dees Branch and west of the Lowery Road, and runs to the southeast, crossing the Atlantic Coast Line Railway 1,700 feet north of Back Swamp and entering Back Swamp about 1½ miles east of the railroad. In planning the improvement of Cypress Branch two methods were considered. One, to start a ditch at the point shown on the map and follow Cypress Branch, crossing the Atlantic Coast Line Railway track

[Bull. 246]

and entering Back Swamp $1\frac{1}{2}$ miles east of the railroad. This plan would require the rebuilding of the present 2-span plate-girder bridge and the removal of the present concrete pier to enable the dredge to pass through, and would require approximately 110,000 cubic yards of excavation. The plan adopted was to construct the ditch in Cypress Branch, as shown on the maps (figs. 2 and 3, p. 12), dividing the ditch into two sections—section No. 1, draining that part of Cypress Branch watershed east of the railroad, and section No. 2, draining that part of the watershed west of the railroad. This plan gives the advantage of having only one ditch in the district crossing the Atlantic Coast Line Railroad, and reduces the amount of excavation about 8,000 yards. Section No. 1 can be excavated by the same dredge that excavates the Back Swamp ditch; it was planned with this idea in view, and can readily be constructed by a dredge working upstream. Two highway bridges will be necessary on this branch, one on each section. Both ditches are to be standard minimum ditches, with depths as shown on the profile. (See fig. 6, p. 12.)

Excavation per mile section and total excavation in Cypress Branch.

SECTION NO. 1.

	From station—	To station—	Cubic yards excavation.
Mile 1.....	0	40+00	21,100

SECTION NO. 2.

Mile 1.....	63+96.5	116+76	22,200
Mile 2.....	116+76	163+56	23,000
Mile 3.....	169+56	222+36	24,100
Mile 4.....	222+36	240+00	8,900
Total.....			98,300

Estimate of cost.

Section No. 1:

21,100 cubic yards excavation, at 8 cents per yard.....	\$1,688
One 32-foot highway bridge, at \$500.....	500
10 per cent for engineering, legal, and incidental expenses.....	219
Total.....	2,407

Section No. 2:

78,200 cubic yards excavation, at 9 cents per yard.....	7,038
One 32-foot highway bridge, at \$500.....	500
43 acres right of way, at \$10 per acre.....	430
10 per cent for engineering, legal, and incidental expenses.....	797
Total.....	8,765
Total Cypress Branch.....	11,172

[Bull. 246]

TURKEY BRANCH.

Turkey Branch heads in the flat woods along the Atlantic Coast Line Railway, south of the Rockingham Road. The proposed ditch is to start in the branch on the east side of the railroad and follow the course of the branch as shown on the general map. (Fig. 3.) After the survey was completed it was decided that it would be best to locate a sublateral which would drain the branch that leaves Turkey Branch about $1\frac{1}{2}$ miles above Back Swamp. No ditch line was located on this branch. The approximate location that the ditch should have is shown on the map. It will be approximately 6,500 feet long and will require the excavation of 25,000 cubic yards. Both ditches are to be standard minimum ditches. The Turkey Branch main ditch is shown in profile in figure 6, page 12.

Excavation per mile section and total excavation in Turkey Branch.

	From station—	To station—	Cubic yards excavation.
Mile 1.....	0	52+80	21,100
Mile 2.....	52+80	105+60	23,400
Mile 3.....	105+60	158+40	23,600
Mile 4.....	158+40	182+00	9,900
Total.....			78,000

Estimate of cost.

Main ditch:

78,000 cubic yards excavation, at 9 cents per yard.....	\$7,020
2 highway bridges, at \$500 each.....	1,000
43 acres right of way, at \$10 per acre.....	430
10 per cent for engineering, legal, and incidental expenses.....	845
Total.....	9,295

Sublateral:

25,000 cubic yards excavation, at 9 cents per yard.....	2,250
12 acres right of way, at \$10 per acre.....	120
10 per cent for engineering, legal, and contingent expenses.....	237
Total.....	2,607
Total for Turkey Branch.....	11,902

LITTLE BACK SWAMP.

Little Back Swamp drains approximately 1,740 acres lying south of Back Swamp. It heads in the woods and fields west of the Raynham and Moss Neck roads. The ditch is to start in the swamp at the Raynham and Moss Neck roads and is to follow the course of the swamp to Back Swamp. It is to be a standard minimum ditch, with depth as shown on the profile. (See fig. 6, p. 12.)

[Bull. 246]

Excavation per mile section and total excavation in Little Back Swamp ditch.

	From station—	To station—	Cubic yards excavation.
Mile 1.....	0	52+80	22,600
Mile 2.....	52+80	105+60	22,000
Total.....			44,600

Estimate of cost.

44,600 cubic yards excavation, at 9 cents per yard.....	\$4,014
19 acres right of way, at \$10 per acre.....	190
10 per cent for engineering, legal, and incidental expenses.....	420
Total.....	4,624

JACOB SWAMP.

The drainage area of Jacob Swamp and tributaries contains 9,980 acres. The plan adopted for draining this part of the district consists of a main ditch and three lateral ditches, the locations of which are shown on the general map. (See fig. 4, p. 12.)

The main ditch begins in Jacob Swamp, about 1,500 feet below the Harleesville road crossing, and follows the course of the swamp to a point three-fourths of a mile below the Raleigh & Charleston Railroad, where the located ditch leaves Jacob Swamp and cuts across a low flat ridge to the head of Panther Branch, and thence down Panther Branch to Panther Lake, and through the lake to the river. This location was chosen because it discharges the water from Jacob Swamp into the river approximately 1 mile below where it would if the location followed the north branch of Jacob Swamp, thus reducing the elevation to which back water from the river will rise by the amount of the fall in the river between the two outlets. The outlet into the river through Panther Branch has the advantage of not requiring the ditch to cross the wide river swamp in order to reach an outlet, as would be necessary if the ditch followed Jacob Swamp. The fall and the amount of excavation is the same for both locations. An additional reason for choosing this location was the fact that practically all the landowners in the lower end of the district were in favor of this route for the ditch.

The ditch will be a standard minimum dredge ditch throughout, having a fall of 2.64 feet per mile above station 380 and of 3.696 feet per mile below this point and having a capacity at the lower end, when running at a depth of 5.5 feet, of 399 cubic feet per second. It will drain an area of 9,980 acres, which area, on the basis of three-fourths inch in 24 hours, would have a run-off of 319 second-feet. Its average depth is 6.5 feet, as shown on the profile. (See fig. 6, p. 12.)

[Bull. 246]

At the point where the Raleigh & Charleston Railroad crosses the present channel there is a 400-foot trestle. A bridge should be built at this point, and no piling should be allowed in the channel. The construction of the ditch will enable the railroad to fill all of the trestle, leaving only the opening where the ditch crosses the track.

At the point where the river road crosses Jacob Swamp the present bridge across the swamp should be removed, and replaced by a solid embankment to prevent the backwater from the river from backing up Jacob Swamp and flooding the land. This will require approximately 1,500 cubic yards of excavation and can probably be best done with teams. As nearly as can be determined from available data, the water in the Lumber River is about 2 feet higher at this point than at Panther Lake when the river is in flood. Four highway bridges will be necessary across the ditch.

The Lumber River should be improved from the point where Panther Lake enters it to a point 1 mile below. The improvement should consist of removing all trees, snags, logs, and other obstructions from the channel and banks of the river and cutting off the worst bends. The cost of improving the river should not exceed \$1,500. The improved channel was not located at the time the survey was made, as it was impossible to tell how much work would be necessary at this point. The approximate location of the improved channel is shown on the map. (See fig. 4, p. 12.)

Excavation per mile section and total excavation in Jacob Swamp ditch.

	From station—	To station—	Cubic yards excavation.
Mile 1.....	15	52+80	14,300
Mile 2.....	52+80	105+60	24,100
Mile 3.....	105+60	158+40	28,000
Mile 4.....	158+40	211+20	28,000
Mile 5.....	211+20	264+00	26,000
Mile 6.....	264+00	316+80	26,000
Mile 7.....	316+80	369+60	23,700
Mile 8.....	369+60	422+40	29,300
Mile 9.....	422+40	475+20	28,900
Mile 10.....	475+20	482+00	2,700
Total.....			231,000

Estimate of cost.

231,000 cubic yards excavation, at 8 cents per cubic yard.....	\$18,480
1,500 cubic yards embankment, at 15 cents per cubic yard.....	225
4 highway bridges, at \$500.....	2,000
Improving Lumber River.....	1,500
87 acres right of way, at \$10 per acre.....	870
10 per cent engineering, legal, and incidental expenses.....	2,308
Total.....	25,383
[Bull. 246]	

LITTLE JACOB SWAMP.

Little Jacob Swamp heads in the fields southwest of Back Swamp Church and flows to the east, joining Jacob Swamp just west of the Raleigh & Charleston Railroad. It is very low and swampy in the upper part, the water apparently coming from springs in the swamp. The ditch as located follows the run of the swamp and is to be a standard minimum ditch, with depth as shown on the profile. (See fig. 6, p. 12.) Two highway bridges will be required.

Excavation per mile section and total excavation in Little Jacob Swamp ditch.

	From station—	To station—	Cubic yards excavation.
Mile 1.....	0	52+80	18,400
Mile 2.....	52+80	105+60	23,200
Mile 3.....	105+60	158+40	18,200
Mile 4.....	158+40	211+20	22,200
Mile 5.....	211+20	230+00	6,500
Total.....			88,500

Estimate of cost.

88,500 cubic yards excavation, at 9 cents per yard.....	\$7,965
41 acres right of way, at \$10 per acre.....	410
2 highway bridges, at \$500.....	1,000
10 per cent engineering, legal, and incidental expenses.....	938
Total.....	10,313

SOUTH FORK, PANTHER BRANCH.

The south fork of Panther Branch drains the land south of Panther Branch and east of the Raleigh & Charleston Railroad. The proposed ditch starts in the flat woods east of the Raleigh & Charleston Railroad and north of the Pope Road and runs east to Panther Branch, following the general course of the branch. The ditch is a standard minimum ditch, with depth as shown on the profile. (See fig. 6, p. 12.) One highway bridge will be required.

Excavation per mile section and total excavation in South Fork, Panther Branch, ditch.

	From station—	To station—	Cubic yards excavation.
Mile 1.....	0	52+80	23,800
Mile 2.....	52+80	74+00	6,500
Total.....			30,300

Estimate of cost.

30,300 cubic yards excavation, at 9 cents per yard.....	\$2,727
1 highway bridge.....	500
13 acres right of way, at \$10 per acre.....	130
10 per cent for engineering, legal, and incidental expenses.....	336
Total.....	3,693

[Bull. 246]

LATERAL X.

A short lateral ditch 3,175 feet long was located to drain Jacob Swamp below the point where the main ditch leaves it. This is to be a standard minimum ditch with depth as shown on the profile. (See fig. 6, p. 12.) The ditch can best be constructed by the same dredge that constructs the main ditch in Jacob Swamp. The construction of the ditch will require the excavation of 9,600 cubic yards of earth.

Estimate of cost.

9,600 cubic yards excavation, at 8 cents per yard.....	\$768
5 acres right of way, at \$10 per acre.....	50
10 per cent for engineering, legal, and incidental expenses.....	81
Total.....	899

COTTON MILL BRANCH.

Cotton Mill Branch heads in a gum bay or swamp south of the Seaboard Air Line Railway and just east of the National Cotton Mill. It flows to the southeast to Lumber River and is about $1\frac{1}{2}$ miles long. From station 9+00 to station 31+00 the located line follows closely the existing ditch. The balance of the located line follows the general course of the swamp, leaving it at one point to cut across a low ridge, by doing which it was possible to shorten the located ditch line. The ditch has so much fall that it will not be possible to construct it with a dredge working up stream. The small amount of excavation would make it very expensive to construct a dredge at the upper end to excavate the ditch. For this reason it was decided that it would be most economical to make the ditch as small as possible and excavate it by hand. As planned, it is to have a 4-foot base, depth as shown on the profile (see fig. 6, p. 12), 1 to 1 slopes, and 6-foot berms. One highway bridge will be required.

Excavation per mile section and total excavation in Cotton Mill Branch ditch.

	From station—	To station—	Cubic yards excavation.
Mile 1.....	0	52+80	9,000
Mile 2.....	52+80	76+00	3,800
Total.....			12,800

Estimate of cost.

12,800 cubic yards excavation, at 20 cents per yard.....	\$2,560
14 acres right of way, at \$10.....	140
1 highway bridge.....	200
10 per cent for engineering, legal, and incidental expenses.....	290
Total.....	3,190

[Bull. 246]

GUM BRANCH.

Gum Branch heads in a cypress brake about three-fourths of a mile southwest of the National Cotton Mill and flows east to the Lumber River. The ditch as located will be $2\frac{1}{4}$ miles long. For the same reasons as governed the size of ditch adopted on Cotton Mill Branch, a 4-foot bottom was adopted for Gum Branch. The depth of the ditch is shown on the profile. (See fig. 6, p. 12.) Two highway bridges will be required across the ditch.

Excavation per mile section and total excavation in Gum Branch ditch.

	From station—	To station—	Cubic yards excavation.
Mile 1.....	0	52+80	12,000
Mile 2.....	52+80	105+60	11,100
Mile 3.....	105+60	129+00	4,000
Total.....			27,100

Estimate of cost.

27,100 cubic yards excavation, at 20 cents per yard.....	\$5,420
2 highway bridges, at \$200.....	400
23 acres right of way, at \$10 per acre.....	230
10 per cent for engineering, legal, and incidental expenses.....	605
Total.....	6,655

SUMMARY OF ESTIMATES.

Summary of detailed estimates of ditches in Back Swamp and Jacob Swamp drainage district.

Back Swamp.....	\$50,875	
Lateral A.....	763	
Dees Branch.....	13,152	
Cypress Branch.....	11,172	
Turkey Branch.....	11,902	
Little Back Swamp.....	4,624	
Total Back Swamp.....		\$92,488
Jacob Swamp.....	25,383	
Little Jacob Swamp.....	10,313	
South Fork Panther Branch.....	3,693	
Lateral X.....	899	
Total Jacob Swamp.....		40,288
Cotton Mill Branch.....	3,190	
Gum Branch.....	6,655	
Total.....		9,845
Total cost Back Swamp and Jacob Swamp drainage district.....		142,621
[Bull. 246]		

REVIEW AND CONCLUSION.

The poor drainage conditions existing in the territory covered by the Back Swamp and Jacob Swamp drainage district are due to the failure of the natural watercourses within the district to afford efficient outlet, these watercourses being usually broad, flat swamps covered with timber and undergrowth, and having in general little or no well-defined channel in them.

The Lumber River, which is the main outlet for all the drainage of the district, should have certain improvements in the vicinities of the mouths of Back Swamp and Panther Lake. These improvements, as recommended in the report, are in the nature of straightening and clearing the river channel, and are estimated to cost about \$3,500.

The main feature of the improvements, however, is the construction of efficient ditches in the principal drainage channels within the district. These ditches are designed with sufficient capacity to take care of all the water that they may reasonably be expected to be called upon to handle, and they are of sufficient depth to act as outlets for future farm drainage in the district. The ditches are to follow, in general, the natural "runs" of the swamps, but in one or two cases, as, for instance, in Cypress Branch and Jacob Swamp, certain diversions have been made which it is believed will prove advantageous to the construction of the ditches and for the handling of the water.

The total cost of the recommended improvements, which will make available for cultivation all the land within the district, 32,850 acres, is estimated at \$142,621. This gives a cost per acre of \$4.34. Since the expenditure recommended may reasonably be expected to more than double the land values of the district, it would seem that the investment should be an attractive one from this standpoint alone.

The work has been planned with a view to permanence and efficiency rather than to cheapness of first cost, but it is not believed that any recommendations have been made that will not be amply justified by results.

[Bull. 246]

APPENDIX I.

Monthly, annual, and normal precipitation, in inches and hundredths.

LUMBERTON, ROBESON COUNTY, N. C.

Years.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1882				4.21	3.50	5.32	5.73	10.09	4.33	2.84			
1883					4.23	5.00	2.41	2.20	12.50	3.10			
1884					6.46	7.67	7.34	5.31	6.08	.11			
1885								3.02	3.69	4.04			
1886				1.27	3.26	10.51	7.09	3.24	.20				
1887					2.75	1.98	2.97	9.11	1.12	9.51			
1888					3.92	4.00	5.33			2.64			
1889					3.13	6.80	8.65	7.61	1.58	1.34	3.51		
1890					8.00	6.80	6.61	0.99	4.67	3.80	1.11		
1891					3.53	4.82	5.43	10.64	1.59	1.16	2.35		
1892					3.82	6.04	5.22	4.91	2.75	1.16	1.03		
1893					5.99	7.83	7.62	8.15	5.31	6.71	2.78		
1894				1.47	3.80	2.93	8.60	9.39	7.26	7.50	1.24	2.20	
1895	9.04	2.66	5.31	9.98	3.36	4.72	2.66	8.47	.80	2.00	2.02	1.40	52.42
1896	4.65	5.15	1.80	.89	2.99	4.51	4.81	4.28	5.41	.28			
1897					5.39	6.16	8.03	4.37	1.65	2.54	1.90	2.56	
1898	1.92	1.12	2.76	6.60	2.02	2.29	7.38	7.98	4.36	2.26	4.97	2.71	46.37
1899	4.22	8.42	2.97	4.59	3.96	5.30	9.03	3.81	3.08	6.08	2.28	2.20	55.94
1900	2.85	6.11	4.79	5.14	3.88	3.17	3.00	1.50	1.83	3.32	4.17	5.28	45.04
1901	4.02	2.18	3.56	4.25	12.52	5.47	6.54	6.97	9.38	1.21	1.01	5.65	62.76
1902	2.15	5.92	2.52	2.98	3.42	2.29	2.63	4.49	3.32	4.44	4.34	3.28	41.78
1903	3.15	7.43	5.87	3.64	2.13	6.44	6.25	3.55	1.26	4.25	.35	2.62	46.84
1904	2.37	4.44		.91	1.60	5.57	3.44	8.30	7.28	2.96	2.35	2.50	
1905	1.96	5.53	2.39	3.83	8.26	2.32	4.39	4.31	1.50	2.21	1.23	5.19	43.12
1906	4.10	6.34	6.61	.93	2.08	8.17	7.82	4.74	2.91	2.64	1.02	3.31	50.67
1907	.37	4.08	2.22	3.98	4.71	8.41	6.87	7.46	6.17	.97	2.45	5.07	52.76
1908	2.68	4.61	5.82	4.29	1.43	6.51	9.06	8.74	2.60	4.81	1.09	3.17	54.81
1909	1.40	3.97	1.87	2.69	3.01	7.22	3.59	7.57	2.76	1.53	.44	2.38	38.43
1910	4.03	5.35	1.84	2.24	3.44	7.89	3.91	6.05	1.75	1.71			
Normal	3.68	5.03	3.86	3.83	4.29	5.28	5.94	6.25	4.28	3.22	2.22	3.36	50.08

NOTE.—Weather observations at Lumberton are available for the growing season from 1882 to 1894, and for the whole year from 1895 to the present date.

FAYETTEVILLE, CUMBERLAND COUNTY, N. C.

1891	4.50	3.80	7.84	2.74	4.50	3.15	6.05	9.57	1.84	4.51	2.62	2.04	53.12
1892	7.57	2.99	3.04	1.99	4.79	3.75	10.32	4.64	2.44	.34	2.12	3.57	47.56
1893	3.15	4.60	2.08	1.63	7.67	5.77	3.39	7.36	5.10	4.73	2.39	3.44	51.31
1894	4.58	3.47	2.10	1.30	5.31	2.12	4.26	13.45	6.68	9.16	1.51	1.84	55.78
1895	7.67	2.41	6.07	9.21	4.12	1.89	5.61	6.56	2.47	2.50	2.21	2.30	53.02
1896	3.98	5.52	2.13	1.15	8.06	7.15	5.52	1.74	9.01	1.36	2.51	3.45	51.68
1897	1.31	3.63	4.05	2.77	5.88	2.94	11.11	5.41	1.42	2.17	3.43	2.13	46.25
1898	2.19	1.02	2.93	4.75	1.59	5.53	5.97	7.46	2.43	2.70	4.95	2.86	44.38
1899	3.60	10.10	5.32	3.40	2.35	4.03	8.35	3.76	5.29	3.81	1.90	2.76	54.07
1900	1.86	3.75	3.52	3.51	2.53	6.47	2.56	1.26	2.77	1.26	3.52	4.89	37.90
1901	2.62	1.91	3.78	3.46	7.98	4.31	7.81	7.80	5.47	1.21	.73	5.34	52.42
1902	2.20	6.18	2.44	2.75	1.84	2.37	2.50	2.80	5.24	2.00	3.28	3.78	37.38
1903	5.08	5.21	8.79	3.39	2.55	4.42	3.21	5.51	1.98	3.93	.67	2.28	47.02
1904	2.80	4.46	3.89	.53	2.74	4.66	8.02	8.41	3.89	2.97	4.17	2.88	49.42
1905	2.44	5.46	2.86	3.01	6.06	1.86	7.36	6.03	7.37	2.55	.53	5.78	51.91
1906	4.05	5.09	3.90	1.25	2.24	5.94	9.19	7.14	2.22	3.06	.70	3.69	49.07
1907	.40	3.72	1.91	4.89	4.13	6.95	5.34	8.33	4.64	1.03	3.52	5.26	50.12
1908	3.07	4.90	6.12	3.21	3.47	6.28	6.25	13.54	2.03	2.78	1.16	3.60	56.41
1909	.96	3.61	1.80	1.80	5.18	5.31	3.65	6.86	2.91	.85	.21	1.38	34.32
1910	3.62	3.96	1.20	4.13	5.50	9.97	4.47	5.55	2.47	3.20			
Normal	4.42	4.04	5.17	3.89	4.47	4.04	7.18	6.77	4.30	3.49	2.81	4.38	55.04

Monthly, annual, and normal precipitation, in inches and hundredths—Continued.

WHITEVILLE, COLUMBUS COUNTY, N. C.

Years.	Jan.	Feb.	Mar.	Apr.	May.	June.	July.	Aug.	Sept.	Oct.	Nov.	Dec.	Annual.
1903							8.99	6.36	2.92	3.81	1.28	1.89	
1904	2.91	3.05	4.99	1.80	3.54	4.04	4.85	9.34	4.27	3.00	2.26	2.32	
1905	2.16	5.91	2.70	4.69	6.98	3.44	8.58	2.17			1.35	5.68	50.93
1906	4.77	6.56	4.35	1.15	2.52	7.65							
1907				3.92	4.69	6.43	4.94						
1908					2.29	8.54	15.48	8.23	2.96	8.70	1.20	2.60	
1909	1.47	4.23	.99	2.99	6.77	3.96	5.29		5.13	.41	.43	2.68	
1910	2.76	7.15	.77	2.63	3.60	8.51		9.24		2.02			

Storm periods for the years 1896 to 1910, inclusive, as shown by the records of the United States Weather Bureau stations at Fair Bluff, Lumberton, Fayetteville, and Whiteville, N. C.

Stations.					Stations.				
Date.	Fair Bluff.	Lumber-ton.	Fayetteville.	Whiteville.	Date.	Fair Bluff.	Lumber-ton.	Fayetteville.	Whiteville.
1896.	Inches.	Inches.	Inches.	Inches.	1897.	Inches.	Inches.	Inches.	Inches.
Sept. 5	1.15	0.42	0.91		Aug. 21	Trace.		Trace.	
7	.20				22	Trace.	0.38	0.11	
16			.64		24		.63	.01	
17	.78	1.40			Sept. 1			.11	
20		.83	1.20		2	1.80			
21	.60				3		.63		
22		.07	.60		Oct. 11		1.26	.48	
23	1.05	.78	3.24		19	Trace.			
29	2.00	1.91	1.80		20	1.56	.70	.77	
30	.48		.62		21		.10	.05	
Nov. 2	.86		.23		Nov. 1	.98	1.22	1.16	
4	.60		.35		2	.23	.51	.98	
5	1.00		1.54		Dec. 26	1.85	.83	.77	
24	1.26								
Dec. 1	.20				1898.				
2	.55		.82		Mar. 4	1.14	1.29	1.19	
3	1.28		.85		5	.28	.25	.12	
15	1.03		.90		30	.11	.11	.48	
16			.21		31	1.05	.78	.74	
					Apr. 5	1.08	.80	.87	
1897.					6	.10	.10		
Feb. 1			.50		11	1.16	1.02	.56	
2	.95		.02		24	.84	1.67	.03	
5			1.01		25	Trace.	.22	.28	
6	2.03				27	1.57	1.53	1.53	
20	.12		.02		28	.46	.65	.37	
21	1.15		1.18		June 16	.41	.34	.95	
22	.53		.02		17		.48		
23	.10				18	.17	.04		
24			.01		19	.19	.55	.08	
25	1.40				20	.20	.33	.72	
26	.63				21			1.35	
May 1	1.45	1.39	1.18		22	.50			
2	.53	2.54	.82		July 6	.60	.26	1.44	
30		.53	2.26		7	.67	.95	.62	
June 4	.35				8	2.15	1.04	.18	
5	2.02	2.00	.22		23		.17	Trace.	
6	.27	.75	.14		24	.33	.18	1.10	
7	Trace.				25		.09	Trace.	
8	.67	1.64	.48		26		.17	.08	
9	.15	.45	.35		28	.26	.35	.16	
July 9	.39	1.12	.16		29		.39	.70	
10	.34	.24			31	2.06	2.95	.68	
11	Trace.	.01	1.27		Aug. 1	.43		1.22	
12	Trace.		.03		2	.91		Trace.	
13	3.67	1.15	3.36		10	.18	.53		
18		1.00	1.12		11	.82	.63	.52	
19					12	.96	.21	Trace.	
20	1.04	.60	.86		13	2.20	.62	1.33	
21	.68	2.20	2.11		14	.96	.23	.60	
26	1.80	.33			15	.48	.08	Trace.	
27		.87	1.70		17	2.25	.46	.12	
28			.36		18	.07	.05	.10	
Aug. 6	.44	.80	.50		19		.02	.05	
7	.11	.40	2.21		20		.10	.30	
8	.10	.98	.32		21			.45	
16	.05	1.10	1.10		25	.26			
17	Trace.	Trace.			26	2.15	1.27	.48	
19	1.13	.02	.23		27		.72	.38	
20	.25	.04	.04		28	1.25	.62		

Storm periods for the years 1896 to 1910, inclusive, as shown by the records of the United States Weather Bureau stations at Fair Bluff, Lumberton, Fayetteville, and Whiteville, N. C.—Continued.

Date.	Stations.				Date.	Stations.			
	Fair Bluff.	Lumber-ton.	Fayetteville.	Whiteville.		Fair Bluff.	Lumber-ton.	Fayetteville.	Whiteville.
1898.	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	1900.	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>
Aug. 29	0.90	0.21	0.40	.....	Feb. 13	0.62	1.10	0.53	.....
30	.52	1.15	.62	.....	14	.....	.01	.....	.....
31	1.60	.75	.30	.....	Mar. 1	.80	1.04	.81	.....
Sept. 1	.20	.18	.....	.....	19	.80	1.65	.64	.....
2	Trace.	.15	.03	.....	20	.26	.11	.06	.....
7	.....	.....	.10	.....	21	1.94	2.35	2.37	.....
8	.57	2.06	.98	.....	May 18	.40	.74	.22	.....
9	Trace.	.42	.11	.....	19	.....	1.23	1.11	.....
22	.30	.04	.....	.....	June 5	1.86	.09	1.72	.....
23	.14	.42	1.19	.....	8	.40	.10	.....	.....
24	.25	.39	.....	.....	9	.23	.09	.39	.....
Nov. 14	.....	.....	1.15	.....	10	.84	Trace.	.09	.....
16	.....	.....	.18	.....	11	1.06	.01	.....	.....
17	.....	2.11	.93	.....	17	.18	.15	.05	.....
18	.....	.06	.07	.....	18	.24	1.10	1.73	.....
19	.....	.58	1.10	.....	19	.33	.23	.16	.....
1899.	.....	.....	.....	.....	30	.51	Trace.	1.11	.....
Feb. 5	.....	.97	.40	.....	27	.09	.05	.98	.....
6	.....	1.05	1.10	.....	28	.08	.02	.22	.....
7	.....	1.01	2.43	.....	29	.64	.03	.55	.....
8	.....	.94	.80	.....	30	.74	1.93	.....	.....
12	.....	.40	.71	.....	31	.08	1.23	.....	.....
13	.....	.60	1.00	.....	Aug. 16	1.70	.....	.....	.....
27	.....	1.46	2.23	.....	18	.18	.....	Trace.	.....
28	.....	.23	.21	.....	Sept. 14	.....	.12	.70	.....
Apr. 7	.40	.26	.18	.....	15	.....	.80	.96	.....
8	.85	1.60	1.34	.....	16	.....	.44	1.11	.....
May 4	.11	.35	.10	.....	Nov. 4	.....	1.90	1.67	.....
6	Trace.	.02	.11	.....	5	.....	1.50	1.50	.....
7	.35	.32	.....	.....	Dec. 4	.....	1.90	1.38	.....
8	.95	1.10	.62	.....	5	.....	.....	.57	.....
9	.....	.29	.....	.....	21	.....	1.41	1.07	.....
22	.84	.03	.....	.....	22	.....	.....	.02	.....
23	.....	1.78	.64	.....	30	.....	.....	.10	.....
June 1	.07	.26	.....	.....	31	.....	1.43	1.23	.....
2	1.65	.92	.64	.....	1901.	.....	.....	.....	.....
3	.26	.....	.03	.....	Jan. 2	.....	.....	.15	.....
9	.....	.....	.10	.....	3	.....	1.05	.30	.....
10	.....	.....	.85	.....	17	.....	.....	.09	.....
11	.....	2.12	.09	.....	18	.....	1.16	.70	.....
12	.12	.37	.75	.....	Mar. 21	.....	1.40	1.20	.....
13	.11	.38	1.06	.....	25	.....	.21	.....	.....
July 4	.80	.76	1.15	.....	26	.....	1.05	1.42	.....
5	.12	.37	.64	.....	27	.....	.....	.36	.....
7	.55	.62	.10	.....	Apr. 2	.....	.09	.....	.....
8	.37	.31	.36	.....	3	.....	1.70	1.40	.....
9	2.31	.09	1.44	.....	14	.....	1.57	1.30	.....
17	.....	.....	.25	.....	19	.....	.37	.54	.....
18	.68	2.60	.15	.....	20	.....	2.59	1.00	.....
23	.....	.30	.56	.....	21	.....	1.19	.15	.....
24	.84	.07	.67	.....	22	.....	4.12	3.70	.....
25	.48	2.09	1.20	.....	23	.....	1.08	.05	.....
26	1.32	1.01	.87	.....	June 14	.....	1.68	1.25	.....
27	.46	.58	.26	.....	15	.....	.17	.43	.....
28	.....	.16	.08	.....	16	.....	.....	.03	.....
29	.....	.07	.48	.....	17	.....	1.03	1.45	.....
Sept. 8	.....	.17	1.02	.....	18	.....	.32	.16	.....
26	.37	.88	1.18	.....	July 12	.....	.01	.....	.....
Oct. 6	.64	.75	1.20	.....	13	.....	1.38	.70	.....
8	.54	.95	.89	.....	14	.....	.48	.93	.....
30	Trace.	.01	.67	.....	15	.....	.40	.40	.....
31	3.08	4.06	1.60	.....	16	.....	2.22	1.31	.....
Nov. 1	.15	.54	.25	.....	17	.....	.69	.17	.....
26	.98	.80	.41	.....	18	.....	.....	.02	.....
27	1.46	.73	.45	.....	19	.....	.05	1.12	.....
Dec. 24	Trace.	.04	.45	.....	20	.....	.88	.65	.....
28	.....	.79	1.08	.....	25	.....	.....	.35	.....
1900.	.....	.....	.....	.....	Aug. 6	.....	.08	1.25	.....
Feb. 11	1.25	1.52	.73	.....	7	.....	1.92	1.24	.....
12	.97	1.18	.68	.....	8	.....	.25	.08	.....
					13	.....	.13	.08	.....

Storm periods for the years 1896 to 1910, inclusive, as shown by the records of the United States Weather Bureau stations at Fair Bluff, Lumberton, Fayetteville, and Whiteville, N. C.—Continued.

Date.	Stations.				Date.	Stations.			
	Fair Bluff.	Lumberton.	Fayetteville.	Whiteville.		Fair Bluff.	Lumberton.	Fayetteville.	Whiteville.
	Inches.	Inches.	Inches.	Inches.		Inches.	Inches.	Inches.	Inches.
1901.					1903.				
Aug. 14		0.68	0.61		May 22		1.20	0.33	
15		.36	.11		25		.60	1.06	
16		.12			31			1.06	
17		.18	.04		June 4		.08	.03	
18		.53	.71		5		.05	.04	
19		.05			6		.59	.02	
20		1.09	.03		7		.65	.45	
21		.25			8		.04	.30	
22			.36		9			.02	
23		.03	.18		10		.51	1.33	
24		.28	.02		11			.16	
25		.50	1.60		18		.14	.75	
Sept. 1		4.48			19		2.43		
15			Trace.		July 5		1.50	.30	
16		.06	.12		6		.28	.07	
17			.35		7		1.38	.23	
18		2.09	2.07		13		Trace.	.02	
19		1.33	1.74		14		2.33	1.20	
20		.07			Aug. 1		.16		
28		1.10	.98		2		.54	1.48	
29		.22	.21		19		.30	.57	
Dec. 14		.73	.78		20		.22	1.27	
15		1.93	.93		21		.35		
29		1.11	1.00		Oct. 17		.56	.55	
30		.61	.76		18		1.65	1.35	
31		.04			24		.10	.43	
					25		1.04	.61	
1902.					1904.				
Jan. 29		.35	.43		Jan. 23		1.26	1.20	
30		.02	.20		Feb. 20		.39	.80	
31		.45	.42		21		.07	.04	
Feb. 1		.30	.31		22		1.41	1.25	
2		1.45	1.39		23		.07	.11	
28		1.80	1.62		Mar. 27			1.04	
Apr. 8		1.17	1.19		June 11		1.38	1.45	
May 26		1.37	.52		12		.25		
27		.02	.18		29		.16	1.70	
July 8		1.40			30		2.91	1.25	
9		.10	.50		July 21		.56	.23	
Aug. 5		.41	.55		22		.12	.34	
6		.12	.15		23		.03	.32	
7		1.40	.12		24		.21	2.50	
Sept. 9		.44	.51		25		.40	.73	
10		1.27	.12		Aug. 1		Trace.		
26		1.56	3.53		2		.85	.08	
Oct. 5		.15	Trace.		3		.61	.45	
6		1.91	.66		4		.39	.17	
Nov. 6		.51	.58		5		.98	.90	
7		1.00	.67		6		1.40	.20	
8		.42	.04		7				
9		.01	.03		8		.52	.70	
26		1.73	1.44		9		.45	.92	
Dec. 1		1.02	1.83		10		.11	1.12	
					11		.43	Trace.	
1903.					12		.36	.46	
Jan. 2			.03		13		.51	.02	
3		.62	2.65		27		.87	2.12	
4			.22		28		.41	.66	
5		.57	.50		Sept. 14		1.43	.45	
6		.13	.02		15		4.44	2.93	
21		1.17	.87		Oct. 21		2.86	2.80	
Feb. 7		.09	.20		Nov. 3		.17	.03	
8		3.00	1.37		4		.18	1.20	
12		1.08	1.48		5		.45	.90	
28		2.01	.99		13		1.02	1.32	
Mar. 22		.54	2.12		14		.49	.72	
23		1.67	1.88		Dec. 15		.67	1.25	
24		.34	.59		16		.13	.08	
30		2.46	3.20						
Apr. 13		.03	.06		1905.				
14		1.09	.09		Jan. 5				1.05
15		.34	.67		Feb. 12		.38	.10	1.30
16		.03	.04						

[Bull. 246]

Storm periods for the years 1896 to 1910, inclusive, as shown by the records of the United States Weather Bureau stations at Fair Bluff, Lumberton, Fayetteville, and Whiteville, N. C.—Continued.

Date.	Stations.				Date.	Stations.			
	Fair Bluff.	Lumber-ton.	Fayetteville.	Whiteville.		Fair Bluff.	Lumber-ton.	Fayetteville.	Whiteville.
1905.	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	1906.	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>
Feb. 13		1.77	1.88	1.28	Jan. 26	.....	2.14	0.90	2.60
14		.32	.09	.....	27	.....	.24	.80	.....
20		.04	.28	.11	28	.....	.01	.06	.12
21		1.20	1.41	1.41	Feb. 5	.....	.01	.02	.19
22		.22	.09	.12	6	.....	.01	.03	.....
Mar. 10		.48	.80	.26	7	.....	.02	.01	.03
11				.05	8	.....	.38	.08	2.30
12			.72	1.60	9	.....	2.00	2.30	.18
13		.86	.....	.15	12	.....	.37	.30	2.50
14		.55	.15	.49	13	.....	2.64	2.34	.....
15		Trace.	.35	.....	Mar. 8	.....	.72	.20	1.79
May 3		.03	Trace.	.26	9	.....	.53	1.03	.09
4		.47	.74	1.46	19	.....	.10	.04	1.30
5		.04	Trace.	.01	20	.....	1.64	.80	.05
6				Trace.	28	.....	1.35	.74	.25
7		Trace.	.02	.....	29	.....	.26	.18	.12
8		.11	.10	.08	30	.....	1.11	.....	.34
11		2.72	.32	1.34	31	.....	.30	.....	.....
12				.18	May 26	.....	.06	.11	.28
13		.32	.....	.06	27	.....	.05	.08	1.23
14		.42	.14	.....	28	.....	.56	.31	.25
21		Trace.	.....	.53	29	.....	.12	.62	.....
22		.43	.....	.37	June 2	.....	.....	2.00	.15
23		1.12	1.09	.19	3	.....	.22	.08	1.10
24		.10	.....	.....	4	.....	.90	.....	.17
25			.08	.....	5	.....	.31	.....	.....
26			.06	.78	11	.....	Trace.	.....	.10
27		.63	1.26	.34	12	.....	.10	.03	.27
28		.02	.03	.10	13	.....	.52	.40	.68
29		Trace.	.70	.70	14	.....	3.06	.87	1.90
30				.06	15	.....	.40	.15	2.00
July 31		.34	1.58	Trace.	16	.....	1.17	.91	.45
4		.20	.06	.....	17	.....	.04	.09	.10
5		1.38	1.02	.....	July 2	.....	.06	.32	.....
6		.31	.58	.33	3	.....	.....	.07	.....
7		.03	.....	.56	4	.....	.40	.25	.....
8		.06	.....	2.46	5	.....	.23	.85	.....
9		.01	.06	.18	6	.....	.98	.04	.....
10		Trace.	.08	.40	7	.....	.13	.....	.....
11		.11	Trace.	1.34	9	.....	.04	.02	.....
12		.26	.59	1.50	13	.....	.30	.03	.....
13		.26	.41	.67	15	.....	.95	.54	.....
14		.52	2.55	.....	16	.....	.39	.12	.....
15		.02	.20	.....	17	.....	.09	.90	.....
28			1.30	.80	18	.....	.59	.75	.....
Aug. 8			Trace.	.03	19	.....	.14	.92	.....
9		.14	1.33	.80	20	.....	.25	.70	.....
10		1.09	.83	.02	22	.....	.....	.12	.....
11		Trace.	.15	.07	23	.....	.63	.52	.....
12		1.21	1.25	.01	24	.....	1.55	.64	.....
13		Trace.	.....	.02	25	.....	.06	.42	.....
14		Trace.	.29	.30	28	.....	.45	.08	.....
15		.98	.45	.....	30	.....	.03	.....	.....
16		.03	.65	.....	31	.....	.54	1.70	.....
17		.60	Trace.	.05	Aug. 1	.....	.25	.57	.....
Sept. 2			.07	.....	2	.....	.19	.05	.....
3		.73	.16	1.12	3	.....	.04	.52	.....
4		.13	2.42	.10	Sept. 18	.....	1.23	.27	.....
13		.20	3.75	.58	19	.....	.05	.20	.....
16				.05	Oct. 17	.....	.01	Trace.	.....
17		.36	.02	.50	18	.....	.06	.04	.....
18		Trace.	.....	1.00	19	.....	.17	.52	.....
Dec. 2				.04	20	.....	1.07	.53	.....
3		1.55	1.93	1.01	21	.....	.48	.72	.....
14				1.00	22	.....	.01	.....	.....
15		.75	.80	1.05	23	.....	.02	.....	.....
1906					24	.....	.04	.05	.....
Jan. 22		Trace.	.....	.04	25	.....	.04	.04	.....
23		.22	.72	.....	Dec. 11	.....	1.20	.80	.....
24		.02	Trace.	Trace.	19	.....	.02	.....	.....
25		Trace.	.....	.02	20	.....	1.35	1.96	.....
					21	.....	.08	.....	.....

[Bull. 246]

Storm periods for the years 1896 to 1910, inclusive, as shown by the records of the United States Weather Bureau stations at Fair Bluff, Lumberton, Fayetteville, and Whiteville, N. C.—Continued.

Stations.					Stations.				
Date.	Fair Bluff.	Lumber-ton.	Fayetteville.	Whiteville.	Date.	Fair Bluff.	Lumber-ton.	Fayetteville.	Whiteville.
1907.	Inches.	Inches.	Inches.	Inches.	1908.	Inches.	Inches.	Inches.	Inches.
Feb. 4			0.35		June 26		2.51	2.51	1.65
5		1.62	.82		July 2		.37		.20
25		.85	.90		3		1.57	1.02	.32
26					4		.90		.36
27		.35	.11		9		.15	.46	4.90
Apr. 1		1.38	.88	1.35	10		1.19	.96	.10
7			.89		28		1.12	.87	1.50
8		.20	.45	.25	29		.06	.03	.50
9			.31	.12	30		1.04	.35	5.60
22			.74		31		1.82	1.34	1.50
23		1.45	.94	1.23	Aug. 9		.53	1.09	.10
24		.37	.48		19		3.03	.63	2.75
May 9		1.39	1.25	1.25	20		.14	.32	.05
26		1.79	1.84		21		1.32	.86	.65
June 1		1.05	.94	.56	22		.67	.61	.10
2		.39	.26	.81	23		.27		.06
3		.28	.23		24		.20	4.68	Trace.
11		3.90	2.01	1.65	25		.20	1.02	1.00
12		.22		.44	26		.23		2.00
28		.80	.21	.50	27		1.00	1.44	.85
29		.86	.50	1.50	Sept. 6		2.22	.86	
30		.67	.48		Oct. 6			.20	2.00
July 3		.52	1.25		23		2.20	.97	4.80
13		.93	.58	.41	24		.47	.15	
14		.15	.47		28				1.10
15		2.30	.35	1.63	29		1.49	.96	.60
20			2.06		Nov. 14				1.00
30				1.70	Dec. 15		.76	.97	
Aug. 4			1.26		22		.32	.42	.63
16			.54		23		.57	1.30	Trace.
17		1.03	.28		1909.				
18		.55	1.40		Feb. 10		1.22		
19		3.67	1.57		19				1.37
20		.87			20				
21		.10	1.57		22		1.05	1.12	.85
Sept. 5		1.54	.54		23			1.04	.30
28		.05	.12		Apr. 2		1.15		1.15
29		2.76	2.58		May 1		.48	1.88	.30
Nov. 29		.95	.46		10				1.80
Dec. 10		1.65	1.34		19				1.30
14		1.83	1.59		20				3.10
1908.					21		1.39	.83	.17
Jan. 3			.81		22		.57	1.58	
10			1.25		June 3		.30	.38	1.00
12		1.12			4		2.13	1.94	
Feb. 1		.90	.85		14		.49	.06	.05
11		.85	.60		15		.89	.64	
12		.06	.05		16		.06	1.32	.07
13		.15			17		1.26	.12	.22
14		.75	1.35		July 15		.24	.20	
15		.73	.56		16		.53	.22	1.87
Mar. 12		1.43	1.30		17		.02	.88	.21
20		.55	.85		25			Trace.	.10
21		1.03	.90		Aug. 1		.23		1.34
23		.88	1.08		2		.31	.04	
24		.40	.70		3		1.21	1.12	
25		.94	.24		4		.15	.80	
Apr. 23		1.35	.93		11		.77		
24		1.65	1.12		12		.31		
May 19		.66	.84	.94	13		.22	2.02	
20		.10	.05	.35	14			1.02	
21		.30			15		2.32	.20	
22			1.08		30		.36	1.36	
June 4		.15			Sept. 10		.08	.30	.40
5		.98	.30	3.62	11		.89	1.10	.50
6		.15	.28	.25	15				.40
11		.92	1.23	.85	16		.02	.19	.30
12		.65			17		.24		.60
21		.96		.25	18		.34		.70
23		1.16							

[Bull. 246]

Storm periods for the years 1896 to 1910, inclusive, as shown by the records of the United States Weather Bureau stations at Fair Bluff, Lumberton, Fayetteville, and Whiteville, N. C.—Continued.

Date.	Stations.				Date.	Stations.			
	Fair Bluff.	Lumber-ton.	Fayetteville.	Whiteville.		Fair Bluff.	Lumber-ton.	Fayetteville.	Whiteville.
1909.	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	1910.	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>	<i>Inches.</i>
Sept. 19	0.38	0.05	2.19		June 8	Trace.			0.19
25	.11	1.02			9	Trace.			.30
Dec. 13	.23	.23	1.18		10	Trace.	0.31		.11
14	.70	.77			11	1.67	1.54	Trace.	
1910.					12	.41	.02		.56
Jan. 5	.01		.20		13	1.14	1.58		.34
6	1.65	1.44	.55		14	.15	.10		.55
7	.16		.10		15	.70	1.30		.75
21	1.02	.54			16	.42	.26		
22	.01	.22			17		.02		
Feb. 9	.17	.18	.23		20			2.50	
10	.06	.42	.06		24	.14		.65	
11	Trace.		1.12		25	.86	2.28		
12	1.00	1.02	.08		Aug. 5	.62	.24		2.60
24	.15	.08	2.60		6			2.00	
25	1.60	.70	.17		7	1.18	1.50		.60
27	Trace.		.58		8	.90	.78		
28	.88	.23	1.30		9	.11	.02		
Mar. 1	1.02	.22	.28		11			.40	
2	.35	.14	.16		12	.17		.02	
Apr. 13	.74	.41	1.18		13	1.21	.61	Trace.	
17		Trace.	.10		14	.01	.06	1.38	
18	.50	2.88	.08		15	.68	.15	.50	
19	.15	.08	.23		16	.28			
May 7	.02	.20	Trace.		Sept. 1	.19	1.16		
8	.02	.95	.48		2	Trace.			
9	1.56	2.25	.90		3	.47	.83		
24	.02		.22		4	Trace.	.01		
25	1.34	1.68	1.28		7		.10	.38	
26	.16	.02			8	.61	1.08	.28	
June 5	Trace.	.15	Trace.		9	.11	.20	.08	
6	2.16	1.70	2.45		19	.11	.02	.70	
7	.03	.02			20	.84	1.76	.58	

[Bull. 246]

APPENDIX II.

List of bench marks set.

No. of bench mark.	Elevation.	Location and description.
	<i>Feet.</i>	
U. S. B. M	168.76	At intersection of Red Banks Road with Back Swamp Road; standard iron bench mark.
U. S. B. M	193.24	1½ miles S.E. of Maxton; at SW. corner of brick retaining wall, inclosing residence of H. McNair; standard iron bench mark.
U. S. B. M	136.89	At S.E. corner Back Swamp Church; standard iron bench mark.
U. S. B. M	144.98	At intersection of Rockingham Road with Moss Neck Road; standard iron bench mark.
U. S. B. M	106.00	At intersection of Pope and River Roads; standard iron bench mark.
B-1	138.79	Back Swamp, 100 feet E. of station 651; spike in 12-inch black gum.
B-2	155.81	Dees Branch, 90 feet N.E. of station 51+28; spike in 20-inch pine.
B-3	147.58	Cypress Branch, 90 feet E. of station 55+18; spike in 9-inch black gum.
B-4	149.94	Cypress Branch, 60 feet W. of station 100+00; spike in 12-inch maple.
B-5	152-52	Cypress Branch, 80 feet S. of station 151+85; spike in 14-inch pine.
B-6	155.43	Cypress Branch, 70 feet S.W. of station 216+00; spike in 8-inch black gum.
B-7	140.53	Turkey Branch, 75 feet N.E. of station 53+00; spike in 18-inch sweet gum.
B-8	144.26	Turkey Branch, 80 feet S.W. of station 110+25; spike in 16-inch sweet gum.
B-9	147.10	Turkey Branch, 110 feet N.E. of station 176+00; spike in 10-inch black gum.
B-12	122.51	Jacob Swamp, 100 feet W. of station 56+00; on 28-inch black gum.
B-13	121.01	Jacob Swamp, 85 feet S.W. of station 113+55; on 20-inch cypress.
B-14	118.46	Jacob Swamp, 100 feet S.W. of station 160+00; on 12-inch black gum.
B-15	134.39	On cross section south from B. M. M43; spike in 32-inch short-leaf pine.
B-16	138.50	On cross section south from B. M. M43; spike in 16-inch black gum.
B-17	136.66	On cross section ending at a T. B. M. on Rockingham Road, 1½ miles east of Moss Neck Road; spike in 18-inch water oak.
B-18	140.12	On cross section between B. M. M44 and B. M. M40; spike in 9-inch sweet gum.
B-20	106.72	Gum Branch, 100 feet N. of station 9+00; spike in 14-inch black gum.
B-21	114.65	Gum Branch, 160 feet N. of station 68+00; spike in 10-inch pine.
B-22	119.20	Gum Branch, spike in 12-inch S. L. pine near station 128+00.
B-23	114.13	Cotton Mill Branch, 50 feet S.W. of station 65+30; spike in 14-inch black gum.
B-24	119.62	Little Jacob Swamp, 80 feet N.W. of station 171+00; spike in root 24-inch maple.
B-25	116.82	Little Jacob Swamp, 60 feet N. of station 128+00; spike in 14-inch S. L. pine.
B-1	157.46	Turkey Branch, on line near station 223+55; spike in 20-inch gum.
B-2	156.14	Dees Branch, on line near station 90+00; spike in 16-inch gum.
B-3	153.71	Back Swamp, on line near station 380+00; spike in black gum.
B-4	150.80	Back Swamp, near station 463+00; spike in root of 18-inch pine.
B-5	151.33	Turkey Branch meander, on line near station M 123+65; spike in 10-inch gum.
B-6	142.00	Turkey Branch, on line near station 76; spike in 20-inch gum.
B-7	158.44	Dees Branch, north side of line, near station 149; spike in 4-inch black gum.
B-8	148.08	Right side of road, in front of water house, on old Townsend place; spike in 24-inch red oak.
B-10	119.71	East side of Beaufort lumber tram in Little Jacob Swamp; spike in 35-inch poplar.
B-12	120.76	100 feet north of Gum Branch near station M 91+45, on north side of road; spike in 15-inch S. L. pine.
B-13	116.83	Jacob Swamp, 75 feet north of located line near station 200+00; spike in 24-inch water oak.
B-14	117.86	Cypress Branch, 25 feet north of located line near station 121+25; spike in 20-inch black gum.
B-15	130.01	150 feet west of Marion Road, at intersection of Marion and Wiregrass Roads; spike in 20-inch pine.
B-16	128.76	200 feet south of intersection of Pope and Wiregrass Roads; spike in 10-inch pine.
B-17	129.29	On Kingsdale Road and 50 feet north of intersection of Kingsdale and Pope Roads, near a group of mail boxes; spike in 12-inch water oak.
B-18	124.68	On north side of Pope Road, ½ mile east of Raleigh & Charleston R. R.; spike in 12-inch hickory.
B-19	106.82	Northeast of station 380+00, Jacob Swamp line, near intersection of Jacob Swamp and Panther Branch; spike in 15-inch maple.
B-20	105.35	Jacob Swamp, north of station 435+00; spike in 6-inch hickory.
B-50	100.02	5 feet west of intersection of Panther Branch and River Road; spike in 4-inch maple.

¹ The duplication of bench-mark numbers B-1 to B-20, inclusive, was caused by the use of the same initials B. by two levelmen. Bench marks having the same number may be easily identified from their descriptions.

List of bench marks set—Continued.

No. of bench mark.	Elevation.	Location and description.
	<i>Feet.</i>	
B-51	102.61	On bank of Lumber River at end of Jacob Swamp meander; spike in 5-inch gum.
B-52	106.39	At intersection of Panther Branch and cross section near station M 34+10; spike in tree.
M-1	191.97	300 feet south of B. F. Bodford's house, 1 mile east of Maxton; crossed staples in root of 1 of 2 lone pines.
M-2	191.43	South side of Rockingham Road, 600 feet east of H. McNair's; center granite boundary stone.
M-3	192.00	South side Rockingham Road, opposite R. McNair's old house; spike in root of 24-inch persimmon.
M-4	173.90	On north side Rockingham Road, on SE. corner grove lying west of J. B. Sellers; spike in root 16-inch pine.
M-5	168.07	$\frac{1}{2}$ mile east J. B. Sellers; crossed staples in root 24-inch pine.
M-6	166.94	South side of road at bend, 150 feet west of small cabin; staples in root 18-inch pine.
M-7	166.90	North side Rockingham Road, 150 feet east of east end of woven-wire fence; staple in root blazed 14-inch pine.
M-8	162.31	Crossing of Rockingham and Red Banks Road, right side road; spike in root 16-inch pine.
M-9	161.77	Right side of Red Banks Road near Dees Branch located line; staple in root small pine.
M-10	162.21	Right side Red Banks Road, 20 feet right of Back Swamp located line, crossing of road; spike in 10-inch gum.
M-11	167.49	100 feet west of intersection Red Banks Road with Back Swamp Road; spike in root 16-inch pine.
M-12	165.05	SW. side road, 250 feet E. of G. D. Willard's house; spike in root 14-inch gum.
M-13	178.71	South side Back Swamp Road, $\frac{1}{2}$ mile east of turn; spike in root 18-inch pine.
M-16	184.00	Back Swamp, 100 feet left of station 59+00; spike in 16-inch sweet gum.
M-17	172.09	Back Swamp, 100 feet right of station 108+00; spike in root 16-inch short-leaf pine.
M-18	167.26	Back Swamp, 100 feet right of station 170+50; spike in root 12-inch short-leaf pine.
M-21	166.38	100 feet E. of turn in Back Swamp Road, $\frac{1}{2}$ miles east of Red Banks Road; spike in 8-inch short-leaf pine.
M-22	160.56	Side of Monroe's gin on Back Swamp Road; spike in root 60-inch branching mulberry.
M-23	161.45	Intersection of Back Swamp and Elrod Roads; spike in root 10-inch post oak.
M-24	155.91	At crossing of Back Swamp Road and Atlantic Coast Line R. R., front of H. H. Lowery's; spike in root 14-inch black gum.
M-25	153.80	At crossroads and 3 churches, on Back Swamp Road; spike in root 10-inch oak.
M-26	150.42	Crossing Moss Neck and Back Swamp Roads; spike in root 10-inch oak.
M-27	160.55	Left side Rockingham Road, 1 mile east of intersection of Red Banks Road and Rockingham Road; spike in 18-inch persimmon.
M-28	152.94	Left side Rockingham Road, at bend; spike in root 14-inch pine.
M-29	152.50	By mail box Z. B. Brooks, on Rockingham Road; spike in root 14-inch short-leaf pine.
M-30	148.17	On Rockingham Road, at junction with road leading to Pembroke; spike in 16-inch water oak.
M-31	143.51	Left side Moss Neck Road, 2,000 feet south junction of Moss Neck and Rockingham Roads; spike in root 10-inch pine.
M-32	140.31	Right side Moss Neck Road, 600 feet SE. of crossing of road with Turkey Branch located line; spike in 12-inch short-leaf pine.
M-33	139.45	In Back Swamp, on right side Moss Neck Road; spike in 10-inch gum.
M-34	164.54	Back Swamp, 100 feet left of station 228+90; spike in root 14-inch maple.
M-35	158.61	Back Swamp, 125 feet right of station 330+00; spike in 10-inch gum.
M-36	151.09	Back Swamp, 125 feet right of station 431+44, on Lowery Road; spike in 10-inch gum.
M-38	143.91	Corner made by junction of Harleesville and Back Swamp Roads; spike in 14-inch oak.
M-39	101.06	Dees Branch, 125 feet right of station 231+00; spike in 12-inch pine.
M-40	139.13	Junction Harleesville Road and an arm of Rockingham Road; spike in root 18-inch gum.
M-41	141.05	By mile post on Harleesville Road, "Lumberton 7 miles; Raynham 3 miles"; spike in 36-inch red oak.
M-42	143.27	On Rockingham Road, $\frac{1}{2}$ mile from Junction with Moss Neck Road, and in front church; spike in root 10-inch pine.
M-43	136.43	Right side Rockingham Road, on tapped tree 200 feet east of clearing; spike in 20-inch short-leaf pine.
M-44	134.01	On Rockingham Road, by mail box 27; spike in root 30-inch water oak.
M-45	128.46	At crossing of Rockingham Road and road leading to Raft Swamp Church; spike in 18-inch short-leaf pine.
M-46	128.05	On Harleesville Road and on south edge Jacob Swamp; spike in 30-inch water oak.
M-47	125.76	On Harleesville Road, $\frac{1}{2}$ mile north of Rockingham Road; left side road by lane; spike in 8-inch persimmon.
M-48	122.52	Right side Harleesville Road, opposite dairy farm and near junction of ditches; spike in 8-inch sweet gum.
M-49	119.89	By Beaufort Lumber Co. tram, 100 feet left of Jacob Swamp line crossing; spike in 30-inch gum.
M-50	132.05	On left side Pope Road, 1,000 feet west of tram crossing; spike in 8-inch black gum.

[Bull. 246]

List of bench marks set—Continued.

No. of bench mark.	Elevation.	Location and description.
	<i>Feet.</i>	
M-51	135.92	On Pope Road, front G. L. Thompson's house; spike in 24-inch white oak.
M-52	129.66	On Pope Road, 200 feet west of milepost "S 3"; spike in 30-inch water oak.
M-53	148.93	Right side Back Swamp Road, by old 2-story building; $\frac{1}{2}$ miles east of Moss Neck Road; spike in one of three large oaks.
M-54	144.94	Left side Back Swamp Road, 100 feet east of small shack; $\frac{1}{2}$ mile west of Harleesville Road; spike in double maple.
M-55	123.28	Left side Harleesville Road, $\frac{1}{2}$ mile north of Beaufort Lumber Co. tram; spike in 18-inch oak.
M-56	118.99	On Marion Road, front P. G. Campbell's house, 1,000 feet S. of Seaboard Air Line crossing; spike in 30-inch oak.
M-57	110.74	On River Road, 2,000 feet southeast of Raleigh & Charleston R. R.; spike in 20-inch pine.
M-58	109.06	Right side River Road, 300 feet east of house and opposite clearing; spike in 6-inch gum.
M-59	114.47	Left side Pope Road, between G. Pope's and Carter's houses; spike in 25-inch persimmon.
M-60	106.71	Junction of Pope and River Roads; spike in root 20-inch chestnut oak.
W-1	181.71	On Back Swamp Road at junction with old county road, 2 miles east of Maxton; spike in 16-inch pine.
W-2	152.79	South side Lowery Road, 75 feet south John Dees's house; spike in 12-inch water oak.
W-3	154.81	West side Lowery Road in Turkey Branch; spike in 6-inch gum.
W-4	156.31	In NW. corner Lowery and Rockingham Roads; spike in 18-inch pine.
W-5	152.87	Front Little Lowery house; spike in 10-inch oak.
W-6	150.88	On right side Rockingham Road by Atlantic Coast Line R. R.; spike in 16-inch pine.
W-7	165.97	On old county road east of Atlantic Coast Line R. R.; $\frac{1}{2}$ mile north of three churches junction; spike in 18-inch pine.
W-8	145.89	On east side road between runs, on county road east of Atlantic Coast Line R. R.; spike in 15-inch water oak.
W-9	145.86	In small forked black gum on south side of branch.
W-10	145.89	12-inch maple, in branch.
W-11	145.76	On south side road in Turkey Branch; black gum.
W-15	148.18	78 feet S. 39° W. of station 485+15, on Back Swamp line; 16-inch water oak.
W-16	145.77	85 feet left of station 540+00, on Back Swamp line; 16-inch black gum.
W-17	136.87	76 feet S. 25° E. of station 698+75 of Back Swamp line; 18-inch black gum.
W-18	133.96	55 feet left of station 792+60 of Back Swamp line; 18-inch beech.
W-19	130.70	60 feet left of station 815+00 of Back Swamp line; 16-inch black gum.
W-20	129.35	70 feet left of station 832+00 of Back Swamp line; 10-inch water oak.
W-21	129.69	80 feet north of station 847+00 of Back Swamp line; 30-inch cypress.
W-22	130.59	58 feet north of station 869+60 of Back Swamp line; 30-inch beech.
W-23	127.29	45 feet right of station 894+50 of Back Swamp line; 12-inch twin maple.
W-24	120.03	129 feet right of station 966+80 of Back Swamp line; 16-inch cypress.
W-25	132.13	By signpost, "Harleesville R. 2"; 24-inch short-leaf pine.
W-26	136.79	90 feet left of station 715+00 of Back Swamp line; 12-inch water oak.
W-27	135.08	140 feet left of station 737+00 of Back Swamp line; 16-inch maple.
W-28	134.90	95 feet right of station 2+00 of Little Back Swamp line; 10-inch black gum.
W-29	135.17	135 feet right of station 36+00 of Little Back Swamp line; 16-inch sweet gum.
W-30	137.06	75 feet left of station 65+20 of Little Back Swamp line; 24-inch black gum.
W-31	137.12	120 feet right of station 84+60 of Little Back Swamp line; 14-inch sweet gum.
W-32	140.53	95 feet left of station 104+55 of Little Back Swamp line; 14-inch short-leaf pine.
W-33	141.64	Right of station 112+30 of Little Back Swamp line, at Moss Neck Road; 18-inch short-leaf pine.
W-34	135.78	South side Pope Road, $\frac{1}{2}$ mile east from tram; 8-inch oak.
W-35	115.64	West side Marion Road, edge of swamp; 14-inch short-leaf pine.
W-36	116.16	50 feet north of Marion Road; 18-inch short-leaf pine.
W-37	115.78	West side Marion Road near milepost "L 2"; 10-inch black gum.
W-38	113.19	East side Marion Road and 160 feet south of Gum Branch Bridge; 10-inch short-leaf pine.
W-39	113.23	West side Lovett Road, by small branch; 16-inch short-leaf pine.
W-40	112.60	On Lovett Road, west edge of Little Jacob Swamp; 18-inch short leaf pine.
W-41	130.85	125 feet north of crossing Pope and Lovett Roads; 16-inch water oak.
W-42	112.83	75 feet left of station 24+90 of Little Jacob Swamp line; spike in 18-inch sweet gum.
W-43	113.59	100 feet north of station 52+85 of Little Jacob Swamp line; 10-inch black gum.
W-44	115.72	100 feet north of station 84+00 of Little Jacob Swamp line; 10-inch maple.
W-50	119.74	115 feet left of station 166+25 of Jacob Swamp line; spike in 20-inch black gum.
W-51	116.33	130 feet right of station 207+80 of Jacob Swamp line; spike in 24-inch water oak.
W-52	115.83	60 feet left of station 207+40 of Jacob Swamp line; spike in 8-inch maple.
W-53	114.38	60 feet left of station 228+00 of Jacob Swamp line; spike in 16-inch black gum.
W-54	112.50	100 feet right of station 263+25 of Jacob Swamp line; spike in 14-inch black gum.
W-55	111.11	75 feet left of station 289+40 of Jacob Swamp line; spike in 14-inch water oak.
W-56	111.59	On Jacob Swamp line and on east side Lovett Road; on forked black gum.
W-57	110.88	80 feet right of station 118+85 of Jacob Swamp line; spike in 24-inch water oak.
W-60	104.96	125 feet right of station 6+00 of South Fork of Panther Branch line; 10-inch water oak.
W-61	108.20	100 feet left of station 25+00 of South Fork of Panther Branch line; spike in L. S. pine.
W-62	106.88	75 feet left of station 44+00 of South Fork of Panther Branch line; spike in 16-inch L. S. pine.
W-68	112.09	Right of station 60+00 of South Fork of Panther Branch line; spike in 14-inch L. S. pine.

APPENDIX III.

Courses and distances of located lines.

BACK SWAMP.

From station—	To station—	Bearing.	From station—	To station—	Bearing.	From station—	To station—	Bearing.
0+00.0	20+00.0	Abandoned.	355+00.0	358+00.0	S. 21° 20' E.	580+00.0	595+00.0	N. 49° E.
20+00.0	26+25.0	S. 41° 30' E.	358+00.0	366+00.0	S. 54° 30' E.	595+00.0	634+00.0	S. 56° 30' E.
26+25.0	62+00.0	S. 30° E.	366+00.0	370+33.0	S. 3° 45' E.	634+00.0	651+00.0	N. 90° E.
62+00.0	80+79.0	S. 68° E.	370+33.0	387+00.0	S. 34° 30' E.	651+00.0	666+50.0	S. 29° 10' E.
86+79.0	97+57.8	S. 89° 30' E.	387+00.0	391+00.0	S. 52° 35' E.	666+50.0	679+00.0	N. 90° E.
97+57.8	108+00.0	S. 41° E.	391+00.0	397+05.0	S. 82° 30' E.	679+00.0	704+00.0	S. 83° E.
108+00.0	121+16.8	S. 5° 10' W.	397+05.0	406+50.0	S. 42° 30' E.	704+00.0	729+00.0	S. 60° 30' E.
121+16.8	123+72.9	S. 51° 45' E.	406+50.0	414+35.0	S. 73° 15' E.	729+00.0	751+00.0	S. 27° E.
123+72.9	147+50.0	S. 45° 04' E.	414+35.0	420+00.0	S. 0° 35' E.	751+00.0	788+00.0	S. 69° 15' E.
147+50.0	156+00.0	S. 15° 04' E.	420+00.0	426+25.0	S. 44° 50' E.	788+00.0	832+00.0	S. 79° E.
156+00.0	176+00.0	South.	426+25.0	431+44.6	N. 90° E.	832+00.0	850+00.0	S. 56° E.
176+00.0	208+00.0	S. 22° 10' E.	431+44.6	443+00.0	N. 76° 20' E.	850+00.0	890+00.0	N. 90° E.
208+00.0	256+00.0	S. 49° 56' E.	443+00.0	454+25.0	N. 90° E.	890+00.0	904+00.0	S. 66° 30' E.
256+00.0	269+61.2	S. 27° 18' E.	454+25.0	469+50.5	S. 75° 30' E.	904+00.0	933+52.0	N. 80° 45' E.
269+61.2	282+00.0	S. 38° 30' E.	469+50.5	475+33.0	S. 22° E.	933+52.0	940+00.0	N. 8° 30' W.
282+00.0	290+00.0	S. 50° 04' E.	475+33.0	481+75.0	S. 26° E.	940+00.0	952+87.0	N. 30° E.
290+00.0	306+00.0	S. 31° E.	481+75.0	519+50.0	S. 48° E.	952+87.0	966+92.0	N. 7° 15' E.
306+00.0	320+70.0	S. 88° 10' E.	519+50.0	539+00.0	S. 15° 30' E.	Lateral A.		
320+70.0	340+70.0	S. 49° E.	539+00.0	563+26.0	S. 44° 30' E.	0+00.0	12+00.0	N. 10° 30' W.
340+70.0	352+00.0	S. 0° 15' W.	563+26.0	580+00.0	S. 66° 30' E.	12+00.0	20+00.0	N. 18° W.
352+00.0	355+00.0	S. 7° 50' E.						

DEES BRANCH.

0+00.0	8+00.0	N. 24° W.	103+00.0	110+85.0	N. 17° E.	194+00.0	203+54.0	N. 15° 20' W.
8+00.0	15+00.0	N. 42° W.	110+85.0	128+00.0	N. 41° 30' W.	203+54.0	214+00.0	N. 54° 30' W.
15+00.0	26+00.0	N. 16° 30' W.	128+00.0	137+00.0	N. 4° 30' W.	214+00.0	224+00.0	N. 51° 20' W.
26+00.0	37+00.0	N. 78° W.	137+00.0	157+00.0	N. 28° 15' W.	224+00.0	235+00.0	N. 45° W.
37+00.0	63+00.0	N. 47° 40' W.	157+00.0	173+00.0	N. 56° W.	235+00.0	244+00.0	N. 35° 10' W.
63+00.0	95+00.0	N. 38° 30' W.	173+00.0	182+00.0	N. 27° 15' W.	244+00.0	261+00.0	N. 8° 15' W.
95+00.0	103+00.0	N. 3° W.	182+00.0	194+00.0	N. 48° W.			

CYPRESS BRANCH.

0+00.0	37+00.0	N. 58° W.	114+50.0	130+00.0	N. 46° W.	170+00.0	179+50.0	N. 38° W.
37+00.0	40+00.0	N. 23° 10' W.	160+00.0	142+51.0	North.	179+50.0	192+55.0	N. 90° W.
40+00.0	63+96.5	Abandoned.	142+51.0	160+00.0	N. 53° 10' W.	192+55.0	215+50.0	N. 47° 50' W.
63+96.5	80+85.5	N. 32° 30' E.	160+00.0	166+00.0	N. 30° 15' W.	215+50.0	228+00.0	N. 16° 30' W.
80+85.5	99+00.0	N. 24° W.	166+00.0	170+00.0	N. 90° W.	228+00.0	240+00.0	N. 8° W.
99+00.0	114+50.0	North.						

TURKEY BRANCH.

0+00.0	21+00.0	N. 12° 30' W.	49+90.0	68+00.0	N. 79° W.	114+45.0	130+00.0	N. 41° W.
21+00.0	27+00.0	N. 58° W.	68+00.0	85+10.0	N. 38° W.	130+00.0	154+00.0	N. 39° W.
27+00.0	35+70.0	N. 36° 30' W.	85+10.0	101+00.0	N. 30° 30' E.	154+00.0	161+50.0	North.
35+70.0	43+00.0	N. 60° W.	101+00.0	114+45.0	N. 19° W.	161+50.0	182+35.0	N. 33° 55' W.
43+00.0	49+90.0	N. 16° W.						

LITTLE BACK SWAMP.

0+00.0	14+00.0	S. 51° W.	81+34.0	98+00.0	S. 66° W.	109+00.0	112+10.0	N. 28° W.
14+00.0	48+00.0	N. 85° 30' W.	98+00.0	109+00.0	N. 43° 30' W.	112+10.0	116+00.0	N. 59° W.
48+00.0	81+34.0	N. 55° W.						

Courses and distances of located lines—Continued.

JACOB SWAMP AND PANTHER BRANCH.

From station—	To station—	Bearing.	From station—	To station—	Bearing.	From station—	To station—	Bearing.
0+00.0	15+00.0	Abandoned.	140+00.0	158+00.0	N. 71° 15' E.	290+05.0	300+00.0	N. 77° E.
15+00.0	18+00.0	N. 62° E.	158+00.0	173+00.0	S. 44° E.	300+00.0	311+36.0	S. 35° E.
18+00.0	31+00.0	S. 72° 30' E.	173+00.0	180+80.0	S. 87° E.	311+36.0	341+50.0	S. 72° 45' E.
31+00.0	49+26.0	N. 65° 30' E.	180+80.0	208+00.0	S. 41° 30' E.	341+50.0	349+00.0	S. 43° E.
49+26.0	56+00.0	N. 13° 45' E.	208+00.0	216+50.0	S. 10° 30' E.	349+00.0	365+00.0	S. 73° E.
56+00.0	70+00.0	N. 53° E.	216+50.0	228+00.0	N. 90° E.	365+00.0	389+00.0	S. 14° 45' E.
70+00.0	98+00.0	N. 77° 30' E.	228+00.0	240+00.0	S. 46° E.	389+00.0	441+53.0	S. 47° E.
98+00.0	108+50.0	S. 82° 30' E.	240+00.0	249+00.0	N. 66° E.	441+53.0	453+30.0	S. 69° E.
108+50.0	113+55.0	S. 26° 30' E.	249+00.0	275+00.0	S. 75° 30' E.	453+30.0	466+34.0	S. 39° E.
113+55.0	121+64.0	S. 87° E.	275+00.0	281+00.0	S. 28° 30' E.	466+34.0	482+60.0	S. 67° E.
121+64.0	140+00.0	S. 63° E.	281+00.0	290+05.0	S. 55° E.			

LITTLE JACOB SWAMP.

0+00.0	29+00.0	S. 72° 30' W.	107+48.0	125+00.0	N. 52° 30' W.	176+00.0	184+00.0	N. 28° W.
29+00.0	56+82.0	N. 69° W.	125+00.0	145+83.0	N. 66° 15' W.	184+00.0	197+00.0	S. 78° 30' W.
56+82.0	68+30.0	S. 67° 30' W.	145+83.0	161+00.0	N. 84° W.	197+00.0	224+50.0	N. 86° 45' W.
68+30.0	85+50.0	N. 69° W.	161+00.0	176+00.0	N. 45° W.	224+50.0	230+00.0	S. 23° W.
85+50.0	107+48.0	S. 78° 30' W.						

LATERAL "X."

0+00.0	6+85.0	N. 45° E.	392+60.0	403+00.0	S. 29° 45' E.	403+00.0	409+00.0	S. 29° 30' E.
394+10.0	392+60.0	N. 90° E.						

SOUTH FORK PANTHER BRANCH.

0+00.0	40+77.0	N. 77° 30' W.	54+48.0	64+06.0	N. 72° W.	64+06.0	74+00.0	S. 76° W.
40+77.0	54+48.0	N. 45° W.						

COTTON MILL BRANCH.

0+00.0	9+00.0	N. 53° W.	16+58.0	18+58.0	N. 22° 45' W.	31+06.0	41+47.0	N. 19° W.
9+00.0	13+41.0	N. 60° 45' W.	18+58.0	22+00.0	N. 64° 15' W.	41+47.0	76+00.0	N. 57° W.
13+41.0	16+58.0	N. 6° 30' W.	22+00.0	31+06.0	N. 58° 30' W.			

GUM BRANCH.

0+00.0	11+00.0	N. 53° W.	49+41.0	60+00.0	N. 58° 30' W.	80+00.0	100+00.0	N. 68° 30' W.
11+00.0	27+00.0	S. 51° 30' W.	60+00.0	80+00.0	S. 76° W.	100+00.0	129+00.0	N. 31° W.
27+00.0	49+41.0	N. 82° W.						

[Bull. 246]

APPENDIX IV.

General specifications for open ditches in Back Swamp and Jacob Swamp drainage district.

1. The work shall be done under the direction and supervision of the superintendent of construction, who will give directions as to the manner in which the work shall be performed, and the contractor shall conform to such directions and to the plans and specifications hereto attached. The work shall be commenced at such points as the superintendent of construction shall direct and shall conform to his directions as to the order of time in which different parts of the work shall be done.

2. The contractor shall be present at the work at all times or be represented by a competent foreman to whom directions and instructions as to the manner and order of doing the work may be given, and such directions and instructions shall be binding upon the contractor.

3. The contractor shall not transfer or assign this contract, or sublet any part of the work without first securing the written consent of the superintendent of construction, and such transfer, assignment, or subcontract shall in no manner relieve the contractor of his obligations or liabilities under this contract.

4. The contractor will employ such methods, appliances, and forces for the performance of the work as will, in the opinion of the superintendent of construction, secure the completion of the work within the time specified in the contract.

5. The superintendent of construction shall decide all questions as to the true intent and meaning of these plans and specifications, and his decision shall be binding upon both parties. The superintendent of construction may make any alterations in the location, grade lines, or dimensions of the ditches, or any part thereof, either before or after the commencement of the work; provided, that if such alterations increase or diminish the total amount of excavation, the change shall be agreed to by both parties of the contract. The unit price for work required by any change in the plans shall be the same as the price named in the contract for work of similar character. No claim for extra work shall be allowed unless the same shall have been done in execution of a written order by the superintendent of construction, and the unit price allowed for such extra work shall be the price named in the contract for work of similar character. Work omitted shall be treated on the same basis as extra work and the deduction determined in a similar manner.

6. If, at any time, the work be found deficient in any respect, the superintendent of construction shall at once give notice to the contractor, specifying in what respect it is deficient, and the contractor shall remedy such deficiency before proceeding with the work. Failure or neglect to condemn defective work at or before the time of a monthly estimate shall not be construed as acceptance of said work.

7. No charge shall be made by the contractor for hindrance or delay, from any cause, in the progress of any portion of the work of this contract; but such hindrance or delay may entitle him to an extension of the time to be allowed for the completion of the work sufficient to compensate for the detention, this time to be determined by the superintendent of construction.

8. The contractor will be held responsible for all damage which may occur to property or persons in consequence of any neglect or carelessness of himself or his employees; he will be held responsible for all trespass or injury to persons or property which may

result from any acts or omission on the part of himself or employees, and which are not permitted under the North Carolina drainage law, chapter 442, section 24, laws of 1909.

9. The contractor will assume all risks due to the action of the elements, the nature of the work to be done under these specifications, or unforeseen obstruction or delays that may occur before the completion and acceptance of the work, and he shall deliver the same in perfect condition.

10. All directions and instructions given by engineers, inspectors, or other persons representing the superintendent of construction during the construction of the work under this contract shall be fully and implicitly carried out.

11. The work will be inspected at such intervals as the superintendent of construction deems proper; at least one inspection being made each month by the superintendent or his representative. Payments for work done shall be made in accordance with the provisions of the North Carolina State drainage law.

12. The contractor shall give the superintendent of construction at least five days' notice before removing any highway bridge, and the removal of railroad bridges and the crossing of railroad tracks shall be done in the manner provided in the North Carolina State drainage law. Wherever the route of the ditch is traversed or crossed by public or private roads, commodious passing places must be kept open and in safe condition for use at the expense of the contractor. In passing through farms the contractor shall keep up such fences as will be necessary for the preservation of the crops and protection to property, and he shall be liable for all damage resulting from noncompliance with this specification.

13. The location of survey stakes, the maps and profiles, and the engineer's report shall constitute essential parts of these specifications. The locations of the ditches, as indicated by the survey stakes, and the dimensions as given in the engineer's report, shall be strictly adhered to by the contractor, except as provided in paragraphs 5 and 14.

14. No work shall be accepted where the contractor leaves the line of the survey, except when done in the execution of a written order of the superintendent of construction, as provided in paragraph 5.

14. The material taken from the ditches shall be deposited not nearer than 8 feet from the margin of the ditch on dredged ditches, and 6 feet from the margin on hand ditches. The work shall be so finished that the margins shall be clear cut, the slopes of the sides uniform, and the bottoms of even grade. Unless otherwise directed by the superintendent of construction, openings not less than 4 feet wide and not more than 500 feet apart shall be left through the waste banks on each side so that surface water may have free access to the ditch. No natural watercourse emptying into the ditch shall be obstructed by the waste banks. The contractor will be held responsible for the ditches retaining their full dimensions until accepted. The contractor will be permitted to excavate the ditches to larger cross section than required by the specifications, excepting on such portions as shall be limited to the specified dimensions by written order of the superintendent of construction; provided, however, that the contractor shall be paid for the excavation of only that material included within the specified dimensions.

15. The entire width of right of way shall be cleared by the contractor of trees, logs, brush, vines, and undergrowth. The berms shall be cleared of all stumps over 12 inches in height.

16. If, within a reasonable time after being notified to do so by the superintendent of construction, the contractor shall fail to proceed with the work or shall fail to use suitable methods or appliances or sufficient force, or shall fail to correct defective work, the superintendent may then declare this contract void and the board of drainage commissioners may proceed against the contractor as provided in section 23 of the North Carolina drainage law, chapter 442, laws of 1909.

[Bull. 246]



U. S. DEPARTMENT OF AGRICULTURE.

OFFICE OF EXPERIMENT STATIONS—BULLETIN 247.

A. C. TRUE, Director.

ORGANIZATION LISTS OF THE
AGRICULTURAL COLLEGES AND
EXPERIMENT STATIONS
IN THE UNITED STATES.

DECEMBER, 1911.



WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1912.

LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
Washington, D. C., October 25, 1911.

SIR: I have the honor to transmit herewith a manuscript containing the revised organization lists of agricultural colleges and experiment stations in the United States, which has been compiled, under my direction, by Miss Mary A. Agnew, of this office.

In compiling these lists it has been our policy to include only the names of administrative officers and instructors whose work brings them in contact with students in agricultural and home economics courses, omitting those who deal exclusively with mechanic arts or engineering students; but, as formerly, it has in some cases been found impracticable, owing to the complex organization of the institutions concerned, to make the lists entirely consistent.

I recommend the publication of this manuscript as Bulletin 247 of this office.

Respectfully,

A. C. TRUE,
Director.

Hon. JAMES WILSON,
Secretary of Agriculture.

CONTENTS.

	Page.
Key to abbreviations.....	5
The Office of Experiment Stations.....	6
Officers of the Association of American Agricultural Colleges and Experiment Stations.....	8
Officers of the American Association of Farmers' Institute Workers.....	8
Agricultural colleges and experiment stations in the United States, with govern- ing boards, courses of study, boards of instruction, and station staffs.....	9
Index of names.....	79

KEY TO ABBREVIATIONS.

Acad., Academy, Academic.
Acct., Accountant, Accounts.
Acty., Acting.
(Acty.), Acting Professor.
(Adjunct), Adjunct Professor.
Agr., Agriculture, Agriculturist, Agricultural.
Agron., Agronomy, Agronomist.
Ag't., Agent.
Anal., Analytical, Analysis.
Anat., Anatomy.
Arch't., Architecture.
Arith., Arithmetic.
Assoc., Associate.
(Assoc.), Associate Professor.
Asst., Assistant.
(Asst.), Assistant Professor.
Astron., Astronomy.
Bact., Bacteriology, Bacteriologist.
Bibliog., Bibliography, Bibliographer.
Biol., Biology, Biologist, Biological.
Blacksm., Blacksmithing.
Bot., Botany, Botanist, Botanical.
Chair., Chairman.
Chem., Chemist, Chemistry, Chemical.
Climat., Climatology, Climatologist.
Comd't., Commandant.
Com'l., Commercial.
Comp., Comparative.
Comr., Commissioner.
Coop., Cooperate, Cooperative, Cooperation.
Corresp., Correspondence, Correspondent.
Dept., Department.
Dir., Director.
Div., Division.
Dom., Domestic.
Draw., Drawing.
Econ., Economy, Economic, Economics.
Ed., Education.
Elc., Elementary.
Elect., Electrical, Electricity.
Eng'n., Engineer, Engineering.
Engl., English. •
Ent., Entomology, Entomologist.
Expt., Experiment, Experimental, Experiment-
 alist, Experimenter.
Ext., Extension.
Feed., Feeding.
Fert., Fertilizer.
Flor., Floriculture, Florist.
For., Forestry.
Gard., Gardener, Gardening.
Gen., General.
Geog., Geography.
Geol., Geology, Geologist, Geological.
Gov., Governor.
Hist., History, Historical.
Hort., Horticulture, Horticulturist.
Husb., Husbandry, Husbandman.
Hyg., Hygiene.
Indus., Industrial, Industries, Industry.
Inorg., Inorganic.
Insp., Inspector, Inspection.
Insts., Institutes.

Instr., Instruction, Instructor.
Invest., Investigations.
Irrig., Irrigation, Irrigationist.
Lab., Laboratory.
Lang., Language, Languages.
Lat., Latin.
Lect., Lecturer.
Libr., Library, Librarian.
Lit., Literature.
Mach., Machine, Machinery, Machinist.
Math., Mathematics.
Mech., Mechanics, Mechanician, Mechanical.
Met., Meteorology, Meteorologist.
Metal., Metallurgy.
Mfg., Manufacturing.
Mgt., Manager.
Mgt., Management.
Mil., Military.
M'n., Mineralogy, Mineralogist, Mining.
Mod., Modern.
Myc., Mycology, Mycologist.
Nat., Natural.
Nutr., Nutrition.
Oler., Olericulture, Olericulturist.
Org., Organic.
Ornith., Ornithology.
Path., Pathology, Pathologist.
Pedag., Pedagogy, Pedagogics.
Pharm., Pharmacy, Pharmacist, Pharmaceutical.
Philos., Philosophy.
Photog., Photography.
Phys., Physics, Physicist, Physical.
Physiol., Physiology, Physiologist, Physiological.
Polit., Political.
Pomol., Pomology, Pomologist.
Pract., Practice, Practical, Practicums.
Prep., Preparatory.
Pres., President.
Prin., Principal.
Print., Printing.
Prod., Production.
Psych., Psychology.
Rhet., Rhetoric.
Sci., Science, Scientific.
Sec., Secretary.
Sew., Sewing.
Sociol., Sociology.
Sta., Station.
Sten., Stenography, Stenographer.
Substa., Substation.
Supt., Superintendent.
Tech., Technology, Technical.
Treas., Treasurer.
Typew., Typewriting, Typewriter.
Univ., University.
V. Dir., Vice Director.
Veg., Vegetable, Vegetation.
Vet., Veterinary, Veterinarian.
Vit., Viticulture, Viticulturist.
V. Pres., Vice President.
Wheelwr., Wheelwrighting.
Zool., Zoology, Zoologist.

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¹ On leave.

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There are 10 four-year courses, viz: Agronomy, animal husbandry, entomology, forestry, horticulture, civil and irrigation engineering, electrical engineering, mechanical engineering, home economics, and general science (B. S.); post-graduate courses; a three-year course in veterinary science (D. V. S.); three-year courses of six months each in agriculture, mechanic arts, and domestic science, to which may be added a fourth year of six months for college entrance; and a farmers' and housekeepers' week held in January.

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² In cooperation with the U. S. Department of Agriculture.

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The Connecticut Agricultural College, Storrs.¹

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Storrs Agricultural Experiment Station, Storrs.¹

Department of the Connecticut Agricultural College, under the control of the board of trustees.

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¹ Telegraph address, *Storrs via Willimantic*; railroad station, express, and freight address, *Eagleville*.

* In the service of the U. S. Department of Agriculture.

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COURSES OF STUDY.

The following four-year courses, leading to the degrees of B. S., B. Agr., and B. E., respectively, are offered: Scientific, agricultural, and engineering. There are also a four-year normal course, and industrial courses of two years each in woodworking, iron working, blacksmithing, masonry, printing, cooking, sewing, and dressmaking.

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COURSES OF STUDY.

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The college of agriculture offers a four-year course leading to the degree of B. S. in Agr., a two-year course, a one-year special course, two four months' short courses for farmers, a four weeks' farmers' course, and correspondence courses in agriculture for home study. A year's postgraduate work in agriculture is also offered.

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Agricultural Experiment Station of Florida, Gainesville.

Department of the University of the State of Florida, under the control of the board of control.

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COURSES OF STUDY.

The courses of study are: Four-year scientific (B. S.), English-normal (two years), high school and grammar school (three years each), with industrial and agricultural training through all courses. A correspondence course in agriculture and laboratory courses in general agriculture are also offered.

¹ On leave.

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COURSES OF STUDY.

Four courses in agriculture are offered, viz, a four-year course leading to the degree of B. S., one-year course, three months' course, and a ten days' (winter) cotton school; a four-year forest engineering course leads to the degree of B. S. F.; summer short courses in cotton grading and agriculture, and a stockmens' short course are also offered.

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The courses offered are industrial, preparatory, normal, and collegiate (A. B.). Practical agriculture is made one of the industrial features of the college courses. A special one-year dairy course is offered.

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COURSES OF STUDY.

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¹ Telegraph, freight, and express address, *Griffin*.² Address: *Island of Guam, via San Francisco.*

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¹ On leave.

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Agricultural Experiment Station of the University of Idaho, Moscow.

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W. H. Wicks, M. S. A., *Hort.*

L. F. Childers, M. S., *Agron.*

E. J. Iddings, B. S. A., *Animal Husb.*

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There are five four-year courses, leading to the degree of B. S., viz: Agriculture, household science, floriculture, landscape gardening, and a general course for prospective teachers of agriculture; six weeks' summer courses in secondary and elementary agriculture for rural teachers; a four weeks' buttermakers' course; and two weeks' courses in agriculture and domestic science, are offered. Provision is also made for special students.

¹ In cooperation with U. S. Department of Agriculture.

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¹ On leave for one year at the College of Agriculture of the University of Maine.

² Includes only instructors in subjects directly relating to agriculture. Many other members of the university faculty give instruction to students pursuing the course leading to the degree of B. S.

³ In full charge of all substation.

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¹ To resign January 1, 1912.

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COURSES OF STUDY.

Four four-year courses are offered, all leading to the B. S. degree—viz, agronomy and horticulture, animal husbandry and dairying, forestry, and training for teachers in agriculture in secondary schools. The work in home economics is located in the college of arts and sciences. Several winter courses are offered, including a four weeks' course in dairying and creamery management, a five weeks' course in general agriculture, a two weeks' course in domestic science, and a farmers' week. A five weeks' summer school for teachers and others includes courses in agriculture and home economics.

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¹ On leave. ² In charge of cooperative investigations with United States Department of Agriculture.

Vermont Agricultural Experiment Station, Burlington.

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The courses of study are as follows: Four-year agricultural, applied biology, horticultural, applied chemistry, applied geology, metallurgy and metallography, civil engineering, mechanical engineering, electrical engineering, and mining engineering (B. S.); one-year course in practical agriculture and mechanics (certificate), and a farmers' (one month) winter course.

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¹ In cooperation with the U. S. Department of Agriculture.

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¹ On leave.

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Washington Agricultural Experiment Station, Pullman.

Department of the State College of Washington, under the control of the board of regents.

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West Virginia Agricultural Experiment Station, Morgantown.

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INDEX OF NAMES.

- Abbott, J. B., 25.
 Abbott, W. L., 22.
 Adams, A. C., 35.
 Adams, C. F., 12, 13.
 Adams, F., 7.
 Adams, G. E., 62, 63.
 Adams, J. F., 61.
 Adams, J. L., 31.
 Adams, J. Q. (La.), 22.
 Adams, J. Q. (Utah), 68.
 Adams, J. W., 15.
 Adams, M., 46.
 Ade, G., 24.
 Agee, A., 60, 61.
 Agee, H. P., 21.
 Ageton, C. N., 7, 62.
 Ahearn, M. F., 28.
 Ahrends, A. E., 48.
 Alcher, E. H., 41.
 Aicher, L. C., 22.
 Ailman, J. T., 60.
 Akerman, A., 19.
 Alcock, J. R., 37.
 Alderman, L. R., 58.
 Alderman, W. H., 74.
 Aldrich, J. M., 22.
 Alexander, A. B., 75.
 Alexander, C. O., 27.
 Alexander, H. C., 34.
 Alexander, I., 67.
 Alexander-Bahrenberg, Mrs. C. T., 22.
 Aley, R. J., 34.
 Alford, T. G., 24.
 Allen, A. A., 28.
 Allen, B. F., 44.
 Allen, C. S., 45.
 Allen, E. A., 42.
 Allen, E. W., 6, 8.
 Allen, F. W., jr., 26.
 Allen, H. E., 24.
 Allen, H. J., 37.
 Allen, R. F., 38.
 Allen, R. M., 30, 31.
 Allen, R. W., 59.
 Allen, W. M., 53.
 Allis, C. D., 10.
 Allison, E., 25.
 Allison, H. O., 42, 43.
 Allison, I. M. K., 15.
 Allison, J. H., jr., 27.
 Allison, T. F. P., 66.
 Alsop, J. W., 16.
 Alway, F. J., 45, 46.
 Ames, C. T., 42.
 Ames, J. W., 56.
 Ammons, E. M., 14.
 Anderson, A., 64.
 Anderson, A. C., 37, 38.
 Anderson, B. G., 71.
 Anderson, C. B., 45.
 Anderson, C. E., 17.
 Anderson, C. L., 10.
 Anderson, D. W., 37.
 Anderson, E. E., 49.
 Anderson, H. C., 65.
 Anderson, H. W., 24.
 Anderson, J. E., 44.
 Anderson, J. N., 18.
 Anderson, J. T., 10.
 Anderson, L., 13, 14.
 Anderson, R. E., 57.
 Anderson, R. J., 50.
 Anderson, W., 34.
 Anderson, W. B., 26.
 Anderson, W. C., 40.
 Andrews, A. L., 21.
 Angel, W. P., 53.
 Anspen, B. W., 41.
 Anthony, R. D., 51.
 Anthony, S., 40.
 App, F., 47.
 Apperson, J. T., 58.
 Appleman, C. O., 35.
 Appleton, J. L., jr., 61.
 Arbuthnot, J. G., 59.
 Arias, J. B., 62.
 Arkell, T. R., 47.
 Armsby, H. P., 8, 60, 62.
 Armstrong, A. E., 46.
 Armstrong, F. F., 11.
 Armstrong, F. L., 33.
 Armstrong, L. E., 61.
 Armstrong, R. A., 74.
 Armwood, W. A., 19.
 Arnett, C. N., 26.
 Arnett, W. L., 74.
 Arnold, C. L., 56.
 Arnold, F. R., 68.
 Arnold, R. G., 9.
 Arnot, G., 49.
 Arny, A. C., 39, 40.
 Arthur, J. C., 24, 25.
 Arthur, M. J., 72.
 Artley, H. B., 7.
 Arville, Mrs. M. A., 26.
 Arvold, A. G., 54.
 Arzberger, E. G., 56.
 Ashbury, S. E., 67.
 Ashby, R. C., 73.
 Ashe, C. A., 72.
 Ashley, E. L., 36.
 Ashmore, O., 20.
 Ashton, L. H., 51.
 Atkeson, T. C., 74.
 Atkins, J. A., 19.
 Atkinson, A., 44, 45.
 Atkinson, T. W., 32.
 Attaway, D. E., 19.
 Atwood, H., 74.
 Aull, W. B., 64.
 Aumer, J. P., 23.
 Aust, C., 40.
 Austin, A. D., 71.
 Austin, G. A., 11.
 Austin, Mrs. M., 12.
 Auten, J. T., 67.
 Averill, A. W., 34.
 Averitt, S. D., 30, 31.
 Avery, S., 8, 45.
 Ayres, B., 8, 65, 66.
 Ayres, H. L., 51, 52.
 Babb, J. G., 42, 43.
 Babcock, E. B., 13, 14.
 Babcock, O. G., 35.
 Babcock, S. M., 75, 76.
 Babcock, W., 37.
 Babson, H., 24.
 Bach, L., 59.
 Bachelder, N. J., 47.
 Bachman, F., 75.
 Bachtell, M. A., 56.
 Back, E. A., 71.
 Backus, L. S., 43.
 Badenoch, A. H., 49.
 Baer, A. A., 45.
 Baer, A. C., 75, 76.
 Baggs, W. T., 48.
 Bagley, J. B., 67.
 Bahnsen, P. B., 9.
 Bahrenberg, Mrs. C. T. A., 22.
 Bailey, C. H., 40.
 Bailey, D. E., 65.
 Bailey, E. M., 16.
 Bailey, E. W., 23, 24.
 Bailey, F. D., 59.
 Bailey, L. H., 51, 52.
 Bailey, I. M., 43.
 Bain, S. M., 66.
 Baird, R. O., 57, 58.
 Baker, C. A., 15.
 Baker, E. C., 38.
 Baker, E. L., 50.
 Baker, E. T., 22.
 Baker, G. J., 39.
 Baker, G. T., 25.
 Baker, H. J., 36, 37.

- Baker, H. P., 23.
 Baker, J. F., 37, 38.
 Baker, J. H., 44.
 Baker, L. W., 17.
 Baker, M. B., 39.
 Baker, W. C., 51.
 Bakke, A. L., 26.
 Baldwin, C. W., 35.
 Baldwin, L. A., 44.
 Baldwin, L. B., 59.
 Baldwin, S. E., 16.
 Balls, W. H., 32.
 Ball, E. D., 68, 69.
 Ball, L. H., 17.
 Ball, O. M., 66.
 Ballantyne, A. B., 69.
 Ballard, F. B., 64.
 Ballard, W. R., 35.
 Ballenger, T. T., 52.
 Ballentine, M. F., 11.
 Ballinger, F., 44.
 Ballou, F. H., 56.
 Ballou, H. M., 21.
 Banks, N. A., 68.
 Barber, B. M., 45.
 Barber, L. B., 29.
 Barber, W. H., 61.
 Barbour, E. H., 46.
 Barbour, E. L., 48.
 Bardenwerper, K., 46.
 Barding, E. P., 59.
 Barels, G. M., 56.
 Bark, D. H., 7.
 Barker, G. R., 21.
 Barker, H. S., 30.
 Barker, J. F., 50.
 Barker, J. M., 70, 71.
 Barker, P. B., 46.
 Barlow, J., 62.
 Barlow, T. W., 60.
 Barlow, W. E., 70.
 Barnes, C. L., 15.
 Barnes, G. A., 28.
 Barnes, K. W., 53.
 Barnes, R. A., 44.
 Barnes, R. B., 9.
 Barnhart, J. M., 24.
 Barr, J. H., 50.
 Barre, H. W., 64.
 Barrell, E. P., 33.
 Barrell, Mrs. E. P., 33.
 Barrett, J. T., 23, 24.
 Barringer, P. B., 70, 71.
 Barrow, D. C., 19, 20.
 Barrows, H. H., 7.
 Barrows, W. B., 37.
 Barrows, W. M., 56.
 Barrus, M. F., 51, 52.
 Barss, H. P., 73.
 Bartholomew, C. E., 26.
 Bartlett, J. M., 34.
 Barto, D. O., 23.
 Bass, R. P., 47.
 Bassett, L. B., 39, 40.
 Batchelor, L. D., 68, 69.
 Bate, F. E., 48.
 Bates, E. S., 12.
 Bates, M. C., 65.
 Batt, M., 54.
 Battiste, M. J., 64.
 Bauer, F. C., 23.
 Baum, A. M., 28.
 Baus, R., 33.
 Baxter, O. G., 7.
 Baxter, R. B., 40.
 Bayard, E. S., 60.
 Bayha, A., 29.
 Bayless, C. H., 11.
 Baysinger, S. L., 42.
 Beach, B. A., 75, 76.
 Beach, C. L., 16.
 Beach, S. A., 26, 27.
 Beahan, W., 50.
 Beal, A. C., 51, 52.
 Beal, J. M., 53.
 Beal, L. H., 28.
 Beal, W. H., 6, 8.
 Beal, W. J., 37.
 Beale, A., 32.
 Beale, T., 13.
 Bear, F. E., 56.
 Beard, H. L., 59.
 Beardshear, C. B., 26.
 Beattie, R. K., 72.
 Beatty, C., 35.
 Beaty, E. B., 59.
 Beaty, J. Y., 75, 76.
 Beaty, L. L., 59.
 Beaumont, J. W., 37.
 Beaver, J. A., 60.
 Beck, M., 44.
 Beckenstrater, H., 35.
 Becker, A., 28.
 Becker, G. G., 12, 13.
 Beckett, S. H., 7.
 Beckman, F. W., 26, 27.
 Beckmann, H. H., 27.
 Beckwith, T. D., 59.
 Bedford, R. C., 10.
 Beegle, M. F. M., 57.
 Beighle, E. E., 38.
 Bell, A. J., 33.
 Bell, A. T., 32.
 Bell, A. W., 9.
 Bell, C. E., 53.
 Bell, J. C., 14.
 Bell, M. W., 53.
 Bell, W. B., 54.
 Belling, J., 18.
 Bellis, A. E., 77.
 Bemis, B., 39, 40.
 Bemis, H. E., 26.
 Benard, L. L., 18.
 Benedict, P. A., 70.
 Benham, R., 38.
 Benitez, R. A., 62.
 Benjamin, E. W., 51.
 Benkendorf, G. H., 75, 76.
 Bennett, A. A., 26.
 Bennett, B. F., 35.
 Bennett, E. R., 15.
 Bennett, J. W., 19.
 Bennett, R. L., 66, 67.
 Bentgson, N. A., 45.
 Bentley, G. M., 66.
 Bentley, J., Jr., 51.
 Benton, G. P., 69.
 Bentzel, E. H., 72.
 Bentzen, F. W., 38.
 Berchtold, F., 58.
 Berg, H., 38.
 Bergen, T. G., 47.
 Berger, O. F., 18.
 Bergman, H. D., 26.
 Bergman, H. F., 54, 55.
 Berry, J. B., 61.
 Berry, J. T., 72.
 Berry, L. E., 16.
 Berry, W. M., 17.
 Besley, F. W., 35.
 Bessey, C. E., 45.
 Bessey, E. A., 37, 38.
 Betts, C. W., 72.
 Bevan, W. A., 26.
 Bavier, I., 23.
 Bexell, J. A., 58.
 Bias, J. H., 11.
 Biddison, C., 28.
 Bigelow, C. E., 71.
 Biggar, H. H., 65.
 Biggs, J., 17.
 Billetdoux, E. W., 48.
 Billings, T., 25.
 Billsborrow, J. D., 40.
 Bingham, D., 47.
 Bingham, G. H., 47.
 Bingham, S. L., 69.
 Bioletti, F. T., 13, 14.
 Birch, M. T., 63.
 Bird, R. A., 76.
 Birdsong, M. S., 63.
 Bishop, E. C., 27.
 Bishop, E. F., 21.
 Bishop, J. L., 19.
 Bissell, G. W., 37.
 Bittenbender, H. A., 57.
 Bittner, W. S., 38.
 Bixby, F. L., 7, 49.
 Bizzell, J. A., 51, 52.
 Black, C. A., 47.
 Black, H. V., 19.
 Black, J. M., 42.
 Black, W. J., 8.
 Blackburn, W. E., 27.
 Blackmon, G. H., 67.
 Blackshear, E., 68.
 Blackshear, E. L., 68.
 Blain, H. M., 32.
 Blair, A. W., 48.
 Blair, F. G., 22.
 Blair, J. C., 23, 24.
 Blair, J. F., 44.
 Blair, M. J., 39, 40.
 Blaisdell, T. C., 37.
 Blake, G. A., 17.
 Blake, J. C., 66.
 Blake, M. A., 48, 49.
 Blakeslee, A. F., 16.
 Blanchard, C. L., 73.
 Blanchard, H. L., 73.
 Blattner, D. G., 29.

Blasee, C. L., 64.
 Bledsoe, P., 68.
 Bledsoe, W., 53.
 Bielle, A. M., 55.
 Blinn, P. K., 15.
 Bliss, G. R., 27.
 Bliss, R. K., 27.
 Blohm, A. F., 56.
 Blood, C. H., 50.
 Blood, F. B., 56.
 Bluford, J. H., 54.
 Blumenfeld, S. F., 41.
 Boardman, H. P., 46.
 Bock, J. C., 38.
 Bohler, J. F., 73.
 Boldt, G. C., 50.
 Bolley, H. L., 54, 55.
 Boltz, G. E., 57.
 Bomberger, F. B., 35.
 Bond, J. D., 67.
 Bonebright, H. B., 44, 45.
 Bonnet, L., 14.
 Bonns, W. W., 34.
 Bontrager, W. E., 57.
 Boone, L. D., 64.
 Boot, E. M., 23.
 Booth, N. O., 57, 58.
 Borders, J. M., 12.
 Boring, A. M., 34.
 Borland, A. A., 69, 70.
 Boss, A., 39, 40.
 Boston, S. M., 64.
 Bostwick, C. D., 50.
 Bosworth, A. W., 50.
 Bottomley, A. W. T., 21.
 Boucke, O. F., 61.
 Bouquet, A. G. B., 59.
 Bourne, A. I., 37.
 Bouteille, F. C., 39.
 Bouton, R., 45.
 Boutwell, H. L., 47.
 Bouyoucos, G., 38.
 Bowditch, J., Jr., 38.
 Bowditch, N. I., 38.
 Bowen, A. F., 53.
 Bowen, B. L., 55.
 Bowen, J. V., 41.
 Bower, E. B., 61.
 Bower, H. J., 56.
 Bowers, J. H., 57.
 Bowker, W. H., 36.
 Bowles, P. E., 13.
 Bowles, P. S., 42.
 Bowman, A. E., 69.
 Bowman, A. M., 70.
 Bowman, J. C., 26.
 Bownocker, J. A., 55.
 Boyd, T. D., 31, 32.
 Boyd, W. E., 6.
 Boyd, W. L., 39, 40.
 Boyle, J. G., 24, 25.
 Brace, M. C., 27.
 Bracker, E. M. D., 24.
 Brackett, R. N., 63.
 Bradford, F. C., 59.
 Bradford, J. N., 55.
 Bradfute, O. E., 55.

Bradley, J. C., 51.
 Bradley, M. A., 72.
 Bradley, M. E., 63.
 Bradley, W. W., 63.
 Bragg, L. C., 15.
 Bragg, T., 9, 10.
 Bragg, V. W., 41.
 Brainerd, W. K., 70, 71.
 Braman, W. W., 62.
 Bramlett, A., 63.
 Brand, R. E., 23, 24.
 Brandenburg, W. A., 58.
 Brandson, E. B., 42.
 Brandt, L., 23.
 Brandt, P. M., 43.
 Bray, C. I., 57, 58.
 Bray, G. E., 28.
 Breaux, Z. N., 58.
 Breazeale, W. E., 48.
 Breese, L. B., 22.
 Breeze, F. J., 24.
 Bregger, T., 24.
 Brahm, C. E., 24.
 Breithaupt, L. R., 59.
 Brenton, C. R., 25.
 Bresee, E., 76.
 Bressler, R. G., 67.
 Brett, P. M., 48.
 Brewer, C. L., 42.
 Brewer, F. C., 67.
 Brewer, H. R., 44.
 Brewer, O. A., 57.
 Brewer, W. F., 44.
 Brewster, E., 12.
 Bricker, G. A., 56.
 Bridgesforth, G. R., 11.
 Bidwell, J. C., 13, 14.
 Brierly, W. G., 73.
 Briggs, F., 26.
 Brigham, A. A., 65.
 Brimley, H. H., 53.
 Brindley, J. E., 26.
 Brink, C. M., 28.
 Brink, R. W., 22.
 Brinkley, E. H., 35.
 Brinkley, L. L., 53.
 Briscoe, C. F., 23.
 Briscoe, J. M., 34.
 Briscoe, L. S., 33.
 Brittain, T. H., 68.
 Brittingham, T. E., 75.
 Britton, J. A., 13.
 Britton, W. E., 16.
 Brockett, Z. M., 15.
 Broderick, D. C., 21.
 Brodie, R. K., 59.
 Broemel, G. F., 57.
 Brooks, C., 47.
 Brooks, E., 39, 40.
 Brooks, F. E., 14.
 Brooks, H. B., 59.
 Brooks, J. F., 20.
 Brooks, L. H., 76.
 Brooks, N. C., 23.
 Brooks, R. P., 19.
 Brooks, W. E., 53.
 Brooks, W. P., 36, 37.

Broome, F. H., 66.
 Broughton, L. B., 36.
 Broughton, N. B., 52.
 Broussard, J. F., 32.
 Brown, A. G., 74.
 Brown, A. M., 37, 38.
 Brown, B. S., 14.
 Brown, C. E., 40.
 Brown, C. F., 7, 69.
 Brown, C. L., 46.
 Brown, C. W., 38.
 Brown, E. J., 61.
 Brown, F. L., 29.
 Brown, F. M., 69.
 Brown, F. R., 59.
 Brown, G. A., 38.
 Brown, G. C., 65.
 Brown, G. L., 65.
 Brown, H., 65.
 Brown, H. B., 41.
 Brown, J. A., 64.
 Brown, J. G., 12.
 Brown, J. T., 66.
 Brown, J. W., 35.
 Brown, L. A., 30, 31.
 Brown, N. C., 26.
 Brown, P. E., 26, 27.
 Brown, R. H., 28.
 Brown, S., 74.
 Brown, S. B., 74.
 Brown, S. H., 35.
 Brown, W., 47.
 Brown, W. G., 42.
 Browne, J. J., 72.
 Browne, W. H., Jr., 52.
 Bruce, C. A., 56.
 Brumley, O. V., 56.
 Bruner, E. O., 32.
 Bruner, L., 45, 46.
 Brunson, G. H., 41.
 Brush, J. L., 14.
 Bryan, A. B., 63.
 Bryan, E. A., 72.
 Bryan, G. T., 57.
 Bryan, J. E., 33.
 Bryan, W. A., 21.
 Bryant, T. R., 30, 31.
 Buchanan, J., 27.
 Buchanan, J. H., 27.
 Buchanan, R. E., 26, 27.
 Buchanan, W. S., 10.
 Buck, J. L. B., 72.
 Buckhout, W. A., 60, 61.
 Buckley, S. S., 35.
 Buckman, H. O., 51.
 Buckner, F. T. F., 17.
 Buckstaff, Mrs. F. G., 75.
 Budd, J. E., 13.
 Budd, J. T., 48.
 Buell, T. W., 67.
 Bugby, M. O., 56.
 Burgees, E. M., 74.
 Burgess, J. L., 53.
 Bull, A. M., 39, 40.
 Bull, C. P., 39, 40.
 Bull, F., 44.
 Bull, M. L., 39.

- Bull, S., 24.
 Bullard, J. E., 32.
 Bullen, J. C., 42.
 Bullock, F., 45.
 Bundy, L., 59.
 Burch, N. C., 44.
 Burd, J. S., 13, 14.
 Burdick, H., 62.
 Burger, A. A., 27.
 Burgess, J. Ph., 53.
 Burgess, J. M., 63.
 Burghart, L. M., 34.
 Burke, A. K., 34.
 Burke, E., 45.
 Burke, T. F., 76.
 Burlingame, G. E., 62.
 Burlingame, R. S., 62.
 Burnett, E. A., 8, 45, 46.
 Burnett, L. C., 27.
 Burnett, W. L., 15.
 Burns, G. P., 69, 70.
 Burns, J. C., 67.
 Burr, W. W., 46.
 Burrage, F. S., 76, 77.
 Burrage, L. M., 61.
 Burrage, S., 24.
 Burrell, W. P., 71.
 Burrill, A. C., 75, 76.
 Burrill, T. J., 23.
 Burritt, E. M., 45.
 Burson, W. M., 19.
 Burt, F. A., 38.
 Burt, G. J., 51.
 Burt, J. H., 28, 29.
 Burton, P. E., 42.
 Burton, R. W., 9.
 Busey, Mrs. M. E., 22.
 Bush, L. P., 17.
 Bushnell, L. D., 28, 29.
 Buswell, A. M., 34.
 Butler, H. P., 64.
 Butler, O. R., 75, 76.
 Butler, P., 39.
 Butman, C. A., 36.
 Butterfield, K. L., 36.
 Butterfield, M., 28.
 Butts, E. L., 39, 40.
 Byall, S., 33.
 Byars, L. P., 64.
 Cable, E. Y., 27.
 Cade, T. E., 64.
 Cadwallader, J. M., 57.
 Cady, Le R., 39, 40.
 Caffrey, D. J., 16.
 Cage, S., 57.
 Cain, G. D., 33.
 Caine, J. T., Jr., 68.
 Caine, J. T., III, 68, 69.
 Caldwell, A. B., 65.
 Caldwell, H. V., 26.
 Caldwell, R. E., 25.
 Calhoun, F. H. H., 63.
 Call, L. E., 28, 29.
 Callahan, I. B., 59.
 Callaway, G. R., 44.
 Calloway, R. C., 32.
 Calvert, S., 42.
 Calvin, Mrs. H. W., 24.
 Calvin, J. W., 28, 29.
 Calvin, M. V., 20.
 Cammack, A. B., 15.
 Camp, R. H., 45.
 Camp, W. E., 43.
 Campbell, C. R., 74.
 Campbell, G., 59.
 Campbell, J. Ph., 19.
 Campbell, J. R., 55.
 Campbell, L. H., 27.
 Campbell, P. A., 34.
 Campbell, T. M., 11.
 Campbell, T. P., 70.
 Campbell, W. A., 66.
 Campbell, W. W., 10.
 Cance, A. E., 36.
 Canfield, G. M., 48.
 Canfield, R. W., 67.
 Cannon, A., 53.
 Cannon, H. P., 17.
 Cantey, M. A., 64.
 Cantwell, M. A., 44.
 Canty, J. M., 74.
 Capen, C. A., 16.
 Capper, A., 27.
 Carberry, V. J., 49.
 Cardon, P. V., 69.
 Cardozo, F. H., 19.
 Cardullo, F. E., 47.
 Carey, W. L., 35.
 Carlisle, J. N., 50.
 Carlyle, A., 73.
 Carlyle, W. L., 22.
 Carman, A. P., 23.
 Carmichael, B. E., 56.
 Carnegie, A., 50, 60.
 Carney, W. B., 71.
 Carpenter, J. N., 48.
 Carpenter, C. E., 15.
 Carpenter, C. W., 70.
 Carpenter, H. G., 67.
 Carpenter, I. W., 10.
 Carpenter, T., 30.
 Carrel, W. J., 30.
 Carrere, E. A., 33.
 Carrier, L., 70, 71.
 Carrington, J. C., 70.
 Carroll, C. G., 12.
 Carroll, D. H., 35.
 Carroll, N. M., 35.
 Carroll, W. E., 68, 69.
 Carsten, W. J., 64.
 Carter, C. J., 34.
 Carter, Mrs. F. C., 74.
 Carter, H. C., 53.
 Carter, J. C., 71.
 Carter, L. M., 19.
 Carter, N., 43.
 Carter, R. D., 12.
 Carver, G. W., 11.
 Cary, C. A., 9, 10.
 Cary, C. P., 75.
 Casho, E., 38.
 Cassidy, H., 67.
 Cathcart, C. S., 49.
 Cathro, T. E., 22.
 Catlin, C. A., 69.
 Caton, J. E., 29.
 Caulfield, M. C., 33.
 Cauthen, E. F., 10.
 Cavanaugh, G. W., 51, 52.
 Cave, R. A., 27.
 Cehrs, C. M., 44.
 Ceresole, P., 21.
 Cessna, O. H., 26.
 Chadwick, W. D., 41.
 Chaffee, N. K., 69.
 Chaffee, R. R., 61.
 Chalfant, F. C., 72.
 Challender, R. T., 44.
 Challoner, A., 75.
 Chamberlain, F. W., 37.
 Chamberlain, J. S., 36.
 Chamberlain, W. F., 44.
 Chamberlain, W. I., 48.
 Chambers, B. D., 34.
 Chambliss, H., 57.
 Champlin, M., 65.
 Chandler, A., 11.
 Chandler, B. A., 69.
 Chandler, H. A. E., 12.
 Chandler, R. E., 57.
 Chandler, W. H., 42, 43.
 Chapin, L. J., 73.
 Chapman, C. W., 38.
 Chapman, G. H., 37.
 Chappelle, L. L., 67.
 Charlton, I. D., 73.
 Chase, C. F., 28, 29.
 Chase, L. W., 45, 46.
 Chase, M., 26.
 Chastain, O. F., 67.
 Chatburn, G. R., 46.
 Chenet, H. S., 31.
 Cherry, D. K., 54.
 Cheyney, E. G., 39, 40.
 Childster, F. E., 48.
 Chilcott, E. F., 29.
 Childers, L. F., 22.
 Chinn, A., 30.
 Chipman, M. E., 21.
 Chiquelin, G., 32.
 Chisholm, H., 54.
 Chisholm, J., 56.
 Chittenden, F. H., 71.
 Chitty, R. A., 27.
 Chrisman, W. G., 53.
 Christensen, F. W., 49.
 Christenson, J. C., 29.
 Christie, G. I., 8, 24, 25.
 Christopher, C., 12, 13.
 Christy, E. S., 72.
 Chrysler, M. A., 34.
 Church, J. E., 46.
 Churchill, G. W., 50.
 Churchill, J. B., 60.
 Churchill, J. M., 16.
 Churchill, O. O., 57, 58.
 Clagett, W. B., 35.
 Clair, M. W., 35.
 Clancy, F. H., 69.
 Clapp, S. C., 53.

- Clark, A. J., 37.
 Clark, A. W., 60.
 Clark, D. W., 21.
 Clark, G., 76.
 Clark, J. E., 49.
 Clark, J. M., 71.
 Clark, J. W., 60.
 Clark, K., 69.
 Clark, O. L., 52.
 Clark, R. A., 11.
 Clark, R. R., 72.
 Clark, R. W., 44, 45.
 Clark, S. C., 7.
 Clark, T. A., 23.
 Clark, T. W., 46.
 Clark, V. E., 26, 27.
 Clark, W. D., 60, 61.
 Clarke, W. B., 32.
 Clarke, W. T., 13, 14.
 Clawson, B. J., 87, 58.
 Claxton, P. P., 8.
 Clay, C. M., 30.
 Clay, W. T., 52.
 Claybrook, J. I., 30, 31.
 Clearwater, A. T., 48.
 Cleghorn, A. W., 13.
 Clem, R. R., 27.
 Clevenger, C. H., 28.
 Clevenger, J. F., 61.
 Clevenger, W. L., 56.
 Clines, P. J., 20.
 Clinton, G. H., 31.
 Clinton, G. P., 16.
 Clinton, L. A., 16.
 Clopath, H., 39.
 Clothier, G. L., 73.
 Clothier, R. W., 12.
 Costes, C. E., 32.
 Cobb, A. C., 57.
 Cobb, C. A., 41.
 Cobb, G. R., 62.
 Cobb-Carter, Mrs. F., 74.
 Cobleigh, W. A., 44.
 Coburn, H. D., 77.
 Coburn, J. L., 68.
 Cooke, R. P., 71.
 Cochel, W. A., 60, 61.
 Cochrane, D. C., 62.
 Codd, A. A., 46.
 Coe, E. B., 47.
 Coen, B. F., 15.
 Cofer, D. B., 67.
 Coffey, A. B., 32.
 Coffey, G. N., 57.
 Coffey, W. C., 23, 24.
 Coffin, M. L., 39, 40.
 Cohen, J., 10.
 Coit, J. E., 13, 14.
 Colburn, F. E., 27.
 Colby, G. E., 13, 14.
 Cole, D., 48.
 Cole, J. T., 32.
 Cole, L. J., 75, 76.
 Cole, P. T., 71.
 Cole, V. E., 16.
 Coleman, L. L., 31.
 Collett, R. W., 53.
 Collier, E. T., 9.
 Collier, F. J., 48.
 Collins, S. F., 31.
 Collins, V. H., 44.
 Collins, V. S., 35.
 Collison, R. C., 57.
 Collison, S. E., 18.
 Colliver, W. D., 25.
 Colpitts, J. T., 26.
 Colver, C. W., 22.
 Colvin, C., 34.
 Colwell, R. H., 74.
 Comstock, A. B., 51.
 Comstock, J. H., 51, 52.
 Comstock, L., 34.
 Condit, L. M., 65.
 Condra, G. E., 45.
 Cone, V. M., 7, 15.
 Conn, G. W., 29.
 Conn., H. J., 50.
 Conn., H. W., 16.
 Connaway, J. W., 42, 43.
 Connell, J. H., 8, 57.
 Conner, A. B., 67.
 Conner, J. J., 19.
 Conner, S. D., 24, 25.
 Conner, W. G., 70.
 Conolly, H. M., 9, 10.
 Conrad, L. E., 28.
 Conradi, A. F., 63, 64.
 Conser, H. N., 34.
 Converse, G. L., 56.
 Converse, J. E., 66.
 Conway, W. T., 49.
 Conwell, C. S., 17.
 Conwell, S. L., 17.
 Cook, E., 40.
 Cook, G. B., 12.
 Cook, I. S., Jr., 74.
 Cook, L. B., 51, 52.
 Cook, M. T., 48.
 Cook, P., 48.
 Cook, R. B., 68.
 Cook, S. B., 44.
 Cook, W. A., 61.
 Cook, W. M., 56.
 Cooke, A. A., 72.
 Cooke, C. M., 20.
 Cooke, E. B., 10.
 Cooke, J. P., 21.
 Cooke, J. W., 33.
 Cooley, J. S., 71.
 Cooley, R. A., 44, 45.
 Coons, G. H., 38.
 Coope, J., 72.
 Cooper, B., 68.
 Cooper, D. W., 48.
 Cooper, E. L., 26.
 Cooper, H. E., 20.
 Cooper, J. W., 71.
 Cooper, L. L., 32.
 Cooper, R. M., 20.
 Cooper, S. W., 7.
 Cooper, W. B., 52.
 Cooper, W. H., 26.
 Coover, W. F., 26.
 Copson, G. V., 59.
 Corbett, L. C., 71.
 Corbett, L. J., 22.
 Corbett, L. L., 71.
 Corbett, L. S., 30, 31.
 Corbett, V. H., 15.
 Corbit, D. W., 17.
 Cordery, G. T., 36.
 Cordley, A. B., 58, 59.
 Corley, J. W. L., 57.
 Cornelius, A. B., 51.
 Cornell, C. E., 50.
 Corotis, M. E., 56.
 Corput, F., 20.
 Corson, O. T., 55.
 Cortelyou, J. V., 28.
 Corwin, R. W., 14.
 Cory, E. N., 35.
 Cosgriff, H. C., 27.
 Cosh, G. M., 51.
 Costello, M. F. P., 26.
 Cotton, E. C., 66.
 Cotton, W. W., 58.
 Couch, F. F., 48.
 Coulter, S., 24.
 Councilman, C. A., 35.
 Coupland, G., 45.
 Cousins-Dorsey, F., 74.
 Covell, G. A., 58.
 Cowan, J., 46.
 Cowan, T. N., 11.
 Cowles, I. F., 28.
 Cowgill, H. B., 62.
 Cowgill, P. E., 53.
 Cowgill, Mrs. T. W., 46.
 Cowper, R. J., 77.
 Cox, G., 44.
 Cox, H. W., 18.
 Cox, N. H., 18.
 Cox, R., 68.
 Cox, W. H., 30.
 Crabbe, J. B., 15.
 Crabtree, P. E., 29.
 Craig, C. E., 24.
 Craig, F. S., 33.
 Craig, J., 51, 52.
 Craig, M. B., 44.
 Craig, R. A., 24, 25.
 Craig, W., 34.
 Crain, R., 35.
 Crampton, G. C., 36.
 Crandall, C. S., 23, 24.
 Crandall, W. T., 23, 24.
 Crane, B. A., 19.
 Crane, O., 25.
 Cranford, C. C., 53.
 Cravens, W. H., 12.
 Crawford, H. C., 18.
 Crawford, J. F., 76.
 Crawford, J. H., 68.
 Crawford, N. A., Jr., 29.
 Crawley, J. T., 62.
 Crayne, A. Z., 58.
 Creasy, W. T., 60.
 Crebs, J. M., 22.
 Creese, M., 35.
 Crenshaw, B. H., 9.
 Creswell, M. E., 19.

- Crews, M., 18.
 Crider, F. J., 53.
 Crigler, N. B., 23.
 Crisp, H. L., 35.
 Critchfield, N. B., 60.
 Crittenden, R. F., 20.
 Critz, H., 41.
 Crocker, W. H., 13.
 Crockett, J. B., 67.
 Crockett, W. D., 60.
 Cromer, C. O., 25.
 Crookston, J., 69.
 Cropper, L. M., 19.
 Crosby, C. R., 51, 52.
 Crosby, D. J., 6, 7.
 Cross, L. J., 51.
 Cross, M. B., 68.
 Cross, P. J., 38.
 Cross, W. E., 32.
 Crouse, R. W., 72.
 Crow, A. C., 37.
 Crow, C. L., 18.
 Crowe, C. P., 56.
 Crowe, S. E., 38.
 Crowley, T. F., 33.
 Cruess, W. V., 14.
 Crumley, J. J., 56.
 Crutcher, W. H., 19.
 Cummings, M. B., 69, 70.
 Cunningham, C. C., 29.
 Cunningham, G. C., 70.
 Cunningham, J. C., 26.
 Cunningham, O. C., 56.
 Curl, M. J., 61.
 Currie, J. N., 16.
 Currier, G. W., 47.
 Curry, B. E., 47.
 Curtis, A. W., 74.
 Curtis, C. M., 17.
 Curtis, H. E., 30, 31.
 Curtis, M. R., 34.
 Curtis, R. S., 53.
 Curtis, W. C., 42.
 Curtiss, C. D., 38.
 Curtiss, C. F., 8, 26, 27.
 Cusick, J. T., 50.
 Cutler, C., 25.
 Dachnowski, A. P., 56.
 Dacy, A. L., 74.
 Daggett, W. P., 34.
 Dahl, A. H., 75.
 Dale, H. C., 68.
 Dales, J. S., 45, 46.
 Dalrymple, W. H., 32, 33.
 Dame, J. W., 44.
 Damon, S. C., 63.
 Daniel, D. W., 63.
 Daniel, W. E., 52.
 Daniels, A. L., 43.
 Danielson, H. R., 40.
 Darby, A. L., 74.
 Darden, W. A., 53.
 Darling, F. W., 71.
 Darnall, H. J., 66.
 Darst, W. H., 56.
 Daughters, M. R., 59.
 Davee, E. W., 34.
 Davenport, C. C., 31.
 Davenport, E., 8, 23.
 David, E. J., 47.
 Davidson, J. B., 26, 27.
 Davidson, R. J., 70.
 Davies, H., 30.
 Davies, P. M., 24.
 Davis, A. H., 38.
 Davis, B. F., 37.
 Davis, C., 66, 67.
 Davis, C. C., 64.
 Davis, E. A., 19.
 Davis, E. B., 48.
 Davis, E. G., 51.
 Davis, E. H., 24.
 Davis, E. P., 61.
 Davis, G. A., 29.
 Davis, G. J., 72.
 Davis, H., 74.
 Davis, H. L., 45.
 Davis, H. S., 18.
 Davis, J. M., 30.
 Davis, K. C., 48.
 Davis, L. M., 13, 14.
 Davis, Mary E., 11.
 Davis, Minnie E., 11.
 Davis, P. A., 57.
 Davis, P. J., 57.
 Davis, R., 38.
 Davis, T., 17.
 Davis, V. H., 56.
 Davis, W., 41.
 Davis, W. R., 64.
 Day, A., Jr., 68.
 Dean, G. A., 28.
 Dean, W. H., Jr., 67.
 Dearborn, C. S., 44.
 Debnam, W. F., 54.
 De Camp, G. E., 48.
 Deemer, R. B., 25.
 Deerr, N., 21.
 De Lay, F. A., 15.
 Delgado, R. H., 62.
 De Loach, R. J. H., 19.
 Delwiche, E. J., 75, 76.
 Demaree, J. B., 35.
 Demarest, W. H. S., 47, 48.
 De Meritt, M., 47.
 Daneen, C. S., 22.
 Denise, D. D., 48.
 Denney, G., 39, 40.
 Denney, J. V., 55.
 Denny, G. (Nebr.), 45.
 Denny, G. (Wis.), 75.
 Donson, N. D., 9.
 Deputy, G. W., 17.
 Derby, G. E., 28.
 Derby, S. H., 17.
 Derby, W. B., 70.
 de Regt, A. C., 48.
 Dern, J., 68.
 Detjen, L. R., 53.
 Detmers, F., 56.
 Dett, R. N., 44.
 Deuel, R. E., 51.
 Dew, J. A., 64.
 Dewey, D. R., 36.
 De Yarmett, C. H., 72.
 De Yarmett, H. J., 72.
 De Zeeuw, R., 37.
 Dickens, A., 28, 29.
 Dickerson, I. W., 23.
 Dickinson, A. D., 73.
 Dickinson, L. P., 62.
 Dickinson, M. F., 36.
 Didlake, M. Le G., 30, 31.
 Diehl, D., 57.
 Dietrich, W., 23, 24.
 Dill, J. W., 42.
 Dillehunt, H. B., 35.
 Dillingham, F. T., 21.
 Dillingham, W. P., 69.
 Dillon, C., 28.
 Dilts, E. A., 15.
 Dimock, W. W., 26.
 Dinan, A. P., 54.
 Dingus, J. A., 58.
 Dinsmore, S. C., 46.
 Dinwiddie, R. R., 12, 13.
 Dittman, J., 40.
 Dix, J. A., 50.
 Doane, D. H., 42, 43.
 Dobell, R. H., 59.
 Dodge, D. K., 23.
 Dodge, F. H., 48.
 Dodson, W. R., 32, 33.
 Doggett, C. S., 63.
 Doherty, A. J., 37.
 Dohrmann, F. W., 13.
 Dole, C. F., 10.
 Dolman, A. M., 24.
 Dolt, M. L., 54, 55.
 Dolre, R. M., 54, 55.
 Donaghey, G. W., 12.
 Donaghho, J. S., 21.
 Donahue, M. J., 9.
 Donaldson, J. W., 54.
 Donaldson, M. L., 63.
 Donaldson, O., 11.
 Doneghue, R. C., 54, 55.
 Donnelly, J., 54.
 Donovan, E., 16.
 Doran, E. B., 32.
 Dorer, G., 48.
 Dornier, H. R., 23, 24.
 Dorsey, E. C., 74.
 Dorsey, M. J., 40.
 Doryland, C. J. T., 54, 55.
 Doten, S. B., 46.
 Dougherty, J. E., 24, 25.
 Douglass, A. E., 12.
 Douglass, E., 15.
 Douglass, I. W., 12.
 Douglass, T. R., 43.
 Dow, B. K., 16.
 Dow, U. M., 28.
 Dow, V. W., 72.
 Downing, C., 24.
 Downing, G. M., 60.
 Downsett, J. M., 21.
 Dox, A. W., 27.
 Drake, J. H., 9.
 Drew, E. C., 34.

- Drew, J. M., 39, 40.
 Drew, W., 47.
 Drew, W. S., 68.
 Drewry, N. B., 20.
 Drinkard, A. W., 70.
 Drinkard, A. W., Jr., 71.
 Drisdale, C. B., 68.
 Driver, V., 11.
 Drummond, R. R., 34.
 Dryden, C., 26.
 Dryden, J., 58, 59.
 Du Bose, M. D., 19.
 Duckett, J. W., 61.
 Ducongé, E., 33.
 Dudley, J. B., 54.
 Duggar, B. M., 51, 52.
 Duggar, J. F., 8, 9, 10.
 Duke, T. T., 57.
 Dukes, A. L., 64.
 Dulany, H. S., 35.
 Du Mez, A. G., 57.
 Dunbar, B. A., 65.
 Duncan, C., 72.
 Duncan, C. R., 36.
 Duncan, C. S., 56.
 Duncan, L. N., 9, 10.
 Dunford, C. S., 38.
 Dunford, Mrs. H. L., 68.
 Dunlop, R., 58.
 Duppert, W. J., 45.
 Durand, E. J., 42.
 Durgin, A. O., 34.
 Durst, C. E., 23, 24.
 Durward, M., 15.
 Duryee, J. R., 48.
 Dusenbury, E. G., 50.
 Dusham, E. H., 27.
 Dutton, G. C., 51.
 Dutton, G. E., 17.
 Dutton, J. E., 17.
 Dwight, T. W., 64.
 Dwyer, J. K., 32.
 Dye, F., 8.
 Dye, W. S., Jr., 61.
 Dykstra, R. R., 28, 29.
 Dynee, O. W., 54, 55.
- Earhart, R. F., 86.
 Earl, G. C., 13.
 Earle, S. B., 63.
 Easley, C. W., 34.
 Eason, F. G., 7.
 Eastman, F. B., 17.
 Eastwood, G. R., 56.
 Eaton, A. T., 66.
 Eaton, E., 40.
 Eaton, W. H., 53.
 Eberhardt, E. A., 26.
 Eberhart, A. O., 39.
 Eckart, C. F., 21.
 Eckhardt, W. G., 23.
 Eckles, C. H., 42, 43.
 Eckman, O. L., 47.
 Eddy, M. W., 61.
 Edelen, T. L., 30.
 Edgar, C. L., 48.
 Edgerly, G. W., 47.
- Edgerton, C. W., 33.
 Edmiston, H. D., 61.
 Edmond, H. D., 16.
 Edmonds, J. L., 23, 24.
 Edmonds, M., 56.
 Edmunds, E. A., 75.
 Edson, C., 57.
 Edwards, A. A., 14.
 Edwards, A. L., 59.
 Edwards, G. R., 42.
 Edwards, H., 8, 62.
 Edwards, J. H., 50.
 Edwards, N. B., 68.
 Eggleston, J. D., 70.
 Ehrhart, T. J., 14.
 Eichling, H. L., 26.
 Elesland, J. A., 74.
 Elsenlohr, B. A., 56.
 Ekblaw, K. J. T., 23.
 Elder, L. W., 73.
 Eldred, M. D., 62.
 Eldridge, J. G., 22.
 Ellett, W. B., 71.
 Ellington, E. V., 22.
 Ellington, J. O., 52.
 Elliott, C. G., 7.
 Elliott, F. L., 41.
 Elliott, J. C., 57.
 Elliott, P., 54.
 Elliott, T. L., 35.
 Ellis, O. H., 36.
 Ellis, W. T., 52.
 Ellsworth, E. A., 24.
 Ellsworth, J. L., 36.
 Elser, W. L., 56.
 Elwell, A. E., 15.
 Elwell, G., 39, 40.
 Emberson, R. H., 43.
 Embody, G. C., 51.
 Embry, J. F., 44.
 Emerson, F. V., 43.
 Emerson, R. A., 45, 46.
 Emery, E. S., 44.
 Emmett, A. D., 24.
 Emmons, L. C., 38.
 Ende, C. L. von, 22.
 Enders, H. E., 24.
 English, D., 73.
 English, J. N., 19.
 Enloe, W. A., 53.
 Enochs, I. C., 41, 42.
 Enyart, B. A., 28.
 Epple, W. F., 26.
 Erb, E. S., 61.
 Erdman, J., 15.
 Erf, O., 55.
 Erickson, M., 54.
 Erwin, A., 65.
 Erwin, A. T., 26.
 Eskew, M. H., 9.
 Espenshade, A. H., 60.
 Essary, S. H., 66.
 Esten, W. M., 16.
 Estes, C., 62.
 Eswine, H. E., 56.
 Etcheverry, B. A., 13.
 Etheridge, W. C., 53.
- Eubank, M., 74.
 Eudaly, E. R., 10.
 Eustace, H. J., 37, 38.
 Evans, A. L. (Aia.), 11.
 Evans, A. L. (Tex.), 68.
 Evans, C. B., 17.
 Evans, C. H., 35.
 Evans, C. M., 67.
 Evans, E., 75.
 Evans, E. A., 38.
 Evans, H., 56.
 Evans, H. J., 26.
 Evans, Mrs. L. B., 22.
 Evans, M., 57.
 Evans, P., 43.
 Evans, P. N., 24.
 Evans, W. D., 63.
 Evans, W. H., 6.
 Evans, W. L., 56.
 Evans, W. W., 57, 58.
 Evvard, J. M., 27.
 Ewan, A. E., 30, 31.
 Ewell, A. D., 68.
 Ewell, Mrs. R. L., 68.
 Ewing, A. L., 40.
 Ewing, E. C., 41.
 Ewing, H. E., 59.
 Eyer, B. F., 28.
 Eyerly, E. K., 36.
- Fabián, R., 62.
 Fain, J. R., 19.
 Fairfield, Mrs. M. P., 26.
 Faris, B. M., 64.
 Farley, A. J., 49.
 Farmer, E., 42.
 Farmer, M. D., 38.
 Farnham, W. E., 34.
 Farquhar, E. F., 30.
 Farr, J. M., 18.
 Farrington, E. H., 75, 76.
 Fassett, G. S., 69.
 Faurot, F. W., 43.
 Faville, A. D., 77.
 Favrot, L. M., 32.
 Fawcett, G. L., 7, 62.
 Fawcett, H. S., 18.
 Fay, L. E., 66.
 Feagin, W. F., 9.
 Feeley, R. O., 63.
 Fehn, A. R., 29.
 Fehr, C. D., 60.
 Felmy, W., 21.
 Fenton, C. L., 67.
 Fenwick, I. H., 72.
 Ferguson, J. A., 42, 43.
 Ferguson, J. T., 20.
 Ferguson, O. W., 11.
 Fergusson, S. P., 46.
 Fernier, E. J., 67.
 Fernald, C. F., 36.
 Fernald, H. T., 36, 37.
 Ferrin, E. F., 67.
 Ferris, E. B., 42.
 Ferry, E. L., 16.
 Ferry, E. S., 24.
 Fetzner, L. W., 6.

- Fields, M. E., 57.
 Filley, H. H., 45.
 Filley, W. O., 16.
 Fink, D. E., 51.
 Finlayson, W. D., 18.
 Finley, J. B., 73, 74.
 Finner, E. R., 75, 76.
 Finney, E. L., 40.
 Fippin, E. O., 51, 52.
 Firor, G. W., 19.
 Firor, J. W., 19.
 Fischer, E. G., 38.
 Fishburn, H. P., 22.
 Fisher, F. A., 23.
 Fisher, M. L., 24, 25.
 Fisher, O. S., 23.
 Flsk, W. W., 51, 52.
 Fiske, N. W., 69.
 Fitch, C. L., 15.
 Fitch, J. B., 29.
 Fitch, M. A., 25.
 Fitterer, J. C., 77.
 Fitts, E. B., 16.
 Fitts, J. N., 16.
 Fitz, L. A., 28, 29.
 Fitzgerald, J. K., 67.
 Fitzpatrick, H. M., 51.
 Flack, O., 57.
 Fleming, A. M., 68.
 Fleming, A. W., 26.
 Fleming, B., 51.
 Fleming, F. P., jr., 18.
 Fleming, W. L., 32.
 Fletcher, C., 68.
 Fletcher, S. W., 70, 71.
 Flewellen, A. E., jr., 68.
 Flint, A. K., 56.
 Flint, C. L., 59.
 Flint, E. R., 18.
 Flint, P. N., 28, 29.
 Florance, W. E., 48.
 Flossfeder, F. C. H., 14.
 Flowe, B. B., 53.
 Flowerday, G. H., 32.
 Floyd, B. F., 18.
 Floyd, E. V., 28.
 Floyd, J. W., 64.
 Floyd, W. L., 18.
 Foglesong, L. E., 24.
 Folger, H., 45.
 Folk, G. H., 63.
 Folsom, J. W., 23.
 Foord, J. A., 36.
 Forbes, E. B., 56.
 Forbes, R. H., 12.
 Forbes, S. A., 23.
 Forbes, W. P., 45.
 Ford, C., 29.
 Ford, F., 49.
 Ford, F. J. R., 72.
 Ford, F. W., 64.
 Ford, H., 35.
 Forman, L. W., 26.
 Forristall, E. H., 36.
 Forsee, R. B., 65.
 Fortier, S., 7.
 Foss, E. N., 36, 69.
 Foster, A. W., 13.
 Foster, I. L., 60.
 Foster, J. H., 47.
 Foster, L., 49.
 Foster, S., 24.
 Foster, T. D., 25.
 Foster, W. D., 73.
 Fountain, C. P., 66.
 Foust, J. I., 53.
 Fowler, C. C., 27.
 Fowler, J. M., 24.
 Fowler, W. L., 12.
 Fox, W. W., 42.
 Fracker, S. B., 26.
 Francis, C. K., 57, 58.
 Francis, D. R., 42.
 Francis, M., 66, 67.
 Frandsen, P., 46.
 Frandson, J. H., 45, 46.
 Franklin, H. J., 37.
 Frantz, S. O., 60.
 Fraps, G. S., 66, 67.
 Fraser, W. J., 23.
 Frazer, J. S., 9.
 Frazier, J. S., 20.
 Frazier, W. H., 39, 40.
 Frazier, W. W., 71.
 Frear, D. W., 15.
 Frear, J. B., 39, 40.
 Frear, W., 60, 61.
 Fred, E. B., 71.
 Frederick, H. J., 68, 69.
 Freeman, E. M., 39, 40.
 Freeman, G. F., 12.
 Freeman, H. H., 33.
 Freeman, M. L., 41.
 Freeman, M. P., 11.
 Frelinghuysen, F., 47.
 French, G. T., 50.
 French, T. E., 56.
 French, W. H. (Mich.), 37.
 French, W. H. (N. Y.), 50.
 French, W. L., 45, 46.
 Frevert, G. E., 22.
 Freyhofer, L., 38.
 Frieberg, A., 64.
 Friedrich, L., 33.
 Frier, G. M., 25.
 Fries, J. A., 62.
 Friley, C. E., 67.
 Frissell, H. B., 71, 72.
 Frizzell, J. H., 60.
 Frizzelle, B., 67.
 Froerer, F., 69.
 Fromme, N. K., 65.
 Frost, H. L., 36.
 Fry, E. A., 60.
 Fullan, M. T., 9.
 Fullaway, D. T., 6, 21.
 Fuller, F. D., 25.
 Fuller, H. N., 48.
 Fuller, J. G., 75, 76.
 Fuller, P. E., 7.
 Fuller, R. G., 33.
 Fuller, R. M., 72.
 Fulmer, E., 72, 73.
 Fulton, H. R., 60, 61.
 Fulton, J., 58.
 Funchess, M. J., 9, 10.
 Funk, A. B., 25.
 Funk, E., 22.
 Fuqua, H. L., 31, 32.
 Furley, C., 28.
 Furman, C. M., 63.
 Fyfe, D. M., 66.
 Gaede, H. A., 48.
 Gaessler, W. G., 27.
 Gage, E. V., 60.
 Gage, G. E., 36.
 Gahan, A. B., 35.
 Gain, J. H., 45, 46.
 Gaines, E. F., 73.
 Gaines, W. L., 24.
 Gainey, P. L., 43.
 Galtner, E. W., 57.
 Galehouse, D. H., 57.
 Gallagher, E., 57.
 Galpin, C. J., 75, 76.
 Gamble, A., 74.
 Gamble, M. E., 24.
 Gamble, M. G., 20.
 Gantt, J. W., 63.
 Garcia, F., 49.
 Gardner, A. B., 63.
 Gardner, D. C., 22.
 Gardner, F. D., 60, 61.
 Gardner, J. J., 47.
 Gardner, O. M., 52.
 Gardner, V. R., 56.
 Gardner, W., 69.
 Garig, L., 32.
 Garig, M., 32.
 Garman, H., 30, 31.
 Garner, A. W., 41.
 Garner, J. D., 67.
 Garner, P. P., 41.
 Garrett, F. W., 23.
 Garrett, J. B., 33.
 Garrett, W. V., 44.
 Garrety, W. P., 7.
 Garrigus, H. L., 16.
 Garrison, W. D., jr., 64.
 Garrison, W. E., 49.
 Gartley, A., 20, 21.
 Garver, M. M., 60.
 Garver, S., 65.
 Gaskill, E. F., 37.
 Gaskins, W. F., 59.
 Gass, H. A., 44.
 Gasser, G. W., 6, 11.
 Gates, B. N., 36, 37.
 Gates, W. H., 32.
 Gaumnitz, A. J., 14.
 Gearhart, W. S., 29.
 Gee, W. P., 63.
 Geismar, L. M., 38.
 Geist, G. A., 67.
 George, C. P., 49.
 Georgeson, C. C., 6, 11.
 Georgia, A. E., 51.
 Gerac, H., 32.
 Gerlicke, M. L., 6.
 Gernert, W. B., 24.

Gerrett, F., 36.
 Gessner, M. S., 17.
 Gettamy, W. S., 26.
 Getz, Mrs. A. T., 33.
 Gibbons, H., 66.
 Gibbs, C. M., 23.
 Gibbs, W. D., 8, 47.
 Gibson, J. A., 43.
 Giddings, N. J., 74.
 Giesecke, F. E., 66.
 Gieseker, L. F., 45.
 Gilbert, A. G., 72.
 Gilbert, A. H., 30.
 Gilbert, A. W., 51, 52.
 Gilbert, G. A., 15.
 Gilchrist, A. W., 18.
 Gilchrist, M., 37.
 Gikchrist, N. L., 38.
 Gile, P. L., 7, 62.
 Giles, E. A., 67.
 Giles, E. W., 35.
 Gilkey, R., 51.
 Gill, B., 60.
 Gill, E. T., 48.
 Gillette, C. P., 8, 15.
 Gillison, B., 64.
 Gilman, R., 29.
 Gilmore, G., 19.
 Gilmore, J. W., 21.
 Gilmore, R. J., 51.
 Gilreath, B., 10.
 Gilruth, I. T., 44.
 Gilson, I., 38.
 Giltner, W. G., 38.
 Gingery, J. B., 29.
 Giorgetti, E., 62.
 Gissendanner, A. R., 10.
 Given, G. C., 60, 61.
 Gladwin, F. E., 60.
 Glasson, E. J., 6.
 Gleason, C. A., 36.
 Glenn, J. A., 41, 42.
 Glenn, M. A., 9.
 Glenn, S., 58.
 Glover, G. H., 15.
 Glover, L. L., 10.
 Gloyer, W. O., 57.
 Cobblo, C. F., 24.
 Goddard, L. H., 56.
 Goddard, M., 65.
 Godin, F. J., 62, 63.
 Goessmann, H., 36.
 Goetz, C. H., 56.
 Gold, C. W., 52.
 Golder, F. A., 73.
 Goldsborough, F. C., 35.
 Goldsborough, P. L., 35.
 Goldthwaite, N. E., 23.
 Goll, H. L., 56.
 Good, E. S., 30, 31.
 Goodling, C. L., 61.
 Goodwin, S. H., 69.
 Goodwin, W. H., 56.
 Gordon, A. W., 23.
 Gordon, C. E., 36.
 Gordon, C. H., 66.
 Gordon, J., 41, 42.

Gordon, J. H., 7.
 Gordon, R. A., 42.
 Gorman, A. P., 35.
 Goss, A., 25.
 Goos, L. W., 28, 29.
 Goessard, H. A., 56.
 Goucher, J. F., 35.
 Gould, S. W., 34.
 Gourley, J. H., 56.
 Gow, R. M., 12, 13.
 Gowans, E. B., 72.
 Graber, L. F., 75, 76.
 Grady, J., 75.
 Graham, A. B., 8, 56.
 Graham, C. K., 72.
 Graham, K. H., 18.
 Graham, J. C., 36.
 Graham, J. J. T., 41.
 Graham, R., 30, 31.
 Graham, R. D., 37.
 Graham, W. A., 53.
 Granlich, H. J., 45.
 Gramm, O., 76.
 Grant, C. I., 56.
 Grant, J. C., 10.
 Grant, S. A., 20.
 Grantham, A. E., 17.
 Gravatt, F., 70.
 Gravatt, T. E., 60.
 Grave, B. H., 77.
 Graves, A. S., 74.
 Gray, C. E., 23.
 Gray, D. T., 9, 10.
 Gray, G. P., 14.
 Gray, J. C., 60, 61.
 Gray, R. P., 34.
 Graybill, J. L., 72.
 Grayson, D. A., 10.
 Greaves, J. E., 68, 69.
 Green, C. R., 36, 37.
 Green, G. R., 56.
 Green, L. M., 73.
 Green, S. J., 33.
 Green, W. J., 56.
 Green, W. W., 71.
 Greene, C. W., 11.
 Greene, E. B., 23.
 Greene, J. H., 17.
 Greene, L., 27.
 Greenway, J. C., 11.
 Greer, R. A., 65.
 Greever, G., 12.
 Gregg, C. J., 64.
 Gregg, J. W., 60, 61.
 Gregory, C. T., 51, 52.
 Gregory, W. B., 7.
 Grief, A. J., 62.
 Griffin, H. P., 44.
 Griffin, J. T., 71.
 Griffin, L. G., 57.
 Griffin, W., Jr., 69.
 Griffith, J. B., 18.
 Griffith, W. A., 35.
 Griggs, C. H., 68.
 Griggs, R. F., 56.
 Grimes, N. C., 12.
 Grindley, H. S., 23, 24.

Grissold, D. T., 67.
 Grossenbacher, J. G., 50.
 Grossman, J. D., 25.
 Groth, B. H. A., 48.
 Grout, A. P., 22.
 Grout, G. P., 39, 40.
 Grover, A. L., 34.
 Groves, E. R., 47.
 Groves, M. E., 64.
 Grunsky, H. W., 7.
 Guell, A., 32.
 Guell, A. R., 32.
 Guernsey, S. C., 27.
 Guild, F. N., 12.
 Guion, J. I., 66, 67.
 Gulley, A. G., 16.
 Gummere, W. S., 47.
 Gunderson, A. J., 24.
 Gunderson, C., 57.
 Gunness, C. I., 54.
 Gunson, T., 38.
 Gunter, F. G., 67.
 Gurney, L. E., 22.
 Guss, S. H., 74.
 Gustafson, A. F., 23.
 Guthery, J. D., 56.
 Guthrie, C. P., 55.
 Guthrie, D. V., 32.
 Guthrie, E. S., 51, 52.
 Guthrie, J. E., 26.
 Gwinner, H., 35.
 Hackedorn, H., 43.
 Hackleman, J. C., 43.
 Haddon, C. B., 63.
 Haddon, T. C., 63.
 Haden, H. E., Jr., 67.
 Hadley, F. B., 75, 76.
 Hadley, H., 49.
 Hadley, M. B., 18.
 Hadley, P. B., 63.
 Haddock, W. L., 73.
 Haecker, T. L., 39, 40.
 Hagemann, E. H., 13, 14.
 Hagerty, C. T., 49.
 Hagerty, J. E., 55.
 Haggart, A. G., 54.
 Haggart, M. H., 15.
 Hahn, A., 57.
 Haigh, L. D., 43.
 Haines, C. M., 67.
 Haines, W. T., 34.
 Hall, A. G., 7.
 Hall, E. C., 43.
 Hall, E. W., 55.
 Hall, F. H., 50.
 Hall, F. P., 12.
 Hall, G., 22.
 Hall, H. M., 13, 14.
 Hall, J. G., 63.
 Hall, J. T., 42.
 Hall, L. D., 23, 24.
 Hall, W. N., 7.
 Haller, F. L., 45.
 Halligan, C. F., 37, 38.
 Halligan, J. B., 71.
 Halligan, J. E., 32, 33.

- Hallowell, R. N., 37.
 Halsted, A. L., 29.
 Halpin, J. G., 75, 76.
 Halstead, J. E., 52.
 Halsted, B. D., 48.
 Ham, F. W., 44.
 Ham, W. R., 60.
 Hamill, J. L., 60.
 Hamilton, A. B., 76.
 Hamilton, E. W., 22.
 Hamilton, J., 7, 8.
 Hamilton, J. B., 66.
 Hamilton, J. H., 62.
 Hamilton, J. M., 8, 44.
 Hamilton, J. O., 28.
 Hamlin, T. L., 34.
 Hammer, B. W., 26, 27.
 Hammett, F. S., 63.
 Hammond, H. S., 49.
 Hammond, J. W., 56.
 Hammond, M. B., 55.
 Hammond, R. L., 34.
 Hammond, T. M., 75.
 Hammond, W. F., 70.
 Hammond, W. R., 20.
 Hampson, C. B., 22.
 Hand, J. L., 19.
 Hand, W. F., 41.
 Handschin, W. F., 23, 24.
 Haneman, A. H., 33.
 Haner, Mrs. J. L. K., 22.
 Hanford, J. G., 7.
 Hanger, W. E., 35.
 Hansen, A. J., 69.
 Hansen, N. E., 65.
 Hanson, H. H., 34.
 Haralson, C., 40.
 Haralson, F., 40.
 Harbert, J. F., 31.
 Harbert, Mrs. R. B., 68.
 Harbold, R. P., 28.
 Hard, H. A., 54.
 Harden, F. G., 7.
 Hardin, M. B., 63.
 Harding, A. S., 65.
 Harding, H. A., 50.
 Harding, S. T., 7.
 Hardman, L. G., 19, 20.
 Hardy, J. C., 8, 41.
 Hardy, J. I., 66.
 Hare, A. J., 74.
 Hare, B. B., 6.
 Hare, C. L., 9, 10.
 Hare, C. W., 10.
 Hare, R. F., 40.
 Hare, W. B., 51.
 Hargreaves, S., 70.
 Haring, C. M., 13, 14.
 Harkins, L. A., 44.
 Harley, H. L., 61.
 Harmount, W. L., 36.
 Harned, R. W., 41.
 Harper, E. B., 45.
 Harper, J. N., 64.
 Harper, M. W., 51, 52.
 Harrall, N. A., 62.
 Harrelson, J. W., 53.
 Harrington, Mrs. I. S., 51.
 Harrington, W. W., 17.
 Harris, A. C., 24.
 Harris, A. L. (Kans.), 29.
 Harris, A. L. (Tex.), 67.
 Harris, D. N., 63.
 Harris, E. D., 54, 55.
 Harris, F. C., 28.
 Harris, F. S., 68, 69.
 Harris, R. T., 76.
 Harris, T. H., 31.
 Harris, W. H., 72.
 Harrison, A. K., 36.
 Harrison, B. M., 26.
 Harrison, H. T., 35.
 Harrison, O. L., 19.
 Harrison, T. P., 52.
 Harrison, W. H., 44.
 Hart, E. B., 75, 76.
 Hart, E. R., 17.
 Hart, J. H., 72.
 Hart, J. N., 34.
 Hart, J. W., 19.
 Hart, L. C., 19.
 Hart, L. J., 66, 67.
 Hart, R. A., 7, 69.
 Hart, W. R., 36.
 Hartenbower, A. C., 57.
 Harter, G. A., 17.
 Hartman, J. W., 46.
 Hartsock, R. E., 57.
 Hartung, J. R., 48.
 Hartwell, B. L., 62, 63.
 artzell, F. Z., 50.
 Hasbrouck, P. B., 36.
 Haseman, C., 46.
 Haseman, L., 43.
 Haskell, C. G., 7.
 Haskell, E. J., 34.
 Haskell, S. B., 36.
 Haskins, H. D., 37.
 Haslam, T. P., 29.
 Hastings, E. G., 75, 76.
 Haswell, J. R., 7.
 Hatch, F. L., 22.
 Hatch, K. L., 75, 76.
 Hathaway, J. S., 31.
 Rauch, E. F., 48.
 Haugan, H. A., 22.
 Hause, E. B., 40.
 Hausknecht, V. B., 49.
 Haviland, L. P., 50.
 Havner, H. H., 61.
 Hawes, A. F., 69, 70.
 Hawk, P. B., 23.
 Hawkins, R. J., 19.
 Hawley, C. L., 58.
 Hay, M. E., 72.
 Hayden, A., 26.
 Hayden, C. C., 23, 24.
 Hayden, H. E., 67.
 Hayes, F. M., 14.
 Hayes, G. H., 39.
 Hayes, H. K., 16.
 Hayes, M. E., 16.
 Hayes, O. F., 58.
 Hayhurst, P., 12, 13.
 Hays, Mrs. S. H., 21.
 Hayward, H., 17.
 Haywood, W. G., 53.
 Hazel, J. H., 20.
 Headden, W. P., 15.
 Headlee, T. J., 28, 29.
 Healy, D. J., 30, 31.
 Hean, C. S., 75, 76.
 Heard, C. H., 22.
 Hearn, W. E., 53.
 Hearst, Mrs. P. A., 13.
 Hebard, G. R., 77.
 Hechler, W. R., 26.
 Heck, R. C. H., 48.
 Heck, W. C., 67.
 Hedges, C. C., 61, 62.
 Hedges, M., 45.
 Hedrick, U. P., 50.
 Hedrick, W. O., 37.
 Hegnauer, L., 23.
 Heideman, C. W., Jr., 6, 11.
 Heideman, W. H., 22.
 Helder, G. K., 29.
 Heldring, J. J. L., 73.
 Heller, A. A., 46.
 Hellman, I. W., 13.
 Helme, N., 63.
 Helyar, J. P., 69.
 Hemmenway, C. R., 20.
 Hemphill, R. G., 7.
 Henderson, C. B., 46.
 Henderson, C. M., 67.
 Henderson, J. J., 32.
 Henderson, O. H., 27.
 Henderson, V. H., 13.
 Henderson, W., 20.
 Henderson, W. F., 70.
 Hendren, L. L., 19.
 Hendrick, Mrs. M., 38.
 Hendricks, G. B., 68.
 Hendrix, W. J., 43.
 Henke, F. C., 73.
 Henley, W. W., 12.
 Hennessey, P. J., 72.
 Henry, D. H., 63.
 Henry, E. S., 16.
 Henry, W., 6.
 Henry, W. A., 75, 76.
 Henry, W. W. M., 17.
 Hensel, H., 38.
 Hepburn, N. W., 23, 24.
 Hepburn, W. M., 24.
 Heppler, J. R., 75, 76.
 Hepner, F. E., 77.
 Herbert, J. C., 41.
 Herbert, J. W., Jr., 48.
 Herbert, R. O., 12.
 Hergert, A. M., 32.
 Herms, W. B., 13, 14.
 Herren, S. T., 54.
 Herrick, G. W., 51, 52.
 Herrick, R. S., 15.
 Herrington, J. A., 67.
 Herschel, W. H., 34.
 Herse, B., 59.
 Hershey, H. F., 61.
 Hertwig, R., 16.

- Hess, A. M., 44.
 Hess, W. E., 7, 62.
 Hetzel, R. D., 59.
 Hewitt, A. H., 13.
 Hewitt, C. E., 47.
 Hewitt, J. L., 12, 13.
 Heyl, F. W., 77.
 Hibbard, B. H., 26.
 Hibbard, P. L., 14.
 Hibbard, R. P., 38.
 Hibshman, E. K., 61.
 Hicks, C. S., 36.
 Hiddinger, L. L., 7.
 Hiester, G., 60.
 Higbie, E. C., 40.
 Higgins, J. C., 17.
 Higgins, J. E., 6, 21.
 Hilgard, E. W., 13, 14.
 Hill, A. R., 8, 42, 44.
 Hill, C. O., 66.
 Hill, D. H., 8, 52.
 Hill, G., 31.
 Hill, G. R., jr., 51.
 Hill, H., 53.
 Hill, H. A., 33.
 Hill, H. H., 71.
 Hill, H. W. (Nev.), 46.
 Hill, H. W. (Vt.), 69.
 Hill, J. A., 77.
 Hill, J. B., 61.
 Hill, W. F., 60.
 Hills, J. L., 8, 60, 70.
 Hilyer, J. V., 19.
 Himes, J. S., 44.
 Himes, R. L., 32.
 Hinds, G. H., 57.
 Hinds, W. E., 9, 10.
 Hine, G. S., 29.
 Hine, J. S., 56.
 Hingston, N. E., 44.
 Hinman, C. H., 15.
 Hirst, C. T., 69.
 Hiscock, F. H., 50.
 Hitch, H. J., 36.
 Hitchcock, A. E., 64.
 Hitchcock, L. W., 47.
 Hitchings, E. F., 34.
 Hite, B. H., 74.
 Hoagland, R., 39, 40.
 Hobdy, J. B., 9, 10.
 Hobbs, C. M., 24.
 Hobbs, H. V., 29.
 Hoblit, M. L., 49.
 Hodge, E. D., 64.
 Hodges, C. B., 32.
 Hodges, J. T., 68.
 Hodges, R. E., 75, 76.
 Hodges, T. E., 74.
 Hodgkins, M., 47.
 Hodgkiss, H. E., 50.
 Hodgson, E. R., 71.
 Hodson, E. A., 9, 10.
 Hoefler, E. G., 77.
 Hoff, E. J., 7.
 Hoffecker, F. H., 17.
 Hoffer, G. N., 24.
 Hoffman, A. H., 26.
 Hoffman, J. W., 68.
 Hoffman, M. H., 26.
 Hoffmann, C., 75, 76.
 Hogan, J. R., 58.
 Hogenson, J. C., 68.
 Hoknasen, O. M., 26.
 Holaday, H. A., 22.
 Holbrook, P. K., 25.
 Holcomb, G. N., 36.
 Holdaway, C. W., 70.
 Holden, P. G., 27.
 Holden, R. J., 70.
 Holdridge, K., 27.
 Holland, E. B., 37.
 Hollar, J. H., 28.
 Holier, Z. N., 57.
 Holley, T., 68.
 Hollingshead, R. S., 19.
 Hollinshead, L., 40.
 Hollister, G. H., 54.
 Hollister, S. P., 10.
 Holloway, G. A., 20.
 Holloway, W. M., 18.
 Holmes, A. G., 63.
 Holmes, F. S., 70.
 Holmes, H. C., 67.
 Holmes, W., 57.
 Holmes, W. R., 38.
 Holroyd, I. E., 28.
 Holsinger, C. V., 29.
 Holt, C. L., 38.
 Holt, S. V., 23.
 Holt, V. S., 6, 21.
 Holton, E. L., 28, 29.
 Holtz, H. F., 73.
 Hood, G. W., 38.
 Hook, J. N., 64.
 Hooker, C. W., 7, 62.
 Hooker, W. A., 6.
 Hookland, S. S., 49.
 Hooper, A., 35.
 Hooper, J. J., 30.
 Hoopingarner, R. G., 38.
 Hoover, J. M., 54.
 Hope, L., 75.
 Hopkins, C. G., 23.
 Hopphan, K. E., 38.
 Hopson, G. A., 16.
 Hopt, E., 45, 46.
 Horlick, A. J., 75.
 Horne, W. T., 13, 14.
 Horner, J. B., 58.
 Hoskins, E. E., 24.
 Hoskins, H. P., 40.
 Hoskins, J. D., 66.
 Hosmer, F. A., 36.
 Hosmer, R. S., 20.
 Hossinger, J. H., 17.
 Hotchkiss, W. S., 67.
 Hottes, C. F., 23.
 Houghton, C. O., 17.
 House, E. B., 15.
 House, W. L., 28.
 Householder, F. C., 54.
 Houser, J. S., 56.
 Houser, T., 56.
 Houseworth, E. E., 68.
 Houston, F., 59.
 Houston, H., 63.
 Houston, S. T., 35.
 Hovland, H. B., 39.
 Howard, G. F., 39.
 Howard, J. T., 37.
 Howard, R. F., 45, 46.
 Howard, S. F., 36.
 Howard, W. H. A., 19.
 Howard, W. L., 42, 43.
 Howe, E. D., 36.
 Howe, G. H., 50.
 Howell, W. M., 9.
 Hoyt, W. D., 48.
 Hubert, J., 35.
 Hudnall, R. H., 70.
 Hudson, B. M., 19.
 Hudson, R. S., 38.
 Hudson, T. G., 19, 20.
 Huff, L. B., 60.
 Hughes, D. M., 19.
 Hughes, E. T., 63.
 Hughes, H. D., 26, 27.
 Hughes, H. W., 15.
 Hughes, J. S., 28.
 Hughes, T. W., 32.
 Hulce, R. S., 23, 24.
 Humbert, E. P., 49.
 Hume, A. N., 65.
 Hume, E. E., 31.
 Humfeld, N. B., 29.
 Hummel, W. G., 14.
 Humphrey, G. C., 75, 76.
 Humphrey, H. B., 73.
 Humphrey, J. A., 29.
 Humphrey, J. G., 57.
 Hungerford, De F., 39, 40.
 Hunn, C. E., 51.
 Hunn, C. J., 6, 21.
 Hunn, J., 17.
 Hunt, A., 37.
 Hunt, B. P., 10.
 Hunt, L. W., 73.
 Hunt, N. R., 73.
 Hunt, T. F. (Cal.), 14.
 Hunt, T. F. (Pa.), 8, 60, 61.
 Hunt, Mrs. T. M. R., 68.
 Hunter, F. M., 45.
 Hunter, J. E., 63.
 Hunter, O. W., 29.
 Hunter, W. K., 66.
 Hunting, H., 27.
 Huntington, C. C., 56.
 Huntington, E. A., 68.
 Huntsman, S., 66.
 Hunziker, O. F., 24, 25.
 Hurd, W. D., 8, 36.
 Hurd, L. M., 51.
 Huse, H. K., 28.
 Huston, R. C., 37.
 Hutcheson, T. B., 70, 71.
 Hutchings, A. L., 39.
 Hutchins, A. L., 72.
 Hutchinson, W. L., 41.
 Hutchison, C. B., 42, 43.
 Hutchison, G. G., 60.
 Hutchison, J. R., 77.

- Hutt, W. N., 53.
 Hutton, J., 15.
 Hutton, J. B., 17.
 Hutton, J. G., 65.
 Hyatt, E., 13.
 Hyde, E., 72.
 Hyde, H., 65.
 Hyde, J. A., 68.
 Hyslop, G. R., 59.

 Ickelheimer, H. R., 50.
 Iddings, E. J., 22.
 Iles, I. V., 29.
 Ilg, C., 51.
 Imbach, T. F., 74.
 Ince, J. W., 54, 55.
 Ingalls, G. R., 40.
 Ingham, N. D., 14.
 Ingham, W. S., 76.
 Ingraham, E. S., 56.
 Ingram, R. C., 14.
 Irvine, B. F., 58.
 Irvine, W. H., 65.
 Irwin, G. W., 64.
 Isaacs, C. A., 72.
 Isaacs, R. L., 68.

 Jackley, J. G., 29.
 Jackson, C. F., 47.
 Jackson, F. P., 59.
 Jackson, H. L., 69.
 Jackson, H. S., 59.
 Jackson, H. W., 61.
 Jackson, J. Q., 53.
 Jackson, L. F., 73.
 Jackson, M., 20.
 Jackson, S. C., 42.
 Jackson, W. P., 35.
 Jacob, M., 66.
 Jacobson, C. A., 46.
 Jacobson, S. L., 54.
 Jacoby, F. S., 56.
 Jaffa, M. E., 13, 14.
 Jagger, M. H., 16.
 Jahr, M. E., 23.
 James, A. C., 71.
 James, C., 47.
 James, E. J., 23.
 Jamison, G. A., 24.
 Jamison, G. H., 57.
 Jardine, W. M., 28, 29.
 Jarnagin, M. P., 19.
 Jarrell, T. D., 35.
 Jarvis, C. D., 16.
 Jarvis, C. M., 16.
 Jarvis, J. D., 24, 25.
 Jason, W. C., 17.
 Jayne, S. O., 7.
 Jefferson, E., 56.
 Jeffery, J. A., 37, 38.
 Jeffords, T. M., 57.
 Jeffrey, J. S., 52, 53.
 Jeffries, J. H., 53.
 Jenkins, A. E., 51.
 Jenkins, E. E., 19.
 Jenkins, E. H., 18.
 Jenks, A. R., 36.

 Jenness, J. R., 28.
 Jennings, J. M., 33.
 Jennison, H. M., 44.
 Jensen, C. N., 68, 69.
 Jensen, G. C., 68.
 Jensen, W. A., 59.
 Jenson, J. W., 68.
 Jerdan, S. S., 10.
 Jett, W. H., 72.
 Jewett, A. C., 34.
 Jewett, H. H., 30, 31.
 Jinks, J. H., 72.
 Job, H. K., 16.
 Jobbins, D. M., 49.
 Jobson, H. H., 67.
 Jodidi, S. L., 27.
 Johannsen, O. A., 34.
 Johnson, A. R., 48.
 Johnson, C. L., 58.
 Johnson, E. (Fla.), 19.
 Johnson, E. (Kans.), 28.
 Johnson, F. C., 19.
 Johnson, F. E., 14.
 Johnson, G. G., 64.
 Johnson, H. C., 75, 76.
 Johnson, H. W., 13.
 Johnson, J., 75, 76.
 Johnson, J. R., 58.
 Johnson, L., 44.
 Johnson, L. A., 72.
 Johnson, L. E., 70, 71.
 Johnson, L. R., 11.
 Johnson, M. F., 38.
 Johnson, O. M., 56.
 Johnson, O. R., 43.
 Johnson, R. F., 68.
 Johnson, S. A., 15.
 Johnson, T. C., 71.
 Johnson, T. S., 19.
 Johnston, A. D., 39, 40.
 Johnston, Mrs. C. E., 6.
 Johnston, C. L., 10.
 Johnston, E. P., 28.
 Johnston, F. A., 71.
 Johnston, J. R., 62.
 Johnston, W. W., 57.
 Johnstone, A., 63.
 Johnstone, B. H., 63.
 Jones, A., 11.
 Jones, A. A., 57, 58.
 Jones, A. C., 76.
 Jones, A. J., 34.
 Jones, C., 31.
 Jones, C. E., 74.
 Jones, C. H. (S. C.), 64.
 Jones, C. H. (Vt.), 70.
 Jones, C. L., 34.
 Jones, D. C., 67.
 Jones, E. B., 19.
 Jones, E. R., 75, 76.
 Jones, F., 34.
 Jones, G., 12.
 Jones, G. D., 75.
 Jones, G. H., 58.
 Jones, J. C., 46.
 Jones, J. F., 61.
 Jones, J. H., 36.

 Jones, J. S., 22.
 Jones, K. K., 62.
 Jones, L. R., 75, 76.
 Jones, N. A., 58.
 Jones, O. B., 56.
 Jones, O. L., 75, 76.
 Jones, P. W. L., 31.
 Jones, R. C., 44.
 Jones, R. G., 26.
 Jones, R. K., 34.
 Jones, S. B., 54.
 Jones, T. H., 62.
 Jones, T. M., 44.
 Jones, V. R., 61.
 Jones, W. J., Jr., 25.
 Jones, W. M., 26.
 Jordan, A. E., 21.
 Jordan, E. L., 32.
 Jordan, H. B., 11.
 Jordan, W. H., 8, 50.
 Jorgensen, F. A., 24.
 Judd, W. H., 72.
 Judisch, G., 27.
 Judkins, H. F., 47.
 Julian, A. N., 36.
 Jurrjens, J. C., 76.

 Kalkus, J. W., 73.
 Kalmbach, J. E., 54.
 Kammeyer, J. E., 28.
 Kane, A., 29.
 Karraker, P. E., 23.
 Kastle, J. H., 30, 31.
 Kately, F., 44.
 Katz, S. H., 47.
 Kaufman, F. J., 60.
 Kaupp, B. F., 15.
 Kay, M., 28.
 Kean, J. C., 41.
 Kear, R. W., 72.
 Kearney, I. H., 53.
 Kearney, M. M., 32.
 Kedzie, F. S., 37.
 Keene, E. S., 54.
 Keene, J. R., 35.
 Keene, L., 43.
 Keffer, C. A., 66.
 Keith, M. H., 57.
 Keith, W. J., 60.
 Keltt, T. E., 63.
 Keltt, T. W., 64.
 Keller, A. R., 21.
 Kelley, A., 65.
 Kelley, C. W., 54.
 Kelley, F. J., 75, 76.
 Kelley, W. P., 6, 21.
 Kellogg, H. S., 26, 27.
 Kellogg, L. L., 48.
 Kellum, J. G., 18.
 Kelly, C., 75.
 Kelly, H. M., 30.
 Kelly, J. B., 67.
 Kelly, L., 6, 11.
 Kelly, W. A., 7.
 Kelsall, G. A., 38.
 Kelsey, C. H., 71.
 Kelton, F. C., 12.

- Kempner, D. W., 66, 67.
 Kempster, H. L., 43
 Kendall, A., 76.
 Kendall, J. C., 47.
 Kennard, F. L., 22.
 Kennedy, C., 39, 40.
 Kennedy, C. V., 55.
 Kennedy, M. B., 46.
 Kennedy, P. B., 46.
 Kennedy, W. J., 26, 27.
 Kenney, F. C., 36, 37.
 Kenswill, E. F., 19.
 Kent, F. L., 58, 59.
 Kent, F. R., 35.
 Kent, H. L., 29.
 Kenyon, A. M., 24.
 Kephart, C. F., 47.
 Keppel, H. G., 18.
 Kern, C. A., 69.
 Kern, F. D., 25.
 Kerr, A. P., 33.
 Kerr, C., 69.
 Kerr, E. W., 32, 33.
 Kerr, G. G., 17.
 Kerr, W., 71.
 Kerr, W. J., 58.
 Kershaw, J. C., 21.
 Ketcham, V. A., 34.
 Kettle, S. I., 15.
 Keyser, A., 15.
 Kiah, T. H., 26.
 Kidd, J. W., 67.
 Kidd, W. E., 25.
 Kidder, A. F., 32.
 Kidder, F. T., 69.
 Kidder, I. A., 59.
 Kieselbach, T. A., 46.
 Kildee, H. H., 26, 27.
 Kilgore, B. W., 53.
 Kimball, C. D., 62.
 Kimbrough, J. M., 20.
 King, A. C., 51.
 King, C. M., 27.
 King, E. S., 37.
 King, F. G., 25.
 King, H. E., 11.
 King, H. H., 28.
 King, M. L., 27.
 King, T. B., 13.
 Kinghorn, P., 72.
 Kingman, E. D., 88.
 Kingman, H. E., 15.
 Kingsley, D. P., 69.
 Kinkead, E. S., 30.
 Kinley, D., 23.
 Kinman, C. F., 7, 62.
 Kinney, E., 30, 31.
 Kinney, H. B., 27.
 Kinzer, J. C., 22.
 Klipp, H. A., 7.
 Kirkpatrick, B. F., 70.
 Kirkpatrick, K. A., 39.
 Kirkpatrick, J. B., 48.
 Kirkpatrick, W. F., 21.
 Krishman, J. E., 54.
 Kleeberger, F. L., 12.
 Kleinheinz, F., 75, 76.
 Kline, L. D., 70.
 Klugh, W. W., 63.
 Kluttz, W. L., 53.
 Knabe, W. A., 66.
 Knapp, H., 25, 26, 27.
 Kneale, R. D., 44.
 Knepper, M. E., 59.
 Knight, C. S., 46.
 Knight, E. H., 77.
 Knight, F. C., 28.
 Knight, G. W., 55.
 Knight, H. G., 77.
 Knight, H. I., 6.
 Knoll, F. P., 61.
 Knorr, F., 46.
 Knott, W. V., 18.
 Knowles, N. S., 27.
 Knudsen, K. H., 74.
 Knudson, L., 51, 52.
 Kochenderfer, C. C., 61.
 Koebele, A., 21.
 Kohler, A. R., 39, 40.
 Kolb, R. F., 9.
 Kollock, H. G. M., 17.
 Kolshorn, H., 57.
 Kone, E. R., 66, 67.
 Koonce, E. M., 52.
 Koonce, L. F., 53.
 Kortright, F. L., 74.
 Kostalek, J., 22.
 Krak, J. H. B., 74.
 Krall, J., Jr., 7.
 Kramer, W. H., 56.
 Kraus, E. J., 59.
 Krauss, F. G., 21.
 Kreager, F. O., 73.
 Krentel, A. P., 38.
 Krum, W. G., 51.
 Krusekopf, H. H., 43.
 Kubin, E. F., 28, 29.
 Kunerth, W., 26.
 Kunst, F. B., 74.
 Kuny, E. C., 59.
 Kunze, E. J., 37.
 Kyle, C., 69.
 Kyle, E. J., 66.
 Kyle, G. J., 49.
 Kyle, H. G., 65.
 Kyle, J. A., 66, 67.
 Laate, G., 40.
 La Bach, J. O., 30, 31.
 La Crosse, J. F., 72.
 Lacy, E. A. L., 70.
 Ladd, E. F., 54, 55.
 Lafferty, W. T., 30.
 Laidley, G. S., 73, 74.
 Lain, G. E., 49.
 Lamar, W. L., Jr., 9.
 Lamb, C. C., 59.
 Lambert, D. J., 62.
 Lambert, F. A., 56.
 Lamoureux, A. J., 51.
 Lamson, G. H., Jr., 16.
 Lamson, J. B., 39.
 Landacre, F. L., 56.
 Landon, Mrs. L. E., 38.
 Lane, C. H., 6, 7.
 Lane, D. J., 39, 40.
 Lane, G., 44.
 Lang, LeR., 23, 24.
 Langlois, E. C., 73.
 Langridge, F. M., 15.
 Langton, W. S., 68.
 Langworthy, C. F., 6, 7.
 Lansing, R. C., 39, 40.
 Lanxon, W. R., 55.
 Laper, C. G., 57.
 Larkins, L. S., 33.
 Larrabee, E. A., 37.
 Larsen, C. (S. Dak.), 65.
 Larsen, C. (Utah), 68.
 Larsen, L. D., 21.
 Larson, C. W., 60, 61.
 Larson, G. L., 22.
 Larson, R. A., 65.
 Lassalle, L. J., 61.
 Lasseter, W. C., 12, 13.
 Lafané, R. P., 53.
 Laton, T. J., 47.
 Latta, W. C., 8, 24.
 Lauck, W. H., 7.
 Laude, H. H., 29.
 Lauman, G. N., 51.
 Laver, M. R., 56.
 Lawrason, S. McC., 31.
 Lawrence, E. A., 64.
 Lawrence, J. W., 15.
 Lawrence, W. E., 59.
 Laws, A. G., 42.
 Laws, L. P., 17.
 Lawson, J. L., 31.
 Laycock, W. E., 38.
 Layman, J. D., 46.
 Lasenby, W. R., 55.
 Lea, E. J., 13.
 Lea, P., 17.
 Leake, C., 41.
 Leavell, R. H., 67.
 Leavitt, R., 25.
 Lebold, C. H., 57.
 Le Clair, C. A., 43.
 Lee, B., 31.
 Lee, C. B., 45, 46.
 Lee, C. F., 75, 76.
 Lee, F. M., 21.
 Lee, J. G., 32.
 Lee, R. E., 63.
 Lee, W. H., 16.
 Leech, E. V., 59.
 Lefevre, G., 42.
 Le Fevre, J., 47.
 Lehman, D. H., 22.
 Lehmann, E. W., 67.
 Leidigh, A. H., 28, 29.
 Leighton, V. L., 62.
 Leighton, W. L., 34.
 Leighty, W. R., 24.
 Leith, B. D., 75, 76.
 Leland, E. W., 51, 52.
 Lemon, J. G., 20.
 Leonard, A., 28.
 Leonard, W. J., 74.
 Leupp, W. H., 48.

- Levin, W., 87.
 Levister, B., 64.
 Levy, A., 41.
 Levy, E. C., 64.
 Lewers, K., 46.
 Lewers, R., 46.
 Lewis, A. G., 50.
 Lewis, C. E., 34.
 Lewis, C. I., 58, 59.
 Lewis, D. E., 29.
 Lewis, E. M., 36.
 Lewis, H. G., 43.
 Lewis, H. R., 48, 49.
 Lewis, J. G., 72.
 Lewis, J. T., 71.
 Lewis, J. V., 48.
 Lewis, L. L. (Okla.), 57, 58.
 Lewis, L. L. (Va.), 71.
 Lewis, L. M., 59.
 Lewis, T. K., 56.
 Lewis, W. C., 64.
 Lichtenthaler, R. A., 63.
 Liebers, O. H., 45.
 Lill, J. G., 29.
 Lincoln, J. R., 26.
 Lind, J., 39.
 Lindsay, J. I., 69.
 Lindsey, A. E., 28.
 Lindsey, J. B., 36, 37.
 Linfield, F. B., 44, 45.
 Link, G. K. K., 45, 46.
 Linklater, W. A., 57, 58.
 Lintner, W. A., 27.
 Linton, J. O., 38.
 Lipman, C. B., 13, 14.
 Lipman, J. G., 48, 49.
 Lipp, C. C., 39, 40.
 Lippincott, W. A., 28, 29.
 Lipscomb, G. F., 63.
 Little, C. N., 22.
 Little, E. F., 47.
 Littlejohn, A., 56.
 Livermore, K. C., 51, 52.
 Livingston, G., 56.
 Lloyd, E. R., 41, 42.
 Lloyd, E. R., jr., 64.
 Lloyd, F. E., 9, 10.
 Lloyd, J. T., 51.
 Lloyd, J. W., 23, 24.
 Lloyd, O. G., 75, 76.
 Lloyd, W. A., 56.
 Lloyd-Jones, O., 75, 76.
 Loblein, E. L., jr., 48.
 Lockerman, J. H., 35.
 Lockhart, A., 70.
 Lockhart, O. C., 56.
 Lockwood, W. P. B., 36.
 Lodge, W. L., 37.
 Loftin, U. C., 18.
 Logan, C. C., 23.
 Logan, M. J. H., 48.
 Logan, W., 10.
 Logan, W. N., 41.
 Logo, V. L., 60.
 Lombard, P. M., 70.
 Lommen, I. O., 26.
 Long, D. D., 19.
 Long, W. J., 44.
 Longstreth, J. W., 7.
 Longyear, B. O., 15.
 Loomis, A., 75.
 Loomis, H., 65.
 Lord, H. B., 50.
 Loree, L. F., 48.
 Lory, C. A., 14, 15.
 Losh, A. R., 29.
 Lougher, T. H., 62.
 Loughridge, J. E., 45.
 Loughridge, R. H., 13, 14.
 Love, H. H., 51, 52.
 Lovejoy, S. C., 60.
 Loveland, G. A., 46.
 Lovett, A. L., 59.
 Lovette, J. W., 74.
 Low, S., 10.
 Lowman, G. S., 28.
 Lowman, W. R., 64.
 Lowry, Mrs. M. M., 74.
 Lowry, M. W., 60.
 Lowry, W. H., 74.
 Loy, S. K., 77.
 Lozier, A., 48.
 Ludlum, L. C., 67.
 Lueder, C. A., 74.
 Lumbrick, A., 23.
 Lumsden, D., 47.
 Lund, J., 28.
 Lunn, A. G., 59.
 Lustrat, J., 19.
 Lutman, B. F., 69, 70.
 Luttrell, E. G., 12.
 Lyford, V. G., 45.
 Lykes, H. P., 20.
 Lyles, W. M., 31.
 Lyman, E., 69.
 Lyman, J. F., 56.
 Lyman, R., 68.
 Lyman, R. P., 37.
 Lyman, W. T., 17.
 Lyon, H. L., 21.
 Lyon, T. L., 51, 52.
 Lyon, W. S., 51.
 Lyons, J. H., 31.
 McAdams, E. E., 67.
 McAdory, I. S., 9, 10.
 McAfee, C. B., 43.
 McArdle, H. W., 54.
 McArthur, C. L., 22.
 McArthur, J. R., 49.
 McBride, I., 57.
 McBride, R. E., 49.
 McBride, R. V., 57.
 McBryde, J. B., 70.
 McBryde, J. M., 70.
 McBurney, R., 57.
 McCaffrey, M. E., 75.
 McCain, M. J. H., 58.
 McCall, A. G., 56.
 McCall, M. A., 59.
 McCall, T., 40.
 McCallum, A. T., 53.
 McCampbell, C. W., 28, 29.
 McCampbell, E. F., 56.
 McCann, S. D., 30.
 McCarthy, C. F., 73.
 McCarthy, J., 48.
 McCarthy, T. J., 75, 76.
 McCharles, C. H., 13, 14.
 McCheyne, G. M., 25.
 McClelland, C. K., 6, 21.
 McClelland, T. B., 7, 62.
 McClendon, S. E., 33.
 McClendon, W., 33.
 McCloskey, A. G., 51.
 McClung, H. L., 65.
 McClure, L., 39, 40.
 McClure, L. A., 46.
 McCollum, E. V., 75, 76.
 McComber, O., 40.
 McConn, C. M., 22.
 McConnell, W. R., 60.
 McCool, M. M., 51, 52.
 McCormick, E. B., 28.
 McCormick, V. C., 60.
 McCrary, M. L., 58.
 McCreary, O., 50.
 McCreary, P. L., 14.
 McCrory, S. H., 7.
 McCrosky, R. C., 72.
 McCue, C. A., 17.
 McCullough, J. G., 60.
 McCully, B., 72.
 McCune, E. C., 68.
 McDaniel, E. I., 38.
 McDaniel, J. S., 37.
 McDonald, E. M., 23, 24.
 McDonald, M. (Iowa), 27.
 McDonald, M. (Minn.), 39, 40.
 McDonald, M. (Okla.), 57.
 McDonald, W. T., 73.
 McDonnell, H. B., 35.
 McDonough, J. F., 48.
 McDowell, Mrs. C. R., 44.
 McDowell, M. S., 60, 61.
 McElfresh, G. E., 59.
 McElroy, C. H., 57.
 McElroy, T. E., 57, 58.
 McEnerney, G. W., 13.
 McFarland, J. W., 25.
 McFarlin, J. W., 30, 31.
 McFeely, E. A., 60.
 McGalliard, W. V., 48.
 McGarrish, S. W., 28.
 McGeorge, W., 6, 21.
 McGregor, P., 72.
 McGriff, A., 11.
 McGuire, A. J., 40.
 McHatton, T. II., 19.
 McHugh, J. K., 32.
 McIlhenny, G. A., 41, 42.
 McInerney, T. J., 51.
 McIntire, C., 57.
 McIntire, C. McC., 23.
 McIntire, H. K., 52.
 McIntire, W. H., 61.
 McIntosh, D., 23.
 McKay, A. B., 41.
 McKay, G., 72.
 McKee, R. H., 34.
 McKeever, W. A., 28.

- McKell, J. E., 41.
 McKelvie, S., 45.
 McKenzie, A., 71.
 McKenzie, F. A., 56.
 McKenzie, H. B., 12.
 McKeown, J. L., 57.
 McKinley, J. W., 13.
 McKnight, G. H., 56.
 McKnight, H. L., 67.
 McKone, F. E., 47.
 McLane, P., 62.
 McLaughlin, F. A., 36.
 McLaughlin, W. W., 7, 69.
 McLean, H. C., 48.
 McLean, J. A., 36.
 McLendon, C. A., 20.
 McLeod, J. H., 67.
 McLester, Mrs. W. C., 20.
 McLouth, F. D., 59.
 McLurkin, C. P., 64.
 McMeans, A., 54, 55.
 McMillan, S. A., 67.
 McMillin, E., 60.
 McMullan, A. J., 19.
 McMurtry, H. D., 41.
 McNatt, H. E., 23.
 McNell, J. H., 56.
 McNulty, J. B., 15.
 McNutt, J. C., 52.
 McOmie, A. M., 12.
 McPheeters, W. H., 67.
 McPherson, J. H. T., 19.
 McPherson, W., 55.
 McPheters, L. E., 34.
 McQuarrie, C. K., 18.
 McRae, E. M., 24.
 McRae, J. P., 53.
 McSwain, C. W., 63.
 McVey, J. M., 17.
 MacCaughy, V., 21.
 MacDonald, G. B., 26, 27.
 MacDonald, J. A., 69.
 MacDonald, M. B., 60, 61.
 Macdonald, S. L., 15.
 MacDougal, F. H., 67.
 Macfarlane, W., 69.
 Machmer, W. L., 36.
 Mack, H. D., 54.
 Mack, J., 12.
 Mack, J. T., 55.
 Mack, M. A., 28.
 Mack, W. B., 46.
 MacKay, C. J., 26.
 McKenzie, A. St. C., 30.
 Mackimmie, A. A., 36.
 Macklin, J. F., 37.
 Macklin, T. H., 27.
 Maclean, E., 28.
 MacLean, J. A., 22.
 MacLean, J. M., 26.
 Maclin, A. C., 44.
 MacMurray, A., 26.
 MacNider, G. M., 53.
 Macon, E. N., 62.
 Macpherson, H., 59.
 Macpherson, Mrs. M. D., 59.
 Madaus, H. H., 25.
 Madison, E. W., 68.
 Madsen, H. P., 69.
 Madson, B. A., 14.
 Magoon, C. H., 63.
 Magruder, W. H., 41.
 Mahin, E. G., 24.
 Mahoney, R. E., 7.
 Mairs, T. I., 60, 61.
 Major, C., 24.
 Major, D. R., 55.
 Major, E. W., 13, 14.
 Major, H. F., 43.
 Malde, O. G., 76.
 Mullon, G. W., 55.
 Malone, R. E., 11.
 Maltby, R. D., 18.
 Manchester, H. G., 16.
 Mann, A. R., 51, 52.
 Mann, C. D., 63.
 Mann, C. L., 52.
 Manning, A., 69.
 Manning, R. I., 63.
 Manns, T. F., 56.
 Mrsell, R. E., 13, 14.
 Manzur, Z. M., 69.
 Marbut, C. F., 42, 43.
 Marcellus, F. N., 26, 27.
 Marelli, H., 48.
 Marinoni, U., 33.
 Mariotte-Davies, P., 24.
 Markham, E. A., 22.
 Marks, J. D., 32.
 Marlatt, A. L., 75, 76.
 Marquardt, C. E., 61.
 Marr, R. A., 70.
 Marsden, R. D., 7.
 Marsh, H. E., 38.
 Marshall, C. E., 37, 38.
 Marshall, F. R., 56.
 Marshall, G. W., 17.
 Marshall, J. A., 69.
 Marshall, J. D., 15.
 Marsteller, R. P., 67.
 Martin, A. D., 19.
 Martin, A. E., 19.
 Martin, E. B., 10.
 Martin, G. C., 36.
 Martin, G. L., 54, 55.
 Martin, H. L., 9.
 Martin, J. A., 42.
 Martin, J. N., 26.
 Martin, J. W., 75.
 Martin, S. M., 63.
 Martin, S. P., 11.
 Martinett, Mrs. L. M., 33.
 Marvin, W. T., 48.
 Mason, C. E., 10.
 Mason, C. J., 16.
 Mason, H. D., 50.
 Mason, T. W., 61.
 Massey, A. B., 63.
 Mastin, J. C., 31.
 Matheson, K. J., 16.
 Matheson, R., 51.
 Mathews, H. B., 65.
 Mathewson, T. G., 62.
 Mathis, F. K., 57.
 Matthews, C. W., 30.
 Mathews, H., 40.
 Matthews, W. C., 30, 31.
 Mauldin, I. M., 63.
 Maurer, O., 29.
 Maxson, R. N., 30.
 Maxwell, A. M., 41.
 May, D. W., 7, 62.
 May, V. B., 49.
 Mayhew, S. J., 10.
 Maynard, J., 65.
 Maynard, L. A., 27.
 Mayne, D. D., 39.
 Mayne, L. B., 38.
 Mayo, N. S., 70, 71.
 Mayo, W. J., 39.
 Meacham, F. T., 53.
 Mead, E., 14.
 Mead, J. A., 69.
 Mebane, A. L., 54.
 Medcraft, W. G., 12.
 Meears, E. E., 63.
 Meek, E. B., 60, 61.
 Meeker, A., 22.
 Megtjar, E., 61.
 Meighan, H. A., 46.
 Meiklejohn, R., 56.
 Melander, A. L., 72, 73.
 Melcher, C. R., 30.
 Meldrim, P. W., 20.
 Melhus, I. E., 75, 76.
 Melick, C. A., 37.
 Mellen, F. D., 41.
 Melvin, M. E., 19.
 Mengel, C. W., 7.
 Menges, F., 60.
 Menig, O., 73.
 Mensching, J. E., 57.
 Menville, R. L., 32.
 Mercer, W. H., 55.
 Merica, C. O., 76, 77.
 Merick, L. S., 25.
 Merrill, D. E., 49.
 Merrill, L. A., 68, 69.
 Merrill, L. H., 34.
 Merrill, L. S., 34.
 Merrill, N. F., 69.
 Merrill, S. E., 40.
 Merrow, H. L., 62.
 Merryman, E. G., 35.
 Merz, H., 77.
 Messick, J. F., 9.
 Messick, S. H., 17.
 Metcalf, Z. P., 53.
 Meyer, A. J., 43.
 Meyer, G. H., 23.
 Michaelides, H. I., 38.
 Michie, J. N., 67.
 Middlekauff, H., 77.
 Middleton, A. R., 24.
 Milam, A. B., 26.
 Milan, E. B., 59.
 Milbrath, D. G., 55.
 Miles, E. F., 28.
 Millar, C. E., 29.
 Miller, A. McQ., 30.
 Miller, A. M., 67.

- Miller, D. G., 7.
 Miller, E. C. (Cal.), 14.
 Miller, E. C. (Kans.), 28, 29.
 Miller, E. R., 9.
 Miller, E. S., 50.
 Miller, E. T., 19.
 Miller, F. H., 50.
 Miller, G. E., 54.
 Miller, J. H., 8, 29.
 Miller, J. O., 49.
 Miller, M. F., 42, 43.
 Miller, P. C., 49.
 Miller, P. E., 40.
 Miller, R., 57.
 Miller, R. F., 45.
 Miller, Mrs. S. H., 42.
 Miller, S. P., 65.
 Miller, W. C., 59.
 Milliken, F. B., 28, 29.
 Mills, G. F., 36.
 Mills, H. C., 25.
 Mills, S. P., 34.
 Mills, W. J., 49.
 Milner, R. D., 7.
 Milner, R. T., 66.
 Miltimore, C., 57.
 Milward, J. G., 75, 76.
 Minard, A. E., 54.
 Minear, S. A., 57.
 Minkler, F. C., 48, 49.
 Minns, E. R., 51, 52.
 Minor, J. B., 53.
 Miskimen, M., 56.
 Mitcham, G. M., 9.
 Mitchell, A., 67.
 Mitchell, C. E., 74.
 Mitchell, D. C., 39, 40.
 Mitchell, Mrs. E. M., 74.
 Mitchell, G., 27.
 Mitchell, H. F., 58.
 Mitchell, H. W., 60.
 Mitchell, J. F., 14.
 Mitchell, J. R., 38.
 Mitchell, J. W., 67.
 Mitchell, R. V., 61.
 Mitchell, S. C., 71.
 Mitchell, S. R., 49.
 Mitchell, W. L., 9.
 Mobley, H. S., 12.
 Mobley, J. H., 20.
 Moffitt, E. H., 21.
 Moffitt, J. K., 13.
 Mohn, E., 57.
 Mokler, A. J., 76.
 Mollison, A. E., 44.
 Money, P. A., 62.
 Monosmith, P. B., 41.
 Monroe, C. F., 73.
 Monteith, H. R., 16.
 Montgomery, E. G., 51, 52.
 Montgomery, L. M., 56.
 Mooers, C. A., 66.
 Moon, C., 74.
 Moon, F. F., 36.
 Moore, A. F., 22.
 Moore, A. J., 41.
 Moore, E. L., 65.
 Moore, F. C., 47.
 Moore, H. E., 22.
 Moore, H. W., 19.
 Moore, J. B., 68.
 Moore, J. G., 75, 76.
 Moore, J. S., 41.
 Moore, K. T., 11.
 Moore, L. H., 10.
 Moore, M. D., 6.
 Moore, P., 22.
 Moore, R. A., 75, 76.
 Moore, R. S., 32.
 Moorhead, M. B., 39, 40.
 Mooring, D. C., 57, 58.
 Moran, T. F., 24.
 More, R. P., 61.
 Morehouse, A. D., 7.
 Morel, J. F., 59.
 Moreland, C. C., 33.
 Moreland, R. W., 33.
 Morell, F., 66.
 Morgan, A. E., 7.
 Morgan, H. A., 66.
 Morgan, H. H., Jr., 17.
 Morgan, J. O., 66.
 Morgan, L. E., 43.
 Moriarty, G. F., 69.
 Morley, W. S., 22.
 Morphis, R. W., 53.
 Morrell, L. L., 50.
 Morrey, C. B., 55.
 Morrill, A. W., 12.
 Morris, E. L., 14.
 Morris, H., 33.
 Morris, H. E., 45.
 Morris, H. H., 38.
 Morris, J., 19.
 Morris, M. A., 10.
 Morris, O. M., 73.
 Morris, R., 48.
 Morris, R. T., 50.
 Morris, S., 73.
 Morris, T. D., 66.
 Morris, W. F., 53.
 Morrison, C. B., 16.
 Morrison, F. B., 75, 76.
 Morrison, M. M., 49.
 Morrison, W. S., 63.
 Morrow, H. E., 12.
 Morse, B. C., 23.
 Morse, E. W., 6.
 Morse, F. W., 37.
 Morse, J. L., 38.
 Morse, W. C., 56.
 Morse, W. J., 34.
 Mortensen, M., 26, 27.
 Mortland, I., 32.
 Morton, C. A., 28.
 Morton, G. E., 15.
 Morton, J., 49.
 Mosby, T. S., 44.
 Moseley, J. H., 42.
 Moseley, J. M., Jr., 9.
 Moseley, T. W., 45.
 Mosher, A. G., 26.
 Mosher, M. L., 27.
 Mosier, J. G., 23.
 Moes, J. M., 33.
 Motin, F. E., 44.
 Moton, R. R., 72.
 Moulton, C. R., 43.
 Mower, E. C., 69.
 Mowry, J. L., 39, 40.
 Muir, F., 21.
 Muldrow, C., 64.
 Mulford, W., 51.
 Mulligan, C. A., 66.
 Mulvanis, M., 66.
 Mumford, F. B., 8, 42, 43.
 Mumford, H. W., 23, 24.
 Muncie, F. W., 23.
 Mundhenk, C. L., 26.
 Murdock, E., 10.
 Murphree, A. A., 18.
 Murphy, D. D., 25.
 Murphy, E. S., 74.
 Murphy, H. S., 26.
 Murphy, W. J., 11.
 Murray, C., 26.
 Murray, G. S., 44.
 Murray, N. A., 54.
 Musgrave, T. C., 41.
 Musselman, H. H., 38.
 Mustaine, W. W. H., 30.
 Mustard, L. W., 17.
 Mutchie, S., 29.
 Myers, C. E., 61.
 Myers, C. H., 51.
 Myers, C. S., 64.
 Myers, J. J., 37.
 Myers, T. R., 65.
 Myrick, F. H., 62.
 Nabours, R. K., 28, 29.
 Nagle, J. C., 66.
 Nanney, L. C., 26.
 Napier, J. McG., 63.
 Napp, W. G., 33.
 Naquin, W. P., 21.
 Nash, E. M., 29.
 Navarrete, A., 62.
 Naylor, N. M., 27.
 Neal, D. C., 74.
 Neal, J. A., 38.
 Neal, J. W., 6, 11.
 Neal, R. W., 36.
 Neale, A. S., 56.
 Needham, J. G., 51.
 Neal, L. R., 66.
 Neely, R. C., 19, 20.
 Neff, J. B., 13.
 Nehrling, A. H., 23, 24.
 Neldig, R. E., 27.
 Neilson, J., 47, 48.
 Neilson, A., 77.
 Neilson, A. P., 75.
 Neilson, B. F., 39.
 Neilson, D. M., 43.
 Neilson, J., 48.
 Neilson, J. B., 45.
 Neilson, M., 12, 13.
 Neilson, M. A., 69.
 Neilson, P., 6, 20.
 Neilson, S. B., 72, 73.

Nelson, T., 52.
 Nelson, W. P., 67.
 Nelson, W. S., 11.
 Nesbit, A. F., 47.
 Nesbitt, O., 45.
 Ness, H. (Iowa), 26.
 Ness, H. (Texas), 67.
 Netherton, T. M., 15.
 Newell, W., 67.
 Newey, A., 69.
 Newhall, H. W., 38.
 Newins, H. S., 59.
 Newman, C., 37.
 Newman, C. C., 64.
 Newman, C. L., 52.
 Newman, C. M., 70.
 Newman, J. T., 50.
 Newman, P. J., 28.
 Newsom, I. E., 15.
 Newton, H. D., 16.
 Newton, J. T., 19.
 Newton, W. R., 48.
 Nicholas, N., 66.
 Nichols, C. B., 30.
 Nicholson, J. F., 22.
 Nicholson, J. W., 32.
 Nickerson, W. J., 33.
 Niederhausen, S. W., 61.
 Niederman, G., 23.
 Nielsen, H. T., 29.
 Nissley, W. B., 61.
 Niswonger, H. R., 30, 31.
 Niven, L. A., 63.
 Nix, N. C., 61.
 Nixon, C., 51, 52.
 Noble, A. B., 26.
 Noble, E. C., 45.
 Noble, M. C. S., 53.
 Nock, N. W., 71.
 Noel, G. D., 29.
 Noel, H. L., 41.
 Noell, R. J., 70.
 Noian, A. W., 74.
 Noll, C. F., 60, 61.
 Norgord, C. P., 75, 76.
 Norman, A. J., 36.
 Norris, R. S., 21.
 North, H. B., 48.
 Northcott, G. A., 73, 74.
 Northrup, Z. L., 38.
 Norton, G. I., 26.
 Norton, J. B. S., 35.
 Norton, J. H., 13, 14.
 Norton, W. C., 53.
 Norwood, F. J., 42.
 Noyes, G. H., 30.
 Nugent, C. E., 54.
 Nutter, J. H., 35.
 Nutter, J. W., 30, 31.
 Nye, W. McE., 24.
 Nystrom, A. B., 73.

Oak, J. M., 34.
 O'Brien, J. W., 46.
 O'Byrne, A. E., 12.
 O'Byrne, F. M., 18.
 Ockerblad, A. M., 38.

Ocock, C. A., 75, 76.
 Odell, A. F., 32.
 Ogden, E. L., 6.
 Ogden, R. C., 10, 71.
 Ogier, T. L., 67.
 Oglebay, E. W., 73, 74.
 O'Hanlon, W., 50.
 O'Kane, W. C., 47.
 Okey, C. W., 7.
 Olcott, B. W., 58.
 Olin, W. H., 22.
 Olive, E. W., 65.
 Oliver, J. D., 24.
 Oliver, T. E., 23.
 Olmsted, M. E., 60.
 Olson, G. A., 73.
 Olson, L. P., 40.
 Olson, O. M., 39.
 Olwell, J. D., 58.
 O'Neal, E., 9, 10.
 Onell, Mrs. A. T., 31.
 Oosterhuis, A. C., 75, 76.
 Ormsbee, E. J., 69.
 Orr, B. S., 28.
 Orton, C. R., 25.
 Orton, W. A., 7.
 Orvis, E. L., 60.
 Osborn, G. A., 48.
 Osborn, H., 55.
 Osborne, O. M., 22.
 Osborne, T. B., 16.
 Osker, H. S., 38.
 Osmun, A. V., 36.
 Ostrander, J. E., 36, 37.
 Ostrum, C., 57.
 Oswald, W. L., 39, 40.
 Otis, A. H., 12.
 Otis, D. H., 75, 76.
 Oviatt, C. J., 77.
 Owen, A. P., 48.
 Owen, E. B., 53.
 Owen, E. J., 48.
 Owen, I. L., 48.
 Owen, W. L., 32.
 Ozement, B. H., 28.

Packard, W. E., 14.
 Paddock, F. B., 67.
 Paddock, W., 55.
 Page, I. E., 58.
 Page, R., 70.
 Paige, E. O., 19.
 Paige, J. B., 36, 37.
 Paine, G. S., 46.
 Palm, E., 38.
 Palmer, C., 34.
 Palmer, D. N., 64.
 Palmer, E. S., 48.
 Palmer, J. H., 11.
 Palmer, L. S., 43.
 Palmer, M. A., 15.
 Palmer, W. R., 34.
 Pammel, L. H., 26, 27.
 Panter, C. R., 33.
 Park, C. B., 52.
 Park, J. B., 23.
 Park, R. E., Jr., 19.

Parker, B., 52.
 Parker, C. E., 17.
 Parker, J. R., 45.
 Parker, J. T., 28.
 Parker, P. B., 45.
 Parker, T. B., 53.
 Parmelee, C. W., 48.
 Parr, S. W., 23.
 Parrish, G. R., 71.
 Parrish, J. C., 42.
 Parrott, A. H., 54.
 Parrott, J. R., 70.
 Parrott, P. J., 50.
 Parshall, R., 15.
 Parsley, H. M., 34.
 Parsons, A. C., 58.
 Parsons, C. L., 47.
 Parsons, M., 43.
 Parsons, S. R., 36.
 Parsons, T. S., 77.
 Paschall, A. L., 67.
 Patch, E. M., 34.
 Pate, W. F., 53.
 Paterson, A. G., 73.
 Paterson, T. G., 28, 29.
 Patrick, B. S., 9.
 Patrick, I. L., 64.
 Pattee, F. L., 60.
 Pattee, G. K., 60.
 Patten, A. J., 38.
 Patten, D. W., 16.
 Pattengill, E. A., 26.
 Patterson, H. F., 44.
 Patterson, H. J., 35.
 Patterson, J. K., 30.
 Patterson, L. L., 41.
 Patterson, R. S., 48.
 Patterson, S. G., 22.
 Patterson, W. H., 60.
 Patton, C. A., 57.
 Patton, E. H., 42.
 Paxton, E. E., 21.
 Payne, W. O., 19.
 Paynter, E. R., 17.
 Paynter, W. C., 43.
 Payson, E. R., 48.
 Payson, G. H., 48.
 Peabody, F. G., 71.
 Peabody, G. F., 10, 71.
 Peace, W. G., 52.
 Peairs, L. M., 28, 29.
 Pearce, D. L., 40.
 Pearl, R., 34.
 Pearson, C., 14.
 Pearson, Mrs. D. E., 20.
 Pearson, H. A., 20.
 Pearson, R. A., 50.
 Pearson, W. H., 49.
 Pearson, W. W., 58.
 Pease, T. C., 61.
 Peavy, G. W., 59.
 Peck, C., 69, 70.
 Peck, S. S., 21.
 Peckham, H. H., 53.
 Pedersen, N. A., 68.
 Peek, E. L., 20.
 Peeples, A., 35.

- Pegues, B. W., 32.
 Pelton, W. C., 17.
 Pember, F. R., 63.
 Pence, M. L., 30.
 Pence, M. O., 17.
 Pennewill, S. S., 17.
 Penney, R. D., 38.
 Penny, C. L., 17.
 Peppard, Mrs. L. L., 38.
 Perin, S. W., 46.
 Perkins, A. E. (Miss.), 42.
 Perkins, A. E. (Ohio), 57.
 Perkins, H. F., 69.
 Perkins, R. C. L., 21.
 Perley, G. A., 47.
 Perry, F. M., 12.
 Person, F. G., 15.
 Peteet, W., 66, 67.
 Peter, A. M., 30, 31.
 Peters, C. A., 36.
 Peterson, E. G., 68.
 Peterson, F. L., 7, 46.
 Peterson, J. M., 68.
 Peterson, N. F., 32.
 Peterson, P. E., 69.
 Peterson, P. P., 75, 76.
 Peterson, W., 68.
 Peterson, W. H., 75, 76.
 Petrie, G., 9.
 Petry, E. J., 24.
 Pettee, C. H., 47.
 Pettit, J. H., 23.
 Pettit, R. H., 37, 38.
 Pew, W. H., 26.
 Peyton, P. B., 65.
 Plotenhauer, W., 21.
 Phelps, Mrs. C. P., 49.
 Phelps, R. L., 49.
 Phenix, G. P., 72.
 Phillips, A. G., 24, 25.
 Phillips, H., 13, 14.
 Phillips, J. V., 7.
 Phillips, M. W., 41.
 Phillips, T. D., 66.
 Phillips, W. J., 25.
 Pickel, J. M., 63.
 Pickerill, H. M., 51.
 Pickett, B. S., 47.
 Pierce, H., 15.
 Pierce, J. A., 64.
 Pierce, W. M., 58.
 Pierpont, A. J., 16.
 Pierpont, J. H., 47.
 Pierson, P. I., 61.
 Pile, G. E., 18.
 Pilkington, B., 59.
 Pillsbury, J. P., 52, 53.
 Pillsbury, R. W., 47.
 Pinckney, E. H., 18.
 Pinckney, R. M., 45.
 Pincomb, H. M., 23.
 Ping, E. K., 28.
 Pinkett, D. J., 36.
 Pinnell, W. R., 30, 31.
 Pipal, F. J., 25.
 Pittuck, B. C., 57.
 Place, I. A., 50.
 Placeway, L. A., 26.
 Plumb, C. S., 55.
 Plummer, J. K., 53.
 Poats, T. G., 63.
 Pohlers, G. F., 7.
 Pollard, A. G., 36.
 Pollock, C. M., 43.
 Pollock, G. G., 45.
 Polson, J. A., 37.
 Pomerene, F. E., 55.
 Pompey, R. S., 11.
 Pond, G. G., 60.
 Pond, R. S., 19.
 Poole, R. L., 53.
 Poole, R. R., 10.
 Porcher, A. A., 63.
 Porter, C., 57.
 Porter, C. S., 30, 31.
 Porter, C. W., 68.
 Porter, H. E., 28.
 Porter, J. T., 66.
 Porter, S. H., 11.
 Porter, W. M., 59.
 Porter, W. R., 55.
 Porterfield, W. P., 54.
 Potter, A. A., 28.
 Potter, E. L., 59.
 Potter, P. D., 60.
 Potter, W. R. R., 21.
 Potts, A. R., 38.
 Potts, A. T., 67.
 Potts, R. C., 57, 58.
 Potts, R. J., 67.
 Pou, R. L., 41.
 Powell, E. J., 19.
 Powell, H. McL., 12.
 Powell, J. H., 42.
 Powell, J. S., 69.
 Powell, P. P., 9.
 Powell, R. W., 38.
 Powers, D. T., 32.
 Powers, G. D., 46.
 Powers, G. M., 69.
 Powers, M. R., 63, 64.
 Powers, W. H., 65.
 Powers, W. L., 59.
 Pratt, C. D., 72.
 Pratt, F. R., 48.
 Pratt, G., 29.
 Pratt, G. K., 31.
 Pratt, W. F., 50.
 Prentiss, R. W., 48.
 Prescott, A. T., 31, 32.
 Preston, A. W., 46.
 Preston, C. H., 36.
 Preston, J. B., 56.
 Price, H. C., 55.
 Price, H. J., 24.
 Price, H. L., 70, 71.
 Price, J. C. C., 9, 10.
 Price, J. D., 20.
 Price, R. B., 42, 43.
 Price, R. R., 28.
 Prichard, R. S., 61.
 Pridmore, J. C., 66.
 Prien, O. L., 77.
 Prillerman, B., 74.
 Prince, W. E., 34.
 Pritchett, V. C., 53.
 Privott, W. W., 36.
 Proctor, R., 69.
 Proulx, E. G., 25.
 Pryor, J. W., 30.
 Pugsley, C. W., 45, 46.
 Pulley, E. P., 69.
 Puryear, C., 66.
 Putnam, C. S., 54.
 Putnam, F. W., 47.
 Putnam, M., 73.
 Putney, F. S., 62.
 Putt, E. B., 55.
 Qualle, E. L., 36.
 Quayle, H. J., 13, 14.
 Quayle, W. L., 69.
 Quereau, F. C., 33.
 Queenberry, G. R., 49.
 Quigley, J. E., 60.
 Quintero, A., 62.
 Raburn, G. E., 29.
 Rae, R. M., 27.
 Ragan, W. H., 52.
 Raggio, A. P., 34.
 Rahn, O., 37, 38.
 Rail, E., 45, 46.
 Ralston, W. E., 72.
 Ramsey, J. B., 11.
 Ramsey, J. R., 42.
 Ramsower, H. C., 55.
 Ranck, E. M., 41.
 Randlett, G. W., 54.
 Rane, F. W., 36.
 Ranger, W. E., 62.
 Rankin, C. A., 26.
 Rankin, F. H., 8, 23.
 Rankin, F. J., 15.
 Rankin, J. O., 6.
 Ransom, J. H., 24.
 Rasche, W. H., 70.
 Rasmussen, F., 47.
 Rast, L. E., 19.
 Rather, J. B., 67.
 Rausch, M. F., 15.
 Raven, W. F., 38.
 Ravitch, M., 29.
 Rawl, B. H., 63.
 Ray, B. J., 53.
 Ray, P. O., 60.
 Raymond, W. R., 26.
 Read, A. C., 60.
 Read, W. A., 32.
 Reade, J. M., 19.
 Readhimer, J. E., 23.
 Reardon, J., 27.
 Reddick, D., 51, 62.
 Reddy, H., 55.
 Redifer, A. E., 60.
 Redlich, F., 67.
 Redman, R. W., 34.
 Reece, R. H., 38.
 Reed, A. G., 32.
 Reed, B. B., 27.
 Reed, C. C., 36.

- Reed, C. O., 23.
 Reed, E. E., 31.
 Reed, G. M., 42, 43.
 Reed, H. S., 70, 71.
 Reed, J. C., 37.
 Reed, L. J., 34.
 Reed, M. L., 52.
 Reed, O. E., 28, 30.
 Reed, R. C., 17.
 Reed, T. W., 19.
 Reed, W. H., 77.
 Reeder, G., 42, 43.
 Rees, E. L., 30.
 Rees, H. L., 59.
 Rees, R. W., 59.
 Reese, A. M., 74.
 Regenstein, E., 30, 31.
 Regt, A. C. de, 43.
 Reiben, G., 59.
 Reid, C. C., 12.
 Reid, H. E., 46.
 Reid, I. C., 12.
 Reimer, F. C., 59.
 Reinhardt, H., 64.
 Reitz, W. W., 61.
 Remick, B. L., 28.
 Remington, R. E., 54, 55.
 Renney, G. A., 51.
 Resler, E. D., 58.
 Rettger, L. F., 16.
 Reynolds, E. S., 66.
 Reynolds, J. A., 28.
 Reynolds, M. H., 29, 40.
 Rhys, A., 43.
 Rice, A., 28.
 Rice, A. E., 39.
 Rice, F. E., 51.
 Rice, J. E., 51, 52.
 Rice, M., 59, 40.
 Rich, F. A., 69, 70.
 Richards, J. G., Jr., 63.
 Richards, M. W., 26.
 Richards, S. J., 58.
 Richards, W. B., 54, 55.
 Richardson, A. G. G., 56.
 Richardson, C. S., 35.
 Richardson, E. S., 32.
 Richeson, W. L., 33.
 Richmond, M., 73.
 Rickards, B. R., 23, 24.
 Rickman, J. D., 28.
 Ricks, J. R., 41.
 Ricks, R. H., 52.
 Riddick, W. C., 52.
 Ridgaway, C. B., 77.
 Ridgely, H., 17.
 Ridgill, J. McL., 62.
 Ridgway, C. S., 9, 10.
 Ridgway, J. W., 67.
 Riets, H. L., 23.
 Riggs, E. J., 56.
 Riggs, W. M., 8, 63.
 Rigney, J. W., 49.
 Riley, H. W., 51, 52.
 Riley, W. A., 51, 52.
 Rmaker, H. B., 23.
 Rinehart, E. F., 56.
 Rinkle, L. G., 43.
 Ripley, G. E., 12.
 Risley, A. M., 57.
 Ritchey, M., 58.
 Ritter, F. E., 61.
 Ritsman, E. G., 7, 62.
 Rivarde, L. R., 33.
 Rives, J. H., 31.
 Roadhouse, C. L., 14.
 Robb, B. B., 51.
 Robbins, W. W., 15.
 Robert, S. A., 66.
 Roberts, G., 30, 31.
 Roberts, G. A., 52, 53.
 Roberts, G. L., 24.
 Roberts, H. F., 28, 29.
 Roberts, I. P., 51.
 Roberts, M. M., 26.
 Roberts, O. S., 25.
 Roberts, P. L., 24, 25.
 Roberts, R., 69.
 Roberts, R. M., 13.
 Roberts, S. C., 73.
 Robertson, G. H., 21.
 Robertson, J. E., 38.
 Robertson, R. D., 7.
 Robinson, A. L., 15.
 Robinson, C. E., 59.
 Robinson, C. S., 38.
 Robinson, D. E., 69.
 Robinson, F. J., 72.
 Robinson, M., 48.
 Robinson, R. H., 50.
 Robinson, R. H., 11.
 Robinson, W. A., 38.
 Robson, Mrs. G. A., 38.
 Rock, J. F., 21.
 Rockwell, W. L., 7.
 Rocky, N. W., 57.
 Rodeheaver, J. N., 65.
 Rodell, E. N., 28.
 Rodes, W., Jr., 30, 31.
 Rodgers, R. H., 59.
 Rodman, T. C., 62.
 Roe, H. B., 39, 40.
 Roe, R. B., 16.
 Rogers, B. R., 28.
 Rogers, C. A., 51, 52.
 Rogers, F. K., 72.
 Rogers, J. A., 9.
 Rogers, M. C., 16.
 Rogers, S. S., 14.
 Rolfe, C. W., 23.
 Rolfs, P. H., 18.
 Rollins, C. B., 42.
 Rollins, W. C., 68.
 Rood, E. D., 15.
 Roosevelt, T., 10.
 Rose, D. H., 28, 29.
 Rose, F., 51.
 Roseboom, B. B., Jr., 38.
 Rosecrants, F. H., 15.
 Rosenkrans, D. B., 53.
 Ross, B. B., 9, 10.
 Ross, E. C., 67.
 Ross, H. E., 51, 53.
 Ross, L., 29.
 Ross, S. I., 15.
 Ross, W. G., 61.
 Ross, W. H., 12.
 Roston, J. M., 20.
 Rouse, I., 50.
 Roush, G. A., 74.
 Rowan, L. L., 42.
 Rowe, W. E., 30.
 Rowell, C., 13.
 Rowell, E. P., 44.
 Rowell, J. L., 70.
 Rowland, F., 59.
 Rowsey, W. E., 58.
 Roy, R. E., 44.
 Rubert, L., 62.
 Rudd, W. N., 66.
 Rude, T. C., 57.
 Rudnick, A. W., 29.
 Rudy, A., 52.
 Ruehe, H. A., 14.
 Ruehle, G. L. A., 50.
 Ruffner, R. H., 25.
 Ruggles, A. G., 39, 40.
 Rule, W., 65.
 Rumsey, W. E., 74.
 Runge, W. E., 15.
 Runkle, E. W., 60.
 Runyon, M. L., 11.
 Ruprecht, R. W., 37.
 Rusk, H. P., 23, 24.
 Russ, A., 57.
 Russell, A. R., 53.
 Russell, F. L., 34.
 Russell, G. E., 26.
 Russell, H. C., 31.
 Russell, H. L., 8, 75, 76.
 Russell, S. M., 11.
 Rust, E. W., 14.
 Ruth, W. A., 24.
 Ruth, W. E., 56.
 Rutland, J. R., 9.
 Rutledge, Mrs. C. N., 44.
 Ruzek, C. V., 12, 13.
 Ryder, E. H., 37.
 Sacha, W. H., 23.
 Sackett, H. W., 50.
 Sackett, W. G., 15.
 Sadler, S., 58.
 Safto, V. I., 59.
 Sage, A. B., 49.
 Sahr, C. A., 6, 21.
 St. Clair, P. F., 70.
 St. Martin, F. L., 33.
 Salyer, S. M., 19.
 Sammis, J. L., 75, 76.
 Sampson, D. L., 56.
 Sampson, G. R., 59.
 Samra, E. S., 34.
 Sanborn, C. E., 57, 58.
 Sanborn, E. D., 53.
 Sanborn, F. E., 55.
 Sanders, J. G., 75, 76.
 Sanders, J. W., 31.
 Sanders, J. Y., 31, 32.
 Sanders, M. B., 57.
 Sanders, S. T., 32.

- Sanderson, E. D., 8, 74.
 Sanderson, T., 55.
 Sanford, E. T., 65.
 Sanford, F., 64.
 Sanford, F. H., 37.
 Sanford, S. V., 19.
 Sargent, F. H., 40.
 Sargent, L. W., 64, 55.
 Sarvis, J. T., 65.
 Sater, L. F., 55.
 Satterfield, H. E., 52.
 Saunders, W. D., 70.
 Sauter, C. C., 35.
 Savage, E. S., 51, 52.
 Sawyer, A. R., 37.
 Sawyer, C. E., 64.
 Scammell, H. B., 40.
 Schaefer, F. A., 21.
 Schaeffer, A. A., 66.
 Schaeffer, N. C., 60.
 Schafer, E. G., 28, 29.
 Schaffner, J. H., 56.
 Schalk, A. F., 64, 55.
 Schaub, I. O., 52.
 Schell, H., 27.
 Scherffius, B. F., 30, 31.
 Schermerhorn, L. G., 44, 45.
 Schieffelin, W. J., 10, 71.
 Schlick, W. J., 7.
 Schlundt, H., 42.
 Schmelz, H. L., 71.
 Schmidt, L. B., 26.
 Schmitz, N., 35.
 Schnabel, J., 18.
 Schoene, W. J., 50.
 Schoenleber, F. S., 28, 29.
 Schoentgen, E. T., 25.
 Schollander, E. G., 55.
 Schootes, A. J., 44.
 Schoppe, W. F., 34, 45.
 Schrack, C. V., 22.
 Schreiber, W. E., 57.
 Schreiner, T. E., 29.
 Schulte, J. I., 6.
 Schultz, L., 57.
 Schulz, C. G., 39.
 Schurman, J. G., 50, 51.
 Schwab, C. M., 60.
 Schwartz, L. H., 75, 76.
 Scoates, D., 41.
 Soobey, F. C., 7.
 Sooffin, L. B., 66.
 Soothorn, R. A., 56.
 Scott, A., 48.
 Scott, A. C., 58.
 Scott, A. L., 13.
 Scott, C. A., 28, 29.
 Scott, C. W., 47.
 Scott, E. L., 32.
 Scott, E. M. (Ohio), 56.
 Scott, E. M. (Tex.), 68.
 Scott, E. W., 68.
 Scott, F. W., 23.
 Scott, G. E., 56.
 Scott, G. L. (Colo.), 15.
 Scott, G. L. (Mich.), 38.
 Scott, G. T., 72.
 Scott, J. M., 18.
 Scott, J. W., 28.
 Scott, R. W., 53.
 Scott, R. W., Jr., 53.
 Scott, S. J., 72.
 Scovell, M. A., 8, 30, 31.
 Scoville, W. H., 72.
 Scroggs, W. O., 32.
 Scudder, H. D., 58, 59.
 Scudder, M. T., 48.
 Seabright, J. E., 63.
 Seaman, G. E., 75.
 Searle, J. P., 48.
 Sears, F. C., 36, 37.
 Sears, W. J., 55.
 Searson, J. W., 28.
 Sease, L. A., 63.
 Seaton, R. A., 28.
 Secrest, E., 56.
 Sechrist, F. K., 62.
 Seeley, W. L., 18.
 Seely, D. A., 38.
 Segall, J. B., 34.
 Selbert, D., 35.
 Selby, A. D., 56.
 Selby, L. B., 49.
 Seldomridge, H. G., 57.
 Seleen, E. B., 59.
 Selvidge, R. W., 43.
 Selvig, C. G., 40.
 Sessions, H., 27.
 Setchell, W. A., 13, 14.
 Severance, G., 73.
 Severin, H. C., 65.
 Severin, H. H., 21.
 Severson, B. O., 61.
 Sewall, A. H., 50.
 Sexton, J. S., 41, 42.
 Shafer, F. F., 7.
 Shafer, G. D., 38.
 Shafrath, J. F., 14.
 Shanklin, A. G., 63.
 Shanks, L. P., 66.
 Shannon, A. H., 41.
 Shannon, E. F., 12.
 Sharp, J. C., 68.
 Sharp, L. T., 14.
 Shattuck, C. H., 22.
 Shattuck, F. V., 26.
 Shattuck, H. B., 69.
 Shattuck, S. W., 22.
 Shaw, A. B., 14.
 Shaw, C. F., 60, 61.
 Shaw, G. W., 13, 14.
 Shaw, J. K., 37.
 Shaw, R. S., 37, 38.
 Shaw, S. B., 53.
 Shaw, W. T., 72, 73.
 Shawkey, M. P., 73, 74.
 Shedd, C. K., 26.
 Shedd, O. M., 30, 31.
 Shedd, S., 72.
 Shelb, R., 61.
 Sheldon, C. H., 14.
 Sheldon, J. L., 74.
 Shepard, C. E., 16.
 Shepard, C. S., 50.
 Shepard, E. R., 59.
 Shepard, J. H., 66.
 Shepperd, Mrs. A., 55.
 Shepperd, J. H., 64, 55.
 Shepperd, J. L., 39, 40.
 Sherman, C. E., 55.
 Sherman, F., Jr., 53.
 Sherman, M. M., 27.
 Sherrod, C. M., 9.
 Sherwin, M. E., 52.
 Sherwood, F. W., 53.
 Sherwood, R. M., 56.
 Shi, B. L., 9.
 Shields, J. F., 60.
 Shields, R. L., 41.
 Shines, P. L., 10.
 Shockley, A. R., 85.
 Shoemaker, C. E., 24.
 Shoesmith, V. M., 37, 38.
 Shook, L. W., 10.
 Short, C. A., 17.
 Shuford, W. J., 53.
 Shute, W. W., 49.
 Slevers, F. J., 75, 76.
 Silvester, R. W., 35.
 Simmons, A. L., 54.
 Simmons, G. E., 34.
 Simmons, L. Van T., 60.
 Simmons, Mrs. M. E., 29.
 Simms, B. T., 53.
 Simms, F. F., 33.
 Simms, G. I., 35.
 Simms, M. J., 68.
 Simpson, H. H., 49.
 Simpson, J. N., 74.
 Simpson, M., 38.
 Simpson, O. G., 59.
 Simpson, R. O., 10.
 Simpson, R. W., 63.
 Sinclair, W., 34.
 Sirtine, F. A., 50.
 Sisson, S., 56.
 Sjogren, O. W., 45.
 Skeeler, F. J., 67.
 Skinner, J. H., 24, 25.
 Skoofield, P. F., 72.
 Slagle, R. L., 65.
 Slate, W. L., Jr., 34.
 Sletta, I., 40.
 Sloan, P. H. E., 63.
 Sloan, R. E., 11.
 Sloan, W. G., 7.
 Smalley, H. R., 25.
 Smart, T., 68.
 Smart, Z., 69.
 Smiley, G., 29.
 Smith, A., 63, 64.
 Smith, A. B., 28.
 Smith, Mrs. A. G., 31.
 Smith, A. M., 39, 40.
 Smith, A. S., 38.
 Smith, C. A. (Minn.), 39.
 Smith, C. A. (Pa.), 61.
 Smith, C. C., 11.
 Smith, C. M., 24.
 Smith, C. O., 14.
 Smith, C. P. (N. Y.), 51.

- Smith, C. P. (Vt.), 69, 70.
 Smith, D. P., 30.
 Smith, E. C., 69.
 Smith, E. H., 14.
 Smith, E. O., 16.
 Smith, E. R., 60.
 Smith, F., 23.
 Smith, F. H., 62.
 Smith, G., 39, 40.
 Smith, G. A., 50.
 Smith, G. C., 47.
 Smith, G. E. P., 12.
 Smith, H. D., 29.
 Smith, H. E., 67.
 Smith, H. F., 26.
 Smith, H. J., 63.
 Smith, H. R., 45, 46.
 Smith, I. W., 54.
 Smith, J. B., 48, 49.
 Smith, J. E., 36.
 Smith, J. W., 56, 57.
 Smith, L., 19.
 Smith, L. C., 74.
 Smith, L. H., 28.
 Smith, L. M., 38.
 Smith, L. W., 51.
 Smith, M. E., 11.
 Smith, M. M., 37.
 Smith, P. H., 37.
 Smith, O. F., 61.
 Smith, R. E. (Cal.), 13, 14.
 Smith, R. E. (Iowa), 26.
 Smith, R. F., 67.
 Smith, R. L., 52, 53.
 Smith, R. M., 59.
 Smith, R. O., 48.
 Smith, T. O., 47.
 Smith, W. A., 58.
 Smith, W. B., 33.
 Smith, W. H., 23.
 Smith, W. O., 21.
 Smith, W. S. T., 46.
 Smith, W. W., 24.
 Smyth, E. A., jr., 70.
 Snedden, D., 36.
 Sneed, C. F., 58.
 Snelgrove, I. P., 38.
 Snelling, C. M., 19.
 Snepp, H. A., 38.
 Snodgrass, A. C., 42.
 Snodgrass, M. D., 6, 11.
 Snook, J. H., 56.
 Snow, F. C., 44.
 Snow, G. G., 41.
 Snow, O. L., 38.
 Snyder, A. H., 27.
 Snyder, J. L., 87.
 Snyder, W. P., 46.
 Somers, C. L., 39.
 Sommers, S. L., 6.
 Sorrell, E. W., 33.
 Soule, A. M., 8, 19, 20.
 Soulen, P., 22.
 Southall, J. P. C., 9.
 Southwick, L. B., 26.
 Spangler, S. M., 66.
 Sparks, D. A., 19.
 Sparks, E. E., 8, 60.
 Sparks, H. W., 73.
 Spaulding, M. H., 44.
 Speare, A. T., 21.
 Spears, H. D., 30, 31.
 Speidel, J. M., 59.
 Spence, C. E., 58.
 Spence, T. H., 35.
 Spencer, A. P., 18.
 Spencer, J. W., 51.
 Spencer, R. D., 61.
 Spencer, W. S., 62.
 Spinney, L. B., 26.
 Spitzer, G., 25.
 Sponsler, A. L., 27.
 Sponsler, O. L., 45, 46.
 Spooner, C. S., 39, 40.
 Spragg, F. A., 38.
 Sprague, D. B., 73.
 Sprague, R. J., 34, 36.
 Spriggs, W. A., 74.
 Spring, S. N., 16.
 Spurway, C. H., 38.
 Stadtmueller, F. H., 16.
 Stafford, E. W., 58.
 Stahl, H. S., 70.
 Stahl, J. L., 73.
 Stakman, E. C., 39, 40.
 Stanford, J. F., 12, 13.
 Stange, C. H., 26, 27.
 Stanley, C. H., 35.
 Stanley, F. W., 7.
 Stanley, L., 43.
 Stansel, T. B., 53.
 Stanton, E. W., 25, 26.
 Staples, C. H., 33.
 Starcher, G. C., 71.
 Stark, C. R., 41.
 Starring, C., 22.
 Stathers, M., 74.
 Stayner, G. E., 27.
 Stebbins, C. A., 13.
 Steck, C. C., 47.
 Stecker, H. F., 60.
 Stedman, J. M., 7.
 Steeb, C. E., 55.
 Steed, H. N., 52.
 Steele, B. L., 73.
 Steenbock, H., 75, 76.
 Steik, K., 77.
 Steiner, C. D., 56.
 Steinman, D. B., 22.
 Stene, A. E., 62.
 Stenius, J. A., 57.
 Stephens, D. E., 59.
 Stephens, G. W., 34.
 Stephens, J. V., 19.
 Stephens, L., 26.
 Stephens, M., 72.
 Stephens, R. P., 19.
 Stephenson, E. B., 73, 74.
 Stephenson, S. A., 48.
 Stetson, J. M., 69.
 Stevens, A. T., 16.
 Stevens, F. C., 50.
 Stevens, F. L., 52, 53.
 Stevens, Mrs. F. L., 8.
 Stevens, G. E., 38.
 Stevens, H. E., 12, 13.
 Stevens, J. S., 34.
 Stevens, N. E., 28, 29.
 Stevens, O. A., 55.
 Stevens, W. H., 17.
 Stevenson, W. H., 26, 27.
 Stewart, C. A., 22.
 Stewart, E. D., 55.
 Stewart, F., 9.
 Stewart, F. C., 50.
 Stewart, H. C., 67.
 Stewart, H. W., 23.
 Stewart, J. P., 60, 61.
 Stewart, J. S., 19.
 Stewart, J. T., 39, 40.
 Stewart, M. A., 74.
 Stewart, R., 63, 69.
 Stewart, R. L., 49.
 Stickley, M. B., 52.
 Stocker, G. P., 49.
 Stockham, W. L., 55.
 Stocking, W. A., jr., 51, 52.
 Stockly, J. C., 17.
 Stockton, F., 49.
 Stockwell, E. R., 69.
 Stoddard, E. M., 16.
 Stoddard, C. W., 60.
 Stohl, L. N., 68.
 Stokes, M. B., 63.
 Stokes, W. B., 9.
 Stoll, R. C., 30.
 Stoltenberg, F. C., 65.
 Stone, A. L., 75, 76.
 Stone, C. W., 47.
 Stone, G. E., 36, 37.
 Stone, J. F., 55.
 Stone, J. L., 51, 52.
 Stone, W. E., 8, 24.
 Stoneburn, F. H., 16.
 Stoneking, J. B., 49.
 Stoner, M. A., 57.
 Storms, L. B., 29.
 Storrs, L. J., 16.
 Story, G. F. E., 36.
 Stouder, K. W., 28.
 Stout, O. V. P., 7, 46.
 Stover, A. P., 7.
 Stover, M. E., 14.
 Stover, W. G., 57.
 Strahan, C. M., 19.
 Stratton, W. T., 29.
 Straus, I. L., 35.
 Strausbaugh, E. J., 27.
 Straw, O. W., 47.
 Street, J. P., 16.
 Streeter, F. C., 43.
 Strowd, W. H., 53.
 Stryke, A. C., 51.
 Stuart, W. V., 24.
 Stubbs, J. E., 46.
 Stuckey, H. P., 20.
 Stumberg, C. H., 32.
 Sturdevant, L. B., 45, 46.
 Sudro, W. F., 55.
 Sugden, J., 72.
 Suggs, D. C., 20.

- Sullivan, G. L., 44.
 Sulloway, R. W., 47.
 Summers, H. E., 26, 27.
 Summers, J., 34.
 Summers, L. W., 9, 10.
 Summey, G., Jr., 52.
 Surface, F. M., 30, 31.
 Sutherland, G., 27.
 Sutherland, W. A., 49.
 Sutphen, D. D., 48.
 Swanger, J. E., 44.
 Swanson, C. O., 28, 29.
 Swanzy, F. M., 21.
 Swartwout, A. M., 43.
 Sweeney, F. R., 63.
 Sweeney, M. P., 50.
 Sweet, A. T., 43.
 Sweet, E. S., 21.
 Swenk, M. H., 45, 46.
 Swezey, O. H., 21.
 Swift, J. C., 42.
 Swingle, D. B., 44, 45.
 Swingle, L. D., 77.
 Swire, R. P., 31, 33.
 Sykes, G. F., 59.
 Sylvester, D. W., 26.
 Symons, T. B., 35.
 Sypherd, W. O., 17.
 Szymoniak, B., 43.
 Taft, L. R., 37.
 Taft, W. H., 71.
 Taggart, L. M., 26.
 Taggart, W. G., 32.
 Talby, G. W., 51.
 Talby, G. W., Jr., 51, 2.
 Talsne, T., 47.
 Tait, C. E., 7.
 Tallafarro, T. H., 35.
 Tallafarro, W. T. L., 35.
 Tallant, J. G., 47.
 Tallman, W. D., 44.
 Tanner, H. T., 42.
 Tarbox, F. G., Jr., 64.
 Tartar, H. V., 59.
 Tartar, N., 59.
 Tatarian, B., 12.
 Tate, W. A., 11.
 Tatum, C. S., 67.
 Taubenhaus, J. J., 17.
 Tausig, R. J., 13.
 Taylor, A. W., 73.
 Taylor, E., 27.
 Taylor, F. K., 63.
 Taylor, F. W., 47.
 Taylor, G. H., 46.
 Taylor, H. C., 75, 76.
 Taylor, H. L., 50.
 Taylor, J. R., 55.
 Taylor, L. L., 48.
 Taylor, L. M., 14, 15.
 Taylor, O. M., 80.
 Taylor, R. G., 28.
 Taylor, R. M., 38.
 Taylor, S. S., 36.
 Taylor, T. H., 53.
 Taylor, W. J., 44, 45.
 Teele, R. P., 7.
 Teeter, H. W., 51.
 Teetzel, C. T., 68.
 Teller, W., 17.
 Temple, C. E., 22.
 Temple, J. C., 20.
 Templeton, G. S., 67.
 Tener, J. K., 60.
 Ten Eyck, A. M., 28, 29.
 Tennant, H. M., 59.
 Tenney, E. D., 21.
 Terral, W. F., 32.
 Terrell, C. B., 30.
 Terrell, R. C., 30.
 Terrell, W. P., 68.
 Terrill, B. M., 69.
 Terry, J. P., 23, 24.
 Terry, O. P., 24.
 Terry, P. W., 41.
 Terry, W. K., 9.
 Thach, C. C., 9.
 Thackston, J. A., 18.
 Thatcher, G. W., 68.
 Thatcher, R. W., 8, 73.
 Thayer, P., 56.
 Theige, K. J., 22.
 Theophile, E. M., 33.
 Thom, C., 16.
 Thom, C. C., 73.
 Thomas, E. E., 14.
 Thomas, E. K., 62.
 Thomas, G., 68.
 Thomas, L., 55.
 Thomas, M. (Ohio), 56.
 Thomas, M. (Utah), 68.
 Thomas, M. M., 64.
 Thomas, S. F., 65.
 Thomas, W., 61.
 Thomas, W. A., 64.
 Thomas, W. H., 67.
 Thomas, W. R., 15.
 Thompson, A. L., 81.
 Thompson, A. R., 6, 21.
 Thompson, A. R., 26.
 Thompson, B. E., 38.
 Thompson, B. L., 65.
 Thompson, C. A., 47.
 Thompson, Mrs. C. D., 26.
 Thompson, D. O., 25.
 Thompson, E., 52.
 Thompson, E. J., 54, 55.
 Thompson, F., 17.
 Thompson, F. F., 48.
 Thompson, G. A., 34.
 Thompson, G. W., 34.
 Thompson, H. B., 62.
 Thompson, J., 54.
 Thompson, J. B., 6, 20.
 Thompson, J. I., 14.
 Thompson, J. I., Jr., 60.
 Thompson, L., 47.
 Thompson, L. B., 20.
 Thompson, N. L., 29.
 Thompson, O. A., 55.
 Thompson, R., 49.
 Thompson, R. C., 12, 13.
 Thompson, R. E., 32.
 Thompson, F. T., 68.
 Thompson, W. O., 8, 55.
 Thompson, W. R., 51.
 Thornber, J. J., 12.
 Thornburg, M. G., 26.
 Thorne, C. E., 8, 66.
 Thornley, W., 69.
 Thornton, E. W., 53.
 Thornton, J. R., 31.
 Thornton, M. K., Jr., 67.
 Thorpe, J. L., 44.
 Thrash, J. A., 19.
 Thrasher, G. B., 49.
 Throckmorton, R. I., 29.
 Tibert, G. L., 54.
 Tiddball, V. J., 76.
 Tiebout, G. L., 33.
 Tiffany, H. E., 17.
 Tilden, W., 27.
 Tillmar, B. R., 63.
 Tillman, B. W., 6.
 Tillman, J. N., 12.
 Tillman, O. I., 53.
 Timblin, C., 72.
 Tingey, C. S., 63.
 Tinkey, A. K., 28.
 Titlow, C. R., 74.
 Titsworth, A. A., 48.
 Titworth, J., 53.
 Titus, C. M., 14.
 Titus, E. G., 68, 69.
 Tobey, E. R., 34.
 Todd, P., 48.
 Tolstrup, M. R., 66.
 Tomhave, W. H., 39.
 Tompkins, D. A., 52.
 Tompkins, D. G., 26.
 Tonkin, J. C., 47.
 Tooley, F. V., 59.
 Toombs, D., 58.
 Toomer, J. E., 66.
 Tormey, J. L., 75, 76.
 Torrey, J. L., 43.
 Tottingham, W. E., 75, 76.
 Tough, M., 65.
 Tourgee, C. H., 12, 13.
 Towles, E. S., 41.
 Townsend, J. A., 72.
 Tracy, N., 25.
 Trammell, P. W., 18.
 Trask, R. P., 51.
 Treman, C. E., 50.
 Treman, R. H., 50.
 Trescott, K. B., 68.
 Trewin, J. H., 25.
 Trimble, R. E., 15.
 Trimble, W. J., 54.
 Trimmer, F., 47.
 Tripp, W. E., 61.
 Troop, J., 24, 25.
 Trotman, J. F., 75.
 Trout, E. D., 12.
 Trowbridge, E. A., 42, 43.
 Trowbridge, P. F., 42, 43.
 Troy, D. C., 72.
 Troy, H. C., 51.
 True, A. C., 6, 8, 11, 20, 21, 62.

True, G. H., 46.
 Trueman, J. M., 16.
 Trumbull, F., 10.
 Trumbull, R. S., 45, 46.
 Truog, E., 75, 76.
 Truscott, F. W., 74.
 Tubergen, C. B., 60.
 Tuck, C. H., 51.
 Tucker, E. S., 33.
 Tucker, H., 53.
 Tucker, H. M., 53.
 Tucker, H. V., 31.
 Tudor, J. H., 60.
 Tulane, V. H., 10.
 Tull, C. C., 22.
 Tullis, R. L., 32.
 Tulloss, J. O., 27.
 Tune, I. S., 26.
 Tunnell, E. W., 17.
 Tupper, F., jr., 69.
 Turner, A. (Ark.), 12.
 Turner, A. (Wis.), 73.
 Turner, A. A., 11.
 Turner, F. J., 29.
 Turner, H. B., 72.
 Turner, J. B., 30.
 Turner, J. D., 31.
 Turner, J. W., 30.
 Turner, L. G., 66.
 Turner, M. M., 36.
 Turner, W. A., 36.
 Turner, W. F. (Ala.), 9, 10.
 Turner, W. F. (N. C.), 63.
 Turpeau, L. A., 36.
 Turpin, O. M., 66, 69.
 Turrell, C. A., 12.
 Tuthill, J. E., 20.
 Tuttle, E. M., 51.
 Tuttle, F. E., 30.
 Twiss, W. B., 48.
 Tyler, M. H., 62.
 Tylor, A. R., 14.
 Ullsperger, H. W., 75, 76.
 Urey, C., 34.
 Umberger, H. J. C., 29.
 Underwood, E. E., 31.
 Underwood, W., 40.
 Upham, J. S., 35.
 Upson, Mrs. A., 15.
 Upson, I. S., 48, 49.
 Urquhart, J., 72.
 Usher, S., 23.
 Utt, C. A. A., 23.
 Vall, C. E., 15.
 Valdivieso, A. P., 69.
 Valentine, J. A., 75, 76.
 Valley, O., 28.
 Van Alstine, E., 23.
 Vanatta, E. E., 43.
 Vanatta, P. O., 19.
 Van Auken, C. H., 51.
 Van Cleef, M., 50.
 Vanderpoel, S. O., 48.
 Van de Veer, C. W., 22.
 Van Dine, D. L., 62.

Vandiver, M., 35.
 Van Dyck, F. C., 48.
 Van Es, L., 54, 55.
 Van Hise, C. R., 75.
 Van Horn, H. F., 72.
 Vann, T. E., 52.
 Van Norman, H. E., 60, 61.
 Van Rensselaer, M., 51.
 Van Slyke, L. L., 50.
 Van Smith, S., 15.
 Van Steenbergh, W. H., 48.
 Van Storm, A., 26.
 Vanstory, C. M., 53.
 Van Suchtelen, F. H., 38.
 Van Zile, Mrs. M. P., 28.
 Vaplon, W. E., 15.
 Varnum, C. A., 34.
 Varrelman, F. A., 61.
 Vaughan, H. W., 56.
 Vaughan, J. H., 49.
 Vaughan, L. L., 53.
 Vaughn, E. C., 30, 31.
 Vaulx, J. R., 26.
 Vawter, C. E., 70.
 Vedder, H. K., 77.
 Ventresco, F. P., 73.
 Vernon, J. J., 18.
 Verrill, A., 34.
 Viall, G. M., 26.
 Vincent, C. C., 63.
 Vincent, G. E., 39.
 Vinson, A. E., 12.
 Vivian, A., 55.
 Vivian, C. A., 11.
 Volck, W. H., 14.
 von Ende, C. L., 22.
 Voorhees, F. M., 48.
 Voorhees, J. F., 66.
 Voorhees, W., 18.
 Voorhees, W. P., 48.
 Voorhorst, R. G., 48.
 Vredenburg, W. H., 48.
 Vroom, G. D. W., 48.
 Wachter, H. M., 57.
 Wade, C. I., 70, 71.
 Wade, N. B., 7.
 Wadsworth, H. A., 22.
 Waggoner, E. W., 74.
 Waid, E. D., 36.
 Walnwright, T. L., 41, 42.
 Wait, C. E., 66.
 Waite, R. H., 35.
 Walcott, W. H., 11.
 Walden, B. H., 16.
 Waldo, Mrs. C. H., 58.
 Waldron, C. B., 54, 55.
 Waldron, J. W., 21.
 Waldron, L. R., 55.
 Waldron, R. A., 61.
 Walker, A. T., 44.
 Walker, E., 12, 13.
 Walker, E. S., 18.
 Walker, G. B., 42.
 Walker, G. W., 40.
 Walker, H. B., 29.
 Walker, I., 15.

Walker, J., 12.
 Walker, L. L., 30.
 Walker, L. S., 37.
 Walker, M. A., 10.
 Walker, W. H., 60.
 Walker, W. L., 69.
 Wallace, A. J., 13.
 Wallace, A. R., 33.
 Wallace, C., 26.
 Wallace, J. S., 41.
 Wallace, R. C. E., 57.
 Wallace, W. H., 37.
 Waller, C. H., 68.
 Walker, O. L., 72, 73.
 Wallin, F. A., 44.
 Walls, E. P., 59.
 Walsh, H., 35.
 Walster, H. L., 75, 76.
 Walters, E. H., 69.
 Walters, G. D., 15.
 Walters, J. D., 28.
 Wannamaker, J. E., 63.
 Ward, C. E., 36.
 Ward, E. A., 58.
 Ward, H. B., 23.
 Ward, W. F., 10.
 Wardall, R. A., 55.
 Ware, J. F., 70.
 Waring, B. E., 73.
 Warne, N., 48.
 Warner, F., 28.
 Warren, G. F., 61, 62.
 Warren, G. M., 7.
 Warren, J. W., 20.
 Warren, L. J., 21.
 Warren, W. E., 72.
 Wartmann, E. L., 18.
 Wascher, F. W., 23.
 Washburn, F. L., 39, 40.
 Washburn, R. M., 39, 40.
 Washington, A. E., 72.
 Washington, B. T., 10, 11.
 Washington, Mrs. B. T., 11.
 Washington, G. S., 33.
 Wason, E. H., 47.
 Waterbury, I. R., 37.
 Waterbury, L. A., 12.
 Watermann, C. E., 64.
 Waters, E. F., 75.
 Waters, H. J., 8, 27, 28, 29.
 Wathen, R. N., 30.
 Watkins, Mrs. A., 10.
 Watkins, L. J., 11.
 Watkins, O. S., 24.
 Watson, E. J., 33.
 Watson, J., 57.
 Watson, J. P., 27.
 Watson, J. R., 18.
 Watson, J. V., 62.
 Watson, L. O., 64.
 Watson, P. P., 64.
 Watt, A., 38.
 Wattles, W. A., 36.
 Watts, C. F., 57.
 Watts, R. L., 60, 61.
 Watts, R. J., 36.
 Waugh, F. A., 36, 37.

Wayman, J., 11.
 Waymouth, T. J., 62.
 Weakley, C. E., jr., 74.
 Weatherford, J. K., 53.
 Weaver, B. A., 41, 42.
 Weaver, F. P., 61.
 Weaver, L. A., 43.
 Weaver, T. J., 33.
 Webb, J. C., 10.
 Webb, J. H., 18.
 Webb, R. D., 9.
 Webb, W. S. (Ky.), 30.
 Webb, W. S. (Vt.), 69.
 Webber, H. J., 8, 51, 52.
 Weber, H. A., 55.
 Webster, E. H., 28, 29.
 Webster, R. L., 27.
 Webster, S. H., 62.
 Webster, W. A., 72.
 Weddell, F. J., 41.
 Weeks, A. D., 54.
 Weeks, E., 28.
 Weeks, W. S., 74.
 Wegner, E. E., 73.
 Weir, W. W., (U. S. D. A.), 7.
 Weir, W. W. (Wia.), 75.
 Welch, C. H., 39.
 Welch, J. F., 32.
 Welch, J. S., 22.
 Weller, A. S., 33.
 Wellington, C., 36.
 Wellington, J. W., 25.
 Wellington, R., 60.
 Wells, A. A., 27.
 Wells, B. J., 63.
 Wells, R. W., 35.
 Welton, F. A., 56.
 Wendt, W. B., 37.
 Weniger, W., 59.
 Wentling, J. P., 39, 40.
 Wentworth, E. N., 26.
 Werby, A. B., 61.
 Wergeland, A. M., 77.
 Werthmueller, F. R., 21.
 West, C., 56.
 West, F. L., 68, 69.
 West, O., 58.
 West, R. M., 39, 40.
 Westbrook, E. J., 57.
 Westgate, V. V., 45, 46.
 Westinghouse, H. H., 50.
 Weston, C. P., 34.
 Whedon, G. D., 61.
 Wheeler, B. I., 13.
 Wheeler, C. A., 16.
 Wheeler, C. S., 13.
 Wheeler, F. B., 53.
 Wheeler, G. C., 29.
 Wheeler, H. C., 23.
 Wheeler, H. J., 8, 62, 63.
 Wheeler, R. H., 51.
 Wheeler, W., 36.
 Wheeler, W. F., 50.
 Wheeler, X., 65.
 Whelan, J. B., 28.
 Whetzel, H. H., 51, 52.
 Whipple, L. F., 63.

Whipple, O. B., 44, 45.
 Whitechurch, J. E., 23.
 Whitcomb, E. S., 77.
 White, A. D., 50.
 White, A. E., 28.
 White, B., 72.
 White, C. H., 36.
 White, D. S., 55.
 White, E. (Me.), 34.
 White, E. (Okla.), 57.
 White, E. A., 36.
 White, E. N., 56.
 White, F. M., 75, 76.
 White, F. W., 39, 40.
 White, G. B., 64.
 White, G. C., 43.
 White, H. B., 39, 40.
 White, H. C., 8, 19, 20.
 White, H. L., 54, 55.
 White, H. V., 60.
 White, J. G. (Ky.), 30.
 White, J. G. (Pa.), 60.
 White, J. L., 72.
 White, O. K., 38.
 White, P. J., 73.
 White, S., 72.
 White, T. H., 35.
 White, W., 65.
 White, W. J., 74.
 White, W. R., 61.
 Whitecotton, J. W. N., 68.
 Whitehill, A. R., 74.
 Whiteman, J. H., 17.
 Whitesell, R. B., 9.
 Whiting, R. A., 25.
 Whitman, C. H., 48.
 Whitman, F. W., 47.
 Whitmarsh, R. D., 56.
 Whitmore, W. G., 45.
 Whitney, E. M., 16.
 Whitsett, A. T., 53.
 Whitson, A. R., 75, 76.
 Whitson, L. R., 39, 40.
 Whittemore, C. F., 47.
 Whittemore, G. A., 60.
 Whitten, J. C., 42, 43.
 Whittier, A. C., 17.
 Whittier, E. O., 34.
 Whittlesey, E. B., 16.
 Whoriskey, R., jr., 47.
 Wiancko, A. T., 24, 25.
 Wiatt, J. E., 9.
 Wicks, W. H., 22.
 Wickson, E. J., 13, 14.
 Widger, H. De F., 36.
 Widtsoe, J. A., 68.
 Wignall, C. L., 67.
 Wilborn, A. J., 10.
 Wilcox, E. M., 45, 46.
 Wilcox, E. V., 6, 21.
 Wilcox, R. M., 49.
 Wilde, A. H., 12.
 Wiley, R. C., 28, 29.
 Wiley, W. R., 42.
 Wilken, F. A., 38.
 Wilkinson, J. W., 57.
 Wilkinson, R. S., 64.

Wilkus, A. J., 6, 11.
 Willard, H. R., 34.
 Willard, J. M., 60.
 Willard, J. T., 28, 29.
 Willard, R. E., 49.
 Wilcox, W. G., 10.
 Williams, C. B., 53.
 Williams, C. G., 56.
 Williams, C. H., 72.
 Williams, E. L., 50.
 Williams, F., 46.
 Williams, J. E., 70.
 Williams, J. M., 64.
 Williams, J. O., 15.
 Williams, L. F., 52.
 Williams, M. B., 7.
 Williams, M. M., 39.
 Williams, P. E., 9, 10.
 Williams, R. B., 50.
 Williams, R. H., 39, 40.
 Williams, W. G., 32.
 Williams, W. M., 59.
 Williamson, Mrs. C. M., 53.
 Williamson, C. S., 9.
 Williamson, H. H., 67.
 Williamson, J. T., 10.
 Williamson, L. H., 49.
 Williamson W., 40.
 Willingham, H. J., 9, 10.
 Willis, L. G., 61.
 Willis, R. L., 49.
 Wilson, A. E., 30.
 Wilson, C. A., 66.
 Wilmore, J. J., 9.
 Wilson, A. D., 39, 40.
 Wilson, B. D., 30, 31.
 Wilson, B. S., 29.
 Wilson, C. E., 43.
 Wilson, C. S., 51, 52.
 Wilson, E., 47.
 Wilson, E. E., 58.
 Wilson, E. M., 20.
 Wilson, F. D., 70.
 Wilson, F. W., 12.
 Wilson, G. W., 53.
 Wilson, H. F., 59.
 Wilson, H. S., 35.
 Wilson, J., 26, 35.
 Wilson, J. A., 53.
 Wilson, J. K., 50.
 Wilson, J. M., 12.
 Wilson, J. W., 65.
 Wilson, L. B., 35.
 Wilson, M. L., 45.
 Wilson, R. F., 57.
 Wilson, R. H., 53.
 Wilson, T. B., 50.
 Wilson, V. T., 37.
 Wilson, W., 47, 48.
 Wilson, W. M., 51.
 Wilson, Mrs. W. W., 31.
 Windrow, R. J., 67.
 Wing, H. H., 51, 52.
 Wing, L. W., 51, 52.
 Wingard, E. R., 34.
 Wingert, H. S., 56.
 Winn, C. E., 49.

- Winingham, M. F., 49.
 Winsor, L. M., 60.
 Winston, J. R., 61.
 Winter, O. B., 60.
 Winters, R. Y., 51.
 Wish, O. R., 34.
 Withers, W. A., 52, 53.
 Withycombe, J., 58, 59.
 Withycombe, R., 59.
 Wobus, W. W., 43.
 Wold, J. B., 22.
 Wolf, F. A., 10.
 Wolfe, R. P., 72.
 Wolff, W. H., 47.
 Woll, F. W., 75, 76.
 Wood, C. W., 11.
 Wood, E. P., 53.
 Woodard, C. S., 44.
 Woodard, R. L., 53.
 Woodbury, C. G., 24, 25.
 Woode, Mrs. J. E. D., 42.
 Woodfin, O. L., 10.
 Woodford, S. L., 50.
 Woodman, A. M., 29.
 Woodman, J., 37.
 Woodman, L. E., 34.
 Woodruff, W. B., 68.
 Woods, A. F., 39, 40.
 Woods, C. D., 8, 34.
 Woods, D. F., 32.
 Woods, M., 11.
 Woods, W. W., 67.
 Woodward, E. G., 43.
 Woodward, S. M., 7.
 Woodward, W., 43.
 Woodworth, C. M., 65.
 Woodworth, C. W., 13, 14.
 Woofter, T. J., 19.
 Wootton, L. L., 13.
 Work, P., 51, 52.
 Wornall, T. J., 42.
 Worrell, M. E., 11.
 Worsham, E. L., 19, 20.
 Worsham, W. A., jr., 19.
 Worst, J. H., 54, 55.
 Worthen, E. L., 53.
 Wray, J. D., 11.
 Wright, A. H., 58.
 Wright, A. L., 61.
 Wright, A. T., 68.
 Wright, C. S., 51.
 Wright, J. C., 19.
 Wright, J. H., 55.
 Wright, L. L., 37.
 Wright, R. G., 48.
 Wright, R. R., 20.
 Wright, S., 41.
 Wright, S. J., 17.
 Wright, T. R. H., 28, 29.
 Wright, W. H., 75, 76.
 Wright, W. J., 61.
 Wright, W. R., 25.
 Wright, W. T., 67.
 Wurster, P., 23.
 Yarnell, D. L., 7.
 Yates, H. E., 45.
 Yates, R. E. L., 52.
 Yeater, C. E., 42.
 Yeaw, F. L., 36.
 Yoder, M. M., 21.
 Yoder, W. A., 54, 55.
 Yohe, H. S., 7.
 Yonge, P. K., 18.
 York, I. S., 67.
 Yorke, P. C., 13.
 Yothers, M. A., 73.
 Young, C. H., 66.
 Young, G. S., 65.
 Young, Mrs. H. B., 51.
 Young, H. D., 14.
 Young, J. G., 31.
 Young, J. M., 21.
 Young, N. B., 19.
 Youngblood, B., 67.
 Youngblood, S. R., 58.
 Youngburg, G. E., 65.
 Yowell, J., 12, 13.
 Zeigler, P. T., 58.
 Zeiniger, D., 28.
 Zambrod, A. C., 30.
 Zerban, F., 62.
 Zieffle, A., 55.
 Zimmer, M. V., 45.
 Zook, G. F., 61.
 Zundel, G. L., 69.
 Zwich, G. L., 42.

U. S. DEPARTMENT OF AGRICULTURE.

OFFICE OF EXPERIMENT STATIONS—BULLETIN 248.

A. C. TRUE, Director.

EVAPORATION FROM IRRIGATED SOILS.

BY

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[Bull. 248]

(2)

LETTER OF TRANSMITTAL

U. S. DEPARTMENT OF AGRICULTURE,
OFFICE OF EXPERIMENT STATIONS,
Washington, D. C., July 25, 1911.

SIR: I have the honor to transmit herewith a report on Evaporation from Irrigated Soils, prepared by Samuel Fortier, chief of irrigation investigations, and S. H. Beckett, scientific assistant, of this office. This report embodies the results of experiments carried on from 1908 to 1910, inclusive, at seven places in the arid region, to determine the amount of water lost by evaporation from irrigated soils treated in different ways. From 1903 to 1905, inclusive, experiments were conducted in California by the office of irrigation investigations to ascertain the amount of water lost by evaporation from irrigated soils. The results of these experiments were published in Bulletin 177 of this office. The experiments described in the present report were carried on for the purpose of checking the former results, of demonstrating the evaporation losses in colder and more elevated regions, and of broadening the scope of the investigations.

The time seems near when the reclamation of additional areas will depend chiefly upon the storage of flood waters, the pumping from underground supplies, and the utilization of waters now lost by evaporation, percolation, and seepage, or wasted in irrigation. This report should be of value not only to irrigators, but to the cultivators of the vast areas on which dry-farming methods must be practiced.

The office desires to thank the experiment stations of California, Montana, North Dakota, Idaho, New Mexico, Nevada, and Washington for their cooperation and assistance in conducting the experiments.

It is recommended that the report be published as a bulletin of this office.

Respectfully,

A. C. TRUE,
Director.

HON. JAS. WILSON,
Secretary of Agriculture.

[Bull. 248]

(3)

CONTENTS.

	Page.
Introduction.....	7
Equipment.....	8
Plan of experiments.....	9
Effects of soil mulches of different depths.....	11
Results at Davis, Cal.....	11
Results at Reno, Nev.....	15
Results at Agricultural College, N. Mex.....	17
Results at Bozeman, Mont.....	20
Results at Wenatchee, Wash.....	24
Summary of results.....	26
Conclusions.....	29
Effects of cultivation to different depths.....	30
Results at Sunnyside, Wash.....	31
Results at Davis, Cal.....	33
Results at Reno, Nev.....	37
Results at Caldwell, Idaho.....	39
Results at Agricultural College, N. Mex.....	42
Results at Bozeman, Mont.....	44
Results at Williston, N. Dak.....	46
Summary and conclusions.....	48
Effects of shallow and deep furrow irrigation.....	51
Results at Davis, Cal.....	52
Results at Williston, N. Dak.....	55
Results at Reno, Nev.....	57
Results at Bozeman (Mont.), Agricultural College (N. Mex.), and Sunnyside (Wash).....	59
Summary of results at Reno, Nev., and Davis, Cal.....	60
Experiments of 1910.....	62
Results at Davis.....	62
Summary of results at all stations.....	67
Effect of temperature and wind velocity.....	69
General conclusions.....	74

ILLUSTRATIONS.

PLATES.

	Page.
PLATE I. Fig. 1.—Experiment tract, Reno, Nev. Fig. 2.—Experiment tract, Agricultural College, N. Mex.....	16
II. Fig. 1.—Experiment tract, Wenatchee, Wash. Fig. 2.—Experiment tract, Caldwell, Idaho.....	24

TEXT FIGURES.

Fig. 1. Design of tanks used in the experiments.....	9
2. Losses with mulches of different depths, Davis, Cal.,.....	13
3. Losses with mulches of different depths, Davis, Cal.....	15
4. Losses with mulches of different depths, Reno, Nev.....	17
5. Losses with mulches of different depths, Agricultural College, N. Mex.....	20
6. Losses with mulches of different depths, Bozeman, Mont.....	23
7. Losses with mulches of different depths, Wenatchee, Wash.....	26
8. Average losses at five stations, with mulches of different depths.....	27
9. Losses from cultivated and uncultivated tanks of soil, Sunnyside, Wash.....	33
10. Losses from cultivated and uncultivated tanks of soil, Davis, Cal.....	36
11. Losses from cultivated and uncultivated tanks of soil, Reno, Nev.....	39
12. Losses from cultivated and uncultivated tanks of soil, Caldwell, Idaho.....	41
13. Losses from cultivated and uncultivated tanks of soil, Agricultural College, N. Mex.....	43
14. Losses from cultivated and uncultivated tanks of soil, Bozeman, Mont.....	45
15. Losses from cultivated and uncultivated tanks of soil, Williston, N. Dak.....	48
16. Average losses at six stations from cultivated and uncultivated tanks of soil.....	49
17. Losses from flooded and furrowed tanks of soil, Davis, Cal.....	54
18. Losses from flooded and furrowed tanks of soil at Williston, N. Dak.....	56
19. Losses from flooded and furrowed tanks of soil at Reno, Nev.....	59
20. Average losses from flooded and furrowed tanks at Davis, Cal. and Reno, Nev.....	61
21. Losses from tanks cultivated to different depths at Davis, Cal.....	66
22. Average weekly evaporation from water surface at seven stations.....	68
23. Mean temperature, average wind velocity, and evaporation from water surface at Davis, Cal.....	68
24. Mean hourly temperature, wind velocity, and evaporation from water surface, Davis, Cal.....	70
25. Evaporimeter.....	71
26. Evaporimeter record.....	73
27. Temperature of air, soil, and water, Davis, Cal.....	74

EVAPORATION FROM IRRIGATED SOILS.

INTRODUCTION.

With the approaching depletion of the water supply of the arid West, the question of unnecessary losses and wasteful use of water is rapidly rising into prominence. As development progresses, more people seek homes in towns and cities, and for such, water for domestic purposes becomes a necessity. There is at the same time an increasing use for manufacturing and mechanical purposes. The use of water for irrigation, however, creates the greatest of all demands upon the sources of supply. The necessity, therefore, of conserving water once in the soil through irrigation or rainfall, bears a vital relation to the general subject of conservation.

During the past 20 years, considerable data have been collected showing the extent of evaporation from water surfaces; yet this is a loss which human foresight and energy can not prevent. Considerable effort and attention, too, have been given the subject of seepage losses in canals, a type of waste which is entirely preventable. Important as this subject is to the individuals or groups directly affected thereby, these losses are minimized when considered from the point of view of the total water supply, for, ordinarily, seepage from one canal finds its way into another or back into the stream to be picked up again and utilized in other ways.

Water, if lost through evaporation from the soil, however, is permanently lost; yet this is a loss which is in a large measure under the control of human agencies. Thus irrigators who use wasteful quantities of water upon their fields and neglect cultivation simply because they are in position through court decrees or otherwise to do so, are measurably depleting the sources of supply. The purpose of this bulletin is not only to show the extent of evaporation losses from irrigated soils but the advantages to the individual of deep and thorough cultivation as a means of preventing wasteful use.

The relative importance of the inquiry is further shown by a comparison of areas. Throughout the arid region, and more particularly in the Rocky Mountain States, the area covered by water is quite small in comparison with the land area or even with the irrigated area. In the total area of Montana, for example, only 1 acre out of every 190 acres is covered with water and the ratio between the extent of water surface and of irrigated land is as 1 to 3.4.

In determining the extent and rate of evaporation from irrigated soils, this office has followed the plan adopted by hydraulic engineers in making similar determinations from water surfaces. By placing a known quantity of soil in a specially designed vessel, it is comparatively easy to determine the amount of water evaporated from its surface in a given time. Investigations of this kind were carried on in California during 1903 to 1905 and the results summarized in Bulletin 177 of this office. In planning similar work for 1908 and subsequent years, it was deemed advisable to broaden the scope of the investigation by carrying on the same kind of experiments in several Western States during the same season of the year. The records of this office giving the extent of evaporation from water surfaces show a wide difference in the results obtained in different localities of the same State. As an illustration, the annual evaporation at Berkeley, Cal., in 1905 was 41.6 inches, while at Tulare, Cal., it was 62.9 inches. It was thought that like differences might exist in the evaporation from irrigated soils.

The advantages derived from carrying on the same kind of experiments in States widely separated and varying greatly in altitude, temperature, soil, and climatic conditions are obvious. On the other hand, the work is rendered much more difficult to carry out in every essential detail. In dealing with so many agents working under different conditions, it is not easy to secure data that are both complete and comparable. In what follows there are omissions due to agents failing to secure the data. These omissions detract to some extent from the value of the bulletin.

In furtherance of the proposed work, cooperation was sought and obtained from a number of directors of western experiment stations who agreed to conduct the experiments as planned. Under this arrangement the necessary equipment was installed in the spring of 1908 at the experiment farm of the University of California located at Davis, at the experiment station of New Mexico located at Agricultural College, the experiment station at Bozeman, Mont., the experiment station at Reno, Nev., and in a private orchard near Wenatchee, Wash., as well as at the Sunnyside substation of the same State. The spring following, experiments were also started at the substation of the North Dakota Experiment Station at Williston, N. Dak., and at the Caldwell substation of the Idaho Experiment Station near Caldwell.

EQUIPMENT.

The equipment at each station consisted of eight galvanized-iron water-jacketed tanks. The inside tanks of each pair except those at the New Mexico station were $23\frac{1}{2}$ inches in diameter, and the outer tanks 27 inches, thus allowing a free space of $1\frac{1}{2}$ inches on all

sides between the tanks. Both inner and outer tanks were 47 inches deep and of the general form shown in figure 1.¹

Two lugs were fastened on the inner tank so that an iron bail could be fastened in them and the tank raised and lowered by means of a differential pulley suspended from a derrick. Weighings were made either by means of platform scales or scales suspended from the differential pulley.

As auxiliary apparatus, each station was furnished with a thermometer shelter, maximum and minimum recording thermometers, soil and water thermometers, wet and dry bulb thermometers for determining humidities and vapor pressures, an anemometer, a rain gauge, and an evaporation tank with a hook gauge for measuring evaporation in inches. An attempt was made to secure as nearly as possible complete records of temperatures, wind velocities, rainfall, and the evaporation from a free water surface during the time of each experiment.

PLAN OF EXPERIMENTS.

In considering what experiments should be undertaken, the chief object kept in view was to secure results that would show the rate and extent of evaporation from irrigated soils. By making use of a sufficient number of tanks, it was found possible to show also the effect on evaporation of several cultural and irrigation methods of handling soil and applying water. Records were likewise collected for purposes of comparison, showing the extent and rate of evaporation from a free water surface. The cultural methods included the maintenance of dry soil mulches of different depths and shallow and deep cultivation. The irrigation methods included shallow and deep furrow irrigation and irrigation followed by cultivation.

In deciding upon the manner of conducting the experiments, the field rather than the laboratory was chosen. In working with small units in a laboratory the determinations can be more accurately made

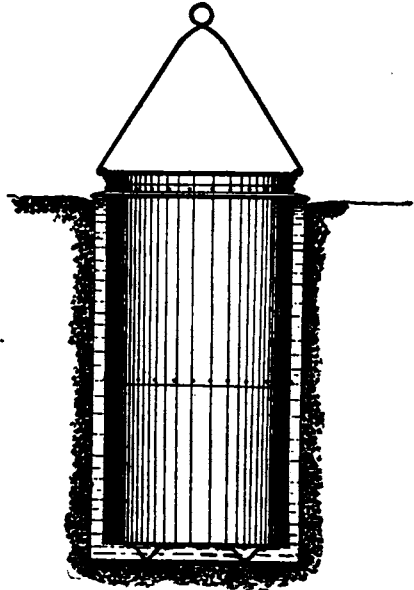


FIG. 1.—Design of tanks used in the experiments.

¹ The New Mexico tanks differed only in that the inner tanks were 27 inches in diameter and the outer ones 32 inches. In preparing the tables, etc., in this bulletin the losses from these larger tanks have been reduced to proportional losses from the smaller tanks.

than with large units in a field. It is, however, impossible to maintain conditions in the laboratory as they exist in the open, subject as they are in the latter case to continuous and endless variations. The sunshine and fog, heat and wind, which act on the soil of a field, can not be made to act in anything like the same way on a sample of soil in a close room.

The plan followed was to remove from a field about a half ton of soil, place it in a vessel as nearly as practicable in its natural position, and by periodical weighings ascertain the amount of moisture evaporated. Free exposure to sunshine, wind, and rain was easy to secure, but the placing of the soil in the vessel in the natural way and keeping its temperature equal to that of the adjacent soil was a harder task. Tests showed, however, that the temperature of the water in the annular space between the outer and inner tanks was about equal to the average temperature in the same depth of soil. Excavations were made for the tanks so that their tops were but slightly above the ground surface. As the soil was excavated to fill the tanks each vertical foot was kept separate and returned to the inner tank in 2-inch layers and tamped so that it duplicated as nearly as possible natural field conditions. Irrigation and cultivation were then practiced as the different experiments required and weighings were made of the inner tanks at least twice a week. The losses due to evaporation were first obtained in pounds and later reduced to their equivalent in inches in depth over the surface.

The summarized results of the data collected during the years 1908, 1909, and 1910 are grouped first in regard to the different experiments undertaken and second in regard to the localities where the experiments were performed. The more important results are shown in tables and diagrams, in both of which the evaporation from an irrigated soil undisturbed after the application of water is given and a comparison made between this loss and that from like irrigated soils upon which mulches were placed or which were subjected to cultural treatment.

There are three general types of experimentation carried on:

(1) Where an artificial mulch of varying depths composed of soil similar to that in the tanks was applied on top of the irrigated soil.

(2) Where the tanks of soil are given, as nearly as possible, a natural cultivation approximating that of actual field conditions; careful note being here taken of the amount of moisture lost in the period between irrigation and cultivation, the length of this period being varied in the different tests.

(3) A comparison of evaporation losses when water is applied in furrows of different depths and by the flooding process.

It will be observed that the methods followed do not accurately represent in every case either irrigation or cultural practice. At the

same time every reasonable effort was made to make the experiments correspond to such practice as is followed by the most experienced orchardists in the West. In the opinion of the authors, the results of the data obtained do not differ in any essential degree from those that actually occur on an irrigated orchard or other cultivated and irrigated field.

EFFECT OF SOIL MULCHES OF DIFFERENT DEPTHS.

To determine the effect of soil mulches of different depths upon the evaporation from the soils, the following experiment was carried on at five of the stations during the year 1908. Tanks 1 and 2 were filled with soil to within 1 inch of the top; tanks 3 and 4 to within 4 inches of the top; tanks 5 and 6 to within 7 inches of the top; and tanks 7 and 8 to within 10 inches of the top. The tanks were then weighed and a sufficient amount of water to approximate a 6-inch irrigation was applied to each by the flooding method. The water was added from 5 to 10 gallon tanks and the flow so regulated that the entire surface of each tank was kept covered during the period of irrigation. After the water had entirely disappeared from the soil surface, fine, dry, granular soil mulches were added, as follows. Tanks 1 and 2, no mulch; tanks 3 and 4, a 3-inch layer; tanks 5 and 6, a 6-inch layer; tanks 7 and 8, a 9-inch layer. Weighings were started immediately and continued semiweekly for a period of four weeks. The losses for each period were recorded and as nearly as possible a complete weather record was kept.

RESULTS AT DAVIS, CAL.

The site selected for the experiments was part of an open field on the university farm at Davis, located in the Sacramento Valley, 76 miles north of San Francisco and 13 miles west of Sacramento. The soil, which is typical of almost all the entire surrounding country, is a rich brown loam, which at a depth of 2½ or 3 feet gradually merges into a lighter, sandy subsoil. There are no intervening impervious strata between this subsoil and the water level. The experiment extended over two periods.

The first run was started June 10 and ended July 1. The tanks after being carefully filled were each given a 6-inch irrigation, and as soon as the water had disappeared from the surface of the soil the granular soil mulches were applied. During the experiment the maximum and minimum daily temperatures, the temperature of the water in an open tank, and the evaporation losses from a free-water surface were recorded. The maximum atmospheric temperatures ranged from 76° to 103° F., and the minimum temperatures from 39° to 59°, the greatest daily range being 45°. The daily maximum temperatures for the period averaged 88° and the daily minimum

temperatures 49.7°. The temperature of the water at the surface varied with the atmospheric temperatures and ranged from 60° to 88°, the average for the period being 76°.¹ These records have been brought together in the following tables:

Mean maximum and minimum temperatures and the temperature of water in an open tank at Davis, Cal., June 10 to July 1, 1908.

Periods.	Mean maximum temperature.	Mean minimum temperature.	Mean maximum temperature of water.¹
	° F.	° F.	° F.
June 10-13.....	90.3	48.3	84
June 13-17.....	83.0	49.7	82
June 17-20.....	83.3	47.3	81
June 20-24.....	83.0	45.7	77
June 24-27.....	91.3	48.0	85
June 27-July 1.....	97.2	58.2	83
Average, 21 days.....	88.0	49.7	81.8

¹ Taken at the surface at 2 p. m.

Evaporation from free-water surface and from tanks with different depth mulches at Davis, Cal., June 10 to July 1, 1908 (6 inches of irrigation water applied).

Periods.	Loss from water surface.	Loss from soil.							
		No mulch, tanks 1 and 2.		3-inch mulch, tanks 3 and 4.		6-inch mulch, tanks 5 and 6.		9-inch mulch, tanks 7 and 8.	
Average weight of tanks June 10, pounds.....		1,206		1,180.7		1,118.7		1,091.5	
Average loss:	Inches.	Lbs.	P. ct.	Lbs.	P. ct.	Lbs.	P. ct.	Lbs.	P. ct.
June 10-13.....	1.07	10.75	11.4	0.50	0.5	0.0	0.0	0.00	0.00
June 13-17.....	1.44	3.50	3.7	.50	.5	.5	.5	.00	.00
June 17-20.....	1.19	1.60	1.6	.50	.5	.5	.5	.00	.00
June 20-24.....	1.35	1.60	1.6	.75	.8	1.5	1.5	.00	.00
June 24-27.....	1.66	2.25	2.4	2.00	2.1	1.0	1.1	.25	.27
June 27-July 1.....	1.50	1.75	1.9	.75	.8	.5	.5	.25	.27
Total loss, 21 days.....	8.27	21.25	22.6	5.00	5.2	2.0	2.1	.50	.54
Equivalent loss in inches.....		1.35		.32		.13		.08	

¹ Due to slight inaccuracies in weighing.

The total losses in inches and the percentage of loss by three and four day periods for the different sets of tanks are also shown graphically in figure 2.

The following facts are derived from the foregoing tables:

(1) The loss of water from the unmulched surfaces was only 1.35 inches as compared with 8.27 inches from the free-water surface.

(2) The loss from the unmulched surfaces was equivalent to 22.6 per cent of the total amount of water used in irrigation.

(3) The losses when 3, 6, and 9 inch mulches were used were only 5.2, 2.1, and 0.54 per cent, respectively, of the total amount of water used.

¹ Readings were made at 8 a. m., 2 p. m., and 5 p. m. This average is an average of the three readings.
[Bull. 248]

The increased evaporation loss from the free-water surface for the three days, June 24–27, is accompanied by a corresponding increase in the evaporation from the soil. Both increases were due to dry north winds during those three days. The losses for the rest of the period are quite uniform, decreasing in the case of the unmulched soil and increasing in the case of the mulched soil toward the end of the experiment as the moisture gradually worked its way upward through the mulches.

A second trial was made at the same place and in the same manner and with the same equipment, beginning September 1 and extending over a period of 32 days. Semiweekly weighings were made from

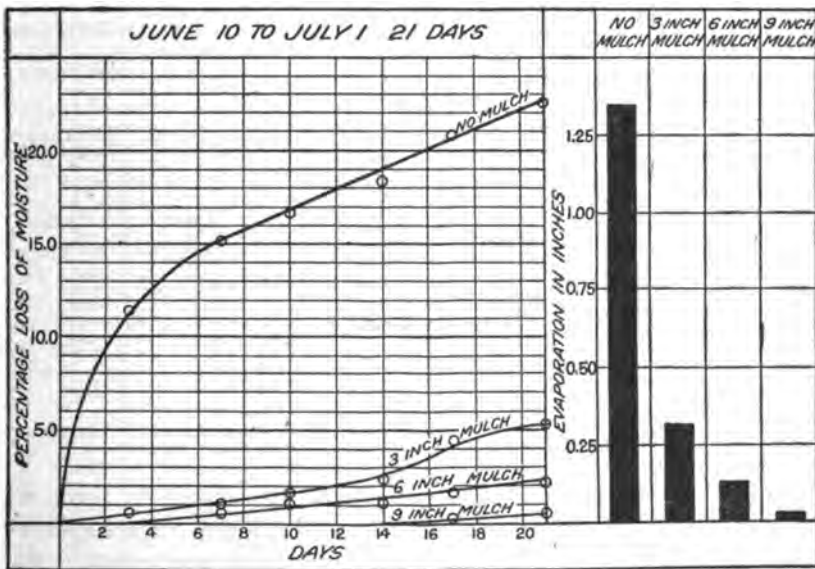


FIG. 2.—Evaporation losses from tanks with soil protected with mulches of different depths at Davis, Cal., June 10 to July 1, 1908.

September 1 to 15, then, owing to the differential pulley being out of order, no weighing was made until the morning of the thirty-third day.

The temperatures did not differ materially from those of the June experiment, the absolute maximum being 103° F. and the absolute minimum 42°, with the greatest daily range 55°. The maximum temperature averaged 88.4° and the minimum 50.7° for the period. An anemometer and soil thermometer had been added to the apparatus, and the maximum soil temperatures, taken at a depth of 6 inches, and mean wind velocities are included in the following tables, together with the atmospheric and water temperatures and the evaporation losses from free-water surface and unmulched and mulched soil surfaces.

[Bull. 248]

Mean maximum and minimum temperatures, mean maximum soil and water temperature, and mean wind velocity at Davis, Cal., Sept. 1 to Oct. 3, 1908.

Periods.	Mean maximum temperature.	Mean minimum temperature.	Mean maximum soil temperature. ¹	Mean maximum water temperature.	Mean wind velocity per hour.
	° F.	° F.	° F.	° F.	Miles.
Sept. 1-4.....	90.7	53.0	79.5	83.3	7.0
Sept. 4-8.....	93.5	53.0	79.5	80.5	8.5
Sept. 8-11.....	91.0	50.0	77.6	78.0	9.1
Sept. 11-15.....	92.7	53.0	79.0	81.7	7.3
Sept. 15-Oct. 3.....	84.0	49.2	73.7	74.0	12.8
Average, 32 days.....	85.3	50.9	76.0	77.0	10.7

¹ Taken 6 inches below surface.

Evaporation from free-water surface and from tanks with mulches of different depths at Davis, Cal., Sept. 1 to Oct. 3, 1908 (6 inches of irrigation water applied).

Periods.	Loss from water surface.	Loss from soil.							
		No mulch, tanks 1 and 2.		3-inch mulch, tanks 3 and 4.		6-inch mulch, tanks 5 and 6.		9-inch mulch, tanks 7 and 8.	
Average weight of tanks Sept. 1, pounds.....		1,104.7		1,090		1,082		1,085.2	
Average loss:	Inches.	Lbs.	P. ct.	Lbs.	P. ct.	Lbs.	P. ct.	Lbs.	P. ct.
Sept. 1-4.....	1.07	16.75	17.8	1.75	1.9	0.00	0.0	0.00	0.0
Sept. 4-8.....	1.40	4.50	4.8	.75	.8	.25	.3	1-.60	-5.5
Sept. 8-11.....	.89	3.00	3.2	2.25	2.4	.75	.8	1-.25	-3
Sept. 11-15.....	1.23	1.50	1.6	2.50	2.7	.00	.0	.00	0.0
Sept. 15-Oct. 3.....	5.00	8.00	8.5	7.00	7.4	4.76	5.0	2.25	2.4
Total loss, 32 days.....	10.19	33.75	35.9	14.25	15.2	5.75	6.1	1.50	1.60
Equivalent loss, in inches.....		2.15		.91		.39		.10	

¹ Due to slight inaccuracies in weighing.

The total losses in inches and the percentage of loss by three and four day periods, September 1 to 22, is also shown graphically in figure 3. In compiling the data for this figure it was assumed that the losses from the fourteenth to the twenty-second day were uniform, the differential pulley being out of order between those dates, as already explained.

The results of this experiment follow very closely those obtained from June 10 to July 1. In all cases greater losses are recorded in the September experiment. This was due to an increase in the percentage of moisture in the soil over that in June and to the longer period over which the experiment extended. The unmulched surfaces show a loss of 2.15 inches of water, while the evaporation from a free-water surface amounted to 10.19 inches. It will also be noticed that 49.5 per cent of the loss from the unmulched surface occurred during the first three days after irrigation. The 3-inch mulch lost an equivalent of 0.91 inch of water, or only 42 per cent of the loss from the unmulched surfaces. There appears to be quite a variation between the 6 and 9 inch mulches, the 6-inch losing 0.39 inch and the

9-inch only 0.1 inch of water, being but 18 and 4.6 per cent, respectively, of the loss from the unmulched surfaces. This variation is due to the length of the experiment, as the weights show that most of the loss from the 6-inch mulch occurred in the last two weeks, the moisture having worked upward through the mulch to the surface. At the end of the test the moisture in the 9-inch mulch was still several inches from the surface.

RESULTS AT RENO, NEV.

The site chosen was on the State agricultural farm near Reno, on a spot free from obstruction to sun, wind, and rain, and inclosed by a woven-wire fence. The location, which has an altitude of 4,490

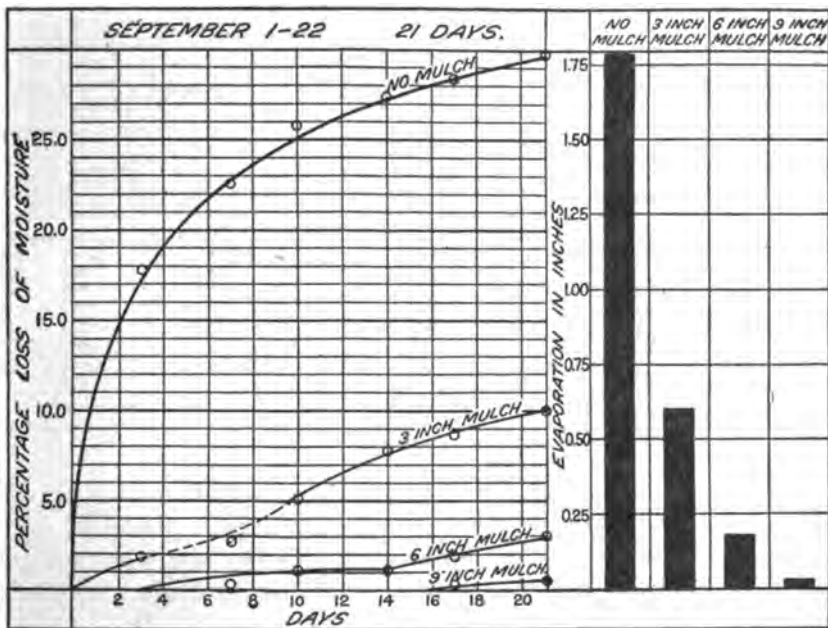


FIG. 2.—Evaporation losses from tanks with soil protected with mulches of different depths at Davis, Cal., September 1-22, 1908.

feet, is one typical of a large amount of irrigated land in Nevada, including that covered by the United States reclamation project. The soil is a sandy alluvial loam, intermixed with a considerable proportion of sand and small rock fragments, and is typical of the locality around Reno. (Pl. I, fig. 1.)

The tanks were filled June 9, soil samples being taken, from which moisture determinations were later made. All tanks were given a 6-inch irrigation and the soil mulches applied immediately after the water had disappeared. Owing to the scales being out of adjustment the weighings of the first three days had to be discarded and the

[Bull. 248]

experiment was really begun three days after the irrigation. September 1 the tanks were refilled with fresh soil and the experiment repeated. During the period of the experiment there was a total of 0.3 inch precipitation, a part of which fell during four days. The apparent evaporation from the tanks was corrected in each case by adding the precipitation to the loss in weight, thus giving the actual evaporation loss. Unfortunately, no record was taken of temperatures or wind velocities.

In the following table the evaporation losses for the two periods have been combined and average results are given:

Average evaporation from soils protected by different depths of soil mulches at Reno, Nev., June 9 to 30 and Sept. 1 to 22, 1908 (6 inches of irrigation water applied).

	Days.	Loss from water surface. ¹	Loss from soil.							
			No mulch, tanks 1 and 2.		3-inch mulch, tanks 3 and 4.		6-inch mulch, tanks 5 and 6.		9-inch mulch, tanks 7 and 8.	
Average weight of tanks June 9, pounds.....			1, 265. 2		1, 261. 2		1, 283. 1		1, 263. 8	
Average loss:		Inches.	Pounds.	Per ct.	Pounds.	Per ct.	Pounds.	Per ct.	Pounds.	Per ct.
First period.....	3	0. 00	8. 00	8. 5	2. 75	2. 9	0. 00	0. 0	0. 00	0. 0
Second period.....	4	1. 53	4. 30	4. 6	2. 80	3. 0	2. 50	2. 7	2. 00	2. 1
Third period.....	3	. 00	3. 10	3. 3	2. 10	2. 2	. 40	. 4	. 25	. 3
Fourth period.....	4	1. 60	2. 10	2. 2	1. 90	2. 0	. 20	. 2	. 00	. 0
Fifth period.....	3	. 00	1. 50	1. 6	. 80	. 8	. 50	. 5	. 00	. 0
Sixth period.....	4	1. 55	3. 20	3. 4	3. 50	3. 7	2. 10	2. 2	. 50	. 5
Total loss.....	21	4. 68	22. 20	23. 6	13. 85	14. 6	5. 70	6. 0	2. 75	2. 9
Equivalent loss in inches.....			1. 41		. 88		. 36		. 17	

¹ Weighings taken but once a week.

The evaporation losses shown are comparatively light, but this is to be expected, as the experiment extends over a period of only three weeks and the evaporation losses from a free-water surface are very light, showing that moderate temperatures and wind velocities must have prevailed.

The unmulched surfaces show a loss during the three weeks of 1.41 inches, which is 23.6 per cent of the 6 inches applied, as against an average loss of 4.68 inches from a free-water surface for the same period. The 3-inch mulch gave a loss of 0.88 inch, or 14.6 per cent of the 6 inches applied, and is only 62.4 per cent of the loss from the unmulched surface. The loss with the 6-inch mulch was 0.36 inch and that with the 9-inch mulch 0.17 inch, being only 25.5 per cent and 12 per cent, respectively, of the loss from the bare surfaces. Practically all of the variation between the losses with the 6 and 9 inch mulches came in the last four days of the experiment.

Moisture determinations, made by exposing the soil in thin layers to air and sunshine before irrigation at the beginning of the September experiment, gave the following results.

[Bull. 248]



FIG. 1.—EXPERIMENT TRACT, RENO, NEV.



FIG. 2.—EXPERIMENT TRACT, AGRICULTURAL COLLEGE, N. MEX.

Percentage of free-moisture content of tanks at the beginning of the September experiment.

Depths.	Tanks 1 and 2.	Tanks 3 and 4.	Tanks 5 and 6.	Tanks 7 and 8.
1 foot.....	Per cent. 9.44	Per cent. 8.68	Per cent. 12.24	Per cent. 9.24
2 feet.....	10.92	12.40	11.94	12.40
3 feet.....	11.26	11.84	12.50	12.00
4 feet.....	11.80	11.54	12.42	12.50
Average.....	10.85	11.12	11.78	11.53

This shows a very even distribution of moisture through the soil, with no indication of free water settling in the bottom of the tanks.

Figure 4 shows graphically the relation between the amounts of the evaporation in the different sets of tanks.

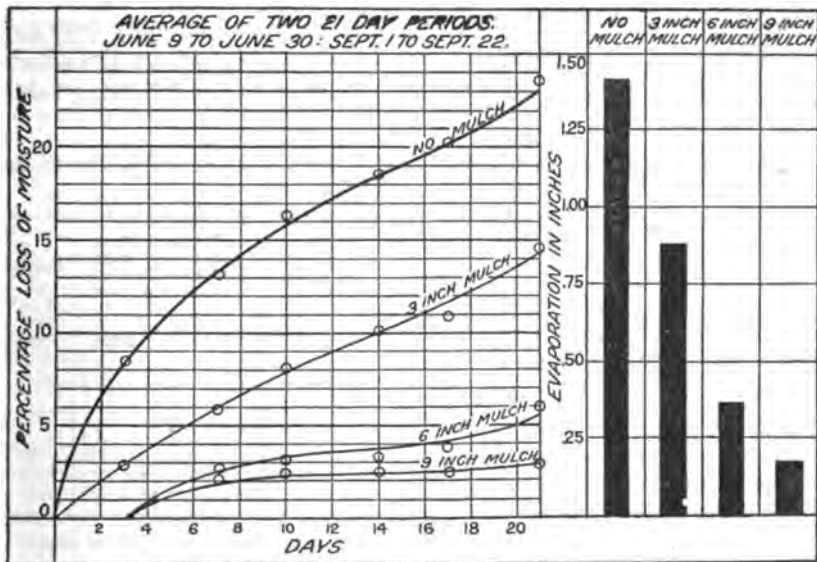


FIG. 4.—Average evaporation losses from tanks with soil protected with mulches of different depths at Reno, Nev., June 9-30 and September 1-22, 1908.

RESULTS AT AGRICULTURAL COLLEGE, N. MEX.

The New Mexico Experiment Station is located in the valley of the Rio Grande, a little west of the center of the State and about 20 miles north of its southern boundary. The soil of the tract is a sandy loam with gravel layers interspersed and some gravel intermixed. It is an alluvial deposit derived from the wash of the bench land to the east. In the fine material there is more silt than clay, and there is practically no distinction between soil and subsoil. The soil conditions and the apparatus used are shown on Plate I, figure 2.

The characteristic features of the climate of the locality are a high daily maximum temperature, which gives a fairly high mean tempera-

ture, a high percentage of clear days, a low relative humidity, a mean annual rainfall of 8.8 inches, and a fairly high-wind velocity. These conditions favor rapid evaporation from water and soil surfaces.

The experiment was started on September 25, 1908, and was repeated six times, the last ending March 2, 1909. No measured amount of water was applied in the irrigations, enough being added each time to thoroughly saturate the soil. Unfortunately soil samples for moisture determinations were not taken in any of these tests, and no idea of the original moisture content of the soil can be obtained. The heavy losses from the unmulched soil surfaces, however, show that the soil in each case must have been thoroughly moistened. During three of the trials 0.5 inch or more of rain fell and entirely spoiled the effect of the mulches. The results for these tests have been excluded in the following tables. The period showing the best results was from February 5 to March 2, during which only 0.09 inch of rain fell. The climatological conditions and losses from the several tanks by three and four day periods are shown in the following tables for this period:

Mean temperature, relative humidity, wind velocity, and rainfall at Agricultural College, N. Mex., Feb. 5 to Mar. 2, 1909.

Periods.	Mean temperature.	Mean relative humidity.	Mean wind velocity per hour.	Rainfall.
	[°] F.	Per cent.	Miles.	Inch.
Feb. 5-9.....	46	43	10.6	.....
Feb. 9-12.....	45	36	5.8	.....
Feb. 12-16.....	41	46	8.4	0.03
Feb. 16-19.....	51	30	11.5	.....
Feb. 19-23.....	41	49	12.6	.06
Feb. 23-26.....	37	45	4.2	.....
Feb. 26 to Mar. 2.....	48	37	5.1	.....
Average, 25 days.....	44.1	41	8.6	.....

Evaporation from free-water surface and from tanks with mulches of different depths at Agricultural College, N. Mex., Feb. 5 to Mar. 2, 1909.¹

Periods.	Loss from water surface.	Loss from soil.							
		No mulch.		3-inch mulch.		6-inch mulch.		9-inch mulch.	
		Tank 1.	Tank 2.	Tank 3.	Tank 4.	Tank 5.	Tank 6.	Tank 7.	Tank 8.
Average loss:	Inches.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.	Pounds.
Feb. 5-9.....	1.00	8.6	7.9	4.5	3.5	0.0	0.6	1.2	0.6
Feb. 9-12.....	.90	4.0	5.1	.0	.0	.0	.0	.0	.0
Feb. 12-16.....	.98	6.7	6.0	.4	2.6	.4	.4	.4	.4
Feb. 16-19.....	.55	7.9	6.9	1.7	1.7	.0	2.3	1.2	.6
Feb. 19-23.....	.66	.0	.0	.0	.0	.0	.0	.0	.0
Feb. 23-26.....	.80	2.9	3.4	1.7	1.7	.0	.0	.0	.0
Feb. 26 to Mar. 2.....	1.05	1.2	3.4	.0	1.2	1.2	1.2	.6	.0
Total loss, 25 days.....	5.94	31.3	32.7	8.3	10.7	1.6	4.5	3.4	1.6
Equivalent of average loss in inches.....		2.04		.61		.19		.16	

¹ The inner tanks were 27 inches in diameter. For uniformity the losses in this and other tables for New Mexico are the proportional losses for tanks 23½ inches in diameter.

The unmulched tanks showed an average total loss of 32 pounds, equivalent to 2.04 inches of water. Twenty-six per cent of the loss occurred in the first four days after irrigation. The 3, 6, and 9 inch mulches showed average losses of 0.61, 0.19, and 0.16 inch of water, respectively. In the case of the 3-inch mulch 42 per cent of the total loss occurred in the first four days, while the losses with 6 and 9 inch mulches seem to be more or less evenly distributed. The loss from the unmulched surfaces was 34.4 per cent of that from a free-water surface. Seventy per cent of this heavy loss was saved by a 3-inch mulch, 90 per cent by a 6-inch mulch, and 92.3 per cent by a 9-inch mulch.

Similar tables showing the averages for the three following periods, January 8 to February 2, February 5 to March 2, and March 5 to March 30, are given below:

Average mean temperature, relative humidity, wind velocity, and average rainfall by three and four day periods at Agricultural College, N. Mex. (Jan. 8 to Feb. 2, Feb. 5 to Mar. 2, and Mar. 5 to Mar. 30, 1909).

Periods.	Days.	Mean temperature.	Mean relative humidity.	Mean wind velocity per hour.	Rainfall.
		^{° F.}	^{Per cent.}	^{Miles.}	^{Inch.}
First.....	4	46	36	7.2	0.00
Second.....	3	43	51	7.5	.85
Third.....	4	43	47	6.1	.03
Fourth.....	3	52	33	10.1	.06
Fifth.....	4	48	38	9.3	.06
Sixth.....	3	47	43	7.9	.05
Seventh.....	4	52	40	6.6	.00
Average.....	25	47.2	41	7.8	.....

Average evaporation from free-water surface and from tanks with mulches of different depths, at Agricultural College, N. Mex., by three and four day periods (Jan. 8 to Feb. 2, Feb. 5 to Mar. 2, and Mar. 5 to Mar. 30, 1909).

Periods.	Days.	Loss from water surface.	Loss from soil.							
			No mulch.		3-inch mulch.		6-inch mulch.		9-inch mulch.	
			Tank 1.	Tank 2.	Tank 3.	Tank 4.	Tank 5.	Tank 6.	Tank 7.	Tank 8.
		^{Inches.}	^{Pounds.}	^{Pounds.}	^{Pounds.}	^{Pounds.}	^{Pounds.}	^{Pounds.}	^{Pounds.}	^{Pounds.}
First.....	4	0.82	9.1	9.1	3.1	2.1	0.3	1.0	1.0	0.8
Second.....	3	.45	4.2	3.6	2.3	2.0	1.3	.8	1.1	1.2
Third.....	4	.68	5.1	4.8	1.0	2.3	1.0	.5	1.0	1.2
Fourth.....	3	.63	7.1	6.9	2.7	1.5	1.0	1.7	1.2	1.2
Fifth.....	4	.77	4.4	5.5	.3	.6	.2	1.9	.2	.0
Sixth.....	3	.78	2.3	2.5	1.2	.9	.2	.6	.8	.6
Seventh.....	4	.54	2.1	2.5	1.3	1.0	1.3	1.4	1.5	.4
Total loss.....	25	4.67	34.3	34.9	11.9	10.4	5.3	7.9	6.8	5.4
Equivalent loss in inches.....			2.20		.71		.42		.39	

These average results covering approximately a period of three months are almost identical with those obtained during the month of

[Bull. 248]

February. The loss from an unmulched surface averaged 2.20 inches of water, or 47 per cent of the total amount evaporated from a free-water surface. Of this, 26.3 per cent was lost in the first four days. The 3-inch mulch shows a loss of 0.71 inch of water, or a saving of 67.7 per cent of the amount lost from an unmulched surface. Between the 6 and 9 inch mulches there seems to be but little choice, the 6-inch mulch, showing a saving of 81 per cent, and the 9-inch showing a saving of 82 per cent, the losses in each being small and evenly distributed throughout the experiment.

The weather records show that very uniform conditions prevailed throughout, and nowhere is the variation large enough to produce a noticeable effect on the evaporation losses. Figure 5 shows graphically the relative evaporation losses reduced to inches. As no defi-

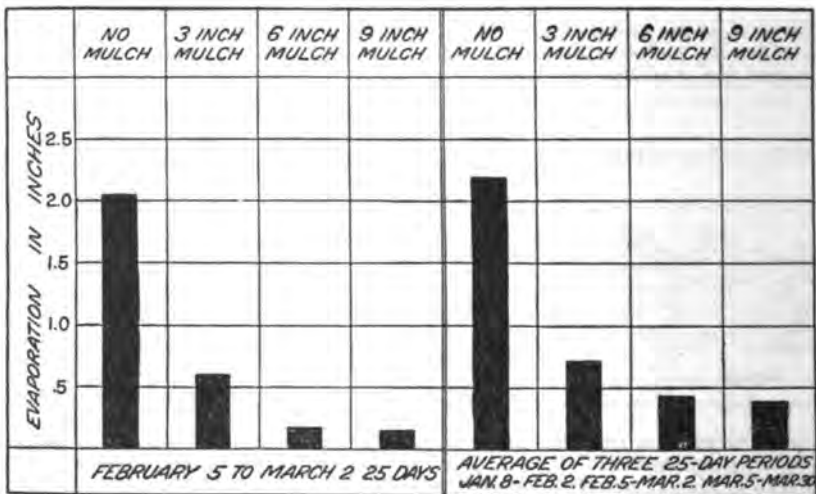


FIG. 5.—Average evaporation losses from tanks with soil protected with mulches of different depths at Agricultural College, N. Mex., January 8 to February 2, February 5 to March 2, and March 5-30, 1908.

nite amount of water was applied it was not possible to show the percentages of the losses graphically.

RESULTS AT BOZEMAN, MONT.

The site chosen for the experiments in Montana was at Bozeman in the Gallatin Valley. This valley covers nearly 330 square miles, located in the south central portion of the State. It was at one time the bed of an old lake and the soil is naturally rich in humus and plant foods of all kinds. The soil is a silty loam with a heavy loam underneath, and the entire valley seems to be underlain with a stratum of sand and gravel at a depth of 1 to 6 feet below the surface.

A small plat upon which to conduct the experiments was set apart at the State experiment station, and the experiments were carried

[Bull. 248]

on in the usual way with apparatus similar to that described in the other experiments.

A record of the temperatures of the air, soil, and water, the rainfall and the evaporation was taken during the period of the experiment. No record was taken of the wind velocities. As this is one of the important factors in evaporation losses, the following table showing the average velocity of the wind at Bozeman during 1905, 1906, and 1907 has been compiled from the Weather Bureau reports:

Average velocity of wind in miles per hour at Bozeman, Mont., 1905, 1906, and 1907.

Month.	Maximum.	Minimum.	Average.
	<i>Miles.</i>	<i>Miles.</i>	<i>Miles.</i>
April.....	26.3	2.5	12.4
May.....	26.1	3.2	12.7
June.....	24.6	2.6	10.8
July.....	23.6	2.2	9.7
August.....	24.7	2.4	10.8

The tanks were filled September 1. Moisture determinations made from the soil samples taken as the tanks were filled showed a very high percentage of moisture, and for that reason a 4.5-inch—68 pounds—instead of a 6-inch irrigation was applied. The mulches were applied as soon as the water had disappeared from the soil surface.

Following is a summary of these moisture determinations made at the beginning and end of the experiment:

Moisture determinations at beginning and end of the experiment.

	Beginning.	End.
	<i>Per cent.</i>	<i>Per cent.</i>
Tanks 1 and 2.....	23.21	26.48
Tanks 3 and 4.....	22.94	26.50
Tanks 5 and 6.....	21.68	26.92
Tanks 7 and 8.....	21.31	28.12

The percentage of moisture in dry mulch was 2.3 per cent of its dry weight.

[Bull. 248]

The climatological data and the losses from the several tanks by three and four day periods are given in the following tables:

Mean maximum atmospheric, soil, and water temperatures, and the rainfall at Bozeman, Mont., Sept. 2 to 30, 1908.

Periods.	Mean maximum temperature.	Mean maximum soil temperature. ¹	Mean maximum water temperature. ¹	Rainfall.
	[°] F.	[°] F.	[°] F.	Inches.
Sept. 2-5.....	65.6	77.5	71.0	.....
Sept. 5-9.....	86.8	79.5	73.5	.....
Sept. 9-12.....	79.3	78.0	67.0	.....
Sept. 12-16.....	82.5	73.7	66.7	0.08
Sept. 16-19.....	60.2	64.3	62.0	.35
Sept. 19-23.....	72.1	73.3	64.7	.....
Sept. 23-26.....	60.8	62.0	55.5	.69
Sept. 26-30.....	61.1	56.5	55.5	.....
Average, 28 days.....	71.8	70.6	64.4	.....

¹ Taken at depth of 3 inches.

Evaporation from a free-water surface and from soils protected by different depths of mulches at Bozeman, Mont., Sept. 2 to 30, 1908.¹

Periods.	Loss from water surface.	Loss from soil.							
		No mulch, tanks 1 and 2.		3-inch mulch, tanks 3 and 4.		6-inch mulch, tanks 5 and 6.		9-inch mulch, tanks 7 and 8.	
Average weight of tanks Sept. 2, pounds.....		1,282.7		1,282		1,286		1,292.2	
Average loss:	Inches.	Pounds.	P. ct.	Pounds.	P. ct.	Pounds.	P. ct.	Pounds.	P. ct.
Sept. 2-5.....	0.54	8.87	9.3	0.50	0.5	² -0.87	-0.9	1.00	1.1
Sept. 5-9.....	.88	10.37	11.0	5.00	5.3	² -2.50	-2.7	.25	.3
Sept. 9-12.....	.56	6.00	6.4	3.25	3.5	1.25	1.3	.12	.1
Sept. 12-16.....	.93	7.00	7.4	5.75	6.2	3.00	3.2	1.12	1.2
Sept. 16-19.....	.75	4.73	5.0	4.00	4.9	3.23	3.4	2.35	2.5
Sept. 19-23.....	.87	8.00	8.5	6.12	6.5	5.25	5.6	4.12	4.4
Sept. 23-26.....	³ + .72	³ -3.19	-3.4	³ -3.56	-3.8	³ -5.19	-3.4	³ -3.81	-4.1
Sept. 26-30.....	.30	4.50	5.3	3.12	3.3	4.37	4.6	5.62	6.0
Total loss, 28 days.....	4.11	46.28	49.5	24.78	26.4	10.46	11.1	10.77	11.5
Equivalent losses in inches.....		2.95		1.58		.66		.69	

¹ Per cent calculated on basis of 6-inch irrigation, owing to high percentage of soil moisture.

² Due to inaccuracies in weighing.

³ Due to rainfall.

The most noticeable feature of the results at this station was the very heavy evaporation losses, especially from the unmulched soils. During the first week 1.23 inches, or 20.5 per cent of the total amount of water added in the irrigation to the unmulched surfaces, was lost by evaporation, and by the end of four weeks a total of 46.28 pounds, or 49.5 per cent of the amount applied, had been lost.¹ Heavy losses were also found with the different mulches, the 3-inch mulch losing 1.58 inches, or 26.3 per cent of the water added in irrigation, in 28 days, showing a saving of 46 per cent of the water lost from an unmulched surface. The 9-inch mulch showed a saving

¹ Owing to the high percentage of soil moisture the amount applied is considered as 6 inches rather than 4½ inches.

of approximately 77 per cent of the loss from the unmulched surface and 57 per cent of the amount lost through the 3-inch mulch. Until rainfall interfered a much greater advantage was being shown in favor of the 9-inch mulch, but after the first two weeks the effect of all the mulches was more or less destroyed by the rainfall, and toward the end of the month heavy losses were recorded from all of the tanks. Although the losses with the 6-inch mulches are included in the table, they have little value, owing to inaccuracies in weight at the end of the first and second periods.

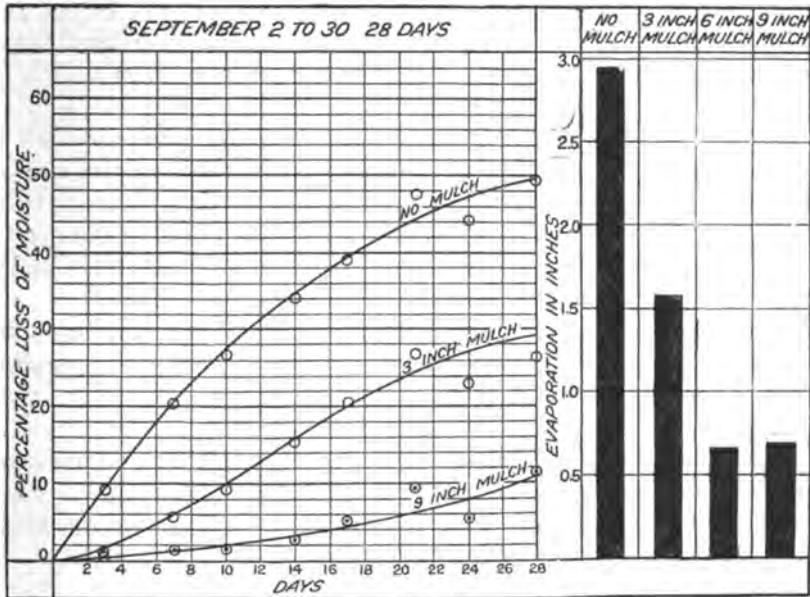


FIG. 6.—Evaporation losses from tanks of soil protected by mulches of different depths at Bozeman, Mont., September 2-30, 1908.

It may be well to call attention to the effect of the percentage of moisture in the soil upon the rate of evaporation. The exceedingly heavy losses from the soil under ordinary climatic conditions, which produced only moderate losses from a free-water surface, can be accounted for only by the wet condition of the soil, analyses of which showed the average free-moisture content to be 22.3 per cent.

Figure 6 shows the total losses from the several tanks¹ in inches, and the percentage of the water applied lost during each three and four day period.

¹ Curve for 6-inch mulch omitted, owing to inaccuracies in weights.

RESULTS AT WENATCHEE, WASH.

The experiments in the State of Washington were made in the Wenatchee fruit district of Chelan County, in an orchard about $1\frac{1}{2}$ miles west of the town of Wenatchee. The spot chosen for the experiment is typical of a large area as to climatic and soil conditions, since the bars and benches farther up the Columbia River and thousands of acres along the tributary streams, even as far north as British Columbia, are similar to those of the Wenatchee district. The soil in the orchard chosen was a sandy loam inclined to be gritty, several feet in depth, and fairly typical of that generally found in the locality. Scarcely a perceptible difference was found in the nature of the soil in the first 4 feet in depth. The subsoil as far as was ascertained consisted of gravelly boulders or loose rock, affording perfect drainage. (Pl. II, fig. 1.)

Records of the United States Weather Bureau station located in the foothills near Wenatchee, at an elevation of 1,150 feet, give a mean annual temperature of 47.9° and a normal precipitation of 15.54 inches, 4.74 inches of which falls between April 1 and October 1. The temperature of Wenatchee is somewhat higher than this, and the precipitation is probably 3 or 4 inches less than the above.

The experiment was started June 3 and continued until June 24, and was repeated September 8 to September 29, a 6-inch irrigation being applied in each case.

The first trial was made June 3 to 24, 1908.

Soil samples were taken as the tanks were being filled, and moisture determinations made later. Another set of determinations was made at the end of the experiment, the results of these determinations being given in the following table:

Soil-moisture determinations at beginning and end of the experiment.

	Mean moisture content before irriga- tion.	Moisture content at end of experiment.			
		First foot.	Second foot.	Third foot.	Mean.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
Tank No. 1.....	6.0	6.5	8.0	15.5	10.0
Tank No. 2.....	13.0	16.0	16.0	17.0	16.3
Tank No. 3.....	8.0	8.0	8.5	16.5	11.0
Tank No. 4.....	6.5	8.0	9.0	15.0	10.7
Tank No. 5.....	2.0	6.0	7.0	15.5	9.5
Tank No. 6.....	7.0	7.0	9.0	18.5	11.5
Tank No. 7.....	11.0	14.0	16.5	19.0	16.5
Tank No. 8.....	7.5	9.0	11.0	18.0	12.7

During the progress of the experiment the weather was warm, with a considerable amount of wind. The rainfall during the period was not enough to interfere with the experiment.

[Bull. 248]



FIG. 1.—EXPERIMENT TRACT, WENATCHEE, WASH.

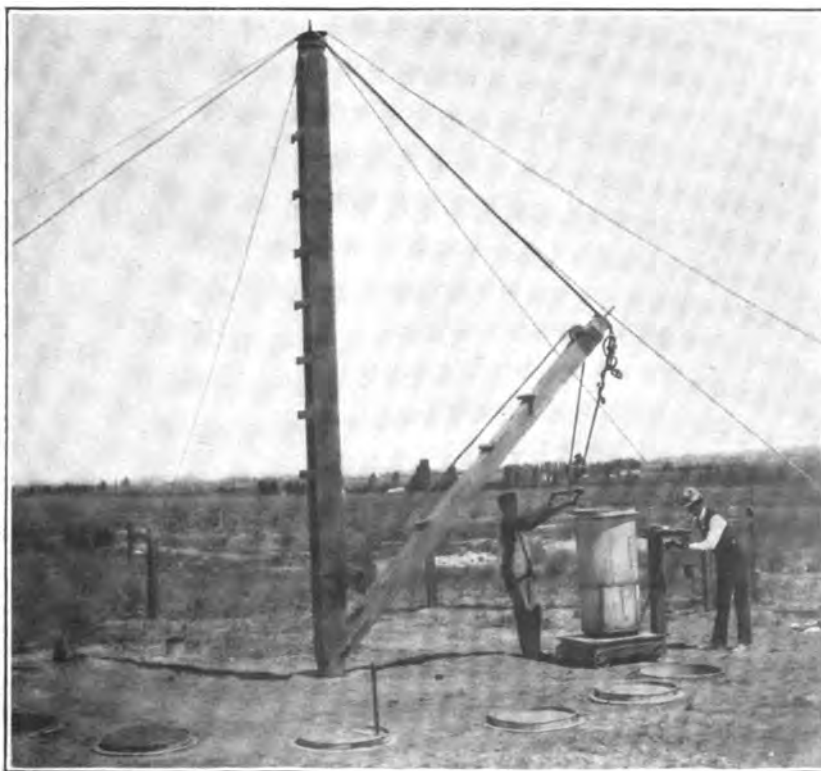


FIG. 2.—EXPERIMENT TRACT, CALDWELL, IDAHO.

The following table shows the maximum temperature of the air, evaporation losses from a free-water surface, and the losses from the several tanks:

Mean maximum temperature and evaporation from free-water surface, and soils protected by mulches of different depths, Wenatchee, Wash., June 3-24, 1908.

Periods.	Mean maximum temperature.	Loss from water surface.	Loss from soil							
			No mulch, tank 1.		3-inch mulch, tanks 3 and 4.		6-inch mulch, tanks 5 and 6.		9-inch mulch, tank 8.	
Average weight of tanks June 3, pounds.....			1,365		1,324.7		1,362.5		1,379.5	
Average loss:	° F.	Inches.	Lbs.	Per ct.	Lbs.	Per ct.	Lbs.	Per ct.	Lbs.	Per ct.
June 3-6.....	78.0		9.0	9.5	1.75	1.9	1.25	1.3	0.50	0.5
June 6-10.....	85.0	2.00	2.5	2.7	1.00	1.1	.25	.3	.25	.3
June 10-13.....	83.3		1.5	1.6	.50	.5	.25	.3	.25	.3
June 13-17.....	83.3	2.25			.50	.5				
June 17-20.....	70.6		.5	.5						
June 20-24.....	74.2	1.87					.25	.3		
Total loss.....	79.0	6.12	13.5	14.4	3.75	4.0	2.00	2.2	1.00	1.1
Equivalent loss in inches.....			.86		.24		.13		.07	

¹ Average, 21 days.

The most noticeable feature of the results of this experiment was the small losses shown throughout, notwithstanding that moderate temperatures prevailed and that a rather heavy evaporation was recorded from the water surface. The losses after the first three days were practically negligible. This may be accounted for in two ways; first, the low percentage of moisture in the soil before irrigation, and, second, the general texture of the soil, which allowed most of the water to collect in the lower layer, as is shown by the high percentage of moisture in the third foot at the end of the experiment. The unmulched surface lost an equivalent of 0.86 inch of water, which is but 14.3 per cent of the total amount applied and 66 per cent of this was lost in the first three days. The 3-inch mulch showed a loss of 0.24 inch, or a saving of 72 per cent of the loss from the unmulched surface. As usual, there is very little difference between the 6 and the 9 inch mulches, the former showing a loss of 0.13 inch and the latter 0.07 inch, being savings of 85 and 92.5 per cent, respectively, of the loss from the bare surface.

The losses from tanks 2 and 7 have been omitted in these results. Tank 2 showed a total loss of 52 pounds and tank 7 a loss of 10.5 pounds for the period. These losses can be accounted for only by the heavy percentage of moisture in the soil before irrigation. The moisture in tank 7 arose through the 9-inch mulch almost as soon as it was applied, completely destroying its value as a mulch. This

[Bull. 248]

shows beyond doubt that the controlling element in evaporation losses is the percentage of moisture in the soil.

Figure 7 illustrates the difference in evaporation losses between the four sets of tanks.

In the second trial, September 8-29, 1908, the auxiliary data such as moisture percentages, temperatures, evaporation from free-water

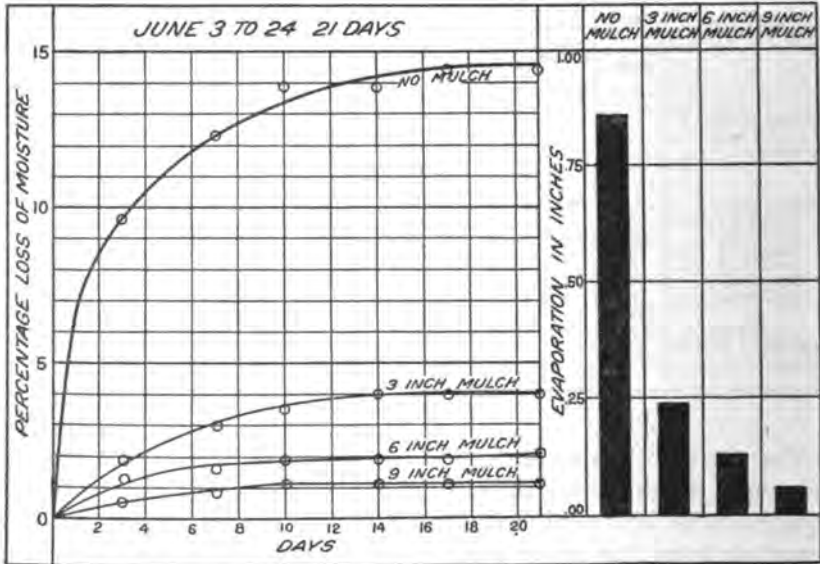


FIG. 7.—Evaporation losses from tanks of soil protected by mulches of different depths at Wenatchee, Wash., June 3-24, 1908.

surface, etc., are entirely missing, so that the results as in the following table possess little comparative value:

Results of experiment Sept. 8-29, 1908.

Kind of mulch.	Loss in 21 days.		Percentage lost of 6-inch irrigation.	Percentage of saving due to mulch.
	Pounds.	Inches.		
None.....	13.50	0.86	14.23	.....
3-inch.....	12.75	.81	13.55	4.8
6-inch.....	8.75	.56	9.29	34.0
9-inch.....	7.75	.49	8.23	38.5

SUMMARY OF RESULTS.

The table following shows the averages of the losses recorded at the five stations.

[Bull. 248]

Average losses by evaporation from free-water surface and from tanks with mulches of different depths at the five stations.¹

Periods.	Days.	Loss from water surface. ²	Loss from soil.			
			No mulch.	3-inch mulch.	6-inch mulch. ³	9-inch mulch.
		Inches.	Pounds.	Pounds.	Pounds.	Pounds.
First.....	3	0.86	9.6	1.9	0.48	0.48
Second.....	4	.95	5.1	2.1	.56	.56
Third.....	3	.87	3.7	1.6	.63	.25
Fourth.....	4	.95	3.6	2.3	.89	.43
Fifth.....	3	.97	2.3	1.5	1.08	.53
Sixth.....	4	.99	3.1	2.4	1.73	1.07
Total.....	21	5.59	27.4	11.8	5.37	3.32
Equivalent loss in inches.....			1.75	.75	.34	.22

¹ In compiling this table the losses used for Agricultural College, N. Mex., and Davis, Cal., are averages of the two experiments at each place.

² Losses at Reno, Nev., assumed to be uniform throughout each week.

³ Owing to inaccuracies in weighing tanks at Bozeman, losses for first seven days assumed to be same as from tanks with 9-inch mulch.

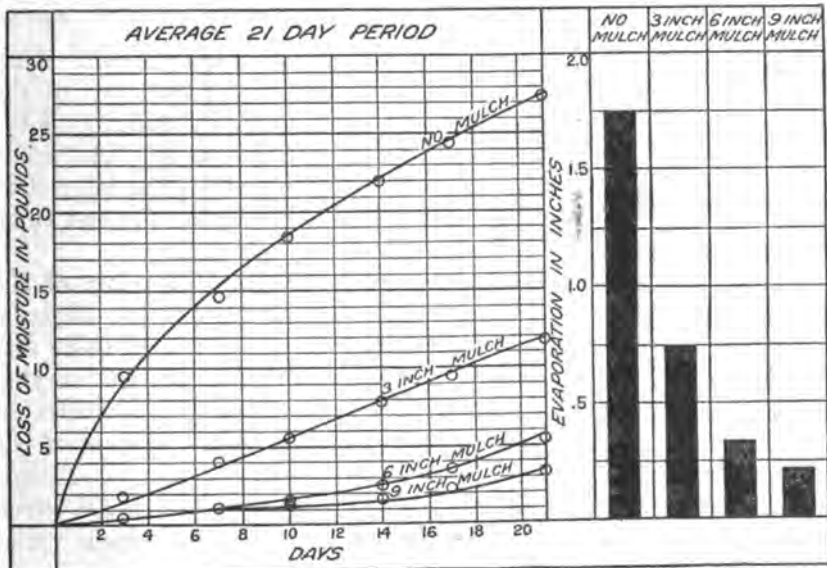


FIG. 8.—Average evaporation losses from tanks of soil protected with mulches of different depths during first 21 days after irrigation. Average of losses at five stations.

Figure 8 is a graphic representation of the foregoing table, showing a summary and comparison of these losses and the evaporation losses by three and four day periods at all of the five stations.

The most noticeable feature of these results is the uniformity of the losses. This is remarkable when it is remembered that they represent an average of the losses at all of the five stations.

The average loss from an open unmulched soil surface for a period of three weeks was 27.4 pounds, which is equivalent to 1.75 inches of water. The average loss during the first three days after irrigation

[Bull. 248]

amounted to 0.61 inch, almost as much as the average loss from a free-water surface. The loss during the first week was over 54 per cent of the total loss for 21 days. After the first week the losses diminished very gradually until during the last four-day period the loss was equivalent to only 0.20 inch of water.

After the first three days the daily loss from a 3-inch mulch was almost constant, a straight line curve passing very close to all of the points, as shown by the curve diagram. The total loss for the three weeks amounted to 0.75 inch, and shows a saving of 57 per cent of the water lost from an unmulched surface. When the dry mulch was applied to the irrigated soil surface, the moisture, due to capillarity, immediately started upward through the mulch, and as this moisture reached the surface, varying losses are recorded for the first few days; after this the mulch seems to adjust itself and constant losses are recorded for the remaining 18 days. At all times the surface of the mulch appeared perfectly dry, moisture not being found at a depth of less than 0.5 inch.

The losses with the 6 and 9 inch mulches were quite small. That with the 6-inch mulch was only 0.34 inch, or 5.7 per cent of the 6-inch irrigation, and a saving of 54.7 per cent of the loss with the 3-inch mulch. The loss with the 9-inch mulch was only 0.22 inch, or 3.7 per cent of the water applied, and only a very little more than one-third of the loss from the unmulched tanks during the first three days after irrigation.

As has been stated, one of the chief objections to many of the experiments which have been carried on by various investigators in the past, is that the results obtained are of only local value and do not cover territory enough to give reliable data for the varying conditions of widely separated localities. The five localities in which this experiment was carried on are far apart, typical of the country surrounding them, and vary greatly in soil conditions, temperatures, wind movement, etc., and the average results given here may be used anywhere in the arid West without serious variation.

In the table following the results from all of the stations have been assembled, temperatures, rainfall, and evaporation from soil and water surfaces being shown.

[Bull. 248]

Results of five stations grouped: Showing temperature, rainfall, and evaporation losses from soils (in tanks) under mulches of varying depths. Period covered 21 days and a 6-inch irrigation the basis of the test.

Locations.	Mean temperature.	Rain-fall.	Loss from water surface.	Percentage of soil moisture before irrigation.	Losses by evaporation.							
					No mulch.		3-inch mulch.		6-inch mulch.		9-inch mulch.	
	<i>° F.</i>	<i>Ins.</i>	<i>Ins.</i>	<i>P. ct.</i>	<i>Ins.</i>	<i>P. ct.</i>	<i>Ins.</i>	<i>P. ct.</i>	<i>Ins.</i>	<i>P. ct.</i>	<i>Ins.</i>	<i>P. ct.</i>
Agricultural College, N. Mex.	44.8	0.56	4.50	1.99	1.61	0.60	0.23	0.23	0.23	0.23	0.23	0.23
Bozeman, Mont.	52.8	.43	4.33	22.3	2.86	47.6	1.61	26.9	.14	2.3	.57	9.6
Davis, Cal.	71.2		8.02	8.8	1.62	27.0	.48	8.0	.14	2.3	.01	.2
Reno, Nev.		.30	4.68	7.2	1.41	23.6	.88	14.6	.36	6.0	.17	2.9
Wenatchee, Wash.	62.3		6.12	6.2	.85	14.4	.24	4.0	.13	2.2	.07	1.2

This table shows that although the stations having highest mean temperatures produced the greatest evaporation from a free-water surface it was not at these that the greatest evaporation losses from the soil occurred. The stations having the lowest mean temperatures and the least evaporation from a free-water surface gauge the highest losses from soils. This indicates quite clearly that climatic conditions are not the controlling factor in evaporation from soils. California, with the highest mean atmospheric temperature and the greatest evaporation loss from a water surface, shows slightly over one-half of the evaporation loss from an unmulched soil surface as does Montana with an average temperature which is 20° lower and an evaporation loss from a water surface of 3.48 inches less for the three-weeks period. At all but the New Mexico station moisture determinations of the soil were made before irrigation and in each case inspection of the results shows that the losses from the soil vary with the percentage of moisture in the top layer. The influence of both temperature and wind movement in causing the evaporation losses from soils appears to be much less than that of the moisture content in the top layer.

CONCLUSIONS.

(1) Soil mulches subserve many useful purposes, chief of which is the lessening of evaporation losses from the surface of cultivated soils.

(2) When western soil containing sufficient moisture to germinate seed and maintain plant growth is irrigated to a depth of 6 inches over the surface (one-half acre-foot per acre) and not cultivated afterwards, it is safe to assume that 1½ to 2 inches of the 6 inches applied will be lost by evaporation in a period of 30 days.

(3) The quantity lost by evaporation will increase with the percentage of moisture in the soil. In extreme cases of heavy moisture

content and high temperatures, 3 to 4 inches may be lost in a 30-day period.

(4) A dry, granular soil mulch 3 inches deep, such as was used in these experiments, will save, other conditions being similar, at least one-half of the loss from an unmulched surface.

(5) A like mulch 6 inches deep will save 75 per cent of the evaporation losses from an unmulched surface.

(6) In comparing the efficiency of a 6-inch mulch with a 9-inch mulch, the results show a considerable saving of water by the deeper mulch but the cost of cultivation and other practical considerations would seem to limit the depth to 6 inches or less. This applies to the greater part of the arid region.

(7) It is also well to remember that the mulches used in these experiments were ideal as regards their efficiency in checking evaporation, and in very few cases could they be produced in actual field cultivation, but obviously the nearer they are approached, the greater is the saving, and this alone should be an incentive to deeper and more thorough cultivation after irrigation.

EFFECTS OF CULTIVATION TO DIFFERENT DEPTHS.

In the foregoing series of experiments, as stated, the mulch was artificially prepared and superimposed on the tanks of irrigated soil.

This method permitted of greater precision in preparing and measuring the depth of mulches; yet in some minor respects differed from field conditions. In the present series the process of natural cultivation was more nearly followed. All tanks were filled to within 1 inch of the top with fresh soil, the same care of arrangement being exercised as in the former series. At a suitable time after irrigation the top soil was mulched by spading and thoroughly cultivating to different depths. Different periods of time were also allowed to elapse between irrigation and cultivation and corresponding effects on evaporation losses noted.

It is generally known among irrigators that there is a saving of moisture and a general improvement in the condition of the soil if cultivation is practiced after irrigation, but too often this knowledge is not put into practice. This is especially true in localities where water is plentiful, it being considered easier to apply another irrigation after the surface soil has dried out than to prevent loss of moisture by cultivation. In general the practice of cultivation seems to depend upon the scarcity and value of water, and where water is scarce and water rentals are high cultivation is quite generally practiced and every effort made to conserve the moisture in the soil.

The main purpose of the experiment outlined below was to determine, first, the losses by evaporation from cultivated and uncultivated soil surfaces after irrigation; second, the percentage of water saved by

[Bull. 248]

cultivation after irrigation; and, third, the amount of water lost in the period between the time of irrigation and cultivation. In addition to the five stations described in the former experiment, apparatus was installed at Caldwell, Idaho, and Williston, N. Dak. In all cases soil containing excessive moisture was avoided, and as the tanks were filled, samples were taken and moisture determinations made. Each tank was then given a 6-inch irrigation, the water being added from 5 or 10 gallon cans and the flow regulated so as to keep the entire surface flooded with at least 0.5 inch of water until the whole had been applied. Immediately after irrigation all of the tanks were weighed, and as soon as the soil was sufficiently dry four of them were cultivated to a depth of 6 inches, an attempt having been made to do this in such a way as to approach as nearly as possible ordinary cultural methods. The soil surfaces of the remaining four tanks were not disturbed during the test.

In each case the period between irrigation and cultivation was noted. This varied with the percentage of moisture in the soil, the general texture of the soil, and the climatic conditions. At the end of two weeks cultivation was again practiced in the cultivated tanks and weighings continued for another two weeks. At the end of four weeks the tanks were emptied, the general condition of the soil observed, and samples taken for moisture determinations. The tanks were again filled, and the experiments repeated during the following month.

RESULTS AT SUNNYSIDE, WASH.

The equipment used the previous season at Wenatchee was transferred to the experiment station near Sunnyside, where the experiment was made. The soil used in these tests is typical of the Yakima Valley, being a sandy loam with no change or intervening strata in the upper 4 feet. This uniform fineness of the soil was found to aid materially in its water-holding capacity.

The tanks were filled on May 17, and a 6-inch irrigation given the following day. Analysis of soil samples taken at the time of filling gave an average of 6 per cent of free moisture and a period of seven hours was noted between the beginning of the irrigation and the time when the water had finally disappeared from the surface of the soil. This short period shows the capacity of the soil for absorbing water. Two days after irrigation tanks 1, 2, 3, and 4 were cultivated to a depth of 6 inches, and after a period of two weeks they were given another cultivation.

The accompanying tables show the climatological data and the losses from the several tanks for three and four day periods. The graphical diagram (fig. 9) shows the daily average rate of loss from

cultivated and uncultivated surfaces in percentage of the 6-inch irrigation and a comparison of the losses figured in inches of water:

Temperatures of air, water, and soil at Sunnyside, Wash. (May 18 to June 15, 1909).

Periods.	Days.	Mean atmospheric temperature.	Mean soil temperature uncultivated. ¹	Mean soil temperature cultivated. ¹	Mean water temperature.
		^{°F.}	^{°F.}	^{°F.}	^{°F.}
First.....	3	61.0	64.4	63.5	67.1
Second.....	4	62.0	68.7	68.4	70.0
Third.....	3	65.3	72.2	70.1	67.4
Fourth.....	4	66.7	73.7	69.5	67.7
Fifth.....	3	71.1	78.7	75.2	75.2
Sixth.....	4	63.7	77.5	72.0	71.3
Seventh.....	3	66.6	77.9	74.3	74.9
Eighth.....	4	65.9	77.4	76.4	73.9
Average.....	28	65.2	74.3	71.3	70.9

¹ Taken at depth of 3 inches.

Evaporation losses from cultivated and uncultivated tanks at Sunnyside, Wash.¹ (May 18 to June 15, 1909).

Periods.	Days.	Cultivated.				Uncultivated.			
		Tanks 1 and 2.		Tanks 3 and 4.		Tanks 5 and 6.		Tanks 7 and 8.	
Average weight of tank May 18, pounds.....		1,196.0		1,183.5		1,200.5		1,196.0	
		<i>Pounds.</i>	<i>Per ct.</i>	<i>Pounds.</i>	<i>Per ct.</i>	<i>Pounds.</i>	<i>Per ct.</i>	<i>Pounds.</i>	<i>Per ct.</i>
First.....	3	14.00	14.9	12.50	13.3	10.50	11.2	10.00	10.6
Second.....	4	3.00	3.2	3.00	3.2	10.25	10.9	19.50	11.2
Third.....	3	2.00	2.1	2.50	2.6	6.75	7.2	5.00	5.3
Fourth.....	4	.75	.8			2.00	2.1	4.00	4.2
Fifth.....	3	3.50	3.7	4.50	4.8	3.50	3.7	3.00	3.2
Sixth.....	4	-2.25	-2.4	-1.25	-1.3	1.75	1.9	1.00	1.1
Seventh.....	3	1.50	1.6	.25	.3	2.00	2.1	1.25	1.3
Eighth.....	4	1.00	1.1	1.25	1.3	2.75	2.9	3.25	3.5
Total loss.....	28	23.50	25.0	22.75	24.2	39.50	42.0	38.00	40.4
Equivalent loss in inches.....			1.47				2.47		

¹ Total evaporation from free-water surface for 28 days, 7.25 inches.

² Probably due to inaccuracy in weighing.

It is well to remember that in this experiment the initial percentage of moisture in the soil was low, and that only a period of two days intervened between irrigation and cultivation. The losses shown for the first three days are higher from the cultivated than from the uncultivated tanks. This is due to the fresh moist soil being exposed in cultivation. After this first loss the losses from the cultivated tanks diminished rapidly until the second cultivation two weeks later, when the losses for one period were again quite heavy. During the remainder of the experiment the losses were very small, and in one case a gain was shown. This gain may have been due to some error in the weighing apparatus. The average total loss for 28 days from the cultivated tanks was 1.47 inches, or 24.5 per cent of the 6-inch irrigation. The loss in the period between irrigation and cul-

[Bull. 248]

tivation was probably approximately 10 pounds, or slightly less than 50 per cent of the total loss.

The average total loss from the uncultivated surface amounted to an equivalent of 2.47 inches, which is 41.2 per cent of the 6-inch irrigation. Fifty-three per cent of the loss occurred in the first week after irrigation. After the first week the losses were quite uniform, a small increase being noticed in the fifth period, which undoubtedly was due to the high mean temperatures at that time.

Although this experiment showed that the average evaporation from the cultivated surfaces was a little less than 60 per cent of that from the uncultivated surfaces, the main feature brought out was the necessity of cultivation as soon after irrigation as possible.

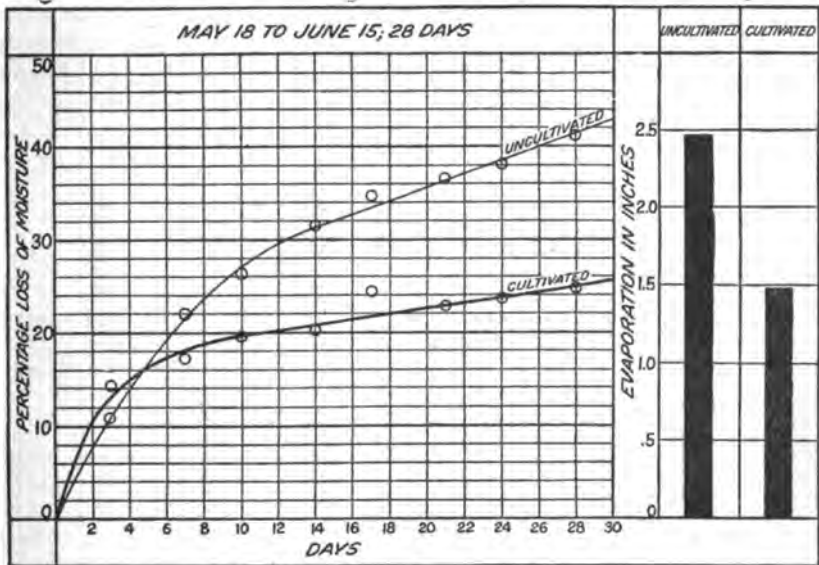


FIG. 9.—Evaporation losses from cultivated and uncultivated tanks at Sunnyside, Wash., May 18 to June 15, 1908.

The soil temperatures taken at a depth of 3 inches follow very closely the changes in the atmospheric temperatures, but there is an average difference of almost 2° in the temperatures of the cultivated and uncultivated soils, the cultivated soil being cooler to that extent.

RESULTS AT DAVIS, CAL.

This experiment extended over two periods—May 5 to June 2 and June 5 to July 3. The same site was chosen and the same equipment used as in the soil-mulch experiments of the season of 1908. The usual care was taken in filling the tanks to produce as nearly as possible natural field conditions, soil samples being taken which gave the following average percentages of free moisture: May 5, 9.8 per cent;

June 5, 15.9 per cent. The higher percentage of free moisture and the higher temperature increased the losses in the second period, although close observations of the results show that the ratios of the losses from the cultivated and uncultivated surfaces were practically the same. In each case the time of the beginning of irrigation and the time at which the water disappeared from the soil surface were recorded. The weight of the soil, the time required for the water to seep away, and the percentages of free moisture for each tank recorded for each period are given below:

Weight of tanks, length of irrigation, time before cultivation, and percentage of free moisture in tanks.

FIRST PERIOD, MAY 5 TO JUNE 2, 1909.

Tanks.	Weight of soil before irrigation.	Time required for irrigation.	Time between irrigation and cultivation.	Percentage of free moisture before irrigation.
	Pounds.	Hours.	Hours.	Per cent.
No. 1.....	1,086.5	6½	42	11.46
No. 2.....	1,108.0	6½	42	10.96
No. 3.....	1,089.5	6½	42	10.81
No. 4.....	1,075.5	6	42	9.64
No. 5.....	1,095.0	6½	42	9.58
No. 6.....	1,101.5	6	42	8.56
No. 7.....	1,098.0	6	42	10.04
No. 8.....	1,093.0	6½	42	7.64

SECOND PERIOD, JUNE 5 TO JULY 3, 1909.

No. 1.....	1,173.0	6½	64	14.64
No. 2.....	1,149.5	5½	64	14.54
No. 3.....	1,153.5	6	64	17.55
No. 4.....	1,147.0	5½	64	17.55
No. 5.....	1,149.0	5½	64	15.45
No. 6.....	1,150.0	6½	64	15.45
No. 7.....	1,137.5	5½	64	16.10
No. 8.....	1,148.0	6	64	16.10

Immediately after irrigation the tanks were weighed and for the next four weeks weights were taken twice a week at the end of each 3 and 4 day period. Tanks 1, 2, 3, and 4 were cultivated a second time to a depth of 6 inches at the end of the first two weeks. At the time of this second cultivation moisture was found at a depth of 1½ inches. Above this depth the soil was dry and acted as a mulch, while at the end of each test soil samples were taken for moisture determinations. These showed that in every case the 6-inch irrigation had penetrated the full depth of the soil, although there was no free water or even an excess of moisture in the bottom layers.

During the next two months quite complete climatological observations were made. These are included in the table following.

[Bull. 248]

Temperature of air, soil, and water, mean humidity, and wind velocity at Davis, Cal. (May 5 to June 2 and June 5 to July 3, 1909).

Periods.	Days.	Mean atmospheric temperature.	Mean soil temperature. ¹	Mean water temperature. ¹	Mean humidity.	Mean wind velocity per hour.
		° F.	° F.	° F.	Per cent.	Miles.
First.....	3	67.2	74.8	74.9	54.0	8.38
Second.....	4	63.7	75.2	72.6	48.0	8.64
Third.....	3	61.8	74.5	71.5	47.7	11.90
Fourth.....	4	59.6	72.6	69.3	64.6	9.10
Fifth.....	3	62.8	74.6	73.5	54.0	8.60
Sixth.....	4	67.5	77.4	74.7	40.1	10.15
Seventh.....	3	60.8	77.9	72.8	45.4	10.65
Eighth.....	4	71.2	78.7	76.6	44.6	7.90
Average.....	28	64.5	75.7	73.2	49.8	9.32

¹ Taken at a depth of 6 inches.

The losses from the several tanks between the different irrigations are shown in the following table:

Average evaporation losses from free-water surface and from cultivated and uncultivated surfaces at Davis, Cal. (May 5 to June 2 and June 5 to July 3, 1909).

Periods.	Days.	Mean loss from water surface.	Cultivated.				Uncultivated.			
			Tanks 1 and 2.		Tanks 3 and 4.		Tanks 5 and 6.		Tanks 7 and 8.	
Average weight of tanks at beginning of experiment, pounds.....			1,133		1,116		1,124		1,119	
		Inches.	Pounds.	Per ct.	Pounds.	Per ct.	Pounds.	Per ct.	Pounds.	Per ct.
First.....	3	1.05	10.25	10.9	10.10	10.7	11.50	12.2	11.40	12.1
Second.....	4	1.22	5.00	5.3	3.40	3.6	6.25	6.7	5.75	6.1
Third.....	3	1.24	1.25	1.3	1.00	1.1	2.75	3.0	3.10	3.3
Fourth.....	4	.99	1.00	1.1	.75	.8	2.00	2.1	2.40	2.6
Fifth.....	3	1.16	4.25	4.5	3.00	3.2	1.85	2.0	2.25	2.4
Sixth.....	4	1.36	.75	.8	.75	.8	2.35	2.5	2.50	2.7
Seventh.....	3	1.22	.60	.6	.50	.5	1.75	1.9	1.25	1.3
Eighth.....	4	1.17	.15	.2	.15	.2	1.75	1.9	1.10	1.2
Total.....	28	9.41	23.25	24.7	19.65	20.9	30.2	32.3	29.75	31.7
Equivalent of average loss of water in inches.....			1.36		1.91					

A comparison of the quantities of water lost from cultivated and uncultivated soils, and the variation of these losses in percentages of the 6-inch irrigation, are shown in figure 10.

The table following shows the variations between the losses during the two periods considered independently of each other.

[Bull. 248]

Variation in temperature, evaporation loss, and percentage of free moisture in two experiments at Davis, Cal.

Periods.	Mean temperature.	Mean soil temperature.	Mean water temperature.	Wind velocity per hour.	Evaporation loss from water surface.	Loss from uncultivated soil.	Loss from cultivated soil.	Loss saved by cultivation.	Free moisture.
First—May 5 to June 2.....	° F. 60.1	° F. 71.6	° F. 70.0	Miles. 9.00	Inches. 8.39	Pounds. 26.29	Pounds. 17.6	Per cent. 32.8	Per cent. 9.8
Second—June 5 to July 3.....	° F. 68.6	° F. 80.0	° F. 76.1	Miles. 9.75	Inches. 10.46	Pounds. 33.50	Pounds. 25.6	Per cent. 28.6	Per cent. 15.9

The heavy losses from June 5 to July 3 as compared with those from May 5 to June 2 are very noticeable both from the cultivated and the uncultivated soils. Although the average temperatures are

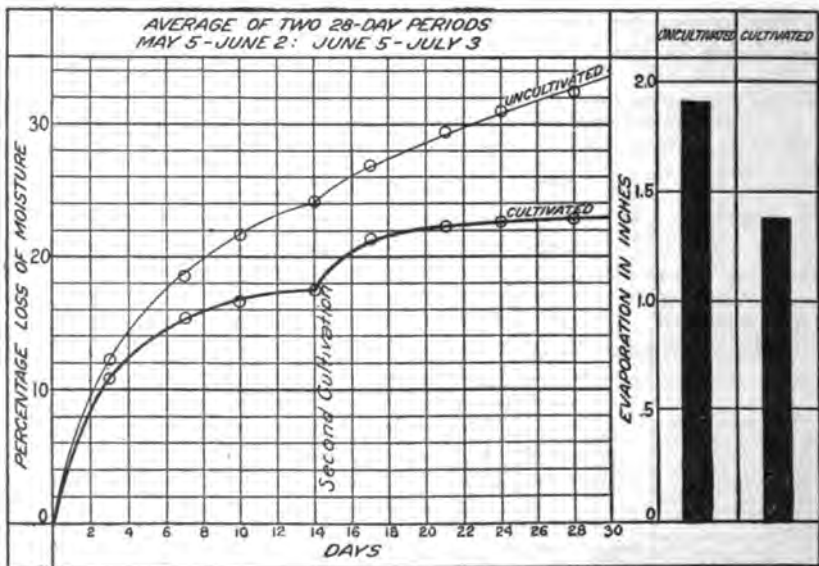


FIG. 10.—Average evaporation losses from cultivated and uncultivated tanks at Davis, Cal., May 5 to June 2 and June 5 to July 3, 1909.

considerably higher from June 5 to July 3, the differences were not great enough to account for the large variations in the evaporation from the soil surfaces, as the ratios existing between the losses from the soil were considerably greater than those existing between the losses from the water surfaces. The cause of the greater losses in the last trial was the excess of moisture in the soil at the beginning of the experiment.

From the results of the combined table for the two experiments, the uncultivated soil surfaces show a loss of 1.91 inches, which is 32 per cent of the 6 inches applied in the irrigation. Thirty-eight per cent of this was lost in the first three days. The cultivated surfaces

[Bull. 248]

show an equivalent loss of 1.36 inches, a saving of 28.2 per cent of the loss from the uncultivated surfaces. At least 40 per cent of the total loss from cultivated surfaces occurred in the period between irrigation and cultivation.

The cultivated surfaces showed an increased loss during the period of the second cultivation, but this loss lasted for only one three-day period, after which the losses became smaller than ever and continued to decrease until the end of the experiment. The losses from the uncultivated surfaces showed a very uniform decrease after the first week, but at the end of three weeks they were still quite heavy.

RESULTS AT RENO, NEV.

The site for those experiments was changed from that of the season of 1908 to the central portion of the Nevada Experiment Station. The new plat had been used previously for dry-farm crops, but the soil conditions were the same as those of the soil-mulch experiment of the previous season. The experiment was begun May 7 and extended through two periods—May 7 to June 4 and June 8 to July 6. The tanks were installed, filled, and irrigated after the methods described for the other stations.

Soil samples taken at the time of filling gave the following percentages of free moisture and show a very even distribution of moisture through the soil:

Percentage of free moisture in each foot of soil at beginning of the experiments.

Depth.	May 7.	June 8.
	<i>Per cent.</i>	<i>Per cent.</i>
1 foot.....	8.35	7.80
2 feet.....	8.35	9.40
3 feet.....	8.80	9.70
4 feet.....	9.20	9.40
Mean.....	8.68	9.08

The light texture of the soil, the low percentage of moisture before irrigation, and the warm weather made cultivation possible in each case within 24 to 30 hours after irrigation. Two weeks later a second cultivation was given.

[Bull. 248]

Climatological data and the average losses from the several tanks are given in the following tables:

Average temperature of air and soil, humidity, wind velocity, and rainfall at Reno, Nev. (May 7 to June 4 and June 8 to July 6, 1909).

Periods.	Days.	Mean temperature.	Mean soil temperature.	Mean humidity.	Mean wind velocity per hour.	Rainfall.
		° F.	° F.	Per cent.	Miles.	Inch.
First.....	3	52.2	64.8	52.3	6.15	.....
Second.....	4	51.2	68.3	51.1	5.40	0.02
Third.....	3	53.5	62.6	56.9	7.50	.26
Fourth.....	4	53.9	63.5	65.1	5.30	.01
Fifth.....	4	56.8	68.0	50.2	5.80	.08
Sixth.....	4	59.3	70.6	68.4	8.10	.....
Seventh.....	3	59.5	68.2	52.9	6.10	.02
Eighth.....	4	65.0	75.5	68.4	6.80	.....
Average.....	28	56.6	67.9	58.9	6.40	.....

Average evaporation losses from free-water surface and from cultivated and uncultivated surfaces at Reno, Nev. (May 7 to June 4 and June 8 to July 6, 1909).

Periods.	Days.	Loss from water surface.	Cultivated.				Uncultivated.			
			Tanks 1 and 2.		Tanks 3 and 4.		Tanks 5 and 6.		Tanks 7 and 8.	
Average weight of tanks at beginning of experiment, pounds.....			1,247		1,227		1,272		1,253	
Average loss:		Inches.	Lbs.	Per ct.	Lbs.	Per ct.	Lbs.	Per ct.	Lbs.	Per ct.
First.....	3	1.12	8.90	9.5	9.00	9.6	11.90	12.6	11.75	12.5
Second.....	4	1.12	2.40	2.6	2.60	2.8	1.90	2.0	3.50	3.7
Third.....	3	.94	.45	.5	.75	.8	1.30	1.4	1.25	1.3
Fourth.....	4	.61	1.40	1.5	.70	.7	2.60	2.8	2.30	2.5
Fifth.....	3	.76	1.29	1.3	1.00	1.1	2.00	2.1	1.85	2.0
Sixth.....	4	1.07	1.25	1.3	1.50	1.6	1.10	1.2	1.35	1.4
Seventh.....	3	1.36	1.00	1.1	1.00	1.1	1.00	1.1	1.40	1.5
Eighth.....	4	1.51	.50	.5	.50	.5	1.00	1.1	1.30	1.4
Average total loss.....	28	8.49	17.10	18.3	17.05	18.2	22.80	24.3	24.70	26.3
Equivalent of average loss in inches.....			1.09				1.51			

The losses are also shown graphically in figure 11.

These results show very small average losses from both cultivated and uncultivated soils, but when it is considered that this soil was a light, sandy, alluvial loam and that it contained a very low percentage of moisture before irrigation, it is probable that little resistance was offered to the passage of the water through the soil and that most of it collected in the bottom of the tanks out of reach of the forces of evaporation. The moisture determinations made at the end of the experiments bear this out, as the soil in the bottoms of the tanks in both instances contained an average of 17 per cent of free water as against an average of 9.2 per cent in the surface soil.

The average loss from the uncultivated surfaces shows a loss equal to 1.51 inches of water, 25.2 per cent of the 6-inch irrigation. Approx-

[Bull. 248]

imately 50 per cent of this was lost in the first three days. The losses are small and quite uniform for the remainder of the experiment. The average loss from the uncultivated surfaces amounts to 1.09 inches, which is a saving of 0.42 inch, or 27.8 per cent of the loss from the uncultivated surfaces. Fifty-two per cent of this loss occurred in the first three days, the period before and immediately after irrigation. No increased loss is shown at the time of the second cultivation, the soil having dried out to a depth of at least 3 inches. The losses after the first week were very uniform, a slight decrease being shown in the last four days of the experiment.

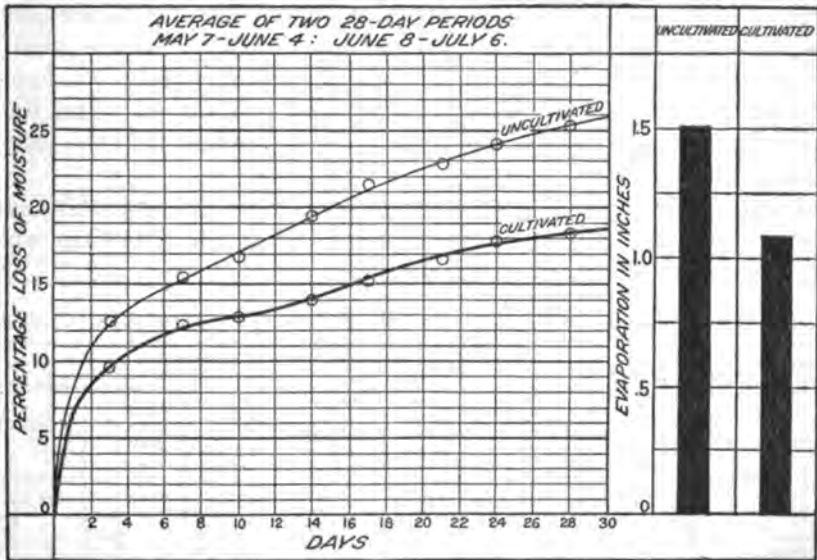


FIG. 11.—Average evaporation losses from cultivated and uncultivated tanks at Reno, Nev., May 7 to June 4 and June 8 to July 6, 1909.

RESULTS AT CALDWELL, IDAHO.

The site chosen for the experiments in Idaho was on the State substation farm at Caldwell, in the Boise Valley, 30 miles west of Boise. (See Pl. II, fig. 2, p. 24). The tanks were installed on a newly cleared tract which had never been plowed or irrigated. Mechanical analysis showed the surface soil to be a clay loam underlain with clay, which grades off into a sandy clay at a depth of 1 foot. This continued to a depth of 4 feet, where a stratum of cement gravel was encountered.

The first experiment ran from June 1 to June 29, and the second from July 3 to July 31. The usual procedure was followed in filling, irrigating, and weighing the tanks. As the tanks were filled, soil samples were taken, which showed the following moisture content—free water.

[Bull. 248]

Moisture content of soil at beginning of experiments.

Depth.	June 1.	July 3.
	<i>Per cent.</i>	<i>Per cent.</i>
1 foot.....	3.35	5.77
2 feet.....	8.70	5.06
3 feet.....	8.14	6.38
4 feet.....	7.00	5.31
Mean.....	6.80	5.63

An average period of 20½ hours elapsed from the time of the beginning of the irrigation until the water disappeared from the surface of the soil. This long period was probably due to the compactness of the soil and its general clay texture, which greatly retarded the percolation. A period of approximately 72 hours elapsed in each case between irrigation and cultivation. This long period was due also to the character of the soil, which held the water close to the surface.

During the month of June thermometers were not available, and the atmospheric and soil temperatures given in the following table are the results of July observations only:

Temperature of air, water, and cultivated and uncultivated soil, and rainfall at Caldwell, Idaho (July 3-31, 1909).

Periods.	Days.	Atmospheric temperature.	Temperature of cultivated soil. ¹	Temperature of uncultivated soil. ¹	Temperature of water. ¹	Rainfall. ²
		^{° F.}	^{° F.}	^{° F.}	^{° F.}	<i>Inch.</i>
First.....	3	79.0	69.3	71.2	70.5	0.01
Second.....	4	67.0	66.5	66.9	66.8	.01
Third.....	3	69.6	66.7	67.8	66.6	.00
Fourth.....	4	73.5	69.4	70.9	68.8	.00
Fifth.....	3	72.4	71.2	70.2	68.3	.09
Sixth.....	4	77.6	70.3	70.0	69.5	.....
Seventh.....	3	75.8	71.6	70.1	69.2	.....
Eighth.....	4	67.2	69.2	68.4	68.7	.03
Average.....	28	72.2	69.2	69.4	68.4	.....

¹ Taken at depth of 6 inches.

² Average of two periods—June 1-29; July 3-31.

[Bull. 248]

The following table gives the average losses from a free-water surface and from cultivated and uncultivated tanks by three and four day periods:

Average evaporation losses from free-water surface and from cultivated and uncultivated surfaces at Caldwell, Idaho (June 1-29 and July 3-31, 1909).

Periods.	Days.	Loss from water surface.	Cultivated.				Uncultivated.			
			Tanks 1 and 2.		Tanks 3 and 4.		Tanks 5 and 6.		Tanks 7 and 8.	
Average weight of tanks at beginning of experiment, pounds.....			1,172.2		1,185		1,172		1,169	
Average loss:		Inches.	Pounds.	Per ct.	Pounds.	Per ct.	Pounds.	Per ct.	Pounds.	Per ct.
First.....	3	1.15	20.40	21.7	20.25	21.6	22.00	23.4	22.50	23.9
Second.....	4	1.19	3.35	3.6	2.50	3.1	7.10	7.6	7.10	7.6
Third.....	3	.95	.65	.7	1.00	1.1	1.25	1.3	1.75	1.9
Fourth.....	4	1.42	.50	.5	.00	.0	1.00	1.1	.75	.8
Fifth.....	3	1.17	3.00	3.2	2.75	2.9	3.40	3.6	3.40	3.6
Sixth.....	4	1.50	1.75	1.9	1.35	1.4	1.75	1.9	1.35	1.4
Seventh.....	3	1.08	.25	.3	.25	.3	.25	.3	.25	.3
Eighth.....	4	1.35	.90	1.0	.90	1.0	1.00	1.1	.75	.8
Total.....	28	9.1	30.80	32.9	29.40	31.4	37.75	40.3	37.85	40.3
Equivalent loss in inches.....			1.91				2.42			

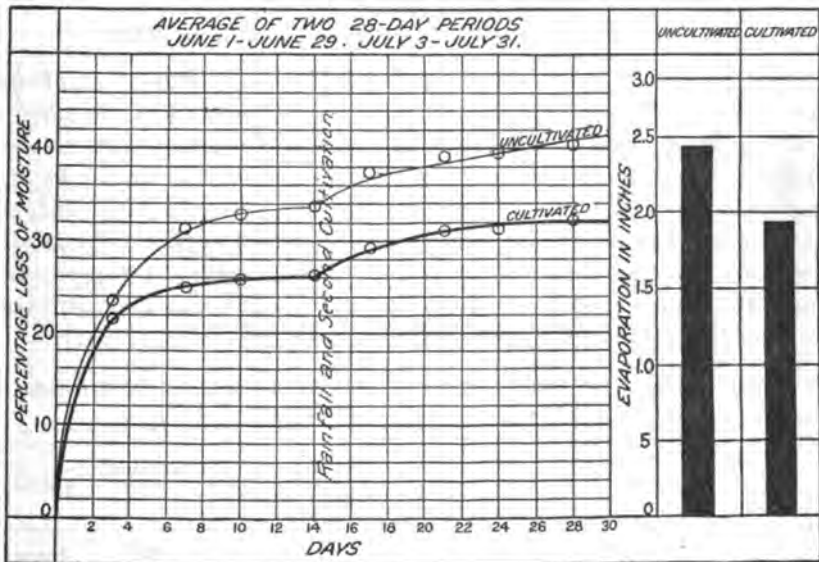


FIG. 12.—Average evaporation losses from cultivated and uncultivated tanks at Caldwell, Idaho, June 1-29 and July 3-31, 1909.

A comparison of the average losses from the cultivated and uncultivated surfaces, and the average losses for the different periods in percentages of the total irrigation, are shown in figure 12.

[Bull. 248]

The table shows very heavy losses from both the cultivated and uncultivated surfaces and that a very large percentage of this occurred in the period immediately after irrigation. These heavy losses were due entirely to the character of the soil. This type of soil allows a very slow penetration of water, and therefore much of the water is held in the surface layer, which has a tendency to compact and run together because of its clay texture, thus producing heavy losses. The increase in loss in the fifth period is due partly to the rainfall, 0.09 inch, and partly to the second cultivation which was practiced in that period. The losses are in a ratio of 1.91 inches for the cultivated to 2.42 inches for the uncultivated surfaces, giving a saving of 21.2 per cent of the loss from an uncultivated surface. Sixty-seven and one-half per cent of the total loss from the cultivated tanks took place in the first three days after irrigation, while the uncultivated tanks lost 59 per cent of the total in the same period. The losses in the first three days were 21.6 per cent and 23.7 per cent of the 6-inch irrigation, respectively, for the cultivated and uncultivated surfaces. This is the only instance recorded where the evaporation from a soil surface in a three-day period is greater than the evaporation from a free-water surface and shows the necessity of early and thorough cultivation.

RESULTS AT AGRICULTURAL COLLEGE, N. MEX.

This experiment was carried on from May 4 to June 1 and from June 4 to July 2, using the same site and equipment as in the experiment with soil mulches the previous season. Unfortunately, no soil samples were taken for moisture determinations either at the beginning or at the end of the experiment. Other valuable data, such as the time between irrigation and cultivation and the time required in irrigation, are also lacking. A record of atmospheric temperature, humidity, wind velocity, evaporation, and rainfall was kept and the averages for the two periods are shown in the following table:

Average temperature, humidity, wind velocity, and rainfall at Agricultural College, N. Mex. (May 4 to June 1 and June 4 to July 2, 1909).

Periods.	Days.	Mean temperature.	Mean humidity.	Mean wind velocity per hour.	Rainfall.
		[°] F.	Per cent.	Miles.	Inches.
First.....	3	77.0	15.0	8.1	.....
Second.....	4	72.0	16.0	8.4	.....
Third.....	3	73.0	20.5	9.4	.....
Fourth.....	4	74.0	25.0	8.4	.....
Fifth.....	3	74.0	24.0	7.3	0.57
Sixth.....	4	76.0	23.0	8.4	.....
Seventh.....	3	75.0	29.0	7.1	.....
Eighth.....	4	75.5	28.0	8.9	.....
Average.....	28	74.5	22.7	8.3	.....

[Bull. 248]

The following table and figure 13 give the average losses from a free-water surface and from the cultivated and uncultivated tanks by three and four day periods:

Average evaporation losses from free-water surface and from cultivated and uncultivated surfaces at Agricultural College, N. Mex.¹ (May 4 to June 1 and June 4 to July 2, 1909).

Periods.	Days.	Loss from water surface.	Cultivated.				Uncultivated.			
			Tanks 1 and 2.		Tanks 3 and 4.		Tanks 5 and 6.		Tanks 7 and 8.	
Average weight of tanks at beginning of experiment, pounds.....			1,441		1,406		1,442		1,446	
Average loss:		Inches.	Lbs.	Per ct.	Lbs.	Per ct.	Lbs.	Per ct.	Lbs.	Per ct.
First.....	3	1.35	11.57	12.3	12.51	13.3	11.57	12.3	10.05	10.7
Second.....	4	1.65	1.37	1.4	.91	1.0	2.73	2.9	2.28	2.4
Third.....	3	1.60	.99	1.1	1.59	1.7	2.62	2.8	2.05	2.2
Fourth.....	4	1.31	1.44	1.5	1.18	1.3	.91	1.0	1.63	1.7
Fifth.....	3	1.16	3.30	3.5	2.15	2.3	3.19	3.4	3.73	3.9
Sixth.....	4	1.38	1.01	1.1	.76	.8	2.20	2.3	1.33	1.4
Seventh.....	3	1.21	1.33	1.4	1.37	1.4	1.90	2.0	1.71	1.7
Eighth.....	4	1.47	.76	.8	.91	1.0	.61	.6	1.48	1.6
Total loss.....	28	11.13	21.77	23.1	21.38	22.8	25.73	27.3	24.25	25.6
Equivalent of average loss in inches.....			1.37				1.59			

¹ Actual losses from 27-inch tanks reduced to proportional losses from 23½-inch tanks.

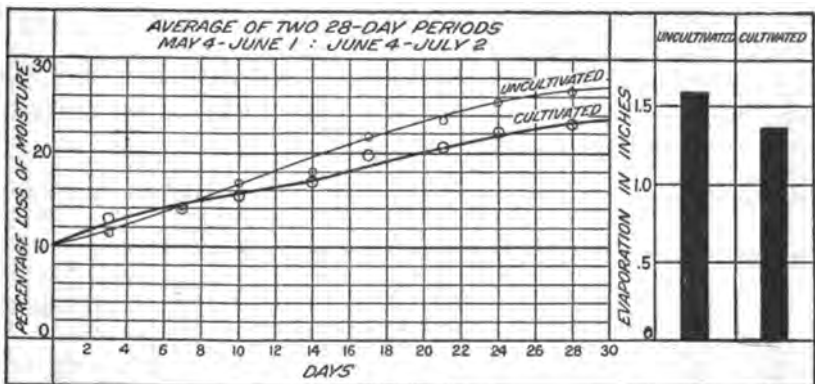


Fig. 13.—Average evaporation losses from cultivated and uncultivated tanks at Agricultural College, N. Mex., May 4 to June 1 and June 4 to July 2, 1909.

This table shows very little in favor of cultivation. The cultivated surface lost an equivalent of 1.37 inches of water; 22.8 per cent of the 6-inch irrigation and 55.8 per cent of this loss occurred in the first three days, probably before cultivation. The uncultivated soil lost 1.59 inches, which is 26.5 per cent of the 6-inch irrigation, and 43.2 per cent of this was lost in the first three days. The heavy losses in all of the tanks during the fifth period were due to the rainfall, 0.57 inch, during that period.

[Bull. 248]

The total saving in favor of cultivation is very small, averaging for the two months only 13.8 per cent of the amount lost from the uncultivated surface. This small difference is due to the character of the soil which, it will be remembered, is a sandy loam intermixed with gravel. This light, sandy soil has a tendency to mulch and after the first few days the losses drop rapidly away and then remain constant for the remainder of the experiment. The temperatures, wind velocities, etc., are very constant, although the mean temperatures are very high, and a heavy constant evaporation from the water surface is produced throughout.

RESULTS AT BOZEMAN, MONT.

Owing to leaks which developed in the tanks after they were installed, the results of the first trial of this experiment had to be discarded and it was not until July 25 that the experiment was finally gotten under way. Analysis of the soil gave 17.8 per cent of free moisture, and for this reason 5 instead of 6 inches of water was applied. Over 24 hours elapsed from the time irrigation was commenced until it was finally finished and a period of 4 full days elapsed between irrigation and cultivation. At the end of the experiment, moisture determinations show an average of 22.5 per cent of free moisture, very evenly distributed through the soil in the tanks. Even with this heavy moisture content no free water seems to have collected in the bottoms of the tanks.

The following tables give the climatological data and the losses from the free-water surface and the cultivated and uncultivated surfaces by three and four day periods:

Temperature of air, water, and cultivated and uncultivated soils, wind velocity, and rainfall at Bozeman, Mont. (July 25 to Aug. 22, 1909).

Periods.	Days.	Mean atmos- pheric tempera- ture.	Mean soil tem- perature unculti- vated.	Mean soil tem- perature culti- vated.	Mean water tempera- ture.	Mean velocity of wind per hour.	Rainfall.
		^{° F.}	^{° F.}	^{° F.}	^{° F.}	<i>Miles.</i>	<i>Inches.</i>
First.....	3	60.0	68.5	68.0	.....	11.4	.....
Second.....	4	61.7	.....	.....	.....	9.4	.....
Third.....	3	64.8	.....	.....	.....	8.3	0.35
Fourth.....	4	63.7	75.0	75.8	74.0	8.6	.....
Fifth.....	3	62.1	78.5	73.3	74.3	11.7	.11
Sixth.....	4	68.0	70.7	72.7	76.0	9.5	.21
Seventh.....	3	67.2	76.0	76.5	73.5	8.8	.31
Eighth.....	4	67.2	79.0	75.0	77.0	8.3	.....
Average.....	28	64.4	74.6	73.9	75.0	9.4	.....

[Bull. 248]

Evaporation losses from cultivated and uncultivated surfaces at Bozeman, Mont.¹ (July 25 to Aug. 22, 1909.)²

Periods.	Days.	Cultivated.				Uncultivated.			
		Tanks 1 and 2.		Tanks 3 and 4.		Tanks 5 and 6.		Tanks 7 and 8.	
Average weight of tanks at beginning of experiment, pounds.....		1, 238		1, 231		1, 264. 4		1, 229. 4	
Average loss:		<i>Lbs.</i>	<i>Per ct.</i>	<i>Lbs.</i>	<i>Per ct.</i>	<i>Lbs.</i>	<i>Per ct.</i>	<i>Lbs.</i>	<i>Per ct.</i>
First.....	3	10.90	11.6	11.40	12.1	11.90	12.6	9.90	10.5
Second.....	4	4.75	5.3	3.50	3.7	6.50	6.9	5.75	6.1
Third.....	3	3.80	4.2	5.50	5.8	6.80	7.2	7.00	7.5
Fourth.....	4	3.25	3.5	4.00	4.3	5.00	5.3	5.75	6.1
Fifth.....	3	4.20	4.5	3.00	3.2	5.20	5.5	4.50	4.8
Sixth.....	4	1.50	1.6	2.50	2.7	2.05	2.2	1.80	1.9
Seventh.....	3	7.10	7.5	5.10	5.4	6.10	6.5	4.10	4.4
Eighth.....	4	1.50	1.6	.35	.4	3.25	3.5	5.80	6.2
Total.....	28	37.00	39.8	35.35	37.6	46.80	49.7	44.60	47.5
Equivalent of total loss in inches.....		2.30				2.92			

¹ Although only 5 inches (78.5 pounds) was applied, owing to the high percentage of moisture (17.8 per cent) in the soil at the beginning of the experiment, the percentages of loss have been based on a 6-inch irrigation.

² Total loss by evaporation from free-water surface for 28 days, 4.38 inches.

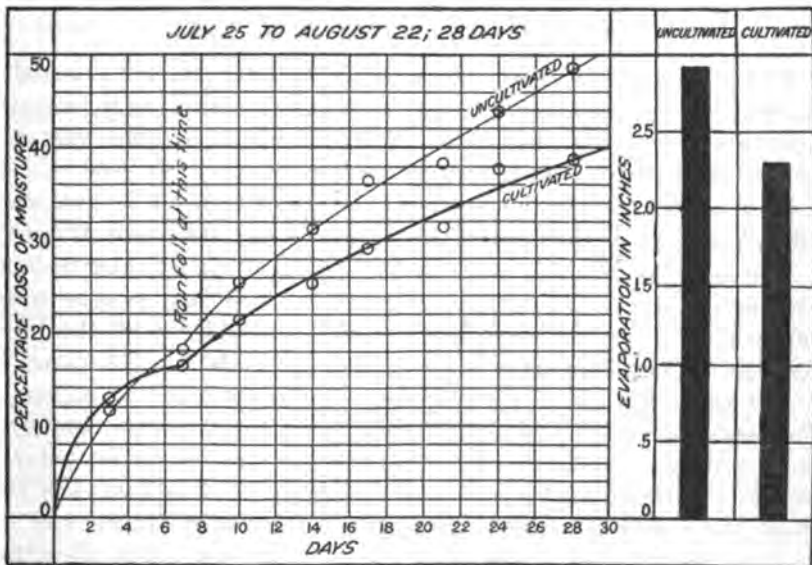


FIG. 14.—Evaporation losses from cultivated and uncultivated tanks at Bozeman, Mont., July 25 to August 22, 1909.

The total losses in inches and losses in percentage of a 6-inch irrigation by 3 and 4 day periods are shown in figure 14.

The most noticeable feature of these results is the enormous losses during every weighing period of the experiment, both from the cultivated and the uncultivated soils. These total losses amount to 2.30 inches and 2.92 inches, respectively, and show a saving of

[Bull. 248]

21 per cent in the loss on the cultivated as compared with the uncultivated soil.

These heavy losses are due to two causes: First, to the very heavy percentage of free moisture in the soil before irrigation; and second, to the rainfall, the heavy losses in the third and seventh periods being due to the latter cause. The rainfall affected both cultivated and uncultivated soils alike, increasing the evaporation and decreasing the difference between the cultivated and uncultivated surfaces. It is nevertheless seen that 31.5 per cent of the total loss, including the rainfall losses from the cultivated soils, takes place before cultivation. The rainfall, which amounted to 0.99 inch, came in light showers and was equivalent to adding 15½ pounds of water to each tank. This 15½ pounds corresponds to 42.8 per cent of the total moisture lost from the cultivated and 33.9 per cent of that lost from the uncultivated tanks. Deducting the loss before cultivation (first period) and the probable loss of all the added rainfall from the total loss gives 9.52 pounds loss from the cultivated and 19.30 pounds loss from the uncultivated soil. This gives a better idea of the saving by cultivation.

RESULTS AT WILLISTON, N. DAK.

Equipment similar to that used at the other stations was installed in 1909 at the Williston substation, in Williams County in the extreme northwestern part of the State. Williston has an average elevation of 1,875 feet, with a temperature ranging from 107° F. to -59° F., and a mean of 39.4°. The average annual rainfall is 15.07 inches, about 10 inches of which falls during April, May, June, July, and August.

The soil, typical of the lands included in the United States reclamation project at Williston, is largely bench lands, and ranges from a sandy gumbo on the lower benches to a sandy loam on the upper benches. Very little alkali is found, and that only in a few spots.

The tanks were filled early in August and the test was continued for three weeks. At the end of this period the moisture content of each tank was equalized by adding the amount lost by evaporation during the three weeks. An additional 4-inch irrigation was then given, four of the tanks being cultivated as soon as the soil was sufficiently dry, and the weighings were continued for another three weeks. Analysis of soil samples taken at the time of filling shows that they contained the low average of 3.7 per cent moisture in the first 4 feet of soil.

During the six-week period of the experiment a total of 1.26 inches of rain fell and this, coupled with the 10 inches of water applied in irrigation, produced a constant heavy loss from both the cultivated and the uncultivated surfaces, and in the end only a slight advantage was shown in favor of cultivation.

The following data were obtained for the six-week period: Mean temperature, 69° F.; mean soil temperature, 61.4°; mean water temperature, 69.6°; total rainfall, 1.26 inches; evaporation from free-water surface, 4.21 inches; average loss from cultivated tanks, 56.4 pounds, equivalent to 3.59 inches; average loss from uncultivated tanks, 62.4 pounds, equivalent to 3.98 inches.

The following tables give the climatological data and the average losses from the several surfaces for the different periods of the two experiments:

Average temperature of air, soil, and water, and rainfall at Williston, N. Dak. (Aug. 4 to 24 and Aug. 24 to Sept. 14, 1909.)

Period.	Days.	Mean temperature.	Mean soil temperature. ¹	Mean water temperature. ¹	Rainfall.
		° F.	° F.	° F.	Inches.
First.....	3	70.9	64.0	71.3	0.18
Second.....	4	62.8	58.2	67.7	.17
Thrd.....	3	70.7	65.8	71.4	.....
Fourth.....	4	67.7	58.2	72.0	.54
Fifth.....	3	67.8	61.3	69.7	.....
Sixth.....	4	67.3	60.8	65.6	.37
Average.....	21	64.5	61.1	69.5	.....

¹ Taken from depth of 3 inches.

Average evaporation losses from free-water surfaces and from cultivated and uncultivated surfaces at Williston, N. Dak. (Aug. 4 to 24 and Aug. 24 to Sept. 14, 1909.)

Period.	Days.	Loss from water surface.	Cultivated.				Uncultivated.			
			Tanks 1 and 2.		Tanks 3 and 4.		Tanks 5 and 6.		Tanks 7 and 8.	
Average weight of tanks at beginning of experiment, pounds.....			1,042		1,040		1,050		1,010	
Average loss:		Inches.	Lbs.	Per ct.	Lbs.	Per ct.	Lbs.	Per ct.	Lbs.	Per ct.
First.....	3	0.62	11.15	11.9	12.45	13.2	11.55	12.3	9.45	10.0
Second.....	4	.83	3.85	4.1	2.65	2.8	4.35	4.6	3.75	4.0
Thrd.....	3	.56	3.00	3.2	4.10	4.4	4.95	5.3	3.40	3.6
Fourth.....	4	.74	3.50	3.7	2.25	2.4	4.10	4.4	4.60	4.9
Fifth.....	3	.57	2.30	2.4	3.80	4.1	6.35	6.8	5.70	6.1
Sixth.....	4	.89	4.45	4.7	3.70	3.9	2.30	2.4	2.00	2.1
Total.....	21	4.21	28.25	30.0	28.95	30.8	33.60	35.8	28.90	30.7
Equivalent of average total loss in inches.....			1.82		1.90		1.90		1.90	

The total losses in inches and the losses in percentages of a 6-inch irrigation by 3 and 4 day periods are shown in figure 15.

[Bull. 248]

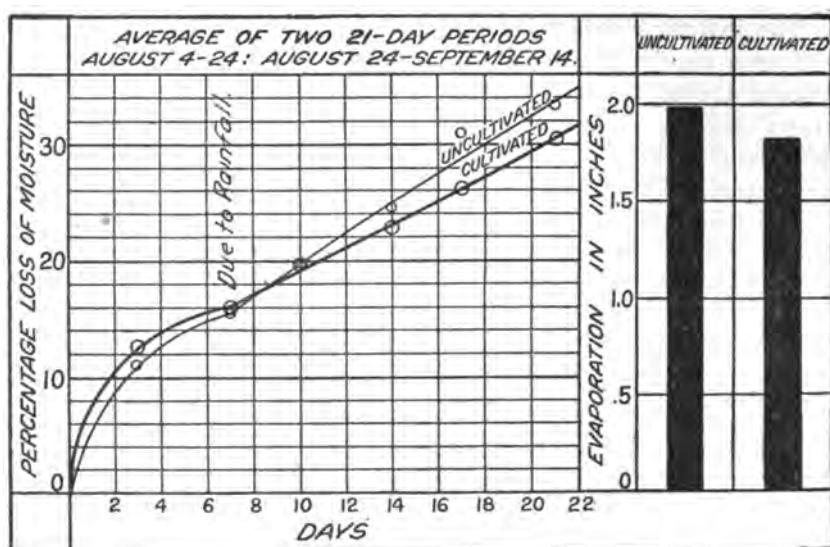


FIG. 15.—Average evaporation losses from cultivated and uncultivated tanks at Williston, N. Dak., August 4-24 and August 24 to September 14, 1909.

SUMMARY AND CONCLUSIONS.

The results of the observations from six of the seven stations ¹ have been compiled into the accompanying table, showing average evaporation losses from soil and water, rainfall, mean wind velocity, humidity, and atmospheric temperatures for each three and four day period of the experiment:

*Average mean temperature of soil, mean humidity and wind velocity, and average loss from free-water surface and from cultivated and uncultivated surfaces at the six stations, by three and four day periods.*²

Period.	Days.	Mean temperature of air.	Mean humidity. ³	Mean velocity of wind per hour. ⁴	Loss from water surface. ⁵	Cultivated.				Uncultivated.			
						Tanks 1 and 2.		Tanks 3 and 4.		Tanks 5 and 6.		Tanks 7 and 8.	
		° F.	P. ct.	Miles.	Ins.	Lbs.	P. ct.	Lbs.	P. ct.	Lbs.	P. ct.	Lbs.	P. ct.
First.....	3	66.1	40.4	8.5	1.17	12.67	13.5	12.63	13.4	13.23	14.1	12.60	13.4
Second.....	4	62.9	38.8	8.0	1.29	3.31	3.5	2.72	2.9	5.79	6.2	5.81	6.2
Third.....	3	64.7	41.7	9.3	1.18	1.32	1.6	2.06	2.2	3.58	3.8	3.36	3.6
Fourth.....	4	65.2	51.6	7.9	1.08	1.39	1.5	1.10	1.2	2.25	2.4	2.81	3.0
Fifth.....	3	66.5	42.7	8.3	1.06	3.24	3.4	2.73	2.9	3.19	3.4	3.12	3.3
Sixth.....	4	68.7	43.8	9.0	1.33	.67	.7	.93	1.0	1.87	2.0	1.55	1.6
Seventh.....	3	67.5	42.4	8.2	1.22	1.96	2.1	1.41	1.5	2.17	2.3	1.66	1.8
Eighth.....	4	68.8	47.0	7.9	1.38	.80	.9	.68	.7	1.73	1.8	2.28	2.4
Average.....	28	66.3	43.8	8.4									
Total for 28 days.....					9.71	25.56	27.2	24.26	25.8	33.81	36.0	33.19	35.3
Equivalent of total loss in inches.....							1.58				2.13		

¹ Williston, N. Dak., omitted, as experiments were run only 21 days.

² In compiling averages, the losses at Agricultural College, New Mexico station have been reduced to proportional losses from tanks of similar size to those used at other stations.

³ Average of three stations: Davis, Cal.; Reno, Nev.; Agricultural College N. Mex.

⁴ Average four stations: Davis, Cal.; Reno, Nev.; Bozeman, Mont.; and Agricultural College, N. Mex.

⁵ Average four stations: Davis, Cal.; Reno, Nev.; Agricultural College, N. Mex.; and Caldwell, Idaho.

The average evaporation losses in pounds by three and four day periods and the total losses in inches for the different periods of the experiments are also shown in figure 16.

The average total losses shown by the above data are 2.13 inches from the uncultivated and 1.58 inches from the cultivated soils, being 35.5 and 26.3 per cent, respectively, of the total 6 inches used in irrigation. Thus it is seen that cultivation reduced the loss more than 25.8 per cent. Fifty-one per cent of the loss from the cultivated surface occurred in the first three days; that is, during the average period between irrigation and cultivation, while during the same period the uncultivated tanks lost 38.5 per cent of the total. The saving due to cultivation when figured in percentages is naturally

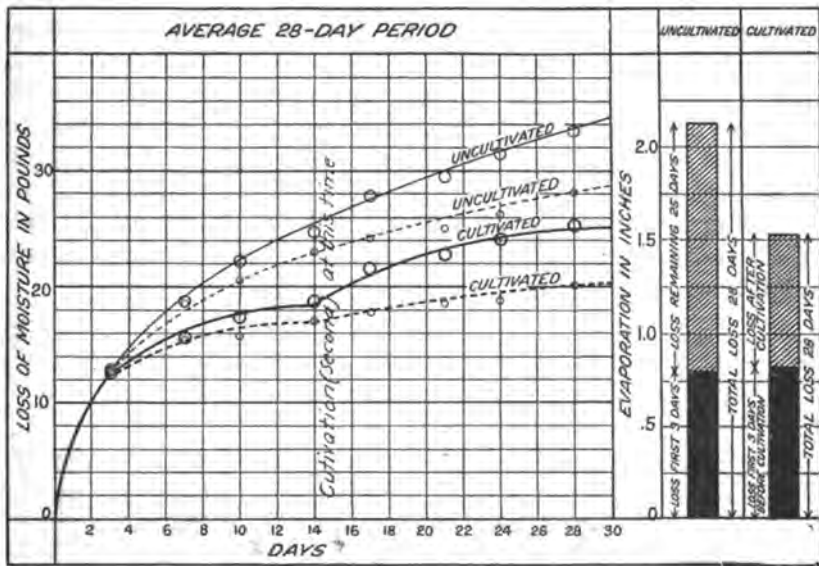


FIG. 16.—Average evaporation losses from cultivated and uncultivated tanks during first 28 days after irrigation; average of losses at six stations.

low because of these heavy first losses. If the losses during the first three days in each case are disregarded, however, and only the losses after the first cultivation are considered, the saving due to cultivation averages 40 per cent of the loss from the uncultivated soil.

The most noteworthy feature of this experiment was the uniformly heavy losses immediately after irrigation. This emphasizes the necessity of early cultivation, especially in the heavier soils, where the percolation of moisture through the soil is slow and the moisture content of the surface soil is high. The actual saving of water may be small to the irrigator having an abundant water supply at hand, but it is well to remember that the saving of 0.5 to 1 inch of water per

irrigation amounts to several inches during the season and often marks the dividing line between success and failure as regards the crop.

The value of deep mulches in checking evaporation and in improving the condition of the soil has been discussed under the previous experiment, and these advantages are directly applicable to cultivation as well, because it is by cultivation that the soil mulch is produced, the depth and fineness of the mulch depending entirely upon the depth, the manner, and the frequency of cultivation.

In figure 16 the solid lines represent the total loss in pounds from cultivated and uncultivated soils, and the dotted lines represent the same losses after the rainfall for the different periods has been deducted. The irregularities in the solid curves are no doubt due to the evaporation of the rainfall, and when this has been deducted more uniform curves result.

Both curves of the cultivated soils show a decided break after the fourteenth day, due to the increased evaporation from the fresh soil turned up by cultivation at that time. After this small increase in loss the curves drop back and the losses for the remainder of the experiment appear smaller than ever. The results obtained at each of these stations have been assembled for the sake of comparison in the following table:

Summary of temperature of air, soil, and water, humidity, wind velocity, rainfall, free water in soil, and losses from free-water surface and from cultivated and uncultivated tanks at the several stations.

Stations.	Number of trials.	Temperatures.				Humidity.	Average wind velocity per hour.	Total rainfall.	Free water in soil.	Evaporation from free-water surface.	Loss from cultivated soils.	Loss from uncultivated soils.	Saved by cultivation.
		A t m o s - pheric.	Cultivated soil.	Uncultivated soil.	Water.								
		^{° F.}	^{° F.}	^{° F.}	^{° F.}	<i>P. ct.</i>	<i>Miles</i>	<i>In.</i>	<i>P. ct.</i>	<i>In.</i>	<i>In.</i>	<i>In.</i>	<i>P. ct.</i>
Sunnyside, Wash.....	1	65.2	71.3	74.3	70.9	.....	.....	0.00	6.00	7.25	1.47	2.47	40.3
Davis, Cal.....	2	64.5	.....	75.7	73.2	49.8	9.3	.00	12.85	9.41	1.36	1.91	28.2
Reno, Nev.....	2	56.6	.....	67.9	.....	58.9	6.4	.39	8.88	8.49	1.09	1.51	27.8
Caldwell, Idaho.....	2	72.2	69.2	69.4	68.4	.....	.....	.14	6.21	9.81	1.91	2.42	21.0
Agricultural College, N. Mex.....	2	74.5	.....	.....	.....	22.7	8.3	.57	.....	11.13	1.37	1.59	13.8
Bozeman, Mont.....	1	64.4	73.9	74.6	75.0	.....	.....	.99	17.80	4.38	2.30	2.92	21.2
Average.....	.....	66.2	71.5	72.4	72.9	43.8	8.4	.35	10.35	8.41	1.58	2.14	26.4

There are three factors which may be said to control the evaporation from soil surfaces: (1) The percentage of moisture in the soil; (2) the general character of the soil, its composition, compactness, and general texture; and (3) climatology, including temperatures, humidity, wind movement, etc. Of these the percentage of moisture in the soil again seems to have the most decided influence. The table above shows that the percentage saved by cultivation varies through-

[Bull. 248]

out with the rainfall, and consequently with the percentage of moisture in the top layer of soil. Thus in Washington and California, where no rain fell during the experiment, the effects of cultivation showed up to far better advantage than in Montana and New Mexico, where the initial percentage of moisture in the soil was large and the rainfall the greatest shown. Montana, with low temperatures and a small evaporation from a free-water surface, 4.38 inches, other things being equal, should give the least loss from soil surfaces. This was not the case, as the climatological effect was entirely overbalanced by the rainfall and moisture content of the soil before irrigation.

It is further noticeable that the best results were obtained from the heavier soils, which, when irrigated, have a tendency to compact and run together, affording an excellent opportunity for heavy losses from the uncultivated surfaces, and therefore showing a larger saving when cultivation is practiced. There is a tendency in light, sandy soils for the uncultivated surfaces to mulch themselves, and after the first few days following the irrigation the losses diminish very rapidly, and in the end little advantage is shown in favor of cultivation.

EFFECTS OF SHALLOW AND DEEP FURROW IRRIGATION.

The heavy evaporation losses from soil surfaces during the period between irrigation and cultivation exemplified in the foregoing experiments (see pp. 31-51) naturally led to the investigation of methods designed to check the heavy losses occurring before cultivation is possible. As stated formerly, these losses depend principally upon the percentage of moisture in the soil and to a lesser extent upon the character of the soil and the climate.

In localities where the available water supply is limited and where the duty of water is high, conditions have forced the irrigator to adopt methods of irrigation less wasteful of water than that of flooding the entire surface. This accounts in part for the introduction of furrows. Of late years, in orchard irrigation in particular, where this method is most in vogue, there has been a growing tendency toward fewer and deeper furrows with one heavy irrigation every four to six weeks, rather than a greater number of shallow furrows with a lighter irrigation at short intervals. The advantages and disadvantages of both of these methods are discussed in a former bulletin of this office,¹ but, generally speaking, the adoption of any one method is controlled almost entirely by local conditions, such as the available water supply, the character of the soil, and the character of the crop irrigated.

In order to gain some idea of the actual saving, if any, of deep irrigation over shallow irrigation, the part of the season of 1909

¹ U. S. Dept. Agr., Office Expt. Stas. Bul. 177.

remaining after the other experiment was completed was devoted to experiments dealing with that subject. These experiments were carried on at each of the seven stations already described. Each of the eight tanks was refilled with fresh soil, replaced foot for foot in as nearly its natural position as possible, and tamped to its original compactness.

After taking soil samples for moisture determinations the tanks were weighed and 94 pounds, equivalent to a 6-inch irrigation, was given to each of the tanks in the following manner: Tanks 1 and 2 were flooded over the entire surface; tanks 3 and 4 were irrigated in furrows 3 inches deep; tanks 5 and 6 were irrigated in furrows 6 inches deep; and tanks 7 and 8 were irrigated in furrows 9 inches deep. In applying the water the flow was so regulated that only the bottom of each furrow was wet, and the water at no time stood more than 2 inches deep in the furrows.

As soon after irrigation as the soil in any tank became sufficiently dry it was cultivated thoroughly to a depth of 6 inches. The tanks were weighed regularly twice a week for a period of four weeks, when they were emptied, refilled with fresh soil, and the test repeated during the next 28 days. In making the furrows and in cultivating after irrigation an effort was made to approach as nearly as possible actual field conditions.

As the local conditions, sites, and equipment have been described previously, mention will be made only of those cases where changes occurred.

RESULTS AT DAVIS, CAL.

The experiment was carried on during two periods—July 7 to August 7 and August 7 to September 7, 1909. In applying the water the flooded surfaces were covered continually to a depth of at least 1 inch, and an attempt was made to maintain a depth of one-half to 1 inch of water in the furrows.

The following preliminary observations were made:

Preliminary observations in tank experiments at Davis, Cal.

Method of irrigation.	Weight of soil before irrigation.	Free moisture in soil.	Length of irrigation.	Time between irrigation and cultivation.
	Pounds.	Per cent.	Hours.	Hours.
Flooded.....	945	5.6	3	74
3-inch furrows.....	941	5.5	4½	45
6-inch furrows.....	904	6.0	5½	26½
9-inch furrows.....	888	5.2	5½	22

The different periods required to irrigate are due to the fact that in the deeper furrows a slower application was necessary to prevent

[Bull. 248]

the furrows from being destroyed. In each case cultivation was practiced as soon as the soil was sufficiently dry.

The average evaporation losses and climatology summary are shown in the following table:

Climatological data and the mean temperature of the soil and water at Davis, Cal. (average of two periods—July 7 to Aug. 7 and Aug. 7 to Sept. 7, 1909).

Periods.	Days.	Mean atmos- pheric tempera- ture.	Mean soil tempera- ture. ¹	Mean water tempera- ture. ¹	Humid- ity.	Velocity of wind per hour.
		^{° F.}	^{° F.}	^{° F.}	Per cent.	Miles.
First.....	3	68.5	82.1	77.0	47.8	8.53
Second.....	4	72.4	83.0	77.3	48.7	8.80
Third.....	3	72.2	83.5	78.5	45.6	7.07
Fourth.....	4	72.3	83.6	76.8	41.8	9.05
Fifth.....	5	71.6	83.0	77.7	43.3	7.73
Sixth.....	6	72.7	83.3	80.0	41.3	5.96
Seventh.....	3	71.1	83.1	78.0	45.3	7.28
Eighth.....	4	72.1	84.2	78.9	44.7	6.68
Total and average.....	32	71.8	83.3	78.1	44.4	7.85

¹ Taken at depth of 6 inches.

Evaporation losses from free-water surface and from surfaces irrigated by flooding and with furrows of different depths at Davis, Cal. (averages of two periods—July 7 to Aug. 7 and Aug. 7 to Sept. 7, 1909).

Periods.	Days.	Loss from water surface.	Flooded, tanks 1 and 2.		3-inch furrows, tanks 3 and 4.		6-inch furrows, tanks 5 and 6.		9-inch furrows, tanks 7 and 8.	
Average weight of tanks at begin- ning, pounds.....			1,039		1,036		1,010		982	
Average loss:		Inches.	Pounds.	Per ct.	Pounds.	Per ct.	Pounds.	Per ct.	Pounds.	Per ct.
First.....	3	1.04	10.10	10.7	6.60	7.0	5.40	5.7	4.50	4.8
Second.....	4	1.48	4.40	4.7	3.15	3.3	3.25	3.5	2.50	2.7
Third.....	3	1.03	1.35	1.4	1.75	1.9	1.85	2.0	2.10	2.2
Fourth.....	4	1.54	1.25	1.3	1.60	1.7	1.00	1.1	.90	1.0
Fifth.....	5	1.00	1.50	1.6	2.15	2.3	1.75	1.9	1.40	1.5
Sixth.....	6	1.33	1.50	1.6	1.00	1.1	.90	1.0	1.10	1.2
Seventh.....	3	1.06	1.75	1.9	.40	.4	.60	.6	1.00	1.1
Eighth.....	4	1.31	.90	1.0	.25	.3	.60	.6	.40	.4
Total loss.....	32	9.79	22.75	24.2	16.90	18.0	15.35	16.4	13.90	14.9
Equivalent loss in inches.....			1.45		1.08		.98		.88	

The results for the first 28 days in the above table are shown graphically in figure 17.

In case of the 3-inch furrows it was observed that although no more than 1 inch in depth of water was maintained in the furrows during irrigation, the moisture rose until practically the whole of the surface was covered. The surface soil, however, contained much less moisture than that of the flooded tanks. With the 6-inch furrows, the moisture rose to the surface of the soil immediately adjoining the furrows, the moisture showing over about one-half of the

[Bull. 248]

area of the tanks. The moisture did not rise within 3 inches of the surface at any one place with the 9-inch furrows, and a perfectly dry mulch covered the entire surface with the exception of the wet part of the furrow, which averaged one-fourth of the soil surface. When the tanks containing the 9-inch furrows were cultivated, moist soil was turned up. In each case the percentage of moisture at a depth of 6 inches seemed to vary with the depth of the furrows. The moisture percentage in the top soil determined the period between irrigation and cultivation and the smaller percentage present accounts for the shorter period in the case of the deep-furrowed tanks. Of course the distribution of moisture in the top soil after irrigation

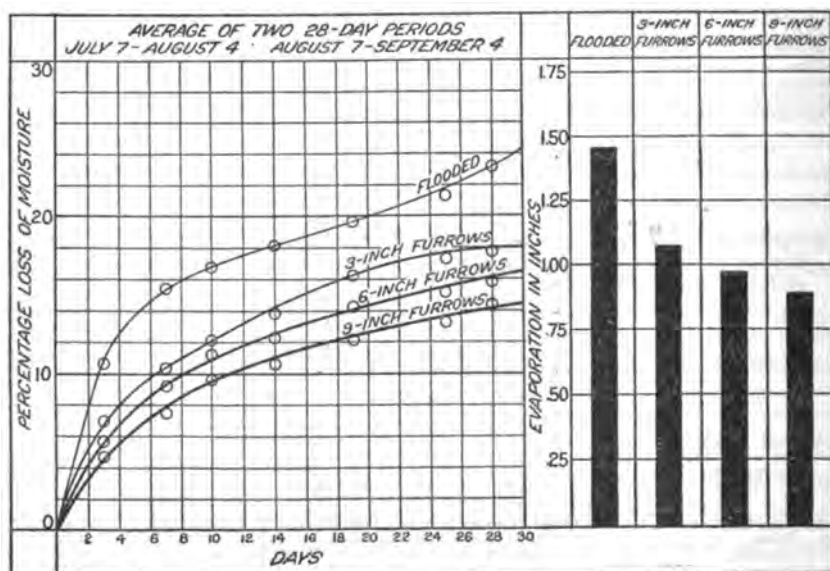


FIG. 17.—Average evaporation losses from tanks irrigated by flooding and with furrows of different depths at Davis, Cal., July 7 to August 4 and August 7 to September 4, 1909.

depends upon the amount of water applied, the time required to apply it, the compactness and general texture of the soil, and the percentage of moisture present before irrigation.

The table given above shows that the chief advantage in deep-furrow irrigation comes in the period immediately following the application of water. The total loss from the flooded surface was 1.45 inches, of which 45 per cent was lost during the first three days, the period between irrigation and cultivation. The application of the water in the 3, 6, and 9 inch furrows reduced the losses during the first three days 35, 47, and 55 per cent, respectively. The most noticeable feature in this experiment was the very uniform climatic conditions existing throughout, and the corresponding uniform losses

[Bull. 248]

from both soil and water surfaces. A range of but 4.2° was shown in the mean atmospheric temperatures, and but 4.7 per cent in the humidities, while a maximum daily variation of but 0.05 inch was recorded in the evaporation losses from a free-water surface.

RESULTS AT WILLISTON, N. DAK.

This test was started on September 15 and ended October 9, 1909. The same sort of tanks was used as at the other stations. The tanks were filled with fresh soil, after the usual method, and soil samples were taken which gave the following free-moisture content: Tanks 1 and 2, 3.50 per cent; tanks 3 and 4, 4.03 per cent; tanks 5 and 6, 4.40 per cent; tanks 7 and 8, 4.25 per cent.

Irrigation was commenced at 7.30 a. m. September 15, and continued six hours, the water being allowed to run slowly into the furrows, the intention being to approach as nearly as possible the natural field conditions. Only a 3-inch irrigation, 47 pounds, was applied at this time. As soon as the irrigation was completed the furrows were filled with dry soil, but the tanks were not cultivated until three days later. On September 25, another irrigation of 2 inches, 31.4 pounds, was given in a four-hour period, the furrows were refilled immediately, and a 6-inch cultivation given at the end of three days.

The records of the atmospheric, water, and soil temperatures, and the rainfall during the experiment are given in the following table:

Mean temperature of air, water, and soil and the rainfall at Williston, N. Dak., Sept. 15 to Oct. 9, 1909.

Period.	Mean atmospheric temperature.	Mean water temperature.	Mean soil temperature. ¹	Rainfall.
	$^{\circ}$ F.	$^{\circ}$ F.	$^{\circ}$ F.	Inches.
Sept. 15-18.....	60.0	60.8	51.3	.....
Sept. 18-21.....	57.6	57.8	49.8	.....
Sept. 21-25.....	49.2	52.8	39.9	0.36
Sept. 25-28.....	62.6	57.5	48.5	.....
Sept. 28-Oct. 2.....	64.2	60.8	52.4	.....
Oct. 2-5.....	55.4	55.3	48.0	.....
Oct. 5-9.....	58.0	53.5	43.0	.....
Average 24 days.....	57.6	56.8	47.3	.....

¹ Taken at depth of 3 inches at 8 a. m.

The losses by evaporation from the free-water surface and the several tanks are given in the table following by three and four day periods.

[Bull. 248]

Evaporation losses from free-water surface and from surfaces irrigated by flooding and with furrows of different depths, Williston, N. Dak., Sept. 15 to Oct. 9, 1909.

Period.	Loss from water surface.	Flooded, tanks 1 and 2.		3-inch furrows, tanks 3 and 4.		6-inch furrows, tanks 5 and 6.		9-inch furrows, tanks 7 and 8.	
Average weight of tanks at beginning, pounds.....		1,030.0		1,033.2		1,020.8		1,010.5	
Average loss:	<i>Inches.</i>	<i>Lbs.</i>	<i>Per ct.</i> ¹	<i>Lbs.</i>	<i>Per ct.</i>	<i>Lbs.</i>	<i>Per ct.</i>	<i>Lbs.</i>	<i>Per ct.</i>
Sept. 15-18.....	0.485	4.85	10.3	1.95	4.1	2.35	5.0	1.95	4.1
Sept. 18-21.....	.556	4.25	9.0	1.50	3.2	1.50	3.2	1.75	3.7
Sept. 21-25.....	.300	5.90	12.6	4.40	9.4	2.90	6.2	3.15	6.7
<i>2-inch irrigation.</i>									
Sept. 25-28.....	.444	7.15	8.5	3.40	4.0	.45	.5	.40	.6
Sept. 28-Oct. 2.....	.749	4.50	5.4	3.25	3.9	1.70	2.0	.75	.9
Oct. 2-5.....	.480	3.50	4.2	2.00	2.4	1.25	1.5	1.25	1.5
Oct. 5-9.....	.526	1.75	2.1	1.25	1.5	1.50	1.8	.50	.6
Total loss.....	3.600	31.90		17.75		11.65		9.75	
Equivalent loss in inches.....		2.03		1.13		0.74		0.62	

¹ The percentage of loss for the first 10 days is figured on a basis of 47 pounds (3-inch irrigation), that of the other periods and total loss on a basis of 84 pounds (5-inch irrigation plus 0.36 inch rainfall).

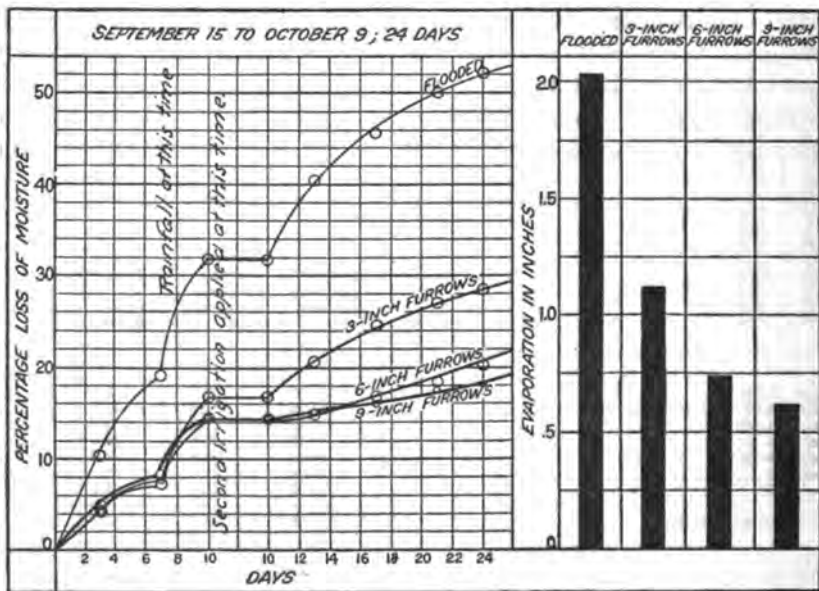


FIG. 18.—Evaporation losses from tanks irrigated by flooding and with furrows of different depths at Williston, N. Dak., September 15 to October 9, 1909.

The total losses and the percentages of the losses of the total irrigation by 3 and 4 day periods are shown graphically in figure 18.

Although the method of procedure varied considerably from that of the other stations, nevertheless, interesting results were obtained. The heavy losses in all of the tanks from September 21 to 25 were due to the rainfall of 0.36 inch in that period. The loss from the

[Bull. 248]

flooded surfaces during this period almost equaled the evaporation loss from a free-water surface, while in the three days succeeding the 2-inch irrigation the same tanks showed a loss of 0.01 inch greater than that from a free-water surface. These results show that the controlling factor in evaporation from soils is the content of free moisture in the surface layer of soil.

The first losses from the tanks which were furrowed were comparatively small, due to the furrows being filled with dry soil. The smallness of the losses was most noticeable after the second irrigation of September 25, at which time the losses from the 6 and 9 inch furrows showed no increase until after cultivation had been practiced.

The total loss from the flooded surface was 2.03 inches, which was over 56 per cent of the loss from a free-water surface. The application of the water in 3, 6, and 9 inch furrows prevented 44.2, 62.5, and 69.5 per cent, respectively, of the loss from the flooded surfaces.

RESULTS AT RENO, NEV.

This experiment extended through two periods of 28 days each—July 8 to August 5, and August 10 to September 7, 1909. The irrigation in each case continued seven and one-half to eight hours, and the flow was so regulated that water was kept standing in all of the furrows during the entire period of application. Within one-half hour after the completion of the irrigation the tanks irrigated with 6 and 9 inch furrows were cultivated to a depth of 6 inches and 24 hours later the other tanks were cultivated. No rain fell during July, but toward the last of August 0.1 inch was recorded and consequently on September 2 all tanks were given a 6-inch cultivation, but the rainfall was so slight that no appreciable effect was noticeable in the results.

Soil analyses of the samples taken when the tanks were filled gave the following moisture percentages: July 8: Tanks 1 and 2, 7; tanks 3 and 4, 8.7; tanks 5 and 6, 8.76; tanks 7 and 8, 9.40. August 10: Tanks 1 and 2, 5.67; tanks 3 and 4, 7; tanks 5 and 6, 8.78; tanks 7 and 8, 8.22.

[Bull. 248]

The following table, based on the averages of the two periods, gives the climatological data and the mean water and soil temperatures:

Climatological data and the mean water and soil temperatures for Reno, Nev. (average of two periods—July 8 to Aug. 5 and Aug. 10 to Sept. 7, 1909).

Periods.	Days.	Mean atmospheric temperature.	Mean soil temperature. ¹	Mean water temperature.	Humidity.	Velocity of wind per hour.	Rainfall.
		° F.	° F.	° F.	Per cent.	Miles.	Inches.
First.....	3	64.6	78.3	76.2	60.0	5.90	.....
Second.....	4	66.2	78.8	76.0	44.1	5.35	.....
Third.....	3	67.0	79.8	74.7	50.3	6.12	.....
Fourth.....	4	68.6	78.4	75.2	44.3	5.90	.....
Fifth.....	3	64.1	80.8	75.3	33.0	6.90	.....
Sixth.....	4	64.3	79.7	74.7	27.0	4.72	0.05
Seventh.....	3	65.2	81.6	77.8	29.1	5.12	.05
Eighth.....	4	63.4	84.7	77.6	25.1	5.40	.....
Average.....	28	65.5	80.4	75.9	38.2	5.63	.....

¹ Taken at depth of 6 inches.

The following table gives the average evaporation from the free-water surface and the average losses from the several tanks in pounds and in percentage of total amount applied:

Evaporation losses from free-water surface and from surfaces irrigated by flooding, and with furrows of different depths at Reno, Nev. (average of two periods—July 8 to Aug. 5 and Aug. 10 to Sept. 7, 1909).

Periods.	Days.	Loss from water surface.	Flooded, tanks 1 and 2.		3-inch furrows, tanks 3 and 4.		6-inch furrows, tanks 5 and 6.		9-inch furrows, tanks 7 and 8.	
Average weight of tanks at beginning, pounds.....			1,326.5		1,286.5		1,263.5		1,279.0	
Average loss:		Inches.	Lbs.	Per ct.	Lbs.	Per ct.	Lbs.	Per ct.	Lbs.	Per ct.
First.....	3	1.17	8.15	8.7	5.30	5.6	2.60	2.8	1.20	1.3
Second.....	4	1.51	1.95	2.1	2.00	2.1	1.75	1.9	1.20	1.3
Third.....	3	1.37	2.30	2.4	1.40	1.5	1.00	1.1	1.15	1.2
Fourth.....	4	1.66	1.05	1.1	.70	.7	1.00	1.1	.80	.9
Fifth.....	3	1.24	.70	.7	1.45	1.6	1.60	1.7	.85	.9
Sixth.....	4	1.61	.75	.8	1.45	1.6	1.40	1.5	1.05	1.1
Seventh.....	3	1.08	.90	1.0	1.40	1.5	1.40	1.5	1.45	1.6
Eight.....	4	1.49	.75	.8	.65	.7	.75	.8	1.00	1.1
Total loss.....	28	11.13	16.55	17.6	14.35	15.3	11.50	12.4	8.70	9.4
Equivalent loss in inches.....			1.05		.91		.73		.55	

The data contained in these tables are shown graphically in figure 19.

These results compare very favorably with those obtained at the California station, although a greater advantage is shown in favor of the deeper furrows. At each of these two stations very uniform temperatures were recorded, which alone accounts for the uniformity in the evaporation from soil and water surfaces. The rainfall was not heavy enough to materially affect the losses, and the percentage

[Bull. 248]

of moisture in the soil was small enough to keep the evaporation within reasonable limits. The entire advantage shown in furrow irrigation in this case appears in the losses during the first three days after irrigation, and the decrease in the losses varies uniformly with the increasing depth of the furrows. Forty-nine and two-tenths per cent of the total loss from the flooded soils occurs in the first three days, and the use of 3, 6, and 9 inch furrows saved 13.3, 30.5, and 47.6 per cent, respectively, of the total loss from the flooded surface in 28 days. This seems to indicate that for such soil the practical limit of the depth of the furrow lies between 6 and 9 inches.

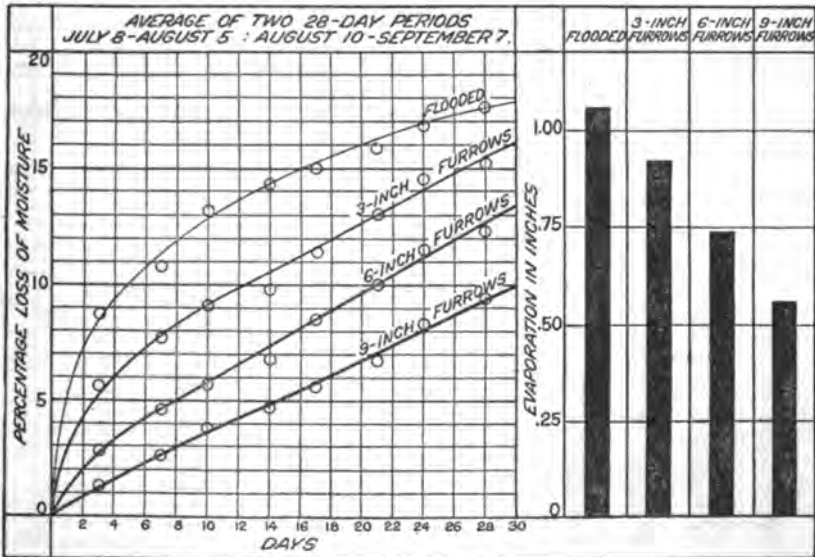


Fig. 19.—Average evaporation losses from tanks irrigated by flooding and with furrows of different depths at Reno, Nev., July 8 to August 5 and August 10 to September 7, 1909.

RESULTS AT BOZEMAN, MONT., AGRICULTURAL COLLEGE, N. MEX., AND SUNNYSIDE, WASH.

The experiment extended through two months at each of these stations, but in no case was any noticeable advantage observed in favor of furrow irrigation. Rainfall interfered with the experiments and entirely counterbalanced the effect of deep irrigation by destroying the mulches created by cultivation and thus allowing an almost constant heavy evaporation. This fact is shown in the table following, which gives the rainfall, the evaporation from a water surface, and the average losses in pounds from the several pairs of tanks irrigated in the different ways.

[Bull. 248]

Rainfall, evaporation from free-water surface, and from surfaces irrigated with furrows of different depths at Bozeman, Mont., Agricultural College, N. Mex., and Sunnyside, Wash.

Station.	Date.	Rainfall.	Loss from water surface.	Flooded surface.	3-inch furrows.	6-inch furrows.	9-inch furrows.
		<i>Inches.</i>	<i>Inches.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>	<i>Pounds.</i>
Agricultural College, N. Mex....	July 20	1.56	17.90	47.0	54.5	53.0	55.0
	Aug. 31						
	Sept. 3						
Bozeman, Mont.....	Oct. 1	1.12	7.70	38.5	39.5	37.0	36.5
	(Aug. 25)						
	Sept. 27						
Sunnyside, Wash.....	June 25	5.45	5.31	54.0	52.2	50.7	43.4
	July 27						
		1.07	9.65	24.5	24.75	25.25	25.25

SUMMARY OF RESULTS AT RENO, NEV., AND DAVIS, CAL.

The results of the observations at the Nevada and California stations have been combined into the following tables:

Summary of climatological data at Davis, Cal., and Reno, Nev. (average of tables on pp. 53 and 58).

Period.	Days.	Mean maximum temperature.	Mean minimum temperature.	Humidity.	Mean wind velocity per hour.
		<i>° F.</i>	<i>° F.</i>	<i>Per cent.</i>	<i>Miles.</i>
First.....	3	90.0	43.2	53.9	7.22
Second.....	4	85.3	43.2	46.4	7.07
Third.....	3	83.3	45.8	48.0	6.60
Fourth.....	4	83.8	47.2	43.0	7.48
Fifth.....	3	91.6	44.0	38.2	7.32
Sixth.....	4	91.6	44.5	34.2	5.34
Seventh.....	3	88.5	47.8	37.2	6.20
Eighth.....	4	90.1	45.3	35.0	6.04
Average.....	28	91.9	44.8	41.7	6.64

Summary of evaporation losses from free-water surface and from surfaces irrigated by flooding and with furrows of different depths at Davis, Cal., and Reno, Nev. (averages of tables on pp. 53 and 58).

Periods.	Days.	Loss from water surface.	Flooded, tanks 1 and 2.		3-inch furrows, tanks 3 and 4.		6-inch furrows, tanks 5 and 6.		9-inch furrows, tanks 7 and 8.	
Average weight of tanks at beginning, pounds.....			1,182.7		1,145.0		1,136.7		1,130.5	
Average loss:		<i>Inches.</i>	<i>Lbs.</i>	<i>Per ct.</i>	<i>Lbs.</i>	<i>Per ct.</i>	<i>Lbs.</i>	<i>Per ct.</i>	<i>Lbs.</i>	<i>Per ct.</i>
First.....	3	1.10	9.14	9.7	5.95	6.3	4.00	4.3	2.85	3.0
Second.....	4	1.50	3.17	3.4	2.57	2.7	2.50	2.7	1.85	2.0
Third.....	3	1.20	1.83	2.0	1.58	1.7	1.43	1.5	1.63	1.7
Fourth.....	4	1.60	1.15	1.2	1.15	1.2	1.00	1.1	.85	.9
Fifth.....	3	1.12	1.10	1.2	1.80	1.9	1.68	1.8	1.12	1.2
Sixth.....	4	1.47	1.12	1.2	1.22	1.3	1.15	1.2	1.08	1.2
Seventh.....	3	1.07	1.32	1.4	.90	1.0	1.00	1.1	1.22	1.3
Eighth.....	4	1.40	.82	.9	.45	.5	.68	.7	.70	.7
Total loss.....	28	10.46	19.65	21.0	15.62	16.6	13.44	14.4	11.30	12.0
Equivalent loss in inches.....			1.25		.99		.86		.72	

The data given in the above table are shown graphically by figure 20.

This summary indicates that practically all of the saving in furrow irrigation was in the first week after the water had been applied, and it will be seen that after this period the curves in the diagram parallel each other for the remainder of the experiment, showing that the average losses for the different furrows were the same. In combining results such as these it is impossible to account for irregularities in the points of the different curves.

The average time of cultivation after irrigation was as follows: Flooded surface, 52 hours; 3-inch furrows, 36 hours; 6-inch furrows,

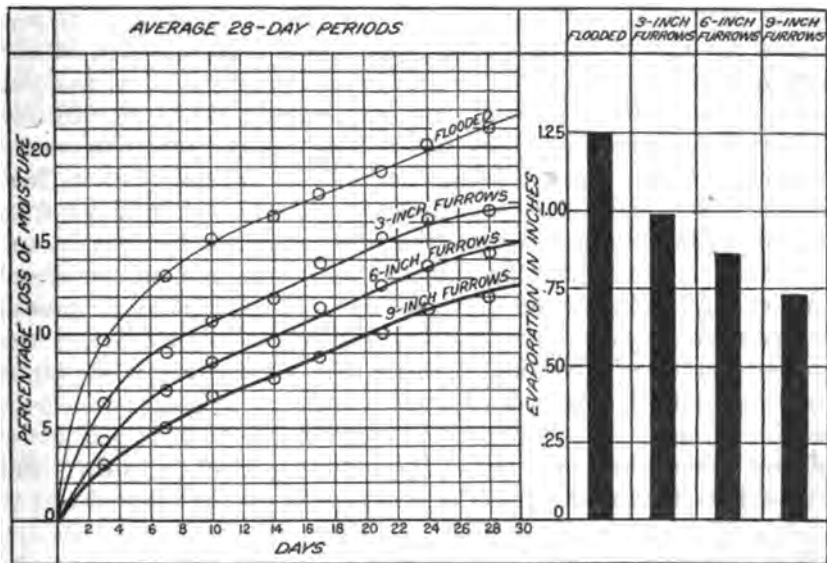


FIG. 20.—Average evaporation losses from tanks irrigated by flooding and with furrows of different depths at Davis, Cal., and Reno, Nev.

7 hours; 9-inch furrows, 12 hours. But even had these periods been the same a large difference in the losses by evaporation would still have existed, due to the varying percentage of moisture in the surface soil.

The loss from the flooded surface in the same period between irrigation and cultivation was 0.58 inch, or 46 per cent of the total loss during the 28 days. The 3, 6, and 9 inch furrows lost 0.38 inch, 0.25 inch, and 0.18 inch, respectively, during this same period. The table following shows the average amounts of water saved in a 28-day period at these two stations by the use of furrows of different depths.

[Bull. 248]

Losses by evaporation and saving resulting from use of furrows of various depths.

	Loss by evaporation.		Amount saved over free-water surface.		Amount saved over flooded surface.		Amount saved over surface irrigated with 3-inch furrows.		Amount saved over surface irrigated with 6-inch furrows.	
	Inches.	Per ct.	Inches.	Per ct.	Inches.	Per ct.	Inches.	Per ct.	Inches.	Per ct.
Water surface.....	10.46									
Flooded.....	1.25	9.21	88.0							
3-inch furrows.....	.98	9.48	90.6	0.27	21.6					
6-inch furrows.....	.86	9.60	91.8	.39	31.2	0.12	12.2			
9-inch furrows.....	.72	9.74	93.0	.53	42.4	.26	26.5	0.14	16.3	

EXPERIMENTS OF 1910.

In order to determine the actual losses from soil surfaces when soil is cultivated to different depths the following experiment was planned to extend through May and June, 1910, at each of the stations where experiments were made during two preceding seasons. The same sites and equipment were used throughout as in 1908 and 1909, and the same care was taken in filling the tanks to secure typical soil and to place it in the tanks in its natural position, foot for foot. As a rule there was just enough moisture in the soil to germinate the seed. As soon as the tanks were filled irrigation was practiced, the depths varying with the local conditions at the several stations, such as the amount of moisture in the soil before irrigation, the probable rainfall during the experiment, etc. In all cases the flooding method of irrigation was used, the soil in each of the tanks being kept entirely covered with water until the irrigation was completed. As soon as the top layer was sufficiently dry the soil in the different tanks was cultivated to the following depths: Tanks 1 and 2, no cultivation; tanks 3 and 4, 2-inch cultivation; tanks 5 and 6, 4-inch cultivation; tanks 7 and 8, 6-inch cultivation.

The same plan of cultivation was also followed as closely as practicable after each rain. Weighings were made at least twice a week and at each of the stations the usual observations of temperatures, humidities, wind velocities, and evaporation from a water surface were made.

RESULTS AT DAVIS, CAL.

The tanks were filled early in May and the experiment gotten under way May 3. A 6-inch irrigation was given in each case, and cultivation was practiced as soon as the soil was sufficiently dry. As the tanks were filled, soil samples were taken and their free-moisture content determined. The period of irrigation and the period between irrigation and cultivation were noted in each case.

Weighings were made every other day during the first 10 days, and twice a week for the remainder of the 28 days. At the end of this period the tanks were emptied, immediately refilled, and the experiment repeated during the next 28 days, beginning June 4.

[Bull. 248]

The data secured in these preliminary observations, taken at the beginning of each of the experiments, are shown in the following table:

Preliminary observations at beginning of each of the experiments at Davis, Cal.

	Weight of soil.		Time required for 6-inch irrigation.		Time between irrigation and cultivation.		Percentage of free moisture in soil.	
	May 3.	June 4.	May.	June.	May.	June.	May 3.	June 4.
	<i>Pounds.</i>	<i>Pounds.</i>	<i>H. m.</i>	<i>H. m.</i>	<i>Days.</i>	<i>Hours.</i>	<i>Per ct.</i>	<i>Per ct.</i>
Tank No. 1.....	1,232	1,163	9 20	2 50	.....	.....	13.7	7.8
Tank No. 2.....	1,228	1,163	8 55	2 45	.....	.....	13.7	7.8
Tank No. 3.....	1,246	1,152	34 20	2 50	5	67	11.5	8.2
Tank No. 4.....	1,196	1,148	7 30	4 45	4	67	11.5	8.2
Tank No. 5.....	1,188	1,162	5 00	4 50	4	67	11.6	7.4
Tank No. 6.....	1,203	1,168	5 15	4 50	4	67	11.6	7.4
Tank No. 7.....	1,198	1,157	5 25	4 00	4	67	13.7	8.4
Tank No. 8.....	1,219	1,165	7 10	4 20	4	67	13.7	8.4

When the tanks were emptied at the end of each experiment, samples were again taken for moisture analysis. In each case tanks 1 and 2 had baked dry and sun-cracked to a depth of 1 to 1.5 inches. Below this depth the moisture gradually graded off until at 4 inches a uniform condition existed, and below the first foot the eye could not detect any variation in the condition of the soil. The soil in tanks 3 and 4 had dried completely through the 2-inch mulch and slightly into the soil below, while the 4 and 6 inch mulches were completely dry for a depth of 1.5 inches. Below the first foot the distribution and degree of moisture seemed to be the same as found in the uncultivated tanks.

The following table shows the even distribution of moisture, as shown from moisture determinations of samples taken as the tanks were emptied:

Distribution of moisture in soil at the end of the experiments.

Depths.	Tanks 1 and 2.		Tanks 3 and 4.		Tanks 5 and 6.		Tanks 7 and 8.	
	May 31.	July 2.	May 31.	July 2.	May 31.	July 2.	May 31.	July 2.
	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>	<i>Per cent.</i>
1 foot.....	16.00	12.5	14.90	15.3	17.10	14.9	16.70	15.6
2 feet.....	18.70	11.7	17.30	18.1	16.60	18.1	18.50	17.4
3 feet.....	19.40	16.6	19.35	18.0	20.20	18.6	20.00	17.7
4 feet.....	22.20	17.5	19.70	18.4	20.40	18.1	20.50	17.8
Mean.....	19.06	14.6	17.81	17.5	18.60	18.4	18.93	17.1

[Bull. 248]

The temperature of the air, water, and soil, and the wind velocity during each of the periods covered by the two experiments, are given in the following tables:

Mean temperature of air, water, and soil, and the mean wind velocity at Davis, Cal., May 3-31, 1910.

Period.	Mean atmospheric temperature.	Mean water temperature. ¹	Mean soil temperature. ¹	Mean wind velocity per hour.
	[°] F.	[°] F.	[°] F.	Miles.
May 3-5.....	52.6	65.8	65.0	8.14
May 5-7.....	57.8	70.6	68.3	4.75
May 7-9.....	65.5	77.9	74.3	6.56
May 9-11.....	63.7	70.9	71.5	8.53
May 11-13.....	63.7	76.0	74.8	5.75
May 13-16.....	67.7	73.3	75.6	20.00
May 16-20.....	67.5	73.8	76.7	10.90
May 20-23.....	60.5	72.6	76.6	6.03
May 23-27.....	64.8	76.1	78.0	8.52
May 27-31.....	75.2	80.2	81.7	7.60
Average for 28 days.....	65.1	74.3	75.4	87.9

¹ Taken at a depth of 6 inches.

Mean temperature of air, water, and soil, and the mean wind velocity at Davis, Cal., June 4 to July 2, 1910.

Period.	Mean atmospheric temperature.	Mean water temperature. ¹	Mean soil temperature. ¹	Mean wind velocity per hour.
	[°] F.	[°] F.	[°] F.	Miles.
June 4-6.....	62.3	72.5	79.6	11.62
June 6-8.....	60.6	73.0	78.9	8.88
June 8-10.....	69.7	80.2	82.8	7.54
June 10-13.....	65.2	73.0	79.2	9.45
June 13-16.....	60.9	72.8	79.2	12.03
June 16-20.....	62.3	73.1	79.0	11.36
June 20-23.....	78.5	74.1	78.9	8.00
June 23-27.....	74.5	81.0	82.6	8.14
June 27-July 2.....	63.9	76.7	83.7	10.00
Average for 28 days.....	66.7	75.4	80.7	9.74

¹ Taken at a depth of 6 inches.

The tables following give the losses of evaporation from a free-water surface and from the tanks cultivated to different depths for the periods covered by the two experiments.

[Bull. 248]

Average losses by evaporation from free-water surface and from surfaces cultivated to different depths, at Davis, Cal., May 3-31, 1910.

Periods.	Loss from water surface.	No cultivation, tanks 1 and 2.		2-inch cultivation, tanks 3 and 4.		4-inch cultivation, tanks 5 and 6.		6-inch cultivation, tanks 7 and 8.	
Average weight of tanks May 3, pounds.....		1,230		1,221		1,195.5		1,211.5	
Average loss:	Inches.	Pounds.	Per ct.	Pounds.	Per ct.	Pounds.	Per ct.	Pounds.	Per ct.
May 3-5.....	0.265	4.50	4.8	5.00	5.3	4.50	4.8	5.00	5.3
May 5-7.....	.435	6.50	6.9	6.75	7.2	7.10	8.0	7.00	7.4
May 7-9.....	.460	6.75	7.2	4.75	5.0	3.00	3.2	3.50	3.7
May 9-11.....	.270	2.75	2.9	2.75	2.9	1.25	1.3	1.00	1.1
May 11-13.....	.430	2.00	2.1	1.25	1.3	1.00	1.1	1.00	1.1
May 13-16.....	1.340	2.75	2.9	1.75	1.9	1.00	1.1	.75	.8
May 16-20.....	1.090	2.50	2.7	1.00	1.1	1.25	1.3	1.25	1.3
May 20-23.....	.905	1.75	1.9	1.60	1.6	.50	.5	1.25	1.3
May 23-27.....	.940	2.25	2.4	3.50	3.7	3.00	3.2	1.25	1.3
May 27-31.....	.960	5.75	6.1	4.00	4.3	3.00	3.2	2.50	2.7
Total, 28 days.....	7.095	37.50	39.9	32.25	34.3	26.00	27.7	24.50	26.00
Equivalent of total loss in inches.....		2.39		2.05		1.65		1.55	

Evaporation losses from free-water surface and from surfaces cultivated to different depths at Davis, Cal., June 4 to July 2, 1910.

Periods.	Evaporation from free-water surface.	No cultivation, tanks 1 and 2.		2-inch cultivation, tanks 3 and 4.		4-inch cultivation, tanks 5 and 6.		6-inch cultivation, tanks 7 and 8.	
Average weight of tanks June 4, pounds.....		1,163		1,150		1,165		1,161	
Average loss:	Inches.	Pounds.	Per ct.	Pounds.	Per ct.	Pounds.	Per ct.	Pounds.	Per ct.
June 4-6.....	0.795	11.25	12.0	8.50	9.0	5.50	5.8	8.50	9.1
June 6-8.....	.515	2.50	2.7	3.50	3.7	5.00	5.3	4.50	4.8
June 8-10.....	.550	5.75	6.1	3.50	3.7	.75	.8	1.00	1.1
June 10-13.....	.815	2.50	2.7	1.75	1.9	1.00	1.1	.25	.3
June 13-16.....	.820	2.50	2.7	1.75	1.9	1.75	1.9	1.25	1.3
June 16-20.....	1.215	2.25	2.4	2.00	2.1	1.00	1.1	.50	.5
June 20-23.....	.905	2.00	2.1	.50	.5	.25	.3	.25	.3
June 23-27.....	1.375	2.25	2.4	.75	.8	1.25	1.3	.50	.5
June 27-July 2.....	1.387	1.25	1.3	.75	.8	.25	.3	.00	.0
Total, 28 days.....	8.377	32.25	34.4	23.00	24.4	16.75	17.9	16.75	17.9
Equivalent of total loss in inches.....		2.05		1.46		1.06		1.06	

The averages of the total losses for each sort of surface during the two experiments and the average variations in the percentages of moisture lost during each period of the two experiments are shown graphically in figure 21.

The results given in the above tables present the same general features—a decided advantage in cultivation up to a depth of 4 inches, beyond which the saving is so small that no conclusion can be drawn.

In the evaporation from a water surface during the two experiments 1.28 inches more is shown in the second than in the first experiment, caused by higher temperatures and climatic conditions favoring

heavier evaporation. On the other hand, the losses from the soil surfaces are just reversed, the variation undoubtedly being caused mainly by the difference in moisture content of the soil before irrigation, as shown on page 63, which overbalanced the effect of the climate as a factor in evaporation.

The average evaporation loss for these two periods from an uncultivated soil surface was 2.22 inches, which is 37 per cent of the total amount of water used in irrigation and 28.7 per cent of the amount evaporated from a free-water surface. As an average 33.8 per cent of this amount was lost in the period between irrigation and cultivation.

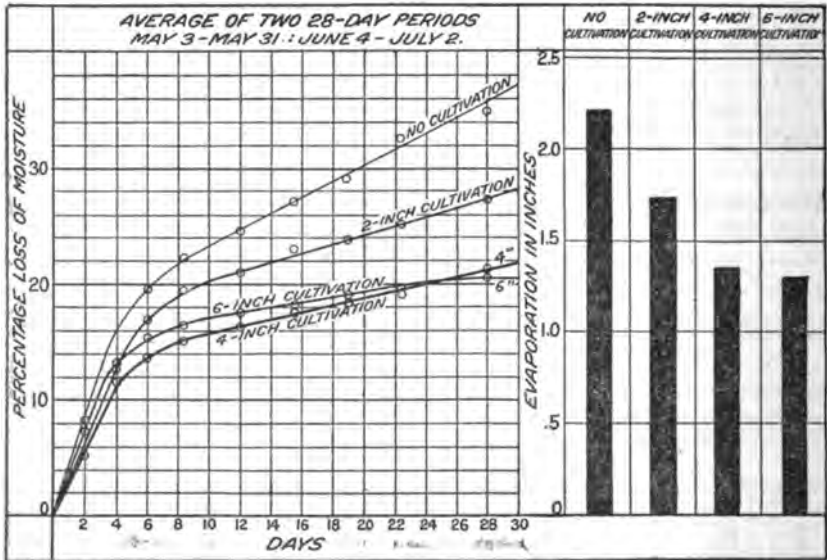


FIG. 21.—Average evaporation losses from tanks cultivated to different depths at Davis, Cal., May 3-31 and June 4 to July 2, 1910.

Of the 2.22 inches lost from the uncultivated surfaces, 21.2 per cent was saved by a 2-inch cultivation, and 39.2 per cent by a 4-inch cultivation. The difference between the 4-inch and the 6-inch cultivation was so small that no attempt is made to draw conclusions. The low percentage of moisture in the soil and the moderate climatic conditions during both periods made a 4-inch cultivation as effective as the 6-inch.

The table following shows the depths in inches and the percentages saved by the different depths of cultivation.

[Bull. 248]

Losses by evaporation from surfaces cultivated to different depths, and by saving due to different depths of cultivation.

Condition of surface.	Loss by evaporation.	Amount saved over free-water surface.		Amount saved over no cultivation.		Amount saved over 2-inch cultivation.		Amount saved over 4-inch cultivation.	
	<i>Inches.</i>	<i>Inches.</i>	<i>Per ct.</i>	<i>Inch.</i>	<i>Per ct.</i>	<i>Inch.</i>	<i>Per ct.</i>	<i>Inch.</i>	<i>Per ct.</i>
Free-water surface.....	7.78								
No cultivation.....	2.22	5.56	71.5						
2-inch cultivation.....	1.75	6.03	77.5	0.47	21.3				
4-inch cultivation.....	1.35	6.43	82.5	.87	39.2	0.40	22.8		
6-inch cultivation.....	1.31	6.47	83.1	.91	40.9	.44	25.1	0.04	3.0

SUMMARY OF RESULTS AT ALL STATIONS.

Similar experiments were carried on at each of the other stations, but in all cases, save one, rainfall interfered to such an extent that the mulches produced by the different depths of cultivation were completely destroyed. In some instances where the soil was cultivated after each shower the losses from the deeper cultivated soils were greater than from the uncultivated surfaces. This was particularly noticeable where the rainfall came in light showers of 0.5 inch or less every three or four days. Immediately following cultivation an additional loss is observed for one or two days, due to moist soil being exposed. If a cultivation is followed by a shower and then another cultivation it is easy to see that deep cultivation may increase rather than diminish the loss by evaporation.

When evaporation losses alone are considered the small saving at each of these stations seems to discourage rather than encourage cultivation during a season of intermittent rainfall, especially when the rainfall occurs in light, evenly distributed showers.

The evaporation losses from a water surface at each of the several stations for the months of May and June during 1909 and 1910 are given in the following table, which shows the great variation in the losses at the stations where experiments were conducted.

Total and average weekly evaporation losses at the seven different stations.

Stations.	1909		1910		1909-1910.
	Months.	Total loss.	Months.	Total loss.	Average weekly loss.
		<i>Inches.</i>		<i>Inches.</i>	<i>Inches.</i>
Agricultural College, N. Mex.	May and June ¹	11.13	May and June ¹	12.98	3.02
Caldwell, Idaho.....	do. ¹	9.81	do. ¹	8.78	2.32
Davis, Cal.....	do. ¹	9.41	do. ¹	7.73	2.14
Reno, Nev.....	do. ¹	8.49		11.03	2.44
Sunnyside, Wash.....	May.....	7.09	May 21-June 15.....	7.25	1.90
Williston, N. Dak.....			May.....	5.21	1.86
Bozeman, Mont.....	June.....	4.26	May and June.....	4.51	1.10

¹ Average for two months.

The average weekly losses for the several stations are shown graphically in figure 22.

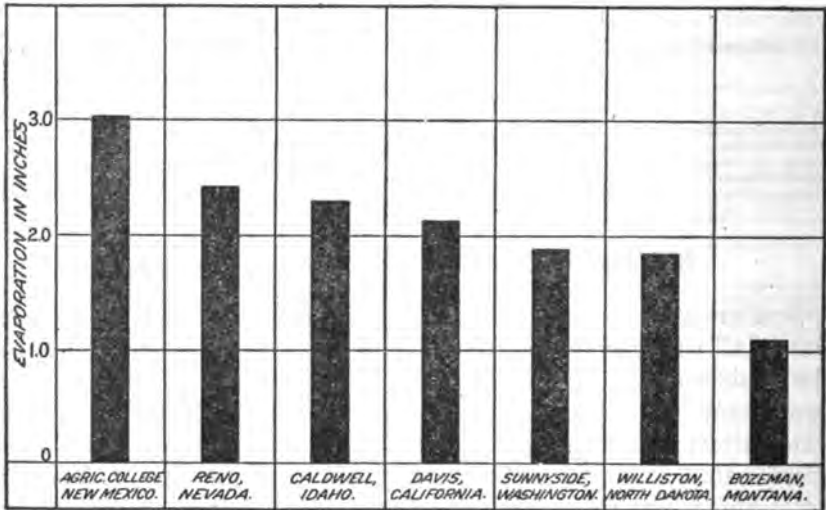


FIG. 22.—Average weekly evaporation from free-water surface at Agricultural College, N. Mex.; Reno, Nev.; Caldwell, Idaho; Davis, Cal.; Sunnyside, Wash.; Williston, N. Dak.; and Bozeman, Mont.

In order to illustrate the effect of temperature and wind velocities on evaporation, the mean daily temperatures, wind velocities, and

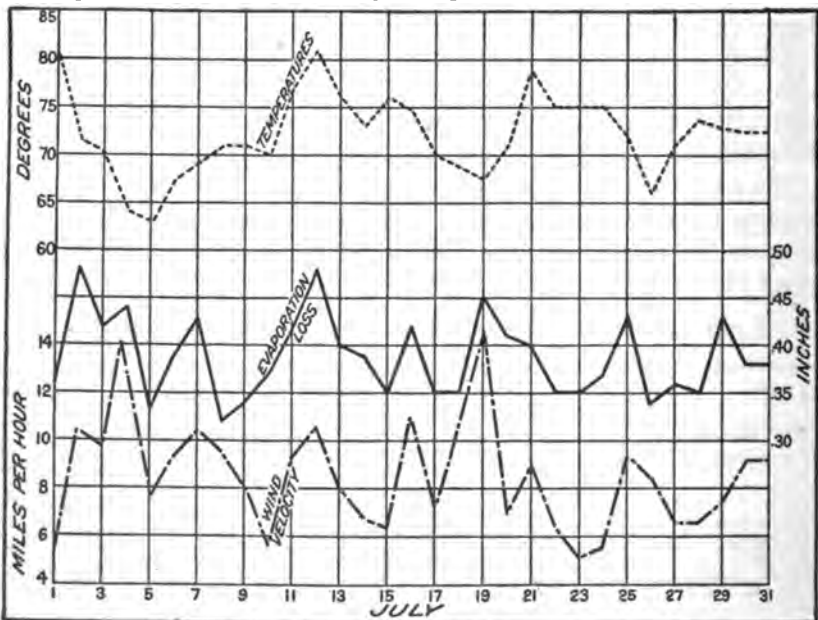


FIG. 23.—Mean temperatures, average wind velocities, and evaporation losses from a free-water surface at Davis, Cal., July 1909.

evaporation losses have been platted from the records taken at the California station during July, 1909. (Fig. 23.)

[Bull. 248]

Although no attempt is made to establish a relation between temperature, wind velocity, and evaporation, it is interesting to notice their general influence by the uniform variation in the curves.

This and the results obtained at the other stations show the wind velocity to be the controlling factor. The temperature influence seems to overbalance that of the wind only when the latter is at a minimum. For instance, July 10, 22, and 23, when the wind velocities were at a minimum, the atmospheric temperatures were comparatively high and moderate evaporation losses are recorded.

EFFECTS OF TEMPERATURE AND WIND VELOCITY.

In the study of evaporation from a free-water surface the controlling factors are the temperature of the water surface, the vapor pressure at the water temperature and dew point, and the wind velocity

The following results were obtained from experiments carried on in California at several widely distributed stations during 1904-5, in a study of the influence of the temperature of the water surface on evaporation.

Average temperature of water and evaporation therefrom.

Average temperature of water surface.	Daily evaporation.
° F.	Inch.
53.4	0.09
61.3	.19
73.5	.36
80.4	.48
88.7	.60

Although this shows no definite ratio existing between the temperature of the water surface and the evaporation, it gives a general idea of the enormous influence which the temperature of the water exerts. As the temperature of the water depends directly upon and follows very closely the atmospheric temperatures, the latter must be recognized as one of the controlling factors in evaporation losses. An evaporation tank for the measurement of evaporation from a water surface was installed at each of the several stations as an auxiliary to the soil tanks. These tanks had an inside diameter of 22 inches and a depth of 28 inches. The upper half of each was double-jacketed, the idea being to fill the annular space in the jacket with water and prevent the temperature of the surrounding soil from influencing the temperature of the water in the upper half of the evaporation tank proper. These tanks were set flush with the ground surface in an unobstructed spot and readings were taken daily or

[Bull. 248]

semiweekly. The measurements were generally taken with a hook gage, and the losses computed in inches.

Figure 24 is a similar diagram in which the mean hourly observations of temperature, wind velocity, and evaporation are plotted for a period of 24 hours and shows more in detail the same general features that are shown in figure 23.

As an aid in measuring the evaporation from water surface, during the experiments of 1910 the station at Davis, Cal., was fortunate in having at its disposal an evaporimeter designed and built by E. J. Hoff of this office. A sketch of the essential features of this instrument is shown in figure 25. A is a double-jacketed evaporation tank,

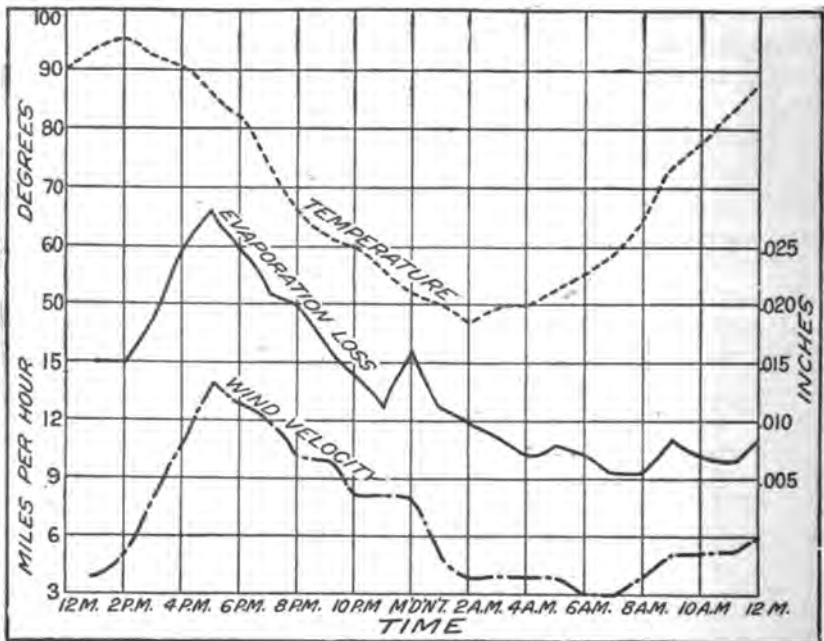


FIG. 24.—Mean hourly temperatures, wind velocities, and evaporation losses from free-water surface from noon July 12 till noon July 13, 1910, at Davis, Cal.

connected to a smaller cylindrical tank B, 7 inches in diameter, by a 1-inch galvanized-iron water pipe. The water in the two tanks obviously stands at the same height. The float D resting in tank B, is connected by a fine brass wire to the marking arm GH of the recording apparatus. This arm is pivoted at the point F to support K, the distance FG being just one-tenth of the distance FH. A light counterweight T serves to keep the wire taut, but is heavy enough to prevent the float from following the changes in the water level, in tank A, due to rainfall or evaporation. The record sheet is fastened to the circular drum N which is pivoted at O and connected with the

[Bull. 248]

clockwork P by means of a series of fine gears. The cylinder N makes one complete revolution every 12 hours. A wire frame RS connected to a ratchet on the clock works brings the arm GH against the paper once every five minutes, making a dotted instead of a solid line, which prevents the friction of the pen II on the paper from interfering with the gradual lowering of the float as the water lowers in tank B.

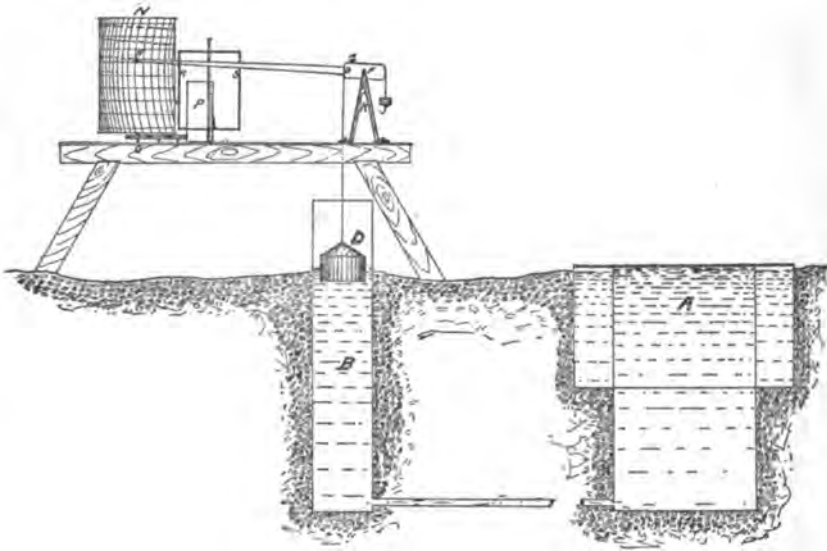


FIG. 25.—Evaporimeter.

This instrument was in constant use for one whole season and gave excellent satisfaction. With it the loss of any period of the day could be read to one-thousandth of an inch. The losses shown on the record sheet are 10 times the actual evaporation loss. A sample record taken from the instrument is shown in figure 26.

Hourly observations were made at several stations for a period of 24 hours, showing the daily range of temperatures, wind velocities, humidities, and evaporation. Those for Davis, Cal., and Caldwell, Idaho, are shown in the tables following.

[Bull. 248]

Hourly temperatures of air, soil, and water at Caldwell, Idaho, 6 a. m., Aug. 28 to 6 a. m., Aug. 29, 1909.

Time.	Temperature of air.			Temperature of soil.						Temperature of water.		
	Five feet above ground.	At surface in the sun.	At surface in shade.	Three inches below surface in tank.	Six inches below surface in tank.	4-inch below surface near tank.	Three inches below surface near tank.	Six inches below surface near tank.	4-inch below surface.	Three inches below surface.	Six inches below surface.	
	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	° F.	
6 a. m.	46	44	44	58½	64½	48	63	72½	56	57½	58	
7 a. m.	44	47	45	58½	64	48	62½	72	57½	57½	57½	
8 a. m.	58	62	62	58½	64	57	62½	72	58	58	58	
9 a. m.	62	70	64	61	64	70	64	71	58	58	58	
10 a. m.	68	83	71	63	64	83	66½	70½	59½	59	58½	
11 a. m.	73½	85	79	66	64½	94	70	70½	61	60½	60½	
12 m.	76½	90	83	69½	65½	101½	75	71½	64	63	61½	
1 p. m.	81	97	86	72½	67	106½	79½	72½	68½	67	64½	
2 p. m.	83	102	88	74½	68	109	82	73	69½	68½	66	
3 p. m.	85	104	89	77	69½	109	84½	74	71½	69½	67½	
4 p. m.	85½	101	88	77	71	105	85½	75½	70½	70½	68½	
5 p. m.	85	98	88	77	72	100	86	76½	71	70	69½	
6 p. m.	85	92	85	77½	72½	93	85½	77½	70½	70	69½	
7 p. m.	80	76	75	75½	73½	78	84	78	69	68½	68	
8 p. m.	78½	68	75	73	72	82	78½	78½	68	67½	67	
9 p. m.	72½	63	72	72½	69	78½	78½	78½	66	65½	65	
10 p. m.	67	63	70	72	61	76½	78	78	64½	64½	64½	
11 p. m.	66½	62	69	71½	61	74½	78	78	63½	63½	63½	
12 p. m.	63½	60	68	70	60	73	77	77	63	63	63	
1 a. m.	62	60	65½	69½	60	71½	70½	70½	62½	62½	62½	
2 a. m.	60	57	65½	69	59	70½	76	76	62½	62½	62½	
3 a. m.	58½	58	64	68½	59	69½	75½	75½	61½	61½	61½	
4 a. m.	60	59	64	67½	59	68½	75	75	61½	61½	61½	
5 a. m.	53½	52	63½	67	57	68	74½	74½	61	61	61	
6 a. m.	55	54	63	66½	57	67	74	74	61	61	61	
Mean.....	68½	85½	72½	68½	68½	74½	74½	74½	64.0	59½	63½	
Range.....	41½	57.0	45.0	19.0	9½	58½	23½	8.0	15½	13.0	11½	

Hourly temperatures of air, soil, and water, humidity, evaporation from free-water surface and velocity of wind at Davis, Cal., noon July 12 to noon July 13, 1910.

Time.	Temperature of air.	Temperature of soil.			Temperature of water.			Humidity.	Evaporation.	Wind velocity.
		4 inch below surface.	3 inches below surface.	6 inches below surface.	4 inch below surface.	3 inches below surface.	6 inches below surface.			
	° F.	° F.	° F.	° F.	° F.	° F.	° F.	Per cent.	Inch.	Miles.
12 m.	90	118	88	86½	84	83	82½	29.0	0.015	4.0
1 p. m.	94	120	89½	87½	87	86	85½	27.0	.015	5.0
2 p. m.	96	122	91	88½	88½	88	87	28.0	.020	8.0
3 p. m.	93	118	93	90½	90	89	89	32.0	.023	11.0
4 p. m.	91½	114	94½	92	89½	89	89	36.0	.027	14.0
5 p. m.	86	106	95	93	88	88	87	41.0	.035	13.0
6 p. m.	80½	96	95	93	87	87	87½	46.0	.031	12.0
7 p. m.	72	82	91½	92½	86	86	86	61.0	.020	10.0
8 p. m.	67	76	92½	92½	84	83	83	66.0	.017	10.0
9 p. m.	62	73	91	91½	81	80	80	70.0	.014	8.0
10 p. m.	60	68	89½	90	77	76	75	74.0	.011	8.0
11 p. m.	56	66	87½	88½	75	74	73½	75.5	.016	8.0
12 midnight.	54	63	86	87	74	73	73	77.0	.011	5.0
1 a. m.	51	60	84½	86½	73½	72½	72½	82.0	.010	4.0
2 a. m.	45½	58	83	85	72½	72	72	86.0	.008	4.0
3 a. m.	50	60	82½	84½	72	72	72	88.5	.007	4.0
4 a. m.	50	60	81½	83½	71½	71	71	81.5	.008	4.0
5 a. m.	53	62	81½	83½	71	70½	70½	72.0	.007	3.0
6 a. m.	57	65	81	82½	71	69	69	70.0	.006	3.0
7 a. m.	59	70	80½	82	70½	68	68	65.0	.006	4.0
8 a. m.	65	75	79½	81	70½	68½	68½	62.0	.008	5.0
9 a. m.	75	88	80	81	74	73	72	50.0	.007	5.0
10 a. m.	79	92	81½	82½	76	75	74	42.0	.007	5.0
11 a. m.	83	102	83	83	78	78	76	41.0	.008	6.0
12 noon.	87	108	84½	83½	80	79	78			
Mean.....	70½	84½	86½	86½	78½	78½	77½	58.4	.0134	6.8
Range.....	47½	64	15½	12½	19½	21	21	61.5	.021	10.0

[Bull. 248]

It is a well-known fact that the temperature of soil and water surfaces directly influence the evaporation from their surfaces, these temperatures being directly influenced by the temperature of the air. From these tables it will be seen that while the atmospheric temperatures range from 40° to 50° F. during the 24 hours that the temperature of the soil surface varies from 60° to 70° F. and at a depth of 3 to 6 inches the variation averages but 17° and 10° , respectively. The surface temperature follows very closely that of the air, while at a depth of 6 inches the maximum is not reached until 4 to 5 hours later, this of course depending upon the compactness and moisture content of the soil.

The water temperatures show but little variations in depth up to 6 inches and a range of 40° to 50° in the atmosphere produces but 15° to 20° variation in the water. The following diagram, figure 27, prepared from the observations of July 12 and 13, 1910, at Davis, shows the hourly variation in temperature at the different depths for both soil and water.

In some localities covered by these experiments maximum temperatures of the surface soil often

[Bull. 248]

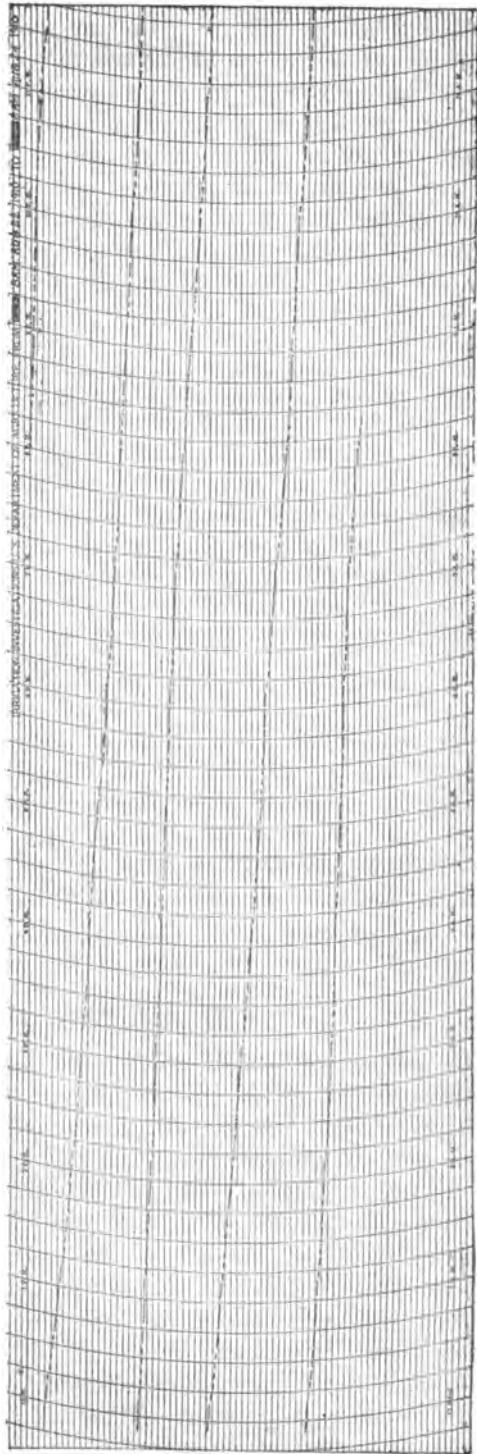


FIG. 26.—Evaporimeter sheet.

reached 120° to 130° F., whereas under the same conditions the temperature of the water surface varies from 80° to 90°. Remembering the influence of water temperatures on evaporation it is easily seen why the loss from a saturated soil surface may exceed that from a water surface. These temperatures given above are for dry soils and the temperature of saturated soils will naturally be much lower.

The results thus far obtained show but little difference in the temperatures of cultivated and uncultivated soils. Where these temperatures have been recorded the uncultivated soils average at a depth of 6 inches from 1° to 2° F. higher than the cultivated.

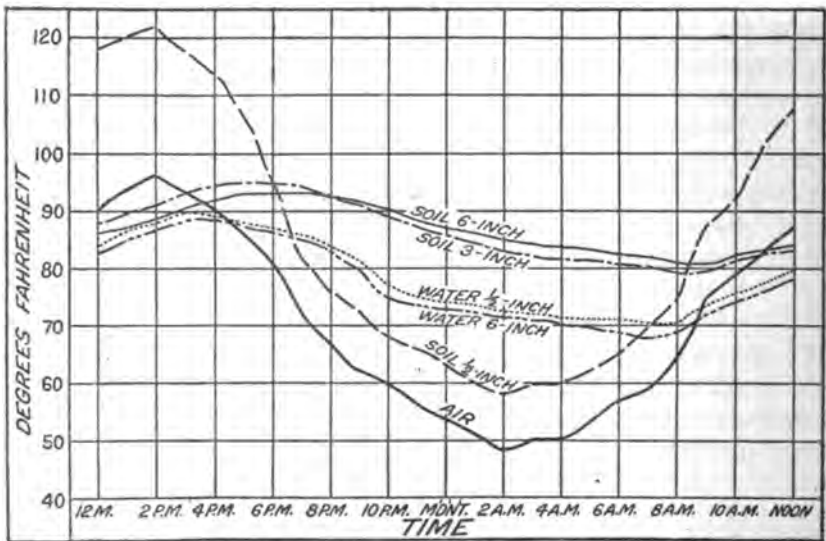


Fig. 27.—Temperature of air and of soil and water at different depths from noon July 12 to noon July 13, 1910, at Davis, Cal.

GENERAL CONCLUSIONS.

The uniform results obtained in the experiment on soil mulches in preventing evaporation losses clearly demonstrate that if in field practice irrigation water could be placed at a depth of 6 to 9 inches below the soil surface but little moisture would be lost by evaporation. This in itself points toward the use of fewer and deeper furrows.

The results thus far obtained show that the saving of moisture increases with the depth of application. Practical considerations, however, limit the depth. Under conditions such as exist throughout the arid region this practical limit lies, it is believed, somewhere between 6 and 9 inches.

Considerations other than the saving of moisture often determine the mode of applying water. Attention is called to the chief of these.

[Bull. 248]

(1) The available water supply and the probable period between irrigations. In the case of a very limited supply of water or where heavy orchard irrigation is practiced at long intervals, fewer and deeper furrows are of greatest benefit. The water is placed well into the soil and during the long period of application only a small per cent of the surface soil is wet, thus lessening the heavy evaporation losses which take place in the period between irrigation and cultivation. Cultivation may likewise be practiced almost immediately after irrigation and the losses further reduced.

(2) The character of the soil. It has been seen that heavy clay soils tend to hold the moisture near the surface, owing to their imperviousness. This type of soil favors capillary movement, and heavy evaporation losses are the result. In such cases deep furrow irrigation not only diminishes the losses but checks any tendency toward the formation of hardpan.

(3) The kind of crop irrigated. Some plants are shallow-rooted and if water is placed deep into the soil the roots are not only destroyed in making the deep furrows, but the water is placed beyond the feeding zone of the plants. On the other hand, in deep soil planted to deep-rooted crops, shallow irrigation would lure the fibrous rootlets to the surface of the soil where they would be destroyed by cultivation or drought.

The advantages and disadvantages of shallow and deep irrigation are discussed in detail in a bulletin of this office.¹ A summary of the advantages and disadvantages of shallow and deep irrigation is given below. In this summary shallow irrigation refers to the application of water on the surface or in furrows not exceeding 3 inches in depth, while deep irrigation refers to irrigation in furrows 6 to 12 inches in depth.

In general, it may be stated that wherever the soil and the crop will permit the water should be applied in deep furrows rather than by flooding; that one deep, heavy irrigation is preferable to numerous lighter irrigations, providing the crop is deep-rooted; that cultivation should be practiced as early as possible after irrigation; and that deep and frequent cultivation prevents evaporation and aerates the soil.

In the general practice of deep furrow irrigation, cultivation approximating the depth of the furrows naturally follows. In flooding and shallow-furrow irrigation, where a large percentage of the surface soil is wet, and the cultivation of the entire ground surface is necessary, the question of deep versus shallow cultivation becomes important. If one considers only the actual saving of moisture apart from other benefits produced by cultivation a determination could be reached readily by comparing the value of the water saved with the

¹ U. S. Dept. Agr., Office Expt. Stas. Bul. 177.

extra cost of deep cultivation. In making such a determination the controlling factors would be the character of the soil and the value of the water supply. In some of the heavier adobe and gumbo soils, deep cultivation is next to impossible, especially within a reasonable period after irrigation or heavy rainfall, while in lighter sandy soils cultivation to a depth of 8 to 10 inches is often practiced and not considered excessive.

In many cases the actual saving of water is one of the least important features of deep mulches. Prevention of the formation of hardpan, the decreasing of the waste by run-off during heavy rainfall, the prevention of valuable salts and plant food in solution from being drawn to the surface and carried away by surface drainage during excessive rainfall, the deep penetration and more thorough circulation of air and water through the soil, the increased water-holding capacity of the soil, and the deep-rootedness of plants and trees are additional reasons for deep and thorough cultivation.

The fertility of soils depends in a great measure upon the percentage of available nitrates, sulphates, and phosphates contained in them. In cases of heavy evaporation losses the capillary rise of water¹ carries the salts held in solution to the surface of the soil and when the water evaporates the salts are left above the feeding zone of the plant roots and thus deprived of their useful function. Analyses of the first inch of mulched and unmulched soils, made by Prof. F. H. King, show that the mulched surfaces contained a much smaller percentage of nitrates, sulphates, and phosphates and prove that a much smaller percentage of these valuable salts had been drawn from the lower strata of soil by capillarity. Again, if the surface soil is well mulched the pore space may approach 50 per cent of the total volume and nearly 2 inches of rainfall may be stored in 4 inches of soil. The water so stored dissolves the salts that have been carried to the surface and carries them back in solution to the root zone of the plants. In the case of an unmulched soil, the pore space is reduced and when heavy rains occur the salts are carried away by surface drainage.²

The depth of the mulch determines to a great extent the capacity of the soil for air and water. The soil is thoroughly aerated by the deep cultivation necessary to produce deep mulches, and its loose condition allows a much freer circulation of air and water, carrying with them oxygen and the soluble salts. Root growth follows the supply of moisture and plant food, and if these are placed deep into the soil deep-rooted plants will be the result. The orange in its natural state is said to be a shallow-rooted tree and the tendency of the roots is to spread out near the surface. This tendency is encouraged

¹ U. S. Dept. Agr., Bureau of Soils Bul. 38.

² "Some Results of Investigations in Soil Management," U. S. Dept. Agr. Yearbook, 1903, pp. 159-174. [Bull. 248].

through the rainy season in California, when the surface is kept moist by frequent rains and when the evaporation is reduced to a minimum by cool weather, fogs, and rain. It is doubtful, however, if the roots found in the upper 6 inches of soil are of any benefit to the tree, for while they may collect both food and moisture during the three months of the rainy season the excessive evaporation during a period of 30 to 45 days between irrigations in summer is quite certain to wither and kill the fibrous rootlets. It is deemed better for this reason to prevent the extension of the roots through the top layer of soil by frequent deep cultivations.

Deep cultivation and deep mulches tend not only to prevent the formation of hardpan, but do much to destroy that already formed. In some orchards long-continued, shallow cultivation of the soil to the same depth has created a compact layer of soil often several inches in depth. This limits the circulation of air and water through the soil and in some cases has been known to cause the total loss of orchards. Such a layer may be prevented and, if already formed, can be broken up by deeper cultivation, in which the depth is varied from year to year.

[Bull. 248]

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