

of the public lands. This commission consists of Governor W. A. Richards, Commissioner of the General Land Office, Gifford Pinchot, Forester, head of the Forest Service, and F. H. Newell, Chief Engineer of the Reclamation Service.

The commission made a first partial report on March 7, 1904, and a second report on February 13, 1905. These reports called attention to the fact that the present land laws are not suited to meet the conditions of the remaining public domain, and that their operation has not tended to promote home-making and the largest development of the country. On the contrary, they have been such as to lead to land monopoly and the restraint of settlement of agricultural lands by the most desirable class of citizens; namely, those who will live upon them, cultivate them, and become owners of small, well-cultivated tracts.

Out of this activity of agencies of the general government, there is growing a larger and better conception of the opportunities of the West, and of the need of broad control of the forests and of the water. It is believed that with this larger knowledge there will be a better grasp by the public of the duties of citizenship in this respect, and a more effective administration on the part of all responsible officers.

F. H. N.

January, 1906.

## CONTENTS.

	PAGE
PREFACE . . . . .	v
CHAPTER I.	
RECLAMATION OF THE PUBLIC LANDS . . . . .	1
CHAPTER II.	
THE ARID REGIONS . . . . .	13
Precipitation . . . . .	16
Forests . . . . .	27
Grazing Lands . . . . .	36
Cultivated Lands . . . . .	49
CHAPTER III.	
SURFACE WATERS . . . . .	57
Periodic Fluctuation . . . . .	62
Seepage . . . . .	72
Importance of Stream Measurements . . . . .	79
Methods of Stream Measurement . . . . .	82
Floats . . . . .	86
Current Meters . . . . .	89
Weirs . . . . .	97



## CHAPTER IV.

	PAGE
CONVEYING AND DIVIDING STREAM WATERS . . . . .	102
Diversion from the Stream . . . . .	102
Distribution of Flow . . . . .	108
Dams and Head Gates . . . . .	115
Measuring Devices or Modules . . . . .	120
Flumes and Wooden Pipes . . . . .	134
Tunnels . . . . .	138
Lining of Canals . . . . .	139
Erosion and Sedimentation in Canals . . . . .	141

## CHAPTER V.

RESERVOIRS . . . . .	149
Requirements for Water Storage . . . . .	150
Keeping Reservoirs Clean . . . . .	156
Masonry Dams . . . . .	159
Rock-filled Dams . . . . .	162
Earth Dams . . . . .	166
Hydraulic Dams . . . . .	170
Stored Waters . . . . .	173

## CHAPTER VI.

METHODS OF IRRIGATION . . . . .	179
Flooding in Checks . . . . .	185
Watering by Furrows . . . . .	193
Wild Flooding . . . . .	199
Orchards and Vineyards . . . . .	202
Subirrigation . . . . .	207
Amount of Water applied . . . . .	212
Arrangement of Irrigated Farm . . . . .	220

## CHAPTER VII.

	PAGE
UNDERGROUND WATERS . . . . .	225
Return Waters . . . . .	226
Underflow . . . . .	229
Ordinary Wells . . . . .	241
Artesian Wells . . . . .	246

## CHAPTER VIII.

PUMPING WATER . . . . .	254
Pumping by Hand or Animal Power . . . . .	255
Use of Water-wheels . . . . .	258
Windmills . . . . .	265
Steam and Gasolene . . . . .	270

## CHAPTER IX.

ADVANTAGES AND DISADVANTAGES OF IRRIGATION . . . . .	272
Sewage Irrigation . . . . .	275
Alkali . . . . .	281

## CHAPTER X.

IRRIGATION LAW . . . . .	286
--------------------------	-----

## CHAPTER XI.

STATES AND TERRITORIES OF THE ARID REGIONS . . . . .	299
Arizona . . . . .	304
California . . . . .	312
Colorado . . . . .	329
Idaho . . . . .	333



## CONTENTS.

	PAGE
Montana . . . . .	338
Nevada . . . . .	341
New Mexico . . . . .	346
Oregon . . . . .	350
Utah . . . . .	353
Washington . . . . .	358
Wyoming . . . . .	361

## CHAPTER XII.

STATES OF THE SEMIARID REGION . . . . .	364
Fluctuations in Water Supply . . . . .	364
Artesian and Deep Wells . . . . .	373
North Dakota and South Dakota . . . . .	376
Nebraska . . . . .	377
Kansas . . . . .	379
Oklahoma and Texas . . . . .	380

## CHAPTER XIII.

HUMID REGIONS . . . . .	383
-------------------------	-----

## CHAPTER XIV.

CONCLUSION . . . . .	393
----------------------	-----

## CHAPTER XV.

RECLAMATION ACT . . . . .	407
---------------------------	-----

## ILLUSTRATIONS.

## PLATES.

	FACING PAGE
I. The isolated home on the wind-swept unirrigated plain . . . . .	2
II. The home made possible by irrigation . . . . .	6
III. Results of attempts to make homes on the public lands without first providing methods of irrigation . . . . .	14
IV. Results attained by irrigation . . . . .	22
V. A, Forests partly destroyed. B, Cultivated fields receiving water from the partly forested mountains . . . . .	30
VI. A, Young forest growth succeeding a fire. B, Sheep grazing in the forests . . . . .	44
VII. Cattle on the open range . . . . .	56
VIII. A flood in Salt River, Arizona . . . . .	62
IX. A, Seepage water appearing on land formerly dry near Rincon, California. B, Dredge cutting canal to receive seepage water . . . . .	76
X. A, Electric current meter, conducting cord, and battery. B, Method of using electric current meter from suspended car . . . . .	90
XI. A, Supports for suspended car. B, Method of using meter from boat . . . . .	94
XII. A, Weir on Genesee River, New York. B, Weir on Cottonwood Creek, Utah . . . . .	98
XIII. A, Digging a ditch from a river. B, The finished ditch . . . . .	106
XIV. Dredge cutting large canal of Central Irrigation District, California . . . . .	110
XV. A, Head gates of canal. B, Timber regulator . . . . .	114
XVI. A, Regulating or measuring device near head of canal. B, Distribution box on farmer's lateral . . . . .	120



	FACING PAGE
XVII. <i>A</i> , Flume on rocky hillside. <i>B</i> , Flume across earth in a sidehill cut . . . . .	130
XVIII. Raising the trestles for a large flume . . . . .	132
XIX. Semicircular wooden flume . . . . .	134
XX. <i>A</i> , Pipe under 160-foot head, Santa Ana Canal, California. <i>B</i> , Old flume and redwood pipe replacing it, Redlands Canal, California . . . . .	136
XXI. <i>A</i> , Tunnel on Turlock Canal, California. <i>B</i> , Tunnel in earth on Crocker-Huffman Canal, California . . . . .	138
XXII. <i>A</i> , Semicircular flume in Santa Ana Canal, California. <i>B</i> , Cement lining of Santa Ana Canal, California . . . . .	142
XXIII. <i>A</i> , Drop in an Arizona canal. <i>B</i> , Check weir and drop . . . . .	146
XXIV. Sweetwater Dam near San Diego, California . . . . .	154
XXV. <i>A</i> , Lagrange Dam, nearly completed. <i>B</i> , Lagrange Dam with flood passing over crest and spillways . . . . .	158
XXVI. <i>A</i> , Dam at Austin, Texas, looking toward power house. <i>B</i> , Portions of Austin Dam immediately after failure . . . . .	162
XXVII. <i>A</i> , Otay Dam, California, showing method of protecting steel plates. <i>B</i> , Construction of timber dam at Blue Lakes, California . . . . .	166
XXVIII. <i>A</i> , Building dam by hydraulic process at Santa Fé, New Mexico, showing hydraulic giant in use. <i>B</i> , Building dam by hydraulic process at Santa Fé, New Mexico, showing outlet pipe . . . . .	170
XXIX. Excavating deep cut for canal by hydraulic process . . . . .	172
XXX. Skyline Canal diverting water across the mountains . . . . .	176
XXXI. <i>A</i> , Field prepared in rectangular checks. <i>B</i> , Irrigation by checks in San Joaquin Valley, California . . . . .	188

	FACING PAGE
XXXII. <i>A</i> , Canvas dam in temporary ditch. <i>B</i> , Irrigating a young alfalfa field . . . . .	194
XXXIII. Furrow irrigation of grove . . . . .	198
XXXIV. <i>A</i> , Furrow irrigation of vines. <i>B</i> , Furrow irrigation of orchard . . . . .	202
XXXV. Cement-lined distributing ditch . . . . .	206
XXXVI. Cultivation after irrigation . . . . .	216
XXXVII. <i>A</i> , Weir measurements of Los Angeles River in San Fernando Valley, California. <i>B</i> , Results of irrigation from rivers of Southern California . . . . .	236
XXXVIII. <i>A</i> , Artesian well in Arizona. <i>B</i> , Artesian well in Kansas . . . . .	246
XXXIX. Outfit for drilling deep artesian wells . . . . .	248
XL. Well at Woonsocket, South Dakota, throwing a three-inch stream to a height of ninety-seven feet . . . . .	252
XLI. Current wheels lifting water . . . . .	260
XLII. <i>A</i> , Jumbo type of home-made windmills. <i>B</i> , Battle-axe type of home-made windmills . . . . .	266
XLIII. Windmill pumping into sod-lined reservoir . . . . .	270
XLIV. The desert reclaimed . . . . .	274
XLV. Sewage irrigation at Plainfield, New Jersey . . . . .	278
XLVI. <i>A</i> , Sewage irrigation at Phoenix, Arizona. <i>B</i> , Sewage irrigation in England . . . . .	282
XLVII. Irrigated vineyard near Phoenix, Arizona . . . . .	304
XLVIII. Drying apricots . . . . .	310
XLIX. <i>A</i> , Irrigation of vineyard in San Joaquin Valley, California. <i>B</i> , Irrigation of orchard in San Joaquin Valley, California . . . . .	320
L. Redwood stave pipe, fifty-two inches in diameter, crossing Warm Springs Canyon, near Redlands, California . . . . .	326
LI. Irrigating a wheat field in Colorado . . . . .	332
LII. <i>A</i> , Twin Falls, Snake River, Idaho. <i>B</i> , Constructing a canal by means of a grader . . . . .	334
LIII. Wooden pipe line on Phyllis Canal, Idaho . . . . .	336
LIV. Canyon of Snake River above Lewiston, Idaho . . . . .	338



	FACING PAGE
LV. Tunnel of Bear River Canal, Utah . . . .	354
LVI. Wheat-fields of Washington . . . .	358
LVII. <i>A</i> , Sunnyside Canal, Washington. <i>B</i> , Fruit orchard, Yakima Valley, Washington . . . .	362
LVIII. <i>A</i> , Irrigation in South Dakota by use of water from an artesian well. <i>B</i> , Stock-watering plant on upland . . . . .	370
LIX. <i>A</i> , Settler trying to cultivate without irrigation. <i>B</i> , Water for irrigation provided by windmill . . . .	374
LX. <i>A</i> , Looking down North Platte River from the Nebraska-Wyoming line. <i>B</i> , Head gates of Farmers and Merchants Irrigation Company on Platte River, near Cozad, Nebraska . . . .	378
LXI. Dutch windmill at Lawrence, Kansas . . . .	382
LXII. <i>A</i> , Clean sweep of the prairie fire. <i>B</i> , The car- pet of grass on the high plains . . . . .	386
LXIII. Head of Gunnison River tunnel . . . .	410
LXIV. Gunnison tunnel, Colorado . . . .	412
LXV. Site of Pathfinder dam, Wyoming . . . .	414
LXVI. Dam in Truckee River, Nevada . . . .	416
LXVII. Cement-lined canal, Nevada . . . .	418
LXVIII. Shoshone dam site, Wyoming . . . .	420

## FIGURES.

	PAGE
1. Map of vacant public lands . . . . .	5
2. Map of humid, semiarid, and arid regions of the United States . . . . .	14
3. Map of humid and arid regions of the world . . . .	15
4. Mean monthly precipitation at twelve localities in western United States . . . . .	18
5. Types of monthly distribution of precipitation . . . .	20
6. Annual precipitation at three points in arid regions . . . .	22
7. Map of mean annual rainfall . . . . .	24
8. Map of mean annual run-off . . . . .	25
9. Forests and woodlands of the West . . . . .	32
10. Relative position of forest and Indian reservations . . . .	34

	PAGE
11. Approximate location and extent of the open range . . . .	39
12. Map of dry farming . . . . .	50
13. Comparison of cultivable and cultivated areas in belt of states . . . . .	52
14. Map of irrigated and irrigable lands . . . . .	54
15. Larger river systems of the United States . . . . .	60
16. Diagram of daily discharge of Rio Grande at Embudo, New Mexico, for 1896, 1897, and 1898 . . . . .	65
17. Diagram of daily discharge of Susquehanna River at Harrisburg, Pennsylvania, for 1896, 1897, and 1898 . . . .	68
18. Double or submerged floats . . . . .	88
19. Method of measuring river from car suspended from a steel cable . . . . .	94
20. Section of flume, illustrating methods of measurement . . . .	96
21. Ordinary weir in a small stream . . . . .	99
22. Diagram showing method of diverting a canal from a river . . . . .	104
23. Levelling device for laying out ditches . . . . .	106
24. Map of ditches along a stream . . . . .	113
25. Plan of diversion works in river . . . . .	116
26. Brush dams of canals heading near each other . . . . .	117
27. Plan of dam and regulator . . . . .	118
28. Details of small head gate . . . . .	119
29. Plan of device for dividing water . . . . .	121
30. Flume for measuring miner's inches . . . . .	125
31. Foote measuring box . . . . .	127
32. Methods of measuring miner's inch in ditch . . . . .	128
33. Rectangular weir . . . . .	131
34. Trapezoidal or Cippoletti weir . . . . .	132
35. Trapezoidal weir with self-recording device . . . . .	133
36. Vertical section of trestle and flume . . . . .	135
37. Siphon passage for canal . . . . .	137
38. Section of cement-lined ditch with stop gate . . . . .	140
39. Cross-section of canal partly filled with sediment . . . .	144
40. Map of a reservoir . . . . .	153
41. Section of masonry dam at La Grange, California . . . . .	160
42. Plan of dam at La Grange, California . . . . .	161



	PAGE
43. Portion of earth reservoir showing outlet . . . . .	168
44. Portion of earth reservoir showing inlet . . . . .	169
45. Section of reservoir bank showing outlet . . . . .	169
46. Section of small distributing ditch . . . . .	183
47. Section of small raised ditch . . . . .	183
48. Sections and elevation of small flumes . . . . .	184
49. Box for taking water from main ditch . . . . .	184
50. Details of construction of box for distributing water . . . . .	186
51. Portion of field, divided by rectangular levees . . . . .	187
52. Application of water by the block system . . . . .	188
53. Flooding in rectangular checks . . . . .	190
54. Plan of irrigated garden divided into compartments or checks . . . . .	191
55. Checks on sloping land . . . . .	193
56. Application of water by furrows . . . . .	195
57. Water turned from furrow by a canvas dam . . . . .	196
58. Canvas dam . . . . .	197
59. Metal tappoons . . . . .	198
60. Wooden tappoon provided with outlets . . . . .	198
61. Metal tappoon with measuring gate . . . . .	198
62. Plan of wild flooding . . . . .	200
63. Plan of distributing water on rolling lands . . . . .	201
64. Box for distributing water in an orchard . . . . .	202
65. Outlet from side of small flume . . . . .	203
66. Orchard irrigation by pools . . . . .	204
67. Irrigation on slope with stepped flume . . . . .	205
68. Pipes and hydrant for distributing water in an orchard . . . . .	208
69. Plan of subirrigating system . . . . .	209
70. Section of small galvanized sheet-iron pipe . . . . .	210
71. Plan of an irrigated farm . . . . .	221
72. Rise of ground water following irrigation . . . . .	223
73. Diagram illustrating inflow and outflow of Ogden Valley, Utah . . . . .	228
74. Dam across a rocky canyon, cutting off the underflow . . . . .	234
75. Ordinary well curbing and windlass . . . . .	244
76. Diagram illustrating evils of insufficient casing . . . . .	245
77. Section of one side of an artesian basin . . . . .	247

	PAGE
78. Section illustrating the thinning out of a porous water-bearing bed . . . . .	248
79. Geologic section from the Black Hills east across South Dakota (western half) . . . . .	250
80. Geologic section from the Black Hills east across South Dakota (eastern half) . . . . .	251
81. The doon, or tilting trough . . . . .	254
82. Series of shadoofs as used in Egypt . . . . .	255
83. A mot, operated by oxen . . . . .	256
84. Horse-power for lifting water . . . . .	257
85. Current wheel lifting water . . . . .	258
86. Impulse water-wheel . . . . .	260
87. Windmills pumping into earth reservoir . . . . .	268
88. Channels and gates for sewage irrigation . . . . .	280
89. United States compared with foreign countries . . . . .	301
90. Western United States compared with foreign countries . . . . .	303
91. California compared with the Atlantic States lying in the same latitude . . . . .	314
92. California compared with Old World countries lying in the same latitude . . . . .	315
93. Canal system from Kern River, California . . . . .	320
94. Ideal section of Columbia River lava . . . . .	361