Supply from flow of streams.

	Cubic feet.
Mean low-water as guaged, 1878, per second	=290
Mean low-water as gauged, 1878, per day	25,056,000
	Cubic feet.
For December, January, February, and March, 120 days	3,006,720,000
Now this is all held back in Leech Lake, and we have only the low-water discharge of Mud and Bear Rivers, which at 75 feet per second for 4 months	=777,600,000
Three-fourths snow and rain	1,204,346,880
One-half rain, April, May, and June	1,516,584,960
	3,498,531,840
Less evaporation, 90 days, at 0.1 inch per day = 9 inches	360,676,800
Total supply	3,137,855,040
Capacity	2,885,414,400
Surplus	252,440,640

LAKE WINNEBAGOSHISH.

Capacity, with rise of 14 feet above high-water, 1874:

Lake surface 74.11 square miles	= 2,066,050,800 square feet,
Which multiplied by 14 feet depth	=28,924,711,200 cubic feet.
Overflowed surface, 33 square miles	= 919,987,200 square feet,
Which multiplied by 8 feet depth	= 7,359,897,600 cubic feet.
Overflowed on Mississippi River, between Winnebagoshish and Cass Lakes, 2.2 square miles	= 60,984,000 square feet,
Which multiplied by 10 feet depth	= 609,840,000 cubic feet,
Overflowed surface Cass Lake, 45.4 square miles	= 1,265,679,360 square feet,
Which multiplied by 7 feet depth	= 8,859,755,520 cubic feet.

RECAPITULATION.

Capacity for 14 feet rise in Winnebagoshish Lake:

	Cubic feet.
Lake Winnebagoshish proper	28,924,711,200
Marsh overflowed	7,359,897,660
Mississippi River	609,840,000
Cass Lake	8,859,755,520
Total capacity	45,754,204,380

Supply furnished reservoir at Lake Winnebagoshish.

1. From rainfall:

Average rainfall	25 inches.
Available	8.33 inches = 0.7 foot.
Area of basin, 1,892 square miles	=52,745,932,800 square feet.
Which, multiplied by 0.7 foot	=36,922,152,960 cubic feet.
Total supply from one-third rainfall	36,922,152,960 cubic feet.
Total capacity at 14 feet rise	45,754,204,380 cubic feet.

2. From flow of stream:

	Cubic feet.
Measured low-water flow = 540 feet per second, or per day	46,656,000
For December, January, February, and March, 120 days	=5,598,720,000
Three-fourths rainfall and melted snow, same period	14,241,401,856
One-half rainfall, April, May, and June	17,933,617,152
Total supply	37,773,739,008

VERMILLION RIVER DAM.

Capacity if water is raised 10 feet above high-water 1874:

Surface overflowed, 34.5 square miles	= 961,804,800 square feet.
Which, multiplied by 6 feet depth	= 5,770,828,800 cubic feet.

Supply from rainfall:

Area tributary, 433 square miles	=12,071,346,800 square feet.
Which, multiplied by 0.7 foot	= 8,449,942,760 cubic feet.

Surplus:

	Cubic feet.
Mud Lake	236,966,400
Rainfall	8,449,942,760
Total entering reservoir	8,686,909,160
Capacity	5,770,828,800
Surplus entering reservoir below	2,916,080,360

Supply calculated from flow of streams:

	Cubic feet.
Mean low-water flow below upper dams per second	100
Mean low-water flow below upper dams per day	8,640,000
For December, January, February, and March, 120 days	1,036,800,000
Three-fourths melted snow for same period	3,259,263,636
One-half rainfall April, May, and June	4,104,257,912
Supply to July 1	8,400,321,548
No evaporation allowed for here.	
Surplus Mud Lake	252,440,640
Total supply	8,652,762,188
Capacity as above	5,770,828,800
Surplus passing into Pokegama Falls	2,881,933,388

POKEGAMA FALLS DAM.

Capacity if water is raised 7 feet above high-water 1874:

Area overflowed, 23.61 square miles	= 658,209,024 square feet.
Multiplied by depth, 5.7 feet	=3,751,791,436 cubic feet.

Supply from rainfall:

Area of watershed	4,990,223,600 square feet.
Multiplied by rainfall, 0.7 foot	3,493,156,520 cubic feet.

Surplus:

	Cubic feet.
From above	2,916,080,360
Supply	3,493,156,520
Total	6,409,236,880
Capacity	3,751,791,436
Surplus pouring over dam	2,657,445,444

POKEGAMA FALLS RESERVOIR.

	Cubic feet.
Mean low-water flow below Vermillion Dam, per second	200
Mean low-water flow below Vermillion Dam, per day	17,280,000
For December, January, February, and March, 120 days	2,073,600,000
Three-fourths snow, &c., same months	1,347,360,372
One-half rain, April, May, and June	1,696,676,024
Supply	5,117,636,396
Add surplus	2,881,933,388
	7,999,569,784
Deduct capacity	3,751,791,436
Surplus passing over dam	4,247,778,348
Or for 90 days, per day	47,197,537
Or for 90 days, per second	548

The above surplus discharge takes place without drawing upon the reservoirs in any way whatever.

FLAMBEAU REGION.

Reservoir at Butternut Lake.

Area of watershed, 55 square miles	1,533,312,000 square feet
Average rainfall, 30 inches.	
One-third rainfall, 10 inches = 0.83 foot.	
Amount of water	1,272,648,960 cubic feet.
Surface area of reservoir, 2.1 square miles	58,544,640 square feet.
Multiplied by depth, 10 feet	=585,446,400 cubic feet.

	Cubic feet.
Supply	1,272,648,960
Deduct capacity	585,446,400
Surplus	687,202,560
Supply for 90 days	1,272,648,960
Supply for 1 day	14,140,544
Supply for 1 second	164
Capacity only	75
Discharge of streams as gauged, per second	22

Reservoir at Rest Lake.

Supply:

Area of watershed, 212 square miles	5,910,220,800 square feet.
Average rainfall, 30 inches.	
One-third rainfall, 10 inches=0.83 foot.	
Amount of water available	4,905,483,264 cubic feet.

Capacity of reservoir, water-rise of dam, 25 feet.

	Square feet.
Area of surface=9.5 square miles	= 264,844,800
To which must be added 10 square miles	278,784,000

	Cubic feet.
Now 264,844,800 by 7 feet depth	=1,853,913,600
And 278,784,000 by 10 feet depth	=2,787,840,000
	4,641,753,600

Now also add for the 10 feet rise an area of 12 square miles =334,540,800 square feet, which averages 3 feet depth =1,003,622,400 cubic feet.

	Cubic feet.
Total capacity	5,675,376,000
Total supply	4,905,483,264
Excess of capacity	769,892,736

Reservoir when filled can discharge for 90 days 730 cubic feet per second.

TURTLE RIVER RESERVOIR, PARK LAKE, ETC.

Area of watershed, 174 square miles	=4,850,841,600 square feet.
Average rainfall, 30 inches.	
One-third of rainfall 10 inches=0.83 foot.	

	Cubic feet.
Available amount of water	4,026,198,428
Total capacity with 15 feet rise at dam	620,782,720
Surplus	3,405,415,708

This must be sought to be retained above this reservoir by future examinations.

	Cubic feet.
Contents of reservoir for 90 days	620,782,720
Contents of reservoir for 1 day	6,897,586
Contents of reservoir for 1 second	82
While from the supply, could it be retained, we could get per second	518

UPPER SAINT CROIX LAKE RESERVOIR.

Total area lake surface, 1.8 square miles	50,172,400 square feet.
Which, multiplied by 12 feet depth	= 602,068,800 cubic feet.
Overflowed area, 14.7 square miles	409,620,100 square feet.
Which, multiplied by 10 feet depth	=4,096,201,000 cubic feet.
Total capacity	4,698,269,800 cubic feet.

Supply:

Area of watershed, 290 square miles	=8,084,736,000 square feet.

	Cubic feet.
Which, multiplied by 0.7 foot, one-third rainfall	5,659,315,200
Deduct capacity	4,698,269,800
Surplus	961,045,400
From reservoir full for 90 days we have per day	52,202,998
From reservoir full for 90 days we have per second	604

TOTOGATIC RESERVOIR.

Capacity:

Area of surface overflowed 7,635 square miles	=212,855,000 square feet.
Which by various depths will give	2,881,095,000 cubic feet.

Supply:

	Square feet.
Area of watershed, 330 square miles	9,199,872 000

	Cubic feet.
Which, multiplied by 0.7 foot, one-third rainfall	=6,439,910,400
Deduct capacity	2,881,095,000
Surplus	3,558,815,400

Which must be sought to be retained by further examinations.

	Cubic feet.
Capacity gives per day	32,012,166
Capacity gives per second	370
Could the surplus be retained above we should have added per day	39,542,393
Per second	457

UPPER SAINT CROIX REGION.

Yellow Lake and River reservoir.

Capacity of reservoir:

	Square feet.
Lake proper, surface 4.664 square miles	= 129,913,344

	Cubic feet.
Which, multiplied by 18 feet depth	=2,340,500,000
Overflowed area, 3.936 square miles, which by varying depths, elsewhere computed, gives	1,062,212,000
Total capacity	3,402,712,000

Supply:

	Square feet.
Area of watershed, 321.5 square miles	= 8,962,905,600

	Cubic feet.
Which, multiplied by 0.7 foot, one-third rainfall	6,274,033,920
Deduct capacity	3,402,712,000
Surplus	2,871,321,920

This must be sought to be retained by further examinations next year.

	Cubic feet.
From reservoir full for 90 days, we can furnish per day	37,807,911
Per second	438
Could we retain surplus above we could add per day	31,903,577
Per second	369

TABLE D.—*Discharge of the Mississippi and Leech Lake rivers.*

Date.	Station.	Height above low-water.	Area of cross-section.	Mean velocity of river.	Discharge in cubic feet per second.
1874.					
September 8	Above Cass Lake	Mean H. W.	482	1. 074	517
August 22	Below Cass Lake	1. 855	443	2. 012	891
August 15	First station Leech Lake River	1. 536	544	1. 121	610
September 26	Second station Leech Lake River	Mean H. W.	1, 427	0. 833	1, 239
September 26	Below junction Leech Lake River	3. 931	1, 197	1. 636	1, 958
October 12	Above Pokegama Falls	2. 561	849	2. 914	2, 474
October 15	Below Grand Rapids	Mean H. W.	731	3. 454	2, 525
October 20	Below Swan River	do	1, 513	1. 963	2, 969
October 27	Below Sandy Lake River	do	1, 738	1. 696	*2, 946
November 3	Below Willow River	do	1, 822	2. 077	3, 784
1878.					
October 14	Below Lake Winnebagoshish	Mean L. W.	561	0. 965	541
October 16	do	do	678	0. 808	548
September 21	First station Leech Lake River	do	415	0. 729	303
September 23	do	do	474	0. 605	226
October 21	Above junction Leech Lake River	do	342	1. 821	622
October 21	Below junction Leech Lake River	do	672	1. 354	909
October 26	Below Vermillion River	do	986	0. 936	922

* Height of banks about 8 feet at low-water.

Fridley's Bar.

FIRST SERIES.

Date.	Height above low-water.	Area of cross-section.	Slope.	Mean velocity of river.	Discharge in cubic feet per second.
1875.		*Square feet.*			
April 30	7. 28	8, 324	0. 00029187	3. 9554	32, 924
May 2	6. 90	8, 057	0. 00028289	4. 0228	32, 412
May 3	6. 74	7, 982	0. 00028289	3. 9627	31, 630
May 4	6. 65	7, 916	0. 00026942	3. 9056	30, 917
May 5	6. 63	7, 894	0. 00026044	3. 8251	30, 190
May 6	6. 58	7, 859	0. 00026942	3. 7300	29, 314
May 7	6. 52	7, 808	0. 00025595	3. 7594	29, 354
May 8	6. 51	7, 786	0. 00025595	3. 7450	29, 159
Sum				30. 9060	
SECOND SERIES.					
June 22	5. 78	6, 944		3. 6803	25, 556
June 23	5. 55	6, 791		3. 6082	24, 503
June 24	5. 43	6, 724		3. 6302	24, 409
June 25	5. 25	6, 594		3. 4855	22, 983
June 26	5. 04	6, 473		3. 4340	22, 327
June 28	4. 57	6, 119		3. 3789	20, 670
June 29	4. 27	5, 926		3. 2324	19, 155
June 30	3. 94	5, 706		3. 1570	18, 014
July 1	3. 63	5, 545		3. 0435	16, 876
				30. 6500	
THIRD SERIES.					
July 23	1. 40	4, 154	0. 00019398	2. 0540	8, 535
July 24	1. 35	4, 133	0. 00019398	2. 0030	8, 278
July 26	1. 26	4, 050	0. 00019847	1. 9927	8, 070
July 27	1. 27	4, 061	0. 00019398	1. 9805	8, 042
July 28	1. 30	4, 081	0. 00018949	1. 9303	7, 878
July 29	1. 22	4, 050	0. 00018949	1. 8733	7, 587
July 30	1. 21	4, 039	0. 00018949	1. 8396	7, 430

Sauk Rapids.

FIRST SERIES.

Date.	Height above low-water.	Area of cross-section.	Slope.	Mean velocity of river.	Discharge in cubic feet per second.
1875.		*Square feet.*			
May 13	6. 36	6, 691	0. 00018998	3. 3839	22, 642
May 14	6. 32	6, 673	0. 00018482	3. 4050	22, 722
May 15	6. 24	6, 601	0. 00017449	3. 4389	22, 700
May 17	6. 20	6, 565	0. 00017965	3. 2385	21, 261
May 18	6. 34	6, 637	0. 00014352	3. 2393	21, 509
May 19	6. 27	6, 583	0. 00014868	3. 2379	21, 315
May 20	6. 17	6, 535	0. 00015384	3. 2439	21, 199
SECOND SERIES.					
June 7	8. 00	7, 679	0. 00022247	4. 0286	30, 936
June 8	7. 76	7, 578	0. 00027666	4. 0049	30, 339
June 10	7. 34	7, 226	0. 00024333	3. 8974	28, 163
June 11	7. 23	7, 140	0. 00022666	3. 8156	27, 243
June 12	7. 10	7, 036	0. 0002100	3. 7540	26, 413
June 14	6. 62	6, 847	0. 00019990	3. 7182	25, 359
June 15	6. 50	6, 778	0. 00019990	3. 6394	24, 668
THIRD SERIES.					
July 16	2. 38	4, 379	0. 00010063	1. 9305	8, 336
July 17	2. 34	4, 350	0. 00009612	1. 8666	8, 120
July 19	2. 15	4, 234	0. 000087093	1. 7802	7, 537

Brainerd.

FIRST SERIES.

Date.	Height above low-water.	Area of cross-section.	Slope.	Mean velocity of river.	Discharge in cubic feet per second.
1875.		*Square feet.*			
May 26	8. 30	4, 467	0. 00015752	2. 9268	13, 084
May 27	8. 32	4, 402	0. 00015123	2. 9099	12, 819
May 28	8. 47	4, 426	0. 00014492	2. 9836	13, 206
May 29	8. 31	4, 402	0. 00013232	2. 9735	13, 089
May 31	8. 46	4, 437	0. 00014492	2. 9485	13, 082
June 1	8. 57	4, 471	0. 00013862	2. 9535	13, 205
June 2	8. 91	4, 586	0. 00013232	2. 9308	13, 441
June 3	9. 05	4, 690	0. 00013862	2. 8666	13, 444
SECOND SERIES.					
July 8	3. 62	2, 785	0. 000070588	2. 2933	6, 387
July 9	3. 48	2, 735	0. 000064052	2. 2234	6, 081
July 10	3. 32	2, 675	0. 000083660	2. 2120	5, 917
July 12	2. 98	2, 571	0. 000083660	2. 1302	5, 477
July 13	2. 82	2, 522	0. 000070588	2. 1243	5, 362

Discharge of the Saint Croix River and tributaries, 1878.

Date.	Station.	Height above low-water.	Area of cross-section.	Slope.	Mean velocity of river.	Discharge in cubic feet per second.
1878.						
Aug. 30	Dam site in section 35, township 24, range 13.	Low-water..	172	....	1.085	172
30	......do	....do	148	....	1.661	234
Nov. 3	Above the Namekagon	Low-water..	266	....	1.358	362
3	......do	....do	302	....	1.212	368
3	......do	....do	302	....	1.269	383
3	......do	....do	302	....	1.263	381
Nov. 1	Below Yellow River	Low-water..	975	....	1.249	1,218
1	......do	....do	978	....	1.305	1,276
1	......do	....do	997	....	1.357	1,352
1	......do	....do	997	....	1.262	1,258
1	......do	....do	997	....	1.295	1,281
Oct. 28	Below Crooked River	Low-water..	1,024	0.000275	1.408	1,442
28	......do	....do	1,024	....	1.418	1,453
29	......do	....do	1,017	....	1.400	1,425
29	......do	....do	1,017	....	1.441	1,467
29	......do	....do	1,017	....	1.329	1,413
Oct. 23	Below Kettle River	0.540	941	0.00132	2.851	2,683
23	......do	0.535	941	....	2.834	2,667
23	......do	0.530	938	....	2.897	2,716
23	......do	0.520	935	....	2.826	2,642
23	......do	0.520	935	....	2.894	2,705
Oct. 18	Below Snake River	0.580	1,494	0.000551	2.176	*3,252
19	......do	1.888	1,872	0.000771	3.489	*6,533
19	......do	1.886	1,858	....	3.284	*6,103
19	......do	1.884	1,849	....	3.421	*6,425
19	......do	1.670	1,801	....	3.355	*5,740
19	......do	1.090	1,658	....	2.605	*4,321
21	......do	1.224	1,387	....	2.177	*4,010
Oct. 15	Below Rush City	0.340	2,420	0.00031	1.059	2,564
16	......do	0.480	2,420	....	1.117	2,705
16	......do	0.480	2,420	....	1.109	2,685
16	......do	0.490	2,426	....	1,124	2,718
Oct. 5	Three miles above Taylor's Falls	0.815	1,962	0.000148	1.782	3,499
5	......do	0.835	1,948	....	1.724	3,360
5	......do	0.875	1,967	....	1.733	3,410
7	......do	0.730	1,906	....	1.679	3,199
7	......do	0.715	1,899	....	1.640	3,177
8	......do	0.620	1,860	....	1.618	3,010
8	......do	0.620	1,860	....	1.642	3,055
8	......do	0.620	1,860	....	1.594	2,964
8	......do	0.635	1,866	....	1.654	3,086
9	......do	0.620	1,860	....	1.622	3,019
9	......do	0.635	1,866	....	1.611	3,008
9	......do	0.660	1,877	....	1.623	3 041

* These large discharges were caused by the opening of Snake River Dam at Chengwatana. The height above low-water will show this.

Discharge of the Saint Croix River and tributaries, 1878—Continued.

Tributaries.

Date.	Station.	Height above low-water.	Area of cross-section.	Slope.	Mean velocity of river.	Discharge in cubic feet per second.
1878.						
Oct. 11	Totogatic dam site	Low-water..	201	....	1.468	221
11	......do	....do	230	....	1.193	260
12	......do	....do	202	....	1.487	284
12	......do	....do	230	....	1.286	279
Nov. 4	Namekagon River	Low-water..	557	....	1.243	692
4	......do	....do	557	....	1.378	768
4	......do	....do	557	....	1.418	790
4	......do	....do	557	....	1.427	795
Oct. 30	Yellow River at dam site	Low-water..	528	....	0.414	209
31	......do	....do	528	....	0.361	181
Oct. 25	Kettle River	Low-water..	458	0.001037	0.850	390
25	......do	....do	458	....	0.682	313
25	......do	....do	458	....	0.795	365
25	......do	....do	458	....	0.739	339
25	......do	....do	458	....	0.739	338
25	......do	....do	458	....	0.711	326
25	......do	....do	458	....	0.809	373
Oct. 21	Snake River (dam open)	Low-water..	591	0.00691	4.302	2,545
21	......do	....do	591	....	4.240	2,517
21	......do	....do	578	....	4.153	2,402

Discharge of the Chippewa River and tributaries.

Date.	Station.	Height above low-water.	Area of cross-section.	Mean velocity of river.	Discharge in cubic feet per second.
1878.					
Nov. 15	Above the Flambeau	0.700	738	1.326	979
16	Below the Flambeau	0.700	1,621	1.132	1,834
Oct. 7	Above the Yellow River	2.000	2,649	....	3,501
14	At mouth	1.500	1,886	3.284	5,713
Sept. 27	......do	0.700	1,256	2.425	3,046

Tributaries.

Date.	Station.	Height above low-water.	Area of cross-section.	Mean velocity of river.	Discharge in cubic feet per second.
Sept. 30	Manatonish River	Mean L. W..	231	0.637	147
Oct. 20	......do	....do	262	0.789	205
Sept. 4	Turtle River	....do	144	0.280	40
Aug. 27	Butternut Creek	....do	76	0.280	22
	Flambeau River	....do	....	....	....
Nov. 16	East Channel	0.700	358	2.002	717
	West Channel	0.700	297	1.378	410
Oct. 7	Yellow River	Mean L. W..	112	1.089	122
7	Eau Claire River	0.800	243	1.299	317
12	Menomonee River	Mean L. W..	332	1.669	555
12	Aux Galets	....do	125	0.931	116
13	Beef Slough	1.750	731	1.741	1,273

TABLE E.—*List of the elevations above the sea of different points on the Mississippi River from Cass Lake to Saint Paul, Minn. The low-water surface of river is given.*

Station.	Distance.	Elevation.	Total fall.
	Miles.		
Lake Superior	....	602.00	....
Cass Lake	....	1,300.08	....
Lake Winnebagoshish	20	1,290.04	10.04
Leech Lake	....	1,292.78	....
Junction of Leech and Mississippi Rivers	38	1,279.23	20.85
White Oak Point	15	1,275.65	24.83
Outlet of Pokegama Lake	27	1,269.32	30.66
Head of Pokegama Falls	3	1,266.71	33.27
Foot of Pokegama Falls	3	1,252.56	47.52
Head of Grand Rapids	$3\frac{1}{2}$	1,249.72	50.26
Foot of Grand Rapids	$\frac{1}{2}$	1,244.69	55.39
Junction of Sandy and Mississippi Rivers	$82\frac{1}{2}$	1,208.55	91.53
Aitken	61	1,190.00	110.08
Brainerd	45	1,152.43	147.55
Crow Wing	10	1,145.74	154.34
Fort Ripley	6	1,139.54	160.54
Head of Little Falls (ferry)	15	1,090.55	209.43
Foot of Little Falls	....	1,083.20	216.88
Platte River	16	1,026.07	274.01
Watab	9	1,000.81	299.27
Head of Sauk Rapids	6	988.33	311.75
Foot of Sauk Rapids	....	977.00	323.08
Saint Cloud Mill	$3\frac{1}{2}$	960.50	339.58
Saint Augusta	$5\frac{6}{10}$	946.5	353.58
Clear Water	$8\frac{8}{10}$	936.0	364.08
Monticello	$14\frac{3}{10}$	890.90	409.18
Elk River	$12\frac{5}{100}$	850.90	449.18
Anoka	$13\frac{2}{10}$	826.60	473.48
Minneapolis	$17\frac{3}{10}$	794.40	505.68
Saint Paul (low water)	13	682.00	618.00
	445.55		

REPORT OF MR. JOSEPH P. FRIZELL, ASSISTANT ENGINEER.

UNITED STATES ENGINEER OFFICE,
Saint Paul, December 20, 1878.

SIR: In reply to your request of the 13th instant, for my views as to the quantity of water that may be expected for filling the proposed reservoirs on the headwaters of the Mississippi, and other scientific questions involved in this project, I have the honor to submit the following:

Although the flow of streams depends upon rainfall, and every considerable fall of rain is usually followed by a greater or less increase of volume in streams, the portion of the rainfall finding its way into the streams is a matter of great and perplexing uncertainty, and no province of engineering stands so much in need as this of extended, accurate, and intelligent observation of the various circumstances which affect this result.

Observations have been made for some 25 years past at Lake Cochituate, from which the city of Boston has, until recently, derived its supply of water, of the rainfall on, and discharge from, a district some 19 square miles in area. I am in possession of the results from 1852 to 1875, inclusive, a period of 24 years. The average flow is about 45 per cent. of the rainfall, which has averaged some 50 inches. To show the extreme uncertainty of these results, it may be mentioned that in 1857 the rainfall was 63.1 inches, 74 per cent. of which was represented by the discharge. In 1866, the rainfall was nearly the same, viz, 62.3 inches, only 25 per cent. of which appeared in the discharge. The latter was the lowest percentage shown during the 24 years. The highest was in 1859, being 78 per cent. on a rainfall of 49 inches. The highest rainfall of the period was 69 inches in 1863; the lowest, 35 in 1855. In other words, the variations in the rainfall are as 2 to 1. The variations in the discharge with the same rainfall are as 3 to 1. In 1857 the aggregate discharge was equivalent to 47 inches on the entire drainage-basin. In 1871 it was 15 inches.

The flow of the west branch of the Croton River, which has a drainage area of about 20 square miles, was observed for a period of six years by Mr. J. J. R. Croes, an engineer of the New York water-works. The aggregate flow was 63 per cent. of the rain-

fall. From data obtained in my professional experience I find that the Concord River, in Massachusetts, which has a drainage area of 375 square miles, carried off during a period of 34 months, in 1874, '75, '76, about 41 per cent. of the rainfall.

Mr. T. G. Ellis, under authority of the United States Engineer Department, determined the flow of the Connecticut River, at Thompsonville, Conn., for a period of 47 months, commencing February, 1871. The results are detailed in the Report of the Chief of Engineers for 1875. The aggregate flow, after making a slight correction which appears necessary, amounts to 25 inches per annum, rather more than 50 per cent. of the rainfall.

Whether these results can afford us any guidance under climatic conditions so essentially different, is very doubtful. It will appear that even for the localities to which they relate, they form a very unsatisfactory basis of calculation. If, for instance, we attempt to predict the product of the Lake Cochituate drainage district for any given year, knowing the area of the district, the average rainfall, 50 inches, and the average percentage of flow, 45, the second element of our calculation is liable, for any particular year, to vary between the limits 35 and 69, and the third between the limits 25 and 78. So that it appears within the limits of possibility that the flow might be as low as $8\frac{3}{4}$ inches or as high as 54 inches. According to the theory of probabilities both these results might be expected in the course of 576 years, *i. e.*, assuming every succeeding period of 24 years to present the same variations in rainfall and flow as the one embraced in these records, the lowest rainfall might be expected to occur in the course of 24 years, and in 24 periods of 24 years each, it might be expected that the year of lowest percentage would coincide with the year of lowest rainfall.

Of the quantity of water which falls upon the drainage ground of any stream, a portion flows directly into the stream. It does so, at least, when the rain falls faster than it can be absorbed by the ground. A portion may or may not reach the stream indirectly by sinking into the ground, and reappearing at a lower level. A portion is evaporated, from the ground, from foliage, water surface, and morasses. A portion, at certain seasons, is taken up by plants. Still another portion, in some localities, passes under impervious strata and flows for long distances, often never reappearing till it reaches the sea. Of this character is the water of artesian wells.

The determination of the proportions in which the water of rains is thus distributed has latterly, to a large extent, engaged the attention of hydraulicians. I present a brief summary of their labors in this direction, rather to exhibit the extreme uncertainty which prevails on this subject, than in the hope of deducing conclusions of practical value. Evaporation is one of the most active causes of the waste of waters. Water surfaces are constantly exposed to it, and the water which enters the ground is not safe from it till it has reached a depth of 2 or 3 feet. The most extended series of observations of evaporation from water surfaces in the United States was made by the officers of the Lake Survey, in 1861–'67, at different points on Lakes Superior, Michigan, Huron, and Erie. The average monthly results are given in Table 1. A second column, headed "New York," gives the results obtained by the engineers of the New York water-works at one of their receiving reservoirs in 1876. The evaporation was observed by means of a wooden box, filled with water and imbedded in the earth of the embankment. The results are given in inches of water evaporated from a water surface.

TABLE 1.

Month.	Lakes.	New York.
January	0.69	....
February	0.72	....
March	0.92	1.36
April	3.06	2.13
May	4.84	5.18
June	5.57	5.49
July	5.79	6.05
August	5.28	7.29
September	3.38	4.19
October	2.37	2.85
November	1.49	2.60
December	0.84	0.47
Total	34.95	....

Mr. J. J. R. Croes, above mentioned, observed the evaporation at one of the storage reservoirs of the New York water-works, from 1866 to 1870. He made the average annual evaporation 24 inches, which is about half the rainfall. He thinks his result entitled to more confidence than that given in the table, which, if it embraced the whole year, would show about 39 inches. It is customary among hydraulic engineers