SECTION IV.—RIVERS AND FLOODS.

RIVERS AND FLOODS, SEPTEMBER, 1916.

By ALFRED J. HENRY, Professor in Charge.

[Dated: Weather Bureau Washington, Oct. 26, 1916.]

There was a rather marked absence of floods in all of the larger rivers of the United States during September, 1916. In the lower Rio Grande flood stage was reached on the 14th, Rio Grande City, Tex., but evidently the flood was confined to the extreme lower reaches of the stream, since the river at Eagle Pass, Tex., the next station upstream was below flood stage throughout the month.

Freshet stages prevailed on the Nueces River on the 15th, evidently due to local rains in the watershed. The rivers of South Carolina were near flood stage during the early days of the month, but fell steadily thereafter.

Hydrographs for typical points on several principal rivers are shown on Chart I. The stations selected for charting are Keokuk, St. Louis, Memphis, Vicksburg, and New Orleans, on the Mississippi; Cincinnati and Cairo, on the Ohio; Nashville, on the Cumberland; Johnsonville, on the Tennessee; Kansas City, on the Missouri; Little Rock, on the Arkansas; and Shreveport, on the Red.

SNOW DENSITIES IN THE SIERRA NEVADA.

By HENRY F. ALCIATORE, Meteorologist.

[Dated: Weather Bureau Office, Reno, Nev., Aug. 10, 1916.]

Students of meteorology can not but be impressed by the paucity of information that characterizes most of the present-day textbooks as to the density of snow and its underlying causes, and we may say, in passing, that some of the information contained therein is of doubtful value, if not actually misleading. For instance, in one of the latest works on meteorology (published in 1912) the author states that: "It requires from 6 to 30 inches of snow to make an inch of water, depending on the lightness of the snow; the average value, however, is about 10."

Now, in terms of density this means that one kind of snow may have a density of 17 per cent and another kind 3 per cent. As this writer does not tell his readers whether freshly fallen or old snow is meant, that statement leaves much to be desired as to accuracy and completeness. As a matter of fact, Ward [1] has found densities of 0.008 (March, 1876) and 0.020 (December, 1874), and Chassant [2] mentions one of 0.024 (L'Hérault, March 1887); Mougin and Bernard [2] (July, 1903) found a density of 0.344; all of the above values are for fresh snow. As to old snow, densities of 0.450 are very common in the spring; Cole,[3] of the United States Weather Bureau, found a density of more than 80 per cent near the ground in a deep snow cover in the Sierras. As a rule fresh snow is less dense than old snow, but exceptions are met with occasionally. Schreiber [4] made some measurements at Potsdam in 1896 with the following results:

Results of measurements of snow densities by Schreiber at Potsdam-Berlin, 1896.

Dates.	Old snow.		New snow.	
	Depth.	Density.	Depth.	Density.
	Mm.		*Mm.*	
Jan. 9	39	0.27	11	0.04
Jan. 16	71	0.16	31	0.18
Feb. 15	78	0.07	78	0.07

"A simple consideration of the difference between fresh and old snow," says Bracke,[4] "shows that temperature, humidity, direction of the wind, fogs, and clouds, are many factors which intervene to produce variations in the physical state of a snow cover; it is of the greatest importance to state the condition of the weather when making measurements."

In the spring of 1916 a series of snow surveys was made by the United States Weather Bureau in the Tahoe, Carson, and Walker watersheds, in cooperation with the University of Nevada. The several snow courses lay within a quadrangle about 58 miles long, by 45 wide, with its northern edge in latitude 38° 58′ N., and its eastern edge in longitude 119° 25′ W. According to A. H. Palmer,[5] this includes the region of heaviest snowfall in the United States. In all, 11 courses were laid out, in each of which 39 to 40 measurements, 50 feet apart, were made with a snow sampler and spring balance devised several years ago by Dr. J. E. Church, jr., meteorologist of the University of Nevada. The depth of the snow cover, in inches, was measured with the sampler tube, while the water content was obtained by weighing the tube and its core of snow with the spring balance, the dial of which gives directly the water equivalent of the snow in inches. The mean density of the snow is obtained by dividing the water content by the depth of the snow.

The courses at Meyers Station, Cal., Genoa Summit, Nev., and Freels Peak, Cal., were surveyed on March 17 and 18, and April 16, respectively; those at Grass Lake, Blue Lakes, Burnside Lake, and Williams, Cal., on March 17, 24, and 26, respectively; and those at Pickle Meadow, Willow Flat, Cinque Mountain, and Big Meadow, Cal., on April 4, 5, 8, and 9, respectively. This work was not undertaken by the Government and the university for experimental purposes, but with the view of establishing a basis for the correlation of snowfall and run-off in these watersheds, and estimating the available water supply stored in the snow.

To ranchers, hydroelectric engineers, and managers of municipal water plants and reclamation projects in Nevada, each season's available run-off from Lake Tahoe (whose sole outlet is the Truckee River) is of great importance. How the snowfall and run-off in the Lake Tahoe watershed have been correlated, and forecasts of the probable maximum summer level in that lake made possible thereby by the writer, have been explained in another paper.[6] Here we shall confine ourselves to a considera-

[1] *Wengler, Fritz.* Spezifische Dichte des Schnees. Berlin, 1914. p. 14.
[2] *Bracke, A.* La densité de la neige. Bruxelles, 1906. pp. 5, 18.
[3] In an unpublished MS. report of 1913, in Weather Bureau files.
[4] Bracke, op. cit., p. 9, 23.
[5] This REVIEW, May, 1915, 43:217.
[6] *Alciatore, Henry F.* A method of forecasting the maximum summer level in Lake Tahoe ... MONTHLY WEATHER REVIEW, July, 1915, 44:407-9.

tion of the various relationships between depth and mean density; altitude and depth; age and mean density; and pressure and density of snow covers.

Relation between depth and density.

Table 1 has been prepared to show the relationship between the mean density and depth of the several snow covers in the Sierra Nevada Mountains. The 438 measurements made in that region have been tabulated in numerical order, according to depths, which are given for each half inch, regardless of geographical location, topography, altitude, or physical condition of the snow. (Wherever two or more measurements were made at the same depth, the number of such measurements is indicated by a small figure prefixed to the depths, but the density given is the arithmetic mean of all the densities for the given depth.)

In Table 2 are given the mean densities for snow layers of different depths arranged in steps of 10 inches progressively in the order of total depth of snow cover for the same region.

As we glance down the columns of Table 1, the first thing that strikes the eye is that the densities are remarkably uniform; in fact, 90 per cent of them fall between 0.40 and 0.49; in 13 exceptional cases, the densities vary from 0.332 to 0.399, and in 5 others, from 0.501 to 0.538. The highest individual mean density, **0.538**, occurred in a layer of total depth of 48.5 inches, while the lowest, **0.332**, was found in a layer having a total depth of 142 inches. These abnormalities are so interesting that we consider it worth while to give them in tabular form (Table 3), together with depths, watersheds, elevations, and the dates of surveys. They have occurred in all basins, and at different depths, altitudes, and dates.

It is interesting to note that at equal depths, the same mean densities have been observed at points a considerable distance from each other and of different elevations. For example: At a depth of 54.5 inches, a density of 0.455 was found at Meyers Station, Tahoe Basin, elevation, 7,000 feet, March 17; and also at Freels Peak, same basin, *one month later*, at an elevation of 8,500 feet.

TABLE 1.—*Depths and average densities of snow cover in the Tahoe, Carson, and Walker basins, March–April, 1916.*

Number of measurements.	Depth.	Density.	Number of measurements.	Depth.	Density.
	Inches.			*Inches.*	
	12.5	0.352	3	40.5	0.452
	17.0	.394	4	41.0	.438
	22.0	.468	3	41.5	.452
3	23.0	.448	3	42.0	.460
	23.5	.472	3	42.5	.482
2	24.0	.458	3	43.0	.471
2	27.0	.459		43.5	.487
	28.0	.479	4	44.0	.489
2	29.5	.458	3	44.5	.472
	30.0	.477	3	45.0	.498
	30.5	0.456		45.5	0.446
	32.0	.484	3	46.0	.430
3	32.5	.455	2	47.0	.436
2	33.5	.481	2	47.5	.413
3	34.0	.418	5	48.0	.448
3	34.5	.487		48.5	.538
2	35.0	.480	2	49.0	.437
4	35.5	.423	2	49.5	.463
	36.5	.468		50.0	.456
6	37.5	.444			
8	38.0	.476	3	50.5	0.463
3	39.5	.478	5	52.0	.444
5	40.0	.462	7	53.0	.462

TABLE 1.—*Depths and average densities of snow cover in the Tahoe, Carson, and Walker basins, March–April, 1916*—Continued.

Number of measurements.	Depth.	Density.	Number of measurements.	Depth.	Density.
	Inches.			*Inches.*	
4	53.5	0.430		98.5	0.469
7	54.0	.452	2	99.0	.414
2	54.5	.455		99.5	.501
2	55.0	.451			
			2	100.0	0.449
3	55.5	0.425	3	101.0	.459
4	56.0	.416	2	103.0	.423
3	56.5	.480	2	104.0	.408
3	57.0	.439		104.5	.428
3	58.0	.412	4	105.0	.457
4	58.5	.455		107.0	.447
2	59.0	.509	3	108.0	.409
2	59.5	.454	3	109.0	.399
2	60.0	.403		109.5	.447
			4	110.0	.425
3	60.5	0.469			
5	61.0	.436	3	112.5	0.450
3	61.5	.444	2	113.0	.474
2	62.0	.445		114.5	.366
2	62.5	.461		115.0	.418
3	63.0	.498		115.5	.448
4	63.5	.454	2	116.0	.444
4	64.0	.414	3	118.0	.407
	64.5	.462		118.5	.449
6	65.0	.438		119.0	.469
			4	120.0	.420
	65.5	0.406			
4	66.0	.430		121.0	0.464
2	66.5	.417		121.5	.438
3	67.0	.441		122.0	.468
6	67.5	.430		122.5	.460
8	68.0	.421		123.5	.429
4	69.0	.435		125.5	.436
2	69.5	.445		126.5	.427
5	70.0	.413	4	127.0	.457
				127.5	.456
3	71.0	0.431	2	128.0	.391
3	71.5	.421			
	73.0	.432		128.5	0.424
4	73.5	.435		129.0	.467
4	74.0	.416	2	131.0	.441
	74.5	.498	3	132.0	.415
	75.5	.403		133.0	.458
	76.0	.438	2	134.0	.402
5	78.0	.447		135.0	.416
	78.5	.493		137.0	.425
			3	138.0	.430
	81.0	0.430	2	139.0	.452
	81.5	.474			
2	82.0	.438		140.0	0.444
	82.5	.502		142.0	.332
	83.0	.447		142.5	.437
	83.5	.436		144.5	.436
7	84.0	.456		148.0	.390
2	84.5	.405	3	149.0	.404
4	85.0	.454		149.5	.401
	85.5	.416	2	150.0	.437
4	86.0	0.444	2	151.0	0.385
	86.5	.503		152.0	.397
3	87.0	.421	3	153.0	.422
2	88.0	.443		154.0	.362
2	89.0	.393	2	156.0	.437
2	89.5	.472		157.0	.417
2	90.0	.424		158.0	.423
2	91.0	.405		159.0	.436
2	92.0	.485		159.5	.404
2	92.5	.445			
				160.0	0.356
2	93.0	0.480		163.0	.420
2	94.0	.466		165.0	.439
3	95.0	.460		166.0	.473
2	96.0	.448		168.0	.384
	96.5	.492		170.0	.412
6	97.0	.446		172.0	.415
	97.5	.431		172.5	.417
4	98.0	.451		173.0	.418

TABLE 2.—*Depth and average density of snow layers in the Tahoe, Carson, and Walker basins, March–April, 1916 (compiled from Table 1).*

Depth.	Average density.	Depth.	Average density.
Inches.		*Inches.*	
10–20	0.373	100–110	0.430
20–30	0.465	110–120	0.434
30–40	0.462	120–130	0.433
40–50	0.465	130–140	0.431
50–60	0.450	140–150	0.405
60–70	0.439	150–160	0.404
70–80	0.441	160–170	0.426
80–90	0.445	170–173	0.417
90–100	0.460		

TABLE 3.—*Exceptionally high and low average snow densities in the Tahoe, Carson, and Walker watersheds, March–April, 1916.*

Low.

Density.	Depth.	Watershed.	Elevation.	Date of survey.
	Inches.		*Feet.*	
0.332	142.0	Carson	8,000	Mar. 24.
0.352	12.5	Walker	7,950	Apr. 5.
0.356	160.0	...do	8,800	Apr. 8.
0.362	154.0	Carson	8,000	Mar. 24.
0.366	114.5	Walker	7,050	Apr. 5.
0.384	168.0	...do	8,800	Apr. 8.
0.385	151.0	Carson	8,000	Mar. 24.
0.390	148.0	...do	8,000	Do.
0.391	128.0	Walker	8,800	Apr. 8.
0.393	89.0	Carson	7,500	Mar. 17 and 26.
0.394	17.0	Tahoe	8,500	Apr. 16.
0.397	152.0	Carson	8,000	Mar. 24.
0.399	109.0	...do	8,000	Mar. 24 and 26.

High.

0.501	99.5	Walker	7,525	Apr. 9.
0.502	82.5	...do	7,280	Apr. 4.
0.506	86.5	...do	7,280	Do.
0.509	59.0	Tahoe	7,000	Mar. 17.
0.538	48.5	Walker	7,280	Apr. 4.

Altitude and depth of snow cover.

As to the relationship between altitude and the depth of the snow cover, we give in Table 4 the names of the "courses" and watersheds, and the elevations and average depths of snow cover for the 11 courses surveyed in 1916, with dates.

TABLE 4.—*Altitude and depth of snow cover in the Tahoe, Carson, and Walker watersheds, March–April, 1916.*

Name of course.	Watershed.	Elevation.	Average depth of snow cover.	Date of survey.
		Feet.	*Inches.*	
Meyers Station	Tahoe	7,000	64	Mar. 17
Pickle Meadow	Walker	7,200 7,750	43	Apr. 4
Grass Lake	Carson	7,500	65	Mar. 17
Big Meadow	Walker	7,525	78	Apr. 9
Willow Flat	...do	7,900 8,025	50	Apr. 5
Genoa Summit	Tahoe	8,000	55	Mar. 18
Burnside Lake	Carson	8,000	94	Mar. 26
Williams	...do	8,000	88	Do.
Blue Lakes	...do	8,000	139	Mar. 24
Freel Peak	Tahoe	8,500	44	Apr. 16
Cinque Mountain	Walker	8,800 9,050	126	Apr. 8

The greatest average depth was found at Blue Lakes, at an altitude of 8,000 feet, March 24, and the least at Pickle Meadow, elevation 7,200–7,750 feet, April 4, and the depths measured 139 and 42 inches, respectively. It is evident that the several snow covers did not vary directly as to depth either with altitude or with age. This is not unusual.

Age of snow cover in relation to density.

The dates of surveys, watersheds, elevations, and average densities for 11 courses are given in Table 5.

TABLE 5.—*Increase in average density of snow with age in the Tahoe, Carson, and Walker watersheds, March–April, 1916.*

Date of survey.	Watershed.	Elevation.	Average density.
		Feet.	
Mar. 17	Carson	7,500	0.414
Do	Tahoe	7,000	0.427
Mar. 18	...do	8,000	0.440
Mar. 24	Carson	8,000	0.410
Mar. 26	...do	8,000	0.438
Do	...do	8,000	0.444
Average for surveys made in March			0.429
Apr. 4	Walker	72–7,750	0.490
Apr. 5	...do	70–8,025	0.456
Apr. 8	...do	88–9,050	0.436
Apr. 9	...do	7,525	0.462
Apr. 16	Tahoe	8,500	0.472
Average for surveys made in April			0.463

The later surveys, as might be expected, show a greater average density in the snow cover. The last general fall of snow for the season of 1916, a light one, occurred in all basins about March 5.

Relation between pressure and density.

We shall now briefly consider the relationship between pressure and density. For obvious reasons this phase of the subject is approached with hesitancy, for the pressure function is a complex one, and the evidence adduced by various investigators as to the effect of pressure on density is conflicting. Attempts have been made by Abe, Wengler,[7] and others to express this relation in concrete mathematical form, but so far as we know no formula of general application to practical problems has yet been worked out. In working out a logarithmic formula, Abe started out with the assumption that "the density of snow increases in proportion to the pressure." This may be well enough when we are dealing with a per fec ly homogeneous mass of snow, but not otherwise. Abe's deduc d densities differed materially from the observed ones. In one instance, where the snow cover was 65 centimeters in depth and the densities were given for seven layers, the differences between the observed and computed densities ranged from +0.020 to −0.070.

Wengler[8] gives the depths and densities shown in Table 6, quoted from a report by Defant, who made some density measurements on the Goldberg glacier in August, 1908.

TABLE 6.—*Depth and density of snow on Goldberg Glacier, August, 1908.*

Depth.	Density.			Depth.	Density.		
	Mean.	Maximum.	Minimum.		Mean.	Maximum.	Minimum.
Cm.				*Cm.*			
12.5	0.280	0.324	0.205	187.5	0.542	0.647	0.493
37.5	0.388	0.500	0.320	212.5	0.556	0.626	0.501
62.5	0.515	0.579	0.423	237.5	0.556	0.649	0.481
87.5	0.632	0.690	0.518	262.5	0.583	0.650	0.537
112.5	0.608	0.797	0.516	287.5	0.578	0.599	0.562
137.5	0.536	0.606	0.475	312.5	0.607	0.669	0.573
162.5	0.534	0.637	0.512				

[7] *Wengler, F.*, op. cit., p. 70–79.
[8] Op. cit., p. 69.

A very significant feature of Table 6 is that the greatest average density (six measurements were made at each level) did not occur in the lowest layer, but at depth 87.5cms. (fourth layer). Defant [9] explains this abnormality as follows:

After a heavy snowfall there fell an intensive rain, which, however, had only soaked in to the upper *layers*, which lay within depth of 87.5 centimeters; by recurrence of frost, a rough ice crust, 10 centimeters thick, had formed upon which the new snow rested; under that crust was found a real glacier snow extending into greater depths into glacial ice, whose density was found to be 0.85.

It seems to us that the possible and more than probable occurrence of such abnormal strata every season in any watershed where the winters are long, the temperatures alternately high and low, and rains alternate with snows, must necessarily introduce factors which make such formulæ as that proposed by Abe [10] of doubtful value in the solving of practical problems in snow density.

The abnormality referred to above is not an isolated one. Schreiber [11] made some measurements in the region of the Fichtelberg (March, 1904), the results of which are given in Table 7. The total depth of the snow cover was 280 centimeters, and four measurements were made, in layers each 50 centimeters thick.

TABLE 7.—*Depth and density of snow cover in the Fichtelberg, March, 1904.*

Depth.	Density.	Depth.	Density.
Centimeters.		*Centimeters.*	
50	0.51	150	0.53
100	.45	200	.45

Here we have another instance where the greatest density was not found in the layer where the pressure was greatest. Indeed, at depths of 100 and 200 centimeters the densities were the same.

Bracke,[12] in his paper gives some measurements of interest, from which we have prepared Table 8.

TABLE 8.—*Depth and density of snow. (Bracke.)*

Depth.	Density.	Depth.	Density.
Millimeters.		*Millimeters.*	
0-10	0.136	401-10	0.156
41-50	.190	501-10	.287
91-100	.128	601-10	.261
151-160	.143	711-20	.227
191-200	.202	1,500	.362
241-50	.136	2,000	.380
301-10	.185		

It will be seen that while the density at depth 41–50 mm. was 0.190, at depth 401–10 mm. it was only 0.156, yet the pressure at the latter station no doubt was considerably greater.

J. E. Church,[13] of the University of Nevada, under whose supervision thousands of snow measurements have been made in the Sierras during the past six years, has published some of his results, extracts from which are presented in Table 9 of this paper.

TABLE 9.—*Table of snow densities for estimating the water content of snow without a snow sampler. Church.*[13]

April and May in—	Depth.	Density.	Elevation.
	Inches.	*Per cent.*	*Feet.*
Open country	3.2	39.5	
	9.6	37.1	
	18.8	*44.0*	
	29.5	44.7	
	36.5	*39.9*	
Forested country. (Dense forest)	3.3	37.2	
	10.2	*45.6*	
	19.4	40.5	
	28.9	34.1	5,000 to 7,000
	37.5	42.1	
	48.1	42.8	
	59.4	40.3	
	69.5	37.5	
	78.6	37.5	
	89.6	*40.2*	
	97.4	43.8	
Open country	2.1	42.0	
	10.2	33.6	
	19.9	33.0	
	30.2	32.2	
	39.9	41.8	
	50.5	43.2	
	59.9	47.2	
	70.4	44.8	
	80.3	46.2	
	89.5	45.6	9,000 to 10,800
	100.3	*48.5*	
	110.1	47.6	
	118.8	47.9	
	129.8	50.4	
	137.3	49.7	
	149.4	49.0	
	160.5	48.5	
	167.6	*47.8*	
	186.5	52.0	

The title of Table 9 is that used by Dr. Church himself. A comparison of the 3d and 5th, 7th and 15th, and 27th and 34th entries (italicized) in the density column of that table shows that both in the open and the forested areas, and at low and high elevations, wide departures from the rule as to increase of density with increase of pressure have occurred in the Sierra Nevadas.

In order to demonstrate that no relationship between pressure and density may be assumed in the ordinary, or nonhomogeneous, snow cover found in nature, such as that upon which Abe [14] bases the formula $D.dz=dp$, we have computed the pressures by layers for each of the twelve successive layers of the cylindrical column of snow of 1 square-foot base cut out of the snow cover on Goldberg glacier measured by Defant in August, 1908, from which the total pressure on the top surface of the 13th or bottom layer has been deduced. The results are given in Table 10, in which the densities are those taken from the second column of Table 6. It is obvious that here "pressure" means the weight of the snow itself, exclusive of atmospheric pressure. Hence, if we make p equal to W we have

$$W=A\times H\times D\times 62.425 \text{ lbs.}$$

where W is the weight in pounds; A, cross sectional area of column in feet; D, the density; and 62.425, the weight of a cubic foot of water at 39.2° F.

[9] *Wengler*, op. cit., p. 70.
[10] *Wengler*, op. cit., p. 74–75.
[11] *Bracke, A.*, op. cit., p. 6.
[12] *Bracke, A.*, op. cit., p. 25.
[13] See an undated blue print issued by the University of Nevada, Reno, Nev., presenting a "Table of Snow Densities."
[14] *Wengler, F.*, op. cit., pp. 75–76.

TABLE 10.—*Pressure and density of a cylindrical column of snow, Goldberg glacier, August, 1908.*

[Cross sectional area=1 square foot.]

Layer.	Depth.		Density.	Pressure.
	Cm.	*Feet.*		*Pounds.*
1	12.5	0.41	0.280	7.16
2	37.5	1.23	0.388	27.62
3	62.5	2.05	0.515	53.38
4	87.5	2.87	0.632	85.73
5	112.5	3.69	0.608	116.85
6	137.5	4.51	0.536	144.29
7	162.5	5.33	0.534	171.63
8	187.5	6.15	0.542	199.37
9	219.5	6.97	0.556	227.83
10	237.5	7.79	0.556	256.29
11	262.5	8.61	0.583	286.18
12	287.5	9.43	0.578	315.72
Bottom layer	312.5	10.25	0.607	.....

It is clear that despite the great pressure—more than 315 pounds per square foot—exerted by the overlying layers of snow upon the bottom layer, its density, 0.607, is less than that of the fourth and fifth layers, upon which the pressures were only 53 and 86 pounds, respectively.

It seems to us that any attempt to estimate the density of the lowest layers of a snow cover of some depth at the close of winter from measurements of the *pressure* exerted by the snow in the top layer is about as safe a proceeding as that of estimating the density of the lowest layers of a sawdust cover in a sawmill where white pine, gum, mahogany, and teak lumber is milled indiscriminately, by computing the pressure of the top layer and deducing therefrom the probable density of the underlying layers.

CONCLUSIONS.

A careful and unbiased analysis of the foregoing data will, we believe, warrant the following conclusions:

1. That the average density of a snow cover at or near the close of winter depends primarily, if not chiefly, on the various atmospheric conditions (particularly as to freezes and rains) under which the several layers have been deposited, and the age of the snow cover.

2. That the density of snow in late spring does not vary directly as the depth, pressure, or altitude of the cover.

3. That in a given snow cover strata having abnormally high or low densities (relatively to the average density of the whole cover) may occur in open as well as forested areas, and in the upper, middle, and lower layers.

4. That to deduce, by formula, the density of the lowest layers of a snow cover from measurements of the depth or pressure of its top layer is not a practical proposition, except, perhaps, in the case of a homogeneous snow cover.

My colleagues of the Reno station, Messrs. W. Bailey and O. H. Hammonds, whose kind assistance[15] in the proof reading of the tables and the translating of articles by foreign writers is gratefully acknowledged, concur as to the conclusions reached by the writer of this paper.

MEAN LAKE LEVELS DURING SEPTEMBER, 1916.

By UNITED STATES LAKE SURVEY.

[Dated: Detroit, Mich., Oct. 5, 1916.]

The following data are reported in the "Notice to Mariners" of the above date:

Data.	Lakes.			
	Superior.	Michigan and Huron.	Erie.	Ontario.
Mean level during September, 1916:	*Feet.*	*Feet.*	*Feet.*	*Feet.*
Above mean sea level at New York	603.88	580.76	572.33	246.69
Above or below—				
Mean stage of August, 1916	+0.15	−0.28	−0.47	−0.67
Mean stage of September, 1915	+1.48	+0.82	+0.13	+1.24
Average stage for September, last 10 years	+1.27	+0.10	−0.02	+0.59
Highest recorded September stage	−0.20	−2.67	−1.61	−0.92
Lowest recorded September stage	+2.39	+1.10	+1.05	+2.69
Average relation of the September level to:				
August level	±0.0	−0.2	−0.3	−0.4
October level	±0.0	+0.2	+0.2	+0.4

[15] The author further wishes to acknowledge the assistance received from his wife while preparing and revising this paper.