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Water supply in Nebraska / by O.V.P. Stout.

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New NAL Interlibrary Loan Fees

On January 1, 2012 the National Agricultural Library of the U.S. Department of Agriculture (NAL) will update its interlibrary loan fee schedule to a new flat fee of $25 for requests billed through NTIS and $18 for requests billed through IFM. The current $10 quarterly billing surcharge for invoiced requests will be eliminated at the same time.

Summary of Fee Changes

	Current Fee (through 12/31/2011)	**New Fee Invoiced Requests (beginning 1/1/2012)**	**New Fee IFM Requests (beginning 1/1/2012)**
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NAL's fee schedule has not been updated since 2000. The new fee schedule is a response both to requests from our interlibrary loan customers for a simplified fee structure and to the rising cost of providing interlibrary loan. We know that the quarterly billing surcharge has been problematic for many libraries (particularly those who have to charge back fees to individual requesters or their departments) and hope that its elimination will make NAL interlibrary loan service more accessible for all kinds of libraries. We will continue to offer a discounted fee for libraries which use OCLC's IFM payment system since IFM lowers administrative costs for both NAL and the borrowing library.

If you have any questions or comments about this change please contact Kay Derr, Information Services and Collections Branch, National Agricultural Library, U.S. Department of Agriculture at kay.derr@ars.usda.gov.

October 25, 2011

145. White Snakeroot (*Eupatorium ageratoides* L.). Yields honey. Native.

146. Boneset (*Eupatorium perfoliatum* L.). Yields honey. Native.

147. Gum Weed (*Grindelia squarrosa* Dunal). Honey from the flowers (*Stilson*). Native.

148. Sunflower (*Helianthus annuus* L.). Honey and pollen from the flowers. Native.

149. Blazing Stars (*Laciniaria punctata* (Hook.) OK., *L. pycnostachya* (Mx.) OK., *L. scariosa* (L.) Hill, and *L. squarrosa* (L.) Hill). These species are placed in the genus *Liatris* in Gray's Manual. All yield pollen and honey. Native.

150. Wild Lettuce (*Lactuca pulchella* (Pursh.) DC.). Said to yield honey (*Clements*). Native.

151. Purple Coneflower, or "Nigger Head" (*Rudbeckia angustifolia* (DC.) B. & H.). Yields honey and pollen. Native.

152. Coneflower (*Rudbeckia columnaris* Pursh.). Yields pollen and honey. Native.

153. Coneflower (*Rudbeckia pinnata* Vent.). Yields pollen and honey. Native.

154. Ragwort (*Senecio aureus* L.). Yields honey and pollen (*Stilson*). Native.

155. Golden Rods (*Solidago arguta* Ait., *S. canadensis* L., *S. lanceolata* L., *S. rigida* L., *S. rupestris* Raf., and other species). Yield honey and pollen in late summer. Native.

156. Dandelion (*Taraxacum taraxacum* (L.) MacM., or *Taraxacum officinale* Weber, of Gray's Manual). Honey and pollen. Introduced.

157. Ironweed (*Vernonia fasciculata* Michx.). Honey from the flowers in late summer (*Stilson*). Native.

NO. 41.

UNIVERSITY OF NEBRASKA.

BULLETIN

OF THE

AGRICULTURAL EXPERIMENT STATION

OF

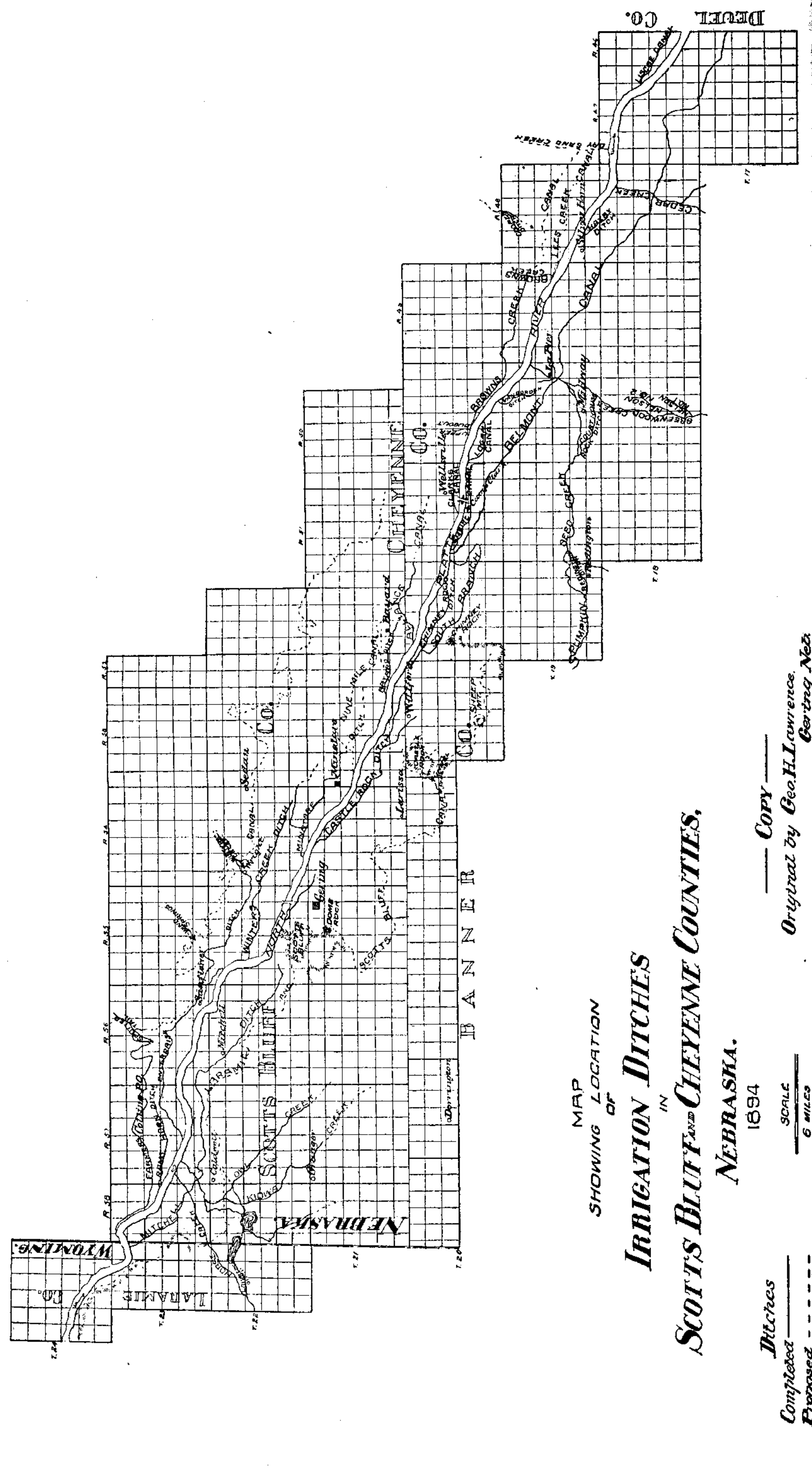
NEBRASKA.

VOL. VII.

ARTICLE V.—*Water Supply in Nebraska.* By O. V. P. STOUT.

DISTRIBUTED FEBRUARY 4, 1895.

LINCOLN, NEBRASKA,
U. S. A.



ARTICLE V.—*Water Supply in Nebraska.* By O. V. P. STOUT.

INTRODUCTORY.

The extreme drouth that has prevailed during the season just past has been, more than anything else, the cause of the fact that for several months general attention has been directed to Nebraska as a field for irrigation development. A considerable portion of the recent and current literature on the subject of irrigation either deals directly with the possibilities in general of Nebraska in this field or with some particular project in the state; or if more extended in its scope, is written with the special needs and conditions of the great plains country in mind. Much of this literature has had a very free and active circulation in the state. Wm. E. Smythe, the editor of *Irrigation Age*, is quoted as saying recently * that "at this time Nebraska, in the extent of visible public interest, leads the procession among the irrigation states of the Union."

In view of all this it is fair to assume in the preparation of this bulletin that information is already accessible to all interested concerning the more general truths and principles in regard to the development of irrigation enterprises and the practice of the art of irrigation as brought out by experience in other states and in other countries. As just noted, much in the form of reports, bulletins, newspaper and magazine articles has also been published which deals more particularly with the subject as it presents itself in Nebraska. It is only when we come to the consideration of some one plan or project to water lands that we realize how little information is available that is really definite and immediately applicable to the case in hand. This is because there are many points upon which the experience of one country cannot be taken as a guide to practice in another, and because a study of conditions such as soil, rainfall, flow of streams, evaporation, and the like, in one section cannot throw all the light needed on these conditions in another section. Irrigation must be old in Nebraska

* Interview in *Nebraska State Journal*, September 2, 1894.

before many of the questions which arise can be answered, if indeed they ever can be. The pioneer irrigators of the state are already gaining the experience which will furnish the answer to many of the problems which perplex, and it is to them and their followers in the actual practice of the art that we must turn for the ultimate answer to any question, or for the test and the verification or disproof of any statement or theory.

The Experiment Station, in the hope of being able to contribute something which will narrow materially the limits of the uncertainty which besets the consideration of the subject as a whole in its local aspect, and the consideration of each particular enterprise, has undertaken the collection of facts and the investigation of conditions which have to do directly with irrigation in Nebraska, and the presentation of results and conclusions in a series of bulletins, of which this one may be considered a preliminary or introductory number. The work has been commenced only, and has not been carried very far along any one line, but a few facts and figures have been obtained which it is believed should be presented now.

The subject which naturally presents itself in this connection as the first to claim attention is

THE FLOW OF STREAMS.

A fully adequate study of this subject can be made only by a state or governmental department, thoroughly equipped and organized for the purpose. Even then it is the work of several years. This being true, it is also true that any discussion based on the isolated facts so far obtained, and the only ones obtainable, cannot be presumed to lead to absolutely definite conclusions. We may say that the information now at hand indicates that certain things are true, and circumstances may compel us to act on the assumption that they are true. But the conclusions that can be given out otherwise than tentatively are very few.

So far as has been learned, no systematic effort has ever been made to determine the amount of water carried each year by the different streams of the state. Except the measurements made in connection with this work, and reported here for the first time, all that have come to my knowledge are included in Table I. Table II presents the results of gaging made under the direction of the Experiment Station.

TABLE I.—*Flow of Nebraska Streams.*

Name of Stream.	Where Measured.	Date of Measurement.	By Whom Measured.	Volume o flow, cu. ft. per sec.
North Platte river*	Douglas, Wyo	June 3, 1891	U. S. Geological Survey	10,130
North Platte river	Fairbanks, Wyo	October 13, 1891	U. S. Geological Survey	579
North Platte river	Douglas, Wyo	November 5, 1892	U. S. Geological Survey	595
North Platte river	Douglas, Wyo	December 4, 1891	U. S. Geological Survey	807
North Platte river	North Platte, Nebr	September 14, 1892	U. S. Geological Survey	770
North Platte river	Camp Clarke, Nebr	October 8, 1892	U. S. Geological Survey	335
North Platte river	North Platte, Nebr	November 2, 1892	U. S. Geological Survey	1,070
North Platte river	North Platte, Nebr	November 22, 1892	U. S. Geological Survey	1,370
North Platte river	Camp Clarke, Nebr	May 29, 1891		8,075
South Platte river	Julesburg, Colo.	October	U. S. Geological Survey	653
South Platte river	North Platte, Nebr	Early November	U. S. Geological Survey	460
South Platte river	North Platte, Nebr	Late November	U. S. Geological Survey	645
White river	West of Chadron, Nebr	June 1, 1891		123
Niobrara river	Dawes county, Nebr	September 4, 1887	Prof. L. E. Hicks	98
Blue creek			U. S. Geological Survey	105
Birdwood creek		September	U. S. Geological Survey	126
Platte river	Fremont, Nebr	Late August, 1894	Andrew Rosewater	1,209
Loup river	Sec. 13, T. 7 N., R. 2 W. of 6th P. M.	August 19, 1894	Computed from notes furnished by L. F. Gottschalk	1,335
North Loup river	Moulton, Nebr	November 2, 1894	Geo. H. Lawrence	460
Middle Loup river	Gates, Nebr	August 25, 1894	Geo. H. Lawrence	850
South Loup river	Georgetown, Nebr	September 10, 1894	Geo. H. Lawrence	68
Dismal river	Near Dunning, Nebr	August 22, 1894	Geo. H. Lawrence	435
Loup river	Near Columbus, Nebr	June 23, 1891		7,065
Elkhorn river	Arlington, Nebr	Late August, 1894	Andrew Rosewater	214
Frenchman river	Culbertson, Nebr	December, 1889		310
Frenchman river	Palisade, Nebr	December, 1889		240
Frenchman river		November	U. S. Geological Survey	177
Republican river	Above Frenchman	November	U. S. Geological Survey	209
Red Willow creek	Red Willow City			52

* See also Table IV.

TABLE II.

NAME OF STREAM.	PLACE OF GAGING.	Date of gaging (1894).	Volume of flow (cubic feet per second).	REMARKS.
North Platte river	Camp Clarke, Nebr.	July 26	1900.0	Approximate measurement by floats.
North Platte river	Gering, Nebr.	July 28	2450.0	Very rough measurement by floats.
Pumpkin Seed creek	Carey's Ranch, Cheyenne Co.	July 26	17.1	Good measurement by floats.
Loup river	Columbus	July 31	1475.0	Approximate measurement by floats.
Loup river	Fullerton	Sept. 16	1704.0	Fair measurement by meter.
Cedar river	Fullerton	Sept. 15	210.6	Good measurement by meter.
Beaver creek	Genoa	Sept. 17	71.0	Good measurement by meter.
Platte river	Fremont	Aug. 14	1420.0	Good measurement by meter.
Platte river	Columbus	Sept. 17	None.	
Platte river	Columbus	Oct. 6	None.	Water 3 feet and 8 inches below surface of sand at low place in bed of river.
Frenchman river	Palisade	Aug. 7	94.2	Fair measurement by meter.
Frenchman river	Palisade	Dec. 8	116.0	Fair measurement by meter.
Republican river	Culbertson	Aug. 7	None.	
Republican river	Culbertson	Dec. 8	None.	
North Fork Republican river	Benkelman	Dec. 9	75.0	Fair measurement by meter.
South Fork Republican river	Benkelman	Dec. 9	Less than 1.0	
Elkhorn river	Waterloo	Aug. 15	280.0	

TABLE III.—*Ditches in Scott's Bluff and Cheyenne Counties.*

NAMES OF DITCHES.	Miles completed.	Miles proposed.	Acres under ditch.	Acres under surveys.	Width on bottom.	Depth.
					Feet.	Feet.
Enterprise ditch	28	....	10,400	....	16	3
Mitchell ditch	26	....	19,200	....	24	3
Minatare ditch	16	....	9,600	....	40	1½
Castle Rock ditch	16	....	5,300	....	16	2½
Chimney Rock ditch	13	....	7,000	....	16	2½
Winter's Creek ditch	14	....	7,200	....	24	2
Central ditch	5	....	1,100	....	24	3
Nichols' ditch	6	....	2,000	....	12	2
Alliance ditch	6	10	5,000	7,000	25	2
Redington ditch	3	....	1,300	....	8	2
Lawrence canal	5	....	4,500	....	16	4
Farmers' canal	20	55	7,200	68,000	30	8
Belmont canal	45	15	40,000	20,000	30	6
Bayard canal	....	35	....	31,000	30	4
Laramie & Scott's Bluff canal	....	82	....	72,000	40	8
Bayard ditch	5	....	2,500	....	8	2
Short Line canal	....	5	....	2,000	(20)	(2)
Clark's canal	3½	....	1,000	....	8	2
Lee's Creek canal	....	10	....	7,000	(48)	(3)
Liscoe canal	6	....	5,000	....	8	3
Cooper ditch	2	....	200	....	3	1
Empire ditch	7	....	1,600	....	8	2
Logan ditch	3½	....	1,200	....	8	2
Nelson No. 1	2	....	500	....	3	1
Nelson No. 2	4	....	800	....	5	2
Haxby ditch	2	....	1,000	....	5	3
Court House Rock canal	4½	....	2,200	....	9½	3
Meredith ditch	1½	....	100	....	4	1½
Ammer ditch	2	....	400	....	4	1½
Van Gorden ditch	3	....	1,800	....	8	2
Totals	249	212	138,100	207,000		

A knowledge of the minimum summer flow of a stream will form the best basis for an estimate of the number and capacity of canals which that stream can supply with water throughout the irrigating season. We may see this if we take, for instance, the case of a stream the water of which is fully appropriated, enough canals having been built and land enough brought under ditch to use all that it can supply. Arrange a list of these canals in the order of their priority of right to the use of the water of the stream. Follow down the list until a sufficient number have been included so that their combined flow, or the whole amount of water to which all of them together are entitled, is equal to the least amount of water supplied by the stream at any time during the irrigating season. All canals below this point on the list are likely, and some are almost sure, to be dry at the time of least flow in the stream. This being the case, it is seen that the most important single measurement of the volume of flow of a stream about to be used for irrigation is that taken at the time of least summer flow. The stage of the water in the streams of this state was unusually low during the months of August and September of this year, and thus an unusual opportunity was afforded to determine what may in most cases be safely assumed as a minimum summer flow.

A word as to the reliability and accuracy of the results presented is in order. Various methods were employed in gaging. In some cases measurements were made of the width of the stream and of the depths at different points of a line across stream; in addition to this the velocity of the current, as indicated by the times of passage of a few floats over a known distance, was noted. The volume of flow of the stream, as computed from such observations, is to be looked upon as little better than a good guess. On the other hand, in some cases where the width and depths at a cross section of the stream were measured very carefully, and a current meter was used to obtain the velocity at frequent intervals of the cross-section, it is believed that the actual amount of water flowing at the time of measurement did not vary by more than a very slight percentage from the result of the measurement.

Proceeding now to a discussion of the separate streams, an estimate will first be made, as definite as the data will warrant, of the capability of each to supply a perennial flow to canals.

North Platte River.

The North Platte river undoubtedly ranks first in importance in regard to irrigation. The truth of this appears when it is remembered that it carries more water during the irrigating season than any other stream in the state; that it flows through a part of the state where irrigation is generally acknowledged to be a necessity, and that this region has adjacent to it on the north a great stock raising district where agriculture cannot be practiced successfully, and which, therefore, will furnish a ready home market for a great part of the surplus products of the irrigated district. This statement is strengthened by

the fact that at this time the development of the North Platte valley by irrigation is well under way, and that the advantageous effect of the conditions just noted is already apparent. The map facing page 153, together with Table III, page 157, for both of which we are indebted to Mr. Geo. H. Lawrence, civil engineer, of Gering, will show very accurately and satisfactorily the extent of this development in Scott's Bluff and Cheyenne counties.

Outside of these counties a considerable acreage is watered from the North Platte river, especially in Lincoln county, where some quite extensive irrigation operations are carried on, and where it is believed that the application of the water is effected in a better manner than at any other place in the state. Complete statistics as to the whole amount of land now under ditch in the valley of the North Platte are not at hand, but it is believed to be considerably in excess of 200,000 acres. Under constructed ditch, and under survey with prospect of construction, there are at least 600,000 acres.

A gaging of the river was made on July 26th of this year at Camp Clarke, above which point water is led out into canals under which lie nearly all of the lands under ditch noted in Table III. Now allowance must be made for the fact that the number of acres under ditch is not necessarily, or even probably, the same as the number of acres under cultivation in any instance, and in the case of new enterprises the amount of land actually irrigated almost invariably falls far short of the amount which it is possible to irrigate from ditches already built; for instance, the North Platte canal, in Lincoln county, which was completed in 1884, reports* 40,000 acres under ditch and 12,000 acres irrigated; the Minatare canal, completed in in 1888, reports* 7,000 acres under ditch and 4,000 acres irrigated; two canals in the Republican valley report, respectively, 12,000 acres under ditch, 1,500 acres irrigated, and 2,000 acres under ditch, 250 acres irrigated. It is fair to assume that were the figures at hand for all of the canals more recently constructed, the difference, or disproportion, would be found to be as great or greater than in the first two instances noted above. Bearing this in mind, it seems probable that the amount of land actually irrigated, during the season just past, by water diverted above Camp Clarke does not exceed 50,000 acres. As

* In August of this year to Chas. P. Ross, chairman of the Nebraska Irrigation Commission. See list of irrigation literature, p. 172.

nearly all of the irrigating there, as elsewhere in Nebraska, is done by persons whose experience in that line is as yet limited, it is probable that an average of one cubic foot of water per second passes the headgates for each forty acres irrigated; so that the amount of water which had been diverted in Nebraska and above Camp Clarke at the time of the gaging will be estimated at 1,250 second feet. Adding this to the 1,900 second feet passing in the stream at Camp Clarke, we obtain, as the total minimum summer flow available for irrigation in Nebraska, an amount not exceeding 3,150 second feet.

Table IV is of gagings made at Fort Laramie, Wyoming, by A. M. Van Auken, a civil engineer. The table is copied from Part II of the Thirteenth Annual Report of the United States Geological Survey, where it is stated that these gagings are considered by Mr. Van Auken to be mere approximations, but "that they give a fair idea of the discharge of the stream, and that the results are more accurate for the smaller discharges than for the larger." It is to be noted that the minimum summer flow, as indicated by this table, is essentially in accord with the estimate given above.

TABLE IV.—*North Platte River.*

MONTH.	DISCHARGE SEC. F.			MONTH.	DISCHARGE SEC. F.		
	Max.	Min.	Mean.		Max.	Min.	Mean.
1887.				1889—Continued.			
May	8,210	3,520	5,255	June	10,260	5,170	8,240
June	10,140	7,680	8,995	July	6,080	4,240	5,506
July	7,680	3,640	5,676	August	4,290	3,220	3,498
August	3,720	3,380	3,560	September	3,240	2,580	2,892
1888.				October	3,210	2,430	2,859
May	4,510	3,780	3,991	November 1 to 15	3,960	2,370	3,205
June 1 to 21	6,490	3,920	5,671	1890.			
July 11 to 31	6,060	4,280	4,711	March	3,400	3,180	3,316
August	5,180	3,900	4,341	April	3,720	3,200	3,457
September	3,920	3,430	3,822	May	6,970	3,840	5,151
October 1 to 22	3,920	3,110	3,517	June	10,240	8,180	8,682
1889.				July	7,960	5,120	6,469
April	3,438	2,970	3,208	August	5,425	3,380	4,160
May	8,120	2,960	4,216	September 1 to 6	3,680	3.440	3,560

Treat in the same manner the gaging of July 28, 1894, at Gering. An estimate made on the same basis as that in connection with the gaging at Camp Clarke gives 500 to 600 second feet as the amount to be assumed as passing head-gates above Gering. When this amount is added to the result of the gaging we obtain 2,950 to 3,050 second feet. Comparing this result with the table of Mr. Van Auken's gagings, and with the estimate which includes our own gaging at Camp Clarke, it is seen that all three agree substantially in indicating that we shall not be far from the truth if 3,000 second feet is assumed as the minimum summer flow of the North Platte river available for irrigation in Nebraska.

It is quite commonly assumed by irrigators, and by the projectors of irrigation enterprises in this valley, that ultimately, after the soil shall have become broken to this style of cultivation, and the farmers shall have learned to apply the water economically, that a flow of one cubic foot per second during the irrigating season will suffice for 100 acres of crops. Believing this to be a reasonably fair estimate we shall adopt it as our own. Then, if the amount of water flowing in the river across the state line falls at no time during the irrigating season below 3,000 cubic feet per second, canals may be built to irrigate 300,000 acres, and dependence be placed upon the river to furnish directly, at all times, an adequate supply. When the fact is taken into consideration that in connection with the 200,000 acres or more under ditch there are already some facilities for storage of flood waters against the time of need, and that such are also contemplated as an essential part of many of the projected enterprises whose acreage is included in the total of 600,000 acres previously noted, it is seen that the era of dry ditches in the North Platte valley is not at all imminent.

Loup Rivers.

The Loup river, with its several branches and tributaries, is next in importance to the North Platte as a source of supply for irrigating canals. The need for irrigation of the lands which it may water is not, however, so imperative as in the case of the North Platte, but the lesson of the present year, read in the light of the experiences of 1890 and 1893, is unmistakably to the effect that here, as elsewhere in Nebraska, outside the eastern counties, some form or method of irrigation must be devised and put into operation if the agricultural population is to have guarantee of a secure living. This being true, and with this region traversed as it is by such streams as the Loups, it stands as a matter of course that these streams should be used to their full capacity for irrigation.

To determine what is the full capacity of the Loups for irrigation is not easy, although a first glance at the conditions observable might lead to the conclusion that the problem is a simple one. The flow of the river is remarkably constant, especially in the cases of the North and Middle Loups. The highest and lowest stages of the water vary from the mean or average stage by only a small percentage. The South Loup alone is subject to extreme variations. Mr. Lawrence, whose gaging of 68 cubic feet per second is noted in Table I, page 155, states that it frequently carries storm waters at a rate exceeding 2,000 cubic feet per second.

Now the same conditions which account for the comparatively slight variations in the volume of flow of these streams go far to complicate the task of making an estimate of their capacity to furnish water for irrigation. The explanation that has been given to account for the steadiness of flow is undoubtedly the true one. This is that the soil of the area which drains into the North and Middle Loups, and along the course of the main stream below their confluence, is so porous, even to considerable depths, that nearly all water falling upon it sinks at once into the ground instead of running rapidly away over the surface to the water-courses, to be conveyed by them to the river and swell it to flood. The water which sinks into the ground is led by subterranean paths directly to the river or to some tributary thereof and appears in the form of springs, so that the delivery of the main supply to the stream is gradual. Now the same permeability of the soil and subsoil will permit a considerable portion of the water which is applied artificially to go down to the subterranean channels to be led through them again to the river from which, further up stream, it was diverted; this water may be again diverted and used. Of course there is a limit, and a not very remote one, to this process of applying water again and again to land on the same drainage area. The difficulty in estimating the supplying capacity of such streams as the Loups lies in determining where this limit is. Very little has been published that will aid in reaching a conclusion on this point. It is frequently noted that this "seepage water" returning to the streams through porous soil after having been applied in irrigation is considerable in amount. There has been opportunity to observe evidences of this already in our own state. At one time last August the Culbertson canal permitted only 7 cubic feet per second of the flow of the Frenchman river to pass its head-gate. At the same time the Solomon-

Crews ditch, some twenty miles below this, was diverting 13½ cubic feet per second from the same stream, and a rough measurement indicated that the amount beyond this discharging into the Republican river at Culbertson was at least 20 cubic feet per second. Also, there is a small canal at Benkelman which was constructed four years ago, and which waters land so porous and permeable that even in the hottest, driest season of this year water trickled in the drainage ditches on every cloudy day. At this time (December) these same drainage ditches are quite lively rills, although the canal itself has been permitted to run dry. The state engineer of Colorado, in October, 1885, made a series of measurements on the Cache La Poudre river which showed that in a distance of about forty miles the flow of this stream was increased, presumably by seepage of water previously diverted, from 127.6 cubic feet per second to 214.5 cubic feet per second, an increase of a little more than two-thirds. On comparing the valleys of the Cache La Poudre and the Loup it is seen that the latter is the greater in extent, and that the sandy soil and subsoil is more pronounced in character and prevails more generally. Hence it seems reasonable to believe that whatever increased duty of water, or other advantage that may follow from seepage, will be available or will obtain to a greater extent in the Loup than in the Cache La Poudre valley.

The valleys of the streams, as well as the streams themselves and their volumes of flow, enter into the determination of any question in regard to irrigation from those streams. Even here in our prairie country some of the streams of strongest, steadiest flow follow a course between steep bluffs which are all along near together on opposite sides of the stream, or approach each other at frequent intervals. The Dismal and long stretches of the Niobrara are marked instances of this class. The South Loup also has a valley that is quite narrow generally.

Where the valleys are so narrow it is usually found that the adjacent table-lands are high; so that, taking these facts together into consideration, it is seen that even where it is physically possible it is rarely financially practicable or advisable to lead the water to such table-lands.

The Middle and the North Loups, and the main stream below their confluence, present favorable conditions for irrigation development. The banks are reasonably low, the flow of the streams is strong and unusually reliable, the valleys are fairly wide, and the slope upward away from the stream to the table-lands is not so abrupt but that opportunity can be found to lead water even out of the immediate valley and upon or near to the table with a reasonable length of diversion line. In fact the diversion line proper is hardly to be mentioned as such, for a canal in these valleys need run but a short distance before its waters become available for valley irrigation.

The failure of crops for two years from drouth has directed attention to the very favorable conditions that have just been noted, and in many instances steps have been taken to utilize them. Thus it is that irrigation enterprise, in the way of actual location and construction of canals, has been more active during the present year in this than in any other part of the state.

Republican River and Tributaries.

The Republican river is not an ideal irrigation stream. It was dry last summer, as noted in Table II. The testimony of old residents along its banks is that it goes dry nearly or quite every summer. Canals have been constructed which depend wholly upon this stream for their supply. It is safe to say that all such have disappointed their projectors. It is also safe to say that none of them have been complete failures, or have even failed to justify their existence. They have simply fallen short of what was expected of them or claimed for them. Built as perennial canals to have an adequate flow throughout the season, they can be utilized only as inundation canals, having full supply only in and near the season of storms and floods. But once recognized and treated as efficient for a limited season only, the owners and users of the water having and encouraging no expectations of a constantly adequate flow, and setting about to devise new methods and to take advantage of standard methods already employed to utilize a flow that is plentiful in its season, the future of these canals in their proper sphere of usefulness abounds with promise. The conservation of the water in the time of plenty can be effected in various ways. A most attractive method, in the prospect that it holds out, as based upon experiments already made on Nebraska soil,* is that of subsoil cultivation. The water applied in the time of plenty will sink

*Particularly those of the Experiment Station, not yet published, and of Younger Bros. at Geneva.

into this prepared subsoil, there to be conserved against the time of need, which will come when the main stream goes dry in July and August.

Some of the canals, water for which is diverted from the bed of the Republican river, cannot really be said to derive their supply from the flow of that stream. Their head-gates are placed but little below the mouth of some small but reliable tributary, the water of which, in a dry season, or at the dry period of the year, flows but this short distance in the Republican before it is withdrawn. At such times it will be found that the bed of the river is perfectly dry above the mouth of the tributary, and again below the head of the canal. If the tributary is reliable, as has been noted, and as is in nearly all cases the fact, the canal will enjoy a perennial flow; provided, of course, that its right to the water is well established. These canals, fed in fact by small streams rather than the larger river, are of necessity themselves small. They are cheaply built, cheaply maintained, are not burdened with debts, are owned by those who use them, and, together with similar instances along the North Platte, constitute on the whole about as satisfactory examples of well directed and firmly established irrigation enterprise as the state can furnish.

The Frenchman river, which flows into the Republican at Culbertson, has some characteristics in common with the Loup. Its flow is steady, its banks low, and, as may be expected where such conditions appear, the soil of the area which drains into it is readily permeable. Canals have already been built which enjoy a copious perennial flow from this stream, but these, when used to their full capacity, and to the full extent of the appropriation claimed by them, will allow none but flood waters to pass, or to remain available for future enterprises. Thus it seems that further construction of canals heading in this stream should not be encouraged at this time, and if a more complete examination of the stream and of the conditions along it than that upon which this paragraph is based goes to verify and establish the conclusion here expressed, the filing of additional appropriations of water from this stream should not be permitted. There seems to be no law now on our statutes which would prevent or even discourage seriously such over-appropriation of the waters of streams.

The area under ditch in the Frenchman and Republican valleys, estimated partly from personal investigation and interviews on the ground, and partly from written replies to inquiries sent out by the Experiment Station, is a little in excess of 50,000 acres. This estimate does not take account of some 30,000 acres which is really under ditch, but the ditch is dry, flumes blown down, and it is probable that it will not be used for another season at least.

The information concerning acres actually irrigated is not complete enough to constitute a basis for a reliable estimate, but the number falls far short of the number of acres under ditch. It is believed that the amount of land under ditch in these valleys will not be greatly increased. Some projects that have in contemplation the storage of flood waters are under consideration, and seem to have some merit, so that through them may come some increase of area which may be irrigated. The chief and proper trend of the further development in this section will be toward the utilization, to the fullest extent, of the canals already built, and toward the construction of individual plants designed to raise ground water to the surface.

South Platte and Platte Rivers.

Our knowledge of the South Platte river is of an extremely general nature. We know that the summer flow, except the flood which passes in the late spring and early summer, is nearly or quite all appropriated by the irrigators in Colorado. There is, and has been, and perhaps will continue to be, more or less said of underflow in the bed of the Platte. Nothing has appeared so far which can be said to demonstrate the existence of such an underflow, and I think we may say that all of those best qualified to know and to judge concerning the matter are very skeptical as to its existence in a form or to an extent even nearly approaching that which has been assumed.

What is known of the main Platte is of much the same character. The late summer or dry weather flow cannot be counted on to furnish an extensive supply. Canals of capacity sufficient to utilize the entire amount in dry years are already constructed. As noted in Table I, the bed of the river at Columbus was perfectly dry, even to a depth of more than three feet in the sand, so that the first sentence of this paragraph refers to the stream further up, and nearer to the confluence of the North and South Plattes, and where at least a small amount of water can be seen during the whole of even such dry seasons as the one just past.

The flood volume of the Platte river is immense. The time of occurrence is about the same each year, the highest stage of the water being noted in May or June, usually the latter. There is plenty of water until well along into July. After that there may or may not be water for irrigation in Nebraska. The regularity in time of occurrence of the Platte river floods is explained by the fact that these floods are caused by the melting of snow in the mountains of Colorado and Wyoming.

With the conditions as stated, and with the additional fact in view that the Platte valley is wide, and that many of the adjoining tablelands are low, it stands to reason that this great volume of flood water should not be allowed to pass, but should in large part be diverted to supplement the insufficient rainfall of the part of western Nebraska which it traverses. This point is only suggested here, and a more detailed consideration is taken up in the pages beyond.

Other Streams.

The Elkhorn river and the Niobrara, while of size and volume sufficient to claim extended notice in this connection, have not as yet been studied by the writer, and therefore will not be treated. It will be noted, however, that a gaging of the Elkhorn was made near its mouth (see Table I), and that gagings made shortly afterward by City Engineer Rosewater, of Omaha, agree fairly well with this.

FLOOD WATERS AND STORAGE.

The preceding discussion has been confined almost wholly to the consideration of the development that is possible from the perennial flow of streams. There are other sources of supply for irrigation. One of the most hopeful and at the same time most perplexing of these, so far as its utilization is concerned, is the flood waters of the rivers and creeks, and even draws or ravines.

In seeking to discover some method by which the water of floods may be saved or secured for irrigation, that of storage in reservoirs is the one which usually comes first to mind, and is the one to which most thought and discussion has been given.

In the states next to us on the west, more thoroughly and undeniably arid than our own, this problem of storage is one that forces itself upon irrigators. In those states deep wide cañons are found, which narrow within rock walls, and whose beds are of rock, and near to which are cheap, durable, and effective materials for works and structures. Even under these favorable conditions the problem is a perplexing one. How much more perplexing, almost hopeless, must it appear to us. Our best reservoir sites are comparatively shallow and of limited area, and the soil is known to be readily permeable.

In the instance of a reservoir which was constructed near the North Platte river, it was observed that when it was first filled with water, the level of the water was lowered by seepage the first two feet in ten days, the next two feet in from fifteen to eighteen days, and so on at gradually decreasing rate. The depressions in the low land between the river and the system of reservoirs to which this one belongs are often flooded with water which rises up out of the soil, and is believed to have seeped through the soil from where it was stored. Considerable losses are still experienced in this manner from these reservoirs, but they are becoming yearly less and less, and those in charge believe that the water will in time be efficiently conserved.

Last August, with the co-operation of the canal officials, a series of measurements was made of the flow of the Culbertson canal, with a view to determining as accurately as possible the losses by seepage and evaporation. The construction of this canal has extended over a period of four years, so that portions of it may be said to be "old ditch" and other portions "new ditch." It was found that the losses in the upper or older stretches of the canal were quite moderate in amount, but that in the lower or newer stretches they were excessive. One-half of the whole amount of water entering the lowest eight miles was lost in its passage through that distance. Water had been turned for the first time into this portion of the canal about three months previously.

Some small reservoirs which have been constructed for use in connection with windmill pumping, and whose beds have been thoroughly puddled by cattle tramping through them, or by other means, are stated by their enthusiastic owners to hold water as well as cemented cisterns.

Buffalo wallows, having been well puddled in times past, hold water quite well, even in the midst of sandy soil.

Thus it seems that by puddling the bed of a reservoir it may be

made at once nearly impervious; but as it would be impracticable to treat large areas thoroughly in this way at reasonable expense, the process is suited only to reservoirs of area not exceeding a very few acres. In the case of those of greater area, we must depend upon the slow and even somewhat doubtful process of a natural soaking and silting up the bed and sides.

The rather discouraging light in which the subject of storage in ponds, lakes, or reservoirs presents itself causes us to turn in another direction as we seek to prevent the flood waters from passing by unused. In the development of one of the most attractive projects now under consideration in the state, it is proposed to place entire dependence upon flood water, which is available in great quantity and is practically all that is available. It is proposed to prepare the subsoil of the fields to receive the excess of water which can be furnished at flood period, and to hold it there until it is needed and drawn up by the crops in the dry part of the growing season. The recorded experience of many years in many countries goes to show that a properly prepared subsoil is efficient as a conserver of moisture, and as previously noted, the results of experiments already made encourage the belief that Nebraska soil will prove to be exceptionally efficient in this way.

It might be said that a difficulty is suggested in this connection, arising from the fact that in nearly all Nebraska streams the floods are caused directly by and follow immediately after the rains, which wet the surface so thoroughly that water applied for irrigation will not be absorbed at all readily. It may be confidently predicted, however, that if the soil and subsoil are prepared properly, enough will go down, either directly from the rains at the time of their occurrence, or from the water conveyed to the land from the streams, to tide over the dry season.

It is to be noted that if the subsoil all over a watershed were loosened, and the whole soil made porous to a considerable depth, that the flood discharge of the stream would be lessened materially, and for storms of ordinary duration and intensity might practically disappear. We may therefore consider that subsoil cultivation, even without a canal or any system of irrigation, does in effect provide to some extent a means for the utilization of the flood volume of streams.

It is to be noted also that the farmer on the higher portions of a watershed, as well as the one in the valley, may by subsoiling secure the benefit of a part of what might otherwise pass away in the flood of a stream.

In concluding under the head of "Flow of Streams" it may be stated that investigations under the direction of the Experiment Station are still in progress. The irrigation branch of the United States geological survey is co-operating quite extensively in the work, and has placed gage rods in a number of the rivers, where daily readings of the height of the water surface are taken and reported by local observers. The Experiment Station makes frequent measurements of the volume of flow at these points, so that at the end of a year the record of these measurements and of the river height throughout the year will constitute data from which a very satisfactory estimate can be made of the whole amount of water discharged by the stream at any one time, or during the whole year.

THE UNDERGROUND WATER SUPPLY.

As to the amount of the underground water supply it is difficult or impossible to predict or estimate at this time. Some idea of it in any particular locality or on an given watershed might be gained if complete records existed of the rain fall on the watershed and of the flow of the stream which drains it. These records, extending over a year or two at least, would furnish data from which might be estimated the proportion of the rainfall which ran off on the surface and was immediately carried away by the stream, and of the proportion which sunk into the ground to be carried by subterranean paths or channels to the stream, there appearing as springs to augment the flow. This latter proportion would be that which under favorable circumstances might be lifted to the surface at different points, and used for irrigation.

Even after having progressed thus far with the investigation, the question would still remain to be answered as to just at what points it may be expected that this underground water will be found in abundance. In some districts, that is on some watersheds, its distribution may be quite uniform, so that a well sunk at almost any point would give about the same yield as if sunk at any other point. This is the case in regard to the "sheet water" about which so much has been said.

It is probable, or more than probable, however, that "sheet water," as thus defined or understood, does not exist beneath all points at which such existence has been assumed and discussed.

On other drainage areas the underground waters may traverse a sort of channels. Actual subterranean rivers of great volume are not unknown. So we may have channels varying in character from the river with open and unimpeded flow to the sheet water with steady but nearly or quite imperceptible velocity of flow toward the stream which drains the area.

Water may also be found filling the voids in sand and gravel in underground basins whose bottoms and sides are formed by impermeable strata.

Now, as noted in the first paragraph under this head, we have not the records that would be necessary to form an idea or estimate as to the total amount of the subsurface water; even if we knew the total amount it would still remain to determine where it could be found, the rate at which it would yield, whether the rate would be practically uniform or variable, and to what extent wells could be multiplied on any given area without affecting the flow of those first put down.

Irrigation by pumping from wells has not yet been practiced to any great extent in Nebraska. It is almost certain, however, that within the next few years nearly every farmer in the western and middle part of the state, where conditions are at all favorable, will have from two to fifteen acres under irrigation by this method. Believing this, it is proposed by the Experiment Station to make such investigations as are practicable, and to secure all the information obtainable on the subject of the underground water supply of Nebraska and irrigation from wells, and to present the results in the next number of this series of bulletins.

LIST OF IRRIGATION LITERATURE.

The following is a brief and somewhat incomplete list of the books, pamphlets, and periodicals in the English language which treat of irrigation and which may be consulted in the libraries of the Experiment Station, and the Departments of Agriculture and Civil Engineering in the University:

Irrigation Canals and Other Irrigation Works, by P. J. Flynn, C. E.
Manual of Irrigation Engineering, by Herbert M. Wilson, C. E.
The Irrigation Works of India, by Robert B. Buckley.
Italian Irrigation, by Capt. Baird Smith.
Irrigation in Egypt, by W. Willcocks, M. I. C. E.
Irrigation for Farm, Garden, and Orchard, by Henry Stewart.
The Law of Irrigation, by Clesson S. Kinney.
Year-Book of American Society of Irrigation Engineers.
Reports of the United States Geological Survey.
Reports of the Bureau of Irrigation Inquiry, Department of Agriculture.
Biennial Reports of the State Engineers of Colorado, Wyoming, and California.
Bulletins of Agricultural Colleges and Experiment Stations of South Dakota, Colorado, Wyoming, Utah, Nebraska, and other states.
Reports of proceedings of the several National and Interstate Irrigation Congresses.
Report of the Nebraska Irrigation Commission to the Third National Irrigation Congress, by Charles P. Ross, Chairman.
Irrigation Age. File and current numbers.
Western America. Current numbers.
Irrigation Farmer. Current numbers.
Irrigation: Its History, Methods, and Results. Issued by the Passenger Department of the Union Pacific Railway.

Much valuable information is often found in trade publications, especially in the catalogues of pump and windmill manufacturers.

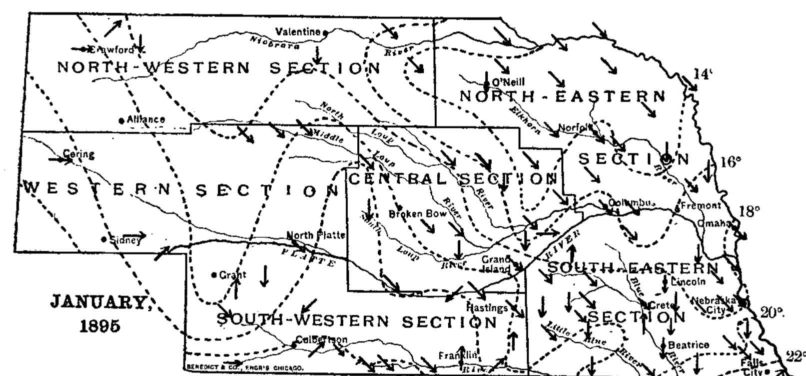
ARTICLE I.—*Nebraska Weather Review for 1895.* By G. D. SWEZEY and G. A. LOVELAND.
Part 1, January.

The month of January was one of deficient precipitation but a nearly normal month as regards temperatures, having no great extremes of temperature and with a mean for the month very near the normal.

GENERAL SUMMARY FOR THE STATE.

Pressure.—The mean pressure of the atmosphere was 30.16 inches, which is 0.06 inches below the normal for January. The highest during the month was 30.91 inches at Lincoln on the 8th, and the lowest 29.49 inches at Omaha, on the 20th.

Temperature.—The mean temperature for the state was 19.0 degrees, which is 0.2 degrees above the normal. The highest temperature reported from the state was 72 degrees at Rulo on the 20th, and the lowest 21 degrees below zero at Bassett on the 26th of the month.



Dotted lines are drawn through points having the same mean temperature; arrows fly with the wind.