51st Congress, 2d Session. | SENATE. | Ex. Doc. 53, Part 2.

LETTER

FROM

THE SECRETARY OF AGRICULTURE,

TRANSMITTING,

In additional response to Senate resolution of December 13, 1890, report of the progress of irrigation in the months of November and December.

FEBRUARY 20, 1891.—Referred to the Select Committee on Irrigation and Reclamation of Arid Lands and ordered to be printed.

DEPARTMENT OF AGRICULTURE,
OFFICE OF THE SECRETARY,
Washington, D. C., February 20, 1891.

SIR: I have the honor to transmit herewith, as a part of the inquiry called for by the Senate, the report of progress work for November and December, 1890, with maps, profiles, and appendix, showing surface elevations and the water plane beneath, prepared by Edwin S. Nettleton, chief engineer of artesian and underflow investigation, and by W. W. Follett, the assistant engineer. This report covers a large section of the central division of the Great Plains, embracing considerable portions of Kansas, Nebraska, and Colorado. It is of great interest, and the accompanying map and profiles will prove of service in illustrating the existence and value, for irrigation purposes, of waters imbibed or soaked in the earth from regional rainfall, held in valley stratum or sand by seepage from streams, or stored below the alluvium from mountain drainage.

I am, sir, very respectfully,

EDWIN WILLITS,
Acting Secretary.

The PRESIDENT OF THE SENATE.

DEPARTMENT OF AGRICULTURE,
IRRIGATION, ARTESIAN AND UNDERFLOW INVESTIGATION,
Denver, Colo., January 21, 1891.

SIR: I herewith transmit my progress report for the months of November and December. The labor of working out the field notes in connection with the survey of the underground waters in the drainage valleys of the Platte and Arkansas has required much more time than I anticipated, and hence the delay in this report.

The nature of the investigation of the so-called "underflow" is such as to require an extended and somewhat connected series of observa-

tions in order to settle conclusively the theories regarding the possibilities of utilizing subterranean waters for irrigation. I have selected the valleys of the two principal rivers in Nebraska and Kansas for this purpose, and the presentation of the facts is better accomplished, I believe, by the graphic method of plan and profile than could be done by text alone.

The profiles which I submit as a part of this report are on a scale too large for publication. I found it was not practicable to make working profiles that would not have to be reduced for the printer. These profiles will furnish an excellent base on which the geologists can place their work in accurate detail in the final closing up of the investigation. As we have not made copies of the profiles, I would suggest that the originals be carefully preserved from any damage.

Very respectfully, yours,

E. S. NETTLETON,
Chief Engineer.

Hon. J. M. RUSK.
Secretary of Agriculture, Washington, D. C.

DEPARTMENT OF AGRICULTURE,
ARTESIAN AND UNDERFLOW INVESTIGATION,
Denver, Colo., January 21, 1891.

SIR: As I have already advised you, we are not attempting to do any field work in the Dakotas this winter, leaving the northern portion of the territory included within the limits of our investigation until next spring. Major Coffin, our assistant in South Dakota, is instructed to do all he can in the mean time by means of correspondence and by personal inquiry in collecting information regarding the artesian-well developments made since our inquiry last spring, and to collect all the facts he can regarding the locality of irrigable streams, reservoir sites, and the probable existence of subterranean waters other than artesian which is believed to be practicable to utilize for irrigation purposes. He reports that he is making good headway in the work assigned him. The artesian-well investigation in Nebraska and Kansas, made by this Department last spring, leaves so little to be done by the engineering branch that we have not pursued this inquiry any further in these States. Our investigations there have been confined to the study of the extent and availability of the underflow, and we have taken the valleys of the Platte in Nebraska, and Arkansas in Kansas, as the two best opportunities for making this examination, believing whatever conditions we find there would, without much doubt, exist in a larger portion of these States.

In addition to the examination of the underflow problem in these two valleys, we have made a similar investigation of the question along the line of the one-hundredth meridian from Norton to Dodge City, Kansas. The plan of investigation followed for the purpose of determining the extent and availability of the underflow waters for irrigation purposes, as required in the act approved September 30, 1890, has been to connect by lines of levels the surface of the subterranean water, wherever it could be found, with the so-called "sheet-water" in the valleys of the large rivers. The surface of the water in the Platte in Nebraska and the Arkansas in Kansas have been made bases of the levels, all of which have been reduced to sea-level elevations.

The annexed plan and profiles show in detail the location and elevation of the surface of the underground water, as found in rivers, wells, springs, and pools, as well as the elevation of the surface of the country along the line surveyed, which is represented on Appendix 1. These lines were carried north and south, or about at right angles from the river, far enough in each direction to obtain the general characteristics and relative positions of the water-bearing stratum. Eight of these lines were surveyed—four on the Platte, three on the Arkansas, and one on the one hundredth meridian. Appendices Nos. 2, 3, 4, 5, 6, 7, and 8 show the exact localities of the lines surveyed, and the elevations of the surface of the country above sea level, which are projected in profile from the plan beneath. Appendix No. 9 shows only the profile of the line and the elevations thereon, as were established by aneroid barometers, corrected to true elevations whenever it could be done, but, as a whole, these elevations should be considered only approximately correct.

In connection with making the survey to obtain the relative levels of the surface of the country and of the water bearing strata the following inquiry was made relative to the wells along the line:

Well examined by W. W. Follett on ——— line in ———.
No. of well, ——. When examined, ———.
Location, ———.
Owner, ———. Post-office? ———.
When put down, ———. Kind of well, ———.
Size, ———. Depth, ———. Depth to water, ———. Depth of water, ———.
Amount of water, ———.
Did water raise when struck? ———.
Is supply changing? ———.
Strata passed through, ———.
Quality of water, ———. How raised, ———.
Kind of mill, ———. Stroke, ———.
Cost of well, ———. Cost of pump, ———. Cost of mill, ———.
Cost of repairs to mill, ———.
Maximum amount pumped per day, ———. Used for ———.
Elevation surface, ———. Elevation water, ———. Elevation bottom, ———.
Remarks, ———.

Copies of the answers to the above inquiry are found in Appendix No. 10.

The line shading on the profiles shows the water line in the wells as well as that on the surface at the time the survey was made. In some localities the water is several feet lower than usual, the cause assigned being the small amount of rainfall this season.

The scale adopted shows considerable distortion, making the apparent slope of the country much steeper than it actually is. This was thought necessary, however, to give room to show the different strata passed through in the wells and yet to keep the length of the profile within reasonable limits.

The following are some of the salient facts and features in connection with the wells and water-bearing stratum that were noticed during the investigation, which are only in part shown on the several profiles of the lines surveyed:

BIG SPRING LINE.

All the wells on this line are positive-artesian in their character, excepting those on the south end; which are negative; that is, they rise in the bore, but do not flow above. The water-bearing stratum is generally overlaid by clay or grit, the water rising in some instances 100 feet above where it is struck, and in all of them it rises above the sheet-

water in the river valley. The water in well No. 4 rises 80 feet above the South Platte and 160 feet above the North Platte. Well No. 23 has been tested for quantity; it was pumped 24 hours at the rate of 80 gallons per minute without exhausting the water.

The somewhat celebrated "State Corner" spring near the northeast corner of Colorado, flows about 5 gallons per minute; it is 180 feet above the river, and 100 feet above the highest water found on the line and does not seem to have any connection with any other water in the vicinity, except, it may be, with the artesian vein.

NORTH PLATTE LINE.

The sheet-water extends across the valley of the Two Rivers, and is very near the surface. About 23 miles north is the head of the South Loup; the water here stands in pools, and about on the same level with the water-bearing stratum to the south of it, which stratum is about 130 feet above the Platte, and has a marked regularity of position and slope. South of the river the wells are quite deep, going down practically to the sheet-water of the Platte rivers, and has a regular inclination towards the south, coming to the surface at Medicine Creek, a branch of the Republican River.

Medicine Creek is a plains stream originating in springs. From its head to Wellfleet, 8 miles, its fall is about 16 feet to the mile, and from Wellfleet South for about 5 miles, it falls about 14 feet to the mile. At one mile from its source (in pools) the water just begins to run. At Wellfleet on November 16, it was carrying 18 cubic feet per second, and 5 miles below on same date it was carrying 30 to 35 cubic feet per second. The water comes from numerous springs along both banks of the stream, it apparently making a break in the water-bearing stratum. From the distance and fall of the stream it is possible that this is the same stratum as supplies the wells at Venango. The water-bearing material is hard fine sand (loess), above Wellfleet, changing to gravel and to grit below. The flow of the stream is said to be nearly constant, flowing more in the fall than any other time.

Medicine Creek is a type of several tributaries of the Republican River, coming from the north and west, including Red Willow Creek, Stinking Creek, Frenchman or Whiteman's Fork, and the two heads of the Republican. These streams all arise from springs in water-bearing strata apparently continuous, and show quite a flow near their heads. The tributaries from the south show a much smaller quantity of water than those from the north and west, although they are long and drain a large territory.

A comparison of sea-level elevations show that it is possible for this water-bearing stratum to be continuous, and to lie at an elevation equal to or below that of the sands of the Platte River. By reference to Appendix No. 1 it will be seen that many springs cluster around the heads of these streams. The springs there shown were located by the Artesian Wells Investigation of the spring of 1890.

LEXINGTON LINE.

At Lexington the river valley proper extends about 10 miles north of this place; the water line gradually raises in that direction with the surface of the ground. From the north side of this valley to the South Loup, 22 miles further north, the same general characteristics of the water-bearing stratum exist as were found on the North Platte line,

north of these rivers. The South Loup has evidently been cut 70 or 80 feet into or through this water-bearing stratum. Springs are abundant along the south side of the Loup, about 80 feet above it, which are undoubtedly the out-cropping of the uppermost water-bearing stratum. A well very close to No. 63 was put down to a depth of 350 feet, or 100 feet below the Platte River, and found no water below 240 feet. South of the Platte to the Republican the regularity of the water-bearing stratum is quite marked and coincides very nearly with that on the North Platte line, except the slope to the south is much greater, it being 10 feet per mile toward the Republican River or about twice as great as the slope of the Platte River.

GRAND ISLAND LINE.

From the Platte north to the Loup, is in the delta of these two rivers, the Loup being 100 feet lower than the Platte and the general surface of the ground slopes towards the Loup, with the exception of a line of drifted sand hills on the south side of the Loup Valley. All of the wells on this line are shallow, except near the sand hills, and afford large quantities of water for stock purposes, some furnishing as high as 3,200 gallons per day, which is pumped by windmills. South from the Platte to the Little Blue there is a great irregularity in the position of the water-bearing stratum, but the general slope is to the south, as found in the other lines. From Little Blue to the Republican there is no well defined water-bearing stratum. The water line here seems to conform more to the surface than on the other lines.

GREAT BEND LINE.

From Hoisington north there is no well-defined water-bearing stratum. The wells on this part of the line have a weak vein of water found in clay, overlying blue shale rock. Well No. 144 was driven through the blue shale 180 feet thick into a thin stratum of sand and gravel. The water is quite salty and artesian in its character, rising 70 feet above where it is struck. Well No. 138 is 16 feet in diameter, and furnishes 90,000 gallons in 24 hours for engine use.

South from Great Bend to the south end of the line is a flat, sandy country, underlaid by alternating layers of sand, gravel, and clay. In nearly all of the sand and gravel strata water is found. Well No. 129 was sunk 40 feet below the upper water stratum into gravel; the water raised to a level with the top-water.

DODGE CITY LINE.

From Dodge City north there is no well-defined water-bearing stratum. The country is underlaid with blue shale with an irregular surface, and water in limited quantities is found at the top of the shale in sand or sandy clay. South from Dodge City the water-bearing stratum has a more uniform position, being very nearly on the same level with the Arkansas River. The south end of this line terminates in the artesian basin in Meade County. Here are between 85 and 100 wells, flowing on an average of 15 gallons per minute. The depths vary from 57 to 220 feet. The elevation of the water-bearing stratum is very unequal in this basin, accounted for as shown in sketch below. The water is soft, and the flow is not decreased by a multiplicity of wells.

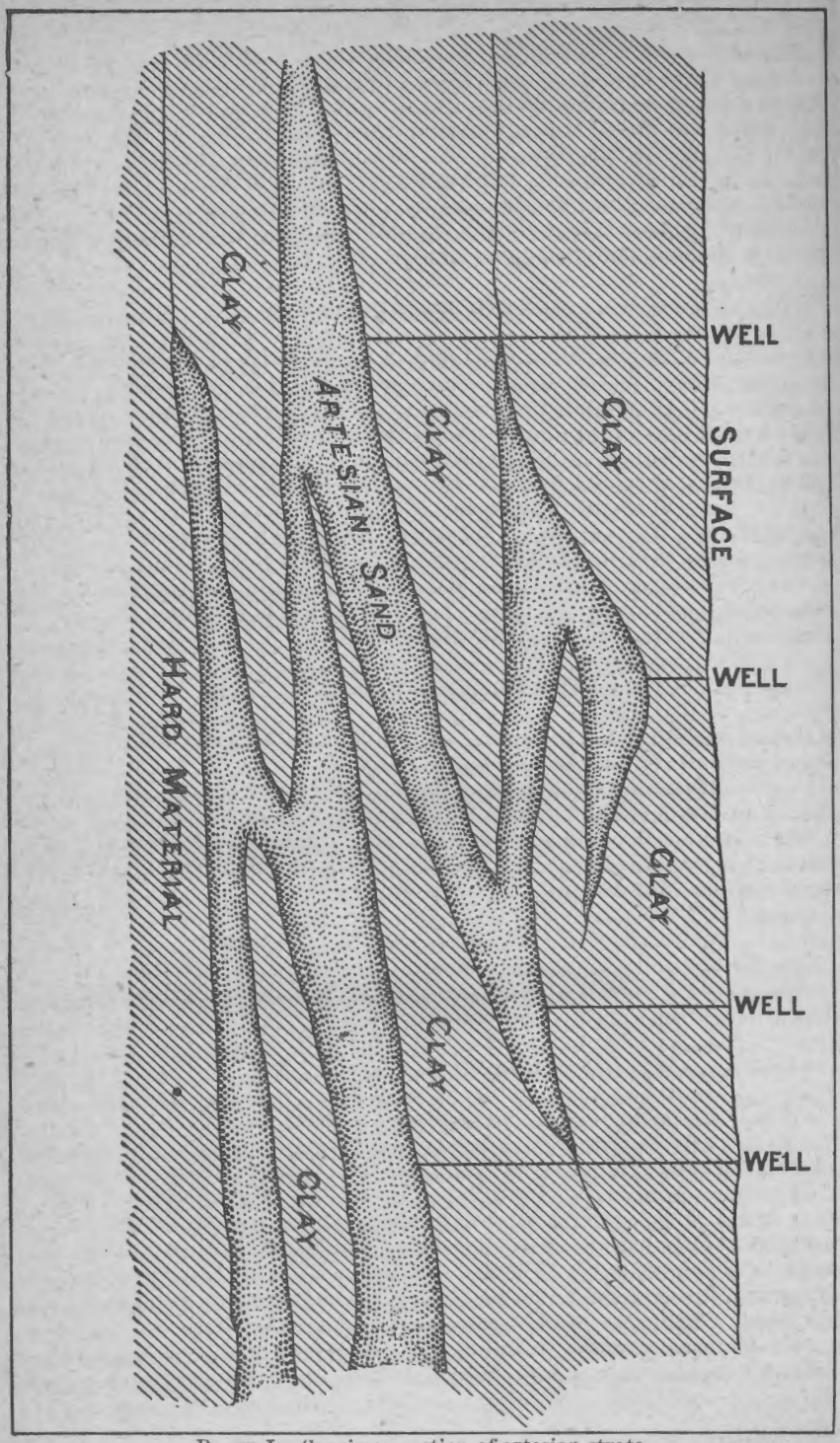

PLATE I.—Specimen section of artesian strata.

GARDEN CITY LINE.

The water-bearing stratum along the entire length of this line has a remarkable uniformity of position and slope, and comes nearer being a continued sheet of underground water than has yet been discovered. The south end of the North Platte line shows a similar condition of the water line, but its continuity is not preserved. By referring to the elevations of the two lines, it will be observed that there is about 240 feet difference between the south end of the North Platte line and the north end of the Garden City line, the former being the lowest, which shows that there must be a break in the stratum somewhere in the country intervening.

The sheet-water, as shown on the Garden City line, conforms quite well to the theories of the people in that vicinity regarding its extent, but instead of the water-bearing stratum receiving its supply from the river, as heretofore supposed, we find the facts do not justify this theory. The wells on the north side of the river are comparatively quite shallow, and have an abundant supply of water which undoubtedly comes from the west. It will be observed by an examination of the map of Kansas that the drainage water of the greater portion of the counties of Finney, Scott, Wichita, and Greeley, flows to the east towards this line and sinks in a flat country in Scott and Finney counties.

Near Scott City there is a depression in the country into which a stream discharges itself, whose head is in Colorado. During wet seasons considerable water stands in this depression for a short time, but sinks rapidly into the ground, and this water, without question, furnishes the subterranean water shown on the north end of this profile. It does not come from the Arkansas River, as the slope is in the wrong direction, it being about 2¾ feet per mile towards the river. It is more probable that the underflow of the river near Garden City is reënforced from the underground waters coming to it from the northwest.

Nearly all the wells on this line are reported as inexhaustible, as far as they have been tested by ordinary pumping by hand, or by wind mills. A few instances were observed where 4 to 7 acres are irrigated in Garden City by water pumped from these shallow wells into reservoirs by wind power. One of these wells (well 177) furnishes 100,000 gallons per day.

THE HUNDREDTH MERIDIAN LINE.

This line was surveyed for the purpose of making a continuous examination of the water-bearing strata from the Platte to the Arkansas River. The line does not quite connect with the Lexington line, and is a short distance to the west of it. As will be seen by the profile, there is no uniformity of position of the water-bearing stratum, the water line following quite closely the contour of the surface of the country. The wells along this line generally furnish water sufficient for domestic use and for stock purposes; in some instances 400 or 500 head are supplied from a single well. In several localities water was not found at all in some wells, while in others in the same neighborhood a very limited supply was found. This is generally the case where no sand or gravel was penetrated, and where the grit rock was absent. The lack of surface water in the large drainage channels like the Solomon, Saline, Smoky Hill, and Pawnee, was very noticeable. Many of the tributaries of these streams, with very much smaller drainage areas compared with those of the main streams, were carrying more water than any single one of the above-named rivers. The water in these smaller

tributaries is supplied by springs which are generally found on the north side of the creek valleys, and issuing at the lower base of the grit when it was underlaid by an impervious rock.

In the immediate valleys of some of the creeks and so-called larger rivers are deposits of sand and gravel which undoubtedly carry more or less water; but the indications are that no great amount of water for irrigation can be obtained in these, especially when long intervals occur when these water-holding sands are not reinforced by a surface flow.

This profile and some of the others show that the Platte and Arkansas Rivers are higher than some of the drainage channels that lie between these rivers. Deep borings in the immediate valleys of both the Platte and Arkansas are reported to have been made without reaching bed rock, passing through sand and gravel the whole distance. This would indicate that these rivers have been gradually raised by the filling up of their deeply eroded cañons with sand and gravel brought down from above, until their surface is, at the present time, almost on a level with their rock-bound sides. The plains streams lying between these rivers have not been filled up to the same extent; hence their difference in elevation.

CLIMATIC CONDITIONS.

From information gathered from the Weather Service records, from the people in the central and eastern parts of the Dakotas, and from those between the ninety-seventh meridian and one hundred and first in western Nebraska and Kansas, it appears that there is usually rainfall sufficient in the whole year, if it were properly distributed throughout the cropping season, to make agriculture quite certain without the aid of irrigation. During the last of June and through July there seems to have been a slight falling off of the amount of rainfall, which, with the hot southerly winds which frequently occur during these months, have made it necessary to bridge over a short interval by substituting irrigation wherever it is possible. It is the general opinion of the people in this belt of country that the hot and dry winds have more to do with the shortage and loss of crops this last season than the lack of rainfall. Further west the losses of crops seem to be more due to the scanty rainfall throughout the whole year.

There are evidences which have come to our knowledge, both from statements of the oldest settlers and from observations of the climatic conditions that must have existed before the settlement of the country, which lead to the belief that there has been a recurrence of wet and dry periods which have extended over the country under consideration. We have not been able to fix the probable return of these periods, but they seem to follow each other with intervals of 11 to 14 years. That the past year is not the dryest that was ever known is proved by the fact that in some of the small lakes on the plains which have dried up during the last season old buffalo trails are found in the bottom of these now dry lakes, leading to the very lowest point where water could be obtained. The drying up of other lakes this year shows small dead trees and brush that were once growing in what has been a lake for many years. It is also observed that the prairie grasses found in the more humid sections of the Great Plains are gradually occupying the country to the west, which was formerly covered by gramma and buffalo grasses. The latter named grasses seem to occupy and mark the country, which is at present doubtful to occupy for agricultural purposes without the substitution of irrigation. On our recent trip along

the hundredth meridian through the State of Kansas we found the gramma and buffalo grasses occupying nearly the whole country, with here and there little patches of the central Kansas grasses growing. These have come within the last few years.

While the observations of the rain gauge do not show any increase of rainfall in these districts, yet it is the experience and judgment of the people who have lived in the country for some time that the rain does not fall in such torrents as formerly; also that dews on the grass in the morning can be seen more frequently than 10 or 15 years ago. New springs of water are showing in many places, and some of the old ones are increasing in their volume; in fact, there are many signs which indicate that the climate is undergoing a gradual change, and that the country is being better fitted for the occupation of man; but the great drawback is the liability of a return of the cycles of dry seasons, when a few weeks during the cropping season must be bridged over by irrigation, or be followed by a failure of crops more or less disastrous.

Judging from the past history of the western movement of the limit where agriculture can be safely carried on, on the great western plains in Kansas and Nebraska, we can safely anticipate that with the occupation and tillage of the country along its front the line will slowly advance, but slower as it moves westward to higher altitudes and toward a country that will always require irrigation.

IRRIGATION PROBLEMS WITHIN NEBRASKA AND KANSAS.

The Platte River traverses the entire length of Nebraska, and the Arkansas enters Kansas near the southwest corner of the State and passes out of it into the Indian Territory at the ninety-seventh meridian, or the eastern limit of this investigation. These rivers have their source in Colorado and Wyoming, where they receive nearly the whole of their water supply. The appropriation of the waters of the South Platte and the Arkansas has been already made by ditches and canals in Colorado, under the constitution and laws of that State, to an extent that no water is left for either Kansas or Nebraska, except possibly a little during the short period of the annual and storm-water floods. In both Nebraska and Kansas irrigation canals have been constructed taking water out of these rivers which antedate many of the large canals in Colorado, hence the possibility of a conflict of rights of an interstate character; and until these rights are adjudicated the surplus waters of the Platte and Arkansas Rivers can hardly be depended on for irrigation purposes.

The various methods of irrigation available for this country are about as follows:

(1) The use of subterranean water obtained by open sub-flow ditches.
(2) The use of subterranean waters raised a few feet by mechanical means
(3) The use of subterranean waters raised from the ordinary farm wells by windmills.
(4) The use of the small perennial flow of the plains streams.
(5) The storage and immediate use of storm waters.
(6) The use of the flow of artesian wells.

1. Fortunately for the benefit and protection of the irrigation development in the valleys of these rivers in western Nebraska and Kansas, there is a deposit of sand and gravel of considerable width and of unknown depth that is charged with water; just how much is available and can be utilized for irrigation purposes remains to be found out. The only practical test of the quantity that can be taken out by a single sub-canal has been made at Dodge City and Hartland. A similar

attempt is being made on the Platte River near Ogallala, Nebr. Other projects of the same kind in the Platte and Arkansas Valleys are contemplated,

The amount of water obtained by the two sub-canals at Dodge City and Hartland is 15 cubic feet per second for each mile in length of the excavation that is made, 6 feet below the water line. It is found that the width of the canal has but little effect on the amount of water percolating into it; the depth and length are the controlling factors, other conditions being equal.

These sub-canals are simply drainage channels extended up and alongside of the river beds until the bottom of the channel has reached about 6 feet below the original water line, then the channel is given the same grade as the river and extended as far upstream as circumstances will admit, or until the desired amount of water is obtained. When the sub-canal is an excavated channel made by scraping out the material in the ordinary way, 6 feet deep below the water line seems to be about the proper depth. I have made some calculations regarding the proportional increase of the inflow due to deeper cut channels, and find it is nearly as the square of the depth. This rule is verified by an instance on the South Platte, 25 miles southwest from Denver, where a company has put in a sub-conduit near the bed of the river which is 18 feet below the water line. In 700 feet of this sub-conduit there is obtained 9,000,000 gallons each 24 hours, or at the rate of 153 cubic feet per second for a mile of such conduit. This shows about ten times the quantity obtained from a sub-channel 6 feet deep, which, if the above rule was applied, would be only nine times as great, or 135 cubic feet.

2. There are many places where large amounts of water exist at a depth too great to be reached by sub-canals, but which can be brought to the surface if lifted a few feet by mechanical means. Carefully made calculations show that it is practicable to raise water for general irrigation a few feet by steam pumps or animal power. It can be put on the land at a cost which will exceed but little if any the cost of water obtained from the more expensive irrigation canals. One great drawback to the early adoption of this method is the first cost of the plant, but as the country grows older and richer a considerable amount of land will be irrigated in this way.

3. For gardening and horticultural purposes considerable irrigation can be done by water pumped by wind power from wells too deep or with too small a water supply to successfully pump by steam. Water obtained in this way must be pumped into a reservoir and used in large quantities. In this way pumping can go on continuously whenever the wind is blowing and the work of irrigation can be done at the times when the crops are in need of it. The area that can be covered by a single well is small, but many wells can be put down and utilized. Water thus obtained can be used only for gardening, as it is far too costly to be used for general farming. The amount of water from each well is small, but the low first cost of such a plant and the extremely small cost of maintenance (see Appendix 10) brings it within the reach of nearly all the settlers.

4. On those small plains streams having a constant flow, careful study of the drainage will show places where small irrigation ditches can be taken out which will use the available water supply in a very advantageous way. There are large numbers of such opportunities in the drainage of the Republican River and in the eastern portion of the semi-arid country in Kansas and Nebraska. The water of streams having a continuous small flow can, by storing it in their channels, be

utilized on their valleys lower down by common irrigation methods. This is probably the cheapest and most feasible method of irrigation now available for the people of this country, and the one they should first adopt.

5. In the western portion of Kansas and Nebraska it does not seem practicable to depend on the storage of storm waters, both on account of the lack of water to store and the scarcity of good storage places. In the eastern part of the semi-arid country there are many good opportunities for storing the waters of the intermittent and flood carrying streams, and the water can be utilized for flooding the adjoining lands. It is not practicable to hold this water for any great length of time, as it would be quickly lost by evaporation and percolation, but it can be used advantageously at any time on these heavy prairie soils with impervious clay subsoil.

6. A great deal of land is now irrigated by artesian wells already in existence, but the area could be largely extended by the use of reservoirs to hold their constant flow.

A BEGINNING MADE.

Although there is so large a portion of Kansas and Nebraska west of the ninety-seventh meridian that is not susceptible of irrigation on account of the lack of water, yet there are thousands of opportunities here and there scattered all over the country outside of the immediate neighborhood of the Platte, Republican, and Arkansas Rivers, for irrigating limited areas. Some of these opportunities are already being improved, and farming and gardening under irrigation in these places has proved very successful and remunerative. We have seen instances where, by a very little expenditure of labor, the little water heretofore running to waste has been turned to a beneficial use, and areas ranging from 10 to 25 acres each have been made to yield a profit of from $25 to $75 per acre for the last two seasons. The success of those who are farming by irrigation is leading others who have the proper facilities to do likewise.

The general failure of crops and the necessity of resorting to irrigation for raising even enough for the subsistence of the family, and the good round profits made during the last season, are awakening an interest in the irrigation question. Meetings and conventions are being held in several of the western counties in these States to discuss this question. An attempt to organize for securing aid from the county, State, and National Governments is also being made. On account of the conflicts that have already arisen regarding water rights, irrigation legislation for these States will be one of the things attempted this winter.

The beginning in this small way, and the agitation of the irrigation question, reminds one of twenty or twenty-five years ago in Colorado when it then was a question with some people in that State whether farming by irrigation could be successfully carried on.

Just what the effect of the periodical recurrence of seasons of sufficient rainfall will have on the irrigation development in these States will largely depend upon the class of people occupying the country. In the western part of these States where water for irrigation can be had with a reasonable outlay of labor and money, we may safely expect work will be pushed with a degree of energy commensurate with the financial condition of the people. The difference in the final outcome of irrigation development in Kansas and Nebraska, and that in Colorado, will

be that irrigation in Kansas and Nebraska will be confined to disconnected and smaller irrigation districts, and a more general utilization of the underground waters, and doubtless a much smaller percentage of land cultivated by aid of irrigation. In one case irrigation is an absolute necessity, in the other, the necessity diminishes as the line of humidity is approached from the west.

CONCLUSIONS.

From an analysis of the information collected with reference to the extent and availability for irrigation of the underflow waters in the territory examined and embraced in this report, and also with reference to other questions closely allied to the subject we arrive at the following:

There are a great diversity of means for irrigation of small areas, all of which it will be necessary to use to irrigate even a small percentage of the lands it is necessary to artificially moisten to tide over the recurring dry seasons.

History and observation teach that the necessity for irrigation is growing less, and that the line separating the humid from the semi-arid regions is moving westward. This movement is, however, growing slower and slower with each degree covered, and the point will somewhere be reached where it will stop. Here will be the battle ground between the courageous immigrant and the elements.

Yet the country is not by any means without a hope and a fair expectation of eventually becoming a region where agricultural and pastoral pursuits properly combined can be carried on at a profit.

Yours, very respectfully,

E. S. NETTLETON,
Chief Engineer.

Hon. J. M. RUSK,
Secretary of Agriculture, Washington, D. C.

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* For detailed information, location of wells, and relative elevations of water-bearing strata, see Appendices Nos. 2 to 10.

APPENDICES.