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Irrigation Waters and Their Effects.

—BY—

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IRRIGATION WATERS AND THEIR EFFECTS.

BY W. P. HEADDEN.

I shall endeavor to set forth in general terms some of the broader features of the questions pertaining to the changes caused by irrigating our lands, without making any attempt to go into details, or any pretense to a thorough discussion of the questions connected with this subject. The following pages are intended as a brief or popular bulletin, presenting some of the conclusions arrived at in bulletin No. 82, but are entirely independent in the manner of presentation.

The waters used for irrigation in earlier years were really derived directly from the melting snows of the mountains to a much greater extent than at the present time. The cold of the higher altitude of the mountains was then the only cause preventing the waters falling in these regions, or formed by the melting of the snow, from flowing rapidly from the place of their precipitation to the lower reaches of the rivers, through which they find their way to join the oceanic waters. This agent is as active now as then but alone it is inadequate to effect a sufficiently regular distribution of these waters to meet the varied and growing requirements of agriculture, and it has been supplemented by the use of reservoirs to store the waters and prevent them from going to waste. Not only has the attempt been made to store the flood and other surplus waters in order to subsequently distribute them, that they might add to the well-being and prosperity of those living in sections further down the stream, but our agriculture has so increased that much more water is required than formerly, and in order to meet this requirement our reservoir systems have constantly grown. All available sources of water are rapidly being made to render service, until the waters of the mountains are taken out of the streams and returned several times, before being finally discharged into the bigger streams of which their natural channels or smaller streams are confluents. We may yet learn to further increase the duty of water, but if we do we will not lessen the questions relative to the changes produced and suffered by these waters used for the purposes of irrigation. We will, on the contrary, intensify them and probably find that new questions will be raised.

It is well known, but still more generally accepted as a fact, that the waters of rivers rising in high mountains where there is little soil, a scanty vegetation and no human beings to pollute them, are comparatively pure, many of them very pure indeed. This is the case with the waters of our mountain streams and is not a fancy arising from the notions which we associate with the mountains and their seclusion. The rocky face which their surface so generally presents does not wholly withstand the attack, gentle though it seem, of the falling rain or melting snow. The rocks yield little by little it is true, but the water is never able to enrich itself greatly in mineral matter at their expense. The work done by the waters in a year, a month, or even in a week, when measured in the aggregate is surprisingly large, but no given quantity of this water, a gallon or so, carries more than an infinitesimal part of the product. This water is usually colorless and free from organic matter because we have no accumulation of decaying organic matter such as peat, etc. to contaminate it. Where the surface is covered with soil there is little difference between the soil and the rocks on which the soil rests. I do not know whether the changes which take place in this soil proceed more rapidly than in the rocks proper or not; it is presumable that they do, but they are essentially of the same kind and this is true throughout the mountain region. These waters suffer little change so long as they continue to flow over the rocky beds which they have cut for themselves in the flanks of the mountains, or so long as they move through the soils which are little more than the pulverized rock on which they lie. This, however, is no longer true when they issue from the mountains and enter the plains.

We think of water flowing in a stream as being the same water that it was at its source. In a certain sense it may be, but if we apply this to mean that the water in our streams after they have issued from the mountains is the same in the quantity and character of the salts that it holds in solution as before, we err and are confronted by a series of facts that prove us to be in error. There may be occasions when the pure waters of the mountains are carried further down their course before they suffer changes than under normal conditions, but that they subsequently fall a prey to the general lot is beyond question.

If flood conditions prevail and the level of the water in the stream is higher than that of the water in the country through which it flows, in which case the velocity of the flow will also be increased, the purer, though turbid flood waters, may flow for miles further down the stream without being perceptibly changed than is the case when the flow of the stream is normal. This question might be of importance and certainly would be an interesting one to study, but the writer has never had occasion to go into this detail of the study of flood waters.

If we think of the water of a stream as a body of water flowing through a channel whose sides and bottom have no influence upon the water, just as though the water were flowing onward through a flume, we misconceive the facts. The sides and bottom, or bed of the stream are not only not tight but they are in places full of water that they discharge into the river. At others they present conditions permitting water to flow from the river into the bed and so disappear. The stream may lose water by evaporation from its surface and by leakage. The latter loss is often very considerable. These facts which are common subjects of discussion in our state suggest sufficient causes for the changes in the waters of our streams upon their issuing from the mountains into the plains. Our climate is comparatively dry but our soils are not devoid of water. The fourteen and one-half inches of rainfall may largely run off, and some of it be lost by evaporation from the surface. There is, however, a sufficient supply stored in the soils, valleys, and the marginal territory of streams to supply enough water differing wholly in character from that of the mountain streams, to modify the composition of the latter and to perceptibly change its character very soon after, if not immediately upon its leaving the mountains.

The mountain masses represent very old rocks which have been changed into schists and granites. Lapping upon the flanks of these are younger and different rocks, some of the latter being made up of fragments of the former. The water gathered within the mountains carries some mineral matter that dissolves out of the rocks, but this amount is not great and its character is very uniform throughout this section. The amount and character of the mineral matter is rather a benefit than a detriment to the water, it not being sufficient to change its character as soft water.

Upon its entering the plains it begins to receive an increased amount of mineral matter and we soon find from four to more than seventy times as much and the water passes from a soft, mountain water to a hard, alkali, plains water. This change can be detected within a short distance of the point where the streams leave the mountains·

The water then that we use for irrigation rarely has the same purity that it possessed in the mountains. In one experiment I found that in flowing about ten miles through a ditch, the mineral matter carried by the water increased fivefold. This mineral matter came, of course, from the land adjacent to the ditch.

In our natural waters, those of our mountains, it is proper and in perfect accord with what we would expect, that they should contain corbonate of lime, magnesia, etc. and we find such to be the fact, but as soon as they pass into the plains section of the stream they begin to exchange these for the sulfates until these latter become the predominating salts. In the meantime the three grains per gallon in the mountain water have become 100 grains per gallon in the plains water. This is not an exaggerated statement, but one far within the limits of fact. The water of the Cache la Poudre carries in the mountain sections of its course 2.9 grains of mineral matter per gallon, and just above Greeley, 115 grains, the carbonates constitute nearly 40 per cent of the former while magnesia sulfate, Epsom salts, constitute nearly one-third of the latter. Almost the same statement can be made of the Arkansas, at Canon City, the river water carries say 10 grains per gallon, below Rockyford 156 grains. The carbonates constitute 50 per cent. of the former while Glauber and Epsom salts constitute 40 per cent. of the latter.

In neither of these statements have I taken any account of the calcic sulfate. It is difficult to judge how much of this change is directly attributable to irrigation. Irrigation may exaggerate these changes but that they would take place in a large measure if there were no irrigation is indicated by the fact that they begin immediately, so far as we can see, upon the waters leaving the mountains, and also by the changes in the water in ditches above which there is but little or no irrigated land.

The cause of these changes is the entrance of water from the land adjacent to the river course, or return waters.

In order to hold the flood and other waters until they can be applied to crops and be made beneficial to the country, large reservoirs have been established and the river waters conducted into them and retained there for varying periods. These reservoir sites are depressions capable of having their holding capacity increased by embankments thrown up or built in the proper place. They must be above the land to be irrigated and are not as a rule in low places, but they are natural collecting basins, many of them having been small lakes before they were converted into reservoirs. These conditions suggest that they might now receive larger quantities of seepage water which in some instances is undoubtedly the case.

These stored waters sometimes suffer as great changes as the river water. It is understood that the water stored is taken from the river, much of it directly and some of it, the seepage water, indirectly in that this water has been taken from the river, applied in irrigating land and has reappeared as seepage water. A small portion has fallen as snow or rainwater.

In studying the changes in the reservoir waters it is not easy to determine just how much is to be attributed to the several causes contributing to them. If the waters were found to be quite pure, with an increase of only 0.5 of a grain per gallon, the gain could justly be attributed to evaporation from the surface of the reservoir. This would be the exact amount in the case of Terry lake. But we find an increase in this instance of upwards of 1·30 grains per gallon instead of 0.5 of a grain and the amount of salts indicated by this small amount, 0.5 grain per gallon, can be wholly neglected without affecting our final results in the least. The only rational explanation that we can offer for this increase is the seepage, together with whatever quantity of soluble salts may be furnished by the bed of the reservoir.

The amount of salts actually present in some of these reservoirs is rather surprising to the layman, and to others too, who are not cognizant of the facts in the case.

In the instance of Terry lake, which presents the most striking results of the four reservoirs which I have studied in anything like detail, the amount of salts held in solution was in round numbers 27,000 tons. The samples on which this estimate is based were taken just before they began to draw off the water and I think were as good as could be gotten. A volume of Poudre river water equal to the content of Terry lake, 9,000 acre-feet, would contain about 500 tons of mineral matter, leaving 26,500 tons as having been brought in by seepage. The other lakes, reservoirs, examined gave smaller figures but indicate the same general fact.

A peculiar fact is that there was a slight increase in the percentage of potash which, for reasons that would take too much space to enter into in this place, we believe to indicate that much of this increase was due to the solution of alkalies by waters flowing over the surface of seeped ground.

The changes which took place in this instance are so patent that they cannot be misinterpreted; the carbonates, relatively abundant in the residue from the river water, have almost disappeared, and we have in their stead sulfates, Glauber and Epsom salts forming 65 per cent. of the total mass. All the reservoir waters studied show the same changes, but Terry lake alone shows it in this extreme degree. Windsor reservoir, however, shows it in a very high degree, only a little less than Terry lake.

The water that is applied to the land then can be said to be of two classes, river water taken for direct irrigation and such as has been stored. Of late years measures have been taken to utilize waste and seepage water wherever available. This may differ a little from the stored water but so far as my knowledge goes it is seldom more heavily laden with mineral matter than the water of Terry lake and we need not consider it as making a separate class.

The amount of mineral substances carried by the river water before it leaves the mountains, which is available as plant food, is very small, 6.25 pounds of potash per acre-foot and the amount of other salts added with such water is of no moment either way. But the water taken for direct irrigation seldom reaches its destination without receiving a decided addition to its stock of mineral matter and a considerable increase in the potassic oxid carried by it. As the question considered relates to the land to which the water is applied, the source from which the potash is obtained is not considered but simply the fact that it is contained in the water as applied to the soil. The amount of potash in the river water ,as distributed on the field, was greater than we have found it to contain as mountain water, almost twice as much, but it was not a large quantity, only 11.6 pounds per acre-foot. This water as a fertilizer was not of much value. It may have been worth 50 cents per acre-foot. Neither did it carry salts which in any reasonable quantities would prove deleterious. The benefit derived from the application of this water is from the application of the water as such and not from any mineral matter held in solution.

The value added to this water by the presence of organic matter and any nitrogen contained in it is also very small, in fact as good as nothing, between 60 and 70 cents per acre-foot. While we do not add any considerable quantity of directly fertilizing salts there is nothing added in sufficient quantities to diminish in the least the good that it does. Is the same the case with stored waters? We can give only a tentative answer to this question. Our soils contain soluble salts whose influence upon our crops is, to say the least, of doubtful benefit, and to add more of the same sort would not seem to be very wise. We have given the capacity of Terry lake as 9,000 acre-feet and its content of salts as 27,000 tons, all of which is distributed with the water, or allowing one foot of water per acre it would add three tons, 6,000 pounds, of these salts. If the potash contained in this quantity of salts were present as sulfates, it would weigh 27 pounds. The remaining salts, 5,973 pounds, are either indifferent or when present in large quantities, undesirable. I have used Terry lake as an example in order to present the question which, as every one will see, is further raised by the use of seepage water.

If these salts are not deposited on or in the soil the question relative to their influence is reduced to one relative to their immediate effect upon the plants.

The salts present in Terry and Windsor lakes are calcic, magnesic and sodic sulfates with very little carbonate, probably sodic carbonate. These two lakes or reservoirs probably represent the greater part of the stored water used for irrigation and the rest will be represented by Long Pond and Warren lake water, which carries relatively more sodic carbonate and less sodic sulfate.

The seepage water that I have examined has varied considerably, a result which was to be expected, but the general composition of the mineral matter held in solution by these waters is fairly represented by the salts found in the stored water. The seepage water in sections where irrigation is not general and the supply of water not abundant, is heavily charged with salts, calcic, magnesic and sodic sulfates, the last being strongly predominant. On the other hand samples collected under different conditions have been found to carry smaller amounts of soluble salts in solution than some of the stored waters, and the salts present were calcic and magnesic sulfates together with carbonate, probably sodic carbonate. These statements are sufficient to set forth the composition of these waters and their similarity in a very rough and general way.

General statements are to be found of the effects of these salts on plants, but it would be more satisfactory if we had series of experiments giving us, conclusive results as to their detrimental or perhaps beneficial effects, when present in known proportions. This question is of interest to us and may become more so, but it has not been of such general interest as to lead to the making of tedious experiments to determine it. The tolerance of these salts by ordinary plants, sodic carbonate excepted, is probably far beyond the limit to which they are at all likely to accumulate in our soils.

The samples of soils which I have found to be richest in alkali salts yielded upon extraction a little less than 4 per cent. This was beyond the limit at which we successfully cultivated plants but we succeeded in soil, the surface portion of which showed one-half this amount or 2.0 per cent., but taking the first four inches of soil there was only 1.4 per cent. The salts found in this case were calcic, magnesic and sodic sulfates principally. The distribution of salts in the soil has an important bearing upon this question. These observations were not the results of prearranged experiments but indicate just as certainly as though they were, that large quantities of these salts may be present in the soils, other conditions being favorable, without precluding successful cropping.

If these figures be nearly correct, we can have in the first foot of soil as much as 25 tons, but probably not more than 50 tons of these salts, the mechanical condition of the soil and the drainage being good, before the salts become decidedly injurious. Accepting this maximum which is tentatively given as approximately correct, and based upon a limited experience, we may get a clearer view of the importance of this question. Taking a water as rich in mineral matter as Terry lake water, carrying three tons of salts in each acre-foot, we see that the application of nine acre-feet would add an amount of salts in excess of our lower limit. These salts would have been applied at the surface of the soil in nine successive portions, and unless it were carried down into the soil with the water, would already appear as an incrustation, especially under favorable weather conditions.

There is no doubt but that the soil does, as it were, strain out some of these salts, but it takes a thick layer to accomplish this. It would be difficult to explain how this is done but the soil particles hold on to these salts in some way and do not permit all of them to pass through the soil with perfect freedom. Indeed it is not probable that it permits any of them to pass through with perfect freedom but it retards some more than it does others. These salts are not collected within the first foot of soil, nor within the second, but may pass down several feet before they are stopped, so that, while there may be an addition of these salts held in solution in the water, as there evidently is, the addition is not necessarily to the surface soil, though the water is applied there. There is another thing that helps us in this case. The soil selects the salts which it retains and it seems to permit the most dangerous ones to pass through it more readily than some others. The ratios of the salts in solution in the water as it is put onto the ground, while it is in the ground, and as it flows out of the ground, are not the same. We cannot attempt to discuss this subject. The following statement is by no means perfectly accurate but it will serve roughly to show how the sodic carbonate, for instance, is permitted to pass through the soil more readily than the sulfate.

In an experiment which we made we found that an acre-foot of irrigation water contained 438 pounds of sodic carbonate, the water in the soil at a depth of from two to four feet contained 543 pounds and a like quantity, an acre-foot, of drain water contained 895 pounds. The water in the ground contained 868 pounds of sodic sulfate while drain water contained 168 pounds in an acre-foot, Evidently the sodic carbonate has passed out of the soil much more freely than the sulfate. If the sodic carborate were retained unchanged by the soil the result would be most unfortunate. This sodic carbonate is none other than "black alkali." We will take an irrigation water, such as we found that of Warren's lake to be in 1902, an excellent irrigation water with only 26 grains of mineral matter in each imperial gallon. We find in this 88 pounds of sodic carbonate per acre-foot, or the application of 20 acre-feet would add 1700 pounds of anhydrous sodic carbonate to each acre of land. Experiments made some years ago led me to conclude that if there were as much as 1750 pounds of sodic carbonate per acre, taken to a depth of one foot, it would under ordinary conditions kill young plants such as beets, etc. If the soil retained the sodic carbonate within a foot of the surface without changing it in any way the result would be that the soil would be rendered perfectly useless. The soil fortunately does not retain this, the most dangerous of alkali salts, but permits its passage rather readily, and its eventual removal by the drain water.

These properties of the soil fortunately prevent to a great measure, the accumulation of the more injurious salts added with the application of seepage water, or such as have been stored and become more or less heavily charged with soluble salts.

The water used for direct irrigation, that is, water taken directly from mountain streams does not carry any notable quantity of plant food. Water that has been stored in reservoirs, especially such as receive off-flow, waste and drainage waters, may carry more potash, but with it a very large amount of other salts. These salts are not very intense in their action on vegetation and are disseminated through a very large mass of soil and the most injurious one of them, sodic carbonate, is not retained by the soil. In other words, is rather readily permitted to pass into the ground water and thence into the drain waters, if drains have been established.

The changes effected by the irrigation water after it has entered the soil and before it sinks below the reach of the plants or passes out of the soil, present an interesting subject of study. The general and important question in this connection is, how efficient an agent it is in bringing plant food into an available form. Perhaps an equally important question is, what part does it play in changing deleterious salts into less injurious ones or in removing them from the soil. These questions are much more easily suggested than answered. It is conceded that food to be available to plants must be soluble. It, however, does not necessarily follow that it must be present in the soil in an ordinary aqueous solution. But when present as such it is capable of being taken up by the plants. The most important mineral substances that the plants need are potash, lime, phosphoric acid, chlorin, sulfur etc. The one used in the largest quantity by them is potash. The total quantity of this substance in our average good soil is probably not far from 40 tons to the acre taken to the depth of one foot; the percentage of this available is small and the form in which the available portion is present is doubtful. The rest is present principally as a felspar. It has long been known that the water attacks this mineral and I have shown that the oat plant can obtain potash from it if it has been finely powdered. The question whether the water in the soil dissolves this element of plant food out of the felspar is important. While we can argue that it must do so we want to know that it does, and how fast. We can not always obtain all the information that we desire but we have tried to find out how much potash was present as a free solution in the soil, or better, how much potash was contained in this water after it had entered the soil. An acre-foot of water, as applied to the field, contained almost 12 pounds of potash. A like amount of water as it was found in the soil after irrigation contained 18 pounds, a definite gain of six pounds per acre-foot of water. This is not a large amount of potash to be gathered by this amount of water but it serves to show positively that work is being done by this water, for it is richer by six pounds of potash than it was before. This problem is not so simple as it seems and there is much more involved in it than is here stated. But the fact as here stated is near the truth in spite of the many things that are left out of consideration. There is in it an abundance of chlorids and sulfur as sulfates to supply the plants with these elements.

I have not been able to find that it plays any direct part in supplying the plants with phosphoric acid. These statements show that the water within the soil is an active agent working constantly in behalf of the plants, but there is other work that it does, likewise beneficial to the plant but less directly so.

The water brings potash into solution within the soil but owing to certain properties of the soil particles it is not able to carry it out except in smaller quantities. I have tried to show that the water draining out of the soil carried the sodic carbonate out more readily than it does the sulfate, and I will now add that it seems still more difficult for it to carry out the potash. We have stated that the irrigation water carried 12 pounds potash per acre-foot and the ground water 18 pounds, taking the average of a good many ground waters we get 20 pounds per acre-foot. The drain waters carry only about five pounds per acre foot. The water then leaves the potash in the soil. I cannot give the ratios between the water applied, the water in the soil and the amount of drainage. It would be much more satisfactory if I could, but we will have to content ourselves with comparing like volumes of water, the acre-foot.

Another question suggests itself. What are these waters doing for us in regard to the salts that we do not want, beside the sodic carbonate which we have seen that they are removing? Their work in this line may be disappointing but still they are efficient and constant friends. We have seen that the water of one of our reservoirs, Terry lake, contained three tons of mineral matter per acre-foot, and we find that an acre-foot of drainage water which came from a pretty bad piece of land, carried July 23, 1900, 2,840 pounds, a little less than half as much as the stored water and very much less than the water within the soil, either after or before irrigation. It is evident that the salts do not pass out of the soil into the drain water as easily as we would expect and yet they carry a large quantity when we calculate it for a year.

The salts that the drain waters carry will vary some with the soil, but in our case we find them much more uniform than the salts carried by the waters while in the ground itself. The salts that we find in these waters are calcic sulfate, magnesic sulfate and the next one in the order of the quantity present is usually sodic carbonate. We have observed one instance in which the quantity of sodic sulfate present was greater than that of the sodic carbonate, but in this neither of these salts were present in large quantities. There was more sodic sulfate present in this sample, and much less sodic carbonate, than is usually found in drain waters.

The salt removed in the largest quantity was found to be calcic sulfate. There is an abundance of this salt in the soil and under our conditions I imagine that it is a matter of indifference whether it is removed or not. The magnesia salts which came next in quantity in the drain waters also occurred abundantly in the soils, especially in those parts of our fields that were in the worst condition. I do not know whether these salts have any part in determining the mechanical condition of the soil or not, it is quite possible that they have, but I am unable to suggest just what that part may be. The presence of magnesic salts in very large quantities in certain ground waters, together with the fact that they are uniformly present, suggest that the series of changes taking place within the soil may end in the elimination of magnesic salts. I thought for a time that we might be able to find still other facts to support this suggestion, perhaps demonstrate that these salts are the last products in the series, but I have not found them and the suggestion seems of doubtful value.

The two most direct services rendered by the drains are, first, the removal of surplus water; second, the elimination of sodic carbonate from the soil. The scope of this bulletin will not permit any further discussion of these subjects, besides we are convinced that the facts are more important than any attempt to explain them would be.

Repeated examinations have failed to show the presence of more than traces of phosphoric acid in the drain and ground waters. This is in marked contrast with the aqueous extracts of some of the soils. The importance of this is that this very valuable, and for our soils particularly desirable substance, is held pretty firmly within the soil, and though the other salts are involved in probably many changes of solution, this substance remains held by the soil particles and is given up under the influence of the plant whose needs it is to supply. How it is held, I do not pretend to say, but we know that it must be retained in some way, for we know that carbonated waters will extract it from the rocks in which it occurs. Phosphoric acid occurs in the soil in which there is both water and carbonic acid, and yet the water within the soil and that which drains out of it carry no more than traces of it.

The exhaustion of the fertility of our soils by the drain waters proceeds then very slowly, so far as the potash and the phosphoric acid is concerned. The former is removed by these means more rapidly than the latter, both in absolute and relative quantities. An acre of good soil taken to a depth of one foot contains about 78,750 pounds of potash and about 9,000 pounds of phosphoric acid. The drain waters contain easily determinable quantities of potash and only traces of phosphoric acid, for the detection of which we have to use large quantities of water or the residues representing it. If we should take a larger quantity of felspar which occurs in these soils, grind and treat it with water and carbonic acid, we could find upon examining the water, after it had been in contact with the felspar for a few days, that it contained easily determinable quantities of phosphoric acid. Why then do the ground and drain waters contain none or only a trace of it? We answer this question by appealing to the observed property of the soil particles in mass to retain certain salts, which we have seen illustrated in a very marked degree in the case of sodic sulfate which we found present in the ground-water of the soil in large quantities, but as good as absent or wholly so in the drain waters.

The claim often presented, that we add a significant quantity of fertilizing ingredients with our irrigation waters, cannot be seriously urged for them. Almost the only good they do is in supplying moisture to the plants. Even such waters as have been stored and have become heavily laden with salts by seepage or solution carry comparatively little of either the potash or nitrogen that is needed by our soils.

Nothing has been said about this latter element, concerning which it is customary to say a great deal. The reason for this is that neither the irrigation, nor ground, nor drain waters showed a content of nitrogen which justified any special notice. There is still another point frequently mentioned in connection with irrigation waters which we will notice a little more fully, i. e., that they fertilize the soil by means of suspended matter which they carry. This point is not in the least applicable to stored waters which remain stored from one to twelve months and sometimes still longer, during which time they would deposit their suspended matter if they ever carried any. This suspended matter tends to silt up the reservoirs which process is evidently proceeding very slowly. The question relative to the value of the suspended matter applies then to water used for direct irrigation and to flood waters. This question, too, is of varying importance according as the streams had in view are mountain streams, whose courses are through massive and metamorphic rocks, as is the case with the upper portions of our rivers, or whether they are plains streams, having their courses through sections of sedimentary material which is easily torn loose by heavy rains and currents. If the section of country through which the rivers run is subject to visitations by torrential rains, the river waters may at such times carry very large amounts of suspended matter. Such conditions do not prevail in this section of Colorado. We occasionally have torrential rains and the river waters may be black or red with mud, according to the character of the country in which the rains fall. But such conditions are of short duration. The period of high water is due to the melting of snow in the high mountains. The water of this season is, it is true, more turbid than during times of low water, times of heavy rain or flood excepted. The amount of suspended matter during this time of high water is insignificant in quantity. I have made observations to establish the amount and found it to be only 0.0016 per cent. of the weight of the water, or about forty-four pounds per acre-foot of water If this sediment were never so rich it would amount to but little as a means of fertilizing our soils. It is no more important from the standpoint of its quality than it is from that of its quantity. It contains just about the same percentage of potash that the soil itself contains and it is even less available if there is any difference at all. The value of this suspended matter is less than I expected to find it.

It is seldom that our waters carry large amounts of suspended matter due to heavy rains, but occasionally they do. On an occasion when the Poudre river was very high and was carrying limbs, stumps, trunks of trees, etc., I had a sample of its water taken to determine the amount and composition of sediment that it would yield. I found that it yielded 0.213 per cent. of its weight. This was a surprising result for one would have judged it to have held much more matter suspended in it than is here designated. The compositon of this suspended matter was quite as much a matter of surprise, for except in moisture and organic matter it was not very unlike the soil to which it would have been applied if used for irrigation.

The results of these examinations may surprise the reader but I am convinced that the facts are as these examinations show, i. e., that the sediments carried by the waters are small in amount and so similar to the soils in composition that they cannot be considered of such benefit as to make their application a matter to be sought after.

This view was more than sustained by the examination of a silt taken from a reservoir filled with flood water from the Arkansas river, which carried less phosphoric acid, potash, and nitrogen than our average quality of soil contains.