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Colorado Irrigation Waters and Their Changes.

—BY—

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COLORADO IRRIGATION WATERS AND THEIR CHANGES.

BY WM. P. HEADDEN.

§ 1. The irrigation waters used in this State are largely furnished by the melting of the snows which accumulate in the higher portions of the mountains during the latter part of autumn, winter, and early spring. The springs feeding our streams are for the most part such as owe their waters to the same source, and are simply the reappearance of these waters retained by the valley soils, which are for the most part shallow and store but a small amount of water, the most of it being free to come down early in the season, before the middle of July.

§ 2. Our rivers do not descend very far into the plains before their waters are diverted from their natural courses, either to be stored or used immediately for the purposes of irrigation. The water supply is becoming a question of such importance and commands so high a price that large expenditures are being made to prevent the storm and flood waters from going to waste by running down to lower levels.

§ 3. The simple diversion of the waters from their natural courses does not change their character provided the character of the course is not changed. This, however, is not the case. These waters flow but short distances through mountainous and sparsely populated sections of country, where the water entering them from the adjacent country is of the same character as that of the stream itself. The collecting grounds are for the most part covered with a thin granitic soil bearing some forest and other mountain vegetation; but a very considerable area consists of naked schists and granites. The lower portions of these streams usually flow through fertile valleys, often under cultivation. The waters are sometimes diverted in the higher portions of their courses and at every point below this where their volume and the contour of the country will permit.

§ 4. The Cache a la Poudre river flows for the first fifty miles of its course over bowlders of schist and granite, and then over gravel and sand of the same character. The North Fork flows for a portion of its course through jura-triassic strata, into which it has cut its bed before emptying into the Poudre. The chief foreign constituents, that is other than those dissolved out of the rocks

of its drainage area, contained in this water are such as are introduced by the people living along its banks. The water of the Cache a la Poudre is an excellent water usually containing less than three grains of solids to the imperial gallon. The water furnished to the inhabitants of Fort Collins is taken from the Poudre about six miles below the point where the North Fork joins the Poudre, and is a mixture of Poudre and North Fork water plus a notable quantity of seepage. This water varies in the amount of total solids contained from 2.5 grains per imperial gallon to 13.5 grains, which is the maximum observed. The former sample was taken when the river was high and the influence of the North Fork and the seepage water together was not perceptible. The latter was taken when the Poudre was low. Their influence is shown by the notable increase in the amount of the total solids present.

§ 5. The conditions given for the Poudre hold for all the streams north of the Arkansas, and for those of the San Luis valley, so long as they are mountain streams. When their waters leave the mountains their courses are over rocks of younger geological formations, from which they receive waters of different quality, and their character is materially changed.

§ 6. I shall give analyses of waters from other streams, but that of the Poudre will be the only one treated of in detail. The considerations which have led me to confine myself to the study of the Poudre river water to so great an extent as I have done are evident: First, the water of the Poudre irrigates at the present time, as much if not more land than that of any other stream within the State; Second, it flows through our home valley, is easy of access, and we have fuller data and more intimate knowledge of it than of any other stream in the State; Third, irrigation has been practiced in this valley almost as long if not as long, as in any other portion of the State (a few sections where irrigation was practiced by the Mexicans excepted), extending over a period of forty-three years; Fourth, the oldest and at the same time an extensive system of reservoirs whose beginning dates back to 1875, has been made to supplement the summer flow of the river.

§ 7. Under these conditions the flow of the return waters has already been established, the first exaggerated effects of irrigating this land have passed away, and the rate at which the return waters are carrying the soluble salts from the soil has presumably approached, if it has not already reached the point, at which it will remain for years to come. The same may be assumed to be true in regard to the character of the salts taken into solution.

§ 8. In this section the period of drainage has begun, land having become valuable enough and water in such demand that drainage has already been instituted for the double purpose of preserving the land from being water-logged or seeped, and for render-

ing the water available for irrigating other land. From this time on water will be made to do duty repeatedly in the production of crops, even more so than at present, especially if the fall of the river and other conditions will permit it.

§ 9. For these reasons the Poudre presents the best subject, and the present is probably the most opportune time that has yet presented itself for such a study. The chemical questions relative to the composition of the return waters will become more involved within the next few years than they are now, because an increasing percentage of such water will have been used repeatedly before it makes its appearance as such in the river. Some of it will have passed into storage reservoirs and suffered whatever changes that may take place during the time of storage. One of the largest reservoirs within this valley has recently been completed, the purpose of which is to collect and render available waste and seepage or return water.

§ 10. The course of the river after it issues from the canyon is over the jura-triassic and cretaceous formations. The character of the river bed has but a slight influence upon the composition of the water compared with that of the return waters, the percentage of which increases as one goes down the stream; not simply because there is an increase in the number or size of the inflowing streams and springs, but also because of the amount of water which has been taken out in the upper parts of the river. There are six larger and several smaller ditches taking water from the Poudre between the mouth of the canyon and the town of Fort Collins. These ditches take at least four-fifths of the water flowing in the river above the first ditch. The gagings show that there is a small loss of water between the gaging station in the canyon, and a point below Bellvue, the city water works; but from this point on to the mouth of the river there is an irregular but increasing gain. The sewage from the town of Fort Collins, and also that of the College, which is an independent system, flows into the river below the town. The college system also carries a considerable volume of drainage water. The total volume of water returned to the river in this way is large, representing the sewage from a population of 5,000; but the total mineral matter added to the river water by the drainage is probably greater than that contained in the sewage, and this represents but a very small fraction of the mineral substances brought in by the return waters.

§ 11. There is much irrigated land in this district, from which the seepage and waste waters together with waste from the ditches, begin to return, as shown by the measurements of the river several miles above Fort Collins. There is a gain beginning a little way below the town of Bellvue, which increases as we go down the river, until at its mouth the total increase reached, in 1895,

164.4 second feet; and in 1901, 167 second feet. This gain, or the amount of water returning to the river, varies for different sections of the river, and also from year to year. The minimum flow of return waters which I find given was in March, 1894, when it amounted to 82.3 second feet. (Bulletin No. 33 of this Station.) The percentage of seepage water in the river at any given point will evidently vary from time to time, but taking the whole course of the Poudre from below Bellvue down to its mouth the amount varies from a small amount to 100 per cent. In order to obtain river water free from seepage, it is necessary to take it above the headgate of the ditch furthest up the stream; in fact we found it advisable to take it above the mouth of the North Fork.

§ 12. The river water as it is delivered to the town of Fort Collins, for domestic consumption, is, from a chemical standpoint, a good water for domestic purposes; but a comparison of it with the river water taken further up the stream shows that it has already suffered a considerable change, due to admixture of seepage which has found its way to the river. The object had in view in taking the samples of this water was not to examine it to determine its fitness as a potable water, but simply as a part of the larger questions relative to the changes suffered by the water when used for the purposes of irrigation.

THE CACHE A LA POUFRE RIVER WATER.

§ 13. The Cache a la Poudre, very generally called the "Poudre," and its tributaries, drain a mountainous area of about 1,050 square miles before it enters the plains section. These 1,050 square miles of drainage area present a varied surface, some of which is wooded or covered with other vegetation, much of it being naked rocks; but whether covered with a thin mountain soil, a rich valley soil or rotten rocks, there is everywhere one constant condition. The rocks are largely granite, and the soil, very naturally, is granitic too. The waters flow over granite boulders, are retained in the interstices of granitic sands or soils, and whatever mineral matter is taken into solution by the waters is derived from the minerals making up the granite, gneiss or schist, as the case may be. The snows on the mountains by their melting yield the water which finds its way to the valleys to be later used for immediate irrigation or stored for subsequent use. I shall endeavor to follow the changes produced in the composition of this water from the time it melts, when I shall assume it to be practically pure water, until it leaves the Poudre to join the Platte. There are many difficulties in this study, and I shall be compelled to leave many questions wholly unanswered and others with very general answers.

§ 14. The most surprising change in the series suffered by this water is perhaps the very first one, that is, the change produc-

ed in the content and composition of its mineral constituents while it is still within its mountain area and before it debouches from its canyon into the plains. As snow we may consider it free from any mineral content, and as river water it is very pure, but not free from mineral matter. It has already been at work upon the rocks. It has taken from the air some carbon dioxid and gotten a little more from the decaying organic matter with which it has come in contact, and with this to aid it, it has taken up from 2.5 to four or five grains of mineral matter to each imperial gallon that flows through its canyon. Even its flood waters find time enough to dissolve out of the rock the smaller quantity, i. e., 2.5 grains per imperial gallon. It may seem to some an incredible thing that this should be so, but we can imitate it, and show that in a comparatively short time pure water in the presence of carbon dioxid can take up upwards of 4.5 grains of mineral matter per gallon from these very rocks, or rather from some of their constituents. There is no doubt about either the fact or the source from which the mineral content of the water is derived. The amount dissolved may surprise us, and we may wonder why the rocks have lasted so long, but we all know that the surface of the rocks is worn and that many of them are rotten for many feet below the surface, even crumbled so that they can be moved with pick and shovel. Some of the streets of the city of Denver are covered with such material as are our walks and drives. Those of us who have traveled on almost any of our mountain railroads have seen cuts of five, ten or more feet in depth made through such material, aggregating many miles. The geologist finds everywhere the products left by the water; sometimes they are thick beds of clay, at others simply rock debris. He sees in the soil a testimony of its persistent action whereby it has loosened the bonds which bound the little grains now constituting the particles of soil to their fellows, dissolving some, changing others, and carrying still others away. Each step that he describes is susceptible of observation or direct proof, however slowly they may seem to proceed or however great their aggregate results.

§ 15. The water of the Poudre, as already stated, is derived from the melting snows of the Laramie and Medicine Bow ranges, but by the time it has reached its canyon it has taken up a considerable amount of matter from the rocks. If we assume the flow to be 300 second-feet and the dissolved matter to be 2.25 grains per imperial gallon, the amount of mineral matter removed from its drainage area per day would be close to twenty-six tons, or taking the specific gravity at 2.6, almost 320 cubic feet of solid rock material every twenty-four hours. Even these figures represent only the amount carried at this point in the course of the stream, and not the total chemical work done by the water, for it is very probable that a series of changes have taken place, beginning with the

first action of the pure water upon the rock particles whereby a part of the substances originally dissolved has been removed, and it is only that portion which has escaped removal from solution that we find in the water in the lower mountain section of the stream. In addition to this the remaining rock has also been altered, and its new condition represents a further fraction of the work accomplished by the water.

§ 16. This is, in general terms, a statement of the process by which our waters obtain their burden, be it great or small, of mineral matter in these mountainous sections where the principal or only source from which they obtain it is the constituent minerals of the rock by direct attack upon them; and the products so formed are not modified, except by the agencies universally present, as for instance, the air or the interaction of solutions, differing only slightly from one another. This is wholly changed, as we shall see, when we come to such conditions as prevail in the soils. A fuller consideration of the changes which we are able to trace will I think help us materially, both in answering the questions arising relative to the points of attack, the course of the changes taking place in the minerals, and prepare the way for a better understanding of the manner of formation and properties of the soil. The object of this bulletin, however, is to take up the study of the river water and the changes it suffers when used for irrigation, in so far as we may be able to unravel them; and if we do not succeed in a satisfactory measure we still hope that the data accumulated may be interpreted by others to the furtherance of the object here attempted.

§ 17. In Bulletin No. 65, entitled "A Soil Study, Part III., The Soil," I stated that, in my own view, the study reduced itself to an investigation of the various decomposition products of felspar; not that other minerals might not be participants in these changes, but simply as a fact in this case, that we had an orthoclase felspar to deal with together with the products of its alteration. What these products are will undoubtedly vary under different conditions. Two conditions, however, obtain everywhere; the presence of water and of carbonic acid, and to these we appeal as the chief agents in the changes whereby, among others, the food elements contained in the rock particles of the soil are made available. It has been customary to consider certain mineral combinations which were supposed to be formed by the action of various agents upon the rock particles within the soil as intermediate agents, serving the purpose of retaining and conveniently giving up certain elements of plant food. This function has been attributed to a group of minerals called zeolites, and to express this property of the soil we find the expression zeolitic constituents. So far as the study of the action of water on felspar goes, it throws no light upon this view, and we de-

tect nothing favoring the assumption of the formation of zeolites in this manner. The general trend of the evidence is that there is a greater similarity to the conditions existing in veins than to those conditions where zeolites are formed. The theory of the existence of zeolitic constituents within the soil is convenient for many reasons, but it is doubtful whether it is correct for all soils, if it is for any.

§ 18. In Bulletin No. 65 I have shown to how great an extent our soils are made up of felspar particles, and have also held that they owe their origin to the disintegration of the granites and gneisses of the Front or Colorado range. It clearly follows that the present rivers or the streams which they now represent, have contributed in the past, as they are now doing, to this work. The contribution made by the Poudre being according to the assumption previously made, 320 cubic feet of solid rock taken into solution daily from the area of 1,050 square miles. This result is entirely apart from its mechanical action by which a manifold greater mass is broken down and moved from one place to another. It may not be removed very far, but it is on its way to a new resting place.

§ 19. The statement that the clear water of the river which we are accustomed to think of as pure snow water, is daily carrying not less than twenty-six tons or 320 cubic feet of solid rock from the mountains down to the plains, is so large that it will undoubtedly strike the average person as over-estimated. But such is not the case, for by direct experiment we have succeeded in bringing into solution a little more than twice the amount per gallon assumed to be present in the calculation.

§ 20. Finely powdered felspar was taken and treated for fourteen and one-half days with water and carbonic acid, and we found that the solution had dissolved out of the felspar constituents equivalent to 4.53 plus grains per gallon, and this amount, 4.536 grains, would not be considered a large quantity of mineral matter to be found, even in the water of mountain streams. This would give us rather more than double as much, or 640 cubic feet per day instead of 320, as previously assumed. The aggregate removed, whether it be measured in tons or cubic feet, is a considerable quantity. The range of total solids contained in the Poudre water is from 2.6 grains to 4.6 grains; in other words, assuming a flow of 300 second-feet, the amount actually removed daily lies between 320 and 640 cubic feet of rock material weighing about 26 tons for the lower figures or 52 tons for the higher.

THE SOURCE OF THE MATERIAL.

§ 21. I have alluded to the felspar as the source from which the water obtained its mineral matter in this case. It is not in-

tended to assert that this mineral is the only one on which the water, carbonic acid, and whatever other agencies co-operate with them act, but it is the principal one; and this is true to such an extent that we may neglect all others. The prevailing rock within the drainage area is either granite, gneiss or mica schist. There are a few eruptives within this area, and locally a little hornblende-schist occurs; but these form no large areas, so we confine ourselves to the consideration of the felspar of the granite, which is an orthoclase. This statement does not exclude the occurrence of other varieties, but they are altogether subordinate. The preceding facts constituted one reason why I chose a typical orthoclase for experimentation. A second reason was the observation that our soil consists largely of grains of this mineral. The results of experiments with this mineral then give us a measure whereby to judge to what extent the Poudre water obtains its mineral matter from this source; and, secondly, a clue as to what is going on in the soil, which, however, is only of incidental interest at this time.

§ 22. A portion of felspar, orthoclase, was ground very fine, passing through a 100-mesh sieve, and treated for 22 days with water containing carbon dioxide in solution. At the expiration of this time air was caused to pass through it whereby any ferrous salts would be oxidized and the ferric hydrate precipitated. By doing this we imitate the action which we see taking place in the river waters, especially when derived from springs in whose waters iron may be held in the form of ferrous salts. We found in this case that we obtained a copious precipitate of the hydrated ferric oxid. The filtered water was evaporated in platinum dishes to avoid obtaining any silica or potash, as might have been the case had we used a porcelain or copper dish to evaporate in. The amount of total solids obtained corresponded to 1.68 grains to the imperial gallon. I will here observe that the results of all the experiments that I made indicate that the amount dissolved is proportional to the time the water is in contact with the felspar, at least for such times as my experiments continued, other conditions being the same. The residue obtained had the following composition:—

TABLE I.—ANALYSIS OF PORTION OF FELSPAR DISSOLVED BY WATER AND CARBONIC ACID IN TWENTY-TWO DAYS.

<i>Analytical Results.</i>	<i>Per Cent.</i>	<i>Combined.</i>	<i>Per Cent.</i>
Silicic Acid	14.353	Calcic Sulfate	16.806
Sulfuric Acid	9.879	Calcic Carbonate	29.432
Carbonic Acid	19.874	Magnesian Carbonate	4.013
Phosphoric acid	0.381	Potassic Chlorid	6.668
Chlorin	3.170	Potassic Carbonate	10.367
Aluminic Oxid	1.119	Sodic Carbonate	3.736
Ferric Oxid	0.136	Sodic Phosphate	1.257
Calcic Oxid	23.412	Sodic Silicate	6.765
Strontic Oxid	Heavy trace.	Aluminic Oxid	1.119
Magnesian Oxid	1.919	Ferric Oxid	0.136
Potassic Oxid	11.279	Ignition	5.464
Sodic Oxid	6.491	Excess Silicic Acid	11.018
Lithic Oxid	Trace.		
Ignition	25.337	Total	96.783
Sum	117.370		
Less carbonic acid and oxygen equivalent to chlorin *	20.588		
Total	96.782		

* Note.—This residue was first dried on a water bath and afterwards in a water oven, as I knew from analyses already made that there was in all probability a considerable excess of silicic acid present in a most favorable form to react with any alkaline carbonates present, which I wished to avoid. I fear that a reaction between the silicic acid and these carbonates took place during the long continued boiling and heating on the water bath necessary to evaporate the water to dryness, especially as the quantity of water was large (in this instance about twenty gallons), and the vessel in which the evaporation was carried on was small. It is also certain that on ignition, even at a gentle heat, the silicic acid reacts upon the carbonates, and perhaps other salts also, causing an excessive loss over that of moisture and organic matter. The ignition in this case was made very cautiously, but there is evidently an uncertainty about its correctness. I have repeatedly observed that in cases of ignition of such residues, even when there was not a sufficient excess of silicic acid to account for it, that the carbonic acid was completely expelled by a very gentle ignition. This may have indicated that the carbonic acid was in combination with lime as calcic carbonate; but the ignition was so gentle that I doubt whether it would have sufficed under ordinary conditions to have decomposed a corresponding amount of calcic carbonate. Other methods of determining this loss might have been adopted, but the amount of material at my disposal made ignition the most feasible one, it being quite certain that there was no loss of bases; and as there still remains an excess of acid, the result emphasizes this fact. I do not know in this case that the whole of the CO_2 was expelled, but I have assumed it to have been, and have accordingly taken it together with the oxygen equivalent to the chlorin found from the sum of the results obtained.

§ 23. The preceding experiment does not stand alone, and was really not our principal one in this connection, but as the statement of others would add only cumulative evidence of the correctness of the conclusion that the source of the inorganic matter contained in the Poudre water is the felspar occurring everywhere

throughout the drainage area, the others will not be given in this place

§ 24. The first two analyses of the Poudre water that I shall give ought, perhaps, to be given in the reverse order, but as I intend to give the rest of the analyses in regular order as we go down the river, I will not deviate from it in the case of these. The only reason which would justify me in doing so would be the fact that, in the case of the second analysis I know that at least one-half of the water flowing in the river at the time the sample was taken, came down the North Fork as flood water, resulting from a heavy rain which fell in the mountains of the remoter portions of its drainage area.

§ 25. For the sake of completeness and for subsequent convenience of reference I shall give with each chemical analysis the sanitary analysis of the sample; but as the latter is of subordinate importance in our study, it will follow the chemical analysis. My object in this bulletin is not to deal with the potability of the waters used for irrigation, but to learn as much as possible about the changes that they suffer and how much they add to the fertility of the land, if any, by virtue of the elements of plant food that they contain in solution, and incidentally in suspension also. The chemical analysis gives us the amount and approximately the character of the inorganic salts held in solution, and I have adopted the ordinary sanitary analysis as the means of determining the various forms in which the nitrogen occurs, as well as its total quantity. In regard to the chlorin given in the two forms of analysis, it will be observed that the amount given by the sanitary analysis is slightly higher than that given by the chemical analysis.

TABLE II.—ANALYSIS OF CACHE A LA POUFRE WATER, SAMPLE TAKEN ABOVE THE NORTH FORK, NOV. 3, 1902.

<i>Analytical Results.</i>	<i>Grs.</i>		<i>Combined.</i>	<i>Grs.</i>	
	<i>Per Cent.</i>	<i>Imp. Gal.</i>		<i>Per Cent.</i>	<i>Imp. Gal.</i>
Silicic Acid	20.871	0.6053	Calcic Sulfate	11.782	0.3417
Sulfuric Acid	6.928	0.1946	Calcic Carbonate...	24.781	0.7186
Carbonic Acid	20.790	0.6029	Magnesian Carbonate	9.063	0.2628
Chlorin	3.575	0.1037	Sodic Chlorid	5.899	0.1711
Sodic Oxid	12.931	0.3750	Potassic Carbonate	4.325	0.1254
Potassic Oxid	2.949	0.0855	Sodic Carbonate....	9.146	0.2652
Calcic Oxid	18.741	0.5238	Sodic Silicate	8.772	0.2544
Strontic Oxid	Trace	Trace	Ferric and Alu. Oxids	0.388	0.0113
Magnesian Oxid	4.336	0.1257	Manganic Oxids....	0.063	0.0018
Ferric and Alu. Oxids	0.388	0.0113	Ignition	[9.233]	0.2678
Manganic Oxid	0.063	0.0018			
Ignition	[9.233]	0.2678	Sum	83.452	-----
Sum	100.805	-----	Excess Silicic Acid	16.546	0.4798
Oxygen Equiv. to			Total	99.998	2.8999
Chlorin .....	.805	-----			
Total	100.000	2.8974			

Total solids, 2.9 grains per imperial gallon.

SANITARY ANALYSIS.

<i>Parts Per Million.</i>		<i>Parts Per Million.</i>	
Total Solids	41.4286	Saline Ammonia	0.0350
Chlorin	1.9804	Albuminoidal Ammonia	0.0900
Nitrogen as Nitrates	Trace.	Oxygen Consumed	2.5500
Nitrogen as Nitrites	None.		

TABLE III.—ANALYSIS OF CACHE A LA POUFRE WATER, SAMPLE TAKEN 150 FEET ABOVE HEADGATE OF LARIMER COUNTY DITCH, JULY 30, 1902.

<i>Analytic Results.</i>	<i>Grs.</i>		<i>Combined.</i>	<i>Grs.</i>	
	<i>Per Cent.</i>	<i>Imp. Gal.</i>		<i>Per Cent.</i>	<i>Imp. Gal.</i>
Silicic Acid	20.542	0.5341	Calcic Sulfate	8.420	0.2189
Sulfuric Acid	4.951	0.1287	Calcic Carbonate...	36.431	0.9471
Carbonic Acid	21.626	0.5622	Magnesian Carbonate	10.758	0.2797
Chlorin	7.619	0.1980	Sodic Chlorid	12.573	0.3276
Sodic Oxid	8.874	0.2307	Potassic Silicate ...	5.391	0.1402
Potassic Oxid	3.286	0.0854	Sodic Silicate	4.342	0.1129
Calcic Oxid	23.884	0.6209	Ferric and Alu. Oxids	0.894	0.0232
Magnesian Oxid	5.147	0.1338	Manganic Oxid	0.093	0.0024
Ferric and Alu. Oxids	0.894	0.0232	Ignition	4.802	0.1248
Manganic Oxid	0.093	0.0024			
Ignition	[4.802]	0.1248	Sum	83.704	-----
Sum	101.718	2.6443	Excess Silicic Acid	16.296	0.4237
Oxygen Equiv. to			Total	100.000	2.6005
Chlorin	1.718	0.0446			
Total	100.000	2.5997			

Total solids, 2.6 grains per imperial gallon.

SANITARY ANALYSIS.

<i>Parts Per Million.</i>		<i>Parts Per Million.</i>	
Total solids	37.1400	Saline Ammonia	0.0200
Chlorin	2.8300	Albuminoidal Ammonia	0.3400
Nitrogen as Nitrates	0.1000	Oxygen Consumed	1.6570
Nitrogen as Nitrites	None		

TABLE IV.—ANALYSIS OF CACHE A LA POWDRE WATER,
SAMPLE TAKEN FROM FAUCET IN CHEMICAL
LABORATORY, MAY 23, 1897.

<i>Analytical Results.</i>	<i>Grs.</i>		<i>Combined.</i>	<i>Grs.</i>	
	<i>Per Cent.</i>	<i>Imp. Gal.</i>		<i>Per Cent.</i>	<i>Imp. Gal.</i>
Silicic Acid.....	36.180	1.664	Calcic Sulfate.....	8.800	0.405
Sulfuric Acid.....	5.180	0.238	Calcic Carbonate....	22.000	1.012
Carbonic Acid.....	20.860	0.960	Magnesian Carbonate	10.580	0.487
Chlorin.....	Trace	Trace	Sodic Carbonate.....	13.680	0.629
Sodic Oxid.....	8.000	0.368	Ferric and Alu. Oxids	2.290	0.105
Calcic Oxid.....	15.960	0.734	Manganic Oxid.....	Trace	Trace
Magnesian Oxid.....	5.060	0.233	Ignition.....	6.470	0.298
Ferric and Alu. Oxids	2.290	0.105	Silicic Acid.....	36.180	1.664
Manganic Oxid.....	Trace	Trace			
Ignition.....	6.470	0.298	Total.....	100.000	4.600
Sum.....	100.000	4.600			
Oxygen Equiv. to Chlorin.....	Trace.				
Total.....	100.000	4.600			

Total solids, 4.60 grains per imperial gallon.
Saline Ammonia, 0.00740 parts per million.
Albuminoidal Ammonia, 0.00280 parts per million.

TABLE V.—SAMPLE TAKEN FROM FAUCET IN CHEMICAL
LABORATORY, SEPT. 21, 1900.

<i>Analytical Results.</i>	<i>Grs.</i>		<i>Combined.</i>	<i>Grs.</i>	
	<i>Per Cent.</i>	<i>Imp. Gal.</i>		<i>Per Cent.</i>	<i>Imp. Gal.</i>
Silicic Acid.....	8.050	0.596	Calcic Sulfate.....	27.174	1.937
Sulfuric Acid.....	15.392	1.139	Calcic Carbonate....	32.631	2.415
Carbonic Acid.....	22.905	1.695	Magnesian Carbonate	16.272	1.204
Chlorin.....	2.248	0.166	Potassic Chlorid.....	1.402	0.104
Sodic Oxid.....	8.095	0.599	Sodic Chlorid.....	2.611	0.193
Potassic Oxid.....	0.886	0.065	Sodic Carbonate.....	0.089	0.006
Calcic Oxid.....	29.067	2.151	Sodic Silicate.....	13.116	0.971
Magnesian Oxid.....	7.750	0.573	Ferric and Alu. Oxids	0.317	0.023
Ferric and Alu. Oxids	0.317	0.023	Manganic Oxid.....	0.050	0.004
Manganic Oxid.....	0.050	0.004	Ignition.....	5.884	0.435
Ignition.....	5.884	0.435			
Sum.....	100.644	7.446	Sum.....	98.546	7.292
Oxygen Equiv. to Chlorin.....	0.506	0.037	Excess Silicic Acid	1.591	0.118
Total.....	100.138	7.409	Total.....	100.137	7.410

Total solids, 7.4 grains per imperial gallon.

SANITARY ANALYSIS.

<i>Parts Per Million.</i>		<i>Parts Per Million.</i>	
Total Solids.....	198.5000	Saline Ammonia.....	0.0250
Chlorin	5.7100	Albuminoidal Ammonia...	0.0571
Nitrogen as Nitrates	0.0400	Oxygen Consumed.....	1.3450
Nitrogen as Nitrites	0.0010		

TABLE VI.—SAMPLE TAKEN FROM FAUCET IN CHEMICAL LABORATORY, SEPT. 6, 1902.

<i>Analytical Results.</i>	<i>Grs.</i>		<i>Combined.</i>	<i>Grs.</i>	
	<i>Per Cent.</i>	<i>Imp. Gal.</i>		<i>Per Cent.</i>	<i>Imp. Gal.</i>
Silicic Acid	6.123	0.6245	Calcic Sulfate	31.179	3.1802
Sulfuric Acid	18.333	1.8699	Calcic Carbonate	30.199	3.0802
Carbonic Acid	23.266	2.3731	Magnesic Carbonate	18.152	1.8515
Chlorin	1.035	0.1055	Strontic Carbonate	0.312	0.0318
Sodic Oxid	6.501	0.6631	Potassic Carbonate	1.338	0.1364
Potassic Oxid	1.883	0.1921	Sodic Chlorid	1.708	0.1742
Calcic Oxid	29.769	3.0364	Potassic Silicate	1.593	0.1614
Strontic Oxid	0.219	0.0223	Sodic Silicate	11.035	1.1255
Magnesic Oxid	8.684	0.8857	Ferric and Alu. Oxids	0.168	0.0171
Ferric and Alu. Oxids	0.168	0.0171	Manganic Oxid	0.110	0.0112
Manganic Oxid	0.110	0.0112	Ignition	[4.144]	0.4226
Ignition	[4.144]	0.4226			
Sum	100.235	.....	Sum	99.938	.....
Oxygen Equiv. to Chlorin	0.235	.....	Total	99.938	10.1921
Total	100.000	10.2235			

Total solids. 10.2 grains per imperial gallon.

SANITARY ANALYSIS.

<i>Parts Per Million.</i>		<i>Parts Per Million.</i>	
Total solids	145.7143	Saline Ammonia	0.1200
Chlorin	19.8040	Albuminoidal Ammonia	0.0500
Nitrogen as Nitrates	0.1000	Oxygen required *	1.2450
Nitrogen as Nitrites	None		

* Note.—The preceding analyses are expressed in two different units: In per cent. and grains per imperial gallon, for ordinary chemical analysis, and parts per million, for the sanitary analysis. I believe that there is no inconvenience caused by this, as the average reader will think of 3.1802 grains per gallon more readily than of 45.4314 parts per million. The term gallon suggests a common measure, as does also the term grain. If any one wishes to convert the term grains per imperial gallon into parts per million to suit his convenience he has simply to multiply by one hundred and divide by seven, which is easily done.

§ 26. The first three of these analyses represent the water of the Cache a la Poudre river as it issues from its mountain section without being modified by waters coming from the surface soil or from the strata of the jura-triassic or cretaceous formations. In order to make our view more general, and to save repetition, we will here include the waters of the Boulder and the Clear Creek, the analyses of which will be given later. The general similarity of the analyses, especially of the analytical results, to those obtained by the analysis of the residue obtained by the evaporation of the water with which we had treated the felspar, leaves no doubt but that the sources of the different residues were the same, and we are justified in considering the felspar which occurs abundantly throughout the drainage areas the source from which the Poudre, the Boulder, and Clear Creek obtain their mineral constituents.

§ 27. This fact is not surprising except when we attempt to express the amounts removed in figures, for everyone conversant with the rocks of the country knows that the predominant minerals are felspar, quartz, and mica, of which the quartz is the least easily attacked by water. The experiment given shows that it is a fact that this is the source of the silica, potash, lime, etc., contained in the water.

§ 28. The presence of sulfuric acid and chlorin in these waters was not easily explainable. In the jura-triassic strata we have an abundance of gypsum from which calcic sulphate might be derived, and in fact this was the source from which I considered much of this salt to have been derived; but this could not possibly be the case where the sample was taken before it had come in contact with this formation, or could have received water which had done so. The analysis of the portion of felspar dissolved by water with the aid of carbonic acid shows a surprising amount of each of these constituents—sulfuric acid, over nine per cent., and of chlorin more than three per cent. The carbon dioxid and even the air drawn through the solution was well washed to avoid the introduction of extraneous substances. The water used was freshly distilled, leaving no residue upon evaporation, and failing to show a trace of chlorin. The felspar had been tested for sulfuric acid, and showed a few hundredths of one per cent.; but it was not tested directly for chlorin. The quantity found in its aqueous extract, however, leaves no doubt of its presence. This mineral, felspar, accordingly may furnish the sulfuric acid and chlorin found in our mountain waters, as well as the total solids in general.

§ 29. There is still stronger evidence, if there were need of it, and that is the presence of strontia and lithia in the water. In Bulletin No. 35, in a note upon the ash of alfalfa, I called attention to the fact that strontia was always present, but lithia was not detected in any single instance. Again in Bulletin No. 72 I called attention to the fact that lithia was found to be generally present in the ground waters which I had examined. I do not think that I have tested a single sample of ground water (and I have tested many within the past five years), that failed to show the presence of lithia. The same may be said of the Poudre water. I have also found it present in the waters of the St. Vrain, the Boulder, Clear Creek, and in the water of the Running Lode mine taken at a depth of 825 feet; also in the waters of the South Platte and the Arkansas. Its presence in the waters of the South Platte is not so significant, for there are several springs discharging into this river which I know carry some lithia, but the relative volume of these springs is small, and I am convinced that the lithia found indicates its more general occurrence in the waters of the Platte, and the same may be said of those of the Arkansas, for I doubt whether the small

quantity brought in by the springs could be detected with ease in the quantities of water actually used. Again, the presence of strontia is demonstrable with comparative ease in both the ground waters and the river waters. These facts were difficult to explain, and puzzled me greatly, leading me to doubt the correctness of my observations until frequent repetitions established it as a fact. The presence of these in the felspar and the power of even slightly carbonated water to take them into solution accounts fully and satisfactorily for their general presence in the river and ground waters, and enables us to trace the source from which the water obtains its original content of mineral matter. It further makes it very probable that all the waters flowing out of the area presenting the same general conditions, whether they flow eastward, as in case of our streams, or westward, as in the case of the streams of the western slope, have the same general properties until changed by new conditions.

CHANGES SUFFERED WHILE FLOWING IN BED OF STREAM.

§ 30. The analyses of the Poudre water already given show clearly that such changes take place before the waters have completed any considerable portion of their course. The sample taken above the mouth of the North Fork, Nov. 3, 1902, Table II, was taken at a time when there was no flood water and after a period of good weather. The snows of the preceding season had either disappeared, or were melting so slowly as to have little or no influence upon the flow, so that the water then flowing represented the normal water of the Poudre as nearly as we could obtain it. The samples taken from a tap in the Chemical Laboratory, especially the samples represented by analyses five and six, both taken in the month of September, one in 1900, the other in 1902, represent the same water after it had flowed for a distance of about eight miles to the water works, where it passed into the city mains.

§ 31. The principal difference that we observe is that the amount of total solids has increased from less than three grains (2.9 grains), to 7.4 grains in the first instance, and 10.2 in the second, that is, from two and one-half to three and one-third times the original amount.

§ 32. The water taken in the first sample had probably flowed sixty miles over the bed of the stream, but it had received water of its own kind, coming, as it had, through granitic sands and rocks. The last two samples had flowed only eight miles further, and only a portion of this distance was over a bed of a different character; and yet in a distance of less than eight miles the amount of mineral matter held in solution has been increased by these multiples. The greatest changes, however, have not been

in the amount, but in the character of the mineral matter, which is perhaps best exhibited by the analytical results, showing that the silicic acid in the solid residue, has been reduced in percentage, but almost exactly proportionally to the increase in the amount of total solids. The sulfuric acid has been increased nearly three times in percentage, and consequently a little less than nine times in absolute amount. The amounts of soda and potash have been doubled, but their percentages reduced, while the percentages of lime and magnesia have been greatly increased, and the absolute quantities are six and eight times greater.

§ 33. The extent of this change will be more fully appreciated when we estimate the difference in the total quantity of solid matter carried by the stream in twenty-four hours, as we have done for the river above the mouth of the North Fork. We found that the river carried about twenty-six tons of inorganic material, or, assuming a specific gravity of 2.6 for the solid substances, about 320 cubic feet. Assuming the same data to hold for the river water as it passes the Fort Collins water works ditch, we obtain from 65 to 87 tons, or from 800 to 1,067 cubic feet. Taking the higher figures, we discover an increase of 62 tons, or 747 cubic feet of inorganic matter carried in solution. These figures represent the ratio of salts perfectly, and the actual amounts under the assumed flow, which, however, is too high for an average year. But if we take 150 second-feet, which is below the average, as the flow, it would still represent an increase of 31 tons daily, or about 373 cubic feet of solid matter which enters the river in the section represented, about eight miles long.

§ 34. It is evident that if a proportionate change takes place, as the water proceeds down the river it will soon be so changed that comparisons cannot profitably be made. In the case of our streams this is so greatly complicated by return waters entering the river and by direct flows being taken out for irrigation or storage that no attempt will hereafter be made to compare the results except as to some particular features.

THE EFFECT OF STORAGE.

§ 35. This problem is not at all simple, for the reason that the water collected in reservoirs is not all river water, and in order to present all the conditions faithfully a detailed study of the supply would be necessary, which is clearly out of the question for me to make. I shall present analyses of some of our principal and older reservoirs which are, so far as I know, filled from the Poudre river and receive but relatively little seepage. The amount of seepage so far as I am informed, has never been determined. The amount of rain-water which they receive may be neglected. The concentration due to evaporation is not neg-

ligible, but the amount of salts with which we shall have to deal is so large that in subsequent statements we will take no note of this factor.

§ 36. The evaporation from an unprotected surface of water at Fort Collins is about forty inches per annum, or, considering the Poudre water to carry 2.9 grains per imperial gallon, there would be added to the remaining water 400 pounds of inorganic salts for each acre of surface exposed, and if the average depth of the reservoir were, as is the case in Terry lake, about twenty feet, the difference would be about 0.5 grain per gallon. This increase may be attributed to evaporation, but it is too high, for the water does not remain in the reservoirs the whole year, as here supposed; at least the reservoirs are not full, and the actual increase due to this cause is less than 0.5 of a grain per imperial gallon. That the aggregate amount of inorganic or mineral matter is large is evident. There is, however, but little profit in indulging in calculations of this sort, as they are modifications of the one already made in regard to the amount of dissolved matter daily brought down from the mountains by the Poudre river.

§ 37. The reservoir known as Terry lake has, when full, a surface area of 470 acres, from which forty inches of water evaporate annually, leaving nearly 400 pounds on each acre, or an aggregate of 94 tons of mineral matter for the entire reservoir, which has been dissolved out of the granite of the mountains where the snows have melted. But when this quantity is compared with the figures which we shall have to use to represent the aggregate of salts carried by these reservoir waters, it will be realized that this increase in the mineral matter in such waters due to evaporation can be neglected.

§ 38. I shall give the reservoir waters in order, going down the valley, beginning with the Larimer & Weld, or Terry lake. This may not be the best order, or rather it might be well to omit Terry lake altogether, because it is not typical of the changes which I most desire to set forth, but presents them in so extreme a form as to overshadow the less extreme but probably more representative results shown by the others. This reservoir, however, is one of the oldest and stores 9,000 acre-feet of water, and although the changes presented by the water of this reservoir may be greater than in the other cases, it may alone serve to give a more adequate idea of the real extent and importance of the solvent action of water upon the soils and of the supply of the soluble salts contained and formed therein than the others.

LARIMER & WELD RESERVOIR (TERRY LAKE).

§ 39. This reservoir is situated about two miles north of Fort Collins and is filled principally by water taken from the

Poudre river, the other sources being seepage and storm water from Dry Creek, and seepage and drainage from the adjacent country. Some years these latter furnish a considerable part of the 9,000 acre-feet contained in this reservoir. While this statement is true as to the amount of water furnished, it seems very probable that these sources always furnish an unusually large amount of soluble salts. The Little Cache la Poudre ditch, which carries water from the Poudre river to the reservoir, is a comparatively short ditch and can scarcely collect more than a small part of the salts which we shall presently find contained in the water of the reservoir. The two analyses given below are of samples taken from near the center of the lake and several feet below the surface, just before the water was drawn out, the reservoir being full. The water was slightly yellow and had a slight odor.

TABLE VII—ANALYSIS OF WATER FROM THE LARIMER & WELD RESERVOIR (TERRY LAKE). SAMPLE TAKEN JULY 28, 1900.

<i>Analytical Results.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>	<i>Combined.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>
Silicic Acid.....	0.125	0.168	Calcic Sulfate.....	19.704	26.502
Sulfuric Acid.....	48.089	64.680	Magnesian Sulfate...	39.741	53.452
Carbonic Acid.....	4.727	6.358	Potassic Sulfate.....	0.237	0.319
Chlorin.....	0.982	1.321	Sodic Sulfate.....	17.574	23.637
Sodic Oxid.....	14.935	20.087	Sodic Chlorid.....	1.620	2.179
Potassic Oxid.....	0.129	0.174	Sodic Hydric Carbonate...	0.463	0.623
Calcic Oxid.....	8.117	10.917	Sodic Carbonate.....	10.590	14.243
Magnesian Oxid.....	13.244	17.813	Ferric and Alu. Oxids	0.020	0.027
Ferric and Alu. Oxids	0.020	0.027	Manganic Oxid.....	0.040	0.054
Manganic Oxid.....	0.040	0.054	Ignition.....	9.938	13.367
Ignition.....	9.938	13.367			
Sum.....	100.346	134.966	Sum.....	99.927	134.353
Oxygen equiv. to Chlorin.....	0.221	0.297	Excess Silicic Acid	0.125	0.168
Total.....	100.125	134.669	Total.....	100.052	134.521

Total solids, 134.5 grains per imperial gallon.

SANITARY ANALYSIS.

<i>Parts Per Million.</i>	<i>Parts Per Million.</i>
Total Solids.....	1,921.4000
Chlorin.....	24.3000
Nitrogen as Nitrates.....	0.2000
Nitrogen as Nitrites.....	2.4000
Saline Ammonia.....	0.0944
Albuminoidal Ammonia...	0.6171
Oxygen required.....	5.9000

TABLE VIII.—ANALYSIS OF WATER TAKEN FROM THE LARIMER & WELD RESERVOIR (TERRY LAKE), JULY 30, 1902.

<i>Analytical Results.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>	<i>Combined.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>
Silicic Acid.....	0.117	0.205	Calcic Sulfate.....	21.606	37.940
Sulfuric Acid.....	53.967	94.766	Strontic Sulfate....	0.346	0.608
Carbonic Acid.....	1.936	3.400	Magnesian Sulfate...	39.136	68.723
Chlorin.....	0.872	1.530	Potassic Sulfate....	0.663	1.164
Sodic Oxid.....	15.071	26.465	Sodic Sulfate.....	26.224	46.049
Potassic Oxid.....	0.359	0.630	Sodic Chlorid.....	1.439	2.527
Calcic Oxid.....	8.893	15.616	Sodic Carbonate....	4.667	8.195
Strontic Oxid.....	0.196	0.344	Sodic Silicate.....	0.237	0.416
Magnesian Oxid.....	13.104	23.011	Ferric and Alu. Oxids	0.063	0.111
Ferric and Alu. Oxids	0.063	0.111	Manganic Oxid.....	Trace	Trace
Manganic Oxid.....	Trace	Trace	Ignition.....	5.441	9.554
Ignition.....	5.441	9.554			
Sum.....	99.822	175.632	Total.....	99.822	175.287
Total.....	99.822	175.632			

Total solids, 175.6 grains per imperial gallon.

SANITARY ANALYSIS.

<i>Parts Per Million.</i>	<i>Parts Per Million.</i>
Total Solids.....	2,508.570
Chlorin.....	28.290
Nitrogen as Nitrates.....	0.100
Nitrogen as Nitrites.....	0.010
Saline Ammonia.....	0.100
Albuminoidal Ammonia...	0.600
Oxygen required.....	2.283

§ 40. Taking the average of the total solids obtained for these two years, 1900 and 1902, determined in each case when the lake was full, we have 155.02 grains per gallon. The present capacity of the lake being 9,000 acre-feet, these figures give us 27,127 tons as the amount of mineral matter, only 507.5 tons of which was originally contained in the water, assuming it all to have been taken from the river. This large amount of salts, 27,127 tons, is annually distributed over the land irrigated by this water, or about three tons per acre-foot. At the present time we are less concerned with its distribution, which we will discuss later, than with the question of its source. It matters not whether it is storm water or river water; neither of these contains the fiftieth part of the salts here represented. If it were all river water containing 2.9 grains per gallon, it would account for only about 507 tons, leaving 26,620 tons to be derived from the seepage of a comparatively small area of country. If the whole of the Dry creek seepage were turned into the reservoir, its volume would not seem to be large enough to account for this result. The distance from Terry lake to the North Poudre canal is less than nine miles, and the average width of country which seeps or drains into it is not more than three and one-half miles, at the most thirty-two square

miles. The North Poudre canal was opened about 1884, and all the seepage and waste water arising from irrigation in this area has been washing out this tract for the past eighteen or nineteen years; and as Terry lake is emptied annually, and the water collected from the Dry creek will not average more than one-third of its contents when full, it is difficult to understand how it can furnish so very large an amount of alkali salts at the present time. To present this more clearly, we will give the actual quantities of the three salts constituting the principal part of our alkalies, which are calcic, magnesian and sodic sulfates. Terry lake contained, as the average for the two years, 1900 and 1902, 23,589.63 tons of these salts, represented as follows: calcic sulfate, 5,859.43 tons; magnesian sulfate, 10,616.42 tons; and sodic sulfate, 7,113.78 tons; all calculated as anhydrous salts. The greatest amount that a like quantity of Poudre river water would have contained would have been 59.73 tons of calcic sulfate, and no magnesian or sodic sulfate; but we have estimated that two-thirds of the water filling the lake is taken directly from the river, and the amount of this salt would be 39.82 tons, leaving 5,819.61 tons to come from the Dry creek drainage area, together with all the magnesian and sodic sulfates.

§ 41. I have spoken of the drainage area as though it extended no further northward than the North Poudre canal; this is not strictly correct, but the land under the North Poudre canal is the most northerly irrigated land. I do not know what proportion of the Dry creek water is originally Poudre river water, coming from either the Poudre or the North Fork.

LONG POND.

§ 42. Long pond lies east of Terry lake and within a mile. This reservoir is filled from the Larimer county ditch, and receives much less seepage than Terry lake. It contains about one-half as much water, or about 4,500 acre feet, but presents a proportionately smaller surface. The question, however, of concentration by evaporation, even in Terry lake, is one of a half-grain or less per gallon, and will be neglected. The changes in the water in this lake are much more nearly representative of those usually taking place than is the case with Terry lake.

TABLE IX—ANALYSIS OF SAMPLE OF WATER TAKEN FROM LONG POND AUGUST 1, 1902.

<i>Analytical Results.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>	<i>Combined.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>
Silicic Acid	1.459	0.382	Calcic Sulfate.....	39.401	10.323
Sulfuric Acid	44.013	11.531	Magnesian Sulfate...	30.177	7.906
Carbonic Acid.....	6.653	1.743	Potassic Sulfate....	1.476	0.387
Chlorin	1.494	0.391	Sodic Sulfate.....	0.128	0.034
Sodic Oxid.....	12.816	3.358	Sodic Chlorid.....	2.465	0.646
Potassic Oxid.....	0.799	0.209	Sodic Carbonate....	16.042	4.203
Calcic Oxid.....	16.217	4.249	Sodic Silicate.....	2.959	0.775
Magnesian Oxid....	10.104	2.647	Ferric and Alu. Oxids	0.225	0.059
Ferric and Alu. Oxids	0.225	0.059	Manganic Oxid.....	Trace	Trace
Manganic Oxid.....	Trace	Trace	Ignition	6.934	1.817
Ignition	6.934	1.817			
Sum.....	100.714	26.386	Sum	99.807	26.150
Oxygen equiv. to			Excess Sodic Oxid..	0.570	0.149
Chlorin	0.336	0.088			
Total.....	100.378	26.298	Total	100.377	26.299

Total solids, 26.2 grains per imperial gallon.

SANITARY ANALYSIS.

<i>Parts Per Million.</i>	<i>Parts Per Million.</i>		
Total Solids.....	374.290	Saline Ammonia.....	0.050
Chlorin.....	7.070	Albuminoidal Ammonia...	0.280
Nitrogen as Nitrates.....	Trace	Oxygen consumed.....	3.296
Nitrogen as Nitrites.....	None		

WARREN'S LAKE.

§ 43. Warren's lake lies six miles due south of Long pond, and is filled from Larimer County No. 2 ditch, receiving a small amount of seepage and waste water. The distance from the head-gate of the ditch to the reservoir is about eight miles. The sample was taken near the gate. Depth of water, ten feet.

TABLE X.—ANALYSIS OF SAMPLE OF WATER TAKEN FROM WARREN'S LAKE, AUGUST 4, 1902.

<i>Analytical Results.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>	<i>Combined</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>
Silicic Acid	2.210	0.407	Calcic Sulfate	47.796	8.794
Sulfuric Acid	30.826	5.672	Magnesian Sulfate	4.064	0.748
Carbonic Acid	14.284	2.628	Magnesian Carbonate	17.636	3.245
Chlorin	3.323	0.611	Potassic Chlorid	2.040	0.375
Sodic Oxid	12.327	2.268	Sodic Chlorid	3.883	0.714
Potassic Oxid	1.361	0.250	Sodic Carbonate	12.264	2.257
Calcic Oxid	19.672	3.620	Sodic Silicate	4.482	0.825
Magnesian Oxid	9.800	1.803	Ferric and Alu. Oxids	0.400	0.074
Ferric and Alu. Oxids	0.400	0.074	Manganic Oxid	0.092	0.017
Manganic Oxid	0.092	0.017	Ignition	6.434	1.184
Ignition	6.434	1.184			
Sum	100.749	18.534	Sum	99.191	18.233
Oxygen Equiv. to Chlorin	0.749	0.138	Excess Sodic Oxid .....	.818	0.151
Total	100.000	18.396	Total	100.009	18.384

Total solids, 18.4 grains per imperial gallon.

SANITARY ANALYSIS.

<i>Parts Per Million.</i>	<i>Parts Per Million.</i>
Total solids	262.860
Chlorin	9.900
Nitrogen as nitrates	0.100
Nitrogen as nitrites	0.001
Saline ammonia	0.180
Albuminoidal ammonia	0.420
Oxygen consumed	4.114

WINDSOR RESERVOIR.

§ 44. The capacity of this reservoir is 14,000 acre-feet and it is filled by the Larimer & Weld canal with water taken from the Poudre below the town of Laporte. The reservoir lies twelve miles east and five miles south of the headgate of the ditch. The actual length of the ditch through which the water flows is probably not far from 13.5 miles. The lake was full at the time the sample was taken. Its owners began to draw out the water while the sample was being taken. I do not know how much seepage and drainage water gathers in this reservoir. The higher amount of total solids present indicates a considerable accession of such waters. Terry lake discharges its water through the same canal that fills the Windsor reservoir, but as I understand the matter, these two reservoirs belong to different companies, and as both reservoirs were full at the time the samples were taken, it is not probable that any of the salts held in the water of Windsor lake came from Terry lake water, but represent the influence of the area from which the lake receives seepage. This, of course, includes the lake bed itself.

TABLE XI.—ANALYSIS OF SAMPLE OF WATER TAKEN FROM WINDSOR RESERVOIR, AUGUST 5, 1902.

<i>Analytical Results.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>	<i>Combined</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>
Silicic Acid.....	0.380	0.264	Calcic Sulfate.....	32.202	22.348
Sulfuric Acid.....	50.149	34.803	Magnesian Sulfate...	37.258	25.857
Carbonic Acid.....	3.854	2.675	Potassic Sulfate....	1.000	0.694
Chlorin.....	1.890	1.312	Sodic Sulfate.....	10.581	7.343
Sodic Oxid.....	12.109	8.404	Sodic Chlorid.....	3.119	2.165
Potassic Oxid.....	0.541	0.375	Sodic Carbonate....	9.294	6.446
Calcic Oxid.....	13.254	9.198	Sodic Silicate.....	0.770	0.534
Magnesian Oxid.....	12.475	8.658	Ferric and Alu.		
Ferric and Alu.			Oxids.....	0.289	0.201
Oxids.....	0.289	0.201	Manganic Oxid....	0.070	0.049
Manganic Oxid.....	0.070	0.049	Ignition.....	[5.415]	3.758
Ignition.....	[5.415]	3.758			
Sum.....	100.426	69.697	Sum.....	100.000	69.395
Oxygen Equiv. to			Excess.....	None	None
Chlorin.....	0.426	0.296	Total.....	100.000	69.395
Total.....	100.000	69.401			

Total solids, 69.4 grains per imperial gallon.

SANITARY ANALYSIS.

<i>Parts Per Million.</i>	<i>Parts Per Million.</i>		
Total Solids.....	991.430	Saline ammonia.....	0.040
Chlorin.....	27.730	Albuminoidal ammonia...	0.360
Nitrogen as Nitrates.....	0.100	Oxygen consumed.....	3.634
Nitrogen as Nitrites.....	0.001		

§ 45. We have in this case, as in that of Terry lake, and in the others to a less degree, a very noticeable increase in the amount of total solids. Taking the capacity of this lake as 14,000 acre-feet (14,004 is the correct capacity) we find that there are 18,894.15 tons of salts held in solution, while a like quantity of Poudre water would contain only 789.5 tons, showing 18,104.6 tons collected by the lake during the period intervening between the two drawings-off—a period of approximately a year. The capacity of Terry lake is 9,000, that of Windsor lake 14,000 acre-feet. Terry lake collected 27,127 tons, and Windsor lake 18,894 tons, of mineral matter in a year. The amount of these salts is very different, the smaller lake or reservoir having collected one-half more than the larger one.

§ 46. The relative quantities of the various salts are also quite different in these cases. For instance, Terry lake collected 5,859.4 tons of calcic sulfate, anhydrous; Windsor lake, 6,083.29 tons. Terry lake collected 10,616.4 tons of magnesian sulfate; Windsor lake 7,029.58 tons. Of sodic sulfate, Terry lake collected 7,113.78 tons; Windsor lake, 1,999.19 tons. Of sodic carbonate Terry lake collected, average of two years, 2,069.25 tons; Windsor

lake, 1,756.02 tons. To the average person, these figures convey but an inadequate idea of the amount of salts dissolved by these lake waters. If we put it, as is sometimes done, in terms of the transportation facilities which would be necessary to move this combined amount, it may give a clearer notion of the quantity of salts moved by these two lakes. The amount of salts carried out by the annual emptying of these lakes is 46,021 tons, which would require 1,534 cars each holding thirty tons, which, allowing 35 feet as the length of a car, would represent a train ten miles long, not including engines.

THE FERTILIZING VALUE OF THESE SALTS.

§ 47. As the water whose composition we have so far presented is used for irrigating purposes, it may not be amiss to discuss the fertilizing value as it is indicated by the various analyses. The only constituent in the ordinary chemical analysis which is of importance in this respect is the potassic oxid. Our soils contain lime enough to meet the requirements of all cultivated crops. The advisability of adding lime because of its chemical action on the soil is left entirely out of the question, and if it were considered, the form in which the lime is present in the waters would render it of little value, except in a very limited range of cases. We will then simply endeavor to find how much potash these waters would add to the soil if the whole of it were retained and were available to plants as food. These assumptions are made for convenience of presentation only, and for the same reason we will make no distinction between the waters of the different reservoirs, but will take them in the aggregate.

§ 48. The capacity of the four reservoirs is 27,672 acre-feet. Allowing two feet per acre, they would together irrigate 13,836 acres of land. The aggregate amount of potassic oxid found in them was 188.06 tons, equivalent to 347.9 tons of sulfate of potash, which would give almost exactly 50 pounds of sulfate of potash per acre irrigated, equivalent to a dressing of 200 pounds of the average kainit of commerce. It will be recalled that the percentage of potash found in the waters was not uniform, that from Warren's lake yielding the highest. It will also be recalled that the Poudre water as taken from the river to fill these lakes furnishes an insignificant part of this potash; therefore, it is evident that the main supply must have come from seepage. Long pond and Warren's lake receive less seepage than the other two, and when we calculate the amount of sulfate of potash which their waters add to the soil irrigated with it, as we have for the four taken together, we find that an acre receives the equivalent of only 31 pounds, instead of 50 pounds; and if we should use water directly from the river, as it comes through the canyon, it would add the

equivalent of only 12.5 pounds. This last quantity is high in proportion to the amount of mineral matter added, owing to the higher percentage of potash present in the total solids.

§ 49. The sanitary analyses show that the changes suffered while the water is stored do not, in their total results, materially affect the quality of the water, the albuminoidal ammonia, and in one instance the nitrites, alone showing material changes. They also show that the amount of nitrogen added in all forms is utterly insignificant—less than four pounds per acre in the most favorable instance.

§ 50. We see that the amount of plant food distributed by means of the irrigation water, whether it be stored water or such as is used directly from the river, is not so great as might have been expected, but its effect, if the potash present is really available for the use of plants, would undoubtedly aid materially in maintaining the fertility of the soil. In the case of the stored water the potash applied in the course of four years would amount to a dressing of 800 pounds of kainit.

§ 51. There is another question, i. e., how much do we add of other salts which are useless and may be deleterious? To this suggestion the answer is that, taking the aggregate results of the four reservoirs, as we did in the case of the potash when we found that the equivalent of 50 pounds of sulfate of potash per acre was added yearly, we find that with this amount of potash there is added 3.49 tons, 6,980 pounds, of other salts. This result seems large, but if we calculate the amount of salts added per acre when two feet of Windsor or Terry lake water is applied, we shall find still larger quantities. Windsor lake is the largest of the four and is intermediate as to the amount of salts held in solution between Terry lake and the others, and we will for this reason analyze the results obtained from the examination of its water. The capacity of the lake is 14,000 acre-feet, and its water holds in solution 18,894.15 tons of total solids. An application of two feet of water per acre will distribute this over 7,000 acres, or 2.7 tons or 5,400 pounds per acre. The potash contained in this is equivalent to 53.6 pounds of sulfate of potash per acre. The calcic sulfate amounts to 1,738 pounds; magnesian sulfate, 2,000 pounds; sodic sulfate, 542 pounds; sodic carbonate, 250 pounds; sodic chlorid, salt, 174 pounds; other substances, 330 pounds.

§ 52. A like application of Terry lake water would add to each acre: potash equivalent to 54.5 pounds of sulfate of potash; 2,604 pounds calcic sulfate; 4,718 pounds of magnesian sulfate; 3,162 pounds of sodic sulphate and 919 pounds of sodic carbonate.

§ 53. The above figures are for anhydrous salts, but they are doubtlessly present in the hydrated condition, and if calculated as such would be represented by large numbers.

THE CHANGES EFFECTED IN THE WATER USED IN IRRIGATION.

§ 54. It seems proper to take up this subject before we present that of the return waters. The changes produced will depend upon the character of the soil irrigated and will probably differ in the case of sod-covered land and in that of land under cultivation.

§ 55. The facts recorded in the preceding paragraphs relative to the changes, which took place during storage for the comparatively short period of one season, clearly indicate that the only proper basis from which to start would be Poudre water taken for direct irrigation and a perfectly typical soil. These conditions might have been met but it would have been with difficulty.

§ 56. The first series of samples taken for the purpose of studying the changes in the composition of the water used in irrigation was taken in 1898, the second in 1899, and the third in 1900, when I availed myself of the opportunity offered by an exceptionally heavy and protracted rainfall whereby the water plane, as indicated by the height of the water in the wells dug in different parts of the plot, was raised to within from 1.0 foot to 0.3 of a foot of the surface. The water in this case being rain water, or water produced by snow melting on the ground, eliminated the question of its composition.

§ 57. The water which I used in the following experiments in 1899 was Poudre water mixed with some seepage, but the plot of ground was not typically good soil but rather an alkali soil. Originally this soil was in a bad condition, but it had been improved by cultivation at the time this experiment was made and a part of it was then in excellent condition. The results therefore may represent those of actual practice more nearly than if the whole plot had been in the very best condition, but it clearly involves the question of alkali. It is a difficult matter to find any land where the drainage is not perfect which is entirely free from this question, especially when considered from a chemical standpoint. The instances of Terry and Windsor lakes accumulating in a single season 27,127 and 18,894 tons of salts respectively, after having been in use as storage reservoirs for at least 12 years, is suggestive of a goodly supply, particularly when we consider the comparatively small area from which these quantities of salts were collected.

§ 58. In 1898 the only water at my disposal was seepage water and the supply of this was limited. The water plane was moderately low and was raised from one to two feet in different parts of the plot. The water in the wells obtained its maximum height in from one to five days and then fell, at first rapidly, afterwards gradually, until it reached the lowest point for the season—the maximum fall being 4.3 feet. The changes in the water will be evident from the following analyses:

TABLE XII—ANALYSIS OF WATER AS IT FLOWED ONTO PLOT JULY 8 AND 9, 1898.

<i>Analytical Results.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>	<i>Combined.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>
Silicic Acid	1.885	0.942	Calcic Sulphate	51.366	25.683
Sulfuric Acid	40.389	20.195	Magnesian Sulfate ..	15.272	7.636
Carbonic Acid	9.245	4.622	Magnesian Chlorid ..	4.296	2.148
Chlorin	3.479	1.740	Potassic Chlorid	0.567	0.284
Sodic Oxid	13.149	6.575	Potassic Carbonate ..	0.735	0.367
Potassic Oxid	0.859	0.429	Sodic Carbonate	21.728	10.864
Calcic Oxid	21.160	10.580	Sodic Silicate	0.851	0.426
Magnesian Oxid	6.900	3.450	Ferric and Alu.		
Ferric and Alu. Oxids	0.077	0.039	Oxids	0.077	0.039
Manganic Oxid	0.058	0.029	Manganic Oxid	0.058	0.029
Ignition	3.256	1.628	Ignition	3.261	1.631
Sum	100.462	50.229	Sum	98.211	49.107
Oxygen Equiv. to Chlorin	1.784	0.392	Excess Silicic Acid ..	1.466	0.733
Total	99.678	49.837	Total	99.677	49.840

Total solids 50.0 grains per imperial gallon.

TABLE XIII.—ANALYSIS OF WATER AS IT FLOWED OFF AT MIDDLE OF NORTH SIDE OF THE PLOT JULY 14, 1898.*

<i>Analytical Results.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>	<i>Combined.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>
Silicic Acid	1.079	0.791	Calcic Sulfate	29.729	21.791
Sulfuric Acid	46.877	34.361	Magnesian Sulfate ..	22.064	16.173
Carbonic Acid	2.895	2.122	Potassic Sulfate	2.534	1.857
Chlorin	4.288	3.143	Sodic Sulfate	24.018	17.605
Sodic Oxid	19.419	14.234	Sodic Chlorid	7.076	5.187
Potassic Oxid	1.376	1.009	Sodic Carbonate	6.981	5.117
Calcic Oxid	12.247	8.977	Sodic Silicate	2.138	1.567
Magnesian Oxid	7.353	5.390	Ferric and Alu.		
Ferric and Alu. Oxids	0.047	0.034	Oxids	0.047	0.034
Manganic Oxid	0.107	0.078	Manganic Oxid	0.107	0.078
Ignition	5.135	3.764	Ignition	5.135	3.764
Sum	100.823	73.903	Sum	99.829	73.173
Oxygen Equiv. to Chlorin	0.966	0.708	Excess Silicic Acid ..	0.026	0.019
Total	99.857	73.195	Total	99.855	73.192

Total solids 73.3 grains per imperial gallon.

* It was an accident that enabled us to obtain this sample of run-off water. The water at our disposal for irrigating was not sufficient to produce any off-flow, but we, by an oversight, left our dam in the ditch and our distributing gates open. On the night of the 13th there was a heavy shower in the foot hills and others also having left their ditches open we obtained water enough to produce a slight off-flow. It is plain that the water which came down thus unexpectedly was storm water and was mixed with the water which we had previously been using for irrigation. The actual result was larger than is presented by the analysis. The volume of this off-flow was small and continued for a short time only.

TABLE XIV.—ANALYSIS OF WATER OF WELL C, JUNE 27, 1898. *

<i>Analytical Results.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>	<i>Combined.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>
Silicic Acid	0.764	0.993	Calcic Sulfate	30.309	39.401
Sulfuric Acid	44.501	57.851	Magnesian Sulfate	20.048	26.062
Carbonic Acid	3.815	4.960	Potassic Sulfate	0.246	0.320
Chlorin	5.521	7.177	Sodic Sulfate	23.439	30.471
Sodic Oxid	21.681	28.186	Sodic Chlorid	9.108	11.840
Potassic Oxid	0.133	0.173	Sodic Carbonate	9.191	11.949
Calcic Oxid	12.489	16.236	Sodic Silicate	1.553	2.019
Magnesian Oxid	6.677	8.680	Ferric and Alu.		
Ferric and Alu.			Oxids	0.050	0.065
Oxid	0.050	0.065	Manganic Oxid	0.031	0.040
Manganic Oxid	0.031	0.040	Ignition	5.531	7.190
Ignition	5.531	7.190			
Sum	101.193	131.551	Sum	99.506	129.357
Oxygen Equiv. to			Excess Sodic Oxid	0.440	0.572
Chlorin	1.244	1.618			
Total	99.947	129.933	Total	99.946	129.929

Total solids 130.0 grains per imperial gallon.

* Before irrigation.

TABLE XV.—ANALYSIS OF WATER OF WELL C, JULY 11, 1898. *

<i>Analytical Results.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>	<i>Combined.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>
Silicic Acid	0.398	1.620	Calcic Sulfate	29.233	118.918
Sulfuric Acid	48.138	195.823	Magnesian Sulfate	27.894	113.473
Carbonic Acid	1.500	6.102	Potassic Sulfate	0.233	0.938
Chlorin	5.504	22.391	Sodic Sulfate	21.738	88.430
Sodic Oxid	17.201	69.975	Sodic Chlorid	9.080	36.938
Potassic Oxid	0.126	0.513	Sodic Carbonate	3.613	14.699
Calcic Oxid	12.046	49.002	Sodic Silicate	0.809	3.290
Magnesian Oxid	9.290	37.793	Ferric and Alu.		
Ferric and Alu.			Oxids	0.276	1.122
Oxids	0.276	1.122	Manganic Oxid	0.070	0.285
Manganic Oxid	0.070	0.285	Ignition	6.529	26.561
Ignition	6.529	26.561			
Sum	101.078	411.187	Sum	99.475	404.654
Oxygen Equiv. to			Excess Sodic Oxid	0.359	1.460
Chlorin	1.241	5.046			
Total	99.837	406.141	Total	99.834	406.114

Total solids 404.8 grains per imperial gallon.

* After irrigation.

TABLE XVI.—ANALYSIS OF WATER OF WELL G, JUNE 27, 1898. *

<i>Analytical Results.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>	<i>Combined.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>
Silicic Acid	0.498	1.175	Calcic Sulfate	40.299	95.106
Sulfuric Acid	44.062	103.986	Magnesian Sulfate	24.050	56.758
Carbonic Acid	3.521	8.309	Potassic Sulfate	0.770	1.817
Chlorin	7.535	17.783	Sodic Sulfate	7.062	16.666
Sodic Oxid	15.055	35.530	Sodic Chlorid	12.434	29.343
Potassic Oxid	0.418	0.986	Sodic Carbonate	8.490	20.036
Calcic Oxid	16.601	39.178	Sodic Silicate	0.790	1.864
Magnesian Oxid	8.015	18.915	Ferric and Alu.		
Ferric and Alu.			Oxids	0.040	0.094
Oxids	0.040	0.094	Manganic Oxid	0.060	0.141
Manganic Oxid	0.060	0.141	Ignition	9.540	14.018
Ignition	5.940	14.018			
Sum	101.745	240.115	Sum	99.935	235.843
Oxygen Equiv. to Chlorin	1.698	4.007	Excess Silicic Acid	0.109	0.257
Total	100.047	236.108	Total	100.044	236.100

Total solids 236.0 grains per imperial gallon.

* Before irrigation.

TABLE XVII.—ANALYSIS OF WATER OF WELL G. JULY 11, 1898. *

<i>Analytical Results.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>	<i>Combined.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>
Silicic Acid	0.337	1.149	Calcic Sulfate	32.866	112.073
Sulfuric Acid	46.106	157.221	Magnesian Sulfate	27.162	92.622
Carbonic Acid	3.456	11.785	Potassic Sulfate	1.845	6.283
Chlorin	6.317	21.541	Sodic Sulfate	13.897	47.389
Sodic Oxid	17.165	58.533	Sodic Chlorid	10.424	35.546
Potassic Oxid	1.002	3.417	Sodic Carbonate	8.333	28.416
Calcic Oxid	13.539	46.68	Sodic Silicate	0.684	2.332
Magnesian Oxid	9.052	30.867	Ferric and Alu.		
Ferric and Alu.			Oxids	0.070	0.239
Oxids	0.070	0.239	Manganic Oxid	0.060	0.205
Manganic Oxid	0.060	0.205	Ignition	4.352	14.840
Ignition	4.352	14.840			
Sum	101.456	345.965	Sum	99.693	339.945
Oxygen Equiv. to Chlorin	1.423	4.852	Excess Sodic Oxid	0.337	1.149
Total	100.033	341.113	Total	100.030	341.094

Total solids 341.0 grains per imperial gallon.

* After irrigation.

TABLE XVIII.—ANALYSIS OF WATER OF WELL B, JUNE 27, 1898. *

<i>Analytical Results.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>	<i>Combined.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>
Silicic Acid	0.638	1.347	Calcic Sulfate	38.592	81.506
Sulfuric Acid	46.128	97.422	Magnesian Sulfate ..	24.068	50.832
Carbonic Acid	3.187	6.731	Potassic Sulfate ...	0.696	1.470
Chlorin	6.745	14.245	Sodic Sulfate	12.552	26.510
Sodic Oxid	16.311	34.449	Sodic Chlorid	11.130	23.506
Potassic Oxid	0.378	0.798	Sodic Carbonate	7.685	16.231
Calcic Oxid	15.898	33.576	Sodic Silicate	0.833	1.759
Magnesian Oxid	8.021	16.940	Ferric and Alu.		
Ferric and Alu.			Oxids	0.070	0.148
Oxids	0.070	0.148	Manganic Oxid	0.060	0.127
Manganic Oxid	0.060	0.127	Ignition	4.524	9.555
Ignition	4.524	9.555			
Sum	101.960	215.338	Sum	100.210	211.644
Oxygen & equiv. to Chlorin	1.520	3.210	Excess Silicic Acid ..	0.228	0.482
Total	100.440	212.128	Total	100.438	212.126

Total solids 211.2 grains per imperial gallon.

* Before irrigation.

TABLE XIX.—ANALYSIS OF WATER OF WELL B, JULY 11, 1898.*

<i>Analytical Results</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>	<i>Combined.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>
Silicic Acid	0.453	1.422	Calcic Sulfate	26.549	83.283
Sulfuric Acid	47.321	148.493	Magnesian Sulfate ..	17.626	55.310
Carbonic Acid	2.086	6.546	Potassic Sulfate ...	0.346	1.086
Chlorin	4.756	14.924	Sodic Sulfate	35.166	110.351
Sodic Oxid	23.015	72.221	Sodic Chlorid	7.849	24.630
Potassic Oxid	0.188	0.590	Sodic Carbonate	5.030	15.785
Calcic Oxid	10.933	34.308	Sodic Silicate	0.920	2.887
Magnesian Oxid	5.874	18.433	Ferric and Alu.		
Ferric and Alu.			Oxids	0.039	0.122
Oxids	0.039	0.122	Manganic Oxid	0.039	0.122
Manganic Oxid	0.039	0.122	Ignition	5.908	18.539
Ignition	5.908	18.539			
Sum	100.612	315.720	Sum	99.463	312.114
Oxygen Equiv. to Chlorin	1.072	3.364	Excess Sodic Oxid ..	0.076	0.239
Total	99.540	312.356	Total	99.539	312.353

Total solids, 313.8 grains per imperial gallon.

* After irrigation.

TABLE XX.—ANALYSIS OF WELL A, JUNE 27, 1898.*

<i>Analytical Results.</i>	<i>Per Cent.</i>	<i>Grs.</i>	<i>Per Cent.</i>	<i>Grs.</i>	
		<i>Imp. Gal.</i>			<i>Gal.</i>
Silicic Acid.....	0.649	1.399	Calcic Sulfate.....	35.648	76.857
Sulfuric Acid.....	46.854	100.017	Magnesian Sulfate.....	28.750	61.985
Carbonic Acid.....	3.099	6.681	Potassic Sulfate.....	0.670	1.444
Chlorin.....	6.115	13.183	Sodic Sulfate.....	11.393	24.563
Sodic Oxid.....	15.289	32.963	Sodic Chlorid.....	10.091	21.756
Potassic Oxid.....	0.364	0.785	Sodic Carbonate.....	7.472	16.110
Calcic Oxid.....	14.685	31.661	Sodic Silicate.....	1.149	2.477
Magnesian Oxid.....	9.581	20.657	Ferric and Al. Oxids	0.040	0.086
Ferric and Al. Oxids	0.040	0.086	Manganic Oxid.....	0.060	0.129
Manganic Oxid.....	0.060	0.129	Ignition.....	4.754	10.249
Ignition.....	4.754	10.249			
Sum.....	101.490	218.810	Sum.....	100.027	215.656
Oxygen Equiv. to Chlorin.....	1.378	2.971	Excess Silicic Acid	0.083	0.179
Total.....	100.112	215.839	Total.....	100.110	215.835

Total solids, 215.6 grains per imperial gallon.
* Before irrigation.

TABLE XXI.—ANALYSIS OF WATER OF WELL A, JULY 11, 1898.*

<i>Analytical Results.</i>	<i>Per Cent.</i>	<i>Grs.</i>	<i>Per Cent.</i>	<i>Grs.</i>	
		<i>Imp. Gal.</i>			<i>Gal.</i>
Silicic Acid.....	0.265	1.092	Calcic Sulfate.....	26.267	108.168
Sulfuric Acid.....	46.461	191.326	Magnesian Sulfate.....	31.016	127.723
Carbonic Acid.....	1.984	8.172	Potassic Sulfate.....	0.162	0.668
Chlorin.....	6.808	28.033	Sodic Sulfate.....	18.217	75.018
Sodic Oxid.....	16.904	69.612	Sodic Chlorid.....	11.230	46.246
Potassic Oxid.....	0.088	0.361	Sodic Carbonate.....	4.781	19.687
Calcic Oxid.....	10.824	44.572	Sodic Silicate.....	0.368	1.515
Magnesian Oxid.....	10.330	42.539	Ferric and Al. Oxids	0.036	0.149
Ferric and Al. Oxids	0.036	0.149	Manganic Oxid.....	0.082	0.339
Manganic Oxid.....	0.082	0.339	Ignition.....	8.140	33.521
Ignition.....	8.140	33.521			
Sum.....	101.992	419.716	Sum.....	100.299	413.034
Oxygen Equiv. to Chlorin.....	1.534	6.319	Excess Silicic Acid	0.084	0.346
Total.....	100.388	413.397	Total.....	100.383	413.380

Total Solids, 411.8 grains per imperial gallon.
* After irrigation.

§ 59. We probably applied eight inches of water in this irrigation and had a very small off-flow, so small that it may be neglected in any estimate of the changes produced by the application of the water. The whole eight inches may, in this case, be regarded as having entered the soil and as resting for the time-being upon the water plane as it stood before irrigation. That this is not correct is evident from what we have observed to be the effect of a comparatively small rainfall upon the height of the

water plane. Further, there must be a rapid diffusion of salts taking place between the two solutions represented by the ground water, which probably moves upward when the surface is first moistened, and the descending irrigation water. This diffusion may be greatly modified by the soil, but that some diffusion takes place can not be doubted.

§ 60. I see no better way to present the general changes than to compare the ground water as actually found before and after irrigation. This varied in the different wells under observation; it is usually a difference of degree rather than of character. While I know that in some respects I do violence to the facts from minor points of view, I think that by taking the averages of results found, we obtain a faithful view of the general results for the given irrigation and, while this does not answer many questions which arise, it seems the best approach that we can make to a knowledge of what takes place. As we estimate the amount of water applied at the rate of eight inches or two-thirds of an acre-foot, we will make our calculations for this amount throughout. The irrigation was begun on the 8th and the samples taken on the 11th instant and, as we know that some diffusion must have taken place in these three days, we will assume that this took place completely with an equivalent of eight inches of the ground water.

§ 61. The two-thirds acre-foot of irrigation water contained a total of 1,297 pounds of salts in solution; a like quantity of ground water before irrigation contained 5,139 pounds of salts and after irrigation, 9,550 pounds. The ground water as it was taken from the wells after irrigation showed an increase of 4,411 pounds in the salts held in each eight inches of water. If, however, we had mixed eight inches of the irrigation water with a like quantity of the ground water before irrigation, each eight inches should have contained 3,218 pounds. But we find 9,550 pounds which is an excess of 6,332 pounds in each eight inches, representing the actual solution of 12,664 pounds of salts, which is probably nearer correct than the 4,411 pounds. But as we wish to present conservative figures, we adopt the latter and assume that the eight inches of irrigation water applied, dissolved from the soil 4,411 pounds of salts which were previously not in solution. It would, however, be better to say that the result of the irrigation was to set this much salt free, that is, that whatever reactions may have been induced between the salts within the soil, resulted in bringing this additional amount into solution in the ground water. That the irrigation water acts not merely as a diluent is proven by the changed ratio of the salts present, which is best presented as follows:

TOTAL SOLIDS IN GROUND WATER BEFORE AND AFTER IRRIGATION, JUNE 27—JULY 11, 1898.

<i>Ground Water.</i>	<i>Before Irrigation.</i>	<i>After Irrigation.</i>	<i>Pounds Gain.</i>
Total Solids	5,139.0	9,550.0	4,411.0
Calcic Sulfate	1,860.2	2,750.4	890.2
Magnesian Sulfate	1,238.5	2,473.5	1,235.0
Sodic Sulfate	698.9	3,129.7	1,430.8
Sodic Carbonate	421.4	515.7	94.3
Sodic Chlorid	560.2	916.8	357.6
Organic Matter, etc.	360.8	763.9	403.1
Total	5,139.0	9,550.0	4,411.0

§ 62. This table is probably too conservative, but it serves to show that in this soil the solution of sodic and magnesian sulfates takes place in a far greater degree than does that of the other salts. The amount of potassic oxid held in solution or involved in the changes produced by irrigation does not seem to be very significant. The average amount of potassic oxid extracted from this soil by a five days' digestion with dilute hydrochloric acid, 1.115 specific gravity, is 1.25 per cent., or in an acre-foot of soil, taking its weight as 3,500,000, we have 43,750 pounds and the total potassic oxid in this soil is about 2.25 per cent., or 78,750 pounds per acre. I have pointed out elsewhere that there is an abundance of felspar in this soil and also that dilute hydrochloric acid acts very perceptibly upon it, as do also water and carbonic acid. The amount of potassic oxid contained in the ground water before irrigation amounted to 16.6 pounds in each eight inches of water per acre, and after irrigation, 31.7 pounds, an increase of 91 per cent., or 15.1 pounds. This quantity is apparently not very significant either as an absolute quantity or in comparison with that soluble in dilute hydrochloric acid but there is a view in which it may be significant. A crop of beets of 14 tons to the acre would at maturity contain about 120 or 125 pounds of potassic oxid, or including the tops, 240 to 250 pounds. This represents the season's gathering by the plants, but the application of eight inches of water has in three days involved an eighth of the quantity used by the roots, and one-sixteenth of that used by the whole crop in changes whereby it has passed into solution in the ground water; it may be a case of simple solution, or the solution may have been preceded by other chemical changes, which seems exceedingly probable.

§ 63. In 1899 we had a very much better supply of water which we obtained through the kindness of Water Commissioner C. C. Hawley; this was water taken from the Poudre but it was impossible to prevent the inter-mixing of some seepage water of which we shall give as full an account as is required without endeavoring to give too many details. The facts concerning these waters will appear from the analyses with sufficient fullness and further explanations would be tedious to the reader.

TABLE XXII.—WATER USED IN IRRIGATING, SEPT. 1, 1899.

<i>Analytical Results.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>	<i>Combined.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>
Silicic Acid	3.172	0.729	Calcic Sulfate	44.112	10.146
Sulfuric Acid	28.578	6.559	Magnesian Sulfate ..	3.866	0.889
Carbonic Acid	14.493	3.332	Magnesian Chlorid ..	4.312	0.992
Chlorin	3.221	0.741	Magnesian Carbonate ..	5.230	1.203
Sodic Oxid	17.371	3.995	Potassic Carbonate ..	1.904	0.438
Potassic Oxid	1.298	0.299	Sodic Carbonate	26.881	6.183
Calcic Oxid	18.172	4.180	Sodic Silicate	3.227	0.742
Magnesian Oxid	5.597	1.287	Ferric and Al. Oxids ..	0.318	0.073
Ferric and Al. Oxids ..	0.318	0.073	Manganic Oxid	0.259	0.060
Manganic Oxid	0.259	0.060	Ignition	8.205	1.887
Ignition	8.205	1.887	Sum	98.314	22.613
Sum	100.624	23.142	Excess Silicic Acid ..	1.583	0.364
Oxygen Eq. to Cl. ...	0.726	0.167	Total	99.897	22.977
Total	99.898	22.975			

Total solids, 23.0 grains per imperial gallon.

TABLE XXIII.—SEEPAGE WATER FROM MERCER DITCH USED IN IRRIGATING, SEPT. 2, 1899.

<i>Analytical Results.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>	<i>Combined.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>
Silicic Acid	1.971	0.976	Calcic Sulfate	43.219	21.393
Sulfuric Acid	35.945	17.793	Magnesian Sulfate ..	15.793	7.818
Carbonic Acid	10.989	5.440	Magnesian Chlorid ..	1.114	0.551
Chlorin	3.381	1.674	Potassic Chlorid	1.014	0.502
Sodic Oxid	18.296	9.056	Sodic Chlorid	3.411	1.688
Potassic Oxid	0.641	0.317	Sodic Carbonate	26.498	13.117
Calcic Oxid	17.804	8.813	Sodic Silicate	19.923	9.952
Magnesian Oxid	5.733	2.838	Ferric and Al. Oxids ..	0.478	0.236
Ferric and Al. Oxids ..	0.478	0.236	Manganic Oxid	0.159	0.079
Manganic Oxid	0.159	0.079	Ignition	5.322	2.634
Ignition	5.322	2.634	Sum	98.931	48.970
Sum	100.719	49.856	Excess Silicic Acid ..	1.024	0.507
Oxygen Eq. to Cl. ...	0.762	0.377	Total	99.955	49.477
Total	99.957	49.479			

Total solids, 49.5 grains per imperial gallon.

TABLE XXIV—OFF-FLOW, N. SIDE SEPT. 2, 1899; 1st SAMPLE. *

<i>Analytical Results.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>	<i>Combined.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>
Silicic Acid	0.688	0.597	Calcic Sulfate	36.408	31.602
Sulfuric Acid	42.183	36.615	Magnesian Sulfate ..	22.259	19.321
Carbonic Acid	6.432	5.583	Potassic Sulfate	2.059	1.787
Chlorin	3.755	3.259	Sodic Sulfate	8.862	7.692
Sodic Oxid	17.140	14.878	Sodic Chlorid	6.197	5.379
Potassic Oxid	1.118	0.970	Sodic Carbonate	15.509	13.462
Calcic Oxid	14.998	13.018	Sodic Silicate	1.397	1.212
Magnesian Oxid	7.418	6.439	Ferric and Al. Oxids ..	0.050	0.043
Ferric and Al. Oxids ..	0.050	0.043	Manganic Oxid	0.050	0.043
Manganic Oxid	0.050	0.043	Ignition	6.981	6.060
Ignition	6.981	6.060	Sum	99.772	86.601
Sum	100.813	87.505	Excess Sodic Oxid ..	0.194	0.168
Oxygen Eq. to Cl. ...	0.846	0.734	Total	99.966	86.769
Total	99.967	86.771			

Total solids, 86.8 grains per imperial gallon.

* Sample taken at beginning of off-flow; on-flowing water was ditch water.

TABLE XXV.—OFF-FLOW E. END, SEPT. 2, 1899; 1st SAMPLE. *

<i>Analytical Results.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>	<i>Combined</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>
Silicic Acid	2.056	0.977	Calcic Sulfate	45.251	21.494
Sulfuric Acid	32.472	15.424	Magnesian Sulfate ..	8.792	4.176
Carbonic Acid	14.188	6.738	Magnesian Chlorid...	3.835	1.827
Chlorin	2.865	1.361	Magnesian Carbonate	3.294	1.565
Sodic Oxid	18.675	8.871	Potassic Carbonate	1.160	0.551
Potassic Oxid	0.791	0.376	Sodic Carbonate	29.162	13.852
Calcic Oxid	18.641	8.854	Sodic Silicate	3.166	1.504
Magnesian Oxid	6.116	2.905	Ferric and Al. Oxids	0.039	0.017
Ferric and Al. Oxids	0.039	0.077	Manganic Oxid	0.010	0.005
Manganic Oxid	0.010	0.005	Ignition	5.069	2.408
Ignition	5.069	2.408	Sum	99.778	47.399
Sum	100.922	47.936	Excess Silicic Acid	0.497	0.236
Oxygen Eq. to Cl. ...	0.646	0.307	Total	100.275	47.635
Total	100.276	47.629			

Total solids, 47.5 grains per imperial gallon.

* Sample taken from the first portion of off-flow after running the full length of the plot, 600 feet.

TABLE XXVI.—OFF-FLOW N. SIDE SEPT. 2, 1899; 2nd SAMPLE. *

<i>Analytical Results.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>	<i>Combined</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>
Silicic Acid	2.069	0.761	Calcic Sulfate	46.511	17.116
Sulfuric Acid	32.676	12.025	Magnesian Sulfate ...	7.986	2.939
Carbonic Acid	14.379	5.291	Magnesian Chlorid...	3.451	1.270
Chlorin	2.578	0.949	Magnesian Carbonate	3.317	1.221
Sodic Oxid	18.247	6.715	Potassic Carbonate ...	0.951	0.350
Potassic Oxid	0.648	0.238	Sodic Carbonate	29.753	10.949
Calcic Oxid	19.160	7.051	Sodic Silicate	1.641	0.604
Magnesian Oxid	5.696	2.096	Ferric and Al. Oxids	0.010	0.004
Ferric and Al. Oxids	0.010	0.004	Manganic Oxid	0.060	0.022
Manganic Oxid	0.060	0.022	Ignition	5.076	1.868
Ignition	5.076	1.868	Sum	98.756	36.343
Sum	100.599	37.020	Excess Silicic Acid	1.261	0.464
Oxygen Eq. to Cl. ...	0.581	0.214	Total	100.017	36.807
Total	100.018	36.806			

Total solids, 36.8 grains per imperial gallon.

* Sample taken just before on-flow was cut off.

TABLE XXVII.—OFF-FLOW E. END, SEPT. 2, 1899, 2nd. SAMPLE. *

<i>Analytical Results.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>	<i>Combined</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>
Silicic Acid	2.725	1.150	Calcic Sulfate	41.989	17.719
Sulfuric Acid	34.007	14.351	Magnesian Sulfate ...	14.588	6.156
Carbonic Acid	12.588	5.312	Magnesian Chlorid...	2.296	0.969
Chlorin	3.029	1.278	Potassic Chlorid ...	1.290	0.544
Sodic Oxid	18.978	8.009	Sodic Chlorid	1.157	0.488
Potassic Oxid	0.815	0.344	Sodic Carbonate	30.353	12.809
Calcic Oxid	17.709	7.473	Sodic Silicate	1.184	0.499
Magnesian Oxid	5.829	2.460	Ferric and Al. Oxids	0.316	0.133
Ferric and Al. Oxids	0.316	0.133	Manganic Oxid	0.010	0.004
Manganic Oxid	0.010	0.004	Ignition	5.116	2.159
Ignition	5.116	2.159	Sum	98.299	41.480
Sum	101.124	42.673	Excess Silicic Acid	2.142	0.904
Oxygen Eq. to Cl. ...	0.682	0.288	Total	100.441	42.384
Total	100.440	42.385			

Total solids, 42.3 grains per imperial gallon.

* Sample taken just before on-flow was cut off.

TABLE XXVIII.—ANALYSIS OF WELL D, AUGUST 31, 1899. *

<i>Analytical Results.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>	<i>Combined.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>
Silicic Acid.....	1.743	1.119	Calcic Sulfate.....	35.410	22.733
Sulfuric Acid.....	38.907	24.978	Magnesian Sulfate ..	23.339	14.984
Carbonic Acid.....	9.398	6.034	Potassic Sulfate.....	0.261	0.168
Chlorin.....	3.968	2.547	Sodic Sulfate.....	4.269	2.741
Sodic Oxid.....	19.144	12.290	Sodic Chlorid.....	6.548	4.204
Potassic Oxid.....	0.142	0.091	Sodic Carbonate.....	22.661	14.548
Calcic Oxid.....	14.587	9.365	Sodic Silicate.....	1.066	0.684
Magnesian Oxid.....	7.778	4.993	Ferric and Al. Oxids	0.079	0.051
Ferric and Al. Oxids	0.079	0.051	Manganic Oxid.....	0.159	0.102
Manganic Oxid.....	0.159	0.102	Ignition.....	5.165	3.316
Ignition.....	5.165	3.316	Sum.....	98.957	63.531
Sum.....	101.070	64.886	Excess Silicic Acid.	1.218	0.782
Oxygen Eq. to Cl. .	0.892	0.572	Total.....	100.175	64.313
Total.....	100.178	64.314			

Total solids 64.2 grains per imperial gallon.

* Before irrigation.

TABLE XXIX.—ANALYSIS OF WELL D, SEPT. 2, 1899.*

<i>Analytical Results.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>	<i>Combined.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>
Silicic Acid.....	0.460	1.211	Calcic Sulfate.....	40.381	106.323
Sulfuric Acid.....	52.466	138.143	Magnesian Sulfate ..	27.663	72.837
Carbonic Acid.....	2.369	6.237	Potassic Sulfate.....	0.871	2.293
Chlorin.....	1.904	5.013	Sodic Sulfate.....	17.540	46.183
Sodic Oxid.....	13.234	34.845	Sodic Chlorid.....	3.152	8.299
Potassic Oxid.....	0.473	1.245	Sodic Carbonate.....	5.712	10.040
Calcic Oxid.....	16.635	43.800	Sodic Silicate.....	0.934	2.459
Magnesian Oxid.....	9.219	24.274	Ferric and Al. Oxids	0.010	0.026
Ferric and Al. Oxids	0.010	0.026	Manganic Oxid.....	0.030	0.079
Manganic Oxid.....	0.030	0.079	Ignition.....	3.651	9.613
Ignition.....	3.651	9.613	Sum.....	99.944	263.152
Sum.....	100.451	264.486	Excess Sodic Oxid.	0.074	0.198
Oxygen Eq. to Cl. .	0.429	1.129	Total.....	100.018	263.347
Total.....	100.022	263.357			

Total solids 263.3 grains per imperial gallon.

* After irrigation.

TABLE XXX.—ANALYSIS OF WELL C, AUG. 31, 1899. *

<i>Analytical Results.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>	<i>Combined.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>
Silicic Acid.....	1.663	1.369	Calcic Sulfate.....	34.075	28.044
Sulfuric Acid.....	40.327	33.189	Magnesian Sulfate ..	20.122	16.560
Carbonic Acid.....	7.788	6.410	Potassic Sulfate.....	0.122	0.100
Chlorin.....	1.557	1.281	Sodic Sulfate.....	12.107	9.964
Sodic Oxid.....	18.846	15.510	Sodic Chlorid.....	2.569	2.114
Potassic Oxid.....	0.066	0.054	Sodic Carbonate.....	18.775	15.452
Calcic Oxid.....	14.037	11.552	Sodic Silicate.....	2.368	1.949
Magnesian Oxid.....	6.706	5.519	Ferric and Al. Oxids	0.090	0.074
Ferric and Al. Oxids	0.090	0.074	Manganic Oxid.....	0.040	0.033
Manganic Oxid.....	0.040	0.033	Ignition.....	8.931	7.350
Ignition.....	8.931	7.350	Sum.....	99.199	81.640
Sum.....	100.051	82.341	Excess Silicic Acid	0.497	0.409
Oxygen Eq. to Cl. .	0.350	0.288	Total.....	99.696	82.049
Total.....	99.701	82.053			

Total solids 82.3 grains per imperial gallon.

* Before irrigation.

TABLE XXXI.—ANALYSIS OF WELL C. SEPT. 2, 1899. *

<i>Analytical Results.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>	<i>Combined.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>
Silicic Acid	0.397	1.366	Calcic Sulfate	25.554	87.957
Sulfuric Acid	47.826	164.617	Magnesian Sulfate	25.422	87.503
Carbonic Acid	2.065	7.108	Potassic Sulfate	0.363	1.249
Chlorin	6.483	22.314	Sodic Sulfate	27.848	95.853
Sodic Oxid	21.438	73.790	Sodic Chlorid	10.698	36.823
Potassic Oxid	0.197	0.678	Sodic Carbonate	4.979	17.138
Calcic Oxid	10.527	36.234	Sodic Silicate	0.806	2.774
Magnesian Oxid	8.472	29.161	Ferric and Al. Oxids	0.030	0.103
Ferric and Al. Oxids	0.030	0.103	Manganic Oxid	0.060	0.206
Manganic Oxid	0.060	0.206	Ignition	3.842	13.224
Ignition	3.842	13.224	Sum	99.602	342.830
Sum	101.337	348.801	Excess Sodic Oxid	0.272	0.936
Oxygen Eq. to Cl.	1.461	5.029	Total	99.874	343.766
Total	99.876	343.772			

Total solids, 844.2 grains per imperial gallon.
*After irrigation.

TABLE XXXII.—ANALYSIS OF WELL B, AUGUST 31, 1899. *

<i>Analytical Results.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>	<i>Combined.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>
Silicic Acid	1.838	2.474	Calcic Sulfate	34.184	46.012
Sulfuric Acid	42.859	57.688	Magnesian Sulfate	21.584	29.052
Carbonic Acid	5.866	7.896	Potassic Sulfate	0.379	0.510
Chlorin	4.790	6.447	Sodic Sulfate	14.552	19.587
Sodic Oxid	19.527	26.283	Sodic Chlorid	7.904	10.639
Potassic Oxid	0.206	0.277	Sodic Carbonate	14.144	19.038
Calcic Oxid	14.082	18.954	Sodic Silicate	1.369	1.842
Magnesian Oxid	7.193	9.682	Ferric and Al. Oxids	0.138	0.186
Ferric and Al. Oxids	0.138	0.186	Manganic Oxid	0.069	0.093
Manganic Oxid	0.069	0.093	Ignition	4.691	6.314
Ignition	4.691	6.314	Sum	99.014	133.273
Sum	101.259	136.294	Excess Silicic Acid	1.164	1.567
Oxygen Eq. to Cl.	1.079	1.452	Total	100.178	134.840
Total	100.180	134.842			

Total solids 134.6 grains per imperial gallon.
* Before irrigation.

TABLE XXXIII.—ANALYSIS OF WELL B, SEPT. 2, 1899. *

<i>Analytical Results.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>	<i>Combined.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>
Silicic Acid	1.048	1.555	Calcic Sulfate	35.087	52.069
Sulfuric Acid	43.021	63.843	Magnesian Sulfate	21.398	31.755
Carbonic Acid	6.358	9.435	Potassic Sulfate	0.123	0.183
Chlorin	4.286	6.360	Sodic Sulfate	14.221	21.104
Sodic Oxid	19.261	28.583	Sodic Chlorid	7.073	10.496
Potassic Oxid	0.067	0.099	Sodic Carbonate	15.331	22.751
Calcic Oxid	14.454	21.450	Sodic Silicate	0.745	1.106
Magnesian Oxid	7.131	10.582	Ferric and Al. Oxids	0.020	0.030
Ferric and Al. Oxids	0.020	0.030	Manganic Oxid	0.040	0.059
Manganic Oxid	0.040	0.059	Ignition	5.381	7.985
Ignition	5.381	7.985	Sum	99.419	147.538
Sum	101.067	149.981	Excess Silicic Acid	0.681	1.011
Oxygen Eq. to Cl.	0.966	1.433	Total	100.100	148.549
Total	100.101	148.548			

Total solids, 148.4 grains per imperial gallon.
* After irrigation.

TABLE XXXIV.—ANALYSIS OF WELL A, AUG. 31, 1899. *

<i>Analytical Results.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>	<i>Combined.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>
Silicic Acid.....	1.370	1.586	Calcic Sulfate.....	30.416	35.191
Sulfuric Acid.....	43.578	50.420	Magnesian Sulfate...	27.369	31.666
Carbonic Acid.....	3.838	4.441	Potassic Sulfate...	0.342	0.396
Chlorin.....	5.755	6.658	Sodic Sulfate.....	12.941	14.973
Sodic Oxid.....	17.006	19.676	Sodic Chlorid.....	9.497	10.988
Potassic Oxid.....	0.186	0.215	Sodic Carbonate...	9.255	10.708
Calcic Oxid.....	12.530	14.497	Sodic Silicate.....	1.763	2.040
Magnesian Oxid.....	9.121	10.553	Ferric and Al. Oxids	0.110	0.127
Ferric and Al. Oxids	0.110	0.127	Manganic Oxid.....	0.060	0.069
Manganic Oxid.....	0.060	0.069	Ignition.....	7.751	8.967
Ignition.....	7.751	8.967	Sum.....	99.504	115.125
Sum.....	101.305	117.209	Excess Silicic Acid	0.502	0.581
Oxygen Eq. to Cl... 1.297	1.297	1.501	Total.....	100.006	115.706
Total.....	100.008	115.708			

Total solids 115.7 grains per imperial gallon.

*Before irrigation.

TABLE XXXV.—ANALYSIS OF WELL A, SEPT. 2, 1899. *

<i>Analytical Results</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>	<i>Combined.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>
Silicic Acid.....	0.907	1.486	Calcic Sulfate.....	32.552	53.320
Sulfuric Acid.....	45.097	73.869	Magnesian Sulfate...	27.354	44.806
Carbonic Acid.....	4.720	7.731	Potassic Sulfate...	0.175	0.287
Chlorin.....	4.621	7.569	Sodic Sulfate.....	13.546	22.188
Sodic Oxid.....	16.900	27.672	Sodic Chlorid.....	7.626	12.491
Potassic Oxid.....	0.095	0.156	Sodic Carbonate...	11.381	18.642
Calcic Oxid.....	13.407	21.964	Sodic Silicate.....	0.552	0.914
Magnesian Oxid.....	9.116	14.932	Ferric and Al. Oxids	0.040	0.065
Ferric and Al. Oxids	0.040	0.065	Manganic Oxid.....	0.030	0.049
Manganic Oxid.....	0.030	0.049	Ignition.....	5.999	9.826
Ignition.....	5.999	9.826	Sum.....	99.255	162.588
Sum.....	100.932	165.329	Excess Silicic Acid	0.635	1.040
Oxygen Eq. to Cl... 1.041	1.041	1.705	Total.....	99.890	163.628
Total.....	99.891	163.624			

Total solids 163.8 grains per imperial gallon.

*After irrigation.

COLORADO IRRIGATION WATERS AND THEIR CHANGES. 41
 SANITARY ANALYSES OF IRRIGATION WATERS, AUGUST 31
 TO SEPTEMBER 2, 1899.

1. Ditch water as it flowed onto the plot. Sept. 1, 1899.
2. Seepage water as it flowed onto the plot.
3. Water as it flowed off at north side of plot. Sept. 2, 1899. Beginning of off-flow.
4. Water as it flowed off at east end of plot. Sept. 2, 1899. Beginning of off-flow.
5. Water as it flowed off at north side of plot. End of off-flow.
6. Water as it flowed off at east end of plot. End of off-flow.
7. Water of well A. August 31, 1899. Before irrigation.
8. Water of well B. August 31, 1899. Before irrigation.
9. Water of well C. August 31, 1899. Before irrigation.
10. Water of well D. August 31, 1899. Before irrigation.
11. Water of well A. September 2, 1899. After irrigation.
12. Water of well B. September 2, 1899. After irrigation.
13. Water of well C. September 2, 1899. After irrigation.
14. Water of well D. September 2, 1899. After irrigation.

SANITARY ANALYSES OF WATER BEFORE AND AFTER IRRIGATION.
 PARTS PER MILLION.

	Total Solids	Chlorin	Nitrates		Nitrites		Ammonia		Albuminoidal Ammonia		Oxygen Consumed
			Nitrogen	Nitric Acid	Nitrogen	Nitrous Acid	Nitrogen	Ammonia	Nitrogen	Ammonia	
1	328.5	9.40	Trace	Trace	0.4400	1.6730	0.3180	0.3860	0.3380	0.4100	4.625
2	707.1	15.30	Trace	Trace	0.0700	0.2340	0.1820	0.2210	0.3140	0.3825	4.450
3	1240.0	50.70	0.440	1.970	0.1400	0.4690	0.3160	0.3840	0.5540	0.6720	7.740
4	678.5	27.10	0.240	1.077	0.2600	0.8700	0.0560	0.0680	0.2490	0.3020	3.875
5	525.7	17.10	Trace	Trace	0.1100	0.3680	0.0630	0.0765	0.3540	0.4290	4.555
6	602.8	18.70	0.080	0.359	0.1000	0.3348	0.0840	0.1020	0.3420	0.4150	5.720
7	1652.8	76.80	0.440	1.970	0.0025	0.0088	0.0320	0.0388	0.2500	0.3029	
8	1922.8	99.50	0.480	2.154	0.0003	0.0010	0.0190	0.0230	0.0950	0.1147	
9	1175.8	57.40	0.560	2.513	0.0025	0.0084	0.0220	0.0267	0.0560	0.0674	
10	917.1	43.10	0.600	2.692	0.0250	0.0837	0.0700	0.0850	0.0860	0.1038	
11	2340.0	108.10	0.720	3.231	0.0025	0.0084	0.0470	0.0570	0.2260	0.2740	
12	2120.0	103.40	0.440	1.970	0.0060	0.0200	0.0600	0.0738	0.1430	0.1730	
13	4917.1	374.30	1.700	7.628	0.0300	0.1000	0.4760	0.5780	2.5680	3.1170	
14	3761.4	107.70	0.360	1.605	0.0900	0.1090	0.4120	0.5000	2.3000	2.7920	

§ 64. We had, as already stated, a good supply of water and can therefore make our calculations on the basis of an acre-foot and approximate closely to the results actually produced. As it was impossible to determine with any approach to accuracy the amount of seepage water which got mixed with the ditch water before it reached the plot, I will neglect it in our estimate but will state separately the amount of salts carried by the seepage as we collected it. The results so far as the amount and character of the salts in the ground water will not be affected thereby.

§ 65. The ditch water carried total solids to the amount of more than twice as much as I have ever found in Poudre water at, or rather a little below, the point where this water was taken out. But I have already pointed out the fact that the Poudre water increases materially in the amount of total solids held in solution from a point just above the mouth of the North Fork to a point below Bellvue, a distance of less than eight miles. The maximum increase observed at a period of low water was about four times the amount contained at the higher point. It is not a matter of surprise then that there should be still greater increase after it has flowed through a cultivated section, for a little more than four miles. This water carried 894.5 pounds of total solids in each acre-foot and the salts represented were not present in the proportions usually found. They were calcic sulfate, 393.6; magnesian sulfate, very little or none; sodic carbonate 239.6 and potassic oxid (K_2O) 11.6 pounds.

§ 66. An acre-foot of the seepage water as it was gathered at the time, carried 1,925 pounds of total solids, but as we do not know the amount of this water flowing in at the time, we cannot make any correction for it. The relative amount was certainly not as much as one-fourth and the weights of salts subsequently dealt with being large and only approximate at best, the seepage water can justly be neglected. The salts held in solution show clearly that it is properly classed as seepage water though evidently mixed with ditch water which had run over the surface of the meadow along the edge of which our lateral ran. These salts were, according to our manner of combining the analytical results, as follows; calcic sulfate, 828.0; magnesian sulfate, 304.0; sodic carbonate, 511.6; potassic oxid (K_2O) 12.4 pounds per acre-foot.

§ 67. The ground water before and after irrigation carried the following quantities of total solids composed of the salts given herewith:

TOTAL SOLIDS IN GROUND WATER AUG. 31.—SEPT. 2, 1899,
PER ACRE-FOOT.

	<i>Before Irrigation.</i>	<i>After Irrigation.</i>	<i>Pounds Gain.</i>
Total Solids	3,868.0	8,809.0	4,941.0
Calcic Sulfate	1,303.5	2,942.2	1,638.7
Magnesian Sulfate	893.5	2,237.5	1,344.0
Sodic Sulfate	425.5	1,612.0	1,186.5
Sodic Carbonate	543.0	740.0	197.0
Sodic Chlorid	255.3	616.6	361.3
Organic Matter, etc.	447.2	660.7	213.5
Total	3,868.0	8,809.0	4,941.0

§ 68. This shows an increase in the total solids contained in each acre-foot of ground water of 4,941 pounds, but if we con-

sider, as suggested in the observations made on the irrigation of 1898, that the ground water as taken after irrigation represents a mixture of equal parts of irrigation water and ground water we find that to produce this change in the amount of total solids 12,856 pounds of salts must have passed into solution.

§ 69. For the experiment of 1898 we found that 4,411 pounds went into solution or, assuming a mixing to the extent of equal parts, 12,664 pounds per acre-foot; for 1899 we have 4,941 pounds and 12,856. When we attempt to find how this gain was distributed between the different salts we find the same order, namely sodic sulfate, magnesian sulfate and calcic sulfate. In 1899, however, the calcic sulfate shows a greater increase than in 1898. This is accounted for by the influence of well D, which in 1898 could not be included, because being near the point of onflow it was not looked after as carefully as it should have been, and the water getting advantage of us ran into the well from the surface. In 1898 the percentage of calcic sulfate in the residue from the ground water was lower after irrigation than before, except in the case of well D, which showed an increase of five per cent. The result is probably correct and represents what actually took place, but it is contrary to our observations. While it modifies our general results, it does not reverse them.

§ 70. The potassic oxid in an acre-foot of the ditch water used was only 11.6 pounds, in the ground water before irrigation 5.8 pounds, in the ground water after irrigation 18.3 pounds, or if we consider the ground water after irrigation as representing a mixture of equal parts, as before, we have 19.2 pounds of potassic oxid brought into solution by the application of an acre-foot of water.

§ 71. The water that flowed over and off of the plot was not large in quantity but we collected samples as near the beginning and end of off-flow as was feasible. The salient features of the results will be seen upon an examination of the analyses.

§ 72. The off-flow took place at two points, one near the center of the north side of the plot, the other at the east end, the water flowing from west to east.

§ 73. The samples obtained of the off-flow on the north side showed a very marked difference in the quantity of total solids present in the first and second samples. The first sample contained 3,390, the second 1,431 pounds per acre-foot. The sample taken at the east end of the plot showed the same fact but much less markedly; the first sample containing 1,847, the second 1,641 pounds per acre-foot. This difference is accounted for, I think, by the fact that we failed to get the first portion of the off-flow at the east end, while we succeeded in getting it at the north side. The decrease in the total salts carried in solution by such water is

very rapid at first and gradually becomes slower which fully explains the differences observed in these two sets of samples. It is evident from what I have said, relative to the amount of off-flow and the fact that it was only by the courtesy of the water commissioner that we obtained this water, that we did all that we could with this subject. When we consider that this water on leaving the plot after flowing over it for 600 feet had only washed off and dissolved out between 800 and 1,000 pounds of salts per acre-foot, under very favorable conditions, and that the rate of action decreases rapidly it would seem to indicate that long continued flooding with off-flow would not be an advisable procedure in order to remove salts from the soil.

§ 74. There is one thing suggested by the analyses, i. e., that in the case of long continued flooding the amount of potash removed might become a matter worthy of consideration. The percentage of this substance present in the residue from the off-flowing waters is not so high as in the residue obtained from the waters applied, but when the increase in the total solids is taken into consideration it indicates a probable loss of this substance. Our data is not adequate to justify general conclusions on this subject. My opinion, however, is that the loss is less serious than one would be inclined to think, judging from the results shown by these samples.

§ 75. The sanitary analyses show the same facts relative to the total solids and chlorin, but they are given in terms of parts per million, instead of grains per gallon. In the total solids we discover an extreme quantity in the well waters after irrigation, equal to 13 times the quantity in the water used for irrigating, and over four times the amount found in the same well before irrigation. The chlorin is 40 times greater in the well water after irrigation than in the ditch water applied, and between six and seven times greater than in the same well before irrigation. The principal object in making the sanitary analyses was to determine the different forms and quantities in which nitrogen was present. The quantities found, even when taken together, are scarcely worth considering so far as their fertilizing value is concerned. The ditch water used in 1899 contained in all forms almost three pounds of nitrogen per acre-foot. The soil to which this water was applied contained in the first foot of soil 3,500 pounds. The three pounds of nitrogen, if it were present as potassic nitrate, would be insignificant, but the analysis shows that none of it was present as nitric acid. This ditch water shows the presence of more nitrous acid than any sample analyzed in connection with the work.

§ 76. The seepage water that mingled with the ditch water was even poorer in nitrogen than the ditch water, so the water

used in this irrigation literally vanishes as a factor in any question pertaining to nitrogen.

§ 77. The nitrates, or rather the corresponding nitric acid in the ground water before and after irrigation, does not show changes on the scale I anticipated. An acre-foot of ground water before irrigation contained 6.413 pounds of nitric acid, as nitrates, and after irrigation 9.861 pounds, which correspond roughly to 2.2 pounds of nitrogen, a wholly insignificant amount from any practical standpoint. The amount is not only small but it must also be considered that at least three and one-half feet of soil have probably been involved in producing this result. Whatever reactions may have taken place, the elimination, or the passing of the nitrates into a free solution, has taken place to a very small extent.

§ 78. Nitrous acid is present, both before and after irrigation, in such small quantities that a much more extended and careful investigation would be required to justify even a tentative interpretation. The quantity present after, is greater than before irrigation, but the quantity present in either case is small, not a tenth of that present in the ditch water.

§ 79. In the spring of 1900 we had an exceptionally heavy precipitation, snow and rain. Beginning March 27, we had 3.5 inches of snow; on the 30th, a little rain, and from April 4 to 9 inclusive, rain or snow daily. During this time we had 12 inches of snow fall, and a total of 4.2 inches of water. This differs materially from an irrigation of 4.2 inches, the whole surface of adjacent land receiving the same amount of water which, I consider, influences the water plane materially, either by movement or pressure. The water plane in this case was brought up to within a few inches of the surface. This may have been the result of water from the adjoining lands. The snow which melted slowly, and to which there was a daily addition of from .2 to .4 inches of rainfall at this time, gave the water opportunity to enter the soil slowly and over the whole area at the same time. Samples of well A were taken April 9 and 17, 1900, when the water plane was perhaps at its highest point, the analysis of which resulted as follows:

TABLE XXXVI.—ANALYSIS OF WELL A, APR. 9, 1900.

<i>Analytical Results.</i>	<i>Gr.</i>		<i>Combined.</i>	<i>Gr.</i>	
	<i>Per Cent.</i>	<i>Imp. Gal.</i>		<i>Per Cent.</i>	<i>Imp. Gal.</i>
Silicic Acid	0.271	1.965	Calcic Sulfate	16.733	121.314
Sulfuric Acid	45.332	328.657	Magnesian Sulfate	36.146	262.059
Carbonic Acid	1.383	10.027	Potassic Sulfate	0.291	2.110
Chlorin	8.931	64.749	Sodic Sulfate	19.993	144.949
Sodic Oxid	18.936	137.286	Sodic Chlorid	14.738	106.850
Potassic Oxid	0.158	1.146	Sodic Carbonate	3.335	24.179
Calcic Oxid	6.893	49.974	Sodic Silicate	0.550	3.987
Magnesian Oxid	12.046	87.333	Ferric and Al. Oxids	0.050	0.363
Ferric and Al. Oxids	0.050	0.363	Manganic Oxid	0.060	0.435
Manganic Oxid	0.060	0.435	Ignition	8.206	59.493
Ignition	8.206	59.493	Sum	100.102	725.739
Sum	102.266	741.428	Excess Sodic Oxid	0.148	1.073
Oxygen Eq. to Cl.	2.012	14.587	Total	100.250	726.812
Total	100.254	726.841			

Total solids 725.0 grains per imperial gallon.

TABLE XXXVII.—ANALYSIS OF WELL A, APRIL 17, 1900.

<i>Analytical Results.</i>	<i>Gr.</i>		<i>Combined.</i>	<i>Gr.</i>	
	<i>Per Cent.</i>	<i>Imp. Gal.</i>		<i>Per Cent.</i>	<i>Imp. Gal.</i>
Silicic Acid	0.284	1.285	Calcic Sulfate	16.832	76.131
Sulfuric Acid	45.565	206.090	Magnesian Sulfate	33.716	152.497
Carbonic Acid	2.347	10.615	Potassic Sulfate	0.160	0.724
Chlorin	7.554	34.167	Sodic Sulfate	23.286	105.323
Sodic Oxid	20.108	90.948	Sodic Chlorid	12.466	56.384
Potassic Oxid	0.087	0.394	Sodic Carbonate	5.659	25.596
Calcic Oxid	6.934	31.362	Sodic Silicate	0.016	0.072
Magnesian Oxid	11.236	50.820	Ferric and Al. Oxids	0.030	0.136
Ferric and Al. Oxids	0.030	0.136	Manganic Oxid	0.030	0.136
Manganic Oxid	0.030	0.136	Ignition	7.618	34.456
Ignition	7.618	34.456	Sum	99.813	451.455
Sum	101.793	460.409	Excess Silicic Acid	0.276	1.248
Oxygen Eq. to Cl.	1.702	7.698	Total	100.089	452.703
Total	100.091	452.711			

Total solids 452.3 grains per imperial gallon.

TABLE XXXVIII.—ANALYSIS OF WELL G, APRIL 17, 1900.

<i>Analytical Results.</i>	<i>Gr.</i>		<i>Combined.</i>	<i>Gr.</i>	
	<i>Per Cent.</i>	<i>Imp. Gal.</i>		<i>Per Cent.</i>	<i>Imp. Gal.</i>
Silicic Acid	0.285	1.340	Calcic Sulfate	24.535	115.364
Sulfuric Acid	44.885	211.049	Magnesian Sulfate	29.200	137.298
Carbonic Acid	1.964	9.235	Potassic Sulfate	0.655	3.080
Chlorin	8.216	38.632	Sodic Sulfate	18.980	89.244
Sodic Oxid	18.741	88.120	Sodic Chlorid	13.558	63.750
Potassic Oxid	0.359	1.688	Sodic Carbonate	4.736	22.268
Calcic Oxid	10.107	47.523	Sodic Silicate	0.579	2.722
Magnesian Oxid	9.731	45.755	Ferric and Al. Oxids	0.040	0.188
Ferric and Al. Oxids	0.040	0.188	Manganic Oxid	0.010	0.047
Manganic Oxid	0.010	0.047	Ignition	7.534	35.425
Ignition	7.534	35.425	Sum	99.827	469.386
Sum	101.872	479.002	Excess Sodic Oxid	0.192	0.903
Oxygen Eq. to Cl.	1.851	8.703	Total	100.019	470.289
Total	100.021	470.299			

Total solids 470.2 grains per imperial gallon.

§ 80. The sample of water taken April 9, 1900, well A, just before the end of an unusually heavy and protracted rainfall, whereby the ground was filled with water, contains in an acre-foot of water 28,197 pounds of salts. The water of this well is usually high, therefore to obtain a better idea of what the actual increase is, I have computed the average amounts of sulfates in this water as given for 11 samples taken in 1898. When the water was low in this well the total solids were also low. In November, 1898, there were 164 grains per gallon.

WATER OF WELL A.

	<i>April 9, 1900.</i>	<i>Average for 1898.</i>
Total solids in an acre-foot.....	28,197 pounds	8,899 pounds
Calcic Sulfate.....	4,708 pounds	3,115 pounds
Magnesian Sulfate.....	10,179 pounds	2,492 pounds
Sodic Sulfate.....	5,639 pounds	979 pounds

§ 81. The sample of water, well A, taken eight days later, serves to show how rapidly the total solids fell at this time. The water plane had in meantime fallen about 0.8 of a foot. The total solids in an acre-foot have fallen from 28,197 to 17,722 pounds, a difference of about 10,000 pounds. Further, the salts remaining in solution have another ratio. On April 9, the calcic to the magnesian to the sodic sulfate stood roughly as 1 : 2 : 1, but on the 17th inst. they stood as 1 : 5 : 3 1/2, from which it appears that the calcic sulfate has receded to the greatest extent, magnesian sulfate next and the sodic sulfate in the least measure.

§ 82. Well G is near well A but is a shallower well and its waters are separated from those in an underlying stratum of gravel as explained in a former bulletin. This sample perhaps represents the water in the soil more faithfully than does the water of well A, but in the main it presents the same general features, the relative quantity of the salts being a little different and their total quantity a little higher.

§ 83. Other samples of water were taken from these wells one month later, when the water plane had fallen 16 inches. These samples show 142.5 grains total solids for well A, a decrease of 582.5 grains; and 379 for well G, a decrease of 91 grains per gallon. The percentage of calcic sulfate had materially increased in well A, but only slightly in G; that of the magnesian sulfate was about the same, while the percentage of sodic sulfate had decreased in each case.

§ 84. We have more potassic oxid in the water from well G than in that from well A. In the latter we have 44.5 pounds, in the former 63.6 pounds per acre-foot, neither of them being very large quantities; the smaller being scarcely 10 times as much as water dissolves from finely divided felspar in a few days.

§ 85. These experiments indicate that either simple solution of salts, feebly held in the soil, takes place on a large scale, or else

a series of reactions whereby these salts pass into solution when the soil is supplied with an abundant quantity of water; but the relative quantities that go into solution vary, and the ratios in which the salts are present are not those of their solubilities.

THE DRAIN WATERS.

§ 86. There was no drain through the plot of ground at the time the irrigation experiments were made, so I can not give analyses of drain waters which are strictly comparable to the waters used in irrigation. I regret this but I could not do better than to take drain water from another point, which I did. This plot was subsequently drained and an analysis of the water from this drain will be given later. The first sample of drain water which I shall give was taken April 20, 1900, three days later than the last sample of well water given, and is fairly comparable to these, though taken at some distance below the plot where the wells were dug.

TABLE XXXIX.—ANALYSIS OF DRAIN WATER, APR. 20, 1900.

<i>Analytical Results.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>	<i>Combined.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>
Silicic Acid	0.846	0.963	Calcic Sulfate	40.406	45.982
Sulfuric Acid	40.284	45.843	Magnesian Sulfate	21.260	24.194
Carbonic Acid	8.537	9.715	Potassic Sulfate	0.145	0.165
Chlorin	3.939	4.483	Sodic Sulfate	4.052	4.611
Sodic Oxid	17.304	19.692	Sodic Chlorid	6.500	7.397
Potassic Oxid	0.079	0.090	Sodic Carbonate	20.585	23.426
Calcic Oxid	16.645	18.941	Sodic Silicate	0.071	0.081
Magnesian Oxid	7.085	8.063	Ferric and Alu. Oxids	0.050	0.057
Ferric and Al. Oxids	0.050	0.057	Manganic Oxid	0.060	0.068
Manganic Oxid	0.060	0.068	Ignition	6.379	7.259
Ignition	6.379	7.259	Sum	99.508	113.240
Sum	101.208	115.174	Excess Silicic Acid	0.811	0.923
Oxygen Eq. to Cl. ...	0.887	1.009	Total	100.319	114.163
Total	100.321	114.165			

Total solids, 118.8 grains per imperial gallon.

§ 87. This sample was taken from a new drain which was being laid beside an old one. The gravel at this time was full of water as is, so far as I know, always the case. This is the same stratum of gravel mentioned in another place, also in former bulletins, as underlying my beet plot. A comparison of the preceding analysis with one of water taken from this gravel under the beet plot, shows a general similarity, but with some differences, the most striking of which is in regard to the sodic sulfate, which is much more abundant in the water taken directly from the gravel than in the drain water. In this connection I would repeat what I have said in Bulletin No. 72, page 33, that the ground and drain waters are not alike; that the total solids decrease with the depth from which the sample is taken, and that while sodic sulfate is abundant in the ground waters, it is not so

in the drain waters. We have in this case an illustration in point. The ground waters taken three days previously showed the presence of 452 and 470 grains total solids per imperial gallon; the above drain water showed 113.8 grains. The ground waters showed respectively 105 and 89 grains of sodic sulfate per gallon, the drain water 4.6 grains, which in proportion is very greatly less, the sodic sulfate amounting to one-fourth of the total in the case of ground water, represented by well A, and 1-24 in that of the drain water; the magnesian sulfate remaining relatively constant, one-third in the well waters and one-fifth in the drain water. The calcic sulfate, on the contrary constitutes 1-6 and 1-5 respectively of the total solids in the two well waters and 2-5 of those in the drain water. I unfortunately do not know even approximately the volume of drainage water, but it is evident that the ratios in which the various salts are removed are wholly different from these in which they are found in the ground water.

§ 88. The following analyses of drain waters establish and strengthen these statements and show that the drain waters are much more nearly constant in composition than the ground waters, and vary much less in the quantity of total solids that they contain.

TABLE XL—ANALYSIS OF DRAIN WATER, JULY 23, 1900.

<i>Analytical Results</i>	<i>Per Cent</i>	<i>Grs. Imp. Gal.</i>	<i>Combined.</i>	<i>Per Cent</i>	<i>Grs. Imp. Gal.</i>
Silicic Acid.....	1.405	1.030	Calcic Sulfate.....	45.265	33.179
Sulfuric Acid.....	42.442	31.110	Magnesian Sulfate...	23.633	17.323
Carbonic Acid.....	7.847	5.752	Potassic Sulfate....	0.147	0.108
Chlorin.....	3.782	2.772	Potassic Chlorid....	0.055	0.040
Sodic Oxid.....	14.663	10.748	Sodic Chlorid.....	6.198	4.543
Potassic Oxid.....	0.115	0.084	Sodic Carbonate....	18.921	13.869
Calcic Oxid.....	18.647	13.668	Sodic Silicate.....	0.589	0.432
Magnesian Oxid....	7.876	5.773	Ferric and Al. Oxids	0.040	0.029
Ferric and Al. Oxids	0.040	0.029	Manganic Oxid.....	0.040	0.029
Manganic Oxid....	0.040	0.029	Ignition.....	4.073	2.985
Ignition.....	4.073	2.985	Sum.....	98.961	72.537
Sum.....	100.930	73.980	Excess Silicic Acid	1.115	0.817
Oxygen Eq. to Cl....	0.852	0.624	Total.....	100.076	73.354
Total.....	100.078	73.356			

Total Solids, 73.3 grains per imperial gallon.

TABLE XLI.—ANALYSIS OF DRAIN WATER, MRS. CALLOWAY'S RANCH, JULY 23, 1900.

<i>Analytical Results.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>	<i>Combined.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>
Silicic Acid	1.425	0.886	Calcic Sulfate	44.734	27.824
Sulfuric Acid	40.202	25.006	Magnesian Sulfate	18.013	11.204
Carbonic Acid	9.549	5.930	Potassic Sulfate	0.212	0.132
Chlorin	3.635	2.261	Sodic Sulfate	3.177	1.976
Sodic Oxid	18.070	11.239	Sodic Chlorid	5.998	3.731
Potassic Oxid	0.115	0.072	Sodic Carbonate	23.025	14.322
Calcic Oxid	18.428	11.462	Sodic Silicate	0.047	0.029
Magnesian Oxid	6.003	3.734	Ferric and Al. Oxids	0.050	0.031
Ferric and Al. Oxids	0.050	0.031	Manganic Oxid	0.080	0.050
Manganic Oxid	0.080	0.050	Ignition	3.405	2.118
Ignition	3.405	2.118	Sum	98.741	61.417
Sum	100.962	62.798	Excess Silicic Acid	1.402	0.872
Oxygen Eq. to Cl.	0.819	0.509	Total	100.143	62.289
Total	100.143	62.289			

Total solids 62.2 grains per imperial gallon.

TABLE XLII.—ANALYSIS OF DRAIN WATER, BEET PLOT, FEB. 23, 1903.

<i>Analytical Results.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>	<i>Combined.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>
Silicic Acid	0.812	1.302	Calcic Sulfate	44.033	70.631
Sulfuric Acid	49.143	78.825	Strontic Sulfate	0.508	0.815
Carbonic Acid	2.955	4.632	Magnesian Sulfate	26.310	42.201
Chlorin	3.545	5.686	Potassic Sulfate	0.353	0.566
Sodic Oxid	12.231	19.618	Sodic Sulfate	9.572	15.354
Potassic Oxid	0.191	0.306	Sodic Chlorid	5.712	9.162
Lithic Oxid	0.033	0.053	Lithic Chlorid	0.092	0.148
Calcic Oxid	18.141	29.098	Sodic Carbonate	7.115	11.371
Strontic Oxid	0.287	0.460	Sodic Silicate	1.646	2.640
Magnesian Oxid	8.822	14.150	Ferric and Al. Oxids	0.075	0.120
Ferric and Al. Oxids	0.075	0.120	Manganic Oxid	0.030	0.048
Manganic Oxid	0.030	0.048	Ignition	4.512	7.237
Ignition	4.512	7.237	Sum	99.988	160.293
Sum	100.777	161.535	Excess	None	None
Oxygen Eq. to Cl.	0.799	1.282	Total	99.988	160.293
Total	99.978	160.253			

Total solids 160.4 grains per imperial gallon.

§ 89. These drain waters present as great a variety as I would probably have obtained had I taken a great number from other localities. I hope and think that they represent such drain waters as we have in this section of Colorado. An examination of them shows that they contain relatively considerably more sodic carbonate than the ground waters, but less potassic salts.

§ 90. The drain on Mrs. Calloway's ranch is 500 feet long, four feet deep at its upper end, nine feet at the lower and has been open for some years. The rainfall during March, April and May of the year 1900 amounted to 13.38 inches, and the sample being taken July 23rd, was taken subsequently to the irrigation, if any were applied, which was probably the case, though I have no specific information on this point. Such were the conditions pre-

ceding the taking of the sample and they also apply to the sample taken from the drain east of the beet plot.

§ 91. The sample taken from the drain underlying the beet plot in 1903 ought to be the nearest representative of the ground waters, analyses of which have been given. This drain was not laid at the time the samples of the ground water were taken. This sample ought to represent the drain water from this plot of ground. There had been but little or no rain for some time, the surface ground was frozen and the sample was taken on this date, Feb. 23, because we feared that a thaw might set in and we would have to wait a long time and perhaps never obtain a more representative drain water than that which we were then able to procure. The presence of strontic and lithic oxids in this analysis is what we would expect from what has been said in connection with the river water. They have been found present whenever tested for, but being of subordinate importance they were not determined in the other samples, the one being included with the lime and the other with the sodic oxid.

§ 92. The potassic oxid found in the ground waters varied from 0.01 of one per cent. of the total solids to 1.2 per cent., with an average of 0.262 for the 92 samples averaged; whereas the average for the drain waters is 0.125 per cent., which calculated per acre-foot of water gives 20.7 pounds in the ground water to 5.0 pounds in the drain water. From the point of its fertilizing value, this amount is not very significant, but it serves to show the ratio which exists between the amounts in the ground and drain waters or the extent to which the soil retains the potash, if we may put it that way.

§ 93. In regard to the sodic salts we find a difference between the sulfates and chlorids. Adopting the average percentage of sodic sulfate found in the total solids of well A in 1898, which is probably a little too high to be accurate but will represent the general facts with sufficient accuracy, we find in an acre-foot of the ground water 868 pounds of sodic sulfate, and in a like quantity of drain water 168 pounds, or one-fifth as much. In Bulletin No. 72 I called attention to the fact that the salts in solution fell as the water plane fell, the salts seeming to remain in the soil. I also called attention to the fact that the upper portions of the ground water were richer in total solids than the lower and at the same time contained higher percentages of sodic sulfate. I find in the drain water further proof of what I then observed by taking samples directly from the soil. We see that sodic sulfate does not pass readily into the drain waters. Not only the absolute amount falls, but its relative amount, showing that the soil particles retain it as there suggested.

§ 94. The sodic chlorid deports itself in the same manner. Again, using well A as an example, we have in an acre-foot of its water 925 pounds of sodic chlorid, or common salt, and 240 pounds in an acre-foot of drain water. I have compared other well waters and find this to be the rule. The difference is not necessarily the same but it is always in the same direction. The only time that the percentage of sodic chlorid in the total solids of the ground waters approaches that of those of the drain waters, is when the water plane has fallen quite low, in other words, when it has approached the level of the drain. These statements do not seem to be in perfect harmony with the theory of absorption of salts by different soils, and the fact that, as a rule, there is an excess of bases in the residues left by these waters, rather than acids, as would be required by the theories set forth in our text books, points to the prevalence of conditions entirely different from those under which the classical experiments, upon which our theories are based, were made.

§ 95. Only two of these drain waters were submitted to sanitary analysis, with the following results:

TABLE XLIII.—SANITARY ANALYSES OF DRAIN WATERS

1. Drain water, Mrs. Calloway's ranch, July 23, 1900.
2. Drain east of beet plot, July 23, 1900.

	Total Solids	Chlorin	Nitrates		Nitrites		Ammonia		Albuminoidal Ammonia		Oxygen Consumed
			Nitrogen	Nitric Acid	Nitrogen	Nitrous Acid	Nitrogen	Ammonia	Nitrogen	Ammonia	
1	880.5	40.7	0.240	1.0770	0.1400	0.4690	0.0410	0.0496	0.1000	0.1210	1.3650
2	1047.1	44.3	0.480	2.1540	1.8000	4.8550	0.0720	0.0871	0.1900	0.2299	2.0500

§ 96. I regret that these samples were not taken at the same time that the samples of irrigation water were taken, but they were not, and these will have to serve our purpose in such measure as they may.

§ 97. It will be seen by referring to the table of analyses of irrigation waters that the well waters taken August 31, 1899, before irrigation, were richer in nitric acid than these drain waters, as were also those taken after irrigation; but the drain waters are very much richer in nitrous acid. The ammonia, both saline and albuminoidal, is less in the drain water than in the irrigation and ground waters. The nitric acid removed per acre-foot by the richer of the two drainage waters is but 5.748 pounds. In the course of a year the amount of nitric acid in pounds avoirdupois transported by such waters, in the form of nitrates, is a comparatively large number, but when we attempt to estimate the area from which this is collected and think of the scale on which na-

ture operates, the amount is trifling. An example will show how thoroughly justified is this statement. If our soil contained 0.1 per cent. of nitrogen and we take two acre-feet of it, it will contain in round numbers 7,000 pounds of nitrogen. It would take 1,227 acre-feet of drain water to contain this amount, taking all forms of nitrogen existing in the water. The drain water does not, unfortunately, represent the water draining from any given acre of soil, but that draining from many acres. It is understood that the value of such examples is purely illustrative.

THE RETURN WATERS.

§ 98. We have considered the Poudre water and seen that it suffers little or no change in character so long as it remains in its mountain course, but that its character changes rapidly as it enters the plains. We have seen that in flowing through the ditches for use in direct irrigation it also changes rapidly. (See table XII—analysis of ditch water as used for irrigation). We have studied the effects of storage upon the amount and character of the salts held in solution. (See analysis of waters of Terry lake, Long pond, Warren's and Windsor lakes). We have further endeavored to present the manner and extent that its composition is changed by flowing over the soil as off-flow water; by entering the soil as ground water; by passing through and flowing out of it as drain water.

§ 99. If possessed with the desire to do so, anyone could make suggestions which, had they been feasible at the time, or perhaps even been seen as they can now be seen, would, if followed out, add greatly to the value of this work. From the very beginning I desired to make a study of the changes taking place upon the application of water for irrigation purposes in a different manner, but it was not feasible and I have done the best that I could. While I think the results of my experiments in this regard exaggerate some of the relations of the individual results to one another, I am not prepared to regret the fact, for I believe that the exaggeration serves a good purpose by emphasizing; for instance, the profound manner in which the laws of diffusion are modified within the soil, and the tenacity with which the soil particles retain the molecules of different salts, without in any appreciable way destroying their value, as a presentation of the typical reactions which take place. I think that it is true everywhere under our conditions that calcic sulfate is permitted to pass with comparatively more freedom than sodic sulfate or chlorid. I do not know whether this is due to the presence of this salt in quantities approaching the point of saturation of the soil and water, or not. With whatever weaknesses and insufficiencies our experiments may be beset, we have placed them upon record and will

examine what the results of the bigger practice, i. e., the irrigation of the whole valley may show.

§ 100. I have stated that seepage or return waters begin to enter the river almost immediately upon its leaving the mountains, and have cited the increase in the total solids in the river water between a point above the North Fork and the water works, in support of it. The amount of such water increases as we go down the river.

§ 101. We can present the matter thus: The water of the Poudre is taken from the river, used for irrigation, and after a time returns. The return waters have passed through or flowed over the soil. The amount returning to the river as waste water, is so small that I would not take note of it, even if I had sufficient data to justify me in attempting to do so. But I have not such data. Much of the water appearing in the lower part of the river has doubtlessly been used several times, but I doubt whether its composition is, on this account, any more or less indicative of the effects of the irrigation waters upon the soil, or of changes which take place within the soil, than water which has not been used repeatedly. I am inclined to think that in such cases the composition of the return waters is dependent almost wholly upon the character of the soil from which it last issued. This question is of great importance in interpreting the results of the analysis of return waters. The river bed may be bordered by a margin of low land, as it frequently is, the water draining from the higher land having to pass through this, either in small streams or by the slower method of percolation. In either event there is opportunity for a material modification of the composition of the water. Still, as has already been said, we have in the return waters the result of all the changes, and a measure of the effects produced by irrigating, not a field, but a whole section of country. Our measure is essentially the drain water of all this larger section, and in this case drain water means water that has passed through, not run over, the soil as rain water or as waste water from ditches.

§ 102. In order to save space and bring the analyses of return waters together, I will anticipate a little and introduce the analysis of the Platte river water below the mouth of the Poudre, it being return water, but I shall give those of the Poudre the first place, not only in order, but in importance.

TABLE XLIV.—ANALYSIS OF POUDBRE RIVER WATER,
SAMPLE TAKEN TWO MILES ABOVE GREELEY,
AUGUST 11, 1902.

<i>Analytical Results.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>	<i>Combined.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>
Silicic Acid	0.904	1.035	Calcic Sulfate	40.186	46.013
Sulfuric Acid	48.009	54.970	Magnesian Sulfate	31.796	36.406
Carbonic Acid	5.171	5.920	Potassic Sulfate	0.628	0.719
Chlorin	2.419	2.770	Sodic Sulfate	5.292	6.059
Sodic Oxid	12.742	14.590	Sodic Chlorid	3.987	4.565
Potassic Oxid	0.394	0.451	Sodic Carbonate	12.469	14.277
Calcic Oxid	16.540	18.938	Sodic Silicate	1.833	2.099
Magnesian Oxid	10.646	12.190	Ferric and Al. Oxids	0.069	0.079
Ferric and Al. Oxids	0.069	0.079	Manganic Oxid	Trace	Trace
Manganic Oxid	Trace	Trace	Ignition	3.660	4.191
Ignition	3.660	4.191	Sum	99.920	114.408
Sum	100.554	115.134	Excess Sodic Oxid	0.084	0.096
Oxygen Eq. to Cl.	0.545	0.634	Total	100.004	114.504
Total	100.009	114.500			

Total solids 114.5 grains per imperial gallon.

SANITARY ANALYSIS.

<i>Parts Per Million.</i>	<i>Parts Per Million.</i>
Total Solids	1,017.140
Chlorin	36.630
Nitrogen as Nitrates	0.400
Nitrogen as Nitrites	0.022
Saline Ammonia	0.060
Albuminoidal Ammonia	0.160
Oxygen consumed	1.160

TABLE XLV.—ANALYSIS OF POUDBRE RIVER WATER,
SAMPLE TAKEN THREE MILES EAST OF
GREELEY, AUGUST 10, 1902.

<i>Analytical Results.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>	<i>Combined.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>
Silicic Acid	1.336	0.951	Calcic Sulfate	48.068	34.124
Sulfuric Acid	42.660	30.374	Magnesian Sulfate	21.621	15.394
Carbonic Acid	7.144	5.087	Magnesian Chlorid	1.431	1.019
Chlorin	3.013	2.145	Potassic Chlorid	0.827	0.589
Sodic Oxid	12.819	9.117	Sodic Chlorid	2.566	1.827
Potassic Oxid	0.523	0.372	Sodic Carbonate	17.227	12.266
Calcic Oxid	19.785	14.087	Sodic Silicate	2.710	1.930
Magnesian Oxid	7.854	5.592	Ferric and Al. Oxids	0.055	0.039
Ferric and Al. Oxids	0.055	0.039	Manganic Oxid	0.110	0.078
Manganic Oxid	0.110	0.078	Ignition	5.433	3.868
Ignition	5.433	3.868	Sum	100.048	71.134
Sum	100.731	71.710	Excess	None	None
Oxygen Eq. to Cl.	0.679	0.483	Total	100.048	71.134
Total	100.052	71.227			

Total solids, 71.2 grains per imperial gallon.

SANITARY ANALYSIS.

<i>Parts Per Million.</i>	<i>Parts Per Million.</i>
Total Solids	1,635.710
Chlorin	45.550
Nitrogen as Nitrates	0.300
Nitrogen as Nitrites	0.015
Saline Ammonia	0.120
Albuminoidal Ammonia	0.180
Oxygen consumed	2.127

sewage of the town of Greeley. The water returning within the next six miles came from land irrigated with this water and carried, in round numbers, 80 tons of salts. Our method shows the net results effected, but the work done by the irrigation waters is actually much greater than the figures indicate.

§ 109. The salts removed stand as follows in the order of their relative quantities; calcic sulfate, magnesian sulfate, sodic carbonate and sodic sulfate. In the case of the Arkansas river water, the sodic sulfate stands next to the calcic sulfate. The samples of ground water from the Arkansas valley which I have examined, have been very rich in total solids with much sodic sulfate. In one there was over 57 per cent of this salt and in another almost 30 per cent.

§ 110. It is true, the area in the Poudre valley under irrigation, the seepage water from which finds its way into the Poudre, is large. In 1894 it was 176,848 acres. It is now much greater, but the amount of salts carried out of the valley under the conditions of 1902 is also large. Assuming the flow of 29.1 feet of water, as found by us, to continue for 270 days—the results will be too low, for the flow is at least six second-feet below the average—we will have removed from the valley 21,532.5 tons of salts, over one-third of which is calcic sulfate, one-fourth magnesian sulfate and a little less than one-eighth sodic carbonate.

§ 111. I am not certain that the Arkansas water is comparable as a return water to these samples of Poudre water. If it is, the ratio would be materially changed and we would have 2.5 for the calcic sulfate, 1.5 for the sodic sulfate, almost 1.5 for the magnesian sulfate and very much less sodic carbonate. The analysis of this water shows a very considerable excess of bases. I have already called attention to the fact that this sometimes occurs and that I am unable to satisfactorily account for it. The alkalies and some other determinations were repeated in this analysis with excellent agreeing results. We therefore leave the excess unexplained.

§ 112. The analysis of the Platte river water gives results in agreement with those of the Poudre water and there is nothing to be gained by further discussion of this. The flow of the Platte at this point is very much larger than that of the Poudre and the amount of salts carried will be almost exactly proportional to their respective flows. All that has been said concerning the Poudre could be repeated concerning the Platte. Its water is made to repeatedly serve the purposes of irrigation. Their waters receive the sewage of several towns, the Platte proportionately more than the Poudre. The general character of the land irrigated is similar and so are the general features of the results produced.

§ 113. Too much emphasis should not be laid upon the similarities between the composition of the drain waters analyzed

and these return waters, for, as already clearly stated, the return water taken near the mouth of the Poudre must have come in within the last six miles of its course. Still it seems that the drain waters and these return waters are representative of the end results produced by water applied to our soils, and passing through it to a depth of say four and one-half feet, and then finding a free channel of escape. These similarities are clearly shown by the analyses, the average percentages of which are as follows: Calcic sulfate in return water, 44.2; in drain water, 43.9; magnesian sulfate in return water, 25.2; drain water, 22.4; sodic sulfate, return water, 3.3; drain water, 4.3 per cent. The reason for the omission of the Arkansas river water at Rockyford from these averages is evident from what has been previously said.

THE WATERS OF SOME OTHER STREAMS.

§ 114. The streams of this section of Colorado including the Laramie, Poudre, Big Thompson, St. Vrain, Boulder, Clear Creek, South Platte and Arkansas, have collecting grounds of essentially the same character. Some of them, it is true, receive drainage from large parks, but these are surrounded by mountains of the same character as those forming the collecting areas of the other streams. The South Platte, for instance, receives drainage from South Park, but this water, springs excepted, some of which in this case are very rich in mineral matter and others are brines which at one time were used as a source of salt, comes from the mountains. Some of the tributaries of the South Platte carry as pure water as is to be found within the state.

§ 115. The analyses of these waters will be given without comment, except such as is necessary to a reasonable understanding of the samples, some of which, like the water served to the town of Fort Collins, fail to represent the true character of the water, but represent it after the stream has become a plains stream and has already received enough seepage to perceptibly modify its composition. This applies to all the following samples with the exception of the Boulder and Clear Creek samples. The sample of Platte river water was taken from a tap in the City of Denver, but inquiry of the Denver Union Water Company elicited the fact that the water obtained was not pure Platte river water, but was a mixture of this with water from some other sources of supply. For analyses of Poudre river water see table II.

TABLE XLVII.—ANALYSIS OF BIG THOMPSON WATER,
SAMPLE TAKEN THREE MILES WEST OF
LOVELAND, AUGUST 20, 1902.

<i>Analytical Results</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>	<i>Combined.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>
Silicic Acid.....	3.890	0.447	Calcic Sulfate.....	60.335	6.939
Sulfuric Acid.....	43.331	4.983	Magnesian Sulfate ..	11.775	1.354
Carbonic Acid.....	6.768	0.778	Magnesian Carbonate	11.789	1.356
Chlorin.....	0.565	0.065	Magnesian Chlorid....	0.482	0.055
Sodic Oxid.....	4.771	0.549	Potassic Chlorid....	0.433	0.050
Potassic Oxid.....	0.430	0.049	Potassic Silicate.....	0.257	0.029
Calcic Oxid.....	24.833	2.856	Sodic Carbonate.....	1.492	0.172
Magnesian Oxid.....	9.790	1.126	Sodic Silicate.....	7.688	0.884
Ferric and Al. Oxids	0.169	0.019	Ferric and Al. Oxids	0.169	0.019
Manganic Oxid.....	0.019	0.002	Manganic Oxid.....	0.019	0.002
Ignition.....	[5.561]	0.640	Ignition.....	[5.561]	0.640
Sum.....	100.127	11.514	Sum.....	100.000	11.500
Oxygen Eq. to Cl....	0.127	0.015	Excess.....	None	None
Total.....	100.000	11.499	Total.....	100.000	11.500

Total solids 11.5 grains per imperial gallon.

SANITARY ANALYSIS.

<i>Parts Per Million.</i>	<i>Parts Per Million.</i>
Total Solids.....	164.290
Chlorin.....	2.970
Nitrogen as Nitrates	0.300
Nitrogen as Nitrites.....	None
Saline Ammonia.....	0.030
Albuminoidal Ammonia.....	0.120
Oxygen consumed.....	1.625

TABLE XLVIII.—ANALYSIS OF ST. VRAIN WATER, TAKEN
THREE MILES WEST OF LONGMONT, AUGUST 19, 1902.

<i>Analytical Results</i>	<i>Per Cent</i>	<i>Grs. Imp. Gal.</i>	<i>Combined.</i>	<i>Per Cent</i>	<i>Grs. Imp. Gal.</i>
Silicic Acid.....	3.074	0.483	Calcic Sulfate.....	50.053	7.858
Sulfuric Acid.....	41.873	6.574	Strontic Sulfate.....	0.305	0.048
Carbonic Acid.....	7.945	1.247	Magnesian Sulfate ..	18.482	2.902
Chlorin.....	0.957	0.150	Magnesian Carbonate	7.729	1.223
Sodic Oxid.....	10.117	1.588	Potassic Chlorid....	0.844	0.133
Potassic Oxid.....	0.533	0.084	Sodic Chlorid.....	0.915	0.144
Calcic Oxid.....	20.601	3.234	Sodic Carbonate.....	9.438	1.482
Strontic Oxid.....	0.172	0.027	Sodic Silicate.....	6.234	0.979
Magnesian Oxid.....	9.892	1.553	Ferric and Al. Oxids	0.199	0.031
Ferric and Al. Oxids	0.199	0.031	Manganic Oxid.....	0.054	0.008
Manganic Oxid.....	0.054	0.008	Ignition.....	5.179	0.813
Ignition.....	5.179	0.813	Sum.....	99.432	15.591
Sum.....	100.596	15.792	Excess Sodic Oxid	0.948	0.149
Oxygen Eq. to Cl....	0.215	0.034	Total.....	100.380	15.740
Total.....	100.381	15.758			

Total solids, 15.7 grains per imperial gallon.

SANITARY ANALYSIS.

<i>Parts Per Million.</i>	<i>Parts Per Million.</i>
Total Solids.....	224.290
Chlorin.....	4.950
Nitrogen as Nitrates	0.100
Nitrogen as Nitrites.....	None
Saline Ammonia.....	0.300
Albuminoidal Ammonia...	0.140
Oxygen consumed.....	2.026

TABLE XLIX.—ANALYSIS OF BOULDER CREEK WATER, TAKEN FROM TAP IN BOULDER, AUG. 27, 1902. *

<i>Analytical Results.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>	<i>Combined.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>
Silicic Acid	21.985	0.6156	Calcic Sulfate	14.124	0.3955
Sulfuric Acid	8.305	0.2325	Calcic Carbonate	31.317	0.8769
Carbonic Acid	17.037	0.4770	Strontic Carbonate	0.235	0.0066
Chlorin	7.425	0.2079	Magnesian Carbonate	6.143	0.1720
Sodic Oxid	6.870	0.1924	Magnesian Chlorid	4.305	0.1205
Potassic Oxid	2.720	0.0762	Potassic Chlorid	4.304	0.1205
Lithic Oxid	Trace	Trace	Sodic Chlorid	3.586	0.1004
Calcic Oxid	23.373	0.6544	Sodic Silicate	9.818	0.2749
Strontic Oxid	0.165	0.0046	Lithic Oxid	Trace	Trace
Magnesian Oxid	4.760	0.1313	Ferric and Al. Oxids	1.098	0.0307
Ferric and Al. Oxids	1.098	0.0307	Manganous Oxid	0.341	0.0095
Manganous Oxid	0.340	0.0095	Zincic Oxid	Trace	Trace
Zincic Oxid	Trace	Trace	Ignition	[7.607]	0.2130
Ignition	[7.607]	0.2130	Sum	52.878	2.3205
Sum	101.676	2.8451	Excess Silicic Acid	17.144	0.4789
Oxygen Eq. to Cl.	1.676	0.0469	Total	100.022	2.7994
Total	100.000	2.7982			

Total solids, 2.8 grains per imperial gallon.

SANITARY ANALYSIS.

<i>Parts Per Million.</i>	<i>Parts Per Million.</i>
Total Solids	40.000
Chlorin	2.970
Nitrogen as Nitrates	0.100
Nitrogen as Nitrites	None
Saline Ammonia	Trace
Albuminoidal Ammonia	0.050
Oxygen consumed	1.170

* Attention is called to the similarity of this analysis to those of the Poudre water, pages 13, 14 and 15.

TABLE L.—ANALYSIS OF WATER DRAWN FROM TAP IN OFFICE OF DENVER FIRE CLAY CO., DENVER, AUG. 26, 1902.

<i>Analytical Results.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>	<i>Combined.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>
Silicic Acid	2.573	0.427	Calcic Sulfate	43.853	7.280
Sulfuric Acid	25.785	4.280	Calcic Carbonate	9.943	1.651
Carbonic Acid	14.110	2.342	Magnesian Carbonate	12.587	2.089
Chlorin	7.508	1.240	Potassic Carbonate	1.849	0.307
Sodic Oxid	13.447	2.232	Sodic Chlorid	12.390	2.057
Potassic Oxid	1.261	0.209	Sodic Carbonate	6.236	1.035
Calcic Oxid	23.640	3.924	Sodic Silicate	5.218	0.866
Magnesian Oxid	6.022	1.000	Ferric and Al. Oxids	0.071	0.012
Ferric and Al. Oxids	0.071	0.012	Manganic Oxid	0.178	0.030
Manganic Oxid	0.178	0.030	Ignition	7.097	1.178
Ignition	7.097	1.178	Sum	99.422	16.505
Sum	101.692	16.874	Excess Sodic Oxid	0.576	0.095
Oxygen Eq. to Cl.	1.692	0.281	Total	99.998	16.600
Total	100.000	16.593			

Total solids 16.6 grains per imperial gallon.

SANITARY ANALYSIS.

<i>Parts Per Million.</i>	<i>Parts Per Million.</i>
Total Solids	237.142
Chlorin	21.780
Nitrogen as Nitrates	0.500
Nitrogen as Nitrites	0.540
Saline Ammonia	0.100
Albuminoidal Ammonia	0.180
Oxygen consumed	1.453

TABLE LI.—ANALYSIS OF CLEAR CREEK WATER, TAKEN FROM WELCH DITCH ONE MILE W. OF GOLDEN, AUG. 27, 1902.

<i>Analytical Results.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>	<i>Combined.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>
Silicic Acid.....	17.953	1.3644	Calcic Sulfate.....	42.252	3.2111
Sulfuric Acid.....	24.844	1.8881	Calcic Carbonate...	6.483	0.4927
Carbonic Acid.....	6.870	0.5221	Magnesian Carbonate	7.707	0.5856
Chlorin.....	2.479	0.1884	Magnesian Chlorid ..	0.764	0.0581
Sodic Oxid.....	7.073	0.5375	Potassic Chlorid.....	4.017	0.3053
Potassic Oxid.....	3.506	0.2665	Potassic Silicate.....	1.578	0.1197
Lithic Oxid.....	Trace	Trace	Sodic Silicate.....	13.952	1.0604
Calcic Oxid.....	21.041	1.5991	Lithic Oxid.....	Trace	Trace
Strontic Oxid.....	Trace	Trace	Aluminic Oxid.....	2.477	0.1883
Magnesian Oxid.....	4.011	0.3048	Ferric Oxid.....	1.916	0.1450
Zincic Oxid.....	0.207	0.0127	Zincic Oxid.....	0.207	0.0157
Aluminic Oxid.....	2.477	0.1883	Cupric Oxid.....	Trace	Trace
Ferric Oxid.....	1.916	0.1456	Plumbic Oxid.....	None	None
Manganic Oxid.....	0.691	0.0525	Manganic Oxid.....	0.691	0.0525
Cupric Oxid.....	Trace	Trace	Ignition.....	7.491	0.5693
Plumbic Oxid.....	None	None	Sum.....	89.535	6.8036
Ignition.....	7.491	0.5693	Excess Silicic Acid	10.464	0.7953
Sum.....	100.559	7.6423	Total.....	99.999	7.5989
Oxygen Eq. to Cl....	0.559	0.0425			
Total.....	100.000	7.5998			

Total solids, 7.6 grains per imperial gallon.

SANITARY ANALYSIS.

<i>Parts Per Million.</i>	<i>Parts Per Million.</i>
Total Solids.....	108.571
Chlorin.....	2.970
Nitrogen as Nitrates.....	0.200
Nitrogen as Nitrites.....	0.013
Saline Ammonia.....	0.040
Albuminoidal Ammonia.....	0.140
Oxygen consumed.....	2.360

TABLE LII.—ANALYSIS OF ARKANSAS RIVER WATER, TAKEN AT CANON CITY, FEBRUARY 2, 1898. *

<i>Analytical Results.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>	<i>Combined.</i>	<i>Per Cent.</i>	<i>Grs. Imp. Gal.</i>
Silicic Acid.....	7.840	0.847	Calcic Sulfate.....	18.863	2.037
Sulfuric Acid.....	11.676	1.261	Calcic Carbonate...	34.565	3.733
Carbonic Acid.....	26.383	2.849	Magnesian Carbonate	17.185	1.856
Chlorin.....	3.699	0.399	Potassic Sulfate.....	1.275	0.138
Sodic Oxid.....	12.364	1.335	Sodic Chlorid.....	6.102	0.659
Potassic Oxid.....	0.689	0.074	Sodic Carbonate.....	5.305	0.573
Calcic Oxid.....	27.149	2.932	Sodic Silicate.....	11.860	1.280
Magnesian Oxid.....	8.193	0.885	Ferric and Al. Oxids	0.215	0.023
Ferric and Al. Oxids	0.215	0.023	Manganic Oxid.....	0.098	0.011
Manganic Oxid.....	0.098	0.011	Ignition.....	2.528	0.273
Ignition.....	2.528	0.273	Sum.....	97.996	10.283
Sum.....	100.000	10.889	Excess Silicic Acid	2.003	0.216
Oxygen Eq. to Cl....	0.834	0.090	Total.....	99.999	10.799
Total.....	100.000	10.799			

Total solids, 10.8 grains per imperial gallon.
No sanitary analysis made of this sample.

TABLE LIII.—ANALYSIS OF ARKANSAS RIVER WATER, TAKEN AT BRIDGE NEAR ROCKYFORD, APRIL 24, 1903.

<i>Analytical Results.</i>	<i>Per Cent.</i>	<i>Grs.</i>	<i>Combined.</i>	<i>Per Cent.</i>	<i>Grs.</i>
		<i>Imp. Gal.</i>			<i>Imp. Gal.</i>
Silicic Acid.....	0.428	0.669	Calcic Sulfate.....	41.523	64.942
Sulfuric Acid.....	48.299	75.540	Magnesian Sulfate ..	17.899	27.994
Carbonic Acid.....	1.858	2.905	Potassic Sulfate ...	0.602	0.942
Chlorin.....	4.667	7.299	Sodic Sulfate.....	20.747	32.449
Sodic Oxid.....	18.662	29.187	Sodic Chlorid.....	7.701	12.044
Potassic Oxid.....	0.326	0.510	Sodic Carbonate.....	4.480	7.007
Calcic Oxid.....	17.090	26.729	Sodic Silicate.....	0.868	1.358
Magnesian Oxid.....	5.993	9.373	Ignition.....	4.346	6.797
Ignition.....	4.346	6.797	Sum.....	98.166	153.533
Sum.....	101.669	159.010	Excess Sodic Oxid	2.450	3.832
Oxygen Eq. to Cl....	1.051	1.644	Total.....	100.616	157.365
Total.....	100.618	157.366			

Total solids 156.4 grains per imperial gallon.

SANITARY ANALYSIS.

<i>Parts Per Million.</i>		<i>Parts Per Million.</i>	
Total Solids.....	2,234.290	Saline Ammonia.....	0.065
Chlorin.....	103.971	Albuminoidal Ammonia...	0.140
Nitrogen as Nitrates.....	1.500	Oxygen consumed.....	2.000
Nitrogen as Nitrites.....	0.040		

TABLE LIV.—ANALYSIS OF WATER FROM QUEEN RESERVOIR, SAMPLE TAKEN JANUARY 23, 1903.

<i>Analytical Results.</i>	<i>Per Cent.</i>	<i>Grs.</i>	<i>Combined.</i>	<i>Per Cent.</i>	<i>Grs.</i>
		<i>Imp. Gal.</i>			<i>Imp. Gal.</i>
Silicic Acid.....	0.273	0.197	Calcic Sulfate.....	36.765	26.581
Sulfuric Acid.....	48.973	35.407	Magnesian Sulfate ..	23.705	17.139
Carbonic Acid.....	3.370	2.437	Potassic Sulfate ...	0.911	0.659
Chlorin.....	3.810	2.755	Sodic Sulfate.....	19.900	14.388
Sodic Oxid.....	17.066	12.339	Sodic Chlorid.....	6.287	4.546
Potassic Oxid.....	0.493	0.356	Sodic Carbonate.....	8.125	5.874
Calcic Oxid.....	15.095	10.914	Sodic Silicate.....	0.554	0.401
Magnesian Oxid.....	7.937	5.738	Ferric and Al. Oxids	0.075	0.054
Ferric and Al. Oxids	0.075	0.054	Manganic Oxid.....	0.075	0.054
Manganic Oxid.....	0.075	0.054	Ignition.....	[3.692]	2.669
Ignition.....	[3.692]	2.669	Sum.....	100.089	72.365
Sum.....	100.859	72.920	Excess.....	None	None
Oxygen Eq. to Cl....	0.859	0.621	Total.....	100.089	72.365
Total.....	100.000	72.299			

Total solids 72.3 grains per imperial gallon.

SANITARY ANALYSIS.

<i>Parts Per Million.</i>		<i>Parts Per Million.</i>	
Total Solids.....	1,032.850	Saline Ammonia.....	0.060
Chlorin.....	47.529	Albuminoidal Ammonia...	0.620
Nitrogen as Nitrates.....	Trace	Oxygen consumed.....	6.415
Nitrogen as Nitrites.....	0.010		

§ 116. In glancing at these analyses, a few things will be noticed. First, that the waters of our mountain streams are of excellent quality and carry a small amount of salts in solution; second, that the amount of salts held in solution is materially increased almost immediately upon their entering the plains, particularly after they emerge from the foothills; third, that the waters of the mountain streams contain calcic sulfate—almost as their only sulfate—after this, carbonates and silicates; fourth, that the carbonates and silicates are rapidly exchanged for magnesian and sodic sulfates upon entering the plains (compare tables LII. and LIII.) While these samples are not strictly comparable as samples of Arkansas river water, because of the length of time elapsing between the dates on which the samples were taken, they illustrate well the differences between the mountain and plains waters. A still better illustration will be found by comparing table III, an analysis of Poudre water, with table XI, an analysis of Windsor lake water, or with table XLIV, an analysis of Poudre river water, taken above Greeley. The influence of the plains is already discernible in the composition of the water drawn from the tap in the chemical laboratory, also in samples of the Big Thompson and St. Vrain, taken a few miles west of the towns of Loveland and Longmont respectively.

§ 117. The sample of the Arkansas river water, taken near Rockyford, probably represents seepage water, but the extremely large amounts of nitrates and nitrites met with in the sanitary analysis suggest sewage. I am satisfied, however, that such is not the case, no sewage entering nearer than Pueblo, which is 70 miles above, and this is taken out by the ditches. The person who took this sample reported the water as very clear and the ditches above as taking all of the river water. We have in this sample, I believe, as good a one of return waters for the river at this point as could possibly have been obtained. It differs somewhat from the Poudre return waters in containing a good percentage of sodic sulfate. This salt is present, however, in the ground waters of this district in large quantities.

§ 118. The analysis of the water of the Queen Reservoir represents flood water which had been stored 22 months and was obtained through the kindness of Mr. W. M. Wiley. The salts held in solution differ in amount and slightly in their relative quantities, but it otherwise agrees with the seepage water taken at the bridge near Rockyford. This may be due to the return waters entering the river during flood time, but this would seem to indicate a very great in-flow of return waters at such a period, and it would seem that a portion, at least, of these salts must find their way into the water, either in the ditch or reservoir, during the period of storage. The Arkansas river in the month of February,

a month of low water, carried only 10.8 grains. This flood water, after storage for twenty-two months, carried 72 grains. Our data is not sufficiently full to enable us to go further with this discussion.

§ 119. The work done by the irrigating waters of the Arkansas valley is evidently similar to that done by them in the Poudre valley, and so far as the rate at which the salts are carried out of the soil is indicated by the contents of total solids per gallon, it is very nearly the same, differing principally in carrying a fairly large percentage of sodic sulfate, while the Poudre return water carries relatively but little or none of this salt.

THE SUSPENDED MATTER CARRIED IN TIMES OF HIGH WATER.

§ 120. This will vary both in amount and character, according to the conditions prevailing within the drainage area of the streams carrying it. The Rio Grande, in New Mexico, would scarcely be expected to carry the same character of suspended matter, especially after a torrential rain somewhere within its plains section, as at Del Norte, Colorado, after a similar rain in the mountain districts to the west of it.

§ 121. The amount of sediment, as I have found it, has been a great disappointment to me, it being very small in amount compared with my preconceived notions, and of a somewhat different quality.

§ 122. On May 22, 1902, we had an excellent opportunity of obtaining a sample of Poudre flood water, caused by a heavy rainfall within the foothills, whereby the river was swollen to such an extent that it passed beyond its bounds. It carried on this date 12,000 second-feet, or about ten times its usual volume at this season of the year. This water was very thick with mud and debris, such as the unusual volume of water would tear loose along its course. I had a large sample, 102 pounds, of this water collected from the middle of the stream. The bucket with which the water was dipped was allowed to sink as far as it would in such a current. The whole sample was allowed to settle for several days, on account of the suspended clay, and then filtered. The suspended matter amounted to 0.213 per cent, or 2,130 parts per million. The analysis of the sediment gave the following results:

TABLE LV.—ANALYSIS OF SUSPENDED MATTER CARRIED
IN FLOOD WATER OF POUDDRE RIVER, MAY 22, 1902.

	PER CENT.
Silicic Acid.....	61.482
Sulfuric Acid.....	None
Carbonic Acid.....	0.350
Chlorin.....	Trace
Phosphoric Acid.....	None
Potassic Oxid.....	2.663
Sodic Oxid.....	1.519
Calcic Oxid.....	2.575
Mangesic Oxid.....	1.948
Ferric Oxid.....	6.826
Aluminic Oxid.....	7.866
Manganic Oxid.....	0.461
Moisture.....	8.040
Ignition.....	6.485
Total.....	100.213
Nitrogen 0.306 per cent.	

§ 123. Our people do not have opportunity to apply such water in irrigating, and there is but little object in calculating what the value of an acre foot of it would be, still some may be curious to see the figures. The total suspended matter per acre foot would be 5,799 pounds. The total potash (K_2O) would be 154 pounds; the total nitrogen, 17 pounds, and the total organic matter 377 pounds.

§ 124. While the suspended matter, in this case, came from the foothills, it is not so different in its composition from that usually carried by this stream as would be anticipated.

§ 125. A sample of Arthur ditch water was taken July 5, 1900, when the river was high, and the water much more turbid than usual. The percentage of suspended matter was found to be only 0.0016, 16 pounds per million, or 44 pounds per acre foot. The sample taken was sufficiently large, over 100 pounds, to give entirely trustworthy results. The analysis was made by fluxing with calcic carbonate, therefore the lime and magnesia are included in the undetermined. The analysis gave the following results:

TABLE LVI.—ANALYSIS OF SUSPENDED MATTER IN ARTHUR
DITCH WATER, SAMPLE TAKEN JULY 5, 1900.

	PER CENT.
Silicic Acid.....	58.838
Potassic Oxid.....	2.818
Sodic Oxid.....	1.998
Ferric Oxid.....	6.985
Aluminic Oxid.....	1.505
Ignition.....	9.722
Undetermined.....	8.084
Total.....	100.000

§ 126. The potassic and sodic oxids in these two sediments are nearly the same; the silicic acid, iron and aluminic oxids are as nearly so as we could expect to find in samples taken on different days, with like conditions prevailing in the river, instead of samples taken under very unlike conditions. In this case, these samples show that there is very little difference in the suspended matter brought from the mountains by the flood water, produced by the melting snow, and that carried into the river by torrential rains within the foothills. This remark applies to the inorganic constituents only, and would not be strictly applicable to heavy rains falling within the sections where the red clays of the juratriassic abound. The ignited suspended matter of May 22, shows an abundance of red clay.

§ 127. The Queen Reservoir was filled with flood water from the Arkansas river. As the reservoirs, of which this is only one, are filled in this manner for the most part, I obtained through the kindness of Mr. W. M. Wiley a sample of the silt deposited in this reservoir. This matter had evidently been some time in accumulating. It is difficult to see how this may have been silt carried by the flood waters of the Arkansas, and yet the judgment of Mr. Wiley and his assistants ought to be thoroughly reliable in this matter. When passed through a fifty mesh sieve 15 per cent of it remained upon the sieve. Before ignition, bits of coal were easily recognizable among the large fragments of roots, stems, etc. It is possible that these bits of coal had been swept along by the flood waters from Canon City or Pueblo. After ignition the mineral and rock particles recognizable were mica, quartz, felspar and grains of a vesicular igneous rock, probably andesite. The latter was abundant. There were also fragments of shells and pear-shaped bodies, being quite sharp at one end. Some of these were spirally marked, others apparently not. These bodies dissolved in hydrochloric acid with effervescence, and were probably seed or spore cases of chara.

§ 128. I am not familiar enough with the country to suggest any source for the particles of igneous rock, but if I have made no mistake they have probably been transported a long way. The part that passed through the sieve was separated into a coarser and finer portion by washing. The particles of the coarser part of this portion were largely quartz, some felspar and mica grains and also some of the eruptive rock. Such was the mechanical composition of this silt. The chemical analysis gave the following results:

TABLE LVII.—ANALYSIS OF SILT FROM QUEEN RESERVOIR,
PROWERS COUNTY, COLO., SAMPLE TAKEN JAN. 23, 1903.

	PER CENT.
Silicic Acid	69.262
Sulfuric Acid	0.080
Carbonic Acid	2.819
Phosphoric Acid	0.120
Chlorin	Trace
Sodic Oxid	1.401
Potassic Oxid	1.807
Calcic Oxid	4.904
Magnesian Oxid	1.081
Ferric Oxid	3.603
Aluminic Oxid	10.428
Manganic Oxid	0.082
Ignition	4.283
Total	99.870
Nitrogen, 0.075 per cent.	

§ 129. The elements of plant food contained in this are the potassic oxid, the phosphoric acid, and perhaps the lime and the organic matter. The exceedingly low content of nitrogen indicates that the value of the organic matter is small. This silt differs from the two previously given in carrying a little phosphoric acid. This may come from the rock particles or from the shells, and may be from fragments of bone, a few of which were found in the silt. The chief value is in the potash, forty pounds per ton, but I can see but little difference between this potash, which, for the greater part at least, is contained in the felspar in the silt, and potash contained in any other finely divided felspar. The only question involved is the one of the degree of fineness. The quantity of potash is small, scarcely greater than that contained in an acre foot of some irrigation waters, especially those which have been stored—an acre foot of the Queen Reservoir water carrying 72.3 grains per gallon, and the salts in solution containing 0.5 per cent of their weight of potassic oxid, contains fourteen pounds of potassic oxid, while a ton of the silt carries forty pounds, every whit of which has to be brought into solution. The three samples of suspended matter, or silts, which have been presented represent very different conditions, and yet the composition is essentially the same. We find the mineralogical constituents the same, and essentially the same percentages of potassic oxid in the two from the Poudre, but less in the third, representing the lower Arkansas, and in none of them is it high, 2.9 per cent in round numbers.

§ 130. The fourth sample of suspended matter, of which I shall give an analysis, is of an entirely different nature. This material is not soil, or the natural products of decay on the surface of the crust, but refuse from mills, the products of decay formed in veins, comminuted gangue rock, slimed ore, etc., which is discharged into the water course and carried by the

stream, even to the distributing furrows in the fields. The analysis of this material gave the following results:

TABLE LVIII. — ANALYSIS OF SUSPENDED MATTER IN WELCH DITCH, SAMPLE TAKEN ONE MILE ABOVE GOLDEN, AUGUST 27, 1902.

	PER CENT.
Silicic Acid.....	53.991
Sulfuric Acid, Sol. in HCl.....	0.034
Sulfur.....	1.903
Ferric Oxid.....	9.420
Aluminic Oxid.....	15.822
Manganic Oxid.....	0.636
Calcic Oxid.....	1.015
Magnesian Oxid.....	1.613
Zinc.....	0.383
Copper.....	0.201
Lead.....	1.214
Potassic Oxid.....	4.650
Sodic Oxid.....	1.057
Loss at 60°.....	2.386
Loss above 260°.....	5.495
Total.....	99.875
Nitrogen 0.121 per cent.	

§ 131. The suspended matter amounted to 0.149 per cent. of the weight of the water, equal to 4,056 pounds per acre foot, carrying 4.9 pounds of nitrogen and 190.6 pounds of potassic oxid. This mud is richer in these elements of plant food than the mud of flood waters. The lead, copper and zinc found indicate the presence of 1.402 per cent. of galena, 2.502 per cent. of pyrites, 0.517 per cent. of sphalerite or zinc blende and 0.581 per cent. of chalcopyrite. These quantities of these minerals have escaped the concentrators and failed to be deposited before they reached this point. We have here to deal with a mixture of clay and felspar, a conclusion entirely in harmony with the facts known concerning the concentrating ores in this district.

§ 132. It appears from the results of the examination of these sediments, that they are composed essentially of the finer particles formed by the decay and comminution of the rocks forming the mountains, or rock particles forming the soil, which in our case amounts to saying the same thing. Our soils contain, as their mass analysis shows, a little over two per cent of potassic oxid, 2.2 to 2.6. These sediments contain less than the soils, except in the case of the mud from Clear Creek, which contains about as much as ordinary granite, 4.6 per cent. These results confirm an opinion which I have long entertained, i. e., that there is danger of our overestimating the value of the silts carried by our streams, as it seems almost impossible for this silt to be other than it appears to be from the study of the silts themselves, and the analysis thereof; namely, a mixture of the fine particles of the minerals constituting the mountain masses of the country.

SUMMARY.

1. The general character of the water of our mountain streams is dependent upon the character of their collecting area and is essentially the same for the streams studied in this bulletin.

2. The character of the water changes rapidly as soon as it leaves the mountain section of its course and enters the plains.

3. In the case of the Poudre water, used by the town of Fort Collins, the total solids contained in the water increases from 2.9 grains per imperial gallon, in the mountain section, to an average of perhaps 10.2 grains as delivered to the town, an increase of three and one-third times the original amount present.

4. This change is produced by its flowing through less than eight miles of its course lying within its plains section.

5. The mineral substances held in solution by the water, as mountain streams, are derived principally from the felspars by the action of water and carbonic acid. Pure water attacks these minerals, but its action is greatly increased by the presence of carbonic acid.

6. Our river and ground waters contain both strontia and lithia, which are shown to be dissolved out of the felspars by carbonated waters, and which are therefore to be considered as their source.

7. The amount of mineral matter which the Poudre carries through its canyon daily, assuming a flow of 300 second feet, is nearly twenty-six tons, equal to 520 cubic feet of solid rock, having the average density of quartz.

8. The Poudre water is not nearly saturated, for by direct experiment with finely ground felspar we were able to bring 4.536 grains into solution in each imperial gallon.

9. The composition of the material dissolved out of the felspar by water and carbonic acid, is almost identical with that held in solution by the river water.

10. The organic matter in the river water is not large in quantity and, while probably of vegetable origin, became exceedingly offensive when the water was evaporated to a small volume.

11. The waters of the Boulder and Clear Creek agree closely in composition and character with that of the Poudre.

12. The influence of the plains section of the stream upon the character of the water is increased by the irrigation of the adjacent lands.

13. The effect of storage is to increase the mineral matter held in solution. Some of the increase is derived from the ditches through which the water flows and from seepage directly into the reservoirs.

14. A small increase, 0.5 grains per gallon, is due to evaporation, but by far the largest increase is shown in instances where seepage water is either intentionally stored or flows into the reservoir.

15. In the case of Terry Lake the total solids found in two different years were 134.5 grains and 175.6 grains per imperial gallon. The average of which shows that this lake held in solution 27,127 tons of solids in its 9,000 acre-feet of water.

16. Windsor Lake, containing 14,000 acre-feet, held 18,894 tons in solution.

17. The water with which these reservoirs were filled was taken, for the greater part, directly from the Poudre, and the rest of it indirectly, it having in the meantime passed into the soil and reappeared as seepage.

18. The mineral matters held in solution in the different reservoirs differ considerably. Those of Terry Lake resemble in their composition

the alkali incrustations, which appear in many localities; those of Long Pond and the Windsor Reservoir resemble the water soluble portion of the soil, rather than the efflorescent alkalies. The water of Warren's Lake has suffered less change in the character of the salts held in solution than the others, and yet, the sulfates compose rather more than 50 per cent. of the salts held in solution.

19. The salts predominating in the water of the Poudre, while it is a mountain stream, are the carbonates, with some chlorids and sulfates, but as, stored in Terry Lake and Windsor Reservoir, the carbonates have almost disappeared and their place has been taken by the sulfates.

20. The amounts of calcic magnesian and sodic sulfates which appear in the stored waters are large. We find in Terry Lake 5,859 tons of calcic sulfate, 10,616 tons of magnesian sulfate and 7,113 tons of sodic sulfate. In the Windsor Reservoir we have the same salts, but in different quantities, 6,083 tons calcic sulfate, 7,029 tons of magnesian sulfate, 1,999 tons of sodic sulfate. These are the salts which constitute our alkalies.

21. The only constituent contained in these stored waters which, under our conditions, may have any great interest or significance as a plant food, and consequently tend to maintain the fertility of the soil, is the potash, K_2O . The quantity of potash held by the stored waters is not great. The aggregate amount present in the four lakes discussed is 188 tons, contained in 27,672 acre-feet of water, which, allowing two acre feet of water to an acre of land, would give an application of fifty pounds of sulfate of potash to the acre, which undoubtedly tends to maintain the fertility of the land to which it is applied.

22. The potash contained in the stored waters is largely brought into the reservoirs by seepage or other than river water.

23. The application of two acre-feet of river water as it flows through the canyon would give only 12.5 pounds of sulfate of potash per acre, or exactly one-fourth as much as the stored waters. As the seepage water contains not more than one-third of the latter in either of these cases, it follows that the amount of potash carried by it and necessarily obtained from the soil through which it has seeped, is much greater than that carried by pure river water, and we may note that the quantity indicated is greater than that carried by drain water or by soil water, as a rule, but is less than that carried by off-flow water, and sometimes by soil water.

24. The amount of nitrogen, including all forms, added with the irrigation water, being less than four pounds per acre, is negligible.

25. The quantities of useless, or even deleterious salts, added to the soil by the application of two acre-feet of stored water to an acre of land, are worthy of consideration. In the case of the Windsor Reservoir we add the equivalent of 54 pounds sulfate of potash, and at the same time 5,347 pounds of other salts; in the case of Terry Lake we add 55 pounds of sulfate of potash and 11,349 pounds of other salts.

26. Water used in direct irrigation, that is, water conveyed by means of ditches directly from the river to the land irrigated, suffers less change than when stored, but does not by any means escape altogether. The best measure that I have of the extent of this change, and one which, judging by the extent that the water supplied to Fort Collins is changed in flowing less than eight miles, is not an extreme or an exaggerated one, indicates that the total solids are not less than five times as much as in the river water when the ditch was not more than ten miles long.

27. The water used in irrigating, in order to study its changes, was water taken directly from the river, so far as we could obtain such. The general results may be stated as follows:

28. The water flowing over the soil carries, in the first portions which flow off, very considerable amounts of salts in solution. The samples which gave the most reasonable results indicated that water flowing for 600 feet over the plot experimented with, carried between 800 and 1,000 pounds more salts in solution, per acre foot, than the on-flowing

water. The first water that flowed off gave much higher results, but subsequent samples showed a rapid falling off.

29. The water entering the soil caused the solution of not less than 4,400 pounds of salts per acre-foot, and probably very nearly three times this amount.

30. The salts taken into solution by the water entering the soil and becoming ground water, are calcic, magnesian and sodic sulfates. The salts dissolved in the next largest quantities were sodic chlorid and sodic carbonate.

31. The amount of salts brought into solution in the ground water, due to the application of water to the surface, varies not only in the total amount of salts, but also in the relative quantities of the individual salts. The salt that went into solution the most freely in 1898, that is, the salt that showed the largest increase in the ground water, due to the irrigation of the plot with which we were experimenting, was sodic sulfate, for which we found an increase of 1,430 pounds in each acre-foot of ground water. In 1899, the largest increase was shown by calcic sulfate, an increase of 1,638 pounds per acre foot.

32. In 1898 there were two causes which may have contributed to bringing about the relatively large increase of the sodic sulfate. One was the scanty supply of water, which did not enable us to fill the soil with water to the same extent that we did in 1899, so that the relative mass of water to that of the soil, or to the salts in the soil, was not the same. This is an important condition and one, for the effect of which we have no measure. The other was the necessity that we were under of excluding the water of well D. from our consideration of the results of this irrigation, because of an accident. The results shown by this well subsequently indicate that it would have showed a greater increase in the amount of calcic sulfate than the other three, and would consequently have reduced the relative increase of sodic sulfate. The general results were slightly influenced by this omission. Still, after all due allowance for these facts has been made, there remains a decided difference in the results of these two experiments, one in 1898, the other in 1899.

33. The character and supply of the water exert an influence upon the relative quantities of the salts that go into solution, but there are evidently other factors that influence these ratios. The general conditions of the soil, the temperature and the season of the year, including all the meteorological conditions, probably have a great influence upon the salts in the soil, and the relative quantities of them in solution in the ground water.

34. The effect of a long continued rain in the spring of 1900, when the temperature of the water entering the soil was not far from zero, as the ground was covered with melting snow, is given in Tables XXXVI, XXXVII and XXXVIII. The salt present at this time, April 9, 1900, in well A, in the largest quantity, was magnesian sulfate. The quantity of this salt present, on this date, was between four and five times greater than the average quantity present during the season of 1898. The quantities of calcic and sodic sulfates were also greater than their respective average quantities for the same time; that of calcic sulfate was one-third higher, while that of sodic sulfate was between five and six times greater. The increase of the sodic sulfate over its average quantity for 1898, is greater than that of the magnesian sulfate, but the amount of the former salt present is just a little more than one-half that of the latter.

35. The following general conditions may have contributed in bringing about these variations. The weather during the preceding weeks, or even months, also the abundant supply of water simultaneously over a large area. I conceive this last condition to differ very greatly from the application of even a copious irrigation applied to a limited area of soil.

36. It is a common observation that the alkali salts effloresce freely during the winter season. It may have been the case in this instance that an unusual amount of this salt, magnesian sulfate, had accumulated in the upper portions of the soil, owing to evaporation during the preceding winter. Such a result is suggested by the presence of this salt in

large, sometimes predominating quantities, in the effloresced alkalis, but I have no other observed fact to support it.

37. The very large quantity of magnesian sulfate present may also be accounted for by supposing that the ground water, under the then obtaining conditions, actually dissolved larger quantities of this salt out of the soil than of the others.

38. It is not clear from any facts which I was able to discover, to which of these conditions, if to any of them, the observed fact ought to be attributed; to the accumulation of the magnesian salt in the upper portion of the soil, due to evaporation from the surface and the consequent action of capillarity, to low temperature, to the abundant supply of water over a large area, or to some other unrecognized cause.

39. The fact is simply this, that the salts in the ground water are essentially the same at all times, and the application of water to the surface, whether it be irrigation water or rainfall, does not change in any material way the salts present. The relative quantities in which they are held in solution in the ground water varies quite widely, while the causes of the variations are not evident. It is not probable, for instance, that the quantity of magnesian sulfate in the soil experimented with, predominates at any time over the calcic sulfate, as the relative quantities of these salts found in the ground water in the spring of 1900 might be held to suggest. The solution obtained by thoroughly exhausting this soil with water, shows that there is from two to three times as much calcic as magnesian sulfate in the top four inches of it. The total lime contained in this soil, as shown by analysis of the whole soil, is in round numbers, double that of the magnesia. The lime in the hydrochloric extract of this soil usually exceeds the magnesia; in the subsoil it is even eight times as great.

40. The ground waters, under ordinary conditions, always contain more calcic than magnesian sulfate, but under the conditions prevailing during the spring of 1900, we find the rule reversed—see analyses XXXVI, XXXVII and XXXVIII. The cause, or causes, of this were evidently not permanent, for within a period of eight days we observe a change, in which the ratio of magnesian to calcic sulfate, in the water of well A, falls from 2:1 to 1.2:1, a ratio which had already been found for these salts immediately after irrigation. In the drain water taken on the same date, April 20, 1900, we observe the usual ratio between these salts. The drain water is at all times different from the ground water, and too much stress should not be placed upon the ratio of these salts observed in it. Its chief value, in this case, is to show that, though the conditions in regard to temperature, water supply, etc., were general, they have produced no noticeable effect upon the kind or relative quantities of the salts carried in the drain water.

41. The water of well A, on April 9, 1900, was intermediate in the character of the salts held in solution between the alkali-incrustations forming on this soil, under favorable conditions, and the water usually present in the well. It differed from the former in having less sodic sulfate, and from the latter in carrying less calcic sulfate and very much more magnesian and sodic sulfates. These facts do not seem to be in any way dependent upon the solubilities of the salts themselves, nor upon any known state of hydration.

42. The quantities of potash involved were not large, being 15.1 and 19.2 pounds respectively, for the two seasons, 1898 and 1899. These quantities are extremely small, when we consider the mass of other salts which was brought into solution. In 1898 we have nearly 2.25 tons, in 1899, 2.5 tons of salts brought into solution, and this on plainly too conservative an estimate, while only these small quantities of potash are carried along with them. If we were to treat an equal amount of ground granite with this amount of water, it would dissolve out more potash than is here shown to have gone into solution, notwithstanding the tendency of such a large quantity of salts, 2.5 tons, to carry others into solution. This is entirely in accord with facts observed long

ago, i. e., that the soil retains potash salts more tenaciously than it does others.

43. The drain waters, as indicated by such data as we have been able to gather, though we have not been able to study this subject as we desired, differ materially from the ground waters. They contain a smaller quantity of salts in solution, and are more uniform in this content than the ground waters. The salts present stand in a different order, especially in regard to their relative quantities, sodic sulfate sometimes disappearing entirely. Calcic sulfate is uniformly first in quantity; magnesian second, sodic carbonate third, and sodic chlorid fourth, with sodic sulfate quite irregular, but usually less than the sodic chlorid.

44. The first significance of these facts is that our drains benefit our lands by removing the surplus water, rather than the useless or deleterious salts, from the soils. This is by no means a small service. Indeed, it is the most important service to be rendered to nearly all of our alkalized land. Of the salts removed, the most injurious one, when present in sufficient quantity, is the sodic carbonate. Relative to the amount of this salt present in the drain and ground waters, a comparison of the analyses of the drain waters with those given of ground waters in this Bulletin, and also with those in Bulletin No. 72, pages 23-26, it will be seen that the grains per gallon remain quite constant. In other words, the sodic carbonate does not seem to be retained by the soil, or removed from solution by passing through it, while the sodic sulfate, or white alkali, is retained to a very marked extent.

45. The only samples of drain and ground waters taken on the same date, are those taken April 17, 1900. The samples of ground water are unusual, as set forth in preceding paragraphs, but the features to which I wish to call attention are so bold that they will not be hidden, or even distorted by these facts. In the ground waters we have 452 and 470 grains respectively, in the drain water 114 grains of total solids. The sodic carbonate in the ground waters amounts to 26 and 22 grains respectively in the drain water 23 grains. The range of this salt in the ground waters, given in this Bulletin, is from 10 to 25 grains per imperial gallon, and in those given in Bulletin No. 72, it is from 9 to 18 grains, while the range of the same salt in the drain waters given in this Bulletin is from 11 to 23 grains. Returning to the samples of April 17, we have in the ground waters 76 and 115 grains of calcic sulfate per gallon, for the drain water 45 grains. We have 152 and 137 grains magnesian sulfate per gallon for the ground water and 24 grains in the drain water. Still more marked than either of these is the case of the sodic sulfate, of which we have 105 and 89 grains respectively in the ground waters, and 5 grains in the drain water. The sodic chlorid is also retained within the soil, but in a less degree than some of the other salts. The ground waters on this date, April 17, 1900, carried 56 and 64 grains respectively, while the drain water carried 7 grains per gallon, or one-eighth as much as one of the samples and one-ninth as much as the other.

46. The analyses of the ground water before and after irrigation show that one of the effects of irrigation is to rather increase the relative amount of sodic chlorid in the ground water, so that the above figures appear more favorable to my statement than the facts as they are found, under less extreme conditions, might appear. Reference to the analyses of ground water, given on pages 30-33 and 38-40 of this Bulletin, and to those given on pages 21-26, Bulletin No. 72, will show that the sodic chlorid in the drain waters is less than in the ground waters, under the wide range of conditions represented by these numerous samples. Some of the analyses referred to, especially some of those in Bulletin No. 72, suggest very pointedly that the character of the soil has a decided influence upon these points; the indications being that the soil experimented with permitted the respective salts to pass through more freely than soils freer from alkali salts, and in better mechanical condition, would have done.

47. The amount of potash salts removed by the drain water is less than that existing in solution in the ground water. The total amount removed in the course of years is a large one and, while we are reminded that the draining is going on all the time, day and night, year after year, we have to consider also that potash is not taken from any single acre-foot of soil, nor from a mass represented by a single acre of surface, but for the sake of keeping our numbers within limits which we can appreciate, I will give the figures showing the amounts of potash, on the basis of the acre-foot. One acre-foot of our soil contains a total of 78,750 pounds. Of this dilute hydrochloric acid dissolves 43,750 pounds. An acre-foot of ground water, before irrigation, in 1898, contained 22 pounds, and in 1899, 6 pounds of potash. After irrigation, in 1898, it contained 41 pounds, in 1899, 18 pounds. An acre-foot of drain water carries but 5 pounds, taking the average of four drains. The water draining from any given acre of land is probably small, not exceeding a hundredth of an acre-foot daily, in which case the amount removed from any single acre of land is very small. We will put this another way, in which the statements may seem more definite. If we take a strip of our land 18 miles long and one mile wide, from which there is discharged 30 acre-feet of drainage water daily, it would take upwards of 50,000 years for it to carry out an amount of potash equal to that contained in the first three feet of soil.

48. The nitrogen carried by the drain waters is only a little more per acre-foot than the potash, it being 5.8 pounds. The supply of nitrogen in the soil is not so great as that of the potash, by any means, but while there is no accession of potash, except it be added, there may be of nitrogen. The amount found in the first two acre-feet of our soil was 7,000 pounds, and it would take 1,227 acre-feet of drain water to contain this much nitrogen.

49. The return waters furnish us a bigger and slightly different measure for the effects of drainage, and as this, with us, is mainly due to irrigation, they furnish us, perhaps, the best criteria by which to judge of the effects of irrigation upon our lands. We would expect to find their composition very similar to that of the drain waters, provided our samples of drain water were numerous enough to represent the various soils and conditions to be met with in the 176,848 acres of land nominally under irrigation within this valley, of which probably 140,000 are actually irrigated. This remark applies, of course, to the Poudre Valley and river.

50. We find the total solids in the return waters lower than in the ground waters, and having the same range as found for the drain waters. We find them characterized by the same salts, and in the same order in regard to their relative quantities; i. e., calcic sulfate, magnesian sulfate and sodic carbonate, with sodic sulfate irregular in its quantity, but always subordinate, except in the sample of Arkansas river water, taken at Rocky Ford, April 24, 1903, concerning which some doubts may be entertained, but which is probably correct, because the ground waters of that section are extremely rich in sodic sulfate.

51. The salts discharged by the Poudre into the Platte river do not amount to less than 22,000 tons annually, which come from the lower section of the river, besides what may be carried from sections further up the river when the waters are not all taken out, as was the case at the time our samples were taken.

52. The chief difference between the drain waters and the return waters taken from the rivers, is in the potash present, which is greater in the return waters than in the drain waters. While some of the drain waters contain almost as much potash as the return waters, the latter are, as a rule, richer in potash than the former. The main features of these two classes of waters are, however, identical.

53. The waters of other streams, which we examined fully, justify us in assuming that the Poudre river water is typical of the mountain waters on this side of the range. They show that the waters of the different streams, while in their mountain sections, are identical; that all

alike suffer changes on entering the plains, and their return waters, as represented by the Platte river below the mouth of the Poudre, indicate that the changes suffered by them are, in all essential particulars, the same.

54. These mountain waters are interesting and worthy of fuller and more detailed study than is proper to devote to them in this place. Therefore the discussion of them will be omitted, except one feature of the Clear Creek sample. Clear Creek presents an instance of a stream whose waters are laden with the mud and slimes from many mills, and whose waters are also used for irrigation. The sample analyzed was taken from an irrigation ditch. A full and careful analysis was made of it, a fuller and more careful one than would probably have been made in the case of a legal controversy, and yet it shows nothing that can be interpreted as a serious pollution of the water. The essential characteristics of a pure mountain water have scarcely been modified in the least. The purest mountain water in any of these streams carried 2.6 grains per imperial gallon, Poudre river water, sample taken July 30, 1902. The sample of water taken from Clear Creek, a stream which drains a section of country with a population of at least 25,000 souls, and receives indefinite quantities of mine water, and the refuse from twenty odd mills, carries less than eight grains to the imperial gallon, an increase which is less than that caused by a flow of a few miles (four to eight) in the plains section. Of the heavy metals, salts of which we might expect to find in this water, due to oxidation of the ores treated in the mills, we find none, a trace of zinc oxid, 0.0157 grain in each imperial gallon, excepted.

55. The suspended matter in our streams and ditches was found to be very much less than was expected, even in time of flood, due to heavy rains in the lower and, largely soil covered sections of the mountains, or in the foothills. The water, at the time the first sample given in the text was taken, corresponded to the colloquial expression, "as thick as mud." The season was one of high water, when the usual flow is 1,200 second-feet, due to the melting of the snow, but at this time it was ten times as great, or 12,000 second-feet. The rain fell in a hilly section and the fall of the river being great, we had conditions favorable to the tearing loose of soil, rocks and other debris. The crest of the flood had not passed at the time the sample was taken, and the amount of suspended matter in this sample probably represents the maximum that we may expect to find in this stream at any time. The amount of sediment equalled 3 tons per acre-foot of water. The aggregate amount of sediment carried by such a flow, 12,000 second-feet, laden as this was, is not far from 2,800 tons per hour, all of which, it is true, must sooner or later be deposited somewhere, and in considering this as a source of fertility we permit the impression of this big aggregate, and the fact that it is deposited somewhere, to lead us to form too high an estimate of its actual available amount, and we at the same time assume that it is feasible to apply it to the land. If it were feasible and we applied two acre-feet of it to an acre we would add six tons of this suspended matter to the acre. This would, if spread evenly over the surface of the acre, form a coating less than 0.04 of an inch in thickness, or twenty-five such floodings would, under very favorable conditions, furnish a dressing of this sediment one inch in thickness. This would, of course, if rich in plant food, be a very desirable addition to the acre of land. There are, on the other hand, several considerations to be weighed before we set this gain down as an easily attainable fact. It is not a fact that we can apply this muddy water to our land when it is in the river, and the occasions when it is in the river are very seldom; this one scarcely having been equalled since the occupancy of this valley by the white man, except once, when it was due to the breaking of a dam. The facts on which the assumed supply of sediment is based, are wholly exceptional. But if we grant the supply, the question of value is an open one, and here, as in the question of quantity, we permit our judgment to be imposed upon. In that case the large total, and the fact that it is deposited, leads us to the

conclusion that it is deposited in large quantities on the soil we have in mind. In this case the color and fineness of the sediment make a general impression of richness upon our minds, and we forthwith accept it as an established fact when it is not. The composition of this sediment does not justify the inference.

56. This sediment, very naturally, resembles in composition the source from which it was derived, which was the soil of the mountain or hillsides and their valleys. These soils have a common source with those of the plains, and it is therefore, on reflection, no matter for surprise that the sediments should not be found to be richer than the latter. There are two respects in which the sediments, in some measure, differ from the soils on which they would be deposited in our case, but this measure is not very great. These two respects are the fineness of division and the amount of organic matter contained in them. The fineness of the sediment is a condition favorable to the alteration of those mineral particles containing elements of plant food, whereby these latter are made available. The amount of organic matter contained is larger than in the average of our plains soil, but is not large when considered by itself. The case resolves itself to about this, that the 0.04-inch of sediment, which an application of two feet of water to an acre of our soil would add, would be equivalent to adding a layer of the same soil only a little more uniformly fine and containing a little more organic matter.

57. The sediments from the ditch waters are of the same character, and resemble more closely still, the soils to which they would be applied with the water.

58. Another sample of sediment examined was one which had been carried by flood waters and deposited as silt in a reservoir, the Queen reservoir, Prowers County, Colo. The mineralogical and chemical composition of this suggests the same considerations, and points to the same conclusions that I have endeavored to set forth in discussing the sediment carried by the flood water of the Poudre. This sediment, however, is less suggestive of the probability of any considerable benefit accruing to the land by its application to it.

59. The fourth sediment examined was of an entirely different origin, and naturally of a different character, and certainly ought to be looked at from two different and opposite points of view. The practically more important one being in regard to the possible injurious effect which any minerals present in it might have upon the vegetation to which it might be applied with the water. The other point of view is the same as that from which we have briefly considered sediments carried by our streams in general.

60. The analysis of the sediment answers the question relative to the presence of minerals, either injurious in themselves, or by the products of their decomposition, in the negative. The amounts of sulphid of lead, zinc, copper and iron do not exceed 35 pounds per ton of sediment, or if the whole of the sulfur found were present as iron pyrites, probably the most dangerous form in which it is likely to be present, the total amount would be 43 pounds per ton, about 86 pounds per acre-foot of water, a quantity, of itself small, and which can be reduced by the use of settling ponds, or other settling devices.

61. From the second point of view the quantity is not only materially in excess of the quantity carried by our streams in times of ordinary high water, but actually carries more potash, nitrogen and organic matter, the former constituting the principal value in either case.

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45. Analysis of Poudre river water; sample taken three miles east of Greeley, Aug. 10, 1902.
46. Analysis of Poudre river water, sample taken one mile south and four east of Greeley, Aug. 11, 1902.
47. Analysis of Big Thompson water, sample taken three miles west of Loveland, Aug. 20, 1902.
48. Analysis of St. Vrain water, taken three miles west of Longmont, Aug. 19, 1902.
49. Analysis of Boulder Creek water, sample taken from tap in Boulder, Aug. 27, 1902.
50. Analysis of water drawn from tap in office of Denver Fire Clay Co., Denver, Aug. 26, 1902.
51. Analysis of Clear Creek water, taken from Welch ditch, one mile west of Golden, Aug. 27, 1902.
52. Analysis of Arkansas river water, taken at Canon City, Feb. 2, 1898.
53. Analysis of Arkansas river water, taken at bridge, near Rocky Ford, April 24, 1903.
54. Analysis of water from Queen Reservoir, sample taken Jan. 23, 1903.
55. Analysis of suspended matter carried in flood water of Poudre river, May 22, 1902.
56. Analysis of suspended matter in Arthur ditch water, sample taken July 5, 1900.
57. Analysis of silt from Queen Reservoir, Prowers County, Colo., sample taken Jan. 23, 1903.
58. Analysis of suspended matter in Welch ditch, sample taken one mile above Golden, Aug. 27, 1902.