SOIL SURVEY OF THE SAN LUIS VALLEY, COLORADO.

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LOCATION AND BOUNDARIES OF THE AREA.

The San Luis Valley is situated in the south central part of Colorado, a small neck of the valley extending for 15 or 20 miles into the Territory of New Mexico. It is the upper valley of the Rio Grande del Norte. The Sangre de Cristo Mountains bound the valley on the east.

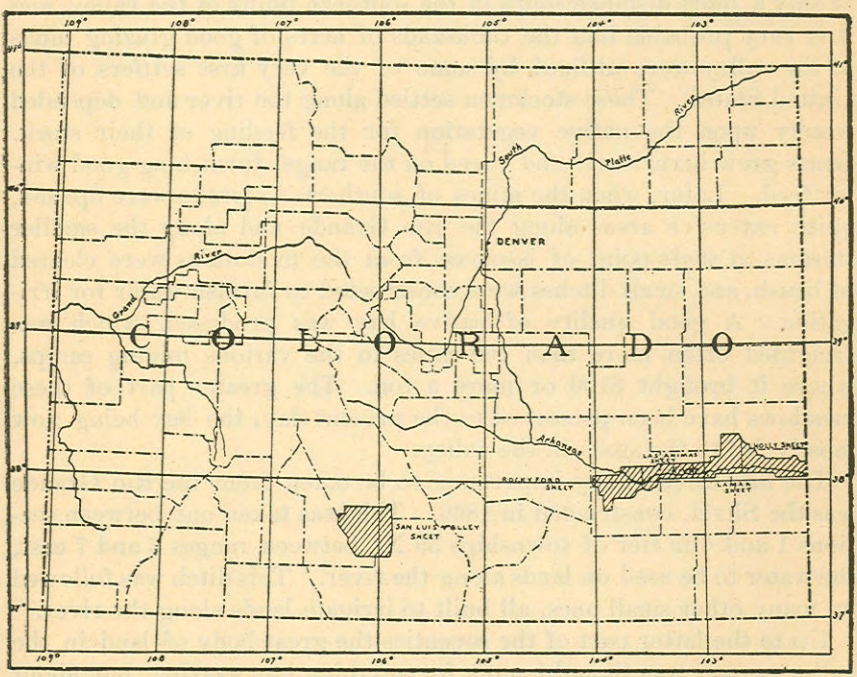

FIG. 54.—Sketch map showing location of the San Luis Valley area, Colorado.

It is in this range, almost opposite the center of the valley, that Sierra Blanca rises to a height of 14,464 feet. The western boundary of the valley is formed by the Saguache Range, which extends nearly parallel to the Sangre de Cristo. The valley is about 150 miles long and has a maximum width of 50 miles, gradually narrowing toward each end.

The portion of the valley surveyed occupies a part of the western slope at about the place of maximum breadth. It is bounded on the

west by the uncultivable bluffs and foothills along the base of the Saguache Range, on the east by range line 10 E., and extends north and south 26 miles, including a strip of 2 miles in the northern part of T. 37 N. and the whole of Tps. 38, 39, 40, and 41 N. This part of the valley has an elevation of between 7,500 and 8,000 feet. In this area are included the towns of Del Norte, Montevista, Alamosa, Mosca, Hooper, and Center. Of these towns all except the last are on the Denver and Rio Grande Railroad or some of its branch lines. Alamosa is the railroad center of the valley and is the point most easily reached by rail.

HISTORY OF SETTLEMENT AND AGRICULTURAL DEVELOPMENT.

The first white settlers of the San Luis Valley were Spanish missionaries and sheepmen, who settled here when all our southwestern territory was a part of the Spanish colonies. Old Santa Fe, N. Mex., is only a short distance south of the southern limits of the valley, and it is very probable that the thousands of acres of good grazing lands of the valley were utilized by some of the very first settlers of the United States. These stockmen settled along the river and depended wholly upon the native vegetation for the feeding of their stock. Grass grew luxuriantly and cured on the range, furnishing good winter feed. Later, when the mines of southern Colorado were opened, quite extensive areas along the Rio Grande and along the smaller streams at their point of issuance from the mountains were cleared of brush, and small ditches were constructed to furnish water for irrigation. A good quality of native hay was produced, which was freighted often more than 100 miles to the various mining camps, where it brought $100 or more a ton. The greater part of these meadows have been preserved to the present day, the hay being now mostly fed to the stock in the valley.

The first ditch of any importance to be taken from the Rio Grande was the Silvia, constructed in 1866. This was taken out between sections 1 and 6 in tier of townships 39 N., between ranges 6 and 7 east, the water to be used on lands along the river. This ditch was followed by many other small ones, all built to irrigate lands along the river.

Up to the latter part of the seventies the great body of land in the valley proper was thought unfit for anything but grazing, but about this time the feasibility of building large canals to cover thousands of acres of the higher lying land began to be considered, and as a result the Rio Grande Canal, the largest in the valley, was built and put in operation in 1881. It covers all that part of the area mapped lying north of the Rio Grande. The Citizens Ditch, on the south side of the river, quickly followed the Rio Grande on the north, and the success met with by settlers under these canals created quite a boom, which resulted in the building of the Empire, Farmers Union, San

Luis, and Prairie canals. All these canals, which are large, are taken out lower down on the Rio Grande, the water being used to irrigate lands in the eastern part of the area mapped.

The first farming in the valley proper was at North farm, just above the river bottoms, in T. 39 N., R. 8 E. From this point operations spread to the north and east. For a number of years wheat was grown almost exclusively and with marked success, whole sections often yielding an average of from 40 to 60 bushels per acre.

Operations were gradually extended to the eastward under the San Luis and Prairie canals, constructed to irrigate what is known as the Mosca country. This great tract of land, which includes the town of Mosca, was opened up in 1888 and 1889, and the town of Mosca was established in 1890. Hooper, which lies north of Mosca about 6 miles, was founded about the same time, irrigation in the vicinity of Hooper being from the Farmers Union Canal. Center, situated in the midst of the best farming community in the valley, is another town that has been the direct outgrowth of agricultural development. It is only about three years old, but has 600 or 700 inhabitants.

Many who settled in the valley did so only for the purpose of selling out. Those who actually farmed their land made such a success that they gladly mortgaged their holdings to buy out this class. At this time very little effort was necessary to produce a crop. One man often farmed from one-half to three-fourths of a section of land. The lands were new, productive, and free from weeds, and wheat, almost the only crop grown, brought a good price. The ground was barely scratched and the grain drilled in. The water was run through the country in small ditches to raise the subsoil water, and the wheat cut, thrashed, and marketed. The people became accustomed to careless methods of farming and were satisfied with the results. A few years of this continuous cropping to wheat caused a decided decrease in the yields; the subirrigation brought alkali to the surface; Russian thistles came in, making stubble drilling a failure, and soon many of the farms were mortgaged.

These unlooked for difficulties had greatly discouraged the farmers, when in 1900 the supply of water was short and no crop was raised on the drier lands. This drought was followed by another in 1901, and again in 1902, so that in 1903 the mortgagees had practically taken much of the land that formerly paid well, and many of the farms were abandoned. Many of these farms will pay well if properly handled; others are high and dry and will likely remain unproductive.

CLIMATE.

Reliable climatological records are not obtainable for any town within the area surveyed, but the county has been settled long enough to show by experience of the farmers the effect of the climate on many

of the more common field crops, fruits, and vegetables. The part of the valley mapped is on an average about 7,500 feet in elevation, surrounded by snow-capped mountains with altitudes ranging from 11,000 to 14,500 feet above the sea. As a result the climate is characterized by long winters and short summers. The minimum temperature for winter is about 30° F. below zero, while the summer maximum is about 85° F. The summer climate is very pleasant, there rarely being days that are too warm for comfort. Many persons come here for pulmonary diseases and seem to be benefited. The winters are dry, and while cold are said to lack the disagreeable features found in more humid regions. The annual rainfall is about 8 inches. This precipitation comes as local showers, any one of which covers only a very small part of the valley. During May and June there is scarcely a day that small storm clouds do not form in the mountains and float over the valley, wetting small areas. This rainfall, coming as it does in the spring months, is a valuable supplement to irrigation, under the system in use, as without the showers much of the grain would fail to come up.

Appended are climatological data for a town having a Weather Bureau station, situated in the valley north of the area surveyed:

Normal monthly and annual temperature and precipitation.

Month.	Saguache.		Month.	Saguache.	
	Temperature.	Precipitation.		Temperature.	Precipitation.
	° *F.*	*Inches.*		° *F.*	*Inches.*
January	17.2	0.25	August	62.4	1.16
February	22.4	.32	September	55.7	.58
March	33.1	.10	October	44.9	.61
April	43.8	.63	November	32.2	.26
May	51.8	.76	December	20.1	.19
June	59.9	.81	Year	42.3	7.38
July	64.6	1.76			

During the spring months a high wind often sweeps down from the mountains and blows across the valley with great force. This wind besides being disagreeable is often a serious menace to the young grain, the sandy soils being shifted and blown about and the grain sometimes blown out, causing the loss of a crop or necessitating resowing. These winds are the most annoying feature of the climate. Occasional hailstorms occur and these, also, sometimes damage the crops.

PHYSIOGRAPHY AND GEOLOGY.

The San Luis Valley is a broad, gently sloping plain surrounded by high, precipitous mountains. The uniformly sloping surface is broken only by small ridges or mounds which do not interfere at all with the

general slope. Canals dug across the valley go for miles without a crook or turn.

The Rio Grande enters the valley in the western part of the area mapped and flows across the valley to the south and east. This river, with its several tributaries in the valley, drains all the western slope of Sangre de Cristo Mountains and the eastern slope of the Saguache Range. The river and some of its larger tributaries have cut out for themselves broad bottom lands in which the soils have been greatly modified by the sorting power of the water and by the presence of moisture at all times.

There are many smaller streams entering the valley from the surrounding mountains, but these do not carry water enough to reach the river except by underflow. The small streams have had a marked effect on the contiguous soils, changing the light soils to heavy by chemically breaking down the particles and by adding materials brought down from the mountains. The whole region to the westward of the area mapped is of volcanic origin, the rock being principally trachyte.

The valley is one great artesian basin, the water coming from sand strata from 100 to 600 feet below the surface. The underlying strata below the surface 20 or 30 feet are alternate layers of sand and clay.

SOILS.

All the upper part of San Luis Valley was at one time a great lake, and the soils must therefore be classed as derived from lacustrine deposits. Since the subsidence of this lake the immediate surface has in many places been modified by the streams issuing from the mountains onto the plain and by the action of the winds, while moisture and irrigation have done much to decompose the coarse sands, wherever standing water has accumulated or moisture has been continuously present in the soil.

As a result of these changes, five types of soil are found in the area. The following table names these soils and gives the area of each:

Areas of different soils.

Soil.	Acres.	Per cent.
San Luis sandy loam	196,992	49.0
San Luis sand	136,960	34.2
Rio Grande sandy loam	35,776	8.9
Rio Grande loam	23,104	5.7
San Luis loam	9,088	2.2
Total	401,920	

All the types, except the Rio Grande sandy loam, are gravelly. Even this soil is underlain at from 2 to 4 feet by gravel, and this deposit outcrops in places to form small gravel patches. Thus the

soils of the valley may in a general way be called coarse, gravelly, sandy soils to distinguish them from soils which have a high clay content or are free from gravel or very coarse sand.

The soils of the entire area have their origin in the volcanic mountain range to the westward of the valley. The characteristic reddish-brown color of the trachyte of these mountains is very apparent throughout the principal soil types of the valley, with the exception of the Rio Grande sandy loam and the Rio Grande loam, which have been worked over by the streams and redeposited under conditions favorable to rank plant growth, the decaying of which has made these soils black.

SAN LUIS SAND.

The San Luis sand is a very coarse, incoherent, loose, reddish-brown sand which contains a high percentage of fine gravel, ranging from the smallest size to one-half inch in diameter. It is simply broken fragments of the volcanic rock of Saguache Mountains. Many of the particles are large enough to show plainly the character of the mother rock. Unless kept continuously wet it becomes very loose in the roads, making travel difficult. In the fields it is apt to be shifted about by winds and the young crops often suffer some damage from this cause. It is underlain by coarser material at from 2 to 4 feet, making deeper boring with a small auger impossible, and only in rare instances was the gravelly subsoil examined to greater depths.

This sand occupies a large area, being the principal soil east of range 8, and altogether forms over 34 per cent of the area. If the whole valley were considered, very probably a still larger proportion of the soil would be of this type, as in points visited outside of the survey this was the predominant soil.

Regionally the San Luis Valley is a very level plain, but here and there the surface is broken by minor ridges, caused no doubt by currents in the lake which once occupied the valley. North of the Rio Grande these ridges occur principally upon the sand areas, where they are quite pronounced and run in a northeasterly direction, paralleling the maximum fall of the country. In places the wind has blown up dunes from 1 foot to 5 or 6 feet high. These irregularities of the surface are a great hindrance to cultivation and irrigation.

As might be expected from the description of this soil, the natural drainage is good. Water passes through it like a sieve whenever the ground water is more than 18 inches below the surface, making necessary almost constant irrigation to supply sufficient moisture for the growth of crops. The regional drainage of the valley being poor, this constant irrigation has made some of the sand soil areas swampy. Wherever this has occurred the surface of the soil is white with alkali salts and crops are killed.

Much of this soil, which when first cultivated grew large crops, has been abandoned on account of the rise of alkali and swamping in the lower levels, and the drying out, under continued cultivation, of the ridges of higher levels. It is notable that the ridges are becoming drier under a system of irrigation that tends to swamp the valley. This is due to the fact that when irrigation began there existed over much of the valley a sort of hardpan at the maximum penetration of the rainfall, a condition found quite generally throughout arid regions. When water was applied in irrigation, the formation of the hardpan was interfered with, for instead of applying a small amount of water, which would penetrate to approximately the same depth each time, an excess was run upon the lands, the soil was filled, and the hardpan dissolved. Before the hardpan was destroyed a few good crops were obtained, but as soon as the hardpan dissolved continued irrigation not only failed to maintain sufficient moisture in the ridges, but swamped the low places with seepage water, carrying much if not all the alkali from the higher to the lower areas.

Just what the average yields of crops grown on this sandy soil now are is hard to estimate. The level parts, not too alkaline and well subirrigated, produce fair crops of wheat, oats, and other small grains, and pease. From 15 to 30 bushels per acre of wheat, and from 20 to 40 bushels of oats are produced. The pease are pastured or cut for hay, for which they are very valuable.

The following table shows the texture of the fine earth of typical samples of this soil:

Mechanical analyses of San Luis sand.

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
9061	S. side, No. 16–40, sec. 36, T. 41 N., R. 8 E.	Sand, 0 to 42 inches.	0.17	7.44	16.06	12.70	32.20	19.90	6.08	5.48
9059	No. 8–40, sec. 1, T. 41 N., R. 8 E.	Gravelly sand, 0 to 24 inches.	.58	13.74	28.84	12.48	13.18	10.54	13.22	7.86
9060	N. side, No. 12–40, sec. 7, T. 41 N., R. 9 E.	Gravelly sand, 0 to 24 inches.	.07	12.24	31.40	16.92	14.76	7.78	8.92	7.98
9058	N. side, No. 1–40, sec. 29, T. 41 N., R. 9 E.	Gravelly sand, 0 to 24 inches.	.26	7.50	26.20	16.30	18.22	10.26	10.32	10.82

The following samples contained more than one-half per cent of calcium carbonate ($CaCO_3$): No. 9061, 1.23 per cent; No. 9060, 2.76 per cent; No. 9059, 1.16 per cent; No. 9058, 1.21 per cent.

SAN LUIS SANDY LOAM.

The San Luis sandy loam is in the main a coarse, gravelly, harsh-feeling, reddish-brown sandy loam, ranging in depth from 18 inches to 3 feet. It occurs throughout the area mapped, occupying a greater area than any other type. Near the mountains on the western side of the valley the shallower soil is found. Here the gravel is quite large, waterworn, and much rounded. The interstitial material is quite sticky, containing a noticeable amount of clay, but below the surface 18 or 20 inches the clay almost wholly disappears, leaving the subsoil, to an undetermined depth, almost pure gravel and sand, with only a small proportion of the latter. As the distance from the mountains increases the gravel become smaller—though still showing the same waterworn characteristics—the soil gets deeper, and the percentage of clay seems to diminish, making the soil more nearly a true sandy loam. The small particles here seem to have been deposited in narrow strips, giving a heavier, less gravelly phase of the soil, surrounded by sand or a sandier sandy loam. On these lower areas the percentage of sand in the subsoil increases so that the coarse, rounded gravel is often not encountered until a depth of 10 or 12 feet is reached.

The heavier strips of this soil are nearly all found in the part of the district affected by alkali. They are locally referred to as adobe and are covered with "chico" brush (*Scarcobatus vermicularis*).

The San Luis sandy loam has a uniform slope of from 7 to 12 feet to the mile, inclining from the mountains in a northeastward direction. The surface is broken by many little knolls and ridges from 8 inches to not more than 2 feet in height, extending in a northeast direction, or parallel with the maximum fall of the country. These minor departures from the general level do not interfere with the running of ditches and might easily be leveled off to prepare for complete flooding, although in some instances where the soil is shallow this might expose the unproductive gravel subsoil.

All of the soil lying near the mountains is well drained and free from alkali. The entire area of it is porous enough to permit the rapid leaching of water, but in the lower levels the present method of subirrigation has resulted in much of it becoming very wet. Such areas must be drained in order to render them productive. The open, porous subsoil existing beneath even the heaviest phases of the type, however, makes this task a simple one. Wherever these wet districts exist, and water continues to evaporate from the surface the year around, the soil has become badly impregnated with alkali salts, although the soil may have been originally free from harmful accumulations. In fact many of the lands at present abandoned on account of alkali were when first cultivated practically free from alkali, the adobe or "chico" lands being an exception, as here there was a slight accumulation at the maximum penetration of rainfall corresponding

to the calcium carbonate hardpan mentioned as often existing in arid regions. Nearly all of this soil now under cultivation is sown to the cereals or to pease. It is well adapted to these crops, as well as to potatoes and all other truck crops suited to the climate.

The following table gives mechanical analyses of typical samples of the fine earth of this soil:

Mechanical analyses of San Luis sandy loam.

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
9057	NW. cor. sec. 7, T. 40 N., R. 8 E.	Gravelly, sandy loam, 0 to 12 inches.	0.91	8.96	22.08	10.26	15.54	11.70	19.84	11.26
9054	Cen. E. side sec. 5, T. 38 N., R. 8 E.	Gravelly, sandy loam, 0 to 24 inches.	.78	6.46	12.44	5.70	16.04	21.40	25.48	12.16
9056	SE. cor. No. 14–40, sec. 33, T. 41 N., R. 9 E.	Loam, 0 to 24 inches.	.22	6.20	23.42	10.42	15.70	14.78	13.68	15.68
9055	Subsoil of 9054....	Fine sandy loam, 36 to 60 inches.	.15	2.14	4.52	1.40	6.32	27.40	52.16	5.96

The following samples contained more than one-half per cent of calcium carbonate ($CaCO_3$): No. 9054, 2.02 per cent; No. 9055, 0.60 per cent; No. 9056, 3.97 per cent.

SAN LUIS LOAM.

The heavier or "adobe" phase of the San Luis sandy loam has, in rare instances, been further broken down, producing a loam. This soil—the San Luis loam—is from 24 to 36 inches deep and of about the same color as the sandy loam, but is decidedly heavier, having a plastic and sticky feel. It is almost free from coarse sand, although the small gravel are present, as in the type already described. When undisturbed, in its natural state, it has a hard, smooth surface, caused by surface accumulations of water, which occur at certain times of the year. When near a sand area small patches of wind-blown sand are often found lodged beside bushes or other wind-breaks. The subsoil is sand or sandy loam, and this is in turn underlain by sand and gravel. The areas mapped were found wholly on the south side of the Rio Grande, in the extreme southern part of the area mapped. The type has a smooth surface, of uniform slope admirably adapted to irrigation by flooding. It is poorly drained, and, as would be inferred from its texture, has been formed by deposition of the sediment of flood waters in rather low places.

All the areas of this soil type contain alkali, which extends to a greater depth in this than in the other soils. In most cases, however, the percentage of alkali is not great.

None of the San Luis loam is in cultivation, but whenever flooded from canals or wells it produces a good crop of the native grasses, which are excellent for pasturage or hay. Wherever water may be obtained for irrigation by flooding, this soil is well adapted to the grain crops grown in the valley.

The following table gives a mechanical analysis of the fine earth of this soil:

Mechanical analysis of San Luis loam.

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
9053	SE. cor. sec. 36, T. 38 N., R. 8 E.	Loam, 0 to 18 inches..	Tr.	1.28	6.66	7.46	22.96	15.56	11.54	34.46

The above sample contained 8.69 per cent of calcium carbonate ($CaCO_3$).

RIO GRANDE SANDY LOAM.

Along the Rio Grande and the other streams traversing the valley the typical coarse sandy soils have been worked over, redeposited, and greatly modified, producing a new series of types, the most important of which is the Rio Grande sandy loam. This is a dark-brown to black, friable, easily cultivated sandy loam, of an average depth of about 2 feet. The subsoil is a sandy gravel to undetermined depth. Scattered throughout the area are small patches, from one-quarter acre to 2 or 3 acres in extent, where the gravel comes to the surface and produces a gravelly phase of the soil, but as these are of such limited extent no attempt was made to outline them on the map.

The Rio Grande sandy loam, as already indicated, is found almost exclusively in long, narrow strips along the Rio Grande and other streams of the valley, but north of Alamosa there is a large area extending northward from the river at this point. The surface is usually flat, smooth, and admirably suited to irrigation by flooding. Old stream beds form an exception to the rule, as the river or creeks from which the soil has been deposited have from time to time changed their course and left these old beds only partially filled with sediment.

The soil is formed in part from recent sediment from the mountains, as brought down in flood time, and in part from the breaking down of the sandy soils of the valley under the action of continual moisture from the river. Vegetation finds a suitable field along the streams, and this upon decaying adds not a little to the soil and gives to it its dark color.

This soil is usually poorly drained, but only in rare cases shows any harmful accumulation of alkali. Areas immediately along the stream beds being naturally flooded at each overflow season, and much of the remainder being artificially flooded to produce native hay, unless this method of handling be changed, no fear need be entertained that this soil will become alkaline.

In the vicinity of the towns of Del Norte and Montevista much of these river lands is planted to potatoes—this being the money crop—while pease and grain are occasionally sown in rotation. The remainder is almost all used for pasture or the growing of native hay. The type is a very rich soil and because of its location exceptionally well watered. These things make it susceptible of a very high state of cultivation, and with the introduction of drainage ditches to carry off the surplus water during flood time truck crops of all kinds might be successfully grown. It may be said to be well adapted to the growing of potatoes and native hay—the crops now principally grown—and the truck crops suited to the climate.

The following table shows the texture of the fine earth of this soil:

Mechanical analyses of Rio Grande sandy loam.

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
9051	NW. cor. sec. 25, T. 39 N., R. 7 E.	Gravelly sandy loam, 0 to 24 inches.	1.08	1.70	5.18	4.82	22.78	23.84	29.18	12.38
9052	E. side No. 8–40, sec. 19, T. 38 N., R. 10 E.	Loam, 0 to 36 inches.	.73	1.66	3.60	1.58	8.26	16.54	39.06	29.20

The following samples contained more than one-half per cent of calcium carbonate ($CaCO_3$): No. 9051, 0.80 per cent; No. 9052, 3.09 per cent.

RIO GRANDE LOAM.

The Rio Grande loam is a sticky, plastic black loam, difficult to till and carrying a considerable percentage of rounded gravel. When wet it is a sticky mass of mud, and when dry it is very hard, baking in a manner similar to the adobes of the Pacific coast. The subsoil consists of gravel and sand and extends to undetermined depths.

This soil is located principally along the upper parts of the smaller streams that debouch from the mountains upon the valley. Next the mountains it often has quite a steep slope, but the water from the streams is easily made to flood it by taking out many small ditches.

This water makes the area quite swampy during the growing season. On the steeper slopes, however, the ground water recedes during dry weather and is often found several feet below the surface.

The Rio Grande loam has been formed partly from sediment brought from the mountains by the small streams, but principally by the action of the water in further breaking down the heavier phase of the San Luis sandy loam.

Along the Rio Grande areas are found which are formed almost wholly from sediment brought down from the mountains and deposited in abandoned courses of that river. Decaying vegetation in all cases has contributed to the soil, being the source of its dark color and increasing the supply of plant food.

The greater part of this soil type is free from alkali salts, only occasional patches that once were flooded but have since become dry containing sufficient quantities to interfere with crop production.

By far the greater proportion of the soil of this type is devoted to the production of native hay, but small areas are farmed to grain and alfalfa. The difficulty experienced in tillage and the density of the soil, making subirrigation difficult, prevent the more extensive cultivation of grain, while the high water table usually maintained makes the reseeding of alfalfa necessary at short intervals, and the cultivation of this crop is not considered a marked success. The introduction of a system of irrigation by flooding in the district near the mountains would in all probability make alfalfa a paying crop, and greatly increase the annual output of this soil.

Along Rock Creek two crops of native hay are at present cut in a season, and as this hay is generally in greater demand than alfalfa hay any change here would be of doubtful value.

The Rio Grande loam is well adapted to the growing of native hay, wheat, and alfalfa when it is possible to keep the water table lowered. The difficulty of cultivation makes the production of potatoes and other truck crops of doubtful profit.

Along La Garita Creek, in the northwestern part of the area mapped, there is a heavier, stickier phase of the Rio Grande loam that nearly approaches a clay. Here the surface soil is deeper than in the typical profile, the subsoil being a yellowish clay containing gravel. The crops, however, are the same as on the typical Rio Grande loam—being almost exclusively native hay, of which fair yields are produced.

The table following shows the texture of samples of the fine earth of the Rio Grande loam.

Mechanical analyses of Rio Grande loam.

No.	Locality.	Description.	Organic matter.	Gravel, 2 to 1 mm.	Coarse sand, 1 to 0.5 mm.	Medium sand, 0.5 to 0.25 mm.	Fine sand, 0.25 to 0.1 mm.	Very fine sand, 0.1 to 0.05 mm.	Silt, 0.05 to 0.005 mm.	Clay, 0.005 to 0.0001 mm.
			P. ct.	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*	*P. ct.*
9049	NW. cor. No. 2–40, sec 36, T. 39 N., R. 8 E.	Black loam, 0 to 24 inches.	0.97	0.64	2.94	1.68	6.98	10.72	48.02	28.94
9048	No. 7–40, sec. 9, T. 41 N., R. 7 E.	Gravelly clay loam, 0 to 14 inches.	1.04	2.72	7.02	4.92	14.08	14.48	27.28	29.22
9047	No. 7–40, sec. 32, T. 40 N., R. 6 E.	Black loam, 0 to 24 inches.	1.70	1.44	3.60	2.10	5.80	16.26	40.36	30.38
9050	NE. cor. No. 2–40, sec. 16, T. 38 N., R. 9 E.	Loam, 0 to 24 inches.	.63	2.84	6.68	3.60	10.00	13.12	29.12	34.64

The following samples contained more than one-half per cent of calcium carbonate ($CaCO_3$): No. 9050, 9.47 per cent; No. 9049, 2.48 per cent.

WATER SUPPLY FOR IRRIGATION.

Nearly all the water now used for irrigation in that part of the San Luis Valley under investigation comes from the Rio Grande, although small amounts are drawn from Rock, La Garita, and Johns creeks, and from artesian wells throughout the valley. The three creeks named furnish water for a considerable area of the hay land, this land being situated principally near the mountains around the points of issuance of the streams. Rock Creek, however, also irrigates hay land throughout its course in the area mapped. All the water of La Garita and Johns creeks is used near the mountains.

Artesian water may be obtained throughout the lower part of the area, from a point a little ways west of Montevista north along the Gun Barrel road, extending southeastward to the southern limit of the area, and including all the eastern side of the sheet. This artesian water is in some places used in a limited way for irrigation, especially on small hay meadows and ranch gardens.

The great body of irrigated land, however, as mentioned above, gets its water from the Rio Grande. This river has its source in the mountains many miles west of the valley. It is fed almost wholly from the melting snows of these mountains; hence the supply of irrigation water is directly dependent upon the snowfall. Varying with the season, the river ranges from a small stream a few inches in depth to a raging torrent. The year 1903 was a season of heavy snowfall, so that for many days during the latter part of May and in June the river filled its banks and furnished water far in excess of the amount required for irrigation. The year 1902 was in striking contrast to this. Only the older canals had water at all, and throughout the year

the river was very low. A series of reservoirs upon the upper part of the river would do much to regulate this flow and would be of great benefit to the valley.

Another means of adding to the water supply would be the conservation of the surplus now used to bring the water to the surface on the higher lands, particularly along the Gun Barrel road. The method of subirrigation of a great body of land where the slope is about 7 feet to the mile must result in the bringing into the country of a great deal of surplus water. Near the Gun Barrel road the underground water is often 25 feet below the surface when irrigation begins. Before the crop can reap any benefit from irrigation this water must be raised to within 2 or 3 feet of the surface, thus making the water table conform very closely to the surface slope. Farther east—from 4 to 8 miles east of Center—the subformation is such that the underground water is naturally near the surface, and all irrigation to the westward acts as a storage for this wetter region. Some lands near the line between ranges 8 and 9 have had no water applied to them for several years, and yet are sufficiently moist to produce crops. In some cases the soil is even too wet, owing to the excessive seepage from higher lands to the westward.

The water from the Rio Grande and the smaller streams is practically pure snow water from the mountains and contains little soluble matter—in no case sufficient to injure the most sensitive crops. The greater part of the artesian water contains noticeable quantities of soluble matter, but in most cases not enough to be detrimental to crops when used on the sandy soils of the valley. Along the western part of the artesian basin there is no sodium carbonate in the water, but eastward near Hooper and Mosca there is quite an appreciable percentage.

The following table gives an analysis of water from one of the many artesian wells found in the area. Samples from a number of other wells were sent in to the laboratory, but were found by the electrolytic method to be too low in salt content to call for analysis:

Chemical analysis of artesian water.

Constituent.	NW. corner sec. 6, T. 40 N., R. 10 E.	Constituent.	NW. corner sec. 6, T. 40 N., R. 10 E.
Ions:	*Per cent.*	Conventional combinations:	*Per cent.*
Magnesium (Mg)	1.50	Magnesium sulphate ($MgSO_4$)	2.00
Sodium (Na)	16.20	Magnesium bicarbonate ($Mg(HCO_3)_2$)	6.60
Potassium (K)	5.50	Potassium bicarbonate ($KHCO_3$)	14.10
Sulphuric acid (SO_4)	1.60	Sodium bicarbonate ($NaHCO_3$)	38.90
Carbonic acid (CO_3)	7.30	Sodium carbonate (Na_2CO_3)	12.90
Bicarbonic acid (HCO_3)	42.40	Total solids	74.50

ALKALI IN SOILS.

Like all carelessly irrigated districts, a part of the area mapped in the San Luis Valley is suffering from alkali. Beginning in the northern part of the area and the eastern part of R. 8 E., a broad belt of alkali-infected land extends in a southeasterly direction across the map. The strip thus highly impregnated is from 4 to 6 miles wide and is practically abandoned. Eastward from this strip to the limit of the area there are strips and patches of land where the alkali is sufficiently strong to injure crops. The bottom lands along the Rio Grande are practically free from alkali, although local patches occur. South of the river, beginning about a mile northwest of Montevista and extending south and east to the boundaries of the area, strips and patches of alkali lands occur, as shown on the map.

The map shows five grades or percentages of alkali for the surface foot only. Cross hatch lines indicate areas where there is an appreciable amount below this surface foot.

Practically all of the alkali in the soil of the San Luis Valley has come from the soil itself as it has been broken down or degraded in its present place. As explained elsewhere, the soils of the valley are in the main coarse and sandy, being merely small particles of the volcanic rock of Saguache Range, which were deposited in the bed of the great fresh-water lake once occupying the valley. Under such conditions it would be impossible for any great deposit of alkali to have been made as the soil was deposited, and as all circumstances point to a hasty drainage of this lake it may be safely concluded that there were no deposits made by concentration of the lake water. The artesian water throughout the most alkaline part of the area is practically free from soluble salts, and the surface ground water shows very little. The river water and water from small creeks are almost chemically pure snow water, and these can be virtually discarded in considering the source of the alkali found in the area. This leaves the soil itself as the only source.

After the recession of the lake the river and small streams continued to pour their waters into the valley, the greater part of which sank into the sandy soils and sought the lower levels as underground streams. The percolating water took up a small amount of soluble matter, and wherever the subformation was such as to force it near enough to the surface to permit evaporation, even for a part of the time, the soluble matter was left behind. The slight rainfall was insufficient to return this soluble matter to the drainage, so that throughout the years it accumulated, thus naturally creating certain alkaline areas.

In the area mapped this natural concentration in all probability occurred when the rainfall of the mountain region was greater than

at present (as it may have been immediately following the drainage of the lake), for the water was not dangerously near the surface when the irrigation of the region began in the latter part of the eighties and early nineties. Since that time the use of water has been continuous and excessive, as is necessary in subirrigation. Under this method the level of the ground water was raised until the roots of plants could draw their supply of moisture from beneath, and this condition not only brought again into existence the agencies which produced the natural alkali areas, but also—because of the large body of water run upon the land—extended these areas upon surrounding lands. At present much land that in the beginning of irrigation was entirely free from salts is white with surface accumulations and abandoned, while the lands that were originally alkaline have gradually become more so. From this it is seen that though the alkali actually comes from the soil itself its presence in harmful quantities is due directly to subirrigation.

The following table shows the chemical composition of the alkali of this soil:

Chemical analyses of salts in alkali soils.

Constituent.	No. 1.—1½ miles west of Montevista, crust, 0 to ½ inch.	No. 2.—Center east side, sec. 18, T. 39 N., R. 8 E., crust, 0 to ½ inch.	No. 3.—East side SE. ¼, sec. 29, T. 40 N., R. 6 E., crust, 0 to ½ inch.	No. 4.—No. 4–40, sec. 6, T. 39 N., R. 7 E., crust, 0 to ½ inch.	No. 5.—NE. ¼, sec. 24, T. 41 N., R. 7 E., crust, 0 to 1 inch.	No. 6.—NE. ¼, sec. 29, T. 41 N., R. 8 E., crust, 0 to 1 inch.	No. 7.—No. 13–40, sec. 33, T. 41 N., R. 8 E., crust, 0 to 1 inch.	No. 8.—7 miles southwest of Alamosa, crust, 0 to ½ inch.	No. 9.—½ mile south of Alamosa, crust, 0 to ½ inch.
Ions:	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*	*Per ct.*
Calcium (Ca)	2.48	6.98	6.32	8.94	5.80	6.87	8.52	1.43	0.83
Magnesium (Mg)	.14	.96	.75	2.43	1.27	1.10	1.02	.08	.15
Sodium (Na)	28.49	22.90	21.92	11.00	23.05	23.82	17.61	30.06	33.05
Potassium (K)	1.59	.24	5.38	9.75	3.39	.18	7.27	1.07	2.06
Sulphuric acid (SO_4)	63.76	67.11	47.99	55.68	40.60	46.79	44.33	66.30	37.27
Chlorine (Cl)	2.33	.....	15.39	.....	17.40	12.91	16.03	.97	2.08
Carbonic acid (CO_3)	.....	.....	.....	.....	.....	.....	.....	.....	17.38
Bicarbonic acid (HCO_3)	1.21	1.81	2.25	12.20	8.49	8.33	5.22	.09	7.18
Conventional combinations:									
Calcium sulphate ($CaSO_4$)	8.42	23.73	21.46	30.28	19.66	23.35	28.97	4.86	2.98
Magnesium sulphate ($MgSO_4$)	.71	4.70	3.69	11.99	6.22	5.40	5.00	.40	.77
Potassium chloride (KCl)	3.04	.....	10.26	.....	6.50	.36	14.09	2.04	3.54
Sodium chloride (NaCl)	1.46	.....	17.23	.....	23.48	20.98	15.57	.....	.99
Sodium bicarbonate ($NaHCO_3$)	1.65	2.53	3.06	17.07	11.88	11.45	7.15	.13	9.90
Sodium carbonate (Na_2CO_3)	.....	.....	.....	.....	.....	.....	.....	.....	30.73
Sodium sulphate (Na_2SO_4)	84.72	68.44	44.30	18.91	32.26	38.46	29.22	92.57	51.18
Potassium sulphate (K_2SO_4)	.....	.60	.....	21.75	.....	.....	.....	.....	.....
Per cent soluble	15.07	1.66	8.20	.98	1.21	2.18	1.76	31.72	10.10

Practically all of the alkali of the area is found as a surface accumulation. In a few isolated areas where a natural accumulation had

taken place in former years and subsequent changes have caused the accumulation to cease, the rainfall has washed the alkali into the subsoil. These subsurface accumulations are indicated on the map. If the surface 6 feet of soil were considered, as is usual in mapping alkali, the slight percentage in the lower feet would so bring down the average that lands now abandoned would be mapped as containing less than 0.20 per cent, which is not considered harmful to ordinary crops. In many cases where the surface foot shows 1 per cent of salt and the surface is white and all field crops die, in the second foot not enough alkali is found to injure the most sensitive crops. Much of the land adjoining the alkaline areas, and classed as containing less than 0.20 per cent, appears from casual observation to be bad, because of this white crust on the surface, but in a considerable proportion of these lands the soil below the surface inch is sweet and affords a good bed for plant roots. Excellent fields of grain or pease may be seen growing in these areas, although the surface is covered with a white crust. But these fields are being subjected to the same influences that have ruined the more easily subirrigated lands; and, unless radical changes are made, will in time be added to the area of unproductive lands. Too much stress can not be laid on the fact that all the alkali in the area is a surface accumulation and is due to subirrigation.

DRAINAGE AND RECLAMATION OF ALKALI LANDS.

While not all of the alkali land of the valley will need to be drained, yet all the lands that need drainage, except those immediately along the streams, are alkaline and some drainage is necessary in any comprehensive scheme of reclamation. Since, as has been several times stated, the accumulation of alkali is caused by the water coming from below or from subirrigation, the obvious thing to do to benefit the lands is to reverse the process and apply the water at the surface and let the current be downward. In order to make this possible drains will have to be constructed on the wettest lands, and all the affected lands will need to be prepared so that in times of abundant water supply they may be liberally flooded.

The soils of the valley are sandy and their capillary power is very slight, so that with care in cultivation a very high water table may exist and yet but slight damage result from the rise of alkali. The principal crops of the country are shallow-rooted annuals which are not injured by water comparatively close to the surface.

In view of the fact that the alkali is wholly a surface accumulation, that the soil is sandy, coarse, open, and porous, and of very low capillary power, and that the crops are such as do not suffer from a high water table, it may be readily seen that any system of drainage, either for alkali reclamation or for purely drainage purposes, may be confined to a very limited part of the surface soil.

The first step in this reclamation is to abandon the old method of exclusive subirrigation and prepare all affected lands for flooding. This will necessitate an initial expenditure of some money and labor, as small ridges and mounds must be leveled. Two dollars an acre, on an average, should be sufficient to cover this. Then, through the worst areas of alkali and in the lowest parts, small drains should be constructed 2 or 2½ feet deep with an outlet into a main drainage ditch. This ditching should be done only after careful surveys and tests for alkali have been made, so that no unnecessary work be done and that the water table be not lowered sufficiently to make the lands too dry. Two dollars an acre, on an average, ought to pay for this ditching, which, together with the expense of leveling, would make a total outlay of $4 an acre for the affected lands. As soon as the lands are leveled and ditched they should be heavily flooded to wash the alkali down, the salty water being carried away by the ditches. If one heavy flooding can be done in the spring before crops are sown, and then the crops flooded from time to time throughout the growing season, a crop can be grown the first year on almost any of the land that once grew crops. On the heavier soils, locally known as adobe but represented on the map as San Luis sandy loam, the ditches would have to be closer together and deeper than on the sandy soils. This loam soil is usually much more alkaline than the sandy soils, as can be seen by comparing the alkali and soil maps accompanying this report. On this heavier soil reclamation will be slower and more expensive, but when once reclaimed the land will be of lasting productiveness and very valuable.

In reclaiming alkali land much loss can be avoided by planting only such crops as will withstand the quantity of alkali in the soil at the time of seeding. Land that will produce a paying crop of barley may be so alkaline as to be worthless for wheat and pease. A safe plan is to try first to grow only the most alkali-resistant crop suited to the climate. In the San Luis Valley this crop is barley. Barley is one of the most alkali-resistant of the cereals, and, with the flooding, ought to produce fair crops the first year on any of the lands mapped as having less than 0.60 per cent of alkali. If the flooding be heavy and the crop shows little damage from alkali, it could be safely followed by a crop of pease. The pease should be grown as soon as possible in the reclamation, as they greatly enrich the land and benefit the crop to follow. After a crop of pease is once grown the ditches may be banked up in dry seasons and crops grown by subirrigation, if care be taken to flood the land every few years, or when there is an abundance of water in the river.

The records show that at least once in four or five years there is sufficient snowfall to make a great surplus of water in the river. When once the lands can be made to produce crops, a copious flooding

in these times of high water should keep the lands sufficiently sweet to grow crops in the intervening years by means of subirrigation. Lands immediately surrounding the abandoned areas have grown good crops for a number of years wholly from seepage from the higher lands, but they are beginning to show alkali on the surface, and should be flooded. These wet lands surrounding the alkali areas are at present considered the most valuable in the valley, because they are not directly dependent upon the seasonal precipitation for their supply of moisture. As soon as the alkali lands are reclaimed they will rank with these lands in value, for a drought need never be experienced. The higher country to the westward acts as a water-storage region for these very lands, regulating the supply and always furnishing sufficient water for subirrigation in dry seasons.

After the lands are sufficiently reclaimed to grow the crops suited to this region, the greatest care should be exercised to prevent evaporation from the surface of the soil. Careful cultivation to preserve a mulch at all times when not actually growing a crop will do much to lengthen the time between floodings.

AGRICULTURAL CONDITIONS.

To rightly estimate the prosperity of the San Luis Valley farmers is a difficult task, and, as in all sections depending upon irrigation, farms in a high state of cultivation, paying well upon money and labor invested, are here found next to farms that have been sold for taxes or that are, if farmed, unprofitable. Only a small fraction of the area mapped is at present profitable farming land. Much of it has never been cultivated, and much that was once very profitable has been abandoned. The land that has never been brought under cultivation is either alkaline or can not be irrigated on account of insufficient water supply. The same is true of the land once cultivated and since abandoned. The area of profitable farms can be quickly increased by a more careful use of irrigation water and by a change in the mode of application.

The prosperous farms in the valley are very profitable investments and make for their owners good livings with a minimum amount of labor. Those who are still farming the alkali lands in the old way—with subirrigation—are as a rule very poor and only persevere in the hope of disposing of their farms to the best advantage.

The State of Colorado and the Rio Grande Canal Company are the two largest landholders in the valley. Many of the farms of the valley are composed of State land, which is leased to the farmers for a term of years at a nominal rental. Occasionally a tract of State land is purchased outright, but as the yearly rental is small the majority of farmers prefer to lease.

When the Rio Grande Canal was built, the promoters received a grant from the State of one-half of all the State land covered by the canal—the northeast and southwest one-fourth of each section. Since that time much of this land has been sold to settlers, but as only a very small first payment is exacted many such farms are heavily mortgaged to the company. A part of the very alkaline land in the eastern part of the area and the high land near the mountains on the west is yet Government land. All the remainder is held either by those actually engaged in farming, or by investors or loan companies who have acquired title by foreclosure.

Rarely do the farms contain less than 160 acres, and many farmers actually cultivate as much as 640 acres. The Government land in the valley was subject either to homestead or desert entry, and many took advantage of the latter and secured 320 acres. Along the river near Del Norte and Montevista, where potatoes are one of the principal crops, there are some farms made from the subdivision of quarter sections, but in the main part of the valley 160 acres is considered as small an area of land as will support an average family, while 320 acres is the preferred size. Some individual holdings of large tracts of inferior land are devoted exclusively to grazing, while along the river and the smaller streams there are large hay and grass ranches from which the hay is sold or fed to stock.

A good deal of the labor of farming is performed by the farmers themselves. When only 160 acres are farmed by one man he can, by exchanging work with his neighbors, get along without employing outside labor except in cases of emergency. On the large farms the laborers are usually young men from the Middle West who themselves expect to become farmers. These men give great satisfaction, as they usually come from the farms in the more congested districts of the Middle West and, already schooled in all the details of farming under humid conditions, have merely to adjust this knowledge to irrigation practices. In a few instances Mexicans are employed on the farms, being detailed principally to the applying of the water in irrigation. In this work they give good satisfaction, as they are usually experienced irrigators.

The principal crops of the valley are wheat, oats, pease, barley, potatoes, and wild hay. A small quantity of alfalfa is grown, and garden vegetables for home consumption are usually produced on each farm. The wheat is of good quality, with high average yields, as is the case with all cereals. Potatoes are considered as good as those from Greeley, and this valley holds the record in yield per acre, as a little more than 10,000 bushels have been grown from a field of 10 acres. The native hay is preferred to alfalfa by nearly everyone and is undoubtedly a very good feed.

There is very little recognition of the adaptation of soils to certain crops among the farmers of the valley. The rule has been to grow grain—wheat principally—upon all lands. Potato production is confined almost exclusively to the Rio Grande sandy loam along the river, but with fertilization might be extended to all the lighter soils of the valley. The Rio Grande loam is devoted almost exclusively to grass for pasture or hay, its texture being such as to make its cultivation difficult.

Alamosa, situated in the southeastern part of the area mapped, is a railroad center. From this point the Denver and Rio Grande system has a branch to Creede, one to Salida, and connections with the Santa Fe to the southward, besides the main line to Pueblo and Denver. These roads give a good outlet for the grain, hay, live stock, etc., shipped from the valley, although freight rates are high. The branches to the north and south are narrow-gauge roads, so that all long-distance freight has to be reloaded. Travel on the lines in the valley is at the rate of 6 cents a mile.

Much of the produce of the valley finds a direct market in the towns of Alamosa, Montevista, and Del Norte. These towns have a population of from 1,000 to 1,500 each, and consume not a little produce. The remainder is shipped principally to the mining camps and stock-raising communities in southern Colorado and northern New Mexico. Much wheat is made into flour in the valley, there being large mills at Hooper, Mosca, Alamosa, Montevista, and Del Norte. The fat stock are shipped to Pueblo, Denver, and Kansas City. The lambs, fattened in the fall upon pease grown in the valley, are very much in demand and bring the highest prices.

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