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REPORT OF INVESTIGATIONS

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THE SURFACE OF A PORTION OF THE JAMES BASIN IN SOUTH DAKOTA

by

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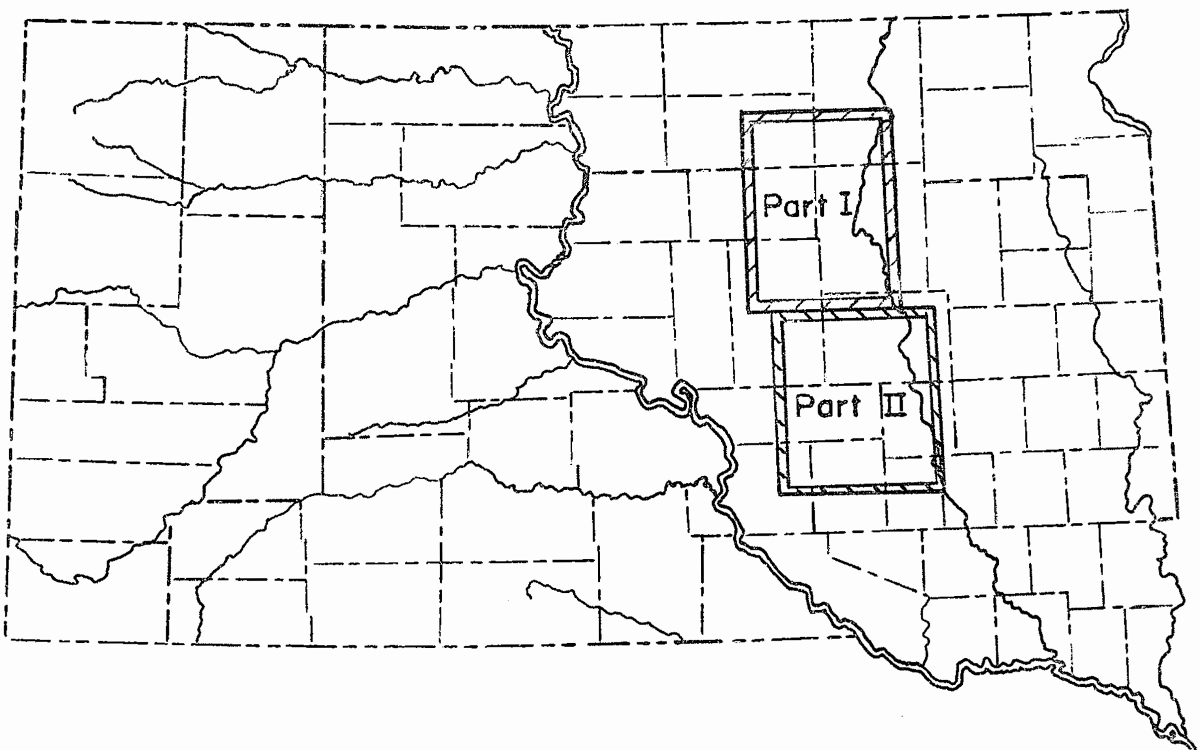

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INTRODUCTION

PURPOSE OF REPORT

The following report is a record of a reconnaissance survey of a portion of the James basin made during the summer of 1945 by a party from the State Geological Survey. It was made with two purposes in mind; first, to map the surface features in the Basin, and, second, to discover the adaptability of this country to irrigation.

The soils of the region are intimately tied up with the glacial geology and land use is dependent in a large measure on the topographic forms that exist. Though portions of the valley had been mapped many years ago by James Todd, the first State Geologist of South Dakota, little attention has been paid to these features for the last thirty years. The present effort, therefore, was an attempt to reclassify the glacial forms made in the earlier mapping and increase the area to cover the portions of the Basin in which there is current interest.

This current interest is derived largely from a proposal involving the use of surplus water obtained by daming the Missouri valley for irrigating the James valley between Aberdeen and Mitchell; such irrigation to be a part of the plan for the development and control of the Missouri river. It was proposed to erect a large dam at Oahe, five miles north of the city of Pierre which would create a lake in the Missouri valley extending from Oahe upstream to Bismark, North Dakota. Directly east of Oahe there is a broad lowland cutting across the high plateau bordering the eastern side of the Missouri valley and forming the divide between it and the James basin. Through this lowland a main ditch was to be dug that would transfer water across a saddle north of Highmore into the James basin. Somewhere near the city of Miller in Hand County the main ditch was to divide; one branch extending northward toward Aberdeen and the second branch extending southward toward Mitchell. Since the general slope of the James basin is eastward, it was thought possible to run laterals to most parts of the region under consideration, thus, putting large areas of the James basin under irrigation.

On casual observation this territory looks like a flat region. However, more careful scrutiny reveals the fact that there are many irregularities in the surface which would affect vitally the course of water being conducted across it. Moreover, the possibility of locating fields which could be flooded with irrigation water economically offers a second problem.

The solution of this problem involves topographic mapping on a scale which will show variations of a foot or two in the surface. Mapping the entire area in such detail would be a long and difficult job. A preliminary mapping, however, can point out where areas of sufficient flatness can be found, rule out certain areas where there is no hope of irrigation, and indicate the physiographic obstacles to the transportation of water and the laying out of irrigable fields.

This report is intended not as a final word on the irrigation possibilities of the James basin but as a preliminary reconnaissance which will point the way to areas where more detailed work will be profitable.

LOCATION AND AREA

The area mapped covers a block in the center of the James basin in South Dakota, one hundred and twenty-six miles north and south and averaging thirty-six miles east and west. Its south boundary was the southern line of Townships 103 N., two miles south of Mitchell, and its northern boundary the northern line to Townships 123 N., two miles north of Aberdeen. The James river formed the eastern boundary since that is as far as the proposed irrigation extended. The western boundary was fixed largely by the elevation of the surface above which it was impossible to carry water by gravity. The Wessington Hills form one such boundary and the Orient Hills another because they rise as steep escarpments some two hundred feet above the James basin floor. Areas north and south of these escarpments were mapped to an elevation of approximately fifteen hundred or sixteen hundred feet. That was thought to be about as high as water could be made to flow by gravity from the divide north of Highmore which had an elevation of seventeen hundred and fifty feet.[1]

In all, one hundred and twenty-five townships (land survey) were mapped, covering a total area of four thousand five hundred square miles. Included in this area are portions of ten counties: Davison, Aurora, Sanborn, Gerald, Beadle, Hand, Spink, Faulk, Brown, and Edmunds. It also contains some of the largest cities in the State, Mitchell, Huron, and Aberdeen and about a dozen other smaller cities. The latter include Wessington Springs, Miller, White Lake, Ipswich, and Woolsey. Whatever is done, therefore, to this region will affect a large portion of South Dakota.

METHODS OF WORK

The survey was made entirely as a reconnaisance. Each section was examined by riding along two or more sides until the type of surface and important features in it could be mapped with sufficient accuracy for the purpose indicated above. Horizontal locations were obtained within an accuracy of one tenth mile by measuring with odometers on the autos used, using the section corners of the land survey as check points. The physical features were plotted on township plats which were later transferred to a land survey grid prepared from U. S. Land Office maps. Vertical elevations were obtained by using U. S. Coast and Geodetic Survey bench marks, topographic maps available for parts of the Basin, and aneroid barometers. Where the above methods could not be used, paced distances and hand level elevations were resorted to.

The work was done by the State Geologist, and Dr. George D. Hubbard, Head of the Department of Geology at Oberlin College. To his long experience with glacial features in Ohio, Pennsylvania, and New York State is due the rapidity and accuracy of this survey. The rest of the party consisted of two drivers, Messrs. Bernt Westre and Robert Bent. Their proficiency in covering ground over bad roads or no roads at all, and their helpfulness in making measurements and general assistance was a large factor in making the reconnaissance possible.

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1. H. E. Brookman, Topography of the Low-Lying Area Across the James Divide in Hyde and Hand Counties, South Dakota, S. Dak. Geol. Surv. R. I. # 51.

SUMMARY OF RESULTS

The survey showed that of the 4428 square miles mapped, about 1300 square miles or 29% lends itself readily to large scale irrigation. About 397 square miles or 8.8% of the area has surfaces so steep and so rough that irrigation is out of the question. The remaining 63% has a surface which undulates and is seamed with deep meltwater channels. Part of the undulating surface is flat enough to offer some prospects for irrigation and small fields could be irrigated anywhere on the surface if they could be reached by a ditch. In short, 29% of the area can be easily irrigated, 63% is questionable, and 8% is out of the picture.

These areas are all indicated on the glacial maps accompanying this report.

ORIGIN OF THE SURFACE

The surface features of the James basin are entirely the result of glacial activity which took place in the recent geologic past known as the Pleistocene Epoch. At this time most of northern United States was invaded by continental glaciers which originated east, west, and south of Hudson Bay. These glaciers moved southward, roughly, to the position of the Ohio and Missouri valleys in north central United States. The ice front at its maximum extent presented a lobate appearance because tongues of ice moved southward through the lowlands while the front was retarded on the higher lands.

Due to variations in climate or other causes not very well understood, these tongues of ice advanced and retreated at least five times in the vicinity of Iowa, and South Dakota. The debris left by the lobe or lobes which occupied the James Valley formed the surface in the region under consideration here.

BED ROCK

The conditions in the James valley before the incursion of the ice are not thoroughly known. It is known, however, that ice rode over soft shales and chalk rock which had been deposited in the last sea to cover South Dakota (the Cretaceous sea). The areal distribution of these sediments is not of particular interest to this report, and therefore will not be described. It is important to note here, however, that the James basin was cut in these soft shales.

The folding of the Rocky mountains had tilted the great plains toward the east setting the course of the rivers in western South Dakota in the valleys they now occupy. They flowed eastward, as they do today, but continued their course beyond the present Missouri which at the time was nonexistent. With the exception of the White river, these streams appear to have worked their way eastward and northward across the James basin, and eventually reached the Arctic Ocean by way of Hudson Bay.

The White river flowed east and south probably into what is now the Vermillion river, and eventually emptied into the Gulf of Mexico. Though the details of the stream carving affected by these rivers are not known, it is known that they are responsible for the lowland in which the James basin lies. It is also known that they carved the escarpments known as the Wessington Hills, and the Orient Hills. The bedrock surface, therefore in most of the area which is being described here, lay as a plain sloping gently eastward. It was bounded on the west, however, by two sharp escarpments which were apparently about half of their present height, since the lower half is made of bedrock shales while the upper half is glacial drift.

In the area covered by this report, bedrock is exposed in the Wessington escarpment, in Firesteel Creek above Mitchell, in the James valley below Mitchell, and at Mina, twelve miles west of Aberdeen. In the first locality it is dark shale belonging to the Pierre formation. In the second, it is chalk rock belonging to the Niobrara formation. In the third it is again shale of the Pierre formation.

This meager information from outcrops is supplemented by a considerable body of facts derived from well drilling in the Basin. This has all shown that these beds are continued under the entire area.

EARLY DRIFT SHEETS

Little is known of the history of the earlier ice invasions in this area. Old drift sheets are found on the highlands, both east and west of the James basin. None have been reported from the Basin itself, however, except at its extreme southern limits where older drifts appear to be present in certain sections of the Missouri bluffs. It is evident that the ancient ice sheets crossed the territory, but whether their deposits were covered by those of the last ice invasion or whether they were entirely scooped up and reworked by the last ice sheet is not known.

It is known, however, that the second ice invasion, known as the Kansan, deposited an enormous amount of debris to a thickness of about 400 feet in the vicinity of the Big Sioux basin. This pile of drift on the bedrock plain made a lowland between it and the Wessington Hills-Orient escarpments which is now known as the James Basin.

THE WISCONSIN ICE SHEET

The last glacier to invade South Dakota belonged to a large ice sheet known as the Wisconsin because its deposits were first studied in that state. The movement of the front of this ice sheet apparently was held up by the enormous pile of glacial debris left at the head of the Big Sioux, but it sent a long tongue of ice down the James basin which spread eastward until the height of the Kansan drift sheet stopped it, and westward until it reached the Wessington-Orient escarpment. Certain moraines on top of these escarpments indicate that the ice may have climbed to their summits, but apparently did not get far over the upland beyond.

Due to climatic changes which have never been fully explained, the ice front began to melt faster than fresh ice could be moved into it from the north. This caused it to retreat northward. In the older descriptions it is apparently assured that the ice front retreated northward as a unit. The mapping here presented makes it appear that there were different rates of movement along different parts of the front, and that the ice front would be fairly static along some sections and retreat rapidly on neighboring sections. In general, however, the retreat at the center of the lobe was faster than at the sides and the resulting deposits are left in a festooned pattern with the James river occupying the axis of the festoons. This process of melting back the ice front continued until the James basin was entirely relieved of ice.

Each sheet of ice that invaded South Dakota was laden with a huge amount of rock debris rasped from the bedrock in Canada and collected from older drifts over which the ice rode. Upon melting, this debris was left behind forming the moraines and the surface features of the Basin.

SURFACE FORMS

Terminal Moraines

Wherever the retreating ice front or a section of it stood for any length of time, a ridge of boulder clay with pockets of sand and gravel accumulated. These were formed much as a pile would form at the end of a loading belt. If the end of the belt remained stationary, its load would be dumped in a pile, but if it was drawn steadily backward, a sheet of material would be left in its wake. Thus when the ice front remained stationary for a time a more or less ridge-like accumulation of glacial drift was formed. The piling, however, was not uniform and a characteristic of these ridges is the rough-hummocky surface. Such ridges are known as terminal moraines, and most of them are good for little accept pasture because their rough surfaces and stony soils prevent cultivation. They also make formidable impediments to travel because of the difficulty of building roads across them. These were well called the "rough moraines" by geologists of a generation ago.

In the area of the James basin considered in this report, there are four more or less distinct areas of terminal moraine topography representing positions where the ice front halted long enough, and where sufficient debris was furnished by the ice for the building of morainic ridges. Perhaps the most characteristic of these should be called the White Lake moraine. It is a distinct ridge, approximately 2 miles in width, extending from the Wessington escarpment, 2 miles south of Wessington Springs, south-westward through the village of White Lake. White Lake itself lies just below the western foot of the moraine. About 24 miles of its length lies in the area mapped. A second and shorter ridge has been called the Rockham moraine.[1] This moraine is about 15 miles in length and 4 miles in width. The city of Rockham lies at its eastern edge.

The largest area of terminal moraine lies south and west of Redfield and might be called the Cottonwood-Twin Lakes moraine. It is a tangle of morainic topography probably caused by several stands of the ice front in this vicinity. The Cottonwood Lake section of this moraine is about 13 miles long and averages two miles in width. Directly east of Cottonwood lake this moraine is connected to a large subtriangular shaped moraine about 14 miles long at its eastern edge and 7 miles from this edge to the westward pointing apex. The city of Redfield is about a mile from its northeastern point. Crandon is on the eastern edge and Twin Lakes lies in the center of the area. South of this moraine two patches of terminal topography occur, the southern and largest of which is about 7 miles in length and runs through the city of Bonilla.

The second largest single moraine lies some ten miles south and west of Aberdeen. It is about 22 miles in length and 4 miles in width. Its southern end lies between the cities of Chelsea and Northville and its northern tip lies a half mile south of Mina.

These are the largest single masses of terminal moraine topography, but scattered through the area are many smaller patches varying from 2 miles to 5 or 6 miles in length.

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1. E. P. Rothrock and R. V. Newcomb, Sand and Gravel Deposits in Potter and Faulk County, S. Dak. Geological Surv., R. I. 11, 1932.

Earlier geologists have connected these small areas to make a continuous line for the ice front at a given period. There is a certain continuity in the patches of moraine, but they probably represent not a single stand of the ice front, but the halt of various portions of the ice front in its retreat. Such a series of small moraines is noticeable at the northern end of the Wessington escarpment from the city of Lane northward to Vayland. Other small patches which appear to connect the Rockham and Cottonwood moraines and northeast of the Chelsea moraine could be considered as part of an ice stand in that region.

No generalization can be made on the height or shape of these terminal moraines. The narrow ones are apt to be very steep sided and rise abruptly above their surroundings. The wide ones may rise gradually developing a rougher and rougher topography up to a morainic crest and then gradually descend and smooth out into the surface of the ground moraine on the other side. Heights up to 80 feet were measured on some of these moraines and larger figures than this can be obtained for the wider ones.

Ground Moraines

When an ice front retreats at a more or less uniform rate, the sheet of debris left behind is spread more or less evenly over the surface. Hummocky slopes are not formed, and the undrained depressions on the surface are much shallower than on terminal moraines. The entire surface consists of gently rolling hills and shallow hollows which has been characterized as "swell and swale" topography, in contrast to the "knob and kettle" topography of terminal moraines. James Todd characterized these as the "smooth moraines".

No generalization can be made on the relief or roughness of ground moraines in the James basin. There may be anywhere from one to four or five swells in a quarter section, and the hollows may vary in depth from near flatness to 20 or 25 feet. Such differences spread over so much territory make a very smooth surface, and areas where relief is not more than 5 feet to the quarter section give the impression of flatness which is accentuated by the levelness of road grades crossing them. Since, as mentioned above, ground moraines cover nearly three fourths of the entire area mapped, particular attention should be given to them in any discussion of this region.

Meltwater Channels

Much of the water released by melting of the ice evaporated or soaked into the ground leaving little evidence of its existence. A major portion of it, however, drained away over the surface in front of the ice, some as sheets of water, but most as streams which had been formed by collection of rivulets on the ice and in front of it. These streams cut deep sluice ways into the moraines which carried the water along the ice front and finally away into the master drainage, the James river. As the meltwater torrents subsided, some of these channels were partially filled with sand and gravel.

These meltwater channels seam the ground moraine, in the area here considered, with steep-sided, flat-bottomed valleys having depths of 40 to 60 feet and widths varying from half a mile to a mile. Most of these channels have lines of swamps in the bottoms which are often connected by sluggish or intermittent streams.

These channels trend in a general southeasterly direction which is most noticeable in the southern part of the area mapped, between Mitchell and Huron. They show a remarkable straightness, until the north boundary of Davison County is reached. South of this line the channels swing eastward and flow toward the master drainage, the James valley. Between Redfield and Aberdeen the channels trend in a more north-south direction, swinging eastward in the vicinity of Redfield into the James river. The festoon pattern of the drainage around the front of the ice lobe is well shown by these channels. The best known channel lies between Lane and Mitchell, and is occupied by the valley of Firesteel Creek. About the middle of its course this channel splits into three parts, probably representing three stands of a reentrant in the ice front hinging at this point. Ten miles down stream the three channels again unite into a single one. A similar network of channels is observed west of Redfield where it crosses not only the ground moraine, but also the Rockham and Cottonwood lake terminal moraines.

Many of these end in flat outwashes into which they apparently emptied and in many cases spread sand and gravel, making loamy surfaces. Some others open directly into the Big Sioux itself, and still others appear to have little or no connection with any other channel or outwash.

Near the terminal moraines these channels usually contain deposits of sand and gravel. They are usually floored with a black silty or loamy soil. Gravels sometimes occur in terraces along their sides. They are, therefore, good prospecting grounds for sand and gravel where the material is not needed in too large quantities.

Kame and Esker Fields

Scattered here and there over the ground moraine are patches of small rounded hills of sand and gravel resembling a bee skep in shape. These hills are formed from sand and gravel which is washed into wells or moulins in stagnant ice. The swirling action of the water usually makes these moulins cylindrical in shape, and when the ice melts the sand and gravel filling the moulin is deposited on the surface like an ash heap. Kames seldom occur alone, but are usually in groups covering an area of anywhere from 40 to 640 acres. Many kames are small, 8 to 10 feet in height at the center. A few, however, were found which were 15 to 25 feet in height. The base diameters vary all the way from one or two hundred feet to an eighth of a mile. Examples of such kame fields are indicated on the accompanying map 6 miles north of Forestburg, 4 miles northwest of Wolsey, and in the vicinity of Miranda.

Long ridges of gravel are sometimes associated with these kame fields and sometimes occur by themselves crossing the hills and hollows of moraine promiscuously. Because of their sinuous courses, they were originally called serpent kames. This was later dropped for the Norse term osar which has become Anglicized to esker. These vary in length all the way from a quarter mile to 6 miles, and in height from 5 feet to 20 or 30 feet. Many are single ridges, others branch.

The material of which they are composed was washed into cracks and crevices in stagnant ice which subsequently melted, letting them down on the surface of the ground in the form in which they are now found.

All these eskers are composed of sand and gravel more or less perfectly sorted. Some have large boulders and clay pockets and so are not particularly good sources of sand and gravel; however, quite a number have been opened and used as a source of these materials.

The longest one mapped lies 4 miles west and 1 mile south of Tulare. From this point it wanders southward for 6 miles. Other long ones occur in the vicinity of Zell and 5 miles west of Broadland. These and many shorter ones are shown on the accompanying maps.

Aside from being possible sources of gravel, these eskers and kames have very little effect on the topography. They do not stand high above their surroundings in most instances, and since they are all on the ground moraine, they add little to the roughness of the topography.

Outwash Plains

Certain rather large, flat areas of particular interest to irrigation have been formed by outwash from the melting glacier. Torrents of water flowing from the ice front often spread sheets of sand, gravel, and silts in front of a terminal moraine. In other cases, waters from the meltwater channels described above, have poured on to low lands filling up the hollows and leaving a flat surface in front of the mouth of the channel. Much of this material is sandy, and in some places gravel pits and sand pits have been opened. Most of the outwash, however, is covered with a light, loamy soil sometimes underlain with gravel and sand, and sometimes with boulder clay.

These surfaces are flat as topography can be, and since most of them cover a township or more, are particularly well suited for irrigation.

The highest of these areas lies at the foot of the Wessington escarpment, the city of Lane occupying a spot on its southeastern end. This area is about 4 miles in width and extends northward from Lane and Wessington Springs approximately 20 miles. Its northern end is not far from the city of Wessington. A similar area lies along the James valley immediately north of Mitchell and along the southern side of Firesteel Valley west of Mitchell. Another outwash covering about four townships, lies south and east of the Cottonwood-Twin Lakes terminal moraine. One section lies about Tulare and a second section between the route of the Milwaukee Railroad and the James valley. Crandon is located on this outwash.

The city of Huron is located near the middle of an outwash which lies along the western side of the James valley.

It extends some 12 miles north of the city and a similar distance to the south of it. Its northern end has a width of about 8 miles and its southern end a width of about 4 miles. Huron lies just north of a constriction where the width is but little over a mile.

The type of outwash plain formed at the mouths of melt-water channels is best illustrated by the large area about Woonsocket. This area covers more than two townships and its southeastern end is very sandy. The flat south of Huron was also formed in a similar fashion. The small flat west of Tulare lies at the mouth of a long channel coming from Miranda and through the Rockham moraine.

Lake Dakota

The largest flat area in the region is the floor of ancient Lake Dakota which stretches from Redfield to Aberdeen and northward. It was mapped only to the James river valley although it lies on both sides of this valley. Its western shore line lay from 6 to 10 miles west of the river.

This lake was first described by James Todd[1] who assumed it was a lake because of certain laminated silts and the flatness of the floor. In the present survey the old beach lines and fore-deeps were recognized leaving no doubt as to its lake-bed character. Over some of this bottom the surface is covered with a loess-like silt. Other parts are covered with a very gummy clay, which bakes to a brick-like hardness. This lake presents an area of more than 10 townships (360 square miles) which slopes gently toward the south, the northern end lying at about 1306 feet sea level elevation, and the southern end at 1280, a slope of about 20 feet in 30 miles.

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1. J. E. Todd, The Moraines of the Missouri Coteau and Their Attendant Deposits, U. S. Geol. Surv., Bull. 144.

SURFACE FEATURES AND IRRIGATION

The details involved in irrigating all or any part of this area are too complicated for consideration in this report. A few generalizations are in order, however, which may be of interest in laying out a plan of irrigation for this region.

One set of problems involves getting the water from the source of supply, which in this case is the main ditch, which is to enter the James basin from the Oahe dam at some point north of Miller, to the various parts of the area where irrigation is contemplated. The second set of problems involves the laying out of laterals and of fields which can be served by water.

TRANSPORTATION OF WATER

It has been shown in another report[1] that the water will have to be brought across a divide north of Holabird at a sea level elevation of 1750 feet. From this divide, therefore, it should be possible for water to flow by gravity northward close to the base of the Orient escarpment passing west of Faulkton and ending somewhere near Ipswich. From the divide southward a ditch could lead water past Miller, close to the base of the Wessington escarpment and end somewhere between White Lake and Kimball. These statements are based on sea level elevations indicated on the map in various parts of the area. From these two mains the entire surface slopes eastward to the James valley, and, therefore, laterals could be constructed which would reach any part of the area which might be designated for irrigation. Over much of the ground moraine, few obstacles will be found which would make the construction of such main ditches and laterals difficult. However, the other glacial features which were mentioned above do offer rather formidable obstacles which must be overcome in carrying water across this region.

1. H. E. Brookman, Topography of the Low-Lying Area Across the Missouri Valley-James Basin Divide in Hyde and Hand Counties, S. Dak., S. Dak. Geol. Surv. R. I. # 51.

Terminal Moraines

Terminal moraines are high and rough and will require deep trenching if the ditches are to cross them. If they are to go around them long routes must be plotted which are more or less circuitous depending on the area to be reached. Heights of 60 or 80 feet, which are not uncommon in the terminal moraine areas, must be considered in any attempt to conduct water across them.

A long high ridge such as the White lake moraine would make a formidable barrier for any water brought from west of it. Such morainic tangels as those about Cottonwood lake and Twin Lakes and the Rockham moraine make long routes necessary if they are to be circumvented. A redeeming feature of these last moraines is the fact that meltwater channels cut through some of them which might be used as waterways for irrigation ditches.

Nearly two thirds of the western shore of the Lake Dakota flat cannot be reached directly from the west without crossing the Scatterwood Lake moraine.

Meltwater Channels

The meltwater channels described above also offer serious obstacles largely because of their depth and the fact that ditches cannot be built around them. The necessity of carrying water across a 40 to 60 foot trench will require expensive aqueducts. In order to reach the Lake Dakota bed from a main ditch passing Faulkton and Ipswich at least two such valleys must be crossed. In the vicinity of Redfield a ditch leaving the main between Faulkton and Orient would have to cross about a half dozen such channels to reach the flat areas along the James valley. At least three such channels would have to be crossed west of Huron and a similar number in the vicinity of Mitchell.

Portions might be used as water ways if main ditches or laterals had to move in the same direction as the channel. Their gravely bottoms, however, could allow undesirable leakage. Water would probably have to be transported across these channels in aqueducts at a considerable expense. The channels might, however, offer drainage for excess irrigation water from irrigated areas on neighboring uplands.

Ground Moraines

The ground moraine itself offers the disadvantage of undulating topography. Some parts of it can be crossed in relatively straight lines. Others, however, will require circuitous courses in order to maintain gradients necessary to cause water to flow without eroding.

These obstacles are not insurmountable. They are mentioned here simply because it is necessary to take them into consideration in any plan for transporting irrigation water into this area.

To outline the exact areas in which the surface lends itself to irrigation is beyond the scope of this report. Large scale mapping of small areas will have to be undertaken before this can be determined. Certain of the glacial features described above, however, offer themselves more readily to the laying out of ditches and irrigated fields than do others and the purpose of this report is to indicate where such mapping can be profitably undertaken.

IRRIGATION

Terminal Moraines

Of the physiographic features found in the area, only one group, the terminal moraines, offer little hope of irrigation. All of them stand above their surrounding ground moraines so that it would be necessary to run water up hill to reach most of their areas. It might be possible to bring water to some, like the northern end of the White Lake moraine south of Wessington Springs, but the irrigator would immediately be faced with the problem of laying out fields on a very rough surface. Reliefs of 20 to 50 feet crammed into a 5 or 10 acre area, with nothing but kettle holes into which to drain excess water, do not make easy irrigation, even though it may be an engineering possibility. The same topographic difficulty will be encountered on all patches of terminal moraine though the roughness varies considerably. The circuitous routes needed to carry water through such a country and the small fields which can be irrigated throws serious doubt on the practicability of such irrigation.

Meltwater Channels

The meltwater channels might offer some possibilities since most of them possess flat bottoms over much of their courses. As they are from a quarter to one-half mile wide, in most cases and in a few instances reach widths of nearly a mile, fair sized farms could be laid out in them. They do not offer tempting irrigation projects, however. The drainage in some is fairly good, but in most of them swamps occupy narrow channels or cover large areas of the bottoms indicating the poor drainage of these features. Such lakes as Platt lake, White lake, and Scatterwood lake are merely accentuated swamps in the bottoms of these meltwater channels. This condition exists in so many of them that no generalizations can be made as to which would be desirable for irrigated land and which would not. In general, however, the bottoms are low, gravel filled, and with an excess of water. Either rain or irrigation water could easily turn these bottoms into swamps.

Ground Moraine

The large area of ground moraine offers some irrigation possibilities. In the foregoing description it was pointed out that the surface of the ground moraine is undulating. Reliefs vary from two or three feet to fifteen or twenty feet in a quarter section. There is, however, great variation in the roughness of various parts of the ground moraine. Much of it is nearly flat and such areas are indicated on the accompanying map. These would offer some possibilities since water could be transported across the areas with a minimum of ditching, and irrigable fields could be laid out from the main ditch systems with a considerable ease. About 15 townships, 540 square miles, was mapped as being unusually flat and is recommended for further investigation. These are sprinkled throughout the area in patches covering one or two townships. In this mapping only those regions having reliefs of less than 5 feet to the quarter mile were considered usable. Nine such areas are indicated on the accompanying maps. Their location and approximate sea level elevation are as follows:

1. South of Ipswich	1600 ft.
2. North of Cresbard	1430 ft.
3. Between Faulkton and Cresbard	1500 ft.
4. Between Faulkton and Orient	1600 ft.
5. South of Burdett	1400 ft.

6. Near Wayland 1450 ft.
7. Near Virgil 1340 ft.
8. About Letcher and Loomis 1300 ft.
9. Near Mt. Vernon 1440 ft.

Though these areas cover only a small part of the total ground moraine, they offer some interesting possibilities if water can be brought to them. The compactness of these plains allows a large number of farms to be serviced in a group. Though they are widely scattered over the area, most of them are in places which would probably be crossed by ditches carrying water to the flater outwash and lake bed areas which are to be described. By using these flat areas in the ground moraine, therefore, it would be possible to spread the benefits of irrigation more widely through the valley than if the extremely flat outwash and lake bed areas alone were used.

Outwash and Lake Bed Areas

The largest and most nearly plane surfaces are those made by meltwaters. Where water flowed off an ice front in sheets, gravels, sands, and silts were spread as an apron before the ice front. Where meltwater channels debouched on land surfaces, large areas were covered with sands and silts deposited by the spreading waters. Where meltwaters ponded, silts and clays brought to it by glacial streams were deposited on the bottoms leaving wide flat floors.

Such areas offer excellent irrigation sites since in most cases they present easily worked soils and level or gently sloping surfaces which are excellent for laying out fields for irrigation. Most of the soils on these areas are light loams though a few areas are sandy enough to be blown into dunes. Portions of the lake beds also contain very heavy clays. These latter are local, however, and not characteristic of the outwash areas.

Though the outwashes and lake beds offer the best topographic conditions for irrigation, there are local disadvantages in soil and underground conditions which must be taken into consideration before irrigation is attempted. In most cases these silts at the surface make excellent irrigation without an excessive loss of water in transportation. Gravelly subsoils are prevelent, however, in some of the outwashes, especially near the source of materials and without a detailed study it would be impossible to indicate which parts of these flats would yield most readily to irrigation.

An investigation with this in mind should include the following areas:

1. The Firesteel Creek Area. This area lies west of Mitchell on the south bluff of Firesteel creek. Its main portion is about one and one half miles wide, and nine miles long in an east-west direction. A second area between Plankinton and Mt. Vernon connected with the Firesteel Creek area by a meltwater channel might also be included. This area contains about 22 square miles and lies at a sea level elevation of approximately 1400 feet.

2. The James Valley north of Mitchell. Along the James valley north of Mitchell there lies an outwash area at an elevation of about 1300 feet. It is cut by the channel of Firesteel creek and two lesser creeks to the north and south of Firesteel dividing it into four units. Part of the city of Mitchell lies at the west side of one of the smaller areas. This flat totals approximately 21 square miles.

3. The Cuthbert Outwash. This is a small area containing about 20 square miles lying between terminal moraines running northwest-southeast between Lane and Woonsocket. The city of Cuthbert is on its southeastern edge. It has an elevation of approximately 1297 feet at Cuthbert.

4. The Forestburg-Woonsocket Outwash. This is a large sub-rectangular area tending northwest-southeast about 4 miles in width and 13 miles in length, and covering approximately 65 square miles. Forestburg is at the southeast end and Woonsocket in the middle of the West edge of this area. Its elevation is about 1292 feet.

5. The Lane-Wessington Springs Area. This is the highest outwash in the region, and includes a belt of territory approximately 3 miles wide lying at the base of the Wessington escarpment. The city of Lane is at the extreme southeastern edge. From this point it reaches northwestward to within 4 miles of Wessington. Its northern extremity lies at an elevation of approximately 1420 feet, and near Lane at about 1380 feet. Terminal morainic topography occurs in patches through this outwash, but flat areas are of sufficient size to warrant their consideration for irrigation

development. There are approximately 70 square miles of this flat topography.

6. The Huron Outwash. This is a large area of flat country which lies along the western bluff of the James valley north and south of the city of Huron. It contains about 85 square miles. Its north-south length is approximately 25 miles and it is 8 miles east and west at its widest part. It is crudely triangular in shape, the northern end being the widest, and the apex of the triangle lying at the James valley 12 miles south of Huron. It lies at about 1280 feet above sea level and does not change much in height from north to south.

7. The Tulare-Crandon Outwash. This is a large area of outwash plain connected with the tangle of terminal moraine south of Redfield which includes Cottonwood and Twin lakes. There are really two areas in this outwash, one containing about a dozen square miles surrounding Tulare and a second and larger area lying east of the Milwaukee Railroad between Hitchcock, Crandon and Redfield. The eastern boundary is again the James valley. The two are separated by a ridge of terminal moraine which runs between Crandon and Tulare. This area contains some sixty square miles. The Tulare flat lies about 1315 feet above sea level while the section east of Crandon has an elevation of about 1300 feet.

8. Glacial Lake Dakota. Glacial Lake Dakota is by far the largest and perhaps the flatest area in the state of South Dakota. At least it is safe to say that there is no surface in the state which so nearly approaches a plane. It is the bottom of an ancient short-lived lake which formed in the James valley during the latter stages of the retreat of the Wisconsin ice.

Some of the deeper valleys which have been cut into this lake bottom have exposed glacial drift, but on top of this drift lies silt, some fine sands, and some very heavy clays. These are the materials which were washed off the ice and from the surrounding land areas into the lake and settled on the bottom filling up the hollows and leaving a surface which was as nearly flat as nature could make it. This surface is broken by a few drainage channels which formed as the lake waters drained off down the James valley during the latter stage of the lake's existence. Along its western edge lie fore-deeps, long swampy troughs in front of the beaches, which were hollowed out by wave action on the shallow bottom of the lake. The southern end of the lake is just north of Redfield and its northern end, north of Aberdeen. Its width, west of the James valley, is about 11 miles (it was not mapped on the eastern side of the valley). Thirty five miles of its length was mapped. In this distance it contains a total area of approximately 395 square miles. This is about half of the total outwash and lake bed area in the region covered by this report.

The elevation of this lake bed in the vicinity of Aberdeen is a little over 1300 feet. Toward Mellette it is a little below 1300 feet and north of Redfield it has an elevation of about 1280 feet. Thus there is a very slight general slope toward the south.

SUMMARY

The total area covered in this investigation included 4428 square miles. Of this total area, only about 1300 square miles, or roughly one third, appears to be easily suited to large scale irrigation. The rest of the region is either too high or too rough, or a combination of both. Of the 1300 square miles available to irrigation, about 770, or 60%, offer an outwash or lake bed surface on which large scale operations could be carried on to advantage. An additional 40%, or 514 square miles, offering similar possibilities, lie on the ground moraine.

The remaining 3100 square miles contain surfaces which cannot easily be irrigated. This is due, in some cases, to the roughness of the surface, in others to its elevation, and in still others to the deep and narrow meltwater channels which act as a barrier to water transportation.

The subject of the available water supply is not within the scope of this report. It will determine to a large extent, however, the amount of land that can be irrigated. It is dependent upon the amount of water storage the proposed Oahe dam makes available and the amount that can be transported into the James basin after evaporation, seepage, and other losses are deducted. These are matters for the consideration of the irrigation engineer. If an adequate supply can be made available and the obstacles to transporting it from the Missouri to the James basin overcome, a large acreage is available for irrigation.