STATE OF SOUTH DAKOTA
William J. Janklow, Governor

DEPARTMENT OF WATER AND NATURAL RESOURCES
Warren R. Neufeld, Secretary

GEOLOGICAL SURVEY
Duncan J. McGregor, State Geologist

Open-File Report No. 5-UR

GROUND-WATER STUDY FOR THE
CITY OF BISON, SOUTH DAKOTA

by

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Science Center
University of South Dakota
Vermillion, South Dakota
1981
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GENERAL INFORMATION

At the request of the City of Bison and the West River Conservancy Sub-District, the South Dakota Geological Survey conducted a ground-water study intermittently during August and September, 1974, and May, 1975. This study included the following work: (1) a review was made of the geology as mapped by the South Dakota Geological Survey (Bolín, 1955; Curtiss, 1955a, 1955b; Hoppin and Curtiss, 1955); (2) a total of 32 test holes were drilled, 30 with an auger rig and 2 with a rotary rig; (3) a well inventory was made (app. A); (4) water samples were collected and analyzed from 28 wells in the Bison area.

The study was financed by the South Dakota Geological Survey, the West River Conservancy Sub-District, and the City of Bison. The cooperation of the residents and especially Joe Delbert, Ron Kopren, and Dennis Lewton, City officials; Dennis Knutson and Stanley Soderstrom, well drillers; and Joe Pogue, US Forest Service, Lemmon, South Dakota, is acknowledged.

Bison has had six wells drilled over the years. The wells range in depth from 565 to 867 feet and produce water from sands and sandy zones in the Fox Hills Formation. Well No. 4 was contaminated during drilling by the private well driller when oil products were added to free stuck drilling rod. This well was abandoned due to the presence of oil product in the water. Water production of individual city wells has not been measured, but the combined total is probably about 50 gallons per minute which is about one-half of the City's needs based on the Farmers Home Administration standard estimate of one-fourth gallon per nin-
ute per person per day.

Since Bison has a population of approximately 400, the City needs about 100 gallons per minute to meet this standard. Water use at Bison has increased since 1968. Per capita consumption (it is assumed that per capita consumption is approximately equivalent to per meter consumption) has increased from 1,488 gallons in 1968 to 2,166 gallons in 1974 (table 1). The per meter consumption rose from 4,121 to 5,505. The total water used in 1968 according to water meter record books in the possession of Mr. Leroy Penor, was approximately 8.1 million gallons as compared to approximately 11.2 million gallons in 1973. Because the data were available only through August, only a projected water use for 1974 could be given; the figure is approximately 11.9 million gallons.

It is obvious that because of increased demands for water by consumers, the overall water use at Bison is increasing rapidly and will continue to do so. The increased use is not so much a matter of increasing population as it is in the increase in the number of home appliances and other domestic water use. Several new homes have been built in Bison during the last 5 years, and each of these is more "modern" than the older homes. Also in the new housing addition is the need for lawn-watering. Because of the inflation spiral, many families are planting gardens to supplement their food supply and these require water also.

GEOLOGIC INFORMATION

The exposed rocks (table 2 and fig. 1) belong to the Lud-
<table>
<thead>
<tr>
<th></th>
<th>1968¹</th>
<th>1973</th>
<th>1974</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total water use (gallons)</td>
<td>8,159,419</td>
<td>11,215,244</td>
<td>11,957,000</td>
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<tr>
<td>Average monthly water use (gallons)</td>
<td>679,952</td>
<td>934,603</td>
<td>996,377</td>
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<tr>
<td>Average number of meters</td>
<td>165</td>
<td>184</td>
<td>181²</td>
</tr>
<tr>
<td>Average monthly consumption per meter (gallons)</td>
<td>4,121</td>
<td>5,079</td>
<td>5,505²</td>
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<tr>
<td>Approximate population of Bison</td>
<td>457³</td>
<td>460³</td>
<td>460³</td>
</tr>
<tr>
<td>Approximate monthly per capita water consumption (gallons)</td>
<td>1,488</td>
<td>2,032</td>
<td>2,166</td>
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¹There is no significant reason that 1968 records were chosen and are shown for comparison purposes only.

²Data complete only through August; figure is projected total

³Source: "Comprehensive Water and Sewer Plan," Perkins County, Table III-7, 1971
<table>
<thead>
<tr>
<th>AGE</th>
<th>FORMATION</th>
<th>MAIN COMPOSITION</th>
<th>THICKNESS</th>
<th>WATER-BEARING CHARACTERISTICS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tertiary</td>
<td>Ludlow</td>
<td>Sand, shale, coal</td>
<td>300</td>
<td>Low permeability; yields small amount of water</td>
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<tr>
<td></td>
<td>Hot Creek</td>
<td>Shale, sand, coal</td>
<td>250</td>
<td>Low permeability; yields small amount of water</td>
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<tr>
<td></td>
<td>Fox Hills</td>
<td>Sandstone, shale, sand</td>
<td>350</td>
<td>Low permeability; yields small amount of water</td>
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<td></td>
<td>Pierre</td>
<td>Shale</td>
<td>1350</td>
<td>Impermeable; not an aquifer</td>
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<td>Niobrara</td>
<td>Chalk, shale</td>
<td>260</td>
<td>Low permeability; poor aquifer</td>
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<td>Garlin</td>
<td>Shale</td>
<td>40</td>
<td>Impermeable; not an aquifer</td>
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<td>Belle Fourche-Mistory</td>
<td>Shale</td>
<td>270</td>
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<td>Dakota (Newcastle)</td>
<td>Sandstone, shale</td>
<td>70</td>
<td>Partly permeable; low yield</td>
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<td>Skull Creek</td>
<td>Shale</td>
<td>170</td>
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<td>Fall River-Lakota</td>
<td>Sandstone, shale</td>
<td>200</td>
<td>Highly permeable; moderate yield (50 ppm); mineralized water</td>
</tr>
<tr>
<td>Jurassic-</td>
<td>Sundance-</td>
<td>Red and gray shale, gypsum, some sand</td>
<td>530</td>
<td>Low permeability; low yield</td>
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<tr>
<td>Triassic</td>
<td>Sp气势</td>
<td>Limestone</td>
<td>50</td>
<td>Low permeability; low yield</td>
</tr>
<tr>
<td>Permian</td>
<td>Minnetashta</td>
<td>Limestone</td>
<td>50</td>
<td>Impermeable; not an aquifer</td>
</tr>
<tr>
<td>Pennsylvanian-</td>
<td>Ophice</td>
<td>Red shale</td>
<td>50</td>
<td>Mostly permeable; average yields (00-200 ppm), highly mineralized water</td>
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<tr>
<td>Permian</td>
<td>Mokelmaus</td>
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<td>Mississippian</td>
<td>Madison</td>
<td>Limestone</td>
<td>1060</td>
<td>Highly permeable; high yield (300-400 ppm), highly mineralized water</td>
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<tr>
<td>Devonian-</td>
<td>Numrous formation</td>
<td>Limestone, dolomite, anhydrite, subaqueous, shale</td>
<td>630</td>
<td>Mostly permeable; yield unknown, water quality unknown, probably highly mineralized</td>
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<tr>
<td>Silurian</td>
<td>Red River</td>
<td>Dolomite, limestone</td>
<td>530</td>
<td>Low to high permeability; yield low to high, highly mineralized water</td>
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<td>Ordovician</td>
<td>Winnepeg</td>
<td>Shale</td>
<td>130</td>
<td>Impermeable, not an aquifer</td>
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<tr>
<td>Cambrian</td>
<td>Deadwood</td>
<td>Sandstone, shale, sand, limestone</td>
<td>500</td>
<td>Highly permeable; yield unknown; quality of water unknown</td>
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<tr>
<td>Precambrian</td>
<td>(Unnamed)</td>
<td>Granite</td>
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<td>Impermeable; not an aquifer</td>
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</table>
low Formation consisting mainly of yellow to gray sand, silt and silty clay. There are some ledges of hard sandstone interbedded with these sediments. Also exposed in various parts of the area are brown to black soft lignite coals and peat-clay layers. The Ludlow sediments are normally too fine to yield much water to wells. These rocks are 220 feet thick in South Dakota Geological Survey rotary test hole 20 south of town (figs. 2 and 3; app. B). The same sequence is about 280 feet thick in South Dakota Geological Survey rotary test hole 3 (Pete Deutschle) on the west side of Bison (figs. 2 and 4; app. B). The rock sequence drilled by these two holes should be representative of the rocks underlying the entire town. Therefore, because the author saw the rock cuttings as they were brought out of the drill hole, and because good electric logs were made on the hole, descriptions of the Ludlow, Hell Creek and Fox Hills Formations are based on information obtained from these two test holes (test holes 3 and 20, app. B).

Alluvial sand and silt lies on top of the Ludlow Formation along the course of Thunder Butte Creek. The alluvium is generally too thin or too fine-grained to be a source of ground water.

Next below the Ludlow is a series of sands, clays, and coals known as the Hell Creek Formation. Because of their drab appearance, early geologists called these the "somber beds". The Hell Creek sand layers can yield water to wells, but usually the sand is mixed with clay and therefore water will not move through these layers and into the well fast enough to supply
Figure 2. Map of Bison area showing test holes and wells with logs.
Figure 3
S&O Test Hole No. 20
SW SW NW Sec. 24 - T. 18 N. - R. 13 E. - Perkins Co.
Elev. 2717 feet - Depth 1010 feet
Date Drilled: May, 1975
by Fred V. Steele

TERTIARY

LUDLOW
Shale, gray, brown and black, silty; sand, gray, clay-filled and thin, hard sandstones; coal.

HELL CREEK
Shale, gray, silty; sand, gray, fine-to-medium, clay-filled; coal with brown and black slate.

CRETACEOUS

FOX HILLS
Shale, gray, sandy; sand, fine, clay-filled to flaky slate.

PIERRE
Shale, gray, smooth; some pyrite.
<table>
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<tr>
<th>FEET</th>
<th>RESISTANCE (OMHS)</th>
<th>(10^2)</th>
<th>(10^4)</th>
<th>(10^6)</th>
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<td>(100)</td>
<td>Shale, light gray, silt; sand, light gray, very fine to medium grained; shale, silt; coal.</td>
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<tr>
<td>(300)</td>
<td>Shale, medium gray to blue gray; sand, light gray, very fine to fine-grained, clay filled.</td>
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<tr>
<td>(500)</td>
<td>Shale, light grayish-blue, and shale, brown; sand, light bluish-gray, clay-filled, &quot;salt and pepper&quot;.</td>
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<td></td>
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</tbody>
</table>

**Figure 4**
SDGS Test Hole No. 3 (Pete Deutsche's Land)
NE NW NE SW - Sec. 13 - T. 18 N. - R. 13 E. - Perkins Co.
Elev. 2777 feet - Depth 910 feet
Date Drilled: May, 1975
by Fred V. Steace
sufficient water. This formation has a thickness of 210 feet in test hole 3 (app. B).

Below the Hell Creek is the Fox Hills Formation which consists of alternating sand, silt, and clay layers. The sand layers, resembling salt and pepper, provide only small amounts of water to wells because the sands are usually mixed with clay. Bison's water wells are completed in several of these sand layers in the Fox Hills Formation. The Fox Hills is at least 320 feet thick in test hole 3 (app. B). The character of these formations is also shown in well logs in Appendices C and D.

Beneath the three formations just described, is a series of rocks as much as 7,500 feet thick which are summarized in table 2. This table is based on information from the Shell No. 1 Veal oil test drilled 8 miles southeast of town in 1952.

GROUND-WATER INFORMATION

Many of the formations described in table 2 are aquifers but there is no definite information on the amount of water a well tapping them would produce (some estimates are shown on the last column of table 2). There is some information on the quality of water from these deeper formations shown in table 3. Quality of water from the shallower formations, namely the alluvium (Qai), the Ludlow (Tpi), Hell Creek (Kh), and Fox Hills (Kf) is generally good, although it is quite variable (table 4).

As a whole, water from the Ludlow Formation is the best in the area, although locally some of this water is highly mineralized. Water with less dissolved chemicals in the upper part of
<table>
<thead>
<tr>
<th>Formation</th>
<th>Depth</th>
<th>Total Solids</th>
<th>Sodium</th>
<th>Chloride</th>
<th>Calcium</th>
<th>Sulfate</th>
<th>Magnesium</th>
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<td>Fall River-</td>
<td>3854-</td>
<td>3,857</td>
<td>1,230</td>
<td>804</td>
<td>6</td>
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<td>Lakota</td>
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<td></td>
<td></td>
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<tr>
<td>Minnelusa</td>
<td>5368-</td>
<td>30,336</td>
<td>10,000</td>
<td>12,660</td>
<td>917</td>
<td>6,000</td>
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<td></td>
<td>5418</td>
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<tr>
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<td>5479-</td>
<td>69,340</td>
<td>22,040</td>
<td>40,320</td>
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<td>Madison</td>
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<td>Devonian</td>
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<tr>
<td>Deadwood</td>
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<td>578</td>
<td>3,850</td>
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<tr>
<td>Sample</td>
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<td>Magnesium</td>
<td>Sodium</td>
<td>Chloride</td>
<td>Bicarbonate</td>
<td>TDS</td>
<td>From Water Supply</td>
</tr>
<tr>
<td>--------</td>
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<td>-----------</td>
<td>--------</td>
<td>----------</td>
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<tr>
<td>Don Hickory</td>
<td><strong>410</strong></td>
<td><strong>820</strong></td>
<td><strong>410</strong></td>
<td><strong>720</strong></td>
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<td><strong>3</strong></td>
<td><strong>4</strong></td>
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<td><strong>380</strong></td>
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<td><strong>610</strong></td>
<td><strong>320</strong></td>
<td><strong>440</strong></td>
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<td><strong>200</strong></td>
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<td><strong>280</strong></td>
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<td><strong>280</strong></td>
<td><strong>430</strong></td>
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<td>Ralph Keel</td>
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<td><strong>590</strong></td>
<td><strong>240</strong></td>
<td><strong>410</strong></td>
<td><strong>240</strong></td>
<td><strong>0</strong></td>
<td><strong>2</strong></td>
</tr>
<tr>
<td>Ralph Keel</td>
<td><strong>240</strong></td>
<td><strong>590</strong></td>
<td><strong>240</strong></td>
<td><strong>410</strong></td>
<td><strong>240</strong></td>
<td><strong>0</strong></td>
<td><strong>2</strong></td>
</tr>
<tr>
<td>Tad Broshol</td>
<td><strong>220</strong></td>
<td><strong>580</strong></td>
<td><strong>220</strong></td>
<td><strong>390</strong></td>
<td><strong>220</strong></td>
<td><strong>0</strong></td>
<td><strong>2</strong></td>
</tr>
<tr>
<td>Tad Broshol</td>
<td><strong>220</strong></td>
<td><strong>580</strong></td>
<td><strong>220</strong></td>
<td><strong>390</strong></td>
<td><strong>220</strong></td>
<td><strong>0</strong></td>
<td><strong>2</strong></td>
</tr>
<tr>
<td>Blue City No. 1</td>
<td><strong>320</strong></td>
<td><strong>630</strong></td>
<td><strong>320</strong></td>
<td><strong>590</strong></td>
<td><strong>320</strong></td>
<td><strong>2</strong></td>
<td><strong>4</strong></td>
</tr>
<tr>
<td>Blue City No. 1</td>
<td><strong>320</strong></td>
<td><strong>630</strong></td>
<td><strong>320</strong></td>
<td><strong>590</strong></td>
<td><strong>320</strong></td>
<td><strong>2</strong></td>
<td><strong>4</strong></td>
</tr>
<tr>
<td>Blue City No. 5</td>
<td><strong>290</strong></td>
<td><strong>600</strong></td>
<td><strong>290</strong></td>
<td><strong>550</strong></td>
<td><strong>290</strong></td>
<td><strong>1</strong></td>
<td><strong>3</strong></td>
</tr>
<tr>
<td>Blue City No. 5</td>
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<td><strong>600</strong></td>
<td><strong>290</strong></td>
<td><strong>550</strong></td>
<td><strong>290</strong></td>
<td><strong>1</strong></td>
<td><strong>3</strong></td>
</tr>
<tr>
<td>Blue City No. 1</td>
<td><strong>320</strong></td>
<td><strong>630</strong></td>
<td><strong>320</strong></td>
<td><strong>590</strong></td>
<td><strong>320</strong></td>
<td><strong>2</strong></td>
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<tr>
<td>Blue City No. 1</td>
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<td><strong>630</strong></td>
<td><strong>320</strong></td>
<td><strong>590</strong></td>
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<td><strong>290</strong></td>
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<td><strong>290</strong></td>
<td><strong>550</strong></td>
<td><strong>290</strong></td>
<td><strong>1</strong></td>
<td><strong>3</strong></td>
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<tr>
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<td><strong>590</strong></td>
<td><strong>240</strong></td>
<td><strong>410</strong></td>
<td><strong>240</strong></td>
<td><strong>0</strong></td>
<td><strong>2</strong></td>
</tr>
<tr>
<td>Ralph Keele</td>
<td><strong>240</strong></td>
<td><strong>590</strong></td>
<td><strong>240</strong></td>
<td><strong>410</strong></td>
<td><strong>240</strong></td>
<td><strong>0</strong></td>
<td><strong>2</strong></td>
</tr>
<tr>
<td>Don Hickory</td>
<td><strong>410</strong></td>
<td><strong>820</strong></td>
<td><strong>410</strong></td>
<td><strong>720</strong></td>
<td><strong>410</strong></td>
<td><strong>3</strong></td>
<td><strong>4</strong></td>
</tr>
<tr>
<td>Don Hickory</td>
<td><strong>410</strong></td>
<td><strong>820</strong></td>
<td><strong>410</strong></td>
<td><strong>720</strong></td>
<td><strong>410</strong></td>
<td><strong>3</strong></td>
<td><strong>4</strong></td>
</tr>
</tbody>
</table>

**TABLE 4. Chemical Analyses of Water Samples from the Bismarck Area**

Sample analysis was performed by the South Dakota Geologist Survey. Source: MTL, Salton, TDL, Salton formation, Ft. Meade Creek formation, FT, For Hills formation. The wells with no number are shown on Figure 1; some of these wells are outside the area of the map.

Sample a United States Environmental Protection Agency "National Interim Primary Drinking Water Regulations" - December 2, 1975 (Modifiable Limits)

Sample b United States Environmental Protection Agency "National Secondary Drinking Water Regulations" - July 19, 1979 (Recommended Limits)
the Ludlow is probably explained by direct percolation of rain and snowmelt into these sandy shales.

The next best quality of water is from the alluvium. Alluvium is found only under the bottomland along Thunder Butte Creek and South Fork of the Grand River. Deposits of alluvium are small and thin and would not yield large amounts of water to wells.

In contrast, water from the Hell Creek and Fox Hills Formations is slightly more mineralized as can be seen in Table 4. Water from the various formations can be characterized as follows:

<table>
<thead>
<tr>
<th>Formation</th>
<th>Quality</th>
<th>Minerals</th>
<th>Total Solids</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alluvium (Qal)</td>
<td>Hard</td>
<td>Calcium Sulfate</td>
<td>Moderate</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Total Solids</td>
</tr>
<tr>
<td>Ludlow (Tpl)</td>
<td>Hard</td>
<td>Sodium Sulfate</td>
<td>Moderate to</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>High</td>
</tr>
<tr>
<td>Hell Creek (Kh)</td>
<td>Soft</td>
<td>Sodium Sulfate</td>
<td>Excessively</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>High</td>
</tr>
<tr>
<td>Fox Hills (Kf)</td>
<td>Soft</td>
<td>Sodium Sulfate and Sodium Chloride</td>
<td>Moderate to High</td>
</tr>
</tbody>
</table>

Test holes drilled by the South Dakota Geological Survey auger drilling rig in the alluvium along the South Grand River, about 6 miles north of Bison, indicated as much as 20 feet of saturated sand and gravel in the SW corner NW 1/4 sec. 7, T. 19 N., R. 14 E. The Survey recommended that the city drill a test well at this location, but no aquifer material was found and the location was abandoned.

ALTERNATIVES FOR CITY WATER SUPPLY

Recommendations to the City of Bison as to a solution to
their water problem are in the form of several alternatives. These alternatives are discussed below.

Alternative 1: Drill additional wells into Fox Hills

The City can continue to use their present water supply and drill additional wells as the need arises for additional water. This probably is the most practical alternative for the City. Because the Fox Hills aquifer is fine-grained, care should be taken to ensure that wells are properly completed and developed.

One consideration to be aware of is that prolonged pumping of water from the Fox Hills Formation throughout the City well field may be causing the static water level to be lowered in a general "cone-of-depression" surrounding the City. (See app. A, water levels in the City wells appear to be considerably lower than several nearby private wells completed in the same formation.) Because the Fox Hills allows the horizontal (and to a lesser extent, vertical) passage of water at a slow rate and because there are no "veins" or other highly permeable zones, sites for future wells can be selected on the basis of convenience to pipelines and surface irregularities. It might be a good idea to select future sites at convenient locations well outside the possible "cone-of-depression," even though the cost of building pipelines is fairly high. Continued sustained water withdrawals from the Fox Hills beneath Bison may continue to lower the static water level.

Alternative 2: Build surface reservoir

Many towns and cities around the State rely on surface reser-
voirs for part or all of their water supplies. Surface reservoirs have disadvantages such as the need for treatment and the risk of drying up during drought. A surface reservoir could provide water for fire protection, irrigation and other similar uses, at the same time saving the well water for drinking, cooking, and other uses. This would require separate water mains and would be an added expense to the town.

Alternative 3: Pipe water from Shadehill Reservoir

The City may wish to consider building a pipeline from Shadehill Reservoir approximately 14 miles across country. Because this reservoir is maintained by the South Dakota Department of Game, Fish and Parks, an agreement would have to be negotiated with that agency.

Alternative 4: Drill North Grand River well

There may be a possibility of obtaining a large yield of shallow ground water from the alluvium along the North Grand River, about 20 miles north of town, upstream from the tailwaters of Shadehill Reservoir. The well or well field should be far enough above Shadehill to ensure exclusion of surface water at times of high water and flood water. Test drilling would have to be done in that area to determine the feasibility of this alternative.

Alternative 5: Drill 4,000-foot well

Another choice left to the City is to drill a well approximately 4,000 feet in depth, to tap the Fall River-Lakota aquifer (table 2). This aquifer probably would provide 50 gallons per
minute, or more, of highly mineralized ground water. The water should be under enough artesian pressure to raise the water to a static level of about 600 to 700 feet below land surface. The quality of water would be similar to the partial analysis below:

Shell No. 1 Yeal, SE 1/4 SE 1/4, sec. 7, T. 17 N., R. 15 E.; drilled in 1952; water from Fall River-Lakota at a depth between 3854 to 3855 feet.

<table>
<thead>
<tr>
<th>Parts per Million</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total solids</td>
</tr>
<tr>
<td>Sodium</td>
</tr>
<tr>
<td>Chloride</td>
</tr>
<tr>
<td>Calcium</td>
</tr>
<tr>
<td>Sulfate</td>
</tr>
<tr>
<td>Magnesium</td>
</tr>
</tbody>
</table>

Other aquifers lie below the Fall River-Lakota that would supply adequate water, but the quality of the water would probably be even less desirable than that from the Fall River-Lakota.

CONCLUSION

The present study did not reveal any coarse-grained water-bearing material within the Ludlow, Hell Creek, or Fox Hills Formations that would yield large amounts of water to high capacity wells. Instead it was found that these formations are fine-grained with low permeability. Thus future wells completed in any of these formations will probably yield water at about the same rate as present wells produce in the immediate Bison area. The City of Bison, therefore, may select one or more of the several
alternatives that are open to them in order to ensure an adequate future water supply.

REFERENCES CITED


Curtiss, R. E., 1955a, Areal geology of the Cash quadrangle: South Dakota Geol. Survey, map and text.

------- 1955b, Areal geology of the Date quadrangle: South Dakota Geol. Survey, map and text.

## APPENDIX A

**Well records in the Bison area**

Information was obtained from interviews with well owners and from city files.

<table>
<thead>
<tr>
<th>Name of owner or tenant</th>
<th>Location</th>
<th>Reported depth (feet)</th>
<th>Reported date of water use</th>
<th>Reported date of water drilled</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rudolph Larson</td>
<td>S, 17 N., R. 15 E.</td>
<td>600</td>
<td>1953</td>
<td>1953</td>
</tr>
<tr>
<td>Errol Hall</td>
<td>S, 17 N., R. 15 E.</td>
<td>420</td>
<td>1975</td>
<td>1975</td>
</tr>
<tr>
<td>David Storm</td>
<td>N, 17 N., R. 13 E.</td>
<td>380</td>
<td>1949</td>
<td>1949</td>
</tr>
<tr>
<td>Bob Hanson</td>
<td>N, 17 N., R. 13 E.</td>
<td>180</td>
<td>1940</td>
<td>1940</td>
</tr>
<tr>
<td>Bob Hanson</td>
<td>S, 17 N., R. 13 E.</td>
<td>167</td>
<td>1940</td>
<td>1940</td>
</tr>
<tr>
<td>Alex Kutsche</td>
<td>S, 17 N., R. 13 E.</td>
<td>110</td>
<td>1940</td>
<td>1940</td>
</tr>
<tr>
<td>Leland Hanson</td>
<td>S, 17 N., R. 13 E.</td>
<td>38</td>
<td>1940</td>
<td>1940</td>
</tr>
</tbody>
</table>

Use of water: S, stock; D, domestic; M, municipal.
<table>
<thead>
<tr>
<th>Location</th>
<th>Coordinates</th>
<th>Depth (FT)</th>
<th>Category</th>
<th>Year</th>
</tr>
</thead>
<tbody>
<tr>
<td>Leland Hanson</td>
<td>SE1/4SE1/4SW1/4 sec. 9, T. 18 N., R. 13 E.</td>
<td>286</td>
<td>S</td>
<td>1959</td>
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<tr>
<td>Leland Hanson</td>
<td>SE1/4NE1/4SW1/4 sec. 10, T. 18 N., R. 13 E.</td>
<td>120</td>
<td>S</td>
<td>1963</td>
</tr>
<tr>
<td>Mick Almen</td>
<td>NE1/4SE1/4SW1/4 sec. 11, T. 18 N., R. 13 E.</td>
<td>180</td>
<td>S</td>
<td>1963</td>
</tr>
<tr>
<td>Mick Almen</td>
<td>NW1/4NW1/4NE1/4 sec. 11, T. 18 N., R. 13 E.</td>
<td>500</td>
<td>D,S</td>
<td>1930</td>
</tr>
<tr>
<td>Leroy Penor</td>
<td>SE1/4NW1/4NW1/4 sec. 12, T. 18 N., R. 13 E.</td>
<td>350</td>
<td>S</td>
<td>1959</td>
</tr>
<tr>
<td>Bison City No. 1</td>
<td>NE1/4NW1/4NE1/4 sec. 13, T. 18 N., R. 13 E.</td>
<td>685</td>
<td>M</td>
<td>2950</td>
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<tr>
<td>SDGS (Deuschle) Test Hole 3</td>
<td>NE1/4NW1/4NE1/4 sec. 13, T. 18 N., R. 13 E.</td>
<td>813</td>
<td>M</td>
<td>1975</td>
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<tr>
<td>Bison City No. 6</td>
<td>NE1/4NW1/4NE1/4 sec. 13, T. 18 N., R. 13 E.</td>
<td>784</td>
<td>M</td>
<td>1969</td>
</tr>
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<td>Bison City No. 2</td>
<td>NE1/4NW1/4NE1/4 sec. 13, T. 18 N., R. 13 E.</td>
<td>729</td>
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<td>Bison City Test Well</td>
<td>NE1/4 sec. 13, T. 18 N., R. 13 F.</td>
<td>1,082</td>
<td>None</td>
<td>1950-52</td>
</tr>
<tr>
<td>Herb Kolb</td>
<td>NW1/4NW1/4NW1/4 sec. 13, T. 18 N., R. 13 E.</td>
<td>136</td>
<td>None</td>
<td>1964</td>
</tr>
<tr>
<td>Bison City No. 3</td>
<td>SE1/4SE1/4NW1/4 sec. 13, T. 18 N., R. 13 E.</td>
<td>867</td>
<td>M</td>
<td>1954</td>
</tr>
<tr>
<td>Bison City No. 5</td>
<td>SE1/4SE1/4NW1/4NW1/4 sec. 13, T. 18 N., R. 13 E.</td>
<td>835</td>
<td>M</td>
<td>1960</td>
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<td>Name of owner or tenant</td>
<td>Location</td>
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<td>Reported depth to water (feet)</td>
<td>Use of water</td>
</tr>
<tr>
<td>-------------------------</td>
<td>----------</td>
<td>-----------------------</td>
<td>-------------------------------</td>
<td>--------------</td>
</tr>
<tr>
<td>Forest White</td>
<td>SW 80N80W 80N80E sec. 13, T. 18 N., R. 13 E.</td>
<td>360</td>
<td>180</td>
<td>D</td>
</tr>
<tr>
<td>Irwin Tescher</td>
<td>SW 80N80W 80N80E sec. 13, T. 18 N., R. 13 E.</td>
<td>240</td>
<td>180</td>
<td>D, S</td>
</tr>
<tr>
<td>Bison City No. 4</td>
<td>SW 80N80W 80N80E sec. 13, T. 18 N., R. 13 E.</td>
<td>1,400</td>
<td>---</td>
<td>None</td>
</tr>
<tr>
<td>Don McKinstry</td>
<td>NE 1/4 SE 1/4 SW 1/4 sec. 13, T. 18 N., R. 13 E.</td>
<td>128</td>
<td>80</td>
<td>D, S</td>
</tr>
<tr>
<td>Alex Krischer</td>
<td>SE 1/4 SE 1/4 SW 1/4 sec. 13, T. 18 N., R. 13 E.</td>
<td>329</td>
<td>200</td>
<td>D, S</td>
</tr>
<tr>
<td>Adolph Aaker</td>
<td>NW 1/4 NE 1/4 SW 1/4 sec. 16, T. 18 N., R. 13 E.</td>
<td>63</td>
<td>20</td>
<td>S</td>
</tr>
<tr>
<td>Alfred Huepel</td>
<td>NW 1/4 NE 1/4 SW 1/4 sec. 16, T. 18 N., R. 13 E.</td>
<td>60</td>
<td>---</td>
<td>S</td>
</tr>
<tr>
<td>Adolph Aaker</td>
<td>NE 1/4 SE 1/4 NE 1/4 sec. 17, T. 18 N., R. 13 E.</td>
<td>225</td>
<td>---</td>
<td>S</td>
</tr>
<tr>
<td>Alfred Huepel</td>
<td>SW 1/4 SE 1/4 SE 1/4 sec. 21, T. 18 N., R. 13 E.</td>
<td>410</td>
<td>---</td>
<td>D</td>
</tr>
<tr>
<td>Don McKinstry</td>
<td>NE 1/4 NE 1/4 NE 1/4 sec. 23, T. 18 N., R. 13 E.</td>
<td>24</td>
<td>12</td>
<td>S</td>
</tr>
<tr>
<td>Don McKinstry</td>
<td>NE 1/4 NE 1/4 NE 1/4 sec. 23, T. 18 N., R. 13 E.</td>
<td>12</td>
<td>4</td>
<td>S</td>
</tr>
<tr>
<td>Don McKinstry</td>
<td>SE 1/4 NE 1/4 NE 1/4 sec. 23, T. 18 N., R. 13 E.</td>
<td>12</td>
<td>2</td>
<td>S</td>
</tr>
<tr>
<td>Name of owner or tenant</td>
<td>Location</td>
<td>Reported depth (feet)</td>
<td>Reported depth to water (feet)</td>
<td>Use of water</td>
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<tr>
<td>-------------------------</td>
<td>----------</td>
<td>----------------------</td>
<td>------------------------------</td>
<td>--------------</td>
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<tr>
<td>Morris Jensen</td>
<td>NW\NW\NW\NW\NW\NW, sec. 13, T. 19 N., R. 13 E.</td>
<td>340</td>
<td>Flowing 2 gpm</td>
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</tr>
<tr>
<td>Morris Jensen</td>
<td>NW\NW\NW\NW\NW\NW, sec. 13, T. 19 N., R. 13 E.</td>
<td>14</td>
<td>---</td>
<td>S</td>
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<tr>
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<td>173</td>
<td>161</td>
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<td>120</td>
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</tr>
<tr>
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<td>400</td>
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<tr>
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<tr>
<td>Morris Jensen</td>
<td>NW\NW\NW\NW\NW\NW, sec. 16, T. 19 N., R. 14 E.</td>
<td>370</td>
<td>190</td>
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<tr>
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<td>NW\NW\NW\NW\NW\NW, sec. 19, T. 19 N., R. 14 E.</td>
<td>120</td>
<td>60</td>
<td>S</td>
</tr>
<tr>
<td>Morris Jensen</td>
<td>NW\NW\NW\NW\NW\NW, sec. 19, T. 19 N., R. 14 E.</td>
<td>340</td>
<td>185</td>
<td>S</td>
</tr>
<tr>
<td>Morris Jensen</td>
<td>NW\NW\NW, sec. 22, T. 19 N., R. 14 E.</td>
<td>110</td>
<td>---</td>
<td>S</td>
</tr>
<tr>
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<td>NW\NW\NW\NW\NW\NW, sec. 35, T. 19 N., R. 14 E.</td>
<td>218</td>
<td>188</td>
<td>D,S</td>
</tr>
</tbody>
</table>
APPENDIX B

Logs of test holes drilled by the South Dakota Geological Survey (for map location, see fig. 2)

SDGS Test Hole 1 (Auger hole)
Location: NW¼,SW¼,NE¼,SW¼ sec. 9, T. 18 N., R. 13 E.
0- 4 Silt, brown, clayey, dry
4- 16 Sand, yellow-brown, dry; fine, some clay; moist
16- 18 Sand, yellow-brown, fine, little clay, saturated(?)

SDGS Test Hole 2 (Auger hole)
Location: SE¼,SW¼,NE¼,SW¼ sec. 10, T. 18 N., R. 13 E.
0- 4 Silt, light brown, some clay, dry
4- 31 Sand, light brown, fine, some clay
31- 36 Sand, gray-black, medium to fine, clayey, saturated
36- 44 Clay, gray, black, brown-black, silty, moist, peat and/or coal

SDGS Test Hole 3 (Rotary hole 2, see enlarged map, fig. 2) (Deutsche)
Location: NE¼,NE¼,SW¼ sec. 13, T. 18 N., R. 13 E.
0- 10 Clay, yellow-brown, sandy
10- 60 Shale, medium gray, silty, smooth
60- 65 Coal, black, soft
65- 75 Shale, medium to dark gray, smooth
75- 83 Sand, fine to medium, some clay filling
83- 120 Shale, medium to dark gray, some sandy
120-129 Coal, black, hard, sharp
125-130 Shale, sandy, black
130-145 Sand, light gray, clay filled
145-165 Shale, gray, smooth, firm
165-170 Coal, black and brown lignite
170-190 Shale, black
190-195 Sandstone, light gray, hard; sandy clay
195-200 Coal, hard, blocky
200-200 Shale, gray, silty, smooth, some coal
300-350 Sand, firm, bluish-gray, clay-filled
350-370 Shale, medium olive-gray, smooth
370-420 Sand, medium gray, very fine to medium
420-425 Shale, medium gray, silty, smooth, firm
425-430 Sand, light gray, very fine, clay-filled
430-513 Shale, gray, green, smooth
SDGS Test Hole 3 -- continued.

510-525 Sand, light bluish-gray, fine to very fine, clay-filled.
525-700 Shale, grayish-green, smooth, silty to sandy
700-780 Shale, gray, some shows pyrite, hard, some clay-filled sand.
780-785 Sand, medium gray, fine, clay-filled, salt and pepper.
785-810 Shale, medium gray, smooth, some sand, some soft brown clay.

SDGS Test Hole 4 (Auger hole)
Location: SE<sub>4</sub>, NW<sub>1/4</sub>, NE<sub>1/4</sub>, sec. 15, T. 18 N., R. 13 E.

0-17 Silt, light brown, clayey, dry, calcareous
17-44 Sand, medium brown, little clay; saturated
44-69 Silt to very fine sand, medium and dark gray, some black clay.

SDGS Test Hole 5 (Auger hole)
Location: SW<sub>1/4</sub>, SW<sub>1/4</sub>, NW<sub>1/4</sub>, sec. 15, T. 18 N., R. 13 E.

0-4 Silt and fine sand, light brown, clayey, dry
4-5 Rocks, crystallines
5-25 Sand, brownish-yellow, fine, clayey; saturated
25-34 Clay, medium to dark gray, little silt; moist
34-35 Silt, dark gray, clayey; moist, wouldn't penetrate.

SDGS Test Hole 6 (Auger hole)
Location: SE<sub>4</sub>, SE<sub>1/4</sub>, SW<sub>1/4</sub>, sec. 15, T. 18 N., R. 13 E.

0-8 Silt, light brown, clayey, dry, plant fragments
8-10 Clay, black, silty; saturated, plant fragments
10-11 Silt, light brown and light gray, saturated, clayey
11-23 Clay, medium gray, silty, moist, fairly hard
23-26 Clay, gray, brown; saturated
26-37 Sand, medium gray, fine; moist
37-49 Clay, gray-brown, silty, moist, hard

SDGS Test Hole 7 (Auger hole)
Location: SW<sub>1/4</sub>, NE<sub>1/4</sub>, sec. 15, T. 18 N., R. 13 E.

0-5 Silt, brown, very clayey, moist.
SDGS Test Hole 7 -- continued.

5- 8 Clay, brown, very silty, moist, some sand and gravel
8- 13 Clay, yellow-brown and red-brown, silty, saturated
13- 18 Silt, brown, clayey, saturated, water started coming up
18- 20 Clay, gray and black, silty, moist, peat(?)
20- 31 Sand, gray, very fine, clayey, moist, some very clayey sand
31- 35 Silt, gray, very clayey, moist
35- 44 Clay, gray, silty, some bentonite

SDGS Test Hole 8 (Auger hole)
Location: NW\(\frac{1}{4}\)SW\(\frac{1}{4}\)SW\(\frac{1}{4}\)SW\(\frac{1}{4}\) sec. 17, T. 18 N., R. 13 E.

0- 3 Sand, light brown, clayey; dry
3- 4 Clay, brown, silty; moist
4- 7 Sand, brown, medium, slightly clayey; saturated
7- 8 Silt, yellow-brown and light gray; saturated
8- 10 Clay, medium gray, silty; moist to saturated, plant fragments
10- 19 Silt, medium and dark gray, clayey, moist

SDGS Test Hole 9 (Auger hole)
Location: SE\(\frac{1}{4}\)SE\(\frac{1}{4}\)SE\(\frac{1}{4}\)SE\(\frac{1}{4}\) sec. 18, T. 18 N., R. 13 E.

0- 4 Sand, brown, coarse, clayey, saturated at 4 feet
4- 8 Clay, yellow-brown, silty, saturated
8- 13 Silt, yellow-brown, clayey, moist
13- 19 Silt, light gray, clayey (upper part may be saturated)

SDGS Test Hole 10 (Auger hole)
Location: NW\(\frac{1}{4}\)NW\(\frac{1}{4}\)NW\(\frac{1}{4}\)NW\(\frac{1}{4}\) sec. 20, T. 18 N., R. 13 E.

0- 4 Sand, brown, very coarse, clayey, dry, some gravel
4- 7 Sand, brown, coarse to very coarse, clayey, moist
7- 8 Clay, brown, sandy, moist
8- 12 Sand, brown, coarse, clayey, very moist
12- 16 Clay, brown and some gray, sandy, moist
16- 24 Silt, gray, clayey, moist, some coal and/or peat fragments

25
SDGS Test Hole 11 (Auger hole)
Location: NE\NW\NW\NW\NW sec. 20, T. 18 N., R. 13 E.
0- 2  Sand, light brown, fine, clayey; dry
7- 3  Gravel, brown, fine; moist
3- 8  Silt, tan, clayey; moist, calcareous
8-10  Clay, medium gray, silty; moist, noncalcareous
10-12 Silt, medium gray, clayey; moist, some black layers
12-19 Clay, medium gray, slightly silty; moist, noncalcareous bentonite

SDGS Test Hole 12 (Auger hole)
Location: SE\NW\NW\NW\NW sec. 21, T. 18 N., R. 13 E.
0- 5  Silt, brown, some very fine sand, clayey, slightly moist
7- 5  Sand, brown, very fine, saturated
5-13 Silt, brown and dark brown, clayey, saturated
8-19 Clay, gray, very silty, saturated

SDGS Test Hole 13 (Auger hole)
Location: NW\NW\NW\NW\NW sec. 21, T. 18 N., R. 13 E.
0- 2  Clay, light tan, sandy; dry
2- 4  Silt to fine sand, brown; moist, some coarse sand
7- 7  Sand, brown, fine, moist
7-11 Sand, brown, medium, very clayey, saturated
11-13 Sand, brown, very fine, clayey, saturated
13-14 Silt, light gray, clayey, moist
14-20 Gravel, brown, coarse, very clayey, saturated
20-27 Clay, gray, very silty; saturated, hard, could not penetrate

SDGS Test Hole 14 (Auger hole)
Location: SE\NW\NW\NW\NW sec. 22, T. 18 N., R. 13 E.
0- 2  Sand, brown, fine; dry, some clay layers
2- 3  Clay, brown, sandy, dry
3- 4  Sand, tan, coarse, dry
4- 8  Gravel, brown, fine; dry, medium to coarse sand, some 15mm pebbles
5-10 Gravel, brown, fine, dry, rock at 7 feet
10-15 Sand, brownish, medium to fine, moist
15-18 Rock
16-22 Sand, brownish-red, medium, moist, some clay
22-25 Clay, medium gray to black, silty, saturated

26
SDGS Test Hole 14 -- continued.

25 - 28 Clay, black, sandy, saturated
28 - 28.5 Hard zone, no sample, did not penetrate

SDGS Test Hole 15 (Auger hole)
Location: SW\(\frac{1}{4}\)W\(\frac{1}{4}\)NE\(\frac{1}{4}\) sec. 22, T. 18 N., R. 13 E.

0 - 2 Clay, light brown, dry
2 - 11 Silt, brown, clayey, saturated
11 - 15 Gravel, brown, very clayey, coarse, saturated
15 - 21 Silt, brown to yellow-brown, clayey, moist
21 - 25 Clay, brown, silty, saturated, some plant fragments

SDGS Test Hole 16 (Auger hole)
Location: NE\(\frac{1}{4}\)SE\(\frac{1}{4}\)NE\(\frac{1}{4}\) sec. 23, T. 18 N., R. 13 E.

0 - 2 Clay, light tan; dry
2 - 5 Clay, brown, silty; moist, calcareous
5 - 7 Silt, yellow-brown, clayey; saturated
7 - 11 Clay, black, silty; saturated, some peat at 8 feet, plant fragments
11 - 22 Silt, light gray, clayey; moist, streaks of light gray (bentonite?)
22 - 28 Clay, tan, dry, hard, silty, moist at 27 to 28 feet

SDGS Test Hole 17 (Auger hole)
Location: NE\(\frac{1}{4}\)SE\(\frac{1}{4}\)NE\(\frac{1}{4}\) sec. 23, T. 18 N., R. 13 E.

0 - 8 Silt, brown, clayey, dry, some very fine sand
8 - 10 Clay, brown, silty, moist
10 - 15 Silt, brown and some gray, very clayey, moist, saturated 14 feet
15 - 17 Clay, gray and brown, very silty, moist
17 - 18 Silt, black, clayey, moist
18 - 24 Silt, gray, clayey, dry

SDGS Test Hole 18 (Auger hole)
Location: NE\(\frac{1}{4}\)NW\(\frac{1}{4}\)NW\(\frac{1}{4}\) sec. 23, T. 18 N., R. 13 E.

0 - 4 Soil, brown, very clayey, silty
4 - 15 Silt, yellow-brown, some light gray, clayey, moist

27
SDGS Test Hole 18 -- continued.

15-29 Clay, light gray, some silt stringers, dry, some gypsum

SDGS Test Hole 19 (Rotary hole)
Location: SW1/4 SW1/4 NW1/4 sec. 24, T. 18 N., R. 17 E. (Hole abandoned; see log 20)

0-25 Clay, fine to coarse, sandy, yellow-brown
25-30 Silt, clay-rich, sandy, yellowish-brown, limonite
30-35 Coal, black, blocky to blade-like, some gray shale
35-50 Shale, medium dark-gray, silty, some slightly sandy
50-55 Sandstone, light gray, medium gray, silty shale
55-85 Shale, medium dark-gray, firm silty
85-95 Sandstone, very fine, clay-filled
95-115 Shale, medium gray, smooth
115-120 Clay, yellow-brown, hard
125-125 Shale, light gray, silty, taking water
125-135 Clay, light gray, soft
135-145 Coal, black, hard, blocky; some brown clay
145-155 Shale, gray; some brownish-black

SDGS Test Hole 20 (Rotary Hole 1)
Location: SW1/4 SW1/4 NW1/4 sec. 24, T. 18 N., R. 13 E.

0-20 Clay, black to yellow-brown, silty, sandy (road fill?)
20-25 Sand, light gray, fine, clay-filled; some coal
25-35 Shale, medium gray, silty, salt and pepper
35-40 Sandstone, light greenish-gray, hard, gray clay, coal
40-55 Shale, medium gray, silty, smooth
55-60 Coal, small flakes and blocks
60-65 Shale, dark brown to dark gray; coal
65-70 Sand, light gray, silty, clay-filled, salt and pepper
70-85 Sand, fines: quartz, pyrite, coal, clay, iron-stained pyrites
85-90 Sandstone, light gray, fine, hard, small sharp chips
90-95 Sand, light gray, silty, salt and pepper
95-140 Shale, medium gray, clay-rich, smooth
140-145 Coal, black, blocky, choppy drilling at 143
145-155 Shale, black, smooth; and shale, brown-gray, smooth
155-160 Coal, light gray, silty, soft
160-185 Shale, light gray, silty, some coal
SDGS Test Hole 20 -- continued.

185-205 Sand, tan, silty, clay-filled; fines: quartz, mica, gypsum, coal
205-280 Shale, dark brownish-gray, smooth; some coal
280-280 Sand, coarse
285-325 Shale, grayish-green, sandy, some clay and coal
325-370 Sand, grayish-green, silty, clay-filled, salt and pepper
330-410 Shale, black, hard, abundant coal, some brown, smooth
410-430 Sand, medium blue-gray, clay-rich, salt and pepper
430-435 Shale, medium gray, smooth, some brown compact shale, sand
435-465 Sand, medium green-gray, fine to medium, clay-filled, some shale
465-470 Shale, medium gray, smooth, some sand
470-475 Sand, blue-gray, very fine, clay-filled
475-500 Sand, greenish and blue-gray, clay-filled
500-610 Shale, bluish-gray, smooth, silty, some clay
610-615 Clay, light gray, fine, sandy, soft
615-655 Shale, light medium-gray, silty to sandy
655-660 Siltstone, tan, hard, and smooth firm shale, light gray
660-665 Sand, fine; some dark shale
665-740 Sand, fine, light bluish-gray, clay-filled; some shale
740-780 Shale, medium gray to dark gray, firm drilling from 768 to 770 feet, choppy at 771 feet
780-785 Sand, very light gray, very fine shale
785-830 Shale, medium gray, smooth, firm, somewhat silty
830-845 Clay, light gray to very light gray, some sand and shale
845-1010 Shale, gray, firm; tan siltstone, soft clay (bentonitic?)

***

SDGS Test Hole 21 (Auger hole)
Location: SE4 NW4 SE4 SE4 sec. 25, T. 13 N., R. 13 E.

0-4 Sand, brown, very fine, clayey, dry
4-15 Silt, dark brown, clayey, moist, some fine sand
15-18 Coal, and/or peat fragments
18-24 Silt, black, very clayey, moist, calcareous, some coal

***

SDGS Test Hole 22 (Auger hole)
Location: SW4 SE4 SE4 SE4 sec. 25, T. 18 N., R. 13 E.

0-4 Gravel, brown, clayey, dry

29
SDGS Test Hole 22 -- continued.

4- 8 Sand, brown, very coarse, clayey, moist
8- 17 Clay, yellow-brown, sandy, moist
17- 19 Clay, black, very silty, moist
19- 24 Silt, light gray, clayey, not very moist

SDGS Test Hole 23 (Auger hole)
Location: SW¼NE¼NW¼SW¼ sec. 27, T. 18 N., R. 13 E.
0- 9 Clay, yellow-brown, very silty, dry
9- 13 Silt, brown, very clayey, saturated, calcareous
13- 29 Clay, gray, very silty, saturated, peat or coal fragments

SDGS Test Hole 24 (Auger hole)
Location: SW¼NW¼SW¼NW¼ sec. 30, T. 18 N., R. 14 E.
0- 1 Clay, tan, silty, dry
1- 5 Clay, brown, silty, moist
5- 14 Silt, brown, clayey, saturated
14- 24 Clay, brown, silty, moist, hard

SDGS Test Hole 25 (Auger hole)
Location: NE¼NW¼NW¼NE¼ sec. 31, T. 18 N., R. 14 E.
0- 4 Sand, tan, medium, clayey; dry, some 8-10 mm pebbles
4- 12 Sand, light red-brown, medium, clayey, dry to moist
12- 15 Sand, tan to brown, very fine, little clay, moist
15- 20 Sand, medium, little clay, moist
20- 30 Clay, brown, silty, moist
30- 39 Silt, medium gray, clayey, moist, hard

SDGS Test Hole 26 (Auger hole)
Location: NE¼SE¼SE¼NE¼ sec. 31, T. 18 N., R. 14 E.
0- 9 Sand, brown, very coarse, clayey, dry, some gravel
9- 11 Clay, yellow-brown, very silty, moist, calcareous
11- 12 Clay, red-brown, very silty, dry, noncalcareous
12- 14 Silt, brown, clayey, moist, slightly calcareous
14- 18 Silt, brown and black, very clayey, moist to dry, noncalcareous

30
SDGS Test Hole 26 -- continued.

18- 29 Silt, brown and gray, clayey, dry

SDGS Test Hole 27 (Auger hole)
Location: SW ¼ NW ¼ se. 34, T. 18 N., R. 14 E.

0- 4 Silt, yellow-brown, dry, noncalcereous
4- 5 Rock, limey deposits, calcereous, very light gray
5- 6 Silt, gray-brown, clayey, moist, noncalcereous
8- 14 Silt, brown, clayey, moist, calcereous
14- 23 Silt, gray-brown, clayey, moist, noncalcereous
20- 23 Sand, dark gray, medium, clayey, saturated
23- 28 Silt, dark gray and black, clayey, moist

SDGS Test Hole 28 (Auger hole)
Location: SW ¼ SW ¼ se. 7, T. 19 N., R. 14 E. (not shown on fig. 2)

0- 5 Silt, light brown to tan, clayey, dry, calcereous
5- 7 Clay, brown, silty, moist, slightly calcereous
7- 23 Silt, brown, clayey, moist, calcereous
23- 24 Sand, brown, medium to fine, clayey, moist
24- 30 Silt, dark brown, clayey, saturated
30- 32 Sand, brown, medium, clayey, moist
32- 43 Gravel, brown, fine, clayey, saturated
43- 50 Sand, medium gray, coarse to fine, saturated
50- 64 Clay, gray, saturated, lumpy

SDGS Test Hole 29 (Auger hole)
Location: SW ¼ SW ¼ se. 7, T. 19 N., R. 14 E. (not shown on fig. 2)

0- 3 Sand, brown, fine to medium, some clay, dry
3- 13 Sand, brown, some clay, saturated at 6 feet
13- 18 Silt, dark brown, very clayey, moist, some green zones
18- 24 Silt, gray-brown, clayey, moist
24- 34 Sand, gray, very fine to fine, some clay, moist
34- 44 Sand, gray, very fine, very clayey, moist

SDGS Test Hole 30 (Auger hole)
Location: NW ¼ NW ¼ se. 18, T. 19 N., R. 14 E. (not shown on fig. 2)
SDGS Test Hole 30 -- continued.

0-  2  Sand, light brown, medium, dry
 2- 11  Gravel, brown, fine, dry, mostly coarse sand
11- 13  Sand, bluish-green, very fine, clayey, saturated
13- 18  Clay, medium gray, very silty, moist, hard
18- 20  Silt, medium gray, clayey, moist
20- 22  Clay, medium gray, silty, moist
22- 38  Silt, medium gray, clayey, moist, hard
38- 44  Clay, dark gray, slightly silty, moist, hard, lumpy

SDGS Test Hole 31 (Auger hole)
Location: NW\(^{1/4}\)SW\(^{1/4}\)NW\(^{1/4}\)SW\(^{1/4}\) sec. 3, T. 17 N., R. 14 E. (not shown on fig. 2)

0-  1  Silt, brown-black, sandy, clayey, dry
 1-  4  Sand, brown, very fine, some clay, moist
 4- 12  Sand, brown, very fine, very clayey, saturated at 6 feet (?)
12- 24  Silt, gray, very clayey, moist

SDGS Test Hole 32 (Auger hole)
Location: NE\(^{1/4}\)NE\(^{1/4}\)NE\(^{1/4}\)NE\(^{1/4}\) sec. 4, T. 17 N., R. 14 E. (not shown on fig. 2)

0-  3  Silt, brown
 3-  6  Gravel, brown, clayey; moist, rocky, some 10 to 20 mm pebbles
 6-  8  Gravel, red-brown, little clay, moist; fewer rocks
 8-  9  Silt, gray-green, clayey; moist, noncalcareous
 9- 11  Clay, grayish-tan, silty; moist, noncalcareous
11- 14  Silt, grayish-tan, little clay; saturated, some limonite, hard
14- 27  Clay, medium gray, silty, moist
27- 34  Silt, medium gray, sandy (very fine), clayey; moist

* * * *
APPENDIX C

Logs of private wells drilled in the area. These logs were obtained from Dennis Knutson, Hettinger, North Dakota, and Stanley Soderstrom, Bowman, North Dakota.

Alex Krischen Well  -  A
Location: SE\¹\²\³\⁴ sec. 14, T. 18 N., R. 13 E.

0- 9  Clay, buff
9-10  Sandstone, soft
10-12  Clay, buff
12-13  Sandstone, soft
13-16?  Clay, buff to gray; some sand and coal
167-168  Coal
168-181  Clay
181-241  Sandstone ledge
241-269  Clay
269-300  Sand, gray, medium
300-303  Sandstone
303-306  Sand, gray, medium
306-309  Coal
309-329  Clay; coal streak

Irwin Tescher Well  -  B
Location: SW\¹\²\³\⁴ sec. 13, T. 18 N., R. 13 E.
(See enlarged map, fig. 2)

0- 5  Surface
5- 39  Clay, buff and brown, with trace of rock and gravel
39-45  Sand, gray/blue, with mica
45-78  Clay, gray, some sand
78-79  Rock
79-93  Clay, gray, with sandstone
93-105  Sand, gray
105-109  Rock
109-117  Clay, sandy, gray
117-118  Rock
118-188  Clay, gray, some sandy
188-188  Rock ledge
188-215  Clay, gray
215-218  Rock
218-224  Clay, gray, sandy
224-247  Sand, some blue sandy, clay

Alfred Heupel Well  -  C
Location: SE\¹\²\³\⁴ sec. 21, T. 18 N., R. 13 E.

33
Alfred Heupel Well - C -- continued.

<table>
<thead>
<tr>
<th>Depth</th>
<th>Description</th>
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<tbody>
<tr>
<td>0-15</td>
<td>Clay</td>
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<tr>
<td>15-16</td>
<td>Coal, soft</td>
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<tr>
<td>16-67</td>
<td>Clay and shale, rock</td>
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<td>67-68</td>
<td>Coal, hard</td>
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<td>68-69</td>
<td>Clay</td>
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<tr>
<td>69-72</td>
<td>Rock</td>
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<tr>
<td>72-93</td>
<td>Clay, sandy, some rock</td>
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<td>93-120</td>
<td>Clay, some rock</td>
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<td>128-145</td>
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<td>145-151</td>
<td>Sand</td>
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<td>151-154</td>
<td>Rock</td>
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<td>154-156</td>
<td>Sand, coarse</td>
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<td>156-171</td>
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<td>171-173</td>
<td>Coal</td>
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<td>173-245</td>
<td>Clay, coarse, sandy and green shale</td>
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<td>382-385</td>
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<td>385-386</td>
<td>Clay, sandy</td>
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<td>386-392</td>
<td>Sand, coarse, and sandstone</td>
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<td>392-405</td>
<td>Clay</td>
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Ralph Veal Well - D

Location: NE4NE4 sec. 24, T. 18 N., R. 13 E.

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<td>Sand, blue</td>
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<td>47-48</td>
<td>Rock</td>
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<td>48-60</td>
<td>Clay, dark</td>
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<td>60-64</td>
<td>Coal</td>
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<td>64-85</td>
<td>Clay</td>
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<td>85-98</td>
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<td>98-120</td>
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<td>120-123</td>
<td>Coal</td>
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<td>123-176</td>
<td>Clay, coarse, sandy</td>
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<td>176-177</td>
<td>Rock</td>
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<td>177-254</td>
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<td>265-400</td>
<td>Clay, sandy, some shale, water at 400 feet</td>
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<td>400-428</td>
<td>Clay, sandy, 3-inch rock</td>
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<td>440-441</td>
<td>Rock</td>
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<tr>
<td>441-460</td>
<td>Clay, sandy</td>
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</tbody>
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* * * *
US Forest Service – E
Location: SE\(\frac{1}{4}\)NW\(\frac{1}{4}\) sec. 31, T. 19 N., R. 13 E.
(not shown on fig. 2)

0-  3  Topsoil
  3- 26  Shale, sandy
  26- 34  Clay
  34- 45  Clay
  45- 66  Rock
  46-130  Clay, sandy
 130-132  Coal
 132-162  Clay, soft, sandy
 162-163  Rock
 163-205  Clay, sandy
 205-207  Rock, hard
 207-235  Clay
 235-237  Coal
 237-250  Clay, green, sandy
 250-252  Coal
 252-275  Clay, sandy
 275-360  Clay
 360-381  Rock, hard
 381-384  Clay
 384-385  Rock, hard
 385-430  Clay, green
 430-450  Sand, coarse (clay?)

Errol Hall Well – F
Location: NW\(\frac{1}{4}\) sec. 12, T. 17 N., R. 14 E.
(not shown on fig. 2)

0-  94  Clay, buff, sandy, some gray, brown, and blue
  94- 95  Rock
 95- 96  Clay, gray
 96- 99  Rock
 99-113  Clay, with coal streaks, gray
 113-123  Sand, gray, medium
 123-135  Clay, gray, with coal
 135-175  Clay, with coal streaks
 175-176  Rock ledge
 176-205  Clay, with coal and rock
 205-216  Sand, gray, with clay streak
 216-254  Clay, with coal streak
 254-265  Sand, fine, blue
 265-265  Rock
 265-270  Sand, fine, blue
 270-271  Rock
 271-274  Clay, sandy
 274-275  Rock
 275-300  Clay, with blue sandstone
Errol Hall Well - F -- continued.

300-347  Clay, sandy, gray
347-420  Clay, fine blue sand, good hard

Herb Kolb Well - G
Location: Center 5½ sec. 17, T. 17 N., R. 13 E.
(not shown on fig. 2)

0- 10  Clay, yellow
10- 28  Shale, gray
28- 33  Coal
33- 41  Shale, gray
41- 45  Rock
45-142  Shale, gray, with hard streaks
142-152  Sand
152-182  Shale, sandy
162-182  Sand
182-242  Shale, sandy

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APPENDIX D

Logs of city wells and test holes drilled for the City of Bison by private drillers. These logs were obtained from the City files.

City of Bison Well 1
Location: NE4NW4NE4SE4 sec. 13, T. 18 N., R. 13 E.
(see enlarged map, fig. 2)

0- 10 Clay, sandy
10- 25 Sandstone
25- 40 Clay
40- 50 Shale, blue
50- 87 Shale, sandy
87- 93 Coal
93- 95 Shale
95-145 Sand and shale
145-145 Rock
145-200 Shale, blue, sandstone
200-202 Rock (hard)
202-250 Shale, sand; water
250-292 Shale, and sandstone shells
292-350 Shale, sand and rock
350-350 Rock
350-372 Sand; water
372-483 Shale, some sand and water
483-525 Sand; water
525-545 Shale, blue
540-555 Sand; water
555-565 Shale
565-580 Sand; water
580-585 Shale
585-600 Sand; water
600-602 Rock
602-636 Shale
636-656 Sand
655-675 Shale
675-695 Sand

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City of Bison Well 2
Location: SW1/4SW1/4NE1/4SE1 sec. 13, T. 18 N., R. 13 E.
(see enlarged map, fig. 2)

0- 36 Clay and siltstone, buff to gray; some gray sandstone
36- 44 Sand, well sorted, slightly cemented
44- 52 Clay, very sandy, buff
52- 56 Sandstone, buff

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City of Bison Well 3 -- continued.

66-422 Clay, gray, silty, trace sandstone, some free sand
422-434 Shale, gray to greenish-gray, some sandy
434-750 Clay, medium gray to greenish, some free sand

City of Bison Well 5
Location: SW\SW\SW\NW\SE\K sec. 13, T. 13 N., R. 13 E.
(see enlarged map, fig. 2)

<table>
<thead>
<tr>
<th>Depth</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-2</td>
<td>Dirt, black</td>
</tr>
<tr>
<td>2-4</td>
<td>Clay, yellow</td>
</tr>
<tr>
<td>4-10</td>
<td>Shale, broken</td>
</tr>
<tr>
<td>10-16</td>
<td>Clay, sandy, gray</td>
</tr>
<tr>
<td>16-26</td>
<td>Shale, sand and dark</td>
</tr>
<tr>
<td>26-40</td>
<td>Clay, sandy</td>
</tr>
<tr>
<td>40-60</td>
<td>Sand, coarse; shale</td>
</tr>
<tr>
<td>50-68</td>
<td>Shale, gray</td>
</tr>
<tr>
<td>68-110</td>
<td>Coal; shale</td>
</tr>
<tr>
<td>110-150</td>
<td>Clay, sandy, gray</td>
</tr>
<tr>
<td>150-151</td>
<td>Rock</td>
</tr>
<tr>
<td>151-230</td>
<td>Shale; sticky, black, clay</td>
</tr>
<tr>
<td>230-232</td>
<td>Rock</td>
</tr>
<tr>
<td>232-634</td>
<td>Shale, hard gray, some sticky clay, some coal</td>
</tr>
<tr>
<td>634-680</td>
<td>Sand, fast drilling</td>
</tr>
<tr>
<td>680-700</td>
<td>Shale, sandy; fair shale</td>
</tr>
<tr>
<td>700-750</td>
<td>Sand, fair to good</td>
</tr>
<tr>
<td>760-780</td>
<td>Sand; rock</td>
</tr>
<tr>
<td>780-835</td>
<td>Sand; hard shell</td>
</tr>
</tbody>
</table>

City of Bison Well 6
Location: NW\NW\NW\SE\K sec. 13, T. 18 N., R. 13 E.
(see enlarged map, fig. 2)

<table>
<thead>
<tr>
<th>Depth</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>0-8</td>
<td>Sand, yellow sand</td>
</tr>
<tr>
<td>8-15</td>
<td>Shale</td>
</tr>
<tr>
<td>15-20</td>
<td>Sand</td>
</tr>
<tr>
<td>20-37</td>
<td>Shale</td>
</tr>
<tr>
<td>37-38</td>
<td>Clay</td>
</tr>
<tr>
<td>38-77</td>
<td>Coal, hard</td>
</tr>
<tr>
<td>77-79</td>
<td>Coal, hard</td>
</tr>
<tr>
<td>79-132</td>
<td>Clay, sandy</td>
</tr>
<tr>
<td>132-137</td>
<td>Coal, hard</td>
</tr>
<tr>
<td>137-158</td>
<td>Clay, sandy</td>
</tr>
<tr>
<td>158-160</td>
<td>Rock</td>
</tr>
<tr>
<td>160-186</td>
<td>Clay, light, sandy</td>
</tr>
<tr>
<td>186-260</td>
<td>Shale</td>
</tr>
</tbody>
</table>
City of Bison Well 6 -- continued.

280-282 Coal, hard
292-299 Clay, sandy
299-309 Coal, hard
295-325 Sand, coarse
325-332 Shale
432-433 Rock, hard
432-784 Sand, coarse, dark, hard, some sandy clay

* * * *

City of Bison (test well drilled by Caywood)
Location: NE¼ sec. 1½, T. 18 N., R. 13 E.
(not shown on fig. 2)

0- 170 Clay, silty, gray, lignitic; light to greenish-gray
170- 185 Silt, light gray
185- 338 Clay, light gray, silty
338- 399 Siltstone, light greenish-gray
399- 685 Clay, some sandy, gray, specks of organic material
685- 687 Shale, dark gray, lignitic
687- 691 Clay, light gray
691- 882 Sandstone, fine, some clay
882-1082 Clay, dark gray, non-silty

* * * *