Soil Types + Elevations

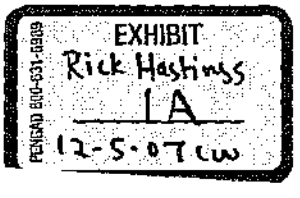
Descriptions of soil types

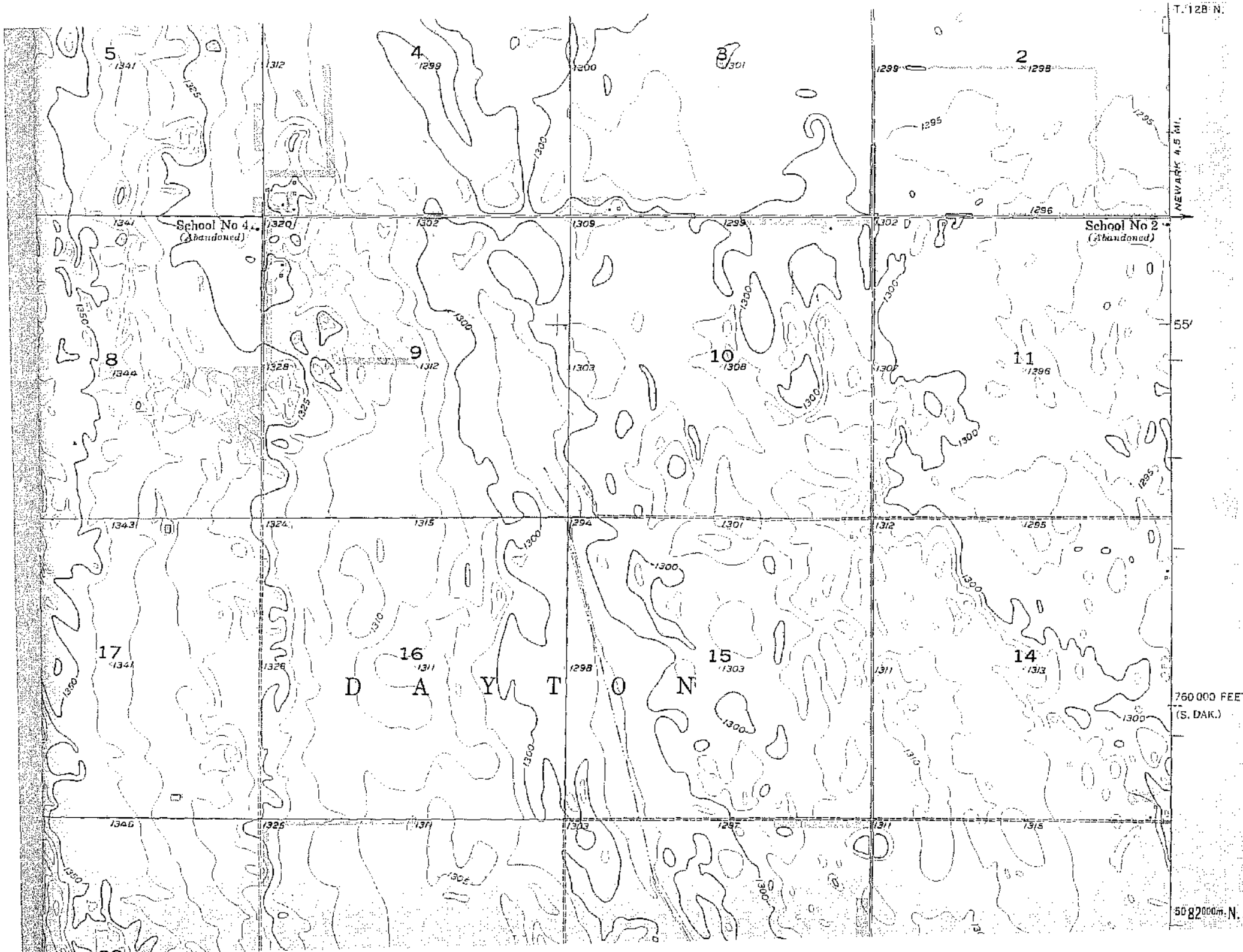
From Soil Survey

of Marshall Co.

Richard Hastings

Testimony

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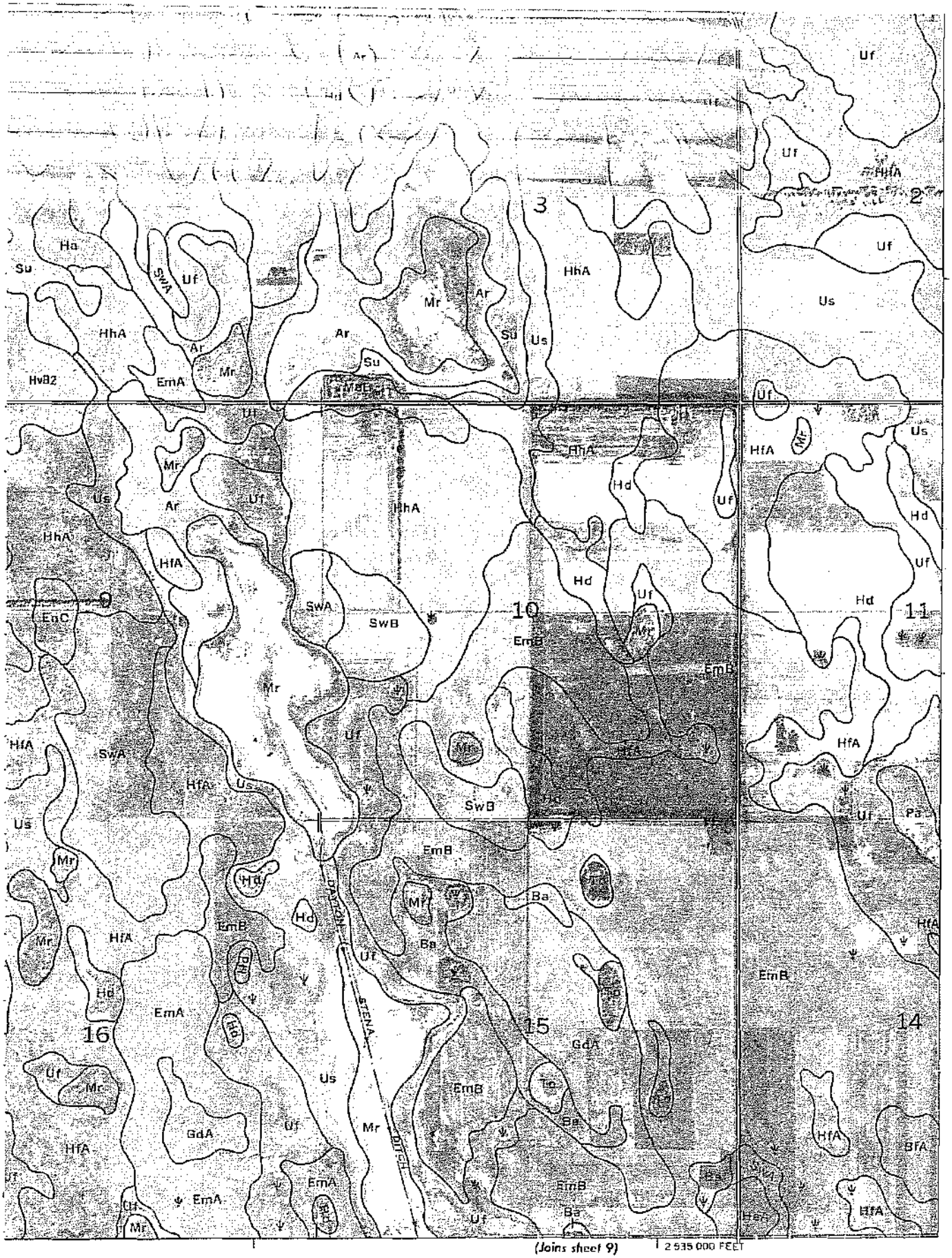
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C1—27 to 41 inches, light-gray (2.5Y 7/2) shaly clay loam, dark grayish brown (2.5Y 4/2) moist; few, fine, distinct mottles of strong brown (7.5YR 5/6) moist; massive; slightly hard, friable, sticky, plastic; 40 percent shale chips; few fine segregations of lime; strong effervescence; moderately alkaline; abrupt, smooth boundary.

IIC2—41 to 60 inches, gray (5Y 6/1) shale, very dark gray (5Y 3/1) moist; many, fine, medium and coarse, prominent mottles of strong brown (7.5YR 5/6) moist; bedded shale breaks to fine to coarse platy structure; few fine segregations of lime; slight effervescence in spots; mildly alkaline.

The A horizon, when moist, is black or very dark gray, and hue is 10 YR or 2.5Y. It is commonly loam. The combined thickness of the A and B horizons ranges from 16 to 36 inches.

The C1 horizon ranges from loam to clay in texture. The content of shale chips in the C1 horizon ranges from 10 to 60 percent. In places the C horizon is noncalcareous. Depth to bedded shale ranges from 30 to 60 inches.

Edgeley soils are near Buse, Forman, Kloten, and Kranzburg soils. They differ from Buse, Forman, and Kranzburg soils in having bedded shale at depths between 30 and 60 inches. They are deeper over shale than Kloten soils.

Edgeley loam, 2 to 6 percent slopes (EdB).—This soil is gently sloping. The areas are irregular in shape and commonly less than 20 acres in size. This soil has a profile similar to the one described as representative for the series, except that the surface layer is slightly thicker and in some areas it is silty clay loam.

Included with this soil in mapping were areas of Aastad and Forman soils. Aastad soils are on foot slopes and in swales. Forman soils are in spots that are deeper over shale or shaly till.

Permeability is moderate above the shale in this Edgeley soil. It is somewhat droughty. Tilth is good. Runoff is medium, and there is some hazard of erosion.

Many areas of this soil are cultivated. Controlling erosion is the main concern of management. Capability unit IIe–1; Silty range site; windbreak group 6.

Edgeley loam, 6 to 9 percent slopes (EdC).—This soil is sloping. The areas are irregular in shape and are mostly less than 40 acres in size. It has the profile described as representative for the series. In some areas the surface layer and subsoil are silty clay loam.

Included with this soil in mapping were areas of Aastad, Buse, and Forman soils. Aastad soils are on foot slopes and in swales. Buse soils are on the tops of ridges and knolls. Forman soils are in places that have underlying material of clay loam till instead of shale or shaly till.

Runoff is medium in this Edgeley soil. It is easily worked, but it is somewhat droughty. The hazard of erosion is moderate.

Many areas of this soil are in native grass and are used for pasture and hay. Other areas are cultivated. Controlling erosion is the main concern of management. Capability unit IIIe–1; Silty range site; windbreak group 6.

Edgeley loam, 9 to 15 percent slopes (EdD).—This soil is strongly sloping. The areas are irregular in shape and are mostly less than 50 acres in size. This soil has a profile similar to the one described as representative for the series, except that in places the surface layer and subsoil are thinner. Small areas that are stony on the surface *are in some areas, and in a few areas the surface layer* and subsoil are silty clay loam.

Included with this soil in mapping were areas of Aastad, Buse, and Forman soils. Aastad soils are on foot slopes and in swales. Buse soils are on the higher parts of the landscape. Forman soils are in spots where the mantle of glacial till is thicker.

Runoff is medium in this Edgeley soil. Available water capacity is moderate. This soil is somewhat droughty. The hazard of erosion is severe.

Most areas of this soil are in native grass and are used for pasture and hay. This soil can be cultivated, but the hazard of erosion is a limitation. Capability unit IVe–1; Silty range site; windbreak group 6.

Embden Series

The Embden series consists of deep, nearly level to gently undulating, well drained or moderately well drained, loamy soils that formed in fine sandy loam deposited by wind or glacial melt water. These soils are on uplands.

In a representative profile the surface layer is dark-gray and dark grayish-brown fine sandy loam about 18 inches thick. The subsoil is grayish-brown fine sandy loam about 19 inches thick. It is slightly hard when dry and very friable when moist. The underlying material is pale-brown loamy fine sand and fine sandy loam.

Fertility is medium in Embden soils. Available water capacity is moderate or high. Permeability is moderately rapid. These soils are highly susceptible to blowing.

Many areas are cultivated. Other areas are in native grass and are used for hay and pasture.

Representative profile of Embden fine sandy loam, 0 to 2 percent slopes, 2,580 feet north and 280 feet west of the southeast corner of sec. 32, T. 128 N., R. 58 W.:

Ap—0 to 6 inches, dark-gray (10YR 4/1) fine sandy loam, black (10YR 2/1) moist; weak, fine and medium, granular structure; soft, very friable; neutral; abrupt, smooth boundary.

A12—6 to 15 inches, dark grayish-brown (10YR 4/2) fine sandy loam, black (10YR 2/1) crushing to very dark brown (10YR 2/2) moist; weak, very coarse and coarse, prismatic structure parting to weak, medium, subangular blocky structure; soft, very friable; neutral; clear, smooth boundary.

B2—15 to 34 inches, grayish-brown (10YR 5/2) fine sandy loam, very dark brown (10YR 2/2) crushing to very dark grayish brown (10YR 3/2) moist; weak, coarse, prismatic structure parting to weak, medium, subangular blocky structure; slightly hard, very friable; mildly alkaline; clear, smooth boundary.

C1—34 to 40 inches, pale-brown (10YR 6/3) loamy fine sand, dark grayish brown (10YR 4/2) moist; single grained; loose; mildly alkaline; clear, smooth boundary.

C2—40 to 60 inches, pale-brown (10YR 6/3) fine sandy loam, dark grayish brown (10YR 4/2) moist; common, fine, faint mottles of yellowish brown (10YR 5/6) moist; single grained; soft, very friable; mildly alkaline.

The A horizon ranges from very dark gray to gray. It is fine sandy loam or sandy loam. This horizon ranges from 10 to 20 inches in thickness.

In places the lower part of the B horizon is loamy fine sand. The combined thickness of the A and B horizons ranges from 20 to 44 inches.

In places the C horizon is calcareous, and in places it is [illegible] depth of more than 60 inches.

Embden soils are similar to Hecla, Maddock, and Swenoda soils. They are less sandy than Hecla and Maddock soils.

They differ from Swenoda soils in not having silty material in the C horizon at a depth of less than 40 inches.

Embden fine sandy loam, 0 to 2 percent slopes (EmA).—This soil is nearly level. The areas are irregular in shape and range from 10 to 80 acres in size. This soil has the profile described as representative for the series.

Included with this soil in mapping were areas of Maddock and Swenoda soils. Maddock soils are on the crests of rises or very gentle undulations. Swenoda soils are intermingled with Embden soils in some areas.

This Embden soil takes in water readily, is easy to work, and has moderate or high available water capacity.

Many areas of this soil are cultivated. The soil is well suited to irrigation, but it blows easily. Controlling soil blowing is the main concern of management. Capability unit IIIe–7; Sandy range site; windbreak group 1.

Embden fine sandy loam, 2 to 6 percent slopes (EmB).—This soil is gently undulating. Slopes are short and convex. Included in mapping were areas of Maddock soils.

Erosion and soil blowing are hazards on this Embden soil. It has good tilth, takes in water readily, and has moderate or high available water capacity.

Many areas of this soil are cultivated. Controlling erosion and soil blowing are the main concerns of management. Capability unit IIIe–8; Sandy range site; windbreak group 1.

Embden-Buse complex, 2 to 9 percent slopes (EnC).—Embden soils make up 60 percent of this complex, Buse soils 20 percent, and other soils 20 percent. These soils are gently undulating to undulating. The areas are irregular in shape and commonly are less than 60 acres in size. Embden soils are in the lower parts of the landscape and are mostly gently undulating. Buse soils are on the upper parts of the landscape where the glacial till is not mantled with wind-deposited sandy material. Stones and cobblestones are on the surface of the Buse soils in some areas, mainly on the tops of ridges and knolls.

Included with these soils in mapping were small areas of Maddock soils intermingled with Embden soils. Also included in some areas near the Buse soil is a soil that has a surface layer and a subsoil of fine sandy loam, underlain by loam or clay loam glacial till at a depth of about 20 inches.

Runoff is slow on the Embden soil but is medium on the Buse soil. Erosion and soil blowing are hazards.

More than half of the areas are in native grass and are used for hay and pasture. Small grains, flax, alfalfa, and tame grasses are the main crops in cultivated areas. Controlling soil blowing and erosion are the main concerns of management. Capability unit IIIe–8; Embden soils are in Sandy range site and windbreak group 1; Buse soils are in Thin Upland range site and windbreak group 8.

Estelline Series

The Estelline series consists of nearly level, well-drained, silty soils that formed in silty material over sand and gravel. These soils are moderately deep over sand and gravel. They are on uplands.

In a representative profile the surface layer is dark-gray silt loam about 8 inches thick. The subsoil is silt loam about 22
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TABLE 6.—*Interpretations*

Soil series and map symbols	Degree and kind of limitation for—						Suitability as source of—
	Septic-tank absorption fields	Sewage lagoons	Shallow excavations	Dwellings with basements	Sanitary landfills [1]	Local roads and streets	Road fill
Colvin: Co	Severe: seasonal high water table; hazard of flooding.	Severe: seasonal high water table; hazard of flooding.	Severe: poorly drained; hazard of flooding; seasonal high water table.	Severe: poorly drained; hazard of flooding.	Severe: poorly drained; seasonal high water table; hazard of flooding.	Severe: poorly drained; hazard of flooding; high susceptibility to frost heave.	Poor: poorly drained.
Divide. Mapped only with Benoit soils.	Severe: seasonal high water table.[2]	Severe: seasonal high water table; moderately rapid to rapid permeability.	Severe: moderately well drained to somewhat poorly drained; gravel below a depth of 20 to 36 inches; seasonal high water table at a depth of 3 to 6 feet.	Moderate to severe: moderately well drained to somewhat poorly drained.	Severe: seasonal high water table; moderately rapid to rapid permeability.	Moderate: moderately well drained to somewhat poorly drained; moderate shrink-swell potential above sand and gravel.	Fair: moderately well drained to somewhat poorly drained.
Downy: Do	Severe: very slow permeability.	Slight	Severe: poorly drained; silty clay.	Severe: poorly drained; high shrink-swell potential.	Severe: poorly drained; silty clay.	Severe: poorly drained; high shrink-swell potential.	Poor: poorly drained; high shrink-swell potential.
Edgeloy: EdB, EdC, EdD.	Severe: shale at a depth of 30 to 60 inches.	Moderate to severe where slopes are less than 6 percent. Severe where slopes are greater than 6 percent; shale below a depth of 30 to 60 inches.	Moderate: clay loam; rippable shale below a depth of 30 to 60 inches.	Moderate: moderate shrink-swell potential; rippable shale below a depth of 30 to 60 inches.	Moderate: rippable shale below a depth of 30 to 60 inches.	Moderate: moderate shrink-swell potential.	Poor: moderate shrink-swell potential in solum; bedded shale below a depth of 30 to 60 inches; limited quantity of material.
*Embden: EmA, EmB, EnC. For Buse part of EnC, see Buse series.	Slight [3]	Severe: moderately rapid permeability.	Slight to moderate: well drained to moderately well drained.	Slight to moderate: well drained to moderately well drained.	Severe: moderately rapid permeability.	Moderate: more than 30 percent fines.	Fair: more than 30 percent fines.
Estelline: EsA	Slight [3]	Severe: rapid permeability in substratum.	Severe: sand and gravel below a depth of 30 to 40 inches.	Slight	Severe: rapid permeability in substratum.	Slight	Good
*Exline: ExA [3]. For Aberdeen part, see Aberdeen series.	Severe: very slow permeability.	Slight	Severe: somewhat poorly drained; silty clay.	Severe: high shrink-swell potential.	Severe: silty clay	Severe: high shrink-swell potential.	Poor: high shrink-swell potential
Fordville: FoA, FoB	Slight [3]	Severe: rapid permeability in substratum.	Severe: sand and gravel below a depth of 20 to 36 inches.	Slight	Severe: rapid permeability in substratum.	Slight	Good

See footnotes at end of table.

engineering properties of the soils—Continued

Suitability as source of—Continued		Soil features affecting—					
Sand and gravel	Topsoil	Pond reservoir areas	Dikes, levees, and other embankments	Drainage	Irrigation	Terraces and diversions	Grassed waterways
Unsuited: no sand or gravel.	Poor: poorly drained.	Moderately slow permeability; seasonal high water table.	Fair stability and compaction characteristics; medium compressibility; moderately slow permeability.	Poorly drained; seasonal high water table; hazard of flooding.	Seasonal high water table; generally not applicable.	Generally not applicable.	Generally not applicable.
Poor: seasonal high water table; more than 15 percent fines in places.	Good	Seasonal high water table; rapid permeability in sand and gravel.	Fair to good stability and compaction characteristics; low to medium compressibility; poor to good resistance to piping.	Seasonal high water table at a depth of 3 to 5 feet; rapid permeability in substratum.	Moderately slow water intake rate; low to moderate available water capacity; sand and gravel below a depth of 20 to 30 inches.	Generally not applicable.	Generally not applicable.
Unsuited: no sand or gravel.	Poor: silty clay; poorly drained.	Very slow permeability; seasonal high water table.	Fair to poor stability and compaction characteristics; high compressibility.	Water table below a depth of 4 feet; very slow permeability.	Very slow intake rate; moderate available water capacity; seasonal high water table below a depth of 4 feet.	Generally not applicable.	Generally not applicable.
Unsuited: no sand or gravel.	Good to a depth of 15 inches where slopes are less than 9 percent; Fair where slopes are 9 to 15 percent.	Moderate permeability; shale below a depth of 41 inches; hazard of seepage in fractured shale.	Bedded shale below a depth of 30 to 60 inches.	Moderate permeability; bedded shale below a depth of 30 to 60 inches.	Moderate available water capacity; slopes of 2 to 15 percent; shale below a depth of 30 to 60 inches.	Fair stability; bedded shale below a depth of 30 to 60 inches.	Hazard of erosion on slopes; moderate available water capacity.
Poor for sand: more than 15 percent fines; no gravel.	Good: subject to soil blowing.	Moderately rapid permeability.	Good stability; fair to good compaction characteristics; slight compressibility; poor resistance to piping.	Moderately rapid permeability.	Moderately rapid water intake rate; moderate to high available water capacity.	Susceptible to soil blowing; moderately rapid permeability.	Moderate to high available water capacity; hazard of erosion; sandy.
Poor to good below a depth of 30 inches depending on percentage of fines.	Good	Rapid permeability in substratum.	Rapid permeability when compacted; poor to good resistance to piping of substratum material; fair to good stability.	Rapid permeability in sand and gravel substratum.	Moderately slow water intake rate; moderate available water capacity; sand and gravel below a depth of 30 to 40 inches.	Underlain by sand and gravel; rapid permeability below a depth of 30 inches.	Moderate available water capacity; sand and gravel below a depth of 30 inches.
Unsuited: no sand or gravel.	Poor: silty clay below a depth of 4 inches.	Very slow permeability; seasonal high water table.	Fair to poor stability and compaction characteristics; high compressibility.	Very slow permeability; seasonal high water table at a depth of 4 to 8 feet.	Very slow permeability; salts in subsoil and substratum; generally not applicable.	Very slow permeability; slopes of less than 2 percent; generally not applicable.	Claypan subsoil; low to moderate available water capacity; somewhat poorly drained.
Good to poor depending on fines.	Good	Rapid permeability in substratum; high seepage.	Moderate to high permeability when compacted; poor to good resistance to piping of substratum material.	Rapid permeability in substratum; sand and gravel below a depth of 20 to 36 inches.	Low to moderate available water capacity; moderate water intake rate; sand and gravel below a depth of 20 to 36 inches.	Rapid permeability below a depth of 20 to 36 inches; sand and gravel substratum limits channel cuts.	Hazard of erosion where sloping; low to moderate available water capacity; sand and gravel below a depth of 20 to 36 inches.

weak or moderate, medium or coarse, prismatic structure that parts to strong, very fine through medium, blocky structure.

In places the C horizon is stratified with silt, fine sand, and clay. Segregated salts in fine nests and striations in the C horizon range from few through many. The solum ranges from 16 to 34 inches in thickness.

Harmony soils are mapped with or are near Aberdeen and Beotia soils. They are somewhat similar to Peever and Sinai soils. Harmony soils contain less sodium and are better drained than Aberdeen soils. They have a more clayey B horizon and are not so well drained as Beotia soils. Dark-colored horizons extend to a greater depth in Harmony soils than in Peever soils. Harmony soils have a more distinct contrast in texture between the A and B horizons than Sinai soils

Harmony-Aberdeen silty clay loams, 0 to 2 percent slopes (HeA).—Harmony soils make up about 60 percent of this complex, Aberdeen soils 25 percent, and other soils 15 percent. These soils are nearly level. Areas are irregular in shape. Aberdeen soils are in the lower, flatter areas.

Included with these soils in mapping were areas of Bearden, Beotia, and Exline soils. Bearden soils are in bands around small, low spots of Exline soils. Beotia soils are on slight rises.

The Harmony soil has properties favorable to crop growth, but permeability is slow in the dense subsoil of the Aberdeen soil. In wet years these moderately well drained soils are slow to dry out, and farming operations are delayed. If cultivated when wet, these soils lose their tilth.

Nearly all areas of these soils are cultivated. Maintaining tilth is the main concern of management. The Harmony soil is suitable for irrigation, but the Aberdeen soil is not. Capability unit IIs–1; Clayey range site; windbreak group 4.

Hecla Series

The Hecla series consists of deep, nearly level to gently undulating, moderately well drained sandy soils that formed in eolian sands. These soils are on uplands.

In a representative profile the surface layer is dark-gray loamy fine sand about 27 inches thick. Below this is a transitional layer of grayish-brown loamy fine sand about 8 inches thick. The underlying material is light-gray fine sand that has mottles of reddish yellow.

Fertility is medium in Hecla soils. Available water capacity is low or moderate. Permeability is moderately rapid or rapid in the upper part of the profile and rapid in the underlying material. The water table seasonally rises to depths between 4 and 10 feet. Soil blowing is a severe hazard.

Many areas are cultivated. Other areas are in grass and are used for hay and pasture.

Representative profile of Hecla loamy fine sand in a cultivated area of Hecla-Hamar loamy fine sands, 0 to 3 percent slopes, 500 feet west and 150 feet south of the northeast corner of sec. 7, T. 128 N., R. 58 W.:

Ap—0 to 9 inches, dark-gray (10YR 4/1) loamy fine sand, black (10YR 2/1) moist; very weak, fine, granular structure; soft, very friable; neutral; abrupt, smooth boundary.

A12—9 to 27 inches, dark-gray (10YR 4/1) loamy fine sand, black (10YR 2/1) moist; very weak, medium, subangular blocky structure parting to very weak, fine, granular structure; soft, very friable; neutral; gradual, smooth boundary.

AC—27 to 35 inches, grayish-brown (10YR 5/2) loamy fine sand, very dark grayish brown (10YR 3/2) moist; few, medium, faint mottles of yellowish brown (10YR 5/6) moist; very weak, coarse, subangular blocky structure; soft, very friable; neutral; clear, smooth boundary.

C—35 to 60 inches, light-gray (2.5Y 7/2) fine sand, grayish brown (2.5Y 5/2) moist; common, fine and medium, distinct mottles of reddish yellow (7.5YR 6/6) moist; single grained; loose; neutral.

The A horizon is very dark gray or dark gray. It is loamy fine sand or loamy sand. Thickness of the A horizon or combined A and AC horizons ranges from 16 to 40 inches.

The C horizon has colors in hue of 10YR or 2.5Y. The C horizon, to a depth of 40 inches, ranges from loamy fine sand to fine sand. In places it is loam, clay loam, or silt loam below a depth of 40 inches. Mottles below a depth of 20 inches are faint through prominent. Depth to carbonates ranges from 24 to more than 60 inches.

Hecla soils are mapped with Hamar and Venlo soils and are near Embden, Maddock, and Ulen soils. They are more sandy than Embden soils and better drained than Hamar and Venlo soils. Hecla soils are not so well drained as Maddock soils, and they have a thicker A horizon. They are less calcareous than Ulen soils.

Hecla loamy fine sand, 0 to 3 percent slopes (HfA).—This nearly level to very gently undulating soil has mostly short, convex slopes. It has the profile described as representative for the series. Included in mapping were areas of Hamar soils in low spots.

Available water capacity is low or moderate, and this Hecla soil takes in water easily. It is somewhat droughty, however, and soil blowing is the main concern in management of the many cultivated areas. Capability unit IVe–9; Sands range site; windbreak group 2.

Hecla-Hamar loamy fine sands, 0 to 3 percent slopes (HhA).—Hecla soils make up about 65 percent of this complex and Hamar soils about 35 percent. These soils are nearly level to gently undulating. Hamar soils are in low spots about 3 feet below undulations.

Included with these soils in mapping were areas of Arveson, Maddock, and Ulen soils. Arveson and Ulen soils are in some of the depressions. Maddock soils are on the crests of some of the undulations.

Available water capacity is low or moderate on these Hecla and Hamar soils. These soils take in water readily. The water table fluctuates in areas of this complex, and it rises to a depth of less than 3 feet in the Hamar soils.

About half of the areas of these soils are cultivated. Controlling soil blowing is the main concern of management, but wetness also is a concern during wet years. Capability unit IVe–9; Hecla soils are in Sands range site; Hamar soils are in Subirrigated range site; both soils are in windbreak group 2.

Hecla-Venlo complex, 0 to 6 percent slopes, eroded (Hv82).—Hecla soils make up 60 percent of this complex, Venlo soils 25 percent, and other soils 15 percent. Many convex-shaped undulations or dunes rise 3 to 8 feet above the low areas, many of which are sand blowouts caused by past soil blowing. Hecla soils are on the dunes, and Venlo soils are in the low areas.

Included with this soil in mapping were areas of Hamar soils in some of the low positions or depressions.

The available water capacity is low or moderate in these Hecla and Venlo soils. These soils take in water

TABLE 6.—*Interpretations of*

Soil series and map symbols	Degree and kind of limitation for—						Suitability as source of—
	Septic-tank absorption fields	Sewage lagoons	Shallow excavations	Dwellings with basements	Sanitary land fills[1]	Local roads and streets	Road fill
Forman: FrA, FrB, FrC, FrD, FsC2, FsE, FtD, FxC, FxD. For Anstad part of FrA, FrB, FrC, and FrD, see Anstad series; for Buse part of FsC2, FsE, and FtD, see Buse series; for Polnsett part of FxC and FxD, see Polnsett series.	Severe: moderately slow permeability in underlying material.	Slight where slopes are less than 2 percent. Moderate where slopes are 2 to 6 percent. Severe where slopes are greater than 6 percent.	Moderate where slopes are less than 15 percent. Severe where slopes are greater than 15 percent; clay loam.	Moderate to severe: moderate to high shrink-swell potential.	Moderate: clay loam.	Severe: moderate to high shrink-swell potential; AASHO Group Index more than 8.	Poor: AASHO Group Index more than 8; moderate to high shrink-swell potential.
Great Bend: GbB, GdA, GeB, GeC. For Beotia part of GdA, see Beotia series; for Zell part of GeB and GeC, see Zell series.	Moderate: moderate permeability.	Moderate where slopes are less than 6 percent. Severe where slopes are greater than 6 percent; moderate permeability.	Slight	Slight to moderate: low to moderate shrink-swell potential.	Slight	Severe: AASHO Group Index more than 8.	Poor: AASHO Group Index more than 8; high susceptibility to frost heave.
Lamar: Ha, Hd	Severe: high water table.	Severe: high water table.	Severe: high water table at a depth of 1 to 3 feet; poorly drained to somewhat poorly drained.	Severe: poorly drained to somewhat poorly drained.	Severe: high water table; rapid permeability.	Moderate to severe: somewhat poorly drained to poorly drained.	Fair to poor: somewhat poorly drained to poorly drained.
Marly. Mapped only with Peever soils.	Severe: seasonal high water table.	Moderate to severe: seasonal high water table at a depth of 3 to 4 feet.	Moderate: moderately well drained to somewhat poorly drained; seasonal high water table at a depth of 3 to 4 feet.	Moderate to severe: moderate shrink-swell potential; moderately well drained to somewhat poorly drained	Severe: seasonal high water table.	Moderate: moderate shrink-swell potential.	Fair: moderate shrink-swell potential.
Parmeny: HeA. For Aberdeen part, see Aberdeen series.	Moderate: moderate permeability.	Moderate: moderate permeability.	Moderate to severe: moderately well drained; silty clay and silty clay loam.	Moderate to severe: moderate to high shrink-swell potential.	Moderate to severe: silty clay loam and silty clay.	Moderate to severe: moderate to high shrink-swell potential.	Fair to poor: moderate to high shrink-swell potential.
Venlo: HfA, HhA, HvB2. For Hamar part of HhA, see Hamar series; for Venlo part of HvB2, see Venlo series.	Slight to moderate: water table at a depth of 4 to 10 feet.[2]	Severe: rapid permeability.	Severe: sandy	Moderate: moderately well drained.	Severe: rapid permeability.	Slight	Good
Wilden: KbE. For Buse part, see Buse series.	Severe: steep; shale below a depth of 10 to 20 inches.	Severe: steep; shale below a depth of 10 to 20 inches.	Severe: steep; shale below a depth of 10 to 20 inches.	Severe: slopes are greater than 15 percent; shale below a depth of 10 to 20 inches.	Moderate where slopes are 15 to 25 percent. Severe where slopes are greater than 25 percent; rippable shale below a depth of 10 to 20 inches.	Severe: steep	Poor: shale below a depth of 10 to 20 inches; limited quantity of material.

See footnotes at end of table.

engineering properties of the soils—Continued

Suitability as source of—Continued		Soil features affecting—					
Sand and gravel	Topsoil	Pond reservoir areas	Dikes, levees, and other embankments	Drainage	Irrigation	Terraces and diversions	Grassed waterways
Unsuited: no sand or gravel.	Good where slopes are less than 9 percent. Fair where slopes are 9 to 15 percent.	Moderate permeability in subsoil and moderately slow in underlying material.	Fair to good stability and compaction characteristics; medium compressibility; good resistance to piping.	Moderately slow permeability in substratum.	High available water capacity; slow water intake rate; salt layers in substratum in places; hazard of erosion where sloping.	Short irregular slopes; moderately slow permeability in substratum.	High available water capacity; hazard of erosion where sloping; well drained.
Unsuited: no sand or gravel.	Good	Moderate permeability.	Fair to poor stability and compaction characteristics; medium to high compressibility; poor to good resistance to piping.	Moderate permeability.	High available water capacity; moderate water intake rate; hazard of erosion where sloping.	Moderate permeability; slopes are generally short and irregular.	Hazard of erosion where sloping; moderate permeability.
Poor for sand: more than 15 percent fines; unsuited for gravel.	Poor: sandy	Favorable for dugouts; high water table.	Fair stability; poor resistance to piping; erodible; fair to good compaction characteristics.	High water table; rapid permeability.	High water table; low to moderate available water capacity.	Generally not applicable.	Generally not applicable.
Unsuited: no sand or gravel.	Good to a depth of 8 inches, fair below; loam to a depth of 8 inches, clay loam below.	Moderate permeability; seasonal high water table.	Fair to poor stability and compaction characteristics; medium to high compressibility; poor to good resistance to piping.	Seasonal high water table at a depth of 3 to 4 feet.	High available water capacity; seasonal high water table at a depth of 3 to 4 feet; high lime content; moderately slow water intake rate.	Short irregular slopes; high lime content; moderately slow permeability in substratum.	High available water capacity; high lime content; moderately well drained to somewhat poorly drained.
Unsuited: no sand or gravel.	Fair to a depth of 8 inches, poor below; silty clay loam to a depth of 8 inches, silty clay below.	Moderate permeability; lenses of fine sand in substratum in places.	Fair to poor stability and compaction characteristics; fair to poor resistance to piping; medium to high compressibility.	Moderate permeability.	High available water capacity; slow water intake rate; salt layers in substratum in places.	Fair to poor stability; slopes of less than 2 percent; moderate permeability.	High available water capacity; slopes of less than 2 percent; moderately well drained.
Poor for sand: more than 15 percent fines; unsuited for gravel.	Poor: sandy	High seepage; rapid permeability.	Good stability; erodible; fair to good compaction characteristics; poor resistance to piping.	Rapid permeability; water table at a depth of 5 to 10 feet.	Low to moderate available water capacity; very rapid water intake rate; susceptible to soil blowing.	*Susceptible to soil* blowing; rapid permeability.	*Susceptible to soil* blowing; low to moderate available water capacity.
Unsuited: no sand or gravel.	Poor: steep	Steep; seepage excessive in fractured shale in places.	Shale below a depth of 10 to 20 inches; subject to slippage; limited quantity of material.	Steep; shale below a depth of 10 to 20 inches.	Shallow to shale; generally not applicable.	Shale below a depth of 10 to 20 inches; steep.	Hazard of erosion; shale below a depth of 10 to 20 inches.

These soils are easy to work. Available water capacity is moderate or high. The calcareous Zell soil is low or medium in fertility. Runoff is medium on soils of this complex. The hazards of erosion and soil blowing are high on the Zell soils.

Most areas of these soils are cultivated. Controlling erosion and soil blowing are the main concerns of management. Capability unit IIe–1; Great Bend soils are in Silty range site and windbreak group 3; Zell soils are in Thin Upland range site and windbreak group 8.

Great Bend-Zell silt loams, 6 to 9 percent slopes (GeC).—Great Bend soils make up 70 percent of this complex and Zell soils 30 percent. These soils are sloping and undulating. Areas are long and narrow. These soils are on side slopes along broad drainageways. Great Bend soils are in the mid and lower parts of the areas. Zell soils are on the tops of knolls and ridges. They have a profile similar to the one described as representative for the series, except in some cultivated areas their surface layer is thinner and has been mixed with the underlying material by plowing.

Included with these soils in mapping were areas of Beotia and Embden soils on foot slopes.

These soils are easy to work. Available water capacity is moderate or high. The calcareous Zell soils are low or medium in fertility. Runoff is medium on soils of this complex. Erosion and soil blowing are hazards.

Many areas of these soils are cultivated. Controlling erosion and soil blowing is the main concern of management. Capability unit IIIe–1; Great Bend soils are in Silty range site and windbreak group 3; Zell soils are in Thin Upland range site and windbreak group 8.

Hamar Series

The Hamar series consists of deep, nearly level, poorly drained or somewhat poorly drained, sandy soils that formed in eolian sand over glacial-lacustrine material. These soils are in swales and depressions on uplands.

In a representative profile the surface layer is loamy fine sand about 23 inches thick. It is dark gray in the upper part and grayish brown in the lower part. The underlying material is grayish-brown and light-gray fine sand that has mottles of dark yellowish brown and dark gray.

Fertility is medium in Hamar soils. Available water capacity is low or moderate. Permeability is moderately rapid or rapid in the surface layer and rapid in the underlying material. A fluctuating water table is at a depth of 1 to 3 feet and seasonally is near the surface during wet years.

Many areas of these soils are cultivated. Other areas are in native grass and are used for hay or pasture.

Representative profile of Hamar loamy fine sand in native grass, 1,190 feet west and 285 feet north of the southeast corner of sec. 6, T. 128 N., R. 58 W.:

A11—0 to 16 inches, dark-gray (10YR 4/1) loamy fine sand, very dark gray (10YR 3/1) moist; very weak, medium, subangular blocky structure parting to weak, fine, granular structure; loose; very friable; mildly alkaline; gradual, smooth boundary.

A12—16 to 23 inches, grayish-brown (10YR 5/2) loamy fine sand, very dark grayish brown (10YR 3/2) moist; many, fine, distinct mottes of yellowish brown (10YR 4/4) moist; very weak, medium, subangular blocky structure; loose, very friable; mildly alkaline; gradual, wavy boundary.

C1g—23 to 28 inches, grayish-brown (2.5Y 5/2) fine sand, dark grayish brown (2.5Y 4/2) moist; common, medium, distinct mottles of yellowish brown (10YR 4/4) moist; single grained; loose; mildly alkaline; clear, smooth boundary.

C2g—28 to 40 inches, light-gray (2.5Y 7/2) fine sand, grayish brown (2.5Y 5/2) moist; common, fine, distinct mottles of dark yellowish brown (10YR 4/4) moist; single grained; loose; mildly alkaline; clear, smooth boundary.

C3g—40 to 60 inches, light-gray (2.5Y 7/2) fine sand, grayish brown (2.5Y 5/2) moist; many, medium, prominent mottles of dark yellowish brown (10YR 4/4) and dark gray (5Y 4/1) moist; single grained; loose; slight effervescence; mildly alkaline.

The A horizon ranges from very dark gray to grayish brown. It is loamy sand to fine sandy loam. This horizon ranges from 12 to 24 inches in thickness. Distinct or prominent mottles are in the lower part of the A horizon, and they are throughout the entire horizon in places.

In the C horizon mottles range from few through many, fine through coarse, and fine through prominent. In places loamy or silty material is in the C horizon at a depth of more than 40 inches. Depth to lime ranges from 30 to 60 inches or more.

Hamar soils are near Arveson, Hecla, and Ulen soils. They are more sandy, less calcareous, and not so poorly drained as Arveson soils. They have mottled colors at shallower depths and are more poorly drained than Hecla and Ulen soils. They are less calcareous than Ulen soils.

Hamar loamy fine sand (0 to 3 percent slopes) (Ha).—This soil is nearly level. Areas are irregular in shape and are mostly less than 40 acres in size. This soil has the profile described as representative for the series.

Included with this soil in mapping were areas of Arveson, Hecla, and Ulen soils. Arveson soils are in depressions. Hecla and Ulen soils are on very gentle undulations.

This Hamar soil blows easily if it is cultivated. Available water capacity is low or moderate. Runoff is very slow or ponded. The water table is at a depth of 1 to 3 feet and is near the surface in wet years.

Most areas of this soil are used for hay or pasture. A few areas are cultivated, but seeding in spring is delayed in some years because of wetness. Wetness and controlling soil blowing are concerns of management. Capability unit IVw–2; Subirrigated range site; windbreak group 2.

Hamar fine sandy loam (0 to 3 percent slopes) (Hd).—This soil is nearly level. Areas are irregular in shape and are mostly less than 40 acres in size. This soil has a profile similar to the one described as representative for the series, except that the surface layer is fine sandy loam in most areas and in places loamy or silty material is at a depth of more than 40 inches.

Included with this soil in mapping were areas of Embden and Ulen soils on convex undulations.

A water table rises to a depth of less than 3 feet early in the growing season in this Hamar soil. Farming operations are delayed in some years because of wetness. Available water capacity is moderate. Runoff is slow.

Many areas of this soil are cultivated. The choice of crops is affected in some years by wetness. Capability unit IIIw–5; Subirrigated range site; windbreak group 2.

Hamerly Series

The Hamerly series consists of deep, nearly level, moderately well drained or somewhat poorly drained, cal-

TABLE 6.—*Interpretations of*

Soil series and map symbols	Degree and kind of limitation for—						Suitability as source of—
	Septic-tank absorption fields	Sewage lagoons	Shallow excavations	Dwellings with basements	Sanitary land fills [1]	Local roads and streets	Road fill
Forman: FrA, FrB, FrC, FrD, FsC2, FsE, FtD, FxC, FxD. For Aastad part of FrA, FrB, FrC, and FrD, see Aastad series; for Buse part of FsC2, FsE, and FtD, see Buse series; for Polnsett part of FxC and FxD, see Polnsett series.	Severe: moderately slow permeability in underlying material.	Slight where slopes are less than 2 percent. Moderate where slopes are 2 to 6 percent. Severe where slopes are greater than 6 percent.	Moderate where slopes are less than 15 percent. Severe where slopes are greater than 15 percent; clay loam.	Moderate to severe: moderate to high shrink-swell potential.	Moderate: clay loam.	Severe: moderate to high shrink-swell potential; AASHO Group Index more than 8.	Poor: AASHO Group Index more than 8; moderate to high shrink-swell potential.
Great Bend: GbB, GdA, GeB, GeC. For Beotia part of GdA, see Beotia series; for Zell part of GeB and GeC, see Zell series.	Moderate: moderate permeability.	Moderate where slopes are less than 6 percent. Severe where slopes are greater than 6 percent; moderate permeability.	Slight	Slight to moderate: low to moderate shrink-swell potential.	Slight	Severe: AASHO Group Index more than 8.	Poor: AASHO Group Index more than 8; high susceptibility to frost heave.
Humar: Ha, Hd	Severe: high water table.	Severe: high water table.	Severe: high water table at a depth of 1 to 3 feet; poorly drained to somewhat poorly drained.	Severe: poorly drained to somewhat poorly drained.	Severe: high water table; rapid permeability.	Moderate to severe: somewhat poorly drained to poorly drained.	Fair to poor: somewhat poorly drained to poorly drained.
Innerly. Mapped only with Peever soils.	Severe: seasonal high water table.	Moderate to severe: seasonal high water table at a depth of 3 to 4 feet.	Moderate: moderately well drained to somewhat poorly drained; seasonal high water table at a depth of 3 to 4 feet.	Moderate to severe: moderate shrink-swell potential; moderately well drained to somewhat poorly drained	Severe: seasonal high water table.	Moderate: moderate shrink-swell potential.	Fair: moderate shrink-swell potential.
Harmony: HcA For Aberdeen part, see Aberdeen series.	Moderate: moderate permeability.	Moderate: moderate permeability.	Moderate to severe: moderately well drained; silty clay and silty clay loam.	Moderate to severe: moderate to high shrink-swell potential.	Moderate to severe: silty clay loam and silty clay.	Moderate to severe: moderate to high shrink-swell potential.	Fair to poor: moderate to high shrink-swell potential.
Hecla: HfA, HhA, HvB2. For Humar part of HfA, see Humar series; for Venlo part of HvB2, see Venlo series.	Slight to moderate: water table at a depth of 4 to 10 feet.[2]	Severe: rapid permeability.	Severe: sandy	Moderate: moderately well drained.	Severe: rapid permeability.	Slight	Good
Kranten: KbE For Buse part, see Buse series.	Severe: steep; shale below a depth of 10 to 20 inches.	Severe: steep; shale below a depth of 10 to 20 inches.	Severe: steep; shale below a depth of 10 to 20 inches.	Severe: slopes are greater than 15 percent; shale below a depth of 10 to 20 inches.	Moderate where slopes are 15 to 25 percent. Severe where slopes are greater than 25 percent; rippable shale below a depth of 10 to 20 inches.	Severe: steep	Poor: shale below a depth of 10 to 20 inches; limited quantity of material.

See footnotes at end of table.

engineering properties of the soils—Continued

Suitability as source of—Continued		Soil features affecting—					
Sand and gravel	Topsoil	Pond reservoir areas	Dikes, levees, and other embankments	Drainage	Irrigation	Terraces and diversions	Grassed waterways
Unsuited: no sand or gravel.	Good where slopes are less than 9 percent. Fair where slopes are 9 to 15 percent.	Moderate permeability in subsoil and moderately slow in underlying material.	Fair to good stability and compaction characteristics; medium compressibility; good resistance to piping.	Moderately slow permeability in substratum.	High available water capacity; slow water intake rate; salt layers in substratum in places; hazard of erosion where sloping.	Short irregular slopes; moderately slow permeability in substratum.	High available water capacity; hazard of erosion where sloping; well drained.
Unsuited: no sand or gravel.	Good	Moderate permeability.	Fair to poor stability and compaction characteristics; medium to high compressibility; poor to good resistance to piping.	Moderate permeability.	High available water capacity; moderate water intake rate; hazard of erosion where sloping.	Moderate permeability; slopes are generally short and irregular.	Hazard of erosion where sloping; moderate permeability.
Poor for sand: more than 15 percent fines; unsuited for gravel.	Poor: sandy	Favorable for dugouts; high water table.	Fair stability; poor resistance to piping; erodible; fair to good compaction characteristics.	High water table; rapid permeability.	High water table; low to moderate available water capacity.	Generally not applicable.	Generally not applicable.
Unsuited: no sand or gravel.	Good to a depth of 8 inches, fair below; loam to a depth of 8 inches, clay loam below.	Moderate permeability; seasonal high water table.	Fair to poor stability and compaction characteristics; medium to high compressibility; poor to good resistance to piping.	Seasonal high water table at a depth of 3 to 4 feet.	High available water capacity; seasonal high water table at a depth of 3 to 4 feet; high lime content; moderately slow water intake rate.	Short irregular slopes; high lime content; moderately slow permeability in substratum.	High available water capacity; high lime content; moderately well drained to somewhat poorly drained.
Unsuited: no sand or gravel.	Fair to a depth of 8 inches, poor below; silty clay loam to a depth of 8 inches, silty clay below.	Moderate permeability; lenses of fine sand in substratum in places.	Fair to poor stability and compaction characteristics; fair to poor resistance to piping; medium to high compressibility.	Moderate permeability.	High available water capacity; slow water intake rate; salt layers in substratum in places.	Fair to poor stability; slopes of less than 2 percent; moderate permeability.	High available water capacity; slopes of less than 2 percent; moderately well drained.
Poor for sand: more than 15 percent fines; unsuited for gravel.	Poor: sandy	High seepage; rapid permeability.	Good stability; erodible; fair to good compaction characteristics; poor resistance to piping.	Rapid permeability; water table at a depth of 4 to 10 feet.	Low to moderate available water capacity; very rapid water intake rate; susceptible to soil blowing.	Susceptible to soil blowing; rapid permeability.	Susceptible to soil blowing; low to moderate available water capacity.
Unsuited: no sand or gravel.	Poor: steep	Steep; seepage excessive in fractured shale in places.	Shale below a depth of 10 to 20 inches; subject to slippage; limited quantity of material.	Steep; shale below a depth of 10 to 20 inches.	Shallow to shale; generally not applicable.	Shale below a depth of 10 to 20 inches; steep.	Hazard of erosion; shale below a depth of 10 to 20 inches.

Fertility is medium or low in Maddock soils. Available water capacity is low, and permeability is rapid. These soils are highly susceptible to blowing.

A few areas are cultivated. Most areas are in native grass and are used for pasture.

Representative profile of Maddock loamy fine sand, 2 to 6 percent slopes, 790 feet west and 100 feet north of the southeast corner of sec. 20, T. 128 N., R. 59 W.:

A1—0 to 12 inches, dark-gray (10YR 4/1) loamy fine sand, black (10YR 2/1) moist; weak, fine and medium, granular structure; loose; neutral; clear, wavy boundary.

AC—12 to 15 inches, grayish-brown (10YR 5/2) loamy fine sand, very dark grayish brown (10YR 3/2) moist; very weak, fine, granular structure; loose; neutral; clear, smooth boundary.

C—15 to 60 inches, light brownish-gray (10YR 6/2) fine sand, dark grayish brown (10YR 4/2) moist; single grained; loose; neutral.

The A horizon is very dark gray, dark gray, or gray in hue of 10YR. It is loamy fine sand, fine sandy loam, or sandy loam and ranges from 10 to 16 inches in thickness.

The C horizon ranges from fine sand to loamy fine sand. Buried horizons are common at depths ranging from 30 to 60 inches.

Maddock soils are near Embden, Hecla, and Serden soils. They are more sandy than Embden soils. Maddock soils have a thinner A horizon and are better drained than Hecla soils. They have a darker colored A horizon than Serden soils.

Maddock loamy fine sand, 2 to 6 percent slopes (MaB).—This soil is gently undulating, and slopes are short and convex. It has the profile described as representative for the series.

Included with this soil in mapping were areas of Embden, Hamar, and Serden soils. Embden and Serden soils are intermingled with Maddock soils. Hamar soils are in concave swales and depressions.

This soil is easy to work; but it is droughty, and cultivated areas are subject to soil blowing if not adequately protected. Available water capacity is low.

Many areas of this soil are in native grass, but a few are cultivated. Controlling soil blowing is the main concern of management. Capability unit IVe–9; Sands range site; windbreak group 7.

Maddock loamy fine sand, 6 to 15 percent slopes (MaD)—This soil is undulating to rolling, and slopes are short and convex. It has a profile similar to the one described as representative for the series, except that in places the surface layer is either thicker or thinner because of soil blowing. Included in mapping were small areas of Serden soils.

Available water capacity is low in this Maddock soil. The soil is droughty, and it blows easily when vegetative cover is absent. It takes in water easily, and runoff is slow.

This soil is in native grass and is used for grazing. Controlling soil blowing is the main concern of management. Capability unit VIe–7; Sands range site; windbreak group 10.

Marsh

Marsh (Mr) is in flat, enclosed depressions that range from 5 to 30 acres in size. Slopes are 0 to 1 percent. The areas are wet and are periodically under water most years. Some of the more deeply entrenched areas have open water in the center most of the time. The smaller areas dry out late in summer or in fall except in wet years.

Most areas are too wet for pasture plants and have a vegetation of rushes, cattails, and sedges. These areas are better suited to wildlife habitat than to other uses. Capability unit VIIIw–1; not placed in a range site or windbreak group.

Oldham Series

The Oldham series consists of deep, level, poorly drained, calcareous, silty soils that formed in alluvium washed from adjacent sloping soils. These soils are in depressions on uplands.

In a representative profile the surface layer is dark-gray silty clay loam about 9 inches thick. The subsoil is about 21 inches of dark-gray and gray silty clay loam that has reddish-brown and olive mottles. It is hard when dry and friable when moist. The underlying material is white and light-gray silt loam. Mottles are light olive brown and yellowish brown.

Fertility is medium in Oldham soils. Available water capacity is high, and permeability is slow. A water table is at a depth of 2 to 4 feet during part of the growing season.

Some areas are cultivated. Other areas are in native grass and are used for pasture or hay.

Representative profile of Oldham silty clay loam, 500 feet east and 110 feet north of the southwest corner of sec. 34, T. 126 N., R. 59 W.:

Ap—0 to 9 inches, dark-gray (10YR 4/1) silty clay loam, black (10YR 2/1) moist; weak, fine and medium, granular structure; slightly hard, friable; slight effervescence; mildly alkaline; abrupt, smooth boundary.

B2—9 to 19 inches, dark-gray (10YR 4/1) silty clay loam, black (10YR 2/1) moist; common, fine, faint mottles of reddish brown; weak, very coarse, prismatic structure parting to weak, coarse, subangular blocky structure; slightly hard, friable; strong effervescence; moderately alkaline; clear, smooth boundary.

B3g—19 to 30 inches, gray (5Y 5/1) silty clay loam, very dark gray (5Y 3/1) moist; common, fine and medium, distinct mottles of olive (5Y 5/4) moist; weak, coarse, subangular blocky structure; hard, friable; few fine nests of salts; strong effervescence; moderately alkaline; gradual, smooth boundary.

C1gca—30 to 41 inches, white (5Y 8/1) silt loam, gray (5Y 6/1) moist; common, fine, distinct mottles of light olive brown (2.5Y 5/6) moist; massive; hard, friable; few fine nests of salts; strong effervescence; moderately alkaline; clear, smooth boundary.

C2gca—41 to 60 inches, light-gray (5Y 7/1) silt loam, gray (5Y 5/1) moist; many, fine and medium, distinct mottles of yellowish brown (10YR 5/6) moist; massive; hard, friable; strong effervescence; moderately alkaline.

The A horizon, when moist, is black or very dark gray in hue of 10YR, 2.5Y, or 5Y. It ranges from 8 to 14 inches in thickness.

The B horizon is silty clay loam or silty clay. Nests of salts in the B3 and C horizons range from few through many. They are mostly gypsum. Mottles in the B3 and C horizons range from few through many and from faint through prominent.

TABLE 6.—*Interpretations of*

Soil series and map symbols	Degree and kind of limitation for—						Suitability as source of—
	Septic-tank absorption fields	Sewage lagoons	Shallow excavations	Dwellings with basements	Sanitary landfills [1]	Local roads and streets	Road fill
*Kranzburg: KnA, KnB, KnC2, KrA, KrB. For Aberdeen part of KrA and KrB, see Aberdeen series.	Severe: moderately slow permeability in substratum.	Slight where slopes are less than 2 percent. Moderate where slopes are 2 to 6 percent. Severe where slopes are greater than 6 percent.	Moderate: clay loam.	Moderate to severe: moderate to high shrink-swell potential.	Moderate: clay loam in substratum.	Severe: moderate to high shrink-swell potential; AASHO Group Index more than 8.	Poor: AASHO Group Index more than 8; moderate to high shrink-swell potential.
Lamoure: La	Severe: seasonal high water table; subject to flooding.	Severe: seasonal high water table; subject to flooding.	Severe: subject to flooding; seasonal high water table; somewhat poorly drained to poorly drained.	Severe: somewhat poorly drained to poorly drained; subject to flooding; moderate to high shrink-swell potential.	Severe: subject to flooding.	Severe: subject to flooding.	Poor: moderate to high shrink-swell potential; high susceptibility to frost heave.
Larson. Mapped only with Swenoda soils.	Severe: slow permeability.	Slight	Moderate: moderately well drained.	Moderate: moderate shrink-swell potential.	Moderate: clay loam in subsoil.	Moderate: moderate shrink-swell potential.	Fair: moderate shrink-swell potential.
Loamy alluvial land; Lo. Too variable for valid interpretation.							
Ludden: Lu	Severe: very slow permeability; high water table.	Severe: subject to flooding; high water table.	Severe: poorly drained; subject to flooding; high water table.	Severe: poorly drained; high shrink-swell potential.	Severe: subject to flooding; high water table.	Severe: poorly drained; subject to flooding; high shrink-swell potential.	Poor: poorly drained; high shrink-swell potential.
Maddock: MaB, MaD.	Slight where slopes are less than 9 percent. Moderate where slopes are greater than 9 percent. [2]	Severe: rapid permeability.	Severe: sandy	Slight where slopes are less than 9 percent. Moderate where slopes are greater than 9 percent.	Severe: rapid permeability.	Slight where slopes are less than 9 percent. Moderate where slopes are 9 to 15 percent.	Good
Marsh: Mc. Too variable for valid interpretation.							
Oldham: Od, Oh	Severe: slow permeability; seasonal high water table.	Severe: seasonal high water table; subject to flooding.	Severe: poorly drained; subject to flooding; seasonal high water table.	Severe: poorly drained; subject to flooding; moderate to high shrink-swell potential.	Severe: poorly drained; subject to flooding.	Severe: poorly drained; subject to flooding.	Poor: moderate to high shrink-swell potential; moderate to high susceptibility to frost heave; poorly drained.
Parnell: Pa	Severe: slow permeability; subject to flooding.	Severe: seasonal high water table; subject to flooding.	Severe: poorly drained; subject to flooding; seasonal high water table.	Severe: poorly drained; subject to flooding; high shrink-swell potential.	Severe: poorly drained; subject to flooding; high shrink-swell potential.	Severe: poorly drained; subject to flooding; high shrink-swell potential.	Poor: high shrink-swell potential; poorly drained.

See footnotes at end of table.

engineering properties of the soils—Continued

Suitability as source of—Continued		Soil features affecting—					
Sand and gravel	Topsoil	Pond reservoir areas	Dikes, levees, and other embankments	Drainage	Irrigation	Terraces and diversions	Grassed waterway
Unsuited: no sand or gravel.	Good	Moderately slow permeability in substratum; low seepage.	Fair to good stability and compaction characteristics; medium to high compressibility; good resistance to piping.	Moderately slow permeability in substratum; level to sloping areas.	Slow water intake rate; high available water capacity; erodible on slopes.	Smooth slopes; erodible.	Hazard of erosion; high available water capacity; nearly level to sloping areas; well drained.
Unsuited: no sand or gravel.	Poor: poorly drained.	Seasonal high water table; sand and gravel below a depth of 40 inches in places.	Moderate to high shrink-swell potential; poor stability and compaction characteristics; medium to very high compressibility.	Seasonal high water table at a depth of 2 to 5 feet; subject to flooding.	Slow water intake rate; subject to flooding; high available water capacity.	Generally not applicable.	Generally not applicable.
Unsuited: no sand or gravel.	Good to a depth of 8 inches, fair below; clay loam below a depth of 8 inches.	Slow permeability; low seepage.	Fair to poor stability and compaction characteristics; slight to medium compressibility; good to poor resistance to piping.	Slow permeability; nearly level areas.	High available water capacity; slow intake rate; susceptible to salt accumulation.	Slopes of less than 2 percent; slow permeability; salt in substratum and subsoil.	Slopes of less than percent; high available water capacity; slow permeability; moderately well drained.
Unsuited: no sand or gravel.	Poor: poorly drained; clay.	Very slow permeability; high water table.	Fair to poor stability and compaction characteristics; high compressibility.	Very slow permeability; subject to flooding.	Very slow intake rate; moderate available water capacity; susceptible to salt accumulation.	Generally not applicable.	Generally not applicable.
Poor for sand: more than 15 percent fines; no gravel.	Poor: sandy	Rapid permeability; high seepage.	Good stability; fair to good compaction characteristics; poor resistance to piping.	Rapid permeability; sandy.	Low available water capacity; rapid water intake rate.	Sandy; rapid permeability; hazard of soil blowing.	Hazard of erosion; low available water capacity; sandy.
Unsuited: no sand or gravel.	Poor: poorly drained.	Seasonal high water table; low seepage; slow permeability.	Moderate to high shrink-swell potential; good to poor stability and compaction characteristics; medium to high compressibility.	Slow permeability; seasonal high water table; subject to flooding.	Slow intake rate; needs drainage; susceptible to salt accumulation.	Generally not applicable.	Generally not applicable.
Unsuited: no sand or gravel.	Poor: poorly drained.	Seasonal high water table; low seepage; slow permeability; favorable for dugouts.	Fair to poor stability and compaction characteristics; good resistance to piping; high compressibility.	Slow permeability; seasonal high water table; wet areas lower than available outlets.	Subject to ponding; needs drainage.	Generally not applicable.	Generally not applicable.

Bearden soils are in the western part of the county, and Vallers soils are in the central and eastern parts.

Fertility is medium or high in this Tonka soil. The soil takes in water slowly, and water ponds on the surface. Wetness delays farming operations some years.

Many areas are cultivated. If adequately drained, this soil is suited to most crops commonly grown in the county. Other areas are used for hay or pasture. Wetness is the main concern of management. Capability unit IIw–1, drained, IVw–1, undrained; Closed Depression range site; windbreak group 10.

Ulen Series

The Ulen series consists of deep, nearly level, moderately well drained or somewhat poorly drained, calcareous, loamy soils that formed in sandy glacial-lacustrine material. In places the sandy material has been reworked and redeposited by wind. These soils are on uplands.

In a representative profile the surface layer is dark-gray fine sandy loam about 10 inches thick. Below this is a transitional layer of gray fine sandy loam about 7 inches thick. The underlying material is light brownish-gray fine sandy loam to a depth of 24 inches and light-gray and light olive-gray loamy fine sand below.

Fertility is medium or low in Ulen soils. Available water capacity is low, and permeability is rapid. The water table fluctuates between depths of 3 and 10 feet. Soil blowing is a hazard.

Most areas are cultivated. A few areas are in native grass and are used for hay or pasture.

Representative profile of Ulen fine sandy loam, 1,550 feet west and 100 feet south of the northeast corner of sec. 25, T. 128 N., R. 59 W.:

Ap—0 to 10 inches, dark-gray (10YR 4/1) fine sandy loam, black (10YR 2/1) moist; moderate, fine, granular structure; soft, very friable; slight effervescence; mildly alkaline; abrupt, smooth boundary.

ACca—10 to 17 inches, gray (10YR 6/1) fine sandy loam, dark gray (10YR 4/1) moist; weak, coarse and medium, subangular blocky structure; slightly hard, very friable; strong effervescence; moderately alkaline; gradual, wavy boundary.

C1ca—17 to 24 inches, light brownish-gray (2.5Y 6/2) fine sandy loam, dark grayish brown (2.5Y 4/2) moist; massive; slightly hard, very friable; strong effervescence; moderately alkaline; gradual, wavy boundary.

C2ca—24 to 38 inches, light-gray (2.5Y 7/2) loamy fine sand, grayish-brown (2.5Y 5/2) moist; common, medium, faint mottles of reddish yellow (7.5YR 6/6) moist; massive; soft, very friable; strong effervescence; moderately alkaline; clear, smooth boundary.

C3g—38 to 54 inches, light-gray (5Y 7/2) loamy fine sand, light olive gray (5Y 6/2) moist; common, medium, distinct mottles of reddish brown (5YR 4/4) and reddish yellow (5YR 6/6) moist; massive; soft, very friable; slight effervescence; mildly alkaline; clear, smooth boundary.

C4g—54 to 60 inches, light olive-gray (5Y 6/2) loamy fine sand, olive (5Y 5/3) moist; many, coarse, prominent mottles of reddish brown (5YR 4/4) and dark reddish brown (5YR 3/4) moist; massive; soft, very friable; slight effervescence; mildly alkaline.

The A horizon is black or very dark gray when moist. Texture is fine sandy loam or loam. This horizon ranges from 8 to 16 inches in thickness. The ACca horizon is gray or light brownish gray in hue of 10YR or 2.5Y.

The C horizon commonly averages loamy fine sand, but it is fine sand in places. Nests of salts are at a depth of more than 24 inches in places.

Ulen soils are near Arveson, Bearden, Hamar, and Hecla soils and are mapped with Stirum soils. They contain more sand and have mottled colors at greater depths than the more poorly drained Arveson soils. Ulen soils are more sandy and less calcareous than Bearden soils. They are more calcareous and have mottled colors at greater depths than the more poorly drained Hamar soils. Ulen soils have a thinner A horizon and are more calcareous than Hecla soils. They are more sandy and lack the sodium-affected B horizon of the Stirum soils.

Ulen fine sandy loam (0 to 2 percent slopes) (Uf).—This soil is nearly level. Areas are irregular in shape and are mostly less than 60 acres in size. This soil has the profile described as representative for the series. In a few areas the underlying material below a depth of 40 inches is silty or clayey. Also, the surface layer is thinner in spots where soil blowing has removed part of it.

Included with this soil in mapping were areas of Arveson, Hamar, and Hecla soils. Arveson and Hamar soils are in slight depressions. Slopes of Hecla soils are gently undulating and convex.

Fertility is medium or low in this Ulen soil. The content of lime is high. Available water capacity is low, but a water table that fluctuates at depths between 3 and 10 feet provides moisture for deep-rooted plants. This soil is subject to blowing if cultivated.

Most areas are cultivated. Small grains, corn, flax, alfalfa, and tame grasses are the main crops. Controlling soil blowing is the main concern of management. Capability unit IIIe–14; Sandy range site; windbreak group 2.

Ulen-Stirum fine sandy loams (0 to 2 percent slopes) (Us).—Ulen soils make up 70 percent of this complex and Stirum soils 30 percent. Ulen soils are on slight rises, and Stirum soils are in low areas.

Included with these soils in mapping were areas of Arveson and Embden soils. Arveson soils are in some of the low areas. Embden soils are on some of the rises.

Fertility is medium to low in these Ulen and Stirum soils. The content of lime is high. The soils are highly susceptible to soil blowing if cultivated. In addition, the Stirum soils are wet during part of the growing season because of a high water table. Stirum soils are strongly alkaline in the subsoil and have poor tilth if cultivated.

Many areas are cultivated. Barley, rye, flax, alfalfa, and tame grasses are the main crops. Controlling soil blowing is the main concern of management, but wetness and improving fertility and tilth are also important. Capability unit IIIe–14; Ulen soils are in Sandy range site and windbreak group 2; Stirum soils are in Subirrigated range site and windbreak group 9.

Vallers Series

The Vallers series consists of deep, level, poorly drained, calcareous loamy soils that formed in glacial till or in local alluvium washed from adjacent soils. These soils are in low areas adjacent to depressions on uplands.

In a representative profile the surface layer is dark-gray loam about 8 inches thick. The underlying material is light-gray clay loam that is noticeably higher in lime content in the upper part. It is mottled in various colors.

Fertility is medium in Vallers soils. Available water

TABLE 6.—*Interpretations of*

Soil series and map symbols	Degree and kind of limitation for—						Suitability as source of—
	Septic-tank absorption fields	Sewage lagoons	Shallow excavations	Dwellings with basements	Sanitary land fills [1]	Local roads and streets	Road fill
Binni: SkA, SkB, SkC.	Severe: slow permeability.	Slight where slopes are less than 2 percent. Moderate where slopes are 2 to 6 percent. Severe where slopes are 6 to 9 percent.	Severe: silty clay.	Severe: high shrink-swell potential.	Severe: silty clay.	Severe: high shrink-swell potential.	Poor: high shrink-swell potential.
*Sioux: SmE. For Arvilla part, see Arvilla series.	Severe: slopes are greater than 15 percent.[2]	Severe: rapid permeability.	Severe: very shallow to gravel.	Severe: slopes are greater than 15 percent.	Severe: rapid permeability.	Severe: slopes are greater than 15 percent.	Fair where slopes are 15 to 25 percent. Poor where slopes are 25 to 40 percent.
*Stirum: Su. For Ulen part, see Ulen series.	Severe: high water table.	Severe: high water table.	Severe: poorly drained; high water table.	Severe: poorly drained.	Severe: poorly drained; subject to flooding.	Severe: poorly drained.	Poor: poorly drained; moderate to high susceptibility to frost heave.
*Swenoda: SwA, SwB, SxA. For Larson part of SxA, see Larson series.	Slight to moderate: moderate permeability in substratum.	Moderate: moderate permeability in substratum.	Slight.	Slight to moderate: low to moderate shrink-swell potential; well drained to moderately well drained.	Slight.	Moderate: AASHO Group Index of 4 to 8 in substratum.	Fair: AASHO Group Index of 4 to 8 in substratum.
Tonka: To.	Severe: slow permeability; subject to ponding.	Slight if water is likely to enter lagoon.	Severe: poorly drained; subject to ponding.	Severe: poorly drained; moderate to high shrink-swell potential.	Severe: poorly drained.	Severe: poorly drained; moderate to high shrink-swell potential.	Poor: poorly drained; moderate to high shrink-swell potential; high susceptibility to frost heave.
*Ulen: Uf. For Stirum part of Us, see Stirum series.	Severe: seasonal high water table.	Severe: rapid permeability.	Severe: seasonal high water table; loamy fine sand below a depth of 24 inches.	Moderate to severe: moderately well drained to somewhat poorly drained.	Severe: seasonal high water table.	Moderate: moderately well drained to somewhat poorly drained; moderate susceptibility to frost heave.	Fair: moderately well drained to somewhat poorly drained; moderate susceptibility to frost heave.

See footnotes at end of table.

engineering properties of the soils—Continued

Suitability as source of—Continued		Soil features affecting—					
Sand and gravel	Topsoil	Pond reservoir areas	Dikes, levees, and other embankments	Drainage	Irrigation	Terraces and diversions	Grassed waterways
Unsuited: no sand or gravel.	Poor: clayey.	Low seepage; slow permeability.	Fair to poor stability and compaction characteristics; high shrink-swell potential; high compressibility.	Slow permeability; clayey.	Very slow water intake rate; moderate to high available water capacity.	Clayey; slow permeability; nearly level to sloping areas.	Clayey; moderate to high available water capacity; well drained.
Good to poor: 0 to 25 percent fines.	Poor: sand and gravel at a depth of 7 to 14 inches.	High seepage; rapid permeability; sand and gravel substratum at a depth of 7 to 14 inches.	Good stability; fair to poor resistance to piping.	Rapid permeability; slopes are greater than 15 percent.	Low available water capacity; shallow rooting zone; sloping to very steep areas; generally not applicable.	Very shallow to gravel; rapid permeability.	Very shallow to gravel; low available water capacity.
Poor for sand: more than 15 percent fines; high water table; no gravel.	Poor: poorly drained.	High water table; moderately rapid permeability in substratum.	Poor resistance to piping.	Moderately slow permeability in subsoil, moderately rapid permeability in substratum; high water table; claypan subsoil.	Low to moderate available water capacity; poorly drained; high water table; subject to salt accumulation in subsoil and substratum; generally not applicable.	Generally not applicable.	Generally not applicable.
Unsuited: no sand or gravel.	Good.	Moderately rapid permeability in upper 29 inches; moderate below.	Fair to poor stability; fair to poor shear strength.	Moderately rapid permeability in upper 29 inches, moderate permeability below; nearly level to gently sloping areas.	High available water capacity; susceptible to soil blowing; moderately slow water intake rate.	Susceptible to soil blowing; moderately rapid permeability; in upper 29 inches; moderate permeability in substratum.	High available water capacity; susceptible to soil blowing.
Unsuited: no sand or gravel.	Poor: poorly drained.	Slow permeability; subject to ponding; high water table.	Fair to poor stability and compaction characteristics; medium to high compressibility.	Slow permeability subject to ponding; wet areas lower than available outlets.	Subject to ponding; very slow intake rate; high available water capacity; poorly drained; generally not applicable.	Generally not applicable.	Generally not applicable.
Poor for sand: more than 15 percent fines; no gravel.	Poor: seasonal high water table.	Seasonal high water table; rapid permeability.	Good stability; fair to good compaction characteristics; low compressibility; poor resistance to piping.	Rapid permeability; seasonal high water table; sandy substratum.	Very rapid intake rate; seasonal high water table; low available water capacity; generally not applicable.	Generally not applicable.	Generally not applicable.

Department of Natural Resources

latitude. The next seven digits denote degrees, minutes, and seconds of longitude. The last two digits are sequential numbers for wells within a 1-second grid. The system provides the geographic location of the well and a unique number for each well.

GEOGRAPHY

Location and Size

Marshall County occupies 888 square miles (2,300 km^2) in northeastern South Dakota (fig. 1). The population in 1960 was 6,663, and in 1970 was 5,965. The eight towns in the County had a total population of 2,718 in 1960 and 2,296 in 1970; about one-half of the town population lived in Britton, the County seat. Three state highways (10, 23, and 25) and three railroads (the Chicago, Milwaukee, St. Paul and Pacific, the Burlington Northern, and the Soo Lines) cross the County.

Physiography and Topography

Marshall County is in the western lake section of the Central Lowland physiographic province (Fenneman, 1931). The County is in the following physiographic divisions: James River lowland, Lake Dakota plain (part of the James River lowland), Coteau des Prairies, and Minnesota River-Red River lowland (figs. 1 and 3).

In Marshall County the James River lowland, except for the Lake Dakota plain, is a westward-sloping terraced moraine between the Lake plain and the coteau. Near the end of the Ice Age the terraced moraine deposits were dissected by the large runoff from melting stagnant ice on the coteau. The melt water was carried by many streams which cut deep valleys and ravines locally called coulees.

The Lake Dakota plain is characterized by a very flat surface; local relief is rarely more than 10 feet (3 m). The Lake plain is part of the James River lowland but differs from it in that it is the floor of an ancient lake. South of the recessional moraine (shown as James River lowland in T. 128 N., R. 59 W. and T. 127 N., R. 58 W., in fig. 3), that divides the Lake Dakota plain, the surface is very flat; however, north of the recessional moraine the lake plain is interrupted by isolated patches of recessional moraine, the highest of which, located 6 miles (10 km) north of Britton, is about 65 feet (20 m) above the flat plain.

In the northwestern part of the County the lake floor is covered with windblown sand, which forms a hummocky dune topography.

The Coteau des Prairies is a high plateau of rugged morainal topography. Catlin (1840, p. 144-145) who saw the Coteau des Prairies in 1835, described it thus:

"This wonderful anomaly in nature, which is several hundred miles in length, and varying from fifty to an hundred in width, is undoubtedly the noblest mound of its kind in the world: it gradually and gracefully rises on each side, by swell after swell, without tree, or bush, or rocks, . . . and is everywhere covered with green grass, affording the traveller, from its highest elevations, the most unbounded and sublime views of - nothing at all, - save the blue and boundless ocean of prairies that lie beneath and all around him, vanishing into azure in the distance, without a speck or spot to break their softness."

This description is still true today although farm buildings and trees are also part of the picture in many areas of the coteau.

The coteau is a flatiron-shaped plateau that slopes gently westward and, near the point or nose at the North Dakota State line, slopes gently northward (fig. 4). The Des Moines lobe of the continental glacier advanced southwest in this area and deposited much drift on the eastern side of the coteau. The main force of the James lobe (on the west side of the coteau), however, was to the southwest, into a broadening valley; therefore, there was less piling of ice onto the western side of the coteau and thus less deposition of drift.

The coteau escarpments differ in slope and height. The eastern escarpment rises about 300 feet per mile (57 m/km), from an altitude of 1,400 to 1,750 feet (426 to 533 m) and the less prominent western escarpment rises about 200 feet per mile (38 m/km). Both slopes are cut by many valleys; the wider and deeper valleys are in the eastern slope.

The topography of the coteau was formed by the rock debris deposited from the melting of stagnant glacial ice. This produced high relief, numerous undrained depressions called sloughs or prairie potholes, and, in general, a hummocky topography. The highest point in the County is Pleasant Peak, which as an altitude of 2,080 feet (634 m) and is located in sec. 8, T. 127 N., R. 55 W.

The Minnesota River-Red River lowland is a generally flat, east-sloping ground moraine that contains isolated patches of recessional moraine. The lowest point in the County, at an altitude of 1,194 feet (364 m), is where Shortfoot Creek enters North Dakota.

Drainage

Marshall County is in three main drainage basins, as shown in figure 5: the Missouri River basin covers about 630 square miles (1,632 km^2), the Red River

m). Above normal or near normal precipitation continued to 1952 and produced comparable changes of lake level. The highest level of Buffalo Lake on record occurred in 1952 when the lake depth reached about 17 feet (5.2 m). From 1952 through 1961, below normal precipitation resulted in a decline of lake depth of 7½ feet (2.3 m). From 1962 to 1967 above normal precipitation caused an increase in lake depth of 5½ feet (1.7 m). Near normal precipitation from 1967 to 1972 has maintained lake-depth changes within a seasonal range of 2 feet (0.6 m).

Lake-level changes in Clear Lake are similar to those in Buffalo Lakes in their response to precipitation (fig. 18). Clear Lake was dry in the fall of 1935 except for a few moist spots (Rothrock and Ullery, 1938, p. 6). It became nearly dry again in the fall of 1940 (Caddes, 1947, p. 8). The highest lake level occurred in 1952 when the lake depth reached about 18 feet (5.5 m).

Lake-level changes in Roy Lake follow the same major trends as in Buffalo and Clear Lakes. Roy Lake was dry during the drought in 1894; in 1910 it was a grassy slough (Rothrock and Ullery, 1938, p. 5). In the fall of 1939 the lake again nearly became dry. The highest lake level on record occurred in 1947 when the lake depth reached 21 feet (6 m).

Short-term lake-level changes in Roy Lake differ from those in Buffalo and Clear Lakes (fig. 18). In the spring of 1937 lake levels in Buffalo and Clear Lakes rose 4½ feet (1.4 m), whereas Roy Lake did not rise until the fall and then only by 1 foot (0.3 m). In 1941 Buffalo and Clear Lakes again rose, whereas Roy Lake did not rise until 1942. A possible reason for the lag in water-level change of Roy Lake compared to that of Buffalo and Clear Lakes is that the hydraulic connection between Roy Lake and the outwash deposits discharging ground water to the lake has lower transmissivity than at the other lakes. Therefore ground-water moves to the lake at a slower rate than it moves to the other lakes following periods of above normal precipitation. Water in Buffalo and Clear Lakes is almost surrounded by and is hydraulically connected to ground water in the outwash; thus precipitation that recharges the ground water in the outwash can move quickly to these lakes.

Field analyses, consisting of specific conductance, dissolved oxygen, pH, and temperature, were made of water samples from 37 lakes and ponds (table 5). Laboratory analyses were made of samples collected from Buffalo, Clear, Roy, and Ninemile Lakes. A lake study by Petri and Larson (undated) included periodic analysis of samples from Buffalo, North Red Iron, Roy, Clear, Piyas, and Fort Lakes.

Specific conductance measurements from 42 lakes and ponds ranged from 460 at North Red Iron Lake to 20,000 µmhos/cm at East Stink Lake. Specific conductance in 7 lakes or ponds exceeded 2,000 in 8 lakes or ponds ranged from 1,000 to 2,000, and in 27 lakes or ponds was less than 1,000. Petri and Larson reported that when the dissolved-solids concentration in lake waters was less than about 700 mg/l, magnesium, calcium, and bicarbonate predominated; but if it was more than 700 mg/l, magnesium, calcium, and sulfate predominated. An estimate of the dissolved-solids concentration in the lakes or ponds can be made by multiplying specific conductance by 0.7.

Water from Buffalo and Roy Lakes was analyzed in 1964, 1965, and 1970 as was water from Clear Lakes in 1961, 1962, 1963, and 1970. None of the lakes showed any appreciable change in water quality. Lakes that discharge water through an outlet each spring, such as these, have a tendency to flush the mineral constituents from the lake. Lakes such as East Stink Lake that do not discharge water except by evaporation and by ground-water seepage tend to increase in dissolved-solids concentration.

Ground Water Quantity and Quality

Aquifers in the Glacial Drift

All major aquifers in the unconsolidated materials that overlie the bedrock are deposits of glacial outwash and alluvium. These deposits, composed mostly of sand and gravel, comprise six major aquifers, here named the James, Veblen, Coteau-lakes, Marday, Eden, and Roslyn aquifers. The areal, topographic, and stratigraphic relations of these aquifers, and of some other water-bearing deposits of very limited or local extent, are shown in the sections of figure 19.

Till is not discussed as a major source of water because it has low permeability and in general will not yield large amounts of water. Where small sand lenses occur in the till yields of 1 to 5 gpm (0.06 to 0.3 l/s) of generally poor-quality water can be obtained.

James Aquifer

The James aquifer (fig. 20), in north-central Marshall County, has narrow channels that extend southwest into Brown County and southeast into Day County. The aquifer underlies about 220 square miles (570 km^2) in Marshall County and extends into North Dakota. The aquifer, composed mainly of buried outwash deposits and of alluvium from an ancient river, consists of sorted and stratified gravel, sand, and silt. The narrow channels that extend through central and southern Marshall County contain sand and gravel deposited by a preglacial river that had flowed north to Hudson's Bay. Water in the

Table 5 -- continued.

(1)	(2)	(3)	(4)	(5)
Unnamed Lake or Pond				
125-53-5CCC				
June 30, 1967	1,400			
September 25, 1969	1,770	8.4	10.2	12.5
125-55-6A				
June 30, 1967	1,225			
September 25, 1969	1,500	8.6	11.1	15.5
125-56-25A				
June 30, 1967	1,350			
September 25, 1969	2,000	8.7	12	16.0
126-56-3B				
June 30, 1967	890			19.0
127-54-3				
June 30, 1967	730			24.0
127-54-16D				
June 30, 1967	720			23.5

aquifer occurs under artesian conditions and water levels range from 2 to 111 feet (1 to 34 m) below land surface.

The James aquifer contained about 1½ million acre-feet (2 billion m^3) of water in storage in 1971. Water in storage was estimated by using an average saturated thickness of 50 feet (15 m) and an estimated porosity of 20 percent.

Yields of 500 gpm (32 l/s) or more can be expected from properly constructed wells at locations where more than 40 feet (12 m) of medium or coarser sand occurs.

Thickness and distribution of the deposits that form the aquifer are shown in figures 19 and 20. The thickest part of the aquifer is in the narrow channel extending southeastward into Day County. The greatest known thickness of sand and gravel, 129 feet (39 m), was found at test hole 126N55W31CCCD.

In general, the James aquifer occurs at altitudes of 1,250 to 1,050 feet (381 to 320 m). In low-lying areas, the aquifer is at depths ranging from 100 to 190 feet (30 to 58 m) below land surface; at higher altitudes, on the coteau, it is 580 feet (177 m) or more below land surface.

Test-hole data indicate that permeable sedimentary deposits overlie the James aquifer in Rs. 58 and 59 W. Such cover varies from very permeable, well-sorted beds of very fine to coarse sand, to interbedded sand and clay layers, to sandy or very sandy or silty clay. Where the sand extends close to land surface, the water is under water-table conditions.

At least 50 wells tap the James aquifer on the lake plain where it is shallowest. Where it is deeply buried, as beneath the coteau, no wells have been finished in it.

Recharge to the James aquifer is by subsurface inflow from Brown County and possibly Day County and by percolation of rainfall and snowmelt through overlying lake plain sediments and till. Subsurface inflow is indicated by the direction the water moves, as shown on the map in figure 21. Most recharge to the James aquifer is by percolation of precipitation in Rs. 58 and 59 W. Identification of this area as an important source of recharge was by analysis of several types of data: test-hole logs, to evaluate overburden permeability; water-level measurements and precipitation data to determine the type and rapidity of response of the water surface to precipitation and snowmelt; and water-quality data, because salinity increases and general water quality deteriorates with increasing distance from the recharge area.

Fluctuations of water levels in wells are the result of changes in the amount of water stored in the aquifer. Changes in storage are caused by differences in the rates of recharge and discharge.

Water-level fluctuations in wells in the James aquifer are both seasonal and long term. Seasonal

fluctuations of water levels are caused by differences in recharge or discharge throughout the year. Water levels rise in the spring and early summer when recharge from percolation of snowmelt and spring rains is greater than discharge by subsurface outflow or evapotranspiration. Conversely, water levels decline from mid-summer to mid-winter when discharge is greater than recharge. This type of seasonal water-level fluctuation is shown in figure 22 for wells 128N58W22BBB, 127N58W6BBB, 126N59W4AAA, and 128N56W3BBBB, which are located in recharge areas.

Long-term fluctuations in water levels reflect cumulative differences in recharge and discharge for a period greater than 1 year. Water levels generally rise in years of above-normal precipitation and decline in years of below-normal precipitation. Because only 2 years of water-level measurements are available for the James aquifer, long-term fluctuations of water levels were difficult to evaluate; however, during 1971, as shown in figure 22, water levels declined about 0.5 to 1 foot (0.1 to 0.3 m). This drop in water level correlates with the period of below-normal precipitation that occurred much of the time from mid-1969 to October 1971, and may be an indication of the beginning of a long-term decline in water levels.

Natural discharge from the James aquifer is by subsurface outflow into North Dakota. The rate of movement is only a few tens of feet per year. Water moves from areas of recharge to areas of discharge as shown in figure 21.

The James aquifer may be discharging water to or receiving recharge from the Niobrara Formation near the North Dakota State line, where the Niobrara is in contact with the James aquifer. Although no wells are known to obtain water from the Niobrara in Marshall County, this study found that the formation does contain one or more permeable zones. The permeable zones in the Niobrara were detected when they took drilling water when penetrated. Water-quality data also suggest the possible mixing of water from the Niobrara with water from the James aquifer.

The predominant chemical constituents of water from the James aquifer can be used to classify the water into four groups (fig. 23).

Group 1 is in the western and southern parts of the aquifer, where water enters the aquifer from Brown County in T. 128 N. or recharges the aquifer by percolation through the overlying material. Sodium and bicarbonate predominate and hardness ranges from 110 to 260 mg/l.

Group 2 is in the central area where most recharge to the aquifer takes place. The predominant constituents in the water are calcium and bicarbonate, although magnesium and sulfate constitute a sizable part. Hardness in the water is high, 340 to 440 mg/l.

Group 3 is a mixed water east of the central major recharge area. The major constituents are sodium, calcium, and bicarbonate where the mixing is with water from the south and west and calcium and sulfate where the mixing is with water from the north. Magnesium is also an important constituent in the mixing area. Hardness ranges from 316 to 860 mg/l. In three samples the hardness is higher than in the major recharge area—the high hardness values might be due to water circulating through or coming from the underlying Niobrara Formation.

Group 4 is in the northern, eastern, and southwestern parts of the aquifer where sodium, sulfate, and bicarbonate predominate. In the north and east the aquifer is in contact with the underlying Niobrara Formation. Several test holes indicate that the Niobrara Formation is permeable; James aquifer water, therefore, may undergo a quality change as a result of mixing with water from Niobrara. The major change in quality is an increase in sulfate resulting in sodium, sulfate, and bicarbonate becoming the major constituents. Hardness ranges from 166 to 265 mg/l In the southwestern part the James aquifer also may be connected with the Niobrara; however, the quality is somewhat different indicating that other factors may be involved. Hardness and chloride are considerably higher than elsewhere, possibly the result of local recharge through overlying drift.

The water in the James aquifer has high salinity hazard and ranges from low to high sodium hazard (fig. 17). Water of low sodium hazard is in the calcium bicarbonate type water area or in the mixed-water area to the northeast (fig. 23). Water of high sodium hazard is in the southern and eastern parts of the aquifer.

Field analyses of specific conductance, chloride, and hardness were made of water from 19 wells (table 6).

Veblen Aquifer

The Veblen aquifer underlies 24 square miles (62 km^2) in northeastern Marshall County and extends into Roberts County and into North Dakota (fig. 24) Probably only a small part of the aquifer is within Marshall County. It consists of buried outwash that is mostly sand and gravel. The outwash contained clay lenses at only one test hole (129N53W25AADA). Water in the aquifer occurs under artesian conditions except in some places where overlying clay layers are absent and it occurs under water-table conditions Water levels range from 50 to 100 feet (15 to 30 m) below land surface.

Pleistocene glacial and lacustrine deposits of late Wisconsin age and Holocene sediments make up the surficial deposits. Glacial deposits having a known thickness of 805 feet (245 m) overlie sedimentary rocks of Cretaceous age. Evidence suggests that the late Wisconsin ice margin halted four times during the period of deglaciation and caused major reshaping of the topography and drainage.

The glacial material on what is now called the Coteau des Prairies consists mostly of stagnation moraine. This is evidenced by areas of collapsed outwash and the presence of ice-walled lake plains and collapsed lake plains.

To the west of the coteau, lacustrine sediments were deposited in a large lake called Lake Dakota.

In Marshall County a large end moraine extends along the margins of the coteau, and remnants of two end moraines are found in the central part of the coteau. The large horseshoe-shaped Oaks moraine extends across the Lake Dakota plain.

Surface water consists of many small intermittent streams and numerous marshes, ponds, and lakes. Streamflow takes place in spring from snowmelt and following periods of heavy precipitation; most of the year, however, streams are dry. The streams in Marshall County originate on the coteau. Seven percent of the County is covered by water in marshes, ponds, and lakes. Many small perched marshes, ponds, and lakes occur on the coteau in the clayey ground and on end moraines. Most of the larger surface-water bodies are hydraulically connected to aquifers.

Glacial deposits of sorted sand and gravel are the important water-bearing rocks in Marshall County. Of the six aquifers in drift, the James, Veblen, and Coteau-lakes aquifers can provide yields of 500 gpm (32 l/s) or more.

The James aquifer underlies 220 square miles (570 km^2) in Marshall County. It ranges in depth from 100 to 190 feet (30 to 58 m) below land surface in low-lying areas to more than 580 feet (177 m) below land surface on the coteau. Water in the aquifer is under artesian pressure and the water surface ranges from 2 to 111 feet (1 to 34 m) below land surface. The aquifer contains an estimated 1½ million acre-feet (2 billion m^3) of water in storage.

Recharge to the James aquifer is from ground-water inflow from Brown County and percolation of precipitation and snowmelt through overlying lake plain sediments and till in Rs. 58 and 59 W.

Discharge from the James aquifer is by subsurface outflow into North Dakota.

Sodium and bicarbonate predominate and hardness ranges from 110 to 260 mg/l where water enters the James aquifer from Brown County in T. 128 N. Where most of the recharge takes place calcium and bicarbonate predominate and hardness is high, 340 to 440 mg/l. In the mixed water east of the main recharge area the major constituents are sodium, calcium, sulfate, and bicarbonate and hardness ranges from 316 to 860 mg/l. Where the aquifer water is mixing with water from the Niobrara Formation, sodium, sulfate, and bicarbonate predominate and hardness ranges from 166 to 265 mg/l. The water in the James aquifer has high salinity hazard and ranges from low to high sodium hazard.

The Veblen aquifer underlies 24 square miles (62 km^2) in the northeast corner of Marshall County. Water in the aquifer occurs in some areas under artesian conditions and in other areas under water-table conditions and water levels range from 50 to 100 feet (15 to 30 m) below land surface. The thickness of the aquifer ranges from 40 to 69 feet (12 to 21 m). Well depths range from 80 to 158 feet (24 to 48 m) below land surface.

Recharge to the Veblen aquifer is from percolation through the overlying till and outwash. Discharge is by subsurface outflow into Roberts County and into North Dakota.

Water from the Veblen aquifer is of two types; the predominant constituents in the western part of the aquifer are calcium, sodium, and sulfate and in the eastern part of the aquifer are calcium, magnesium, and bicarbonate. The water has high salinity hazard and low sodium hazard.

The Coteau-lakes aquifer, in the southeastern corner of the County, underlies about 50 square miles (130 km^2). The aquifer, found near land surface, is hydraulically connected with Buffalo, South Red Iron, North Red Iron, Clear, and Roy Lakes. Water levels range from that in adjacent lakes to 40 feet (12 m) below land surface. Water occurs in some areas under water-table conditions and in other areas under artesian conditions. The thickness of the aquifer varies widely from place to place.

Recharge to the Coteau-lakes aquifer is by direct precipitation, percolation through the till cover, surface runoff into the lakes, and subsurface inflow. Discharge is by evapotranspiration and by subsurface outflow.

Major constituents in water in the Coteau-lakes aquifer are calcium and bicarbonate. The water has medium to high salinity hazard and low sodium hazard.

Three minor aquifers, the Marday, Eden, and