Environmental Geology 2

Engineering Geology Report for Planning District 1, State of Colorado

Prepared for the Colorado Geological Survey
and the Colorado Diviision of Planning

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Colorado Geological Survey
Department of Natural Resources
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COLORADO GEOLOGICAL SURVEY
DEPARTMENT OF NATURAL RESOURCES
STATE OF COLORADO

RECONNAISSANCE ENGINEERING GEOLOGY REPORT FOR PLANNING DISTRICT 1 STATE OF COLORADO

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ENVIRONMENTAL GEOLOGY NO. 2

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*In pocket at back of report

S U M M A R Y

The following outline serves to give the planner some idea of what potential problems he should be aware of when dealing with a given geologic unit. It should be noted, however, that not all geologic units are consistent throughout and may not comply with general assumptions. For example, although swelling clay is to be expected in the Pierre shale, not all areas of the Pierre will be troublesome. It would be impossible to define, in the scope of this report, exactly what to expect in a specific area and it is for this reason it is recommended that study be given to each site prior to construction.

In general, problems in alluvium will probably result from consolidation, flooding potential, erosion, high water tables and pollution. Loess will tend to be easily eroded and prone to settling. Dune sand is very erosive and porous. Pollution of ground water can result from improper use of areas covered by dune sand. Characteristics of sediments are varied and the resulting problems will be varied because of this. In general, in Planning District 1, erosive conditions some swelling clays and flood potentials can be expected over much of the area covered by sediments. The Pierre Shale has been set apart from other sediments because of its range of problems which include swelling clays, high sulfate. contents and a high erosion potential. The shale is also impermeable which makes sewage disposal difficult and some areas prone to flooding.

In many cases, more than one geologic unit will be involved and not only should each unit be studied individually, but possible inter-reactions between the two units should be considered. For example, a thin layer of dune sand may cover the Pierre Shale. Foundation problems may result from swelling clays in the Pierre from water percolating down through the dune sand. Although the dune sand has no swelling potential, in such a case, swelling would be a problem.

It is recommended that an engineering geology study take place in areas where such an inter-reaction may take place.

One problem that can be expected in all five units is the potential of polluting the ground water supply. Major potential polluters are poorly located leach fields, improperly constructed landfills, silage pits, wastes associated with oil and gas wells and feed lots. State regulations exist concerning leach fields and their proper location. A non-polluting sanitary landfill would require careful consideration and engineering, and professional help should be required. Foresight, careful planning and constant maintenance would prevent pollution from silage pits and oil production wastes. Planning and consideration of the ground water geology should always be used in the location of a feet lot. Pollution of ground water from such a cause could be extreme. Professional advice should be sought for the location of future feed lots and operation of present ones.

In summary, various problems and limitations can be expected in every geologic unit although these problems are not always consistent throughout an area. Some problems may be absent and unexpected problems may arise in the development of an area. In addition, pollution potentials exist in all five units and should always be given careful consideration. It is recommended that construction in areas of known soil problems, such as the loess and the Pierre Shale, be preceded by testing and engineering recommendations. An engineering geologist should study and make recommendations for the plans and site location of a sanitary landfill, feed lot or other potential ground water polluter. Foresight should be used in construction to avoid erosion, flooding, pollution and foundation problems. With proper planning and the use of professional help when needed, such problems can usually be avoided.

INTRODUCTION

The purpose of this report is to present the results of a comprehensive investigation of the geology and engineering geology of Planning District #1, State of Colorado. Included with the text are maps, illustrations and other pertinent information as it relates to the geology and engineering geology of the subject area.

PURPOSE AND SCOPE

The purpose of the investigation is to identify within the Planning District, specific geologic factors which should be considered to insure safe, efficient and environmentally sound land use decisions. This investigation was done on a reconnaissance basis and the factors include, but are not limited to, the following:

a. Mineral resources which affect land use decisions

b. Massive land movements or other unstable surface conditions

c. Areas of swelling soils, settling soils or other soil factors that will affect foundation construction

d. General areas of flood danger and/or erosional hazards

e. Areas of high water table, both permanent and seasonal

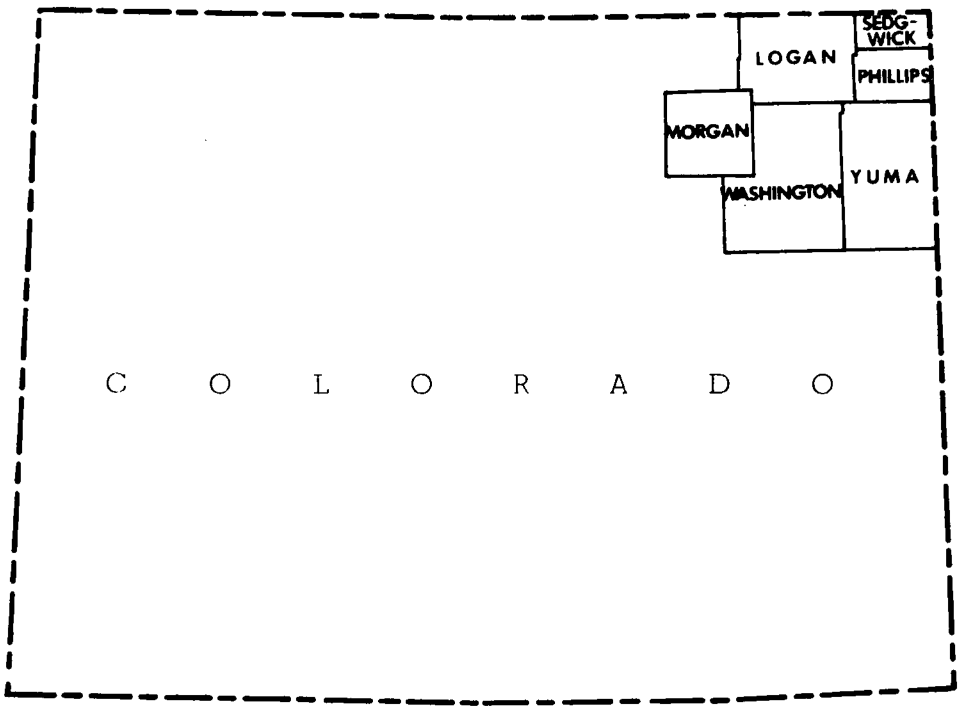
f. General geologic constraints that will affect selection and operation of solid waste disposal sites

g. Pollution potential and other possible hazards associated with old mine tailing dumps.

h. Other critical factors which may become evident during the course of the study.

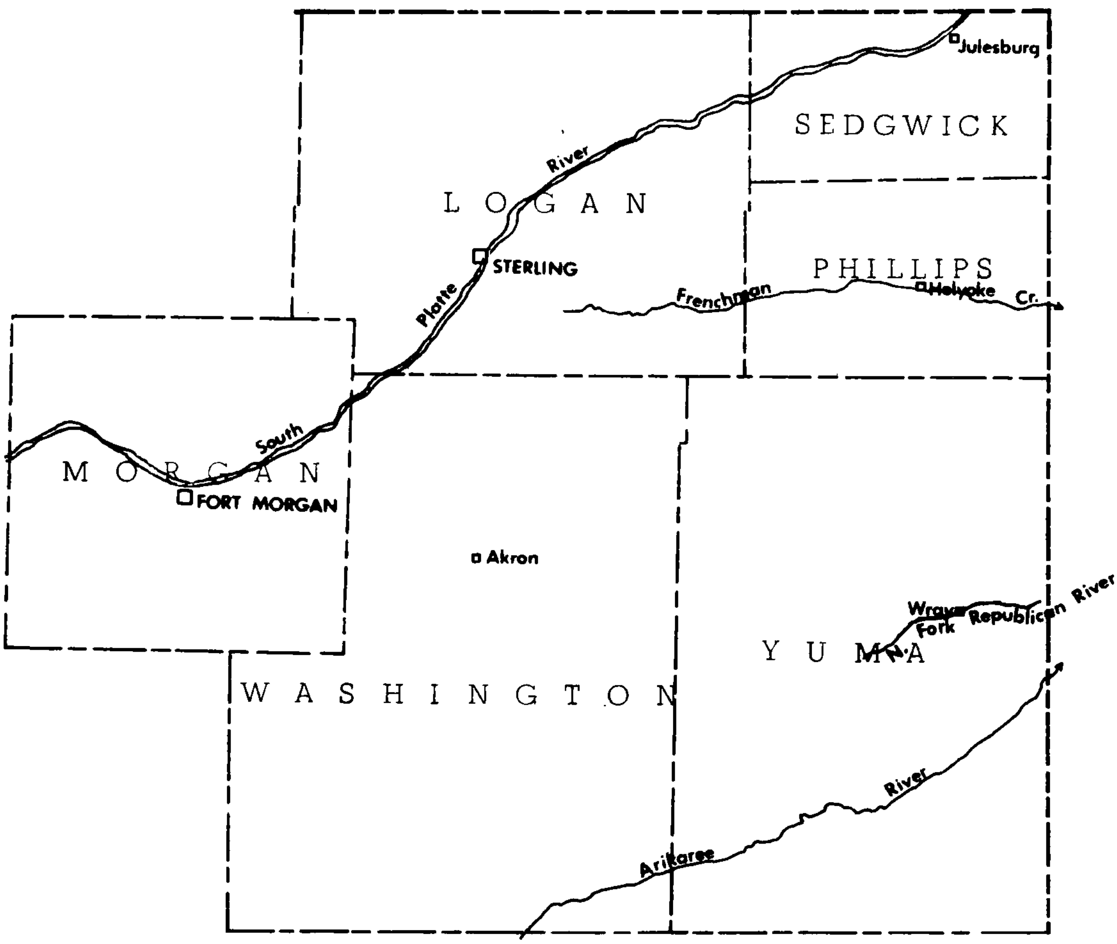
Figure 1 defines the areal extent of the study area. Planning District #1 includes the counties of Morgan, Logan, Washington, Yuma, Phillips and Sedgwick.

Figure 2 shows the major rivers and drainages in the district and identifies the location of each of the county seats. The main river is the South Platte and minor streams are the Arikaree River, the North Fork of the Republican River and Frenchman Creek.



LOCATION MAP OF PLANNING DISTRICT 1

FIGURE 1



MAJOR RIVER SYSTEMS IN PLANNING DISTRICT 1

FIGURE 2

PHYSIOGRAPHIC FEATURES

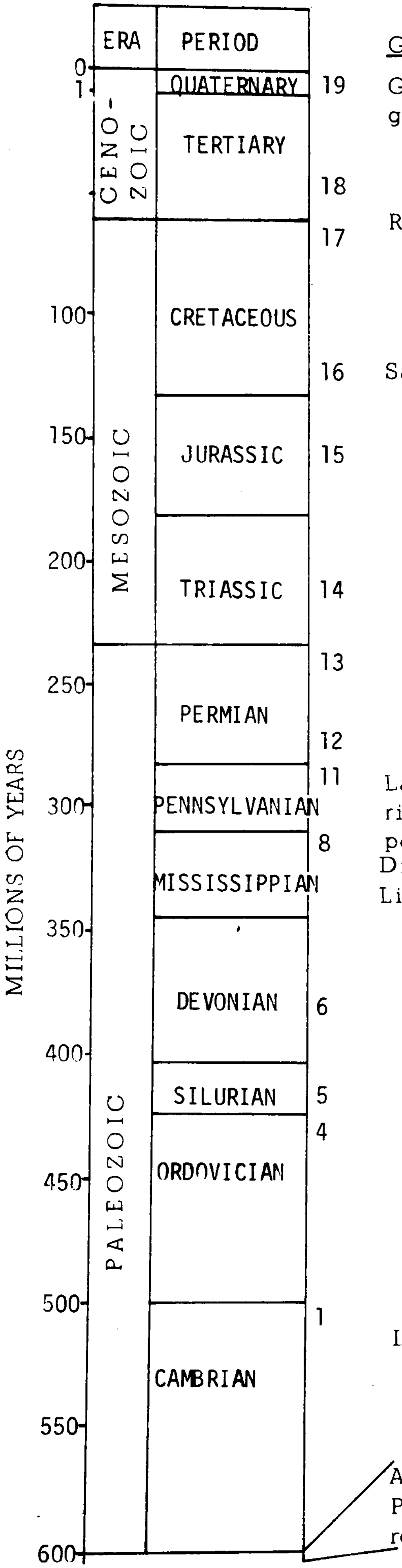
Planning District #1 is located for the most part in the Colorado High Plains. The South Platte River Basin cuts across the northern portion of the district. To the west lies the Colorado Piedmont. Planning District #1 is comprised mainly of level or gently rolling terrain cut by drainages running from southwest to northeast. The highest point in the Planning District is in Washington County with an elevation of 4,800 feet; the lowest point is in Sedgwick County with an elevation of 3,400 feet.

GENERAL GEOLOGY

Figure 3 defines the geologic evolution of the State of Colorado and the Geologic events of Planning District #1 in the order of their occurrence. This figure shows a synopsis of the geologic events which occurred creating the various geologic units and eventually forming the present features of the area; the numbers on the right side of the geologic time column refer to the numbered graphic representations.

Although the geologic history of Earth goes back approximately four billion years when the Earth consisted of nothing more than molten material, the geologic history of interest to this report began about two and one-half billion years ago during the early Precambrian period. Colorado had a varied and complex history during the Precambrian, but little of the exact history can be determined from the highly altered rocks dating from that time. The geologic history can only be speculated, but it is assumed that masses of various types of sedimentary and igneous rocks were repeatedly deposited, buried, altered, resurfaced and injected with new igneous bodies.

About 600 million years ago, the first definable geologic period began. This was the Cambrian period during which Planning District #1 was a low landmass, surrounded by seas to the south and west. During the Ordividian period, this sea began to withdraw to the east, exposing more and more land. In the Silurian time,



GEOLOGIC EVENTS IN PLANNING DIST. 1

Glaciation in the Rockies- Glacial outwash and windborne glacial dust carried onto plains.

ROCKY MOUNTAINS UPLIFTED: Denver Basin subsides.

Sand deposited in shallow seas covering the entire state.

Landmass subsides and mud and sand are deposited as rising seas erode mountains in the central and eastern portion of the state.

District uplifted as low landmass.

Lime deposited as shallow seas cover most of the District.

Low landmass occupies most of the District.

All of earth history to the Cambrian occurs in the Precambrian, little of which is preserved in the rock record.

Figure 3

the entire State of Colorado was a low landmass. The Devonian period still found Planning District #1 as a low landmass, but in Early and Middle Mississippian time, the seas moved in and only a tiny portion of land remained. During this time, the seas were depositing limestone. In the Late Mississippian period, the seas once again receded and Planning District #1 emerged as a low landmass.

In Early Pennsylvanian time, the land subsided once again and Planning District #1 was covered by seas for about 250 million years. During the Pennsylvanian, Permian, Triassic and Jurassic periods, the seas deposited mud and, to the west, some sand as the mountains to the west were gradually eroded down to a low plain. During the Early Cretaceous the entire state was submerged and sand was deposited throughout. During Late Cretaceous time, limestone was being deposited in Planning District #1.

At the close of the Cretaceous period, there was a time of mountain building and the present Rocky Mountains were formed. Planning District #1 emerged from the seas as a dry landmass and the Denver Basin subsided to the west. During the Pleistocene, glaciers carved the mountains to the west. As these glaciers receded, winds swept the mountains of the powdered rock and blew this glacial dust to the east where it was deposited as the loess found there today. More recently, winds deposited the sand dunes from material eroded from the mountains.

Geologically, District #1 is similar throughout and the area has shared a consistent geologic history. The District is comprised mainly of water laid sediments, covered in places by wind deposited sand and silt, and cut in places by streams and rivers.

HOW TO USE THIS REPORT

This report has been specifically prepared and directed to planners as well as county and regional officials. It has been assumed that those reading and using this report will have a cursory understanding of geologic terms and conditions although every attempt has been made to present this report in a combination of technically sound data in layman's terms. As a portion of this report, a glossary follows the text. This glossary defines any terms that we have used within the report which may not be clear to the reader. At the beginning of the investigation, it became obvious that a special compilation of geologic data would be necessary to define the planning and development hazards in the District. Therefore, a rather unusual map has been prepared. This map is found in the pocket at the end of this report. This map does not define specific geologic formations, but instead defines various geologic units which, in general, have similar engineering characteristics.

For example, the loess (wind blown silt) settles when wet and can present construction problems. However, with careful engineering and where there is no danger of flooding, this silt could make an excellent sanitary landfill site. In contrast to this, however, the alluvium should offer few construction problems but is easily polluted and subject to flooding. Each map unit will have a section in the report listing characteristics of the unit and how these characteristics will affect planning. In this way, the planner reviewing a specific area will have some idea of what problems may be anticipated and how these problems are handled properly.

This report is intended to clarify, to all concerned, those problems which can and may arise in developing an area. Some problems may be simply handled, some may require professional help and some may be too great to solve in a practical manner. However, the point remains that the problems are there and must be recognized. It is the express purpose of this report to aid the planner and other local officials in the recognition of these geologic problems. It is not the purpose under the scope of this report to provide detailed geologic information for individual site evaluations.

SPECIFIC CONSIDERATIONS

I. Alluvium 

This unit characteristically consists of unconsolidated rock particles of mixed or sorted sizes, which have accumulated during Recent geologic time. Specific types include:

A-1 Water deposited clay and silt found in stream flood plains.

A-2 Water deposited sand and gravel found in stream channels and valleys.

A-3 River terrace deposits of sands, gravels, silts and clays.

Geological engineering and planning considerations for the above mentioned types of alluvium include:

1. "Mineral resources which affect land use decisions"

   a. Sand and gravel suitable for construction purposes may be found in mineable quantities in alluvium.

2. "Massive land movement, or other unstable surface conditions"

   a. There are no foreseeable problems concerning massive land movements in alluvium in this district.

3. "Areas of swelling or settling soils, or other soil factors that will affect foundation construction"

   a. Consolidation under a load may be anticipated in some coarse grained alluvium (sand and gravel, A-2). The possibility of consolidation increases when the alluvium is wet.

4. "General area of flood danger and/or erosional hazards"

   a. Flooding may be anticipated in areas covered by water deposited alluvium. This would cover most of the alluvial area delineated on Plate 1, especially areas of low elevation. The higher terraces of alluvium on both sides of the South Platte will be in danger of flooding by the side streams and tributaries to the South Platte rather than the river itself. Badger and Bijou Creeks are especially prone to flooding and the presence of wide extents of alluvium on either side of these streams bear witness to former floods.

   b. Areas located near the cutbank of a river are subject to constant erosion.

   c. Erosion may be severe in all types of alluvium owing to the unconsolidated nature of the material. However, areas covered by vegetation are less susceptible to erosion, as plants act as a stabilizing agent and hold the soil.

5. "Areas of high water table, both permanent and seasonal"

   a. High water tables may be encountered in areas covered by water deposited alluvium during the spring months and during periods of flooding.

6. "General geologic constraints that will affect selection and operation of solid waste disposal sites"

   a. Alluvial areas are generally active flood plains. Therefore, solid waste disposal sites should not be located in these areas. The pollution hazard of a sanitary landfill is the movement of water through the landfill. Water dissolves potential pollutants in the landfill material, then as this water percolates out of the landfill, it will carry the pollutants into the ground water supply or back directly into the stream. Impermeable liners should be able to handle rainfall moisture, but standing water in a landfill such as may result in a flood, would probably result in ground water pollution. For this reason, a landfill should not be located in flood prone areas.

7. "Pollution potential and other possible hazards associated with mineral extraction"

   a. There are no mine tailing dumps from hard rock mining located in Planning District #1. There may be a future for coal mining, however, and this will be covered in the sections on sediments later in this report.

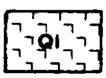
   b. There is a pollution potential from improperly constructed sludge pits located near oil or gas wells. There should be an impermeable seal to prevent downward movement of pollutants into the alluvium and then into the ground water. These open pits are also a hazard to migratory birds who, believing the pits to be ponds, land on them and become covered with oil.

8. "Other critical factors which may become evident during the course of the study"

   a. On-site sewage disposal for residences can be accomplished in most types of alluvium. However, ground water pollution problems will arise in areas of high water table, and sewage disposal sites should not be located in these areas. State regulations offer excellent guidelines for on-site requirements and construction of sewage disposal systems.

   b. In addition to the above (a), solid wastes, including industrial and agricultural, should not be disposed of in alluvium because of the pollution potential. Feed lots should not be located on alluvium because the pollution danger to the ground and surface water is great.

   c. Routes for surface transportation are generally favorable where located on alluvium; however, prior consideration must be given by developers to such potential problems as flooding and areas of high water table.

II. <u>Loess</u>  This is a fine grained, wind blown deposit comprised mainly of silt and minor amounts of very fine sand and clay. Loess is commonly non-stratified and unconsolidated. This loess was deposited by wind action during the last glacial period and covers much of the district. This loess was mapped where it is of significant thickness to affect land use.

Geological engineering and planning considerations for the above mentioned loess include:

1. "Mineral resources which affect land use decisions"

   a. There are no mineral resources of value in the loess.

   b. The impervious nature of the loess should make it a fairly water tight seal when compacted and would be useful where such a seal is needed (i.e., sanitary landfills, man-made ponds, canals).

2. "Massive land movements or other unstable surface conditions"

   a. The loess is generally stable when dry, but becomes very unstable when wet.

   b. Where vegetation covers the loess on fairly level or rolling topography, there is little danger of movement.

   c. The loess, although unconsolidated, erodes readily to unstable vertical faces and columns

3. "Areas of swelling or settling soils, or other soil factors that will affect foundation construction"

   a. Moisture content determines the consolidation of loess under loads. When dry, the loess does not settle appreciably; when wet, however, the loess will consolidate. In many cases, the type and weight of structure, the amount of moisture present, and other factors all have a bearing on the problem and should be considered before construction. Specific engineering soil tests should be conducted in areas covered by loess when subdivisions or other structures are planned.

   b. Once the structure is constructed, additional consideration should be given to the moisture problem. In some cases, the watering of a lawn can lead to compaction.

4. "General areas of flood danger and/or erosional hazards"

   a. There is little danger of flooding in areas covered by loess.

   b. Loess can erode quite rapidly when stripped of its plant cover. This can create special problems on construction sites. Extreme wind erosion and sheet flooding can result when large areas of loess are left exposed for long periods of time. If, however, grade is controlled so that moisture contents in the loess are properly engineered, two purposes are achieved; 1) erosion is kept at a minimum, and 2) compaction is achieved before actual building is begun.

5. "Areas of high water table, both permanent and seasonal"

   a. The loess has a low permeability (i.e., yields little or no water to drilled wells).

   b. Loess is generally located above the water table, thus reducing any water storage potential.

   c. In most cases, the loess does not act as a significant recharge area for ground water.

6. "General geologic constraints that will affect selection and operation of solid waste disposal sites"

   a. The loess could be a suitable area for a sanitary landfill for the following reasons:

      1) The loess is generally not in contact with the water table

      2) There should not be a danger of future contamination

      3) There is little flood danger

      4) The loess should compact to an impermeable seal

      5) Access to the landfill should not be difficult

   b. A problem arises, however, in the fact that the loess has vertical permeability, which means water or pollutants could travel straight down. This permeability is greater in younger loess than in older loess. There could be several solutions to this problem if the proposed site is carefully considered: 1) if there is no horizontal permeability in the loess and the Pierre shale is located not too far beneath the surface, a water tight landfill can be dug using the Pierre Shale as a base, 2) if the loess is fairly old and impermeable, it could be compacted to a water tight seal. In both cases, a qualified geologist or engineer should check the landfill site to be sure the seal is water tight.

7. "Pollution potential and other possible hazards associated with old mine tailing dumps"

   a. There are no mine tailing dumps located in Planning District #1.

   b. There is no pollution danger from other areas of mineral extraction.

8. "Other critical factors which may become evident during the course of the study"

a. Subsurface sewage disposal in the loess is often not recommended. Loess, when in contact with water, will compact and cement to such a degree that a leach field will cease to function properly.

b. Surface transportation routes should be favorable in the loess. The wind erosion potential must be considered in the construction and maintenance of roads.

III. Dune Sand [Qds] This unit characteristically consists of unconsolidated, very fine to medium grained sand with some fine silt and clay. It was deposited in Recent time by wind, much the same as the loess, and forms low, crest-like hills.

Geological engineering and planning considerations for dune sand include:

1. "Mineral resources which affect land use decisions"

   a. The dune sand may have possible uses as an aggregate in construction.

   b. No other minerals of any value are found in the dune sand.

2. "Massive land movements or other unstable surface conditions"

   a. On a level or rolling topography, there should be no danger of massive land movements.

   b. In open cuts, conditions would be unstable until erosion creates a more stable slope. Nothing should be placed near the edge of a cut as erosion would soon undercut the foundations. This is especially true in the case of signs, telephone poles and fence lines placed near a road cut in dune sand.

3. "Areas of swelling or settling soils, or other soil factors that will affect foundation stability"

   a. The dune sand is not known to have a swelling potential.

   b. Dune sand will consolidate, however, the conditions needed and the extent involved could be determined by an engineering soils study. The size of the structure, the amount of water present and the location would all have a varied affect on the settling potential.

4. "General areas of flood danger and/or erosional hazards"

   a. Flooding is not anticipated in any mapped areas of dune sand.

   b. Wind erosion could be a detriment but this would be lessened by the presence of a plant cover. Vegetation will act as a bond and hold the loose sand in place. Problems may arise in road cuts, unpaved roads and construction areas because of a lack of plant cover.

c. Water could create an erosional problem where fairly steep slopes of unprotected sand are exposed. Again, a plant cover would minimize such erosion. On fairly level or gentle slopes, erosion by water would be no problem because the water would be absorbed in the porous sand.

5. "Areas of high water table, both permanent and seasonal"

   a. Although highly porous, the dune sand is, in most places, located above the permanent water table.

   b. The dune sand serves as a recharge area for ground water.

6. "General geologic constraints that will affect selection and operation of solid waste disposal sites"

   a. Dune sand is generally located above the water table, and with some modifications it could be a suitable location for a solid waste disposal site. The primary modification is use of impermeable pit linings as the sand is too porous to seal itself.

7. "Pollution potential and other possible hazards associated with old mine tailing dumps or mineral extraction"

   a. As mentioned earlier, mine tailing dumps do not exist in Planning District #1.

   b. Oil and gas wells in Planning District #1 often result in pollution problems such as the following:

      1) Salty water is sometimes extracted in oil well operations and the disposal of this water can be troublesome. If an evaporation pit is used, the seal must be impermeable so that no salt water seeps into the ground. This is especially a problem in the porous dune sand. If the brine is pumped back into a formation, care must be taken that no aquifers are polluted.

      2) Waste oil is also a problem because it remains on the surface and hinders natural drainage and plant growth. This is also a problem in the dune sand where aquifer recharge and plant cover are important.

8. "Other critical factors which may become evident during the course of the study"

   a. Routes for surface transportation should be favorable over much of the dune sand area. However, study should be given to the foundation stability of the road, especially after wear.

   b. Sewage disposal systems located in dune sand should receive attention as potential polluters. Dune sand can be easily polluted and caution should be taken with all waste disposal in dune sand.

c. Since the dune sand is an active recharge area for aquifers, the ground water of an area can become easily polluted. No industrial or agricultural wastes should be dumped on dune sand. Feed lots are an active pollutant and should not be located on dune sand. Bacterial pollution as well as chemical pollution can result.

IV. Sediments [Sed] This unit characteristically consists of wind or water deposited materials that have been compacted or cemented to form layered rock beds. This consolidated nature distinguishes sediment from alluvium, loess or dune sand of Recent age. Specific types of sedimentary rocks in Planning District #1 include:

SU-1 Shale, claystone and siltstone - fine grained materials derived from pre-existing rocks.

SU-2 Sandstones and conglomerates - rocks made up mainly of sands and/or gravels cemented together.

SU-3 Limestone - a fine grained rock resulting from the precipitation of calcium carbonate.

Geologic engineering and planning considerations for the types of sedimentary rocks found in Planning District #1 include:

1. "Mineral resources which affect land use decisions"

   a. Fuel and energy resources (such as oil and gas as well as a limited amount of coal in Morgan County) have been developed in the sedimentary rock areas of Planning District 1. Continued exploration for and discovery of these resources should be anticipated. Areas where these resources are known are shown on Figures 4 and 5. The host rocks for these resources being developed are fine grained shales, claystones and siltstones (type SU-1) and coarser grained sandstones (type SU-2).

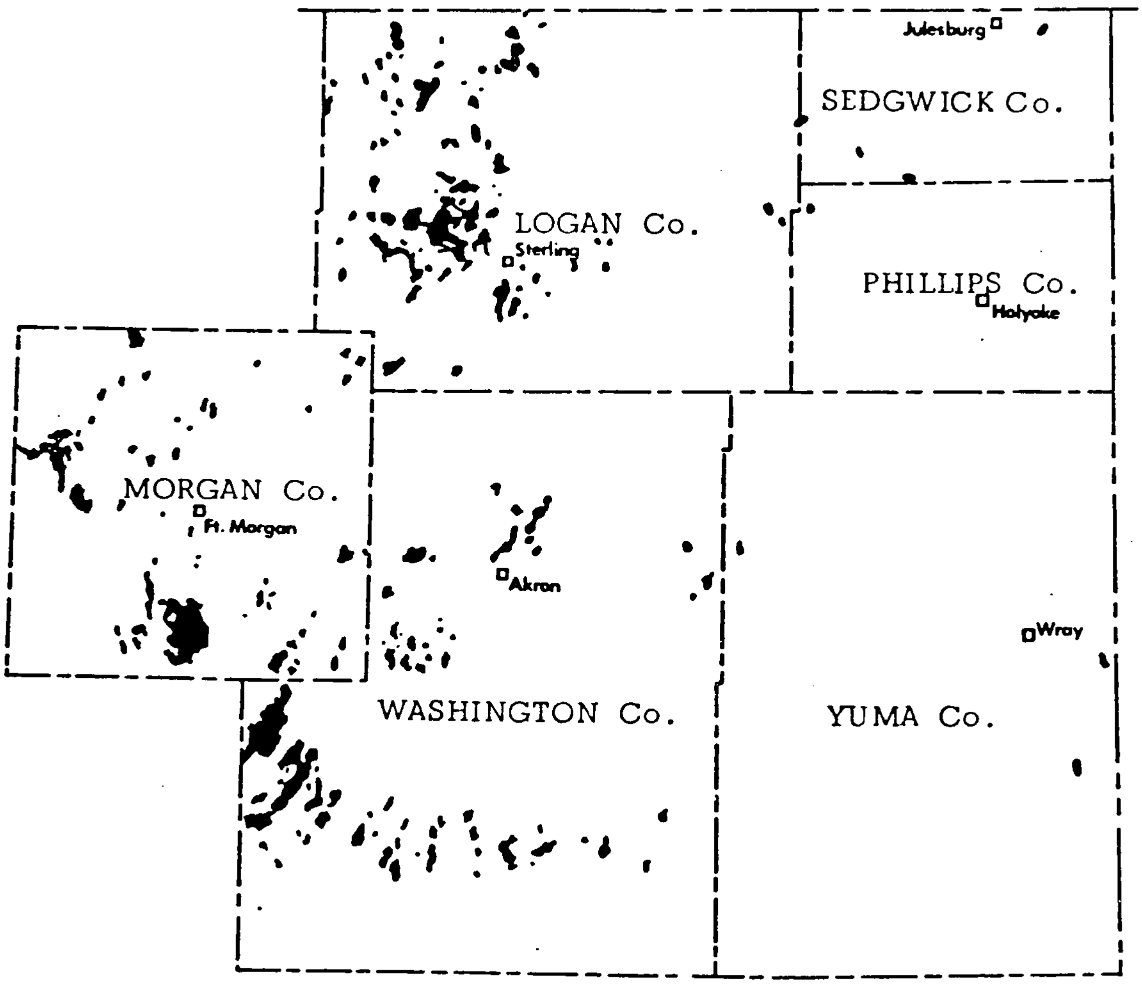
   b. Clay beds are found in several locations in Planning District #1 (see Figure 6). This clay should be suitable for bricks and some earthenware (type SU-1).

   c. Sand and gravel have been removed in places in Washington County from sedimentary beds that have, at one time, been eroded and redeposited (type SU-2).

   d. In the Ogallala formation about four miles south-southwest of Wray, a clay deposit consisting mainly of volcanic ash has been extracted and used as polishing powder.

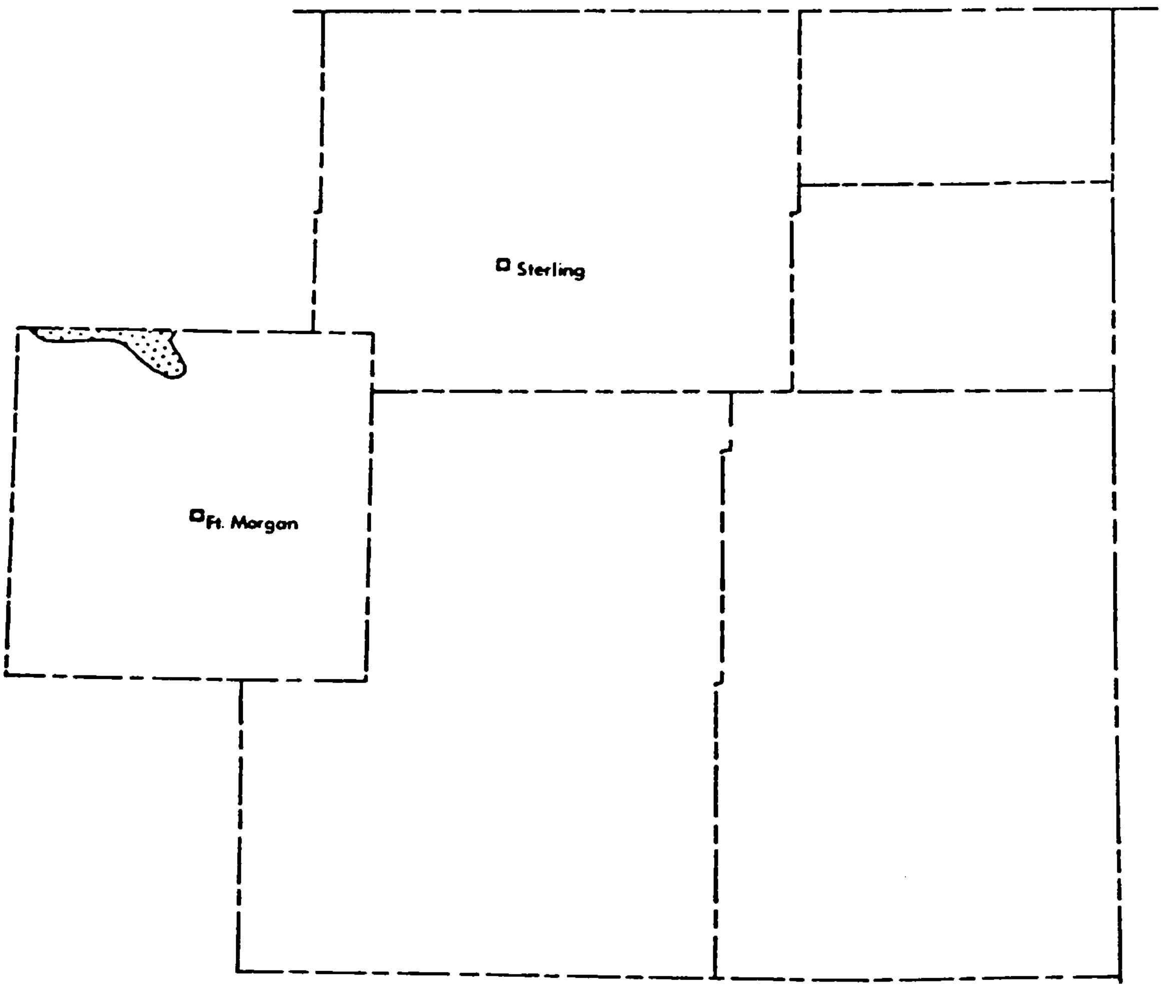
2. "Massive land movements or other unstable surface conditions"

   a. Steep or vertical cuts in some sediments may be unstable.



AREAS OF CURRENT AND POTENTIAL OIL AND GAS PRODUCTION IN PLANNING DISTRICT 1

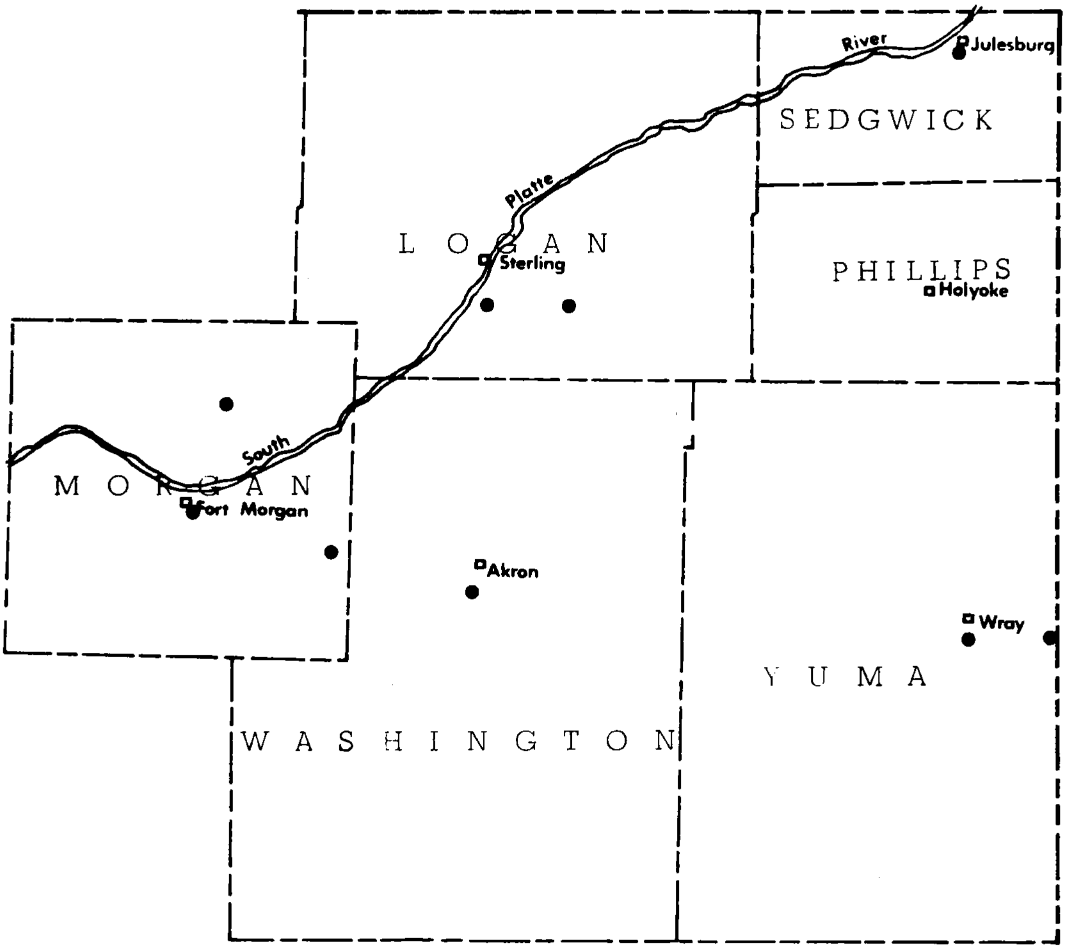
FIGURE 4



COAL BEARING AREAS IN PLANNING DISTRICT 1

SUB-BITUMINOUS COAL
(Production potential doubtful as coal is very poor grade)

FIGURE 5



LOCATIONS OF BRICK CLAY IN PLANNING DISTRICT I

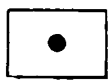


FIGURE 6

b. Areas of exposed sediments may be subject to wind erosion much like dune sand. Plant cover would help prevent this erosion.

c. No other massive land movements are expected in the sediments of Planning District 1.

3. "Areas of swelling or settling soils, or other soil factors that will affect foundation construction"

a. Swelling clays are found in moderate to small amounts in some of the sediments. Detailed engineering soils surveys can identify the problems and make recommendations to overcome them.

4. "General areas of flood danger and/or erosional hazards"

a. Flooding may be anticipated in stream or river valleys which cut through sedimentary rocks. As mentioned earlier, Badger and Bijou Creeks in Morgan County are particularly prone to flooding. The geological potential for flooding is greatest in areas covered by impermeable sedimentary rocks such as shale (SU-1).

5. "Areas of high water table, both permanent and seasonal"

a. High water levels are not anticipated in the sediments under normal conditions.

6. "General geologic constraints that will affect selection and operation of solid waste disposal sites"

a. Solid waste disposal sites should be located well above the water table and in relatively impermeable material. They should not be located in recharge areas for ground water aquifers.

b. A landfill should not be located near a spring, nor should it block a natural drainage.

c. Any white mapped areas subject to flooding (i.e., areas near a river or stream) are not suitable locations for sanitary landfills.

d. All sanitary landfill sites should be evaluated by an engineering geologist prior to construction.

7. "Pollution potential and other possible hazards associated with old mine tailing dumps"

a. As mentioned earlier, pollution potential from mineral extraction in District 1 is mainly from improperly constructed sludge pits located in porous rock. Mine tailing dumps do not exist in District 1.

b. There may also be a pollution of local aquifers from improperly cased oil wells.

8. "Other critical factors which may become evident during the course of the study"

   a. Consideration of the topics of sewage disposal, surface transportation and workability for sedimentary rocks reveals a complete range of conditions. In general, those sedimentary rocks which are dense (such as limestone, SU-3) or well cemented (some sandstone, SU-2) will be least satisfactory for these development conditions. In addition, such potential problems as swelling soils, flooding and erosive conditions (covered in Sections 3 and 4) must be investigated prior to making decisions concerning these topics.

   b. There are some artificial hazards that could result from a lack of foresight. The following would be problems in porous material but are included with sediments:

      1) Feed lots are a pollution potential to both surface runoff and ground water. Feed lots should be located on impermeable material (such as a shale) and all runoff collected to avoid water pollution.

      2) Trench silos or silage pits could be a ground water pollution potential if not properly maintained. Local health department guidelines should be adopted or implemented to handle these matters.

V. <u>Pierre Shale</u> Kp The Pierre shale is a special problem formation and is shown on the map as a specific sedimentary unit. The Pierre Shale is a fine grained sedimentary rock with some very sandy layers and usually is a light greenish-grey, although in some locations it may be dark grey or black. Any building considerations in the Pierre Shale should always be preceded by a soils investigation. This report is not intended to substitute for such an investigation.

<u>Geological engineering and planning considerations</u> for the above mentioned Pierre Shale include:

1. "Mineral resources which affect land use decisions"

   a. There are no known resources of value located in the Pierre Shale in District 1, but this unit has produced natural gas and cement constituents in other areas.

2. "Massive land movements or other unstable surface conditions"

   a. There are no massive land movements expected in the Pierre Shale in Planning District 1.

b. Vertical or steep cuts in the shale will probably be unstable and subject to rapid erosion.

3. "Areas of swelling or settling soils, or other soil factors that will affect foundation construction"

   a. The Pierre Shale has a swelling potential that can be critical in construction. The areas of swelling potential are located throughout the thick sequence of the Pierre and this swelling potential varies with location. It is recommended that an engineering soils investigation be conducted to determine the swelling potential before construction.

   b. In places, this shale contains sulfate minerals which, when dissolved in ground water, can attack and deteriorate hardened concrete. Sulfate-resistant cement is available and should be used wherever this problem may arise. This is commonly identified during the soil investigation.

4. "General areas of flood danger and/or erosional hazards"

   a. Flood danger exists where the Pierre Shale outcrops adjacent to a river or its flood plain. The shale has a low permeability which increases the geological potential for flooding as little water would be absorbed into the formation. The result is uncommonly high runoff rates.

   b. As mentioned earlier under "massive land movements" (Section 2), the shale will erode quite readily when exposed.

5. "Areas of high water table, both permanent and seasonal"

   a. A high water table is not anticipated in the Pierre Shale in Planning District 1.

   b. The impermeable nature of the Pierre Shale, however, can result in seeps along bedding planes and this could create foundation problems.

   c. The impermeability of the Pierre Shale also results in ponding in places and these areas will need artificial drainage.

6. "General geologic constraints that will affect selection and operation of solid waste disposal sites"

   a. In general, the Pierre Shale should be a good geologic formation for the location of a solid waste disposal site for the following reasons:

      1) It is not an aquifer so the danger of polluting ground water is minimized.

      2) The shale is generally impermeable and would probably compact to a good seal.

b. There are some constraints that should be kept in mind when locating a solid waste disposal site in the Pierre Shale:

1) Sanitary land fills should not be located to block natural drainages.

2) Land fill should not be located in any area where there is a danger of flooding.

3) Caution should be taken to prevent ponding in or near the fill.

7. "Other critical factors that may become evident during the course of study"

a. Subsurface disposal of sewage in the Pierre Shale will probably be impossible because of its impermeable nature.

b. Surface transportation along the Pierre Shale may be difficult to maintain because of its swelling potential.

The reader is reminded that the preceding text and illustrations are guidelines for the layman who is vitally concerned with, but not experienced in, engineering geology. The information presented cannot be substituted for the professional, on-site investigations which must be an integral part of urban and rural rejuvination and growth, and must encompass the spectrum from industrial to recreational projects.

The reader is urged to study these guidelines and become familiar with the geologic factors that rightly affect land use and planning decisions. Such efforts will work toward the better use and protection of our environment.

F. M. FOX & ASSOCIATES, INC.

Bruce A. Florquist, Chief Geologist

Robert B. Sennett, Sr. Project Engineer

GLOSSARY

Acidic water - water in which excessive acid-forming constituents have been dissolved. Example: water passing through rock formations containing sulfide picks up these materials and becomes acidic. This water, as a result, is capable of deteriorating certain types of concrete and polluting water supplies.

Alluvium - clay, silt, sand, gravel or mixtures of these rock particles which have accumulated during Recent geologic time and are characteristically unconsolidated. All such materials are referred to collectively in this report as alluvium regardless of the manner in which the materials accumulated (water, wind, gravity or glacial deposits).

Altered rock - a rock that has undergone physical and/or chemical changes. Metamorphic rocks are examples of altered rocks.

Aquifer - a porous rock formation that bears ground water which can be recovered through wells.

Avalanche (rock) - see Gravity deposits, page iii.

Avalanche (snow) - a sudden fall of snow from a high elevation to a lower one. Avalanches commonly follow avalanche "chutes" (long, steep paths down a mountain side, barren of trees or other growth).

Bedded formation - a rock unit which shows successive beds, layers or strata, owing to the manner in which it was formed (such as the layers seen in sedimentary rocks).

Bedrock - any solid rock exposed at the surface of the earth or overlain by unconsolidated material (A.G.I*).

Bentonite - a montmorillonite-type clay formed by the decomposition of volcanic ash. Bentonite swells when wetted which can cause foundation problems.

Cambrian - the geologic period which began about 600 million years ago at the close of the Precambrian period. The Cambrian period lasted about 100 million years and is part of the Paleozoic era.

Carbonates - sedimentary rocks consisting mainly of calcareous material (compounds with the radical CO_3).

Cenozoic - the most recent geologic era which began some 60 million years ago and includes the present. The Cenozoic era saw the extinction of dinosaurs, the ice age and the coming of man.

Clay - an earthy, extremely fine grained material (particle diameter less than .005 mm). Clay becomes plastic when wet and hard upon drying.

Claystone - a sedimentary rock comprised mainly of clay sized material which has been consolidated by compaction or cementation.

Compaction - a decrease in volume of soil or rock particles caused by the action of external forces applied to the material.

*American Geological Institute Glossary of Geology

Conglomerate - a sedimentary rock consisting of large, rounded particles, such as gravel and sand, cemented together.

Consolidation - the process by which loose and/or soft material becomes hard.

Cretaceous - a geologic period lasting about 72 million years, during the Mesozoic era.

Crystalline rock - a general term for igneous and metamorphic rock in contrast to sedimentary rocks (A.G.I.)

Cutbank - the bank of a stream on the outside edge of a curve which is constantly being cut by the motion of the stream. Vertical or overhanging banks may result from this stream action.

Delta - an alluvial deposit found at the mouth of a river. The delta is formed by a river carrying clay, silt and some sand where the velocity decreases as the river enters a larger body of water.

Dense - a term describing the texture of a very fine grained rock. The grain size in such a rock is generally less than .05 to .1 mm in diameter and cannot be seen by the naked eye.

Deposition - the natural accumulation of material deposited by water, wind, glacial or gravity action.

Detrital - sedimentary deposits consisting of particles derived from other rocks. (This is in opposition to a chemical rock - such as salt.)

Devonian - a geologic period lasting about 60 million years in the Paleozoic era.

Dip - the angle at which a bedded rock formation is tilted from the horizontal.

Dip slope - a slope on the surface of the land that has approximately the same angle as the underlying formation.

Dolomite - a calcareous sedimentary rock, similiar in appearance to limestone. (See carbonates.)

Dunes - wind blown deposits of loose sand and silt which may be massive or may resemble wave like forms with the gentle slope facing the wind direction and the steep slope away from the wind. Dunes may be actively moving or may become stabilized.

Embayment - an indentation of a shoreline forming a bay.

Engineering geology - the application of the geological sciences to engineering practice for the purpose of assuring that the geologic factors affecting the location, design, construction, operation and maintenance of engineering works are recognized and adequately provided for (A.G.I.).

Era - a division of geologic time of the highest order, made up of one or more periods.

Erosion - the wearing away of rock or soil and the movement of these rock particles. Wind, water, ice and gravity movements cause erosion.

Evaporate - a sedimentary rock consisting mainly of materials, formerly in solution, deposited by the evaporation of water. Example: rock salt is formed by the evaporation of sea water, leaving the dissolved salts behind.

Evapo-transpiration - a system for disposing of fluids by either evaporation or transpiration from vegetation or a combination of both.

Extrusive - a term applying to igneous rocks which formed by the cooling and solidification of lavas flowing out on the surface of the earth. All volcanic rocks are extrusive.

Fan, alluvial - a fan shaped alluvial deposit formed by a stream descending from a steep slope to a more gentle slope and depositing material on the more gentle slope. On an alluvial fan, the apex points upstream to the steeper slope and the fan portion spreads out on the gentle slope.

Fault - a fracture or zone of fractures along which there has been movement parallel to the plane of breakage.

Flood plain - a level area to each side of a river or stream covered by materials deposited by the stream during stages of flooding.

Fractures - breaks in a solid rock along which there has been little or no movement. Fractures commonly form in association with faulting and folding.

Geochemistry - the science of the chemistry of the earth. Geochemical refers to the chemical composition of a rock and the chemical origin of that rock.

Geology - a science that deals with the history of the earth, especially as recorded in the rocks (A.G.I.).

Glacial deposits - unconsolidated material deposited as a result of glacial activity. Particle sizes vary from boulders which the glaciers "plucked" from a valley floor to very fine "rock flour" resulting from constant grinding. The most common glacial deposit is the moraine.

Glacier (mountain)- a river of ice moving in a mountain valley. Glaciers form by the compaction and remelting of snow which builds up and begins to slowly move down a mountain to the valley. Glaciers were widespread in the Rocky Mountains during the Quaternary period.

Granite - an intrusive igneous rock (as opposed to extrusive or volcanic rock) consisting mainly of certain amounts of feldspar, quartz, mica and a small amount of other minerals.

Gravity deposits - alluvial deposits formed by materials moving or falling from an unstable position to a more stable one. Common types of gravity deposits include landslides, mudflows and rockfalls.

Igneous - a rock formed by the cooling and solidification of a molten mass. This may occur within the earth or on the surface.

Impervious - a term used to describe any dense material through which fluids cannot pass.

Intrusive - an igneous rock formed by the cooling of a molten mass beneath the surface of the earth.

Joints - another term for a fracture in a solid rock along which little or no movement has taken place.

Jurassic - a geologic period lasting about 46 million years during the Mesozoic era.

Land movements (massive) - landslides.

Lava - molten rock flowing on the surface of the Earth until it cools and solidifies. All lavas are classified as extrusives.

Leachfield - a subsurface, porous field into which liquid wastes are drained and purified by percolation.

Limestone - a sedimentary rock comprised mainly of calcium carbonate ($CaCO_3$) formed in water by the gradual settling of calcium carbonate particles. Limestone is usually a hard, resistant rock.

Loess - a wind blown silt deposit that is usually nonstratified and unconsolidated. Loess erodes to steep vertical faces but appears to have a rolling or hilly topography on the upper surface.

Marble - a metamorphosed limestone or other calcareous rock; marble is usually a very hard, resistant rock, often with distinctive color patterns which makes it a popular building stone.

Mesa - a flat topped mountain, surrounded wholly or partially by steep cliffs. A mesa can result when a hard, resistant rock overlies a weak, erosive rock.

Moraine - a glacial deposit of loose rock material pushed or dragged down a valley by a glacier.

Mesozoic - a geologic era lasting approximately 170 million years. The Mesozoic era saw the flourishing of dinosaurs. It was at the close of this era and the beginning of the Cenozoic that the dinosaurs became extinct.

Metamorphic - a rock formed from another rock that has undergone changes due to increased temperatures and pressures or changes in the chemical environment while buried beneath the surface of the earth.

Mississippian - a geologic period lasting about 35 million years in the Paleozoic era.

Mudstone - a general geologic term applied to any extremely fine grained sedimentary rock. Clayey siltstone or silty claystone can be loosely termed as mudstone.

Nonstratified - a term applied to formations that have no distinct bedding.

Ordovician - a geologic period lasting about 75 million years in the Paleozoic era.

Outcrop - the exposure of bedrock at the surface of the Earth.

Paleozoic - a geologic era lasting about 370 million years. The Paleozoic era saw the widespread evolution of life, the first land plants and the first land animals.

Pediment - a sloping plain at the intersection of a valley floor and a mountain. Pediments are bedrock with a thin veneer of alluvium in places.

Pennsylvanian - a geologic period that lasted about 30 million years in the Paleozoic era.

Percolation - movement of water through soil and rock by means of pore spaces between grains, cracks in the rock and along bedding planes. Percolation is limited to small openings and does not include movement of water through such openings as caves.

Period - a classification of time in the geologic time scale - the length of each period is different; however, there is continuity of events within a period over a widespread portion of the earth.

Permeability - the ability of a material to transmit water, oil or other fluids due to the pore spaces within the rock and the degree to which these spaces are connected.

Permian - a geologic period lasting about 50 million years; this is the last period in the Paleozoic era.

Perlite - a volcanic glass similiar to obsidian but having a higher water content. Characteristically, perlites have concentric cracks formed by contraction upon cooling.

Physiographic - a description of the surface and land-form features of a region.

Piedmont - an area located at the foot of a mountain range where materials eroded and washed out of the mountain are deposited.

Planes of weakness - a two dimensional area between two objects that is subject to failure or movement because of weak or nonexistent bonds. Example - a sedimentary rock showing bedding will probably break along these planes rather than across them because they are relative planes of weakness.

Precambrian - all rocks formed before Cambrian time (more than 600 million years old). The Precambrian is divided into two eras, the Early and Late Precambrian (A.G.I.).

Pumice - a very light, cellular lava which is usually white or light grey in color. Pumice has been described as a sort of volcanic froth and is so light it will float on water.

Pyroclastic - a general geologic term for ash and other materials explosively ejected from a volcano through the air.

Quaternary - the most recent geologic period stretching from about one million years ago to the present.

Recent - a subdivision of the Quaternary period which began at the close of the Ice Age (about 10,000 years ago) and extends to the present.

Recharge area - an area of permeable rock and soil which allows the downward movement of surface water and the replenishment of ground water.

Replacement - chemically and physically new material formed in the place occupied by the original matter by simultaneous solution and deposition. This occurs at the molecular level. Example - petrified wood is a replacement in which the mineral, silica, has taken the place of the wood leaving the structure intact.

Rippability - ease of excavation.

Sandstone - a rock comprised mainly of sand-size particles that have been compacted or cemented.

Sanitary landfill - a system of solid waste disposal in which waste is placed in a closed environment and covered daily. A properly constructed sanitary landfill will decompose and not pollute the environment.

Sedimentary - a geologic term describing rocks formed by the accumulation or deposition of particles. These are commonly laid down by water, such as rivers, lakes and seas, but can also be deposited by winds (i.e., dunes).

Seepage pits - a method of liquid waste disposal in which the waste is deposited in a pit and is purified as it percolates down through the soil.

Shale - a rock comprised mainly of clay size particles which have been compacted or cemented. Shale is usually well stratified and in some cases, is weak and crumbly.

Silt - a sediment particle with a diameter between 0.005 mm. and 0.05 mm. (a size between sand and clay). Silt is unconsolidated and is a common type of river alluvium.

Siltstone - a rock comprised mainly of silt-size particles which have been compacted or cemented.

Silurian - a geologic period that lasted about 20 million years during the Paleozoic era.

Slippage - gradual, slight movements along a plane of weakness.

Solubility - a measure of the concentration potential for a material dissolved in a liquid at equilibrium when there is undissolved material also in contact with the liquid; the greatest amount of a material that can be dissolved in a fluid at a specific temperature and pressure.

Stratification - the bedded or layered appearance of sedimentary rocks which results from the depositional origin. However, not all sedimentary rocks show well-defined stratification.

Subside - a sinking or down warping of the earth's crust. This occurs over a wide portion of the crust and is very gradual. During geologic history, seas commonly filled the depressions formed by subsidence. The term "subside" can also be used to describe a smaller feature - such as the subsidence of land over an underground mine where the overburden is collapsing into the mine cavity.

Swelling soils - soils containing clay minerals which have the ability to absorb water into their structures and expand in size. The water can be released through drying, allowing the soil to return to the original size. In general, swelling clays are derived from volcanic ash.

Tailing dump - piles of loose debris and ore of a quality too poor to be used, usually found near a mine. When located on a slope these tailings can be very unstable.

Talus - a pile of broken rock fragments found at the foot of a steep cliff or escarpment which results from the weathering and breaking down of the cliff.

Terrace - a step like feature located on a slope; the terrace itself is flat or gently sloping and bounded above and below by steeper slopes. Terraces are generally considered to consist of alluvium and flank each side of a river valley.

Tertiary - a period lasting about 62 million years in the Cenozoic era.

Thermal springs - springs whose temperatures are warmer than the average surface temperature. The source of the heat is molten magma located below the surface of the Earth.

Topography - the relief of the surface of an area and the expression of this relief on a map using one line to represent one elevation.

Triassic - a period lasting about 49 million years, the first period of the Mesozoic era.

Tuffaceous - a tuff like material; tuff being a rock comprised of tiny (generally less than 4 mm in diameter) volcanic particles.

Unconsolidated - a term used for materials that are loose; rock particles that are not cemented or compacted are considered unconsolidated.

Undercutting - removal by erosion (generally wind, stream or wave action) of the lower portion of a steep escarpment, resulting in a steeper face or even a overhanging cliff.

Uplift - elevation of a part of the Earth's surface relative to some other area (A.G.I.). In geologic history uplift has taken place slowly, generally lasting millions of years.

Volcanic rock - the class of igneous rocks derived from volcanoes. Volcanic rocks are basically of two types -- 1)rocks that were formed by flowing lava, and 2)rocks that were formed by materials ejected through the air, such as ash.

Water sheds - a general term referring to the drainage basin of a stream or river.

Water table - the upper boundary of water saturated formations or soils. Where the water table intersects the ground surface, a surface body of water is found (i.e., marsh).

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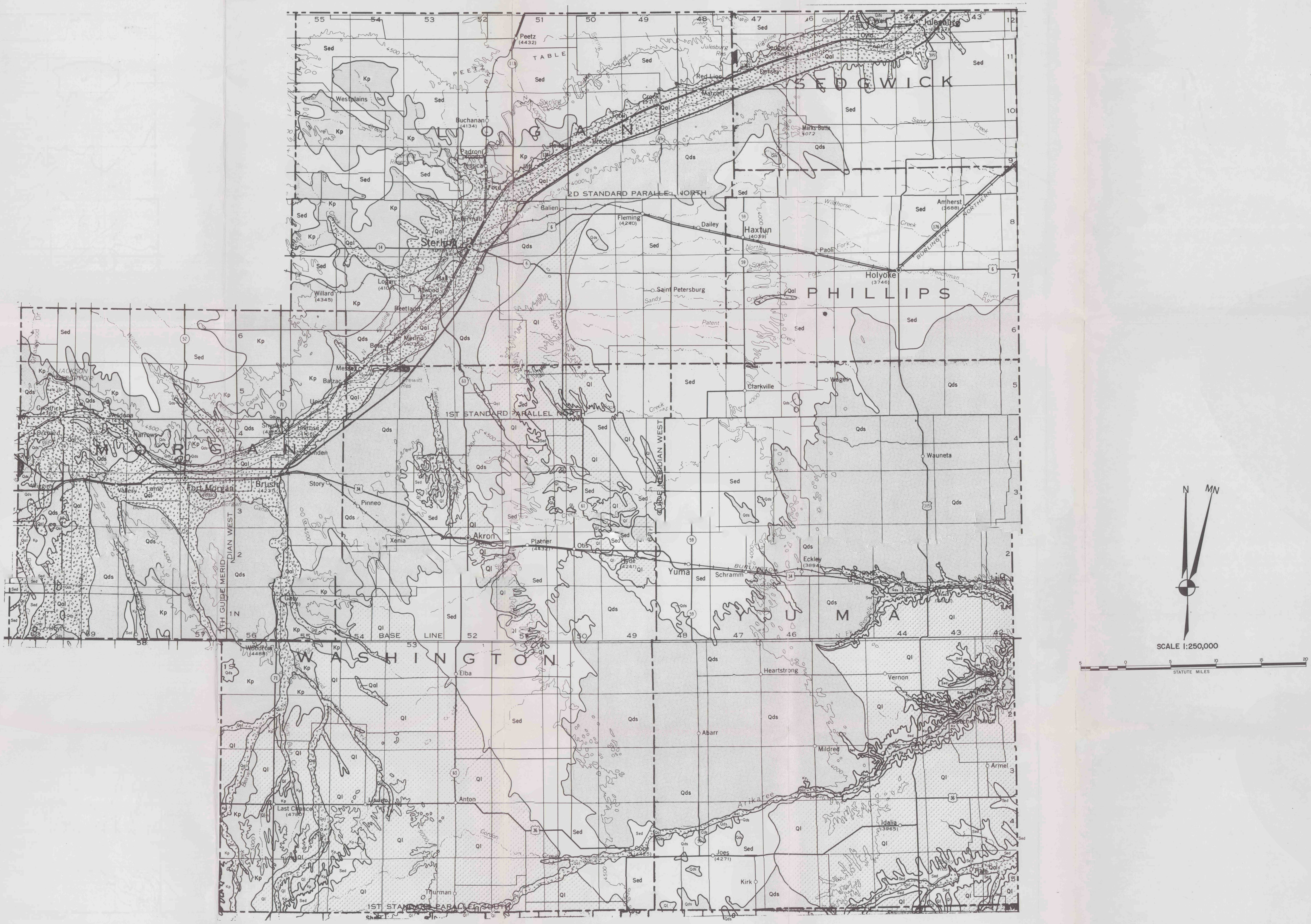
EG-2

SYMBOL	NAME OF MAP UNIT	TYPE OF MATERIAL	FORMATIONS	AGE	PLANNING CONSIDERATIONS
Qal	ALLUVIUM	UNCONSOLIDATED GRAVEL, SAND, SILT, AND CLAY INCLUDING TERRACE DEPOSITS	DEPOSITS HAVE NOT BEEN NAMED	QUATERNARY	FLOODING, EROSION, SOLID WASTE DISPOSAL, WATER POLLUTION
Qds	DUNE SAND	FINE, UNCONSOLIDATED, WIND DEPOSITED SAND IN MOUND-LIKE DUNES, TRENDING NORTHWEST-SOUTHEAST	DEPOSITS HAVE NOT BEEN NAMED	QUATERNARY	EROSION, CONSOLIDATION UNDER LOAD, WATER POLLUTION
Ql	LOESS	UNCONSOLIDATED WIND BLOWN SILT USUALLY CREATING A HILLY TOPOGRAPHY	COMMONLY CALLED PEORIAN LOESS	QUATERNARY	INSTABILITY, EROSION, SEWAGE DISPOSAL
Sed	SEDIMENTARY ROCKS UNDIVIDED	SHALE, CLAYSTONE, MUDSTONE, SILTSTONE, CONGLOMERATE, LIMESTONE, SANDSTONE	OGALLALA, WHITE RIVER, CHADRON, LARAMIE, FOX HILLS	CENOZOIC MESOZOIC	EROSION, FLOODING, WATER POLLUTION
Kp	PIERRE SHALE	GREY TO DARK GREY SHALE, SLIGHTLY SANDY IN PLACES AND THIN BEDDED	PIERRE SHALE	MESOZOIC (CRETACEOUS)	SWELLING SOILS, SULFATE REACTIONS, FLOODING



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ENGINEERING GEOLOGY MAP
COLORADO PLANNING DISTRICT I
LOGAN, SEDWICK, MORGAN, PHILLIPS, WASHINGTON & YUMA COUNTIES

JOB No. 218100632	DATE May 31, 1973
DRAFTING BY RB	CHECKED BY FLORQUIST

PREPARED FOR
COLORADO GEOLOGICAL SURVEY
AND
COLORADO DIVISION OF PLANNING

PLATE I