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ENGINEERING GEOLOGY INVESTIGATION
GAME CREEK - CACHE CREEK ROAD CORRIDOR
TETON NATIONAL FOREST
TETON COUNTY, WYOMING

OPEN-FILE REPORT 81-854

PUBLISHED BY: U.S. Geological Survey

Prepared for:

LAND MANAGEMENT SERVICES
P.O. BOX 2116
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Job No. 6363W-A

November 11, 1980

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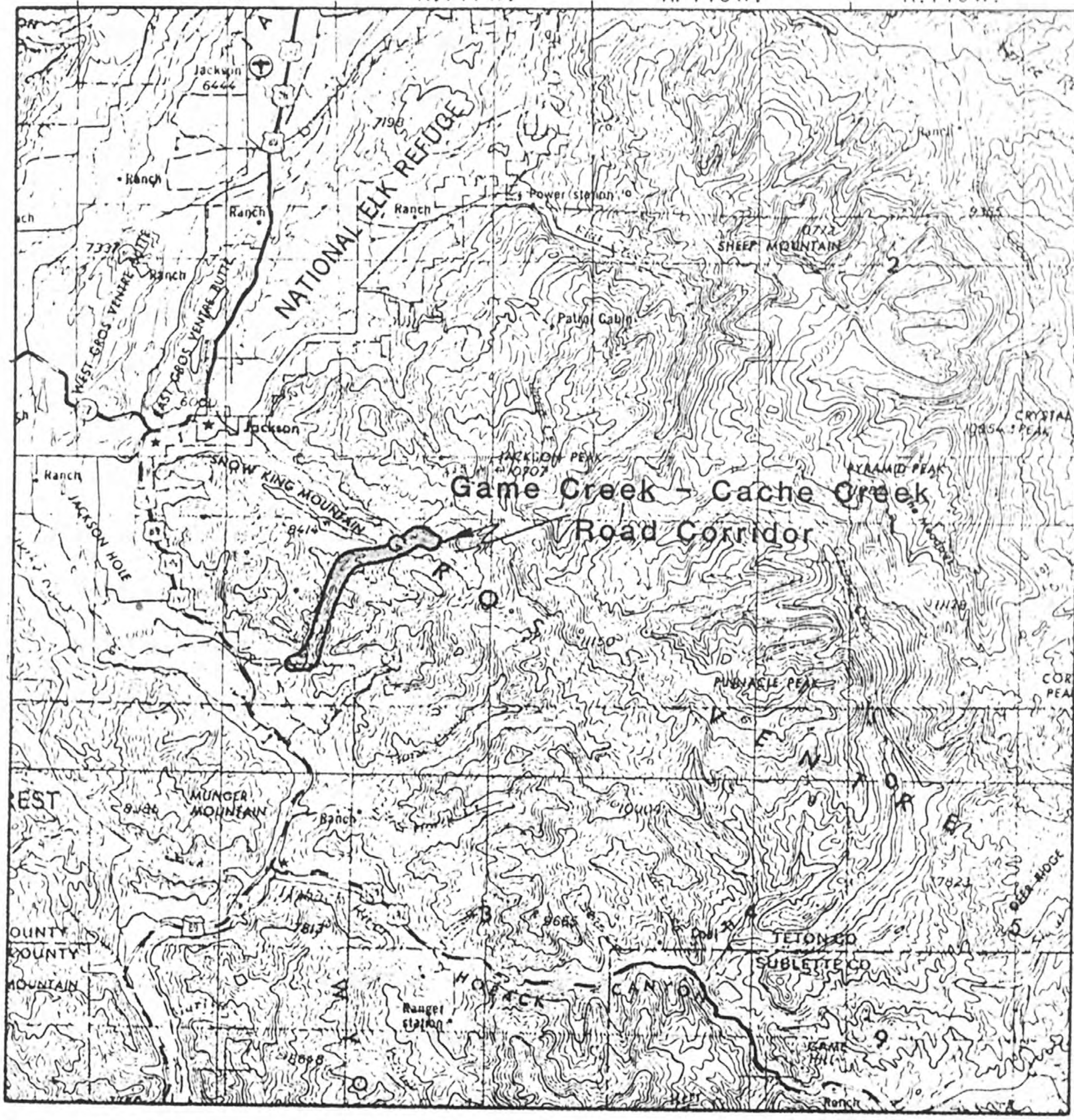
SCOPE AND METHOD OF INVESTIGATION

This report summarizes the results of an engineering geology investigation for the proposed Game Creek - Cache Creek Road Corridor, access to NCRA drill site. The purpose of the investigation was to provide geologic data so that the U.S. Forest Service and U.S. Geological Survey can jointly draft an Environmental Impact Statement. The location of the proposed road corridor is shown on Fig. 1. The general geologic conditions within the corridor are described and their anticipated impacts on the proposed road are discussed. The data and conclusions presented in this report are suitable for evaluating general impacts; however, additional detailed studies will be required for design purposes.

The geologic conditions in the proposed road corridor were evaluated by reviewing published regional geologic maps, a field reconnaissance, and interpretation of aerial photographs. The largest scale geologic map available for the area is the 1:24,000, Geologic Map of the Cache Creek Quadrangle, Love and Love (1978). In early October, 1980, a field reconnaissance was made by Douglas Stack and Ralph Mock of Chen and Associates, Inc. along the proposed road alignment. In addition, colored air photography at a scale of 1:15840 was available for our evaluation.

PROPOSED ROAD CONSTRUCTION

In order to provide access to the proposed NCRA drill site located on Cache Creek, it will be necessary to construct 6.8 miles of road. Construction will start in the Game Creek valley about 1 mile



Scale: 1: 250,000

LOCATION MAP GAME CREEK - CACHE CREEK ROAD CORRIDOR		
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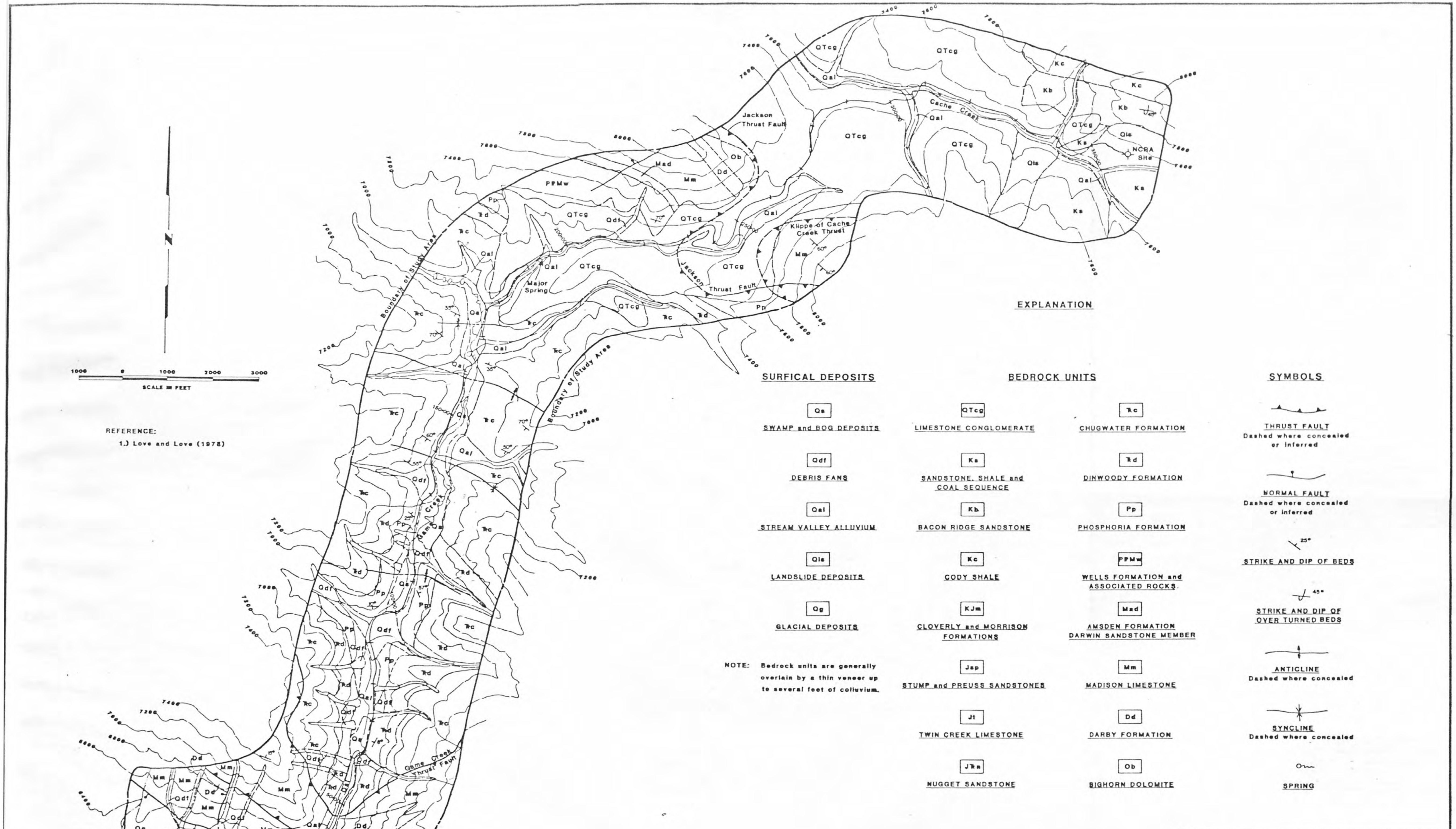
Job Number 6363W-A	Date: Dec. 1980	Fig. 1

upstream from the confluence of Game Creek with the Snake River, as shown on Fig. 1. The road will go up the valley of Game Creek, then cross over a saddle between Game Creek and Cache Creek, and proceeds up the valley of Cache Creek to the NCRA site. The proposed road alignment is shown on Fig. 2. The lower 3 miles of the proposed alignment between Stations 0+00 and 160+05 follow the alignment of an existing unimproved dirt road. The next 2.8 miles of the alignment between Station 160+05 and 308+82 cross through virgin land between the divide of Game Creek and Cache Creek. The last 1.0 miles of road between Stations 308+82 and the NCRA site parallel an existing unimproved dirt road. The width of the road will be kept relatively narrow, about 14 feet, and it is not anticipated that cut slope heights on the majority of the road will be in excess of about 10 feet.

GEOLOGIC SETTING

The proposed Game Creek - Cache Creek Road Corridor is located in the northwestern end of the Gros Ventre mountain range, about 4 miles southeast of Jackson, Wyoming, as shown on Fig. 1. The topography in the area is rugged, consisting of narrow, steep sided valleys which lie from 1,500 to 2,000 feet below the surrounding mountain ridges. The geology of the Gros Ventre Range is very complex. Structurally, the range is a northwest-trending asymmetric anticline with gentle dips on the northeast side and steep dips on the southwest. Precambrian age metamorphic rocks are present in the core of the anticline, and Palezoic through Mesozoic sedimentary rocks form



GEOLOGY MAP
GAME CREEK - CACHE CREEK
ROAD CORRIDOR

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Drawn A.S. M.H. Check R.G.M.	Date December 1980	Fig. 2
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the anticline flanks. The anticlinal structure has been modified by thrust faults and normal faults which trend to the northwest. The thrust faults originated in the Paleocene. Overthrusting has occurred both toward the southwest and northeast. The episode of thrust faulting continued through the Pliocene. During the Pleistocene, the northwest trending Hoback normal fault developed. There is evidence for about 9,000 feet of Pleistocene movement on the Hoback Fault, and the fault is still considered to be active, Behren, B.T. and others (1968).

The Gros Ventre Range lies along the eastern edge of the Intermountain Seismic Belt which is a northeast-trending zone of seismic activity extending northward through Utah, Idaho and Wyoming, Smith (1978). Major earthquakes have occurred in the Intermountain Seismic Belt during historic times. The largest event was the August 17, 1979 Hebgen Lake earthquake which had a magnitude of 7.1. The epicenter was located in the Yellowstone Park area about 100 miles northwest of the Gros Ventre Range. Major earthquakes have not occurred in the vicinity of the Gros Ventre Range during historic times; however, numerous small diffuse earthquakes have occurred in this area, Smith (1978). The magnitudes of these earthquakes have been less than 5.0.

GEOLOGY--GAME CREEK - CACHE CREEK CORRIDOR

The general geologic conditions along the corridor are shown on Fig. 2. Detailed descriptions of the geologic units mapped in the corridor are shown on Table I. Sedimentary rocks ranging from

TABLE I

GEOLOGIC MAP UNITS
GAME CREEK - CASH CREEK CORRIDOR

Map Symbol	Formation and Age	Thickness	Lithologic Character
Qs	Swamp and Bog Deposits (Holocene)	1 to 3 feet	Dark brown, soft, organic, fine, sandy silts
Qdf	Debris Fans (Holocene)	Unknown	Cobbly and gravelly silts and clays.
Qal	Stream Valley Alluvium (Holocene)	Unknown	Silty to clayey sand and and gravel. A fine-grained silty clay layer is generally present at the surface.
Qls	Landslide Deposits (Holocene or Pleistocene)	Unknown	Chaotic mixture of boulders, finer rock debris and soils emplaced by mass movement
Qg	Glacial deposits (Pleistocene)	120 feet	Till and outwash deposits; ranges from nonstratified bouldery clays and silts to stratified silty to clayey sand and gravels. A silt loess layer is generally present at the surface of the deposit.
QTcg	Limestone Conglomerate (Pleistocene or Upper Tertiary)	0 to 400 feet	Gray limestone conglomerate, partially lithified, may be related to glaciation.
Ks	Sandstone, Shale and Coal Sequence (Upper Cretaceous)	5,000 feet	Gray and tan lenticular, fine-grained sandstone, gray plastic shale, carbonaceous shale, marlstone and some coal beds.
Kb	Bacon Ridge Sandstone (Upper Cretaceous)	750 feet	Light gray to tan, fine to to medium-grained, Mesozoic sandstone with some coal, bentonite, and plastic shale beds.
Kc	Cody Shale (Upper Cretaceous)	1,000 to 2,000 feet	Gray to dark gray shale and a few thin sandstone beds.

TABLE I

GEOLOGIC MAP UNITS
GAME CREEK - CASH CREEK CORRIDOR

Map Symbol	Formation and Age	Thickness	Lithologic Character
KJm	Cloverly and Morrison Formations (Lower Cretaceous and Upper Jurassic)	185 to 250 feet	Interbedded gray sandstone with red, green and gray siltstone and claystone
Jsp	Stump and Preuss Sandstones (Upper and Middle Jurassic)	75 to 140 feet	Gray, buff and green, calcareous sandstone with a few thin shale and limestone beds
Jt	Twin Creek Limestone (Middle Jurassic)	800 feet	Gray, calcareous, plastic to hard shale, clayey limestone and limestone.
JTR n	Nugget sandstone (Jurassic and Triassic)	375 feet	Light tan to pink, fine-grained, cross-bedded, hard sandstone
TR c	Chugwater Formation (Triassic)	1,100 feet	Ocher and purple claystone, red shale, purple limestone, pellet conglimerate, and red siltstone
TR d	Dinwoody Formation (Lower Triassic)	200 to 450 feet	Brownish-gray to olive drab, hard, thin-bedded dolomitic siltstone with thin partings of sandstone and silty limestone
Pp	Phosphoria Formation (Permian)	180 to 235 feet	Interbedded dolomite, chert, phosphorite and black shale
PIPMw	Wells Formation and Associated Rocks (Permian, Pennsylvanian and Upper Missippian)	900 to 950 feet	Upper Unit: 450 to 500 feet of light gray, hard, fine-grained, sandstone with some limestone, chalky dolomite and chert beds. Lower Unit: 450 feet of bluish-gray, hard limestone interbedded with red and green shale and tan to white sandstone. Chert nodules and lenses are present.

TABLE I

GEOLOGIC MAP UNITS
GAME CREEK - CASH CREEK CORRIDOR

Map Symbol	Formation and Age	Thickness	Lithologic Character
Mad	Amsden Formation Darwin sandstone member (Upper Mississippian)	75 to 100	Gray to pink, weak, porous cross-bedded, fine to medium-grained sandstone with some shale partings.
Mm	Madison Limestone (Upper and Lower Mississippian)	1,150 to 1,600 feet	Bull Ridge Member: 50 to 100 feet of red shale and siltstone interbedded with sandstone, dolomite breccia and limestone with chert nodules. Main Part: 1,100 to 1,500 feet of light gray to dark gray, thick bedded to massive limestone with thin bedded dolomitic limestone and block chert layers and lenses in lower part.
Dd	Darby Formation (Upper and Middle Devonian)	300 to 500	Dull yellow, thin bedded dolomitic siltstone and shale overlying a lower brown siliceous dolomite with some limestone beds.
Ob	Bighorn Dolomite (Upper Ordovician)	500 feet	Light gray with dark gray mottling, hard siliceous dolomite.

Paleozoic to Cenozoic age are present within the corridor. Intense post-depositional folding and faulting has affected all of the sedimentary rocks with the exception of the limestone conglomerate, Map Symbol QTcg. Within the study area, the Limestone Conglomerate is covered by surficial deposits, and it was not possible to obtain structural attitudes; however, judging from the age of the deposit and its areal distribution, we anticipate that the limestone conglomerate is relatively flat-lying. The structural grain of the underlying older sedimentary rocks is toward the northwest and parallels the trend of both thrust and normal faults. Bedding planes in the older sedimentary rocks generally strike northwest with low to steep dips either to the northeast or southwest. Beds in the Upper Cretaceous rocks which crop out along Cache Creek are overturned and dip to the northeast.

The bedrock in the proposed road corridor is usually covered by surficial deposits. Most of the tributary valley floors are underlain by shallow stream valley alluvium, Map Symbol Qal on Fig. 2, and many of the steep gradient tributaries to Game Creek have debris fans at their mouths, Map Symbol Qdf. Some of the debris fans have been active enough to cause damming of the stream which has resulted in swampy and boggy areas upstream from the fan. The swampy and boggy areas are shown by Map Symbol Qs. Landslide deposits are present in the Cache Creek drainage in areas underlain by Cretaceous age sedimentary rocks as shown by Map Symbol Qls. The landslide appears stable at the present time. The bedrock along the valley sides is generally covered by colluvium which varies from a thin veneer up to deposits of several tens of feet thick. The colluvial deposits along the valley sides have not been shown by a map symbol on Fig. 2. The colluvium is a poorly stratified, silty to clayey sand with numerous angular rock fragments ranging from gravel to boulder size.

The proposed road alignment lies along the central portion of the study corridor as shown on Fig. 2. Geologic materials present along the proposed alignment and the length of road in each geologic material is shown on Table II.

TABLE II

GEOLOGIC MATERIALS PRESENT ALONG THE PROPOSED ROAD ALIGNMENT

Geologic Units	Miles of Road	% Total Road Length
Stream Valley Alluvium (Qal)	1.3	19
Debris Fans (Qdt)	1.0	15
Swamp and Bog Deposits (Qs)	0.5	7
Landslide Deposits (Qls)	0.2	3
Colluvium Over Bedrock	3.8	56
	6.8	100

In the sections of the road which cross stream valley alluvium, debris fans, swamp and bog deposits, or landslide deposits, we do not anticipate that the necessary grading will extend to depths exceeding the depths of these deposits. In areas where the road alignment crosses colluvium overlying bedrock, which accounts for 3.8 miles of the 6.8-mile alignment, we anticipate that grading for the road may be deep enough to encounter the underlying bedrock in many places. Bedrock types which may be encountered and the length of road sections in each bedrock type are shown in Table III.

TABLE III

AREAS OF ANTICIPATED SHALLOW BEDROCK

Rock Underlying Colluvium	Miles of Road	% Total Road Length
Limestone Conglomerate (QTcg)	2.7	40
Sandstone, shale and Coal Sequence (Ks)	0.1	1
Chugwater Formation (TRc)	0.9	14
Dinwoody Formation TRd)	0.1	1
	3.8	56

POTENTIAL IMPACTS OF CORRIDOR GEOLOGY ON ROAD

This section discusses the potential impact to the proposed road and its users related to the geologic processes and conditions present along the road corridor. Because most of the impacts are related to geologic processes which have varying rates of activity, it is necessary to establish a design life for the road in order to rank the potential impacts. A road service life of 25 years was considered. The potential geologic impacts on the road were ranked as high, moderate and low, using the following definitions:

High - Geologic processes or conditions which are likey to impact the road and its users one or more times during the road's service life.

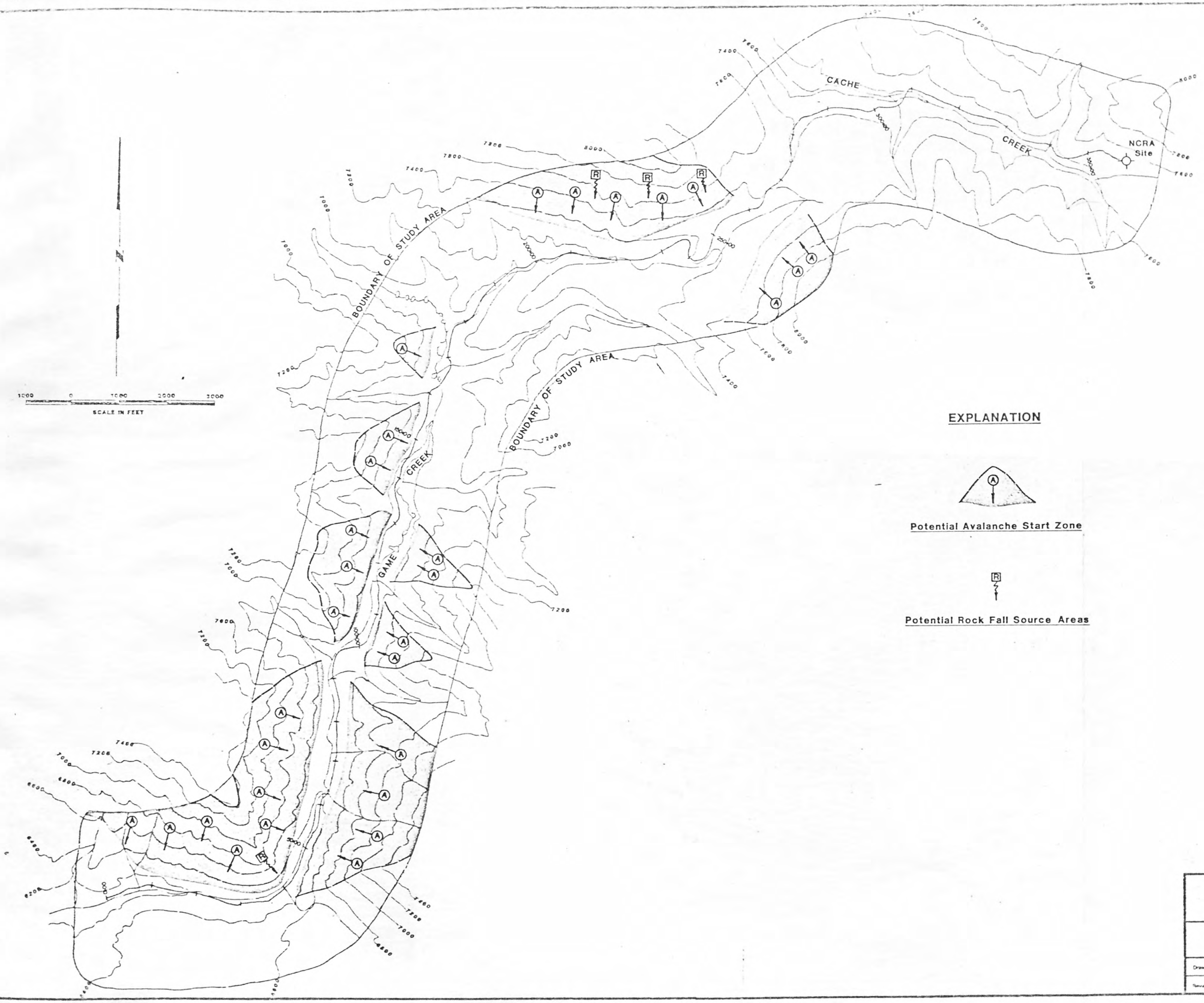
Moderate - Geologic processes or conditions which are not likely to impact the road and its users during the road's service life, but are likely to impact the road during a time period which is severe to several tens times longer than the road's service life.

Low - Geologic processes or conditions which are not very likely to impact the road and its users during the road's service life. These types of events occur relatively infrequently and are likely to have recurrence intervals greater than several tens to several thousands times the road's service life.

The potential impacts considered and their ranking are given on Table IV and discussed in the following sections.

Geologic Impacts	Potential for Impact
Avalanche	High
Flooding	High
Rockfall	Moderate
Debris Flows	Moderate
Earthquake Effects:	
Moderate Ground Shaking	High
Strong Ground Shaking	Low
Surface Fault Rupture	Low
Landslide Movements	Low

Avalanches: Snow avalanches have occurred in the Jackson, Wyoming area in the past, Love (1973), and it is likely that avalanches will continue to occur in the future. The Potential for an avalanche exists whenever the combination of steep slopes and adequate snowfall is present. These conditions occur at several places along the proposed road alignment as shown on Fig. 3. In evaluating the avalanche potential in the road corridor, potential avalanche start zones were considered to be slopes without conifer forests in excess of 50% (27°) or forested slopes with well-defined avalanche tracks through the forests. The potential for avalanches impacting the road and its users is considered to be high, that is, it is anticipated that avalanches will impact some portions of the road during its service life. The adverse effects of avalanches on the road are expected to be small, and it is possible to close the road to travel while avalanche control operations, such as artificial avalanche release, take place as conditions warrant. Consequently, the potential danger to road users can be significantly reduced.



AVALANCHE AND ROCK FALL
GAME CREEK - CACHE CREEK
ROAD CORRIDOR

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Revised Job Number 6363W-A
Fig. 3

Flooding: Periodic flooding is expected to take place along the major drainages and their tributaries as a result of snowmelt runoff and storm runoff. The potential for flooding along the drainages is considered to be high, that is, flooding is expected to occur one or more times during the service life of the road. Flooding should not present a great danger to road users, and the potential adverse impacts to the road can be significantly reduced by engineering adequate surface drainage facilities where the road crosses drainage channels.

Rockfalls: In a few places along the proposed road alignment, steep rock outcrops upslope from the road provide a potential source of rockfall. These areas are shown on Fig. 3. A few boulders in the vicinity of the proposed road alignment downslope from the source areas indicate that rockfalls have occasionally occurred in the past. The rockfall potential is considered to be moderate, that is, the likelihood of a rockfall occurring during the service life of the road is relatively remote; however, giving longer periods of exposure, the potential for rockfall is likely. The adverse effects of rockfall on the road are expected to be small, and the potential dangers to road users are also considered to be small because a vehicle traveling on the road will only be exposed to the potential for a short period of time.

Debris Flows: Evidence of past debris flows is evidenced by the debris fans present along the proposed road alignment in the Game Creek drainage. The fan deposits have resulted from debris flows associated with relatively infrequent, intense storms. The potential for future debris flows is considered to be moderate, that is, debris flows are not likely to occur during the service life of the road; however, debris flows are likely to occur over longer time periods. The adverse effects of debris flows on the road are expected to be relatively minor. If a debris flow were to occur during the road's service life, it would be necessary to clean the debris off the roadway. The danger of debris flows to road users is considered to be small, since debris flows are expected to occur very infrequently and the exposure time of someone using the road in a debris flow area is very short.

Earthquake Effects: The northwestern portion of the Gros Ventre Range in the vicinity of the road corridor is in an area which has experienced moderate levels of historic seismic activity, and it is anticipated that moderate levels of seismic activity will occur during the service life of the road. Judging from post-seismic activity, peak ground accelerations of about 0.05g are likely to occur one or more times during the service life of the road. Ground shaking of this magnitude is not expected to be significant to the road or its users.

Considering the tectonic setting and recent geologic history of the area, there is also a potential for relatively infrequent, large earthquakes associated with the Hoback and Teton Fault Zones. Geologic evidence indicates that both of these fault zones have been active during the Quaternary. Average rates of displacement on the fault zones during the relatively recent geologic past indicate that the faults would be classified as moderately active, Slemmons (1977).

The recurrence interval for displacements along such faults and the generation of magnitude 7.0 or greater earthquakes is generally measured in thousands to tens of thousands of years for a given point on the fault, Slemmons (1977). Earthquakes of this size will produce strong ground shaking. Considering the proximity of these fault zones to the road corridor, it is anticipated that ground shaking in the corridor associated with a major earthquake would result in peak ground accelerations within the range of 0.3 to 0.7g. In addition to strong ground shaking, surface fault displacement is likely to occur along the Hoback Fault during a major earthquake. If a major earthquake were to occur on the Hoback Fault, ground surface displacements of about 10 feet could be expected; however, the recurrence interval for a major earthquake is considered greater than the service life of the road and the potential for strong ground shaking and surface fault rupture is considered to be low.

Landslide Movements: Landslide deposits are present along the Cache Creek valley in areas underlain by Cretaceous sedimentary rocks. The landslides appear to be relatively old and stable at the present time. The potential for renewed landslide activity during the service life of the road is considered to be low. Strong ground motions associated with major earthquakes could cause renewed landslide activity or result in new landsliding in other areas along the road corridor. However, the potential for strong earthquake ground motion is also considered to be low during the service life of the road.

POTENTIAL IMPACTS OF ROAD ON CORRIDOR GEOLOGY

This section discusses the potential impacts of road construction on the geologic conditions present in the proposed corridor. Disturbance of the ground surface associated with road construction can be expected to have some impact on the corridor geology; however, if proper construction techniques are used, these impacts can be kept to a minimum. Potential impacts to the corridor geology are the potential for accelerated soil erosion and accompanying sedimentation and the potential for construction-induced slope instability. By properly engineered design, these potential impacts can be reduced significantly.

The potential for accelerated soil erosion will occur in areas where road cuts remove the protective vegetative cover and where drainage collected along the upslope side of the road is discharged. Soil erosion on road cuts can be reduced by revegetation of the cut slopes, and the potential for accelerated erosion at drainage discharge points can be reduced by controlling the drainage discharges by frequent culverts so that large discharges are prevented. In some cases, it may be necessary to construct erosion control structures at specific discharge points.

The potential for construction-induced slope instability is relatively low because the road will be kept to a minimum width, which will avoid the necessity of having high cut or deep fills. Observation of existing cut slopes in the area indicate that the slopes are generally stable at inclinations of 1:1 when seepage is not present in the cut face. It is likely that the proposed road cuts when dry could be designed as steep as 1:1 and remain stable; however, it has been our experience that cuts at this inclination are very difficult to revegetate. It is advisable that cut slopes in the surficial deposits be no steeper than 1 1/2:1. Cuts in erosion-resistant rock can be made as steep as the jointing in the rock will allow. For cuts on the order of 10 feet high, cut slopes of 1/4:1 are probably feasible in most places. When seepage is encountered in soil cuts, the likelihood of localized small cut slope failures is high. Based on our reconnaissance, it does not appear that many areas will be encountered where cut slope seepage will be a problem. If seepage is encountered during construction, it may be necessary to flatten the slope or provide drainage in order to stabilize the slope.

In order to minimize stability problems with fills, the fills should be compacted when placed. The ground surface below fills should be stripped of vegetation. Fill placed on steep side hills should be keyed into the hillside by benching the foundation. Compacted fill slopes should be stable at angles of 1 1/2:1. Revegetation will minimize the potential for post-construction fill erosion. In areas where fill embankments are placed adjacent to flowing streams, the toe of the fill below flood level should be protected from erosion by riprap or other means.

GEOLOGIC CONSIDERATION FOR CONSTRUCTION

It should be possible to excavate the surficial deposits with heavy duty construction equipment. Shallow excavations into the bedrock can be done with rippers in most cases; however, some blasting may be required.

The swamp and bog deposits can be crossed on fills. In some cases, a granular fill base may be required to stabilize the foundation prior to completing the fill. Drainage should be provided through the fill to prevent damming of subsurface water flow.

If there are any questions concerning this report, please let us know.

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