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LANDSLIDE CONDITIONS ALONG THE FERRY COUNTY HIGHWAY PARALLELING LAKE ROOSEVELT FROM KETTLE FALLS TO THE MOUTH OF THE SPOKANE RIVER WASHINGTON

by

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LANDSLIDE CONDITIONS ALONG THE FERRY COUNTY HIGHWAY PARALLELING LAKE ROOSEVELT FROM KETTLE FALLS TO THE MOUTH OF THE SPOKANE RIVER, WASHINGTON

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INTRODUCTION

As part of the program of the U. S. Geological Survey, landslides are being studied in several localities in the United States. These studies are directed toward assembling criteria for recognition of landslides, classification, and cataloging of remedial or control methods that have been effective. In the gorge of the Columbia River in Washington, landslides of large magnitude have been active intermittently since the valley was first incised. Closure of Grand Coulee Dam, with the consequent rise of water forming Franklin D. Roosevelt Lake, has introduced the factor of a rising and fluctuating water table that accentuates the incidence of landsliding. This area was selected for study because of the magnitude of the landslides and the unknown but significant influence of a fluctuating water table. Data resulting from the studies will be summarized in a final report.

This report describes briefly the landslide conditions along the highway on the west shore of Franklin D. Roosevelt Lake in Ferry County, Washington, between the Kettle Falls bridge and a point opposite the mouth of the Spokane River. Areas which have been affected by landslides are outlined; areas where landslides may occur in the future due to the effect of the reservoir are pointed out; and those areas which are considered safe from landslide action are delineated.

Prior to the construction of Grand Coulee Dam and the creation of Franklin D. Roosevelt Lake in the Columbia River Valley, Ferry County maintained a low-level road along the right bank of the Columbia River. The position of this original road can be examined on the Columbia River maps, which were published by the U. S. Geological Survey in 1930, in cooperation with the Corps of Engineers, entitled "Plan and Profile of the Columbia River from the International Boundary to Wenatchee, Washington." Sheets B and C show the area in Ferry County under consideration. These maps are not an essential part of this report so copies are not included in it.

The creation of the reservoir necessitated the relocation of this vital county transportation route above maximum water level at elevation 1290. The position of the relocated route may be examined on the five quadrangle sheets included in this report (Kettle Falls, Inchelium, Hunters, Wilmont Creek, and Lincoln quadrangle sheets in pocket). For the most part, an entirely new route was selected and the highway built, but in a few places short sections of existing roads were improved and used.

Background of landslide investigations along the upper Columbia River

Owing to the unexpected and great frequency with which landslides occurred along Franklin D. Roosevelt Lake in the first few years of its operation, a study of landslides was begun in 1942 by the Bureau of Reclamation. This study led to a preliminary landslide classification of most of the 600 to 700 miles of lake-shore land. The geologic conditions and topographic relationships were studied, and the reservoir shoreline was classified generally into five groups: "landslides likely," "landslides unlikely," "slide areas," "bedrock," or "indeterminate." The meaning of the classification is self-evident. The indeterminate category was necessary because there were many places where it was impossible to make a valid determination of the landslide potential from the data which existed at the time. In the course of the study, particular attention was directed to areas where landslides might destroy private property or endanger lives.

In 1948 the Geological Survey undertook research studies of the landslides in cooperation with the Bureau of Reclamation, the National Park Service, and the Corps of Engineers. Both the early investigations of the Bureau of Reclamation and the later studies by the Geological Survey were under the direction of the writer. The study now in progress extends from the International Boundary downstream almost to Chief Joseph Dam, which is under construction by the Corps of Engineers. The purposes of this investigation are to contribute to the understanding of landsliding as a geologic process, and to develop criteria for predicting the probable amount of lakeshore land which will be affected by landslides so that maximum utilization can be made of areas believed to be stable.

General Setting

The Columbia River Valley from the International Boundary to its confluence with the Spokane River lies in the Okanogan Highland physiographic province (Pardee, 1918, Culver, 1936, and Flint, 1936, p. 1849-1884). This province occupies that part of the state north of the Columbia and Spokane Rivers, between the Cascade Mountains on the west and the mountains of Idaho on the east (Landes, 1902). It is made up of north-south trending valleys between low, parallel mountain ranges. The most conspicuous of these north-south valleys are the Okanogan, San Poil, Columbia, and Pend Oreille.

During the Paleozoic and Mesozoic eras, the area comprising this province was a sea (Weaver, 1918). On the floor of this sea were deposited sediments of mud, sand, gravel, and other materials which later upon consolidation became shale, sandstone, conglomerate, and limestone. Late in the Mesozoic era great quantities of granite were intruded into these rocks (Pardee, op. cit.) and (Weaver, 1920), and the land was elevated to form mountains higher than those which exist today. These processes resulted in the metamorphism of some of the sedimentary formations to argillite, quartzite, gneiss, schist, and marble.

The intrusions of granite and the regional uplift folded the rocks so that at the present time they are not in a horizontal position but tilted at various angles.

Between the time of these geological events and the Ice Age, the chief process affecting the Okanogan Highland province was erosion of rock valleys now occupied by present streams.

Glacial history.— The Columbia River Valley throughout this north-south section was glaciated and influenced greatly by glacial damming farther downstream in the Big Bend. As the ice sheet formed in the north, the Columbia River became swollen with glacial melt-water and scoured the lower part of its valley nearly clean of sand and gravel (Flint and Irwin, 1939, p. 661-680). The lobes of the ice sheet advanced southward along the Okanogan, San Poil, Columbia, and Pend Oreille Valleys of this physiographic province. Prior to the filling of the Columbia Valley by ice, the lobe moving down the Okanogan Valley crossed the Columbia Valley in the northern part of the Big Bend and formed a dam (Bretz, 1923, p. 573, Willis, 1887, p. 477-480, Flint, 1935, p. 169-194, and Flint, 1936, op. cit.). Into the lake thus created the swollen Columbia River carried great quantities of glacial flour which settled to form beds of light-colored silts and clays known as the Nespelem silt (Pardee, op. cit., and Flint, op. cit.).

After this initial stage of deposition, the ice advanced and filled the valley. It has been estimated that the ice was more than 4,000 feet thick over the floor of the Columbia River Valley at the northern edge of the Colville Indian Reservation (Pardee, op. cit.). The overriding ice mashed, pushed, and consolidated the underlying lake beds. In wasting away, the ice released great quantities of silt, sand, gravel, boulders, and angular rubble. Deposits were laid down alongside the ice tongues and in temporary lakes created by local ice dams. In most places these materials were sorted into beds of silt, sand, and gravel, but locally unsorted deposits of till are found. The details of the glacial history have not been completely worked out. The ice may have advanced and wasted away more than once, each such stage being accompanied by separate stages of damming and lake deposition. The formation of a lake in which silt deposition took place followed the filling of the valley by ice (Flint and Irwin, op. cit., Flint, op. cit., and Walker and Irwin, 1952). During and following the melting of the ice dam downstream, the still-swollen Columbia cut its way through the soft silts, sands, and gravels so rapidly that it did not excavate all these materials along the sides of the valley. These remaining deposits now compose terraces of silt and clay with occasional interbeds of sand and gravel. Some of the beds have been greatly deformed; others appear to have been only slightly deformed; but basically they are all similar in this north-south section of the river. Sands and gravels and a thin layer of soil cap most of the terraces.

Studies of the terraces and fill remnants show that landslides were very active in glacial times and that they have continued ever since. As the river eroded into the fill, steep slopes developed and landslides fed their charge of materials into the river. Terraces at many levels show the topographic forms of old landslides. They appear to have constituted one of the major processes in the dissection of the fill into its present form.

General effect of Lake Roosevelt on landslides

Several large landslides have been recorded in this general north-south section of the Columbia River in historic times prior to the existence of Lake Roosevelt. At least two of the landslides have been large enough to dam partially the flow of the Columbia River for short periods.

The creation of Lake Roosevelt by Grand Coulee Dam caused new landslides along the lake shore. New areas became active and old landslide areas showed renewed activity. The saturation of the banks and the building up of the water table that accompanied the filling of the lake introduce new load factors whenever the lake level is lowered during the operation of the reservoir. Water is retained in the silts and clays because it cannot drain out as quickly as the lake level can be lowered. The additional water, plus structural weakness of the clay, silt, and sand beds due to saturation, makes steep banks unstable.

Bedrock in the Columbia River valley is generally stable, and landslides take place within the unconsolidated terrace and fill deposits, or at their contact with the underlying bedrock surface.

Landslides have occurred at many places along the Ferry County highway due to the effect of Lake Roosevelt on the geologic environment.

Description of landslide areas, potential slide areas, and safe areas along the present highway

For reference purposes numbered monuments[1] have been established along the highway to show locations of the sections to be described (see enclosed maps). The 29 sections described in the following paragraphs begin at the west end of the Kettle Falls bridge in the Kettle Falls quadrangle and extend downstream to a point opposite the mouth of the Spokane River in the Lincoln quadrangle. The first two sections are north of Monument 1.

[1] The monuments are 4" x 4" posts painted white and located as follows:

Monument number	Mileage from junction of State Highway 3 and Sherman Creek Highway	Location of monument with respect to center line of road, proceding southward
1	6.52	30' left
2	11.41	20' left
3	11.88	30' right
4	11.96	20' right
5	12.00	20' left
6	12.10	20' right
7	12.30	20' left
8	12.50	20' right
9	13.00	20' right
10	13.97	20' left
11	14.22	25' right
12	14.40	25' right
13	14.53	30' right
14	15.38	20' right
15	15.59	20' right
16	16.61	20' right
17	17.41	20' right
18	18.07	20' right
19	42.74	20' right
20	44.84	20' right
21	45.40	15' right
22	46.87	20' right
23	55.47	20' right
24	56.16	20' right
25	61.00	15' right
26	62.32	15' right
27	74.62	20' right
28	75.05	25' right

Predictions of landslide possibilities are based on observations of hundreds of landslides and of slopes in unconsolidated materials that have not been affected as yet by landslides, that have been in progress through a 12-year period throughout the extent of the reservoir. Observations have been made of the nature of the unconsolidated sediments, the surface drainage and ground water conditions, the position and shape of the buried bedrock surface, and the height and steepness of the present slope of the unconsolidated deposits, both the submerged portions and those above lake level.

Kettle Falls Bridge to Sherman Creek - Kettle Falls quadrangle.— The highway in this section crosses an area which is underlain by bedrock at a relatively shallow depth, but in only a few places is rock actually exposed in highway cuts. The glacial overburden consists of silt, clay, sand, gravel, and till. The road grade cuts points and ridges of all these materials and the fills are constructed on them. It is not likely that landslides due to the influence of Lake Roosevelt, will develop in this section. Because ground water is present near the surface on the valley side above the highway some failures of the fills may be anticipated where fill rests on silt and clay.

Sherman Creek to Monument No. 1, Kettle Falls quadrangle.— In this section the highway crosses one of the most active landslide areas in the upper Columbia River Valley. This area is known as the Reed terrace, and is composed chiefly of lacustrine silt and clay. A large section of the highway was taken out completely on this terrace in the spring of 1952 (see Plates 1 and 2). The slide necessitated a temporary relocation of the highway. Detailed site studies would be necessary to relocate this section permanently.

Monument No. 1, Kettle Falls quadrangle, to Monument No. 2, Inchelium quadrangle.— Throughout this section the highway is far enough away from the lake, or the geologic conditions are such that landslides will not affect the safety of the highway.

PLATE 1

Reed Terrace Landslide Area, May 15, 1951. Between Sherman Creek and Monument 1

Kettle Falls quadrangle

Photograph 1278

Reed Terrace Landslide Area, May 15, 1951, between Sherman Creek and Monument No. 1,
Kettle Falls Quadrangle

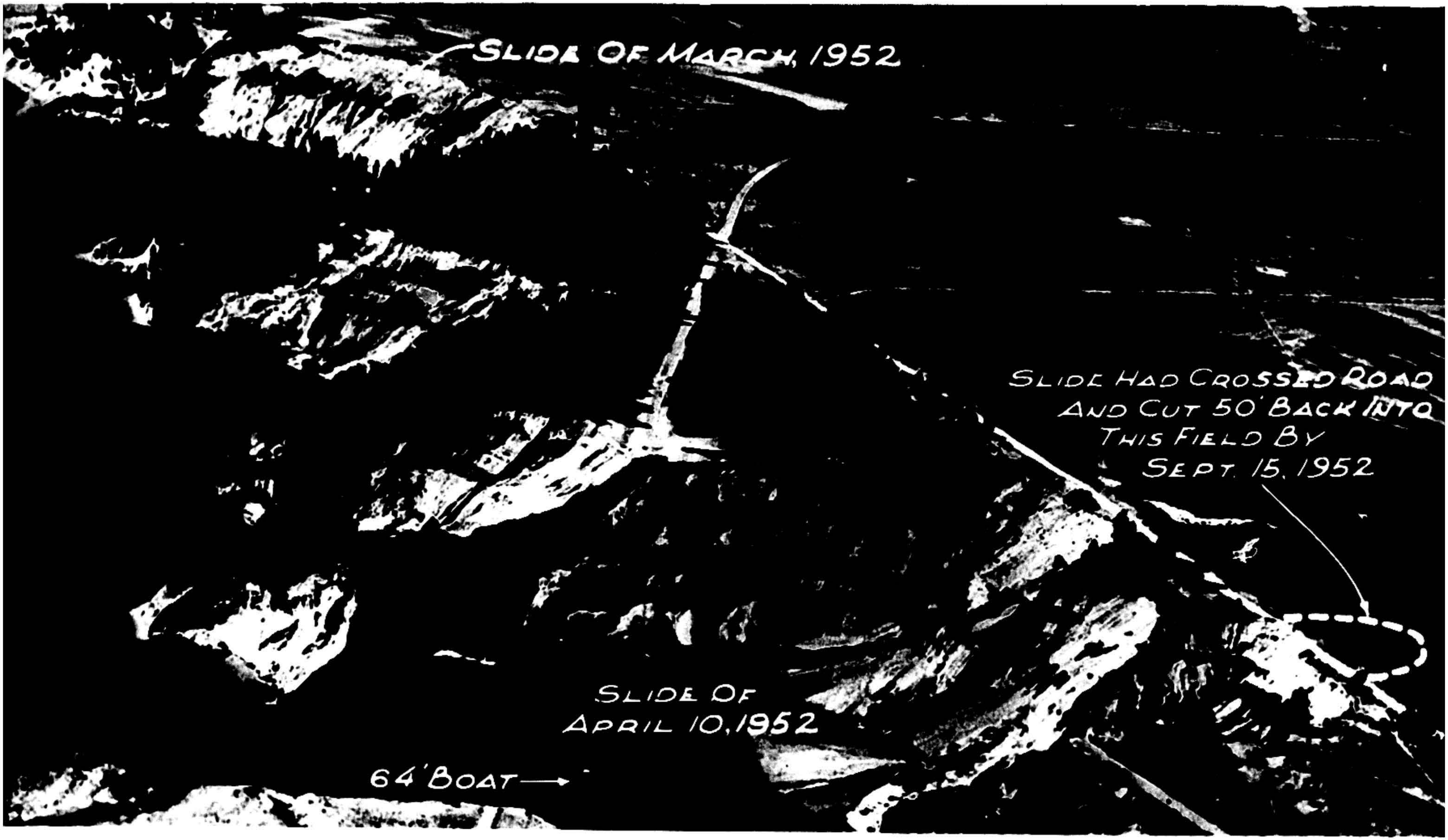
Plate 1

Photograph 1278

PLATE 2

Reed Terrace Landslide Area, August 1, 1952. Between Sherman Creek and Monument 2
Kettle Falls quadrangle

Photograph 1279



Reed Terrace Landslide Area, August 1, 1952, between Sherman Creek and Monument No. 2,
Kettle Falls Quadrangle

Plate 2

Photograph 1279

Monument No. 2 to Monument No. 3, Inchelium quadrangle.--
Along this section the highway is founded partly on bedrock and partly on beds of unconsolidated silt, clay, sand, and gravel. In several places the road dips slightly and one small slide occurred about 1946. It is likely that a part of this road will be lost by small landslides. If this section of the road were widened an average of one-half the highway width on the rock-cut side, a safe foundation would be provided.

Monument No. 3 to Monument No. 4, Inchelium quadrangle.--
In this section the highway crosses an area which is predominantly interbedded silt and clay. Above the highway, ground water is close enough to the surface to subirrigate a steep hillside field. This section is likely to slide out, and additional studies would be necessary either to relocate the highway or to establish a system of drains of adequate size to safeguard the present location.

Monument No. 4 to Monument No. 5, Inchelium quadrangle.--
The foundation for the highway is on bedrock between these two points, and therefore is not subject to sliding.

Monument No. 5 to Monument No. 6, Inchelium quadrangle.--
The highway between Monuments Nos. 5 and 6 is constructed principally on unconsolidated beds of silt and clay. The bedrock surface lies at a shallow depth. Landslides may develop wholly within the surficial materials, or landslides could develop along the contact between the surficial materials and the bedrock. Detailed site studies would be necessary to either relocate this section or drain the potentially unstable material.

Monument No. 6 to Monument No. 7, Inchelium quadrangle.--
Along this section the slopes of the terrace front toward the lake are sufficiently gentle that landslides are not likely and the present location is considered safe.

Monument No. 7 to Monument No. 8, Inchelium quadrangle.--
There are several recent landslides in this section. Ground water is very close to the surface, and water seeps into the ditch on the upper side of the highway. It seems possible that landslides could happen in this section owing to the effect of Lake Roosevelt. The recent failures, however, have not been caused by Lake Roosevelt, but have been caused by the shallow water table and lack of adequate drainage. Detailed site investigation would be needed to determine feasible plans for drainage or relocation in this section.

Monument No. 8 to Monument No. 9, Inchelium quadrangle.-- In this area the highway is far enough away from the lake and geologic conditions are such that landslides will not affect it.

Monument No. 9 to Monument No. 10, Inchelium quadrangle.-- The highway parallels the edge of the lake quite closely in this section. It has been constructed in glacial fill materials such as silt, clay, sand, gravel, and till in most places, but locally is cut into bedrock. Thick slope wash and huge talus deposits extend over the laminated silt and clay in many places, but the only place they can be observed is in the slides and wave banks below the highway. There are three landslides in this section, one of them cutting back to the outer edge of the road surface. Because continued landslide activity may be expected, detailed site studies would be needed as a basis for relocating around the area or of placing the highway grade on bedrock. Plate No. 3 illustrates the conditions along the most unstable part of this section.

Monument No. 10 to Monument No. 11, Inchelium quadrangle.-- The highway is constructed on bedrock along this section and is therefore not subject to sliding.

PLATE 3

Lakeshore between Monument 9 and Monument 10 - Inchelium quadrangle - August 11, 1952

Photograph 1211

Lakeshore between Monument 9 and Monument 10, Inchelium Quadrangle, August 11, 1952

Plate 5

Photograph 1211

Monument No. 11 to Monument No. 12, Inchelium quadrangle.-- The highway skirts a rock cliff in this short section. A rock cut has been made around this point in order to construct the highway. Between one-half and two-thirds of the highway width is on the bench of the rock cut, but approximately one-third is on talus. It is apparent from nearby exposures that this talus rests in part on silt or has a great deal of silt in it. Landslides are likely to occur along the talus section and take out a part of the road. It is unlikely that it will be cut completely, but slides will probably cut far enough back into the road to make it impassable.

Monument No. 12 to Monument No. 13, Inchelium quadrangle.-- The materials in this section are silt, gravel, till, and slope wash. These materials are water saturated because the water table is very high. Landslides are likely, and the problem of relocation or of draining the area would require detailed study at the site.

Monument No. 13 to Monument No. 14, Inchelium quadrangle.-- The highway skirts the lake along most of this section. Due to the low angle of the slope on the unconsolidated materials on which the highway rests, it is unlikely that landslides will do any major damage in this section; however, wave action from the lake may cause damage unless the present riprap is increased.

Monument No. 14 to Monument No. 15, Inchelium quadrangle.--The material along this section is silty, and ground water is close to the surface. There is a spring area just above the highway, and a small stream runs in the ditch above the road. A landslide here would probably be due more to the springs than to any effect of Lake Roosevelt. As a basis for improving this section, studies should be made of opening the spring and draining the water off the area where it might induce landslides.

Monument No. 15 to Monument No. 16, Inchelium quadrangle.--The highway follows close to the lake which is shallow for a considerable distance out from shore in this section. A large part of the highway is on bedrock, but in places the highway fill rests on talus deposits, till, silt, and silty slope wash. There may be minor landslides along this stretch, or it may be damaged by wave action, but failures of major proportion are not expected. Small slides may develop in this section because the road has been constructed on silty foundation materials

Monument No. 16 to Monument No. 17, Inchelium quadrangle.--The highway between these two points is constructed principally in rock cuts. There will be no landslides in this section due to reservoir effects.

Monument No. 17 to Monument No. 18, Inchelium quadrangle.-- In this section the road is farther back from the lake than in the area to the north. There are some rock outcrops between the highway and the lake. Bedrock is shallow throughout most of this area, overlain by varying thickness of silt and clay. The draws are heavily charged with ground water, and the highway itself cuts through silts. Landslides are likely in the draws near the northern end of the area and possibly in sections of the southern end; however, some of this section is safe owing to the position and shape of the bedrock surface. Considerable detailed work would have to be done in outlining the position of bedrock and the depths of silt and clay to determine just how much of the road is safe and how much is not safe.

Monument No. 18 to Monument No. 19, Inchelium, Hunters, and Wilmont Creek quadrangles.-- The highway along this area is far enough away from the lake and the geological conditions are such that landslides are not likely to affect it. The highway lies on rock in places - - in other places it cuts through unconsolidated deposits of silt and till. Some of the road fills across the valleys are placed on silt and show settlement. From time to time small slides have covered the road causing some maintenence difficulties. Small failures are likely in these silty areas in the future, but they would not be caused by Lake Roosevelt, should be of a minor nature, and should not be too expensive to repair and maintain.

Monument No. 19 to Monument No. 20, Wilmont Creek quadrangle.-- One landslide in this section (Falls Creek area) has completely severed the road and another has cut into the shoulder. The highway in this area rests entirely on beds of silt, clay, and fine sand. Steeply dipping bedrock underlies the deposits at varying shallow depths. The water table is very shallow. It is doubtful if measures to drain the ground water from the surficial deposits would be successful. Detailed studies at the site would be needed to relocate this section of the road. Plates Nos. 4 and 5 illustrate the Falls Creek area. Plate No. 6 shows the landslide which cut the highway in the spring of 1951.

Monument No. 20 to Monument No. 21, Wilmont Creek quadrangle.-- In this section the highway is constructed on bedrock, and not subject to slides.

Monument No. 21 to Monument No. 22, Wilmont Creek quadrangle.-- Landslides are likely to cut the highway in this section. One area has already slumped 6 to 8 feet, and another area has cracked. There are small exposures of bedrock near the shoreline, and the surficial materials are a very thin veneer over bedrock. However, the effects of the erosion of the wave bench and the very shallow water table are likely to combine to cause landslides here which will cut the road. Detailed studies at the site would be necessary for relocating around this section, moving into the hillside far enough to secure a safe foundation, or of draining wet silty material both above and below the highway.

PLATE 4

Aerial oblique looking down lake showing the highway in the Falls Creek area between Monument 19 and Monument 20 - Wilmont Creek quadrangle

April 21, 1953 Photograph 1326

Aerial oblique looking down lake showing the highway in the Falls Creek area between
Monument 19 and Monument 20, Wilmont Creek Quadrangle, April 21, 1953

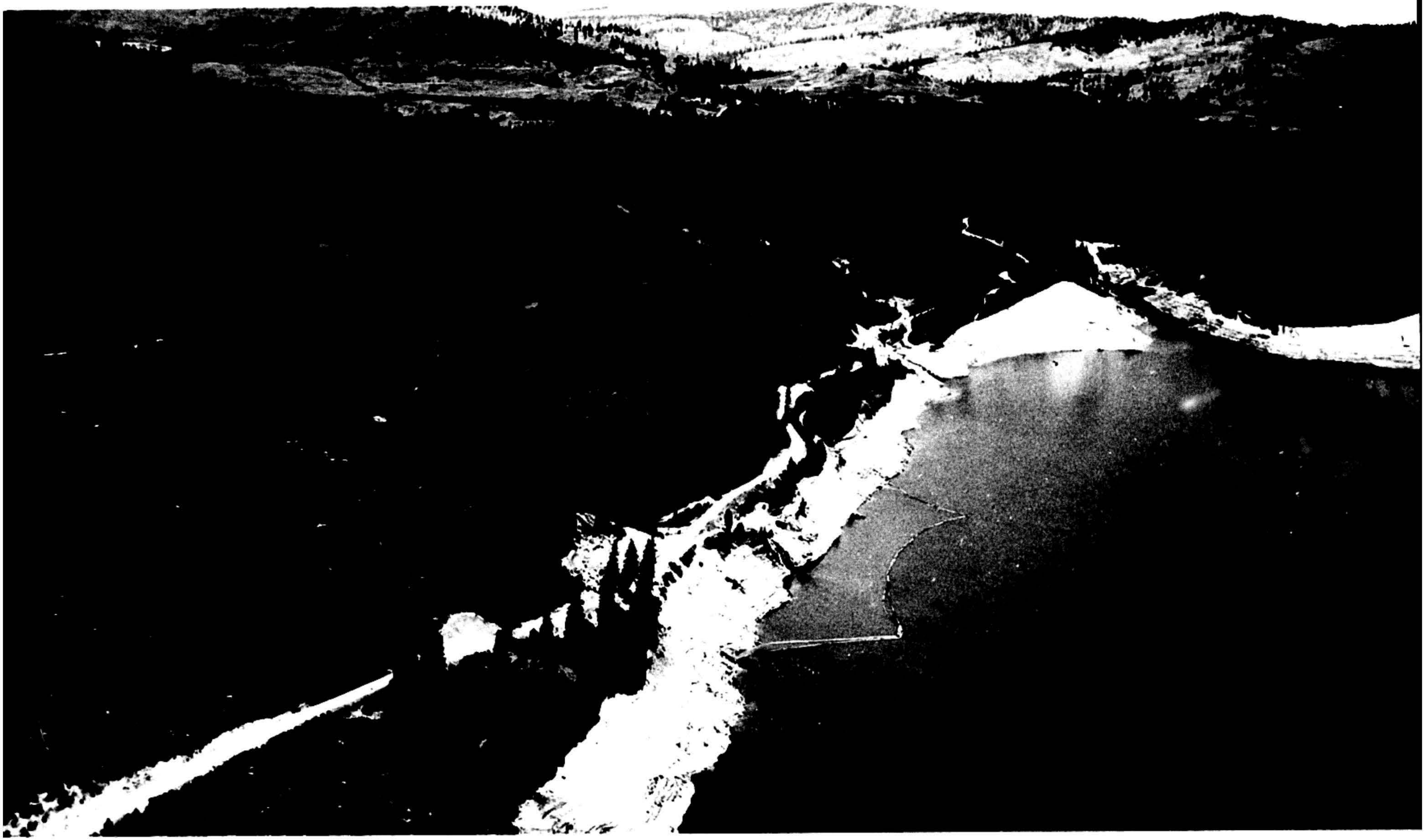
Plate 4

Photograph 1326

PLATE 5

Aerial oblique looking up lake showing the highway in the Falls Creek area between Monument 19 and Monument 20 - Wilmont Creek quadrangle

May 6, 1953 Photograph 1361



Aerial oblique looking up lake showing the highway in the Falls Creek area between Monument 19 and Monument 20, Wilmont Creek Quadrangle, May 6, 1953

Plate 5

Photograph 1361

PLATE 6

Landslide which cut highway in spring of 1951 in the Falls Creek area between Monument 19 and Monument 20 - Gilmont Creek quadrangle

May 16, 1951 Photograph 293

Landslide which cut highway in spring of 1951 in the Falls Creek area between Monument 19 and Monument 20, Wilmont Creek Quadrangle, May 16, 1951

Plate 6

Photograph 293

Monument No. 22 to Monument No. 23, Wilmont Creek quadrangle.--No landslides related to Lake Roosevelt are likely to cut or endanger this section of highway. Much of this stretch rests on, or cuts into, beds of silt and clay. Some of the cuts show small slides. Additional sliding can be expected where the water table is shallow and there are steep slopes in the fills or cuts, but it is not likely that there will be any major landslides.

Monument No. 23 to Monument No. 24, Wilmont Creek quadrangle.--Between these monuments the highway crosses behind the alcove of an ancient landslide, part of which was formed right after the San Francisco earthquake of 1906. The water table is very shallow in the deposits of silt and clay that fill the rock basin behind the alcove. Renewed landslide action which could take out the road is possible in this area; however, relocation could probably be made close around the rock hill to avoid the slide if and when it occurs.

Monument No. 24 to Monument No. 25, Wilmont Creek quadrangle.--It is not expected that there will be any landslides caused by Lake Roosevelt which will cut the highway between these monuments. The highway in this area crosses Nine Mile Flat, which is a thick, deep silt and clay fill. There are huge ancient slides in this area, and the highway lies in the scarp of one of these big ancient slides for a short distance. From study of the slope characteristics, load factors, and ground water conditions, it seems rather doubtful that there will be renewed landslide activity in this area.

Monument No. 25 to Monument No. 26, Wilmont Creek quadrangle.-- In this area the highway skirts Ninemile Bay. Large landslides have completely cut the road in two places, and a small one has partly cut it. Throughout this section the road rests on alternate sections of granite bedrock, beds of unconsolidated silt and clay, and silty slope wash. The places which are entirely on bedrock are safe, but they account for less than 30 percent of the section. Additional sliding can be expected, and detailed site studies would be needed for relocation. The highway has been closed most of the time since a landslide on July 3, 1944 (see Pl. No. 7). Plate No. 8 shows the same slide in May 1951. Plate No. 9 shows a slide which cut the highway in the winter of 1952.

Monument No. 26, Wilmont Creek quadrangle, to Monument No. 27, Lincoln quadrangle.-- Beginning at Monument No. 26 the highway winds over a mountain to Sixmile Creek and then follows a low terrace to Monument No. 27. All of the materials exposed along this section are coarse sands, gravels, and boulders, with silty sand appearing in a few spots. The highway is very close to the lake where it makes sharp turns around Sixmile and Threemile creeks. Small failures could occur at these two points, but the likelihood of major landslides are relatively small.

PLATE 7

Landslide at Ninemile Creek which completely cut highway on July 3, 1949 - Gilmont Creek quadrangle between Monument 25 and Monument 26

July 14, 1949 Photograph 218

Landslide at Ninemile Creek which completely cut highway on July 3, 1949 - Wilmont Creek Quadrangle between Monument 25 and Monument 26

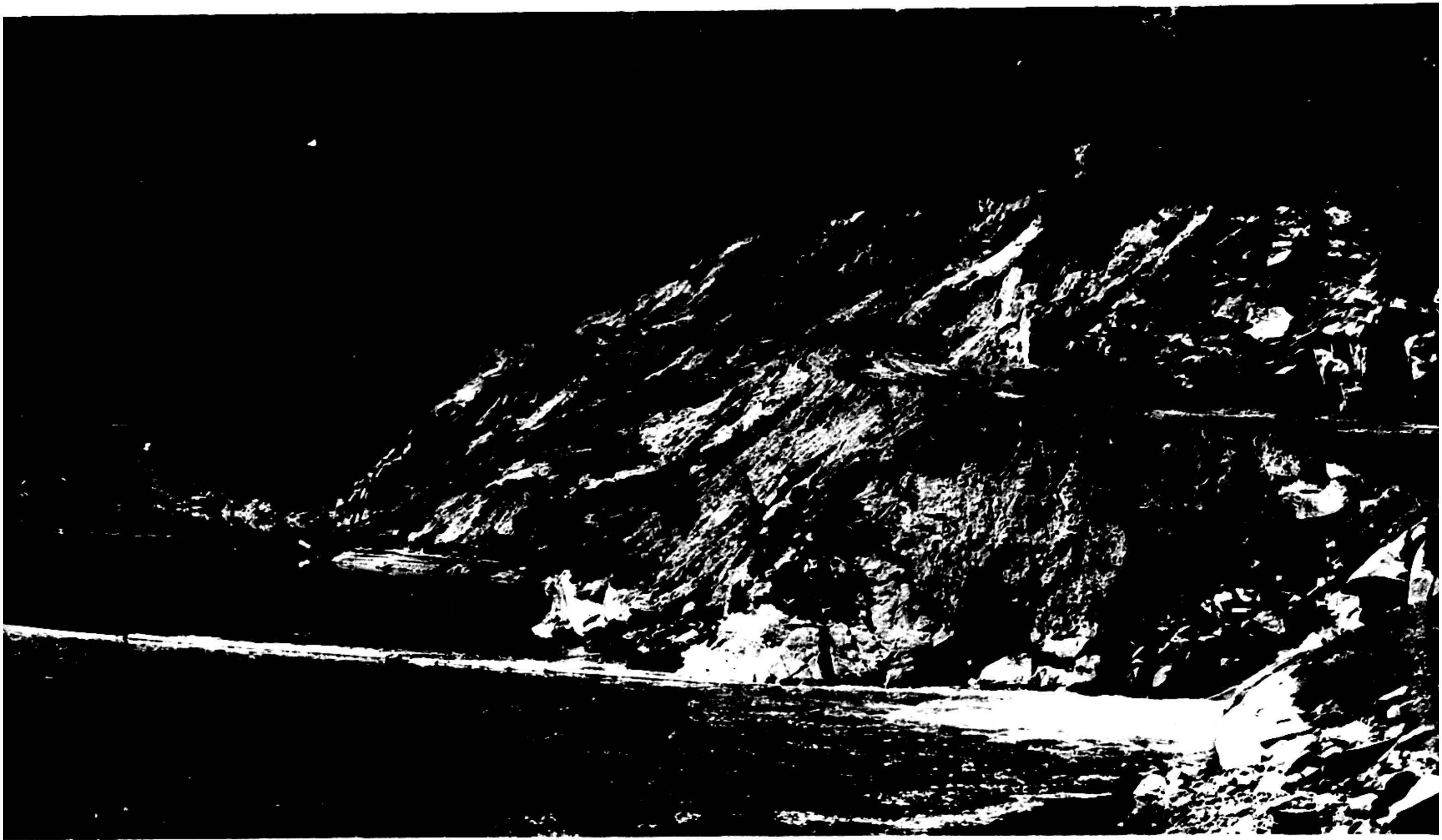
Plate 7

Photograph 218

PLATE 8

Ninemile Creek landslide on May 16, 1951 - Wilmont Creek quadrangle between Monument 25 and Monument 26

May 16, 1951 Photograph 296



Ninemile Creek Landslide on May 16, 1951 - Wilmont Creek Quadrangle
between Monument 25 and Monument 26

Plate 8

Photograph 296

PLATE 9

Landslide just south of Ninemile Bay which severed highway in the winter of 1952 - Wilmont Creek quadrangle between Monument 25 and Monument 26

May 10, 1953 Photograph 1341

Landslide just south of Ninemile Bay which severed highway in the winter of 1952 - Wilmont Creek Quadrangle between Monument 25 and Monument 26

Plate 9

Photograph 1341

Monument No. 27 to Monument 28, Lincoln quadrangle.-- The highway in this section follows along the edge of terrace deposits of silt and clay. The water table is very shallow. There are springs above the road. Some slides are developing between the road and the lake, and this section is threatened. There are a few small local bedrock points but they account for less than 20 percent of the road foundation. In one place a slide in the silt and clay has flowed around bedrock points. Detailed studies at the site would be required as a basis for either relocating or draining this section.

Summary

Landsliding has been a feature of the upper Columbia River Valley since glacial times. The acceleration of sliding in recent years, accompanying the filling of Lake Roosevelt and subsequent fluctuations in the reservoir level, has provided a unique opportunity for geologic study of landslides. The geologic materials involved in slides are the unconsolidated deposits of glacial origin that once filled the bedrock gorge of the Columbia River, and whose remnants constitute the easiest routes of travel and the apparently most desirable sites for development of the lake shore. Determination of safe areas, and areas of potential sliding is based on observation of the nature of the unconsolidated sediments, the local position of the water table, the position and shape of the buried bedrock surface, and the height and steepness of the present slope of the unconsolidated deposits, both the submerged portions and those above lake level.

This report describes landslide conditions along the highway which skirts the west shore of the reservoir in Ferry County between Kettle Falls bridge and a point opposite the mouth of the Spokane River. The Ferry County highway has been completely cut by landslides in four places. In the Reed Terrace and Falls Creek areas, temporary relocations have been provided. Landslide activity in the Ninemile area has posed such difficult and expensive relocation problems that the highway has been closed most of the time since July 1949. Of the 75.05 miles of highway in the area of this report, 13.26 miles are in danger of being partly or wholly destroyed by landslides or wave action, and 61.79 miles appear to be safe.

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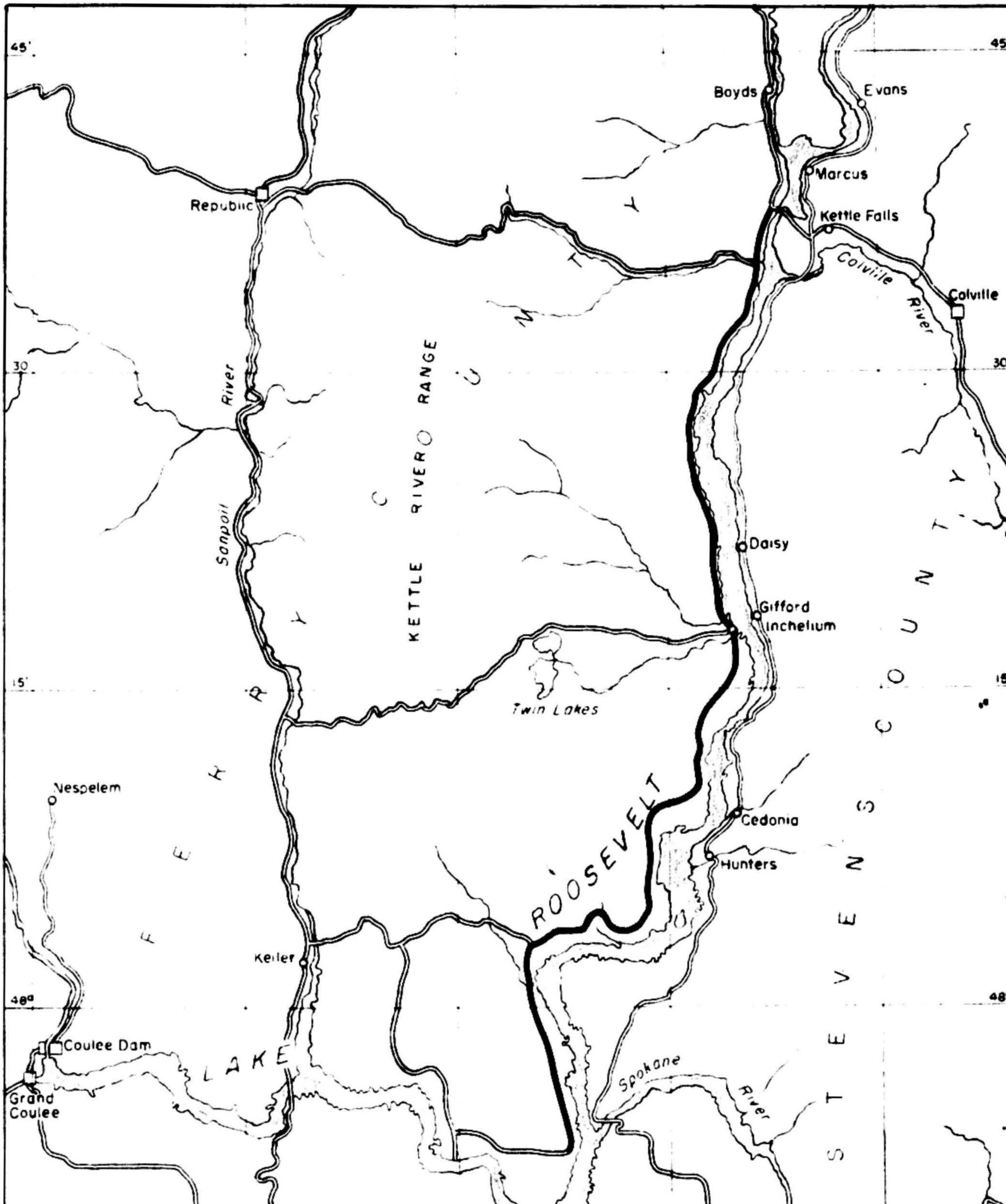

GENERAL LOCATION MAP

Ferry County Highway Paralleling Lake Roosevelt

0 5 10
Miles