IRENE

United States Department of Agriculture

Forest Service

Manti-LaSal N.F.

Reply to 2880 Geologic Services

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Subject 1984 Landslides and Damages

To William H. Boley, Forest Engineer

Major factors which include geology, topography, groundwater, and project activities contributed to the landslide activity and related damages which occurred on the Manti and San Pitch Divisions throughout the spring and early summer of 1984. Each factor considered separately was probably not sufficient to initiate a landslide, but various combinations of factors created unique conditions whereby landslides caused substantial damage to the Forest. These factors were also involved in the 1983 landsliding and should be a significant influence in future recurring problems.

Geology and Stratigraphy

There are twelve rock formations exposed on the Manti and San Pitch Divisions. The formations are composed singularly or in combinations of sandstone, limestone, shale, coal, and minor amounts of igneous rock. The thickness, grain size, cementation, compaction, and the amount of exposure of these rock types affect the formations' competency and susceptibility to failure (Table 1).

Geologic structure, which includes the dip of the formation, the fault systems, jointing, and the amount of exposure of the formation also influences the landslide activity. The Wasatch Plateau is located at the junction of the Overthrust Belt and Hinge Line regions. The general dip of the rock on the east side of the Wasatch Plateau is 1 to 5 degrees to the west. While on the west side of the plateau the rocks dip 2 to 7 degrees to the west due to steepening of the monocline. The dip of the rock is more variable in the San Pitch Division due to the greater amounts of deformation in the rock strata of the Gunnison Plateau. The dip allows the groundwater to flow toward the west.

The fault systems of the Manti and San Pitch Divisions trend north-south following the long dimensions of the plateaus. The fault zones are usually two to three miles wide with rocks in the zones dropped as grabens. Vertical displacement of the rock may be up to 2,500 feet. The Joe's Valley-Paradise Fault Zone runs along the west side of the Wasatch Plateau. The Musinia Fault Zone is located on the southeast side of the Manti Division and the Frontal Fault Zone runs along the west central to northwest area. The northern Wasatch Plateau also has two northwest-southeast trending fault systems which intersect the main north-south systems. The Sevier-Sanpete Valley Fault Zone is located along the east side of the San Pitch Division. Groundwater follows along these fault planes.

Jointing and formation permeability also influence the flow of groundwater. Jointing allows the surface moisture to infiltrate the fractures in the rock and flow into permeable beds. Groundwater exits as springs at formation contacts when the flowing water encounters a less permeable or impermeable formation and forces the water to surface.

Topography

Topographic features, such as degree of slope, slope aspect, and presence of paleo-slides contribute to the amount of landslide activity. Most of the landslides observed began on steep slopes and moved downslope until a more stable position was attained on a lower, less inclined surface. Many slope failures were on north/north-westerly facing slope aspects, which had higher moisture contents due to spring seepage and less direct sunlight. The locations of streams and drainages are also important to slide activity. Removal of the slope support base by stream undercutting may initiate the formation of a landslide. The presence of ancient landslides in an area indicates previous instability and may contribute in the development of recent movements.

Groundwater

The seasonal change in the amount of groundwater in the pores of the soil and underlying unconsolidated material affect slope instability. As groundwater moves downslope, it produces a seepage force which is a driving force that tends to drag soil particles downslope. The uplift force is increased as the amount of groundwater saturation is increased. The buoyancy of each soil particle increases as it is submerged, which decreases the resistance of the soil to sliding and fluid motion. The unusually high amounts of precipitation received during 1983 and 1984 has increased the groundwater levels, along with spring seepage, runoff and percolation, which has increased saturation and slope failure.

Hydraulic bursts have been witnessed to initiate a number of debris flows on the Manti Division (debris flows are discussed under types of landslides). Unusually high amounts of annual precipitation have resulted in high pressure buildups of groundwater in perched aquifers. When flowing groundwater encounters a less permeable or impermeable rock layer, the water usually escapes downslope by spring seepage. However, with the increased recharge rates, the groundwater is unable to escape and violently bursts water and unconsolidated earth material out onto the slope initiating a debris flow. Serious safety hazards are present downslope from hydraulic bursts due to the instantaneous occurrence of the failure and rapid downslope movement of the resulting debris flow.

Project Activities

The presence of project activities such as roads, pipelines, and other projects have influenced landslide activity in some cases. When the projects have crossed potentially unstable slopes as a result of other factors, the amount of landsliding increased due to cuts removing slope support. Less than five percent of the slides on the Forest were due to project activities. In many cases the projects were stable for many years before movement occurred. Alternative locations for these projects in most cases do not exist.

Types of Landslides

Debris flows, earth slumps, and translational slide-earth flows are the types of landsliding that occur on the Forest. Debris flows are generally small (less than two acres), shallow, and move downslope in a fluid motion. The entire slide is usually much longer than it is wide and originates on very steep slopes. These flows mobilize soil, unconsolidated rock, and forest material and deposits the debris on lower, less steep slopes or drainage bottoms. A single debris flow is usually a fairly rapid movement, taking anywhere from minutes to days before motion stops. Debris flows make up approximately 90 percent of the landslides found on the Forest and cover about 55 percent of the acreage affected by sliding. They occur in all the formations exposed on the Manti and San Pitch Divisions, but the majority of the debris flows are found in the North Horn and Indianola formations (Table 2).

Earth slumps are generally 1 to 20 acres in area, deep, and move along a concave surface of rupture. At the head of these rotational slides, the movement is mostly downward; however, the main body commonly tilts backwards, but in some cases, tilts forward. Earth slumps are sometimes associated with streambank failure that oversteepen the toe of the slope. These slides tend to be complicated with other types of slide motions, such as earth flows at the toes. Slump movement is slower, usually taking days to months before motion stops. Some larger slumps may continue to move over a period of years. Earth slumps make up nearly 9 percent of the landslides on the Forest and cover over 17 percent of the acreage affected by slope failure. They occur in 7 of the 12 formations represented on the Manti and San Pitch Divisions. The North Horn, Indianola, and Blackhawk formations contain most of the earth slumps (Table 2).

Translational slide-earth flows are large in area (up to 600 acres), deep, and move downslope in a planar fashion onto the ground surface. The main body of these slides are generally highly deformed. These translational slides usually progress indefinitely over a period of years if the surface on which it rests is sufficiently inclined. These slides are the least common in occurrence on the Forest (less than 1 percent), but cover nearly 28 percent of the total acreage involved in landsliding. These translational slide-earth flows are only found in the North Horn Formation (Table 2).

Field monitoring of landslide movement was done during the spring and early summer of 1984. The slides were monitored by using stake stations to indicate slide displacement. Six landslides were monitored; two in Ephraim Canyon, two in Manti Canyon, one in Twelve Mile Canyon, and one in Six Mile Canyon. The measurements recorded on these slides are reported in Appendix 1.

Three of the six landslides that were monitored were classified as earth slumps, with some earth flow occurring at the toes. These types of slides can be readily measured for movement, since they progress downslope for a long period of time. This also holds true for the Twelve Mile Canyon Twin Lake Slide, which is a translational slide-earth flow. However, the movements on debris flows are more difficult to measure since a major portion of the activity occurs in a very short period of time, usually before stake stations can be placed. The Manti Canyon Slide I and the Six Mile Canyon Slide I are debris flows.

Recurring Problems

The large translational slide-earth flows and less commonly the earth slumps tend to continue to move over a period of years until a stable center of gravity is attained. Many landslides that terminate in active stream channels may move again if the toe of the slides are washed away and the remaining material moves downslope to a more stable position. This may also occur with project activities removing slope support. New landsliding and reactivation of old slides will occur again next spring if the annual precipitation is again higher than average as in 1983 and 1984.

Comparison to 1983 Damages

The 1984 mass movement totals (Table 3) are significantly higher than the 1983 totals. The summary of damages from the 1983 Forest Flood Damage Assessment Report are in Table 4. The number of slide areas increased from 124 in 1983 to 1,012 in 1984; while the acres affected by sliding increased from 2,766 in 1983 to 4,459 in 1984.

There are a few biases which affected these totals. The 1983 count of the number of slides was done in areas in some cases. If a number of small debris flows were located in close proximity, it was counted as one slide area. In the 1984 report, each slide was counted separately, so many of the clustered 1,012 slides counted in the 1984 survey were represented as a single area in the 1983 survey. The total acres involved in the landsliding were assessed in the same manner in both surveys, however, the area covered in the survey in 1984 was greater, so more slide acreage was located and recorded in 1984 than in the 1983 assessments. There was only an estimated 41 percent more new landslides in 1984 than 1983, while about 32 percent of the older slides were reactivated in 1984 on the Forest.

Summary and Recommendations

The landsliding potential of the contributing factors of geology, topography, groundwater, and project activities remains constant. However, large-scale new landsliding and reactivation of old slides as evidenced in 1983 and 1984 was brought on by the unusually high annual precipitations for these years. Movement should be expected again in 1985. The landsliding potential exists on the Forest and mass movements will occur again if the precipitation remains high through the winter. Areas that are expected to be affected are illustrated in the Forest Instability Maps (Maps 1 and 2).

If the landsliding does occur again in 1985 and it becomes necessary to conduct another Forest Flood Damage Assessment or other landslide inventory work, I recommend that the procedures followed in the 1984 assessment be used again. This recommendation is made so that future data could be compared to the present data on an equal basis.

/s/ Irene Savanyo-Lemley

IRENE SAVANYO-LEMLEY
Geologist

Enclosure

cc: D-1
D-2
D-3
I. Savanyo-Lemley

Table 1 ROCK FORMATION LANDSLIDE INVENTORY(1)

Forest Rock Formations	Number of Slides(2)	Percent of Total Number of Slides	Acres of Slides	Percent of Total Acres of Slides
Volcanics (Tiap)	6	0.6	27	0.6
Green River (Tgu)	26	2.6	101	2.3
Colton (Tc)	2	0.2	5	0.1
Flagstaff Limestone (Tf)	32	3.2	206	4.5
North Horn (Tknh)	575	56.8	2950	66.2
Price River (Kp)	80	7.9	166	3.7
Castlegate Sandstone (Kc)	7	0.7	28	0.6
Blackhawk (Kb)	58	5.7	141	3.2
Star Point Sandstone (Ks)	9	0.9	30	0.7
Mancos Shale (Km)	5	0.5	16	0.4
Indianola (Ki)	177	17.5	632	14.2
Arapian Shale (Ja)	35	3.4	157	3.5
Total of Forest	1012	100%	4459	100%

(1) Data for slide count and acreage taken from the 1983 and 1984 Forest Helicopter Reconnaissance Survey for the Forest Flood Damage Assessment.

(2) Total number of slides involved in movements- including pre-1983, 1983 and 1984.

Table 2 INVENTORY OF TYPES OF LANDSLIDES(1)

Forest Rock Formations	Number of Debris Flows	Acres of Debris Flows	Number of Earth Slumps	Acres of Earth Slumps	Number of Translational Slide - Earth Flows	Acres of Translational Slide - Earth Flows
Volcanics (Tiap)	6	27	-	0	-	0
Green River (Tgu)	22	66	4	35	-	0
Colton (Tc)	2	5	-	0	-	0
Flagstaff Limestone (Tf)	25	75	7	131	-	0
North Horn (Tknh)	528	1,315	39	395	8	1,240
Price River (Kp)	75	135	5	31	-	0
Castlegate Sandstone (Kc)	7	28	-	0	-	0
Blackhawk (Kb)	47	92	11	49	-	0
Star Point Sandstone (Ks)	9	30	-	0	-	0
Mancos Shale (Km)	4	13	1	3	-	0
Indianola (Ki)	160	536	17	96	-	0
Arapien Shale (Ja)	31	135	4	22	-	0
Total of Forest	916	2457	88	762	8	1240
Percent of Total Number of Slides	90.5%	—	8.7%	—	0.8%	—
Percent of Total Acres of Slides	—	55.1%	—	17.1%	—	27.8%

(1) Data for slide count taken from the 1983 and 1984 Forest helicopter reconnaissance survey for the Forest Flood Damage Assessment and 1984 Fieldwork.

Table 3 1984 SUMMARY OF LANDSLIDES BY COUNTY(1)

County	Number of Slide Areas	Acres of Slides
Carbon	29	107
Emery	70	139
Juab	217	846
Sanpete	564	3073
Sevier	–	–
Utah	132	294
Forest Total	1012	4459

1984 SUMMARY OF LANDSLIDES BY DISTRICT(1)

District	Number of Slide Areas	Acres of Slides
D-1 Sanpete	642	2895
D-2 Ferron	197	1151
D-3 Price	173	413
Forest Total	1012	4459

(1) Data derived from Forest Flood Damage Assessment of 1984.

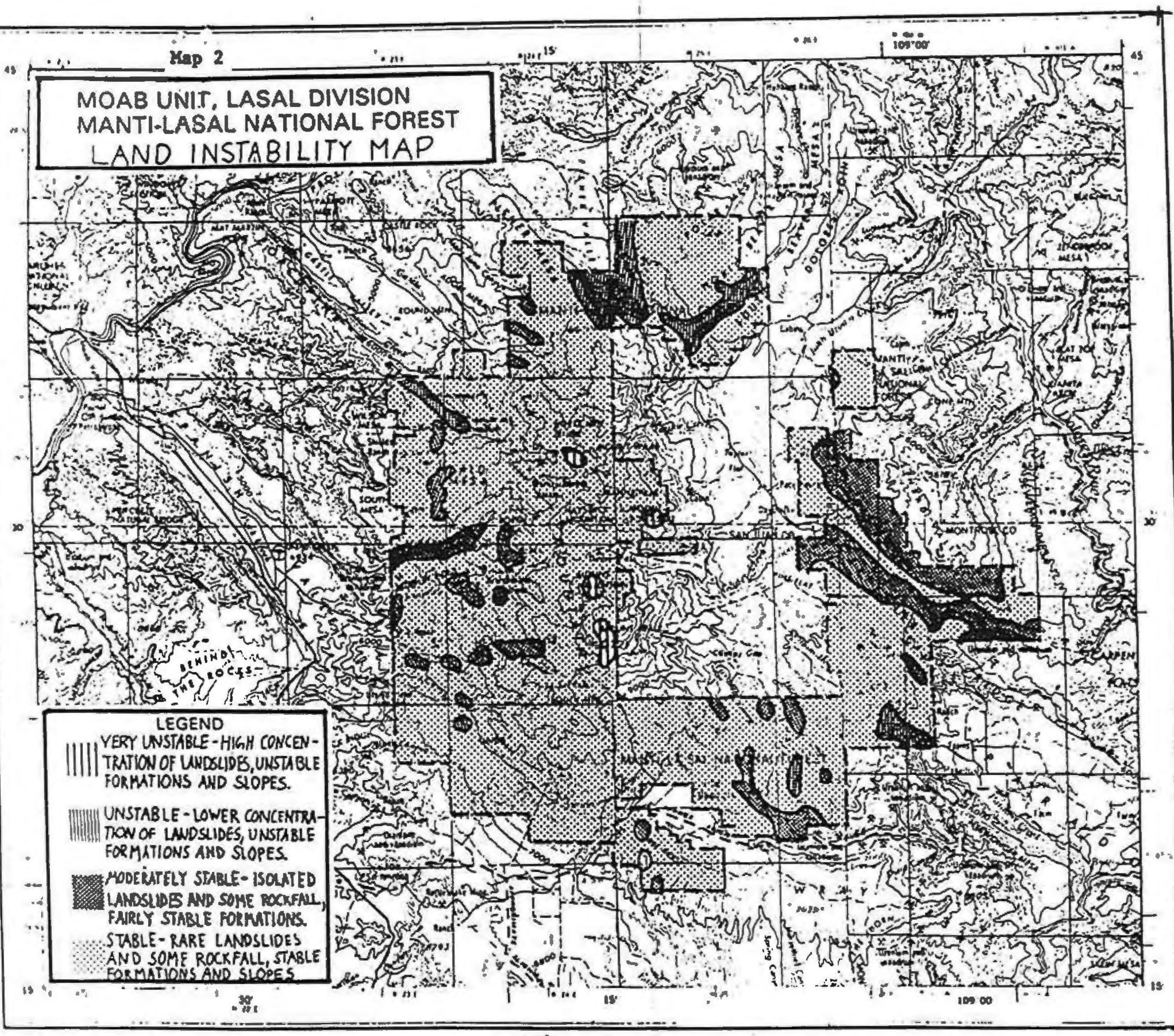
Table 4 1983 SUMMARY OF LANDSLIDES BY COUNTY (1)

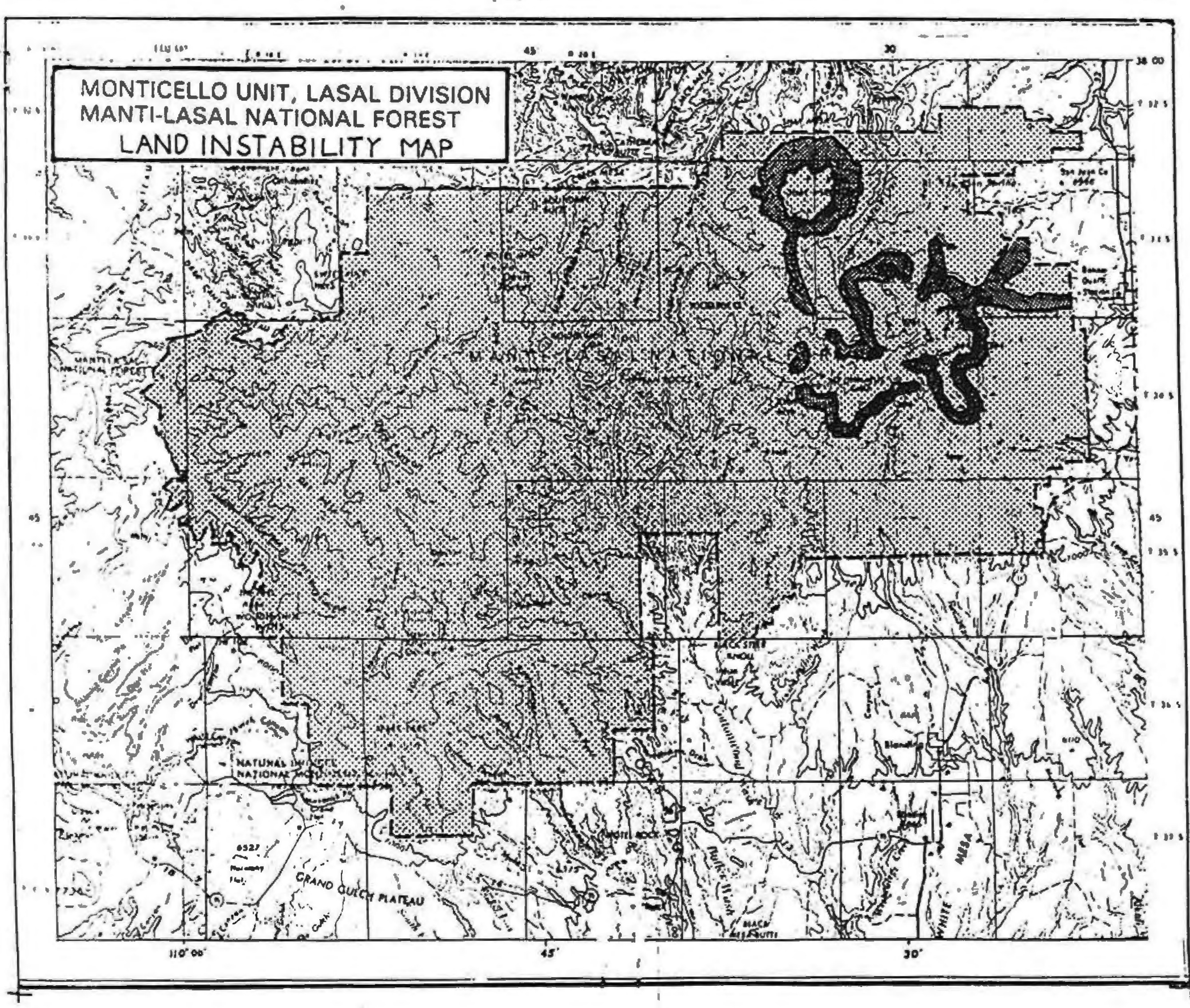
County	Number of Slide Areas	Acres of Slides
Carbon	0	0
Emery	18	142
Juab	19	142
Sanpete	70	2369
Utah	17	96
Forest Total	124	2766

1983 SUMMARY OF LANDSLIDES BY DISTRICT (1)

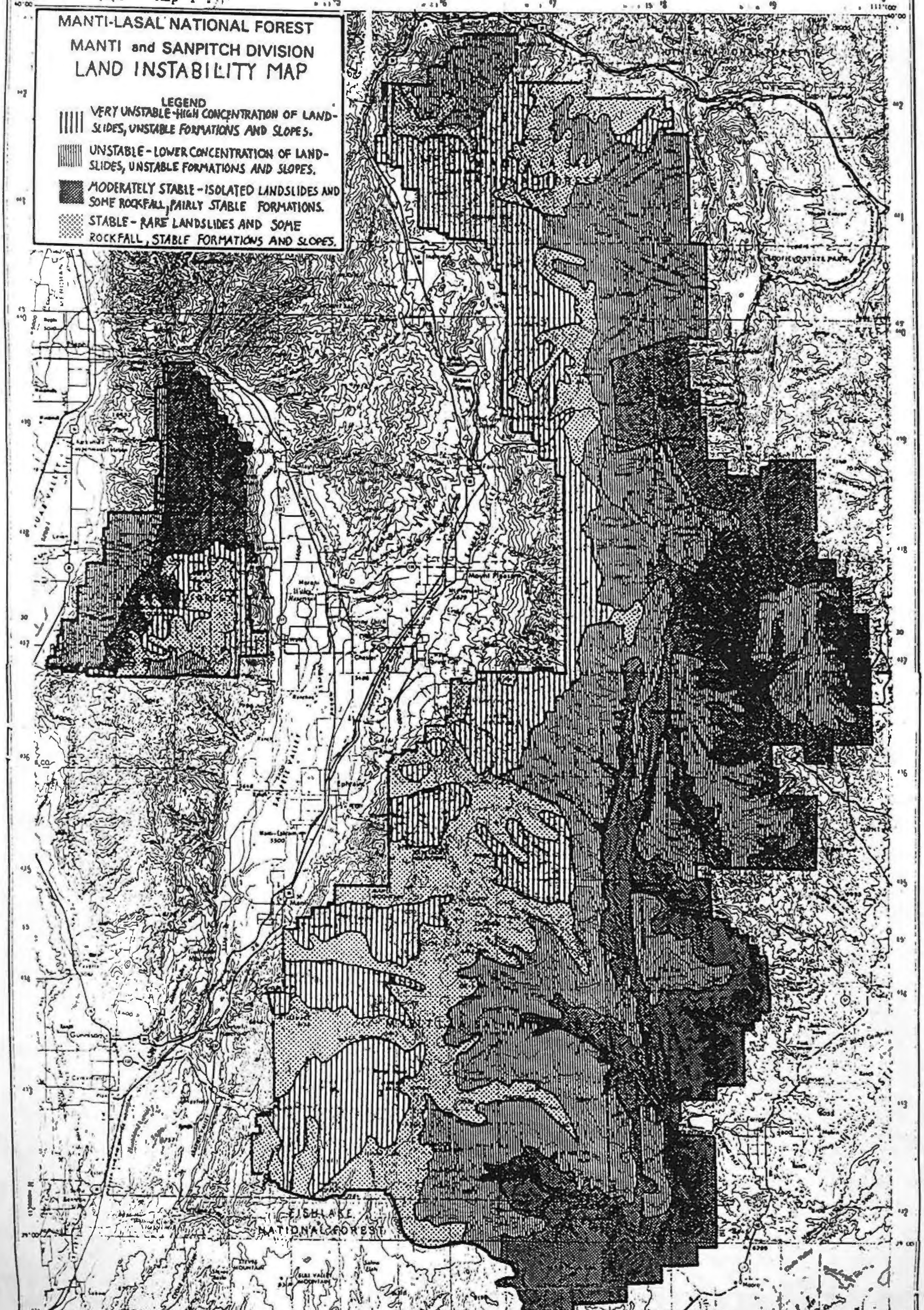
District	Number of Slide Areas	Acres of Slides
D-1 Sanpete	88	2068
D-2 Ferron	8	511
D-3 Price	28	187
Forest Total	124	2766

(1) Data derived from Forest Flood Damage Assessment of 1983


Map 2
MOAB UNIT, LASAL DIVISION
MANTI-LASAL NATIONAL FOREST
LAND INSTABILITY MAP
LEGEND
VERY UNSTABLE - HIGH CONCENTRATION OF LANDSLIDES, UNSTABLE FORMATIONS AND SLOPES.
UNSTABLE - LOWER CONCENTRATION OF LANDSLIDES, UNSTABLE FORMATIONS AND SLOPES.
MODERATELY STABLE - ISOLATED LANDSLIDES AND SOME ROCKFALL, FAIRLY STABLE FORMATIONS.
STABLE - RARE LANDSLIDES AND SOME ROCKFALL, STABLE FORMATIONS AND SLOPES
BEHIND THE ROCKS
109°00'

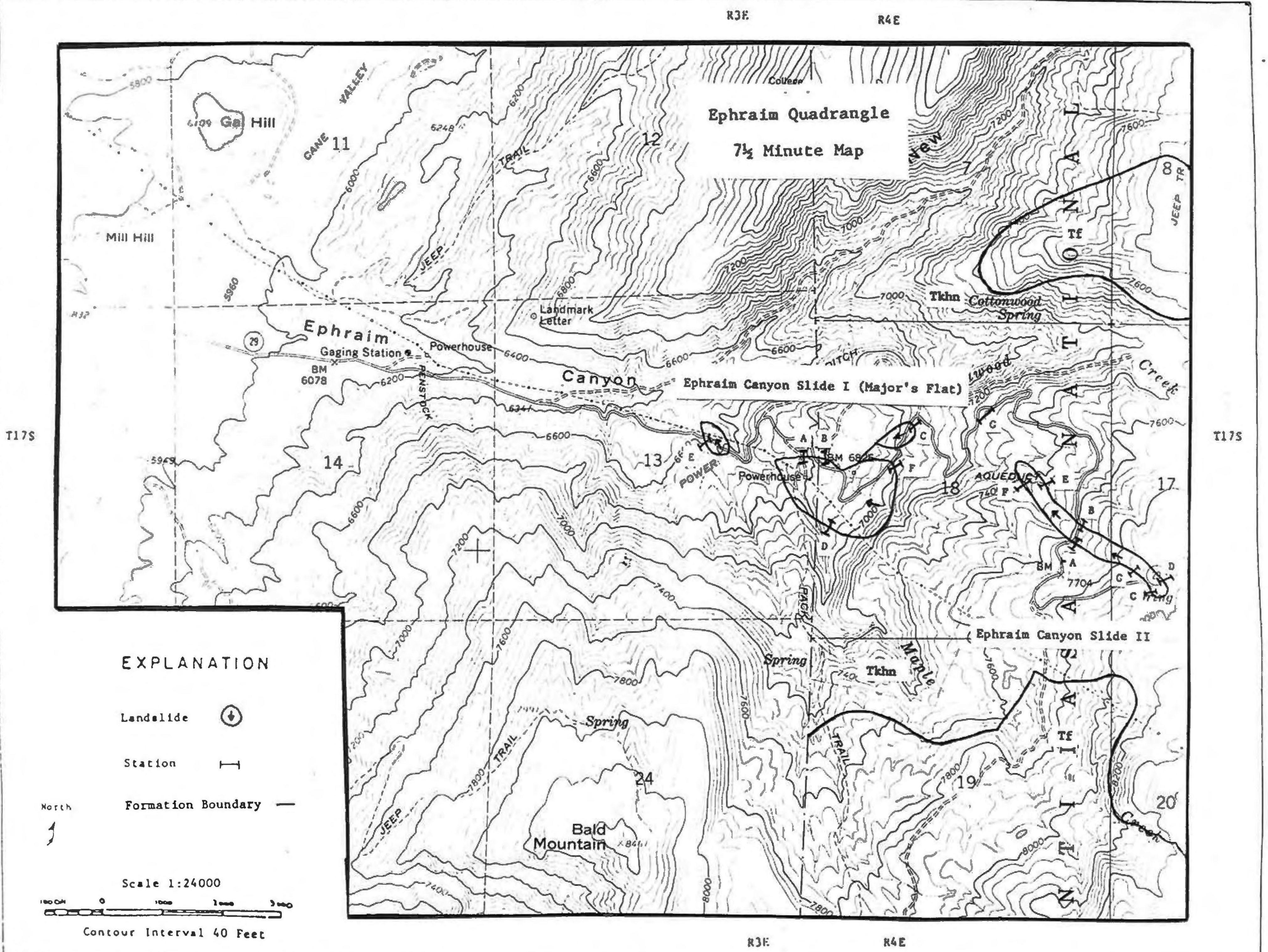

MONTICELLO UNIT, LASAL DIVISION
MANTI-LASAL NATIONAL FOREST
LAND INSTABILITY MAP
GRAND GULCH PLATEAU
110°00'
45'
30'

Map 1


MANTI-LASAL NATIONAL FOREST
MANTI and SANPITCH DIVISION
LAND INSTABILITY MAP
LEGEND
VERY UNSTABLE-HIGH CONCENTRATION OF LANDSLIDES, UNSTABLE FORMATIONS AND SLOPES.
UNSTABLE - LOWER CONCENTRATION OF LANDSLIDES, UNSTABLE FORMATIONS AND SLOPES.
MODERATELY STABLE - ISOLATED LANDSLIDES AND SOME ROCKFALL, FAIRLY STABLE FORMATIONS.
STABLE - RARE LANDSLIDES AND SOME ROCKFALL, STABLE FORMATIONS AND SLOPES.
FISHLAKE
NATIONAL FOREST

APPENDIX I

LANDSLIDE MOVEMENT SUMMARY



Ephraim Quadrangle
7½ Minute Map
R3E
R4E
T17S
Ephraim Canyon Slide I (Major's Flat)
Ephraim Canyon Slide II
Gal Hill
Mill Hill
Cane Valley
Ephraim
Canyon
Gaging Station
BM 6078
Powerhouse
Penstock
Landmark Letter
Power
Ditch
Aqueduct
Cottonwood Spring
Creek
Maple
Spring
Trail
Jeep
Jeep Tr
Bald Mountain
Tf
Tkhn
EXPLANATION
Landslide
Station
Formation Boundary
North
Scale 1:24000
Contour Interval 40 Feet

LANDSLIDE MOVEMENT SUMMARY

Name of Slide Area   Ephraim Canyon Slide I (Major's Flat)

Location   T17S R3E Section 13 SE¼
            T17S R4E Section 18 W½

Date	Total Station Displacement in Inches A	B	C	D	E	F	G	Comments
6/7/83 *		0		0				
6/11/83 *		1		3				
6/15/83 *		3		2				
6/20/83 *		4½		5½				
6/24/83 *		6		6				
7/14/83 *		6½		8				
7/19/83 *		7		8				
4/25/84 *		13½		-				
4/26/84 *		15½		-				
4/27/84 *		20		-				
4/29/84 *		22		-				
4/30/84 *		25		-				

* Taken from Roger Johnson's field notes.

LANDSLIDE MOVEMENT SUMMARY

Name of Slide Area   Ephraim Canyon Slide I (Major's Flat)

Location   T17S R3E Section 13 SE¼

T17S R4E Section 18 W½

Date	A	B	C	D	E	F	G	Comments
	Total Station Displacement in Inches							
5/2/84 *		50		23				Stakes placed
5/3/84 *		61		30				
5/4/84 *		72		48				
5/5/84 *		118		56				
5/6/84 *		150		82				
5/7/84 *		190		112				
5/8/84 *		198		121				
5/9/84 *		198		121				
5/10/84 *		201		123				
5/12/84 *		201		123				
5/13/84 *		201		123				
5/16/84 *		201		123				

* Taken from Roger Johnson's field notes.

LANDSLIDE MOVEMENT SUMMARY

Name of Slide Area Ephraim Canyon Slide I (Major's Flat)

Location T17S R3E Section 13 SE¼
T17S R4E Section 18 W½

Date	Total Station Displacement in Inches							Comments
	A	B	C	D	E	F	G	
5/17/84 *		202		125				
5/19/84 *		203		126				
5/20/84 *		203		126				
5/23/84 *		205		128				
5/15/84	0	188	0	114	0	0	0	Placed Stakes
5/22/84	0	192	7½	115	0	0	0	
5/24/84	0	196	7½	115	0	0	2½	
5/31/84	1½	196	7½	116	0	2	2½	
6/11/84	5½	197½	22	116	0	2	2½	
6/27/84	-	198	34	117	0	2	2½	Station A lost
7/16/84	-	198	34	117	0	2	2½	No movement

* Taken from Roger Johnson's field notes.

LANDSLIDE MOVEMENT SUMMARY

Name of Slide Area: Ephraim Canyon Slide II (Pig Pen)

Location: T17S R4E Section 18 SE¼ and Section 17 SW¼

Date	A	B	C	D	E	F	G	Comments
	Total Station Displacement in Inches							
6/7/83 *	0	0	0				-	Stakes placed
6/11/83 *	1	1	1				18	
6/15/83 *	1	2½	3½				18½	
6/20/83 *	1½	5½	4				20	
6/24/83 *	1	6½	3				22	
7/14/83 *	1	6	4				23	
7/19/83 *	0	6	4				23	
5/16/84 *	9½	16	-				44	
5/17/84 *	10	40	-				46½	
5/19/84 *	14	51	-				54	
5/20/84 *	15	57	-				58	
5/23/84 *	20	65	-				64	

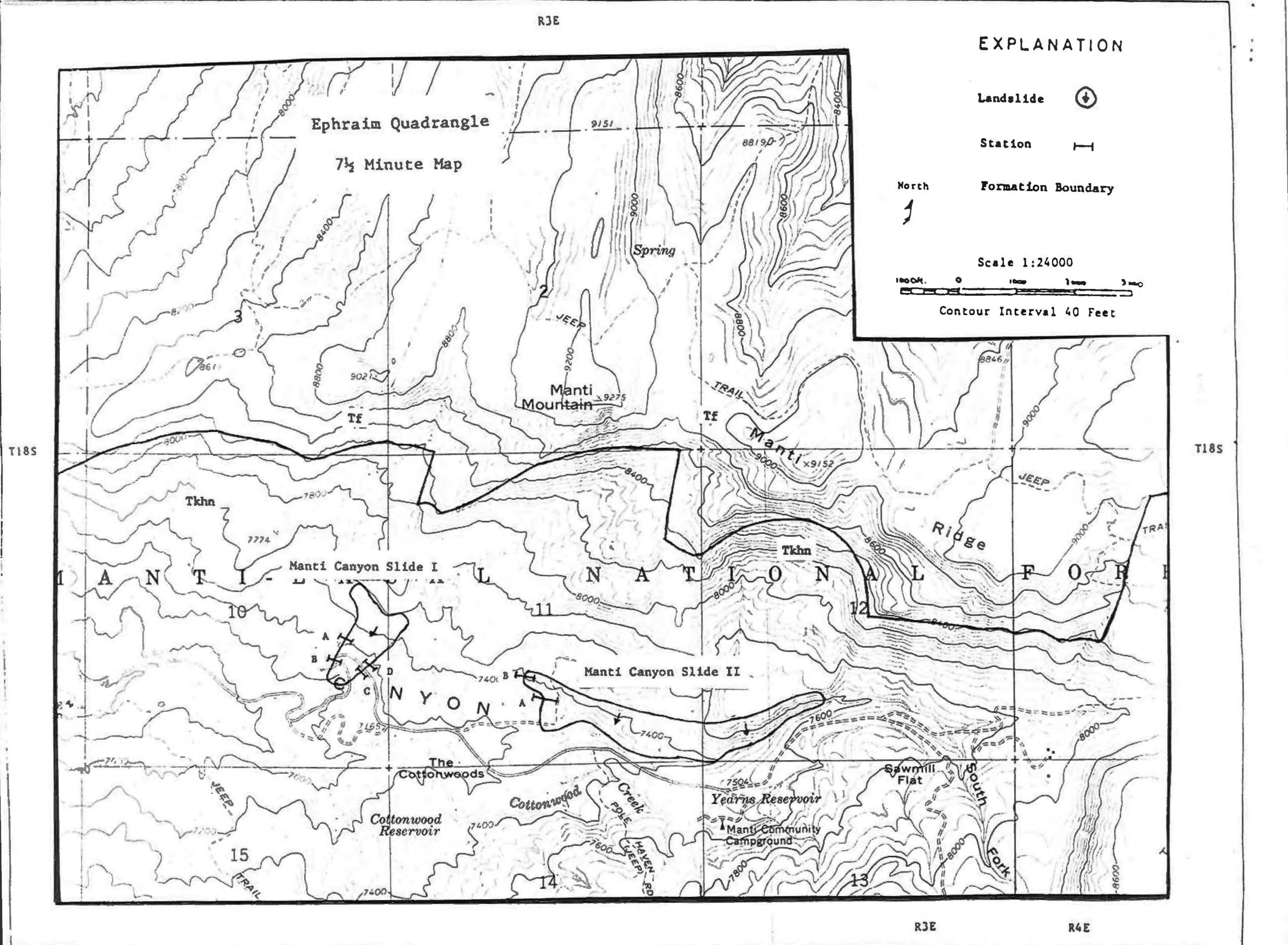
* Taken from Roger Johnson's field notes.

LANDSLIDE MOVEMENT SUMMARY

Name of Slide Area Ephraim Canyon Slide II (Pig Pen)

Location T175 R4E Section 18 SE½ and Section 17 SW¼

Date	Total Station Displacement in Inches							Comments
	A	B	C	D	E	F	G	
5/22/84	0	0	0	0	-	-	—	Stakes placed
5/24/84	4	4	36½	1	-	-	78	
5/31/84	12	21½	192	6	0	0	189	
6/11/84	35½	64	200	14	1½	2	104	
6/12/84	35½	64	200½	14	1½	2	104	
6/20/84	49	71	202	14	1½	2	113	
6/27/84	51	95	213	18	1½	2	114	
7/16/84	53	95	213	18	-	-	119	Stations E and F lost
7/25/84	53	95	213	18	-	-	119	No movement
8/16/84	53	95	213	18	-	-	119	


R3E
EXPLANATION
Landslide
Station
North
Formation Boundary
Scale 1:24000
Contour Interval 40 Feet
Ephraim Quadrangle
7½ Minute Map
Spring
Manti Mountain
Tf
Tkhn
Manti
Ridge
JEEP
TRAIL
T18S
Manti Canyon Slide I
Manti Canyon Slide II
MANTI-LA SAL NATIONAL FOREST
CANYON
10
11
12
2
3
13
14
15
The Cottonwoods
Cottonwood
Creek
Cottonwood Reservoir
Yearns Reservoir
Manti Community Campground
Sawmill Flat
South Fork
POLE HAVEN (JEEP) RD
R3E
R4E

LANDSLIDE MOVEMENT SUMMARY

Name of Slide Area Manti Canyon Slide I

Location T18S R3E Section 10 SE¼

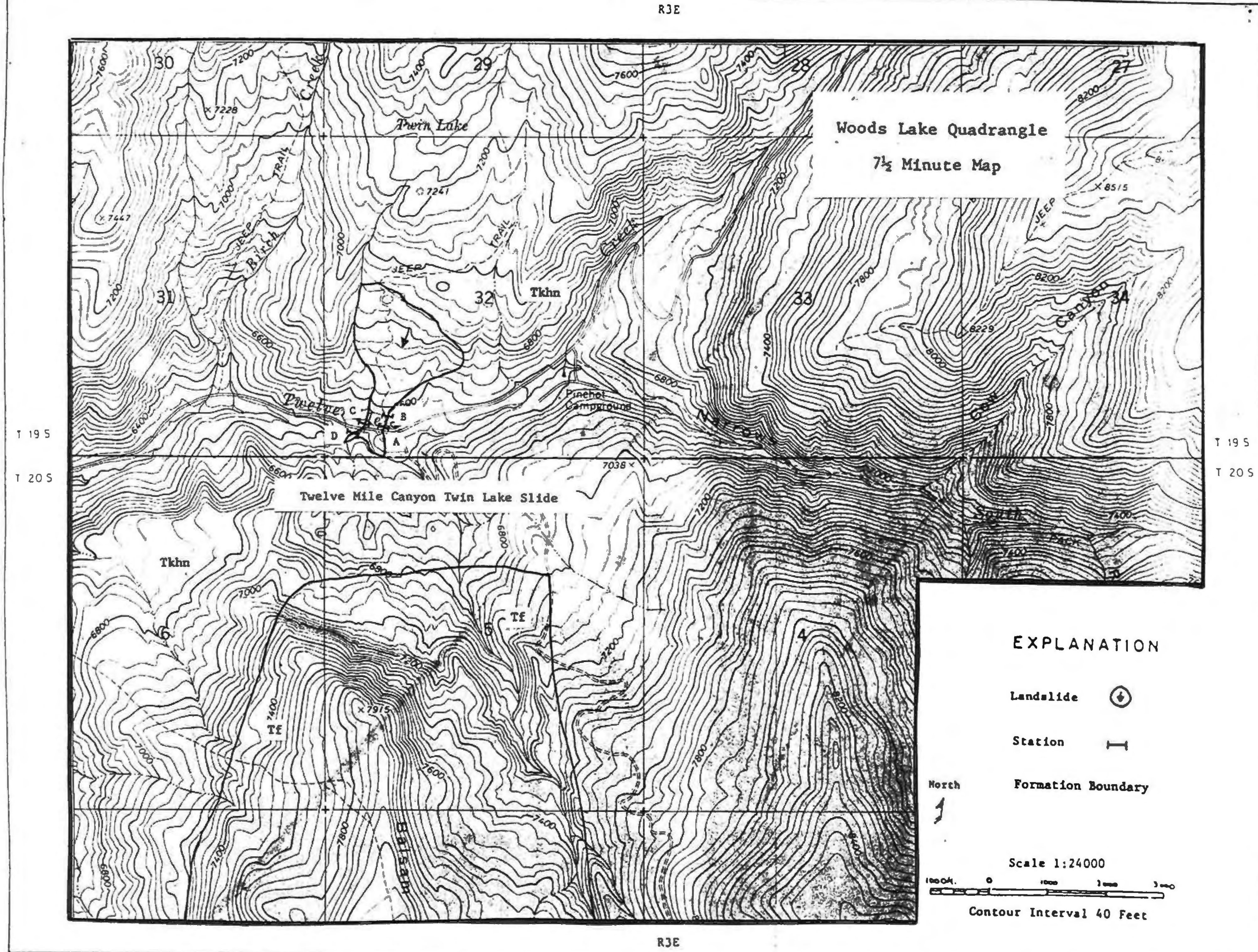
Date	Total Station Displacement in Inches				Comments
	A	B	C	D	
5/16/84	0	0	0	0	Placed Stakes
5/23/84	180	50	0	0	
5/31/84	180	50	3½	5	
6/11/84	-	50	7½	12	Station A lost
6/21/84	-	50	7½	12	No movement
6/27/84	-	50	7½	12	
7/16/84	-	50	7½	12	

LANDSLIDE MOVEMENT SUMMARY

Name of Slide Area Manti Canyon Slide II

Location T18S R3E Section 11 S½ and Sections 12 SW¼

Date	Total Station Displacement in Inches A	B	Comments
5/17/84	0	0	Placed Stakes
5/23/84	0	0	
5/31/84	0	0	
6/11/84	0	4	
6/21/84	0	4	No Movement
6/27/84	0	4	

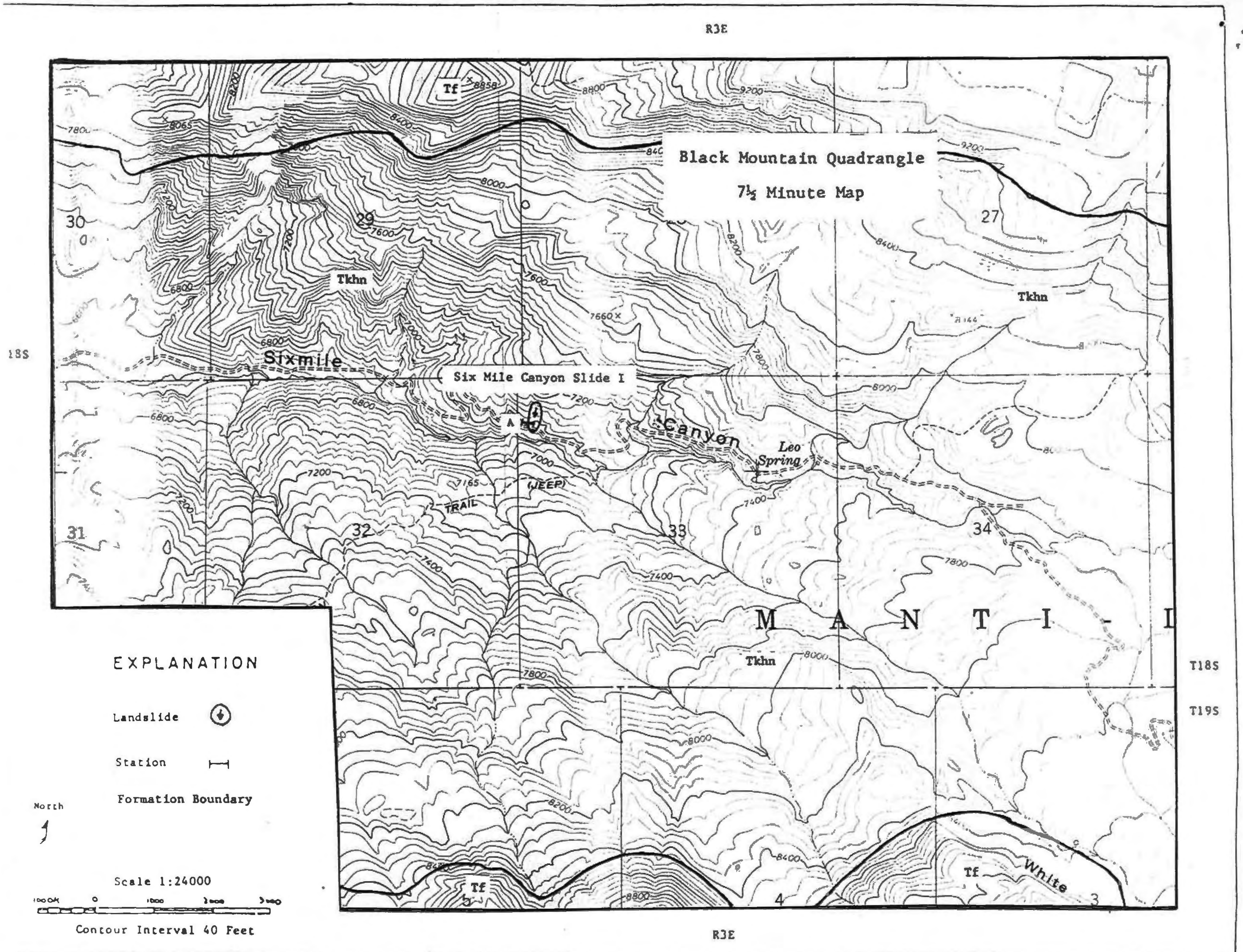

R3E
Woods Lake Quadrangle
7½ Minute Map
Twelve Mile Canyon Twin Lake Slide
Twin Lake
Birch
Creek
Twelve
Pinchot Campground
Narrows
Cow
Canyon
South
Fork
Balsam
Tkhn
Tf
T 19 S
T 20 S
EXPLANATION
Landslide
Station
Formation Boundary
North
Scale 1:24000
Contour Interval 40 Feet

LANDSLIDE MOVEMENT SUMMARY

Name of Slide Area 12 Mile Canyon Twin Lake Slide

Location T19S R3E Section 32 E½

Date	Total Station Displacement in Inches				Comments
	A	B	C	D	
5/24/84	0	0	0	0	Placed Stakes
6/11/84	10	5	17	13	
6/21/84	30	24	41	36	
7/17/84	46	42	76	63	
7/26/84	46	42	76	63	No Movement



R3E
Black Mountain Quadrangle
7½ Minute Map
Six Mile Canyon Slide I
Sixmile
Canyon
Leo Spring
Tf
Tkhn
TRAIL
(JEEP)
M A N T I - L
18S
T18S
T19S
White
EXPLANATION
Landslide
Station
Formation Boundary
North
Scale 1:24000
Contour Interval 40 Feet
R3E