United States
Department of
Agriculture

Forest Service

**Intermountain
Forest and Range
Experiment Station**

Research Note
INT-305

April 1981

Soil Disturbance Caused by Clearcutting and Helicopter Yarding in the Idaho Batholith

James L. Clayton[1]

ABSTRACT

Disturbance to soil from helicopter logging and broadcast burning of slash from a large commercial clearcut in the Idaho batholith was evaluated. Two hundred permanent 10.8 ft^2 (1 m^2) plots were evaluated prior to and for a 2-year period following logging and burning. Measurements included: changes in ground cover, soil horizon mixing, soil erosion, litter layer changes, and slash cover changes. Accelerated erosion was found on 2 percent of the area, and volume estimates indicate a short-term increase of approximately 10 times natural rates. Broadcast burning resulted in litter losses on 14 percent of the treated area. Eroded areas appear to be healing, and these short-term changes in soil conditions are small compared to soil disturbance from other logging systems.

KEYWORDS: soil disturbance, erosion, helicopter logging, Idaho batholith

Coarse-textured granitic soils of the Idaho batholith cause continual concern to land managers because of their high potential for accelerated erosion following disturbance. This is, in part, a result of soil properties, such as low cohesion and poor aggregate stability, and of high climatic stresses associated with frequent high intensity summer rainstorms (Kidd 1964), rapid spring snowmelt, and rain-on-snow events. Following logging and road construction, erosion rates over 750 times normal rates have been reported (Megahan and Kidd 1972).

Damage to the on-site soil and watershed resources coupled with deterioration of downstream values by sediment has had a major impact on land management policy in the Idaho batholith. For example, the 1,300-mi^2 (3 370 km^2) South Fork of the Salmon River watershed was closed to logging and road construction for 11 years from 1966 to 1977 as a result of tremendous inflows of sediment during the 1960's.

During the last two decades, we have seen increasing use of advanced logging systems such as skyline, balloon, and helicopter yarding. These systems require less road construction and generally are less disruptive to soils because they minimize ground surface disturbance from skidding.

Scientists at the Intermountain Forest and Range Experiment Station's research laboratory in Boise began several watershed level studies in the mid-1960's to evaluate the impacts of various logging systems, with emphasis on comparative erosion and sediment production rates. These studies are located in the Silver Creek Study Area, about 75 mi (120 km) north of Boise. This paper reports results of studies of soil disturbance associated with the first logging in the area, clearcutting, and helicopter yarding. Future studies will include group selection and single tree selection harvests, and tractor-jammer skidding and skyline yarding systems.

STUDY DESIGN AND FIELD METHODS

Treatment

The logging treatment evaluated in this study was a 10-inch (25-cm) diameter limit cut, which essentially resulted in a clearcut because the stand was composed primarily of overmature ponderosa pine and Douglas-fir. Three small pockets of young ponderosa pine remained after logging. Total area of the cutting unit was 45 acres (18 hectares) and the volume removed was 12.3 M bd.ft./acre. All logs were yarded by helicopter. Slash was lopped and scattered, and then broadcast burned. Although conditions were fairly dry during the burn, discontinuties in slash cover over the unit resulted in a somewhat incomplete burn. Slash cover following this treatment will be discussed below.

---

[1]Research soil scientist located at the Intermountain Station's Forestry Sciences Laboratory, Boise, Idaho.

Slope steepness ranged from 30 to 50 percent on the cutting unit. Soils on the cutting unit are coarse textured and weakly developed. Two families of soils make up most of the unit: Sandy-Skeletal, Mixed Typic Cryorthents and Sandy-Skeletal, Mixed Typic Xerorthents. The soils are very similar; however, the Xerorthents are drier and warmer than the Cryorthents. These soils have one or more A horizons, typically with a total thickness ranging from 4 to 10 inches (10 to 25 cm), overlying C horizons. Bedrock contacts are generally shallower than 40 inches (10 cm). The texture of both A and C horizons is commonly gravelly loamy coarse sand or gravelly coarse sandy loam. Small inclusions of shallower soils are also found on the unit.

Two habitat types are found on the unit, both in the Douglas-fir series. Most of the unit is in the Douglas-fir/ninebark habitat type, but Douglas-fir/white spirea is also present. Douglas-fir and ponderosa pine were the major trees harvested.

Evaluation

I evaluated soil disturbance on 200 permanent 10.8 ft^2 (1 m^2) plots located at 32.8-ft (10-m) intervals along 10 transects. The transects ran in an east-west direction along the south-facing slopes. Because of the highly dissected nature of the slopes, the transects were only roughly on contour. The transects were spaced evenly through the central portion of the cutting unit.

Soil and cover conditions were evaluated immediately prior to the treatment, and three times over a 2-year period following treatment. Treatment and evaluation dates are shown in the following tabulation:

Date	Event
9/15/76	Pretreatment survey of soil conditions
9/20/76	Logging commences
11/18/76	Logging completed
2/7/77	Slash burned
5/20/77	First posttreatment survey
6/8/77	High intensity rain storm hits area
10/4/77	Second posttreatment survey
8/2/78	Third posttreatment survey

At each permanent transect point the following data were collected:

1. Areal coverage of slash (posttreatment surveys only);
2. Areal coverage of litter (01 and 02 horizons), litter depth;
3. Live ground cover percent, canopy coverage within 1 foot of soil surface;
4. Soil horizon mixing (0 and A, and/or A and subsoil horizons), areal coverage and depth;
5. Erosion, areal coverage and depth;
6. Type and cause of erosion, if ascertainable.

From these data we were able to evaluate slash added to the site after logging, loss of litter protection after logging and burning, live ground cover changes, and soil disturbance (either erosion or mixing) by cause.

Areal coverage was estimated by using a 10.8 ft^2 (1 m^2) frame that was subdivided into 25 equal sized squares, each 0.43 ft^2 (0.04 m^2). The frame was placed over corner stakes marking each permanent plot. Coverage, such as slash, litter, and erosion scars, was visually estimated by direct viewing from above. Each of the 25 smaller squares was viewed individually, and coverage summed to provide a final coverage figure for the plot. I tested the ability of different individuals to replicate litter coverage estimates using this technique. Maximum variance was 2 percent for coverage estimates ranging from 38 to 99 percent on 10 individual plots. Estimates of soil disturbance, live vegetation cover, or slash were not similarly tested. Replication might be expected to be poorer for live vegetation and slash because of the greater vertical zonation.

RESULTS AND DISCUSSION

Ground Cover

The protection afforded soil by ground cover and its influence on erosion have been conclusively demonstrated. Packer (1963) pointed out that surface erosion on elk winter range in Wyoming increased markedly when ground cover density dropped below 70 percent. Meeuwig (1970a,b) also emphasized the importance of ground cover in reducing erosion on Intermountain rangeland sites. He stated that the magnitude of erosion from raindrop impact depended primarily upon surface protection imparted by plants, litter, and surface stone. In the Idaho batholith, Megahan and Kidd (1972) studied surface erosion on disturbed areas and again emphasized that treatments to restore disturbed areas should ensure protection of the soil surface until vegetation is reestablished. Mersereau and Dyrness (1972) showed that surface erosion by dry ravel increases on slopes unprotected by organic debris, and that plant cover is essential to restore stability. The Mersereau and Dyrness (1972) study in western Oregon was made on a conventional clearcut with burned slash, a treatment similar to that used on the study area in this report.

Ground cover protects the soil in a combination of ways, including energy dissipation of rainfall, wind, and, in some cases, overland flow of water. Surface litter also promotes infiltration by detaining large volumes of water that would otherwise result in overland flow.

We measured changes in ground cover protection from slash, litter, and live vegetation before and after logging.

SLASH

The prescription for slash disposal was lop and scatter followed by broadcast burning. The burn was somewhat incomplete and resulted in a fair cover over the soil surface of unburned slash and partially burned logs and limbs. Prior to logging, any limbs or logs lying on the ground were considered part of the litter layer; so the prelogging survey recorded no slash cover.

At the time of the first postlogging survey, areal coverage of slash was 22 percent, and depths ranged from 0.25 inch to 40 inches (0.6 to 100 cm); average depth was 4 inches (10 cm) over the area with slash present. Fourteen percent of the total slash measured (areal coverage) was in needles fastened to branches.

Slash cover decreased to 15 percent when the second postlogging survey was made in October 1977, a year after logging. Four percent of the total slash coverage was needles connected to branches. The decrease in total slash cover was in part attributable to needlefall, but much of the loss may have been due to small twigs and branches breaking off of limbs and no longer recognized as slash. This, however, was not picked up as an increase in the percent litter coverage on the plots.

A high intensity summer rainstorm hit the area between the first and second postlogging surveys. A recording raingage located approximately 1,000 feet (300 m) from the nearest plots indicated a rainfall intensity of 3 inches/h (76 mm/h) with a duration of 2 minutes followed immediately by 0.3 inch/h (8 mm/h) storm lasting 9 minutes. Much of the smaller slash may have been carried by surface wash and concentrated in pockets accounting for part of the decrease in slash coverage.

The third postlogging survey, 23 months after treatment, indicated slash coverage had decreased to 12 percent, with needles still fastened to branches making up only 2 percent of this figure. Over the 2-year period, slash coverage decreased from 22 percent to 12 percent. Although we do not have data on size of slash (except for needles), there was an obvious and logical trend toward larger pieces of slash remaining on the site with time. Percent coverage by needles decreased from 3 percent (14 percent of 22 percent) to 0.2 percent (2 percent of 12 percent) over 2 years. The average depth of slash remained essentially constant, being mainly a function of depth of mutually supporting piles of branches

LITTER

Prior to logging, litter covered 83 percent of the soil surface to an average depth of 0.9 inches (2.3 cm). Most (96 percent) litter was in the form of needles and small twigs; the remainder was in larger branches, logs, and deciduous leaves.

After logging and broadcast burning, litter coverage decreased to 75 percent at the time of the first posttreatment survey. More than 90 percent of this 8 percent decrease was directly attributable to the fire. In other words, the litter decrease from 83 percent to about 82 percent was attributable to mechanical disturbance associated with felling, setting choker cables, and removing logs from the site. The reduction from 82 percent to 75 percent was due to the combustion of dry litter. Average litter depth in this survey was again 0.9 inches (2.3 cm).

Areal coverage of litter decreased to 68 percent by the time of the second postlogging survey. This decrease was similar in magnitude to the slash decrease during this period, and again may be due to the high intensity rainstorm on the area. Of the 200 plots evaluated, 16 were considered totally unchanged between the prelogging and first postlogging surveys. These plots apparently were not disturbed by logging because no merchantable trees were in the immediate vicinity; so there were no slash additions and the fire did not burn these plots. Litter cover on these undisturbed plots averaged 72 percent prior to the rainstorm and 67 percent after the storm. These percentages tend to corroborate the suggestion that the litter decrease from 75 percent to 68 percent on all plots was indeed due to the storm, rather than to some logging-related disturbance.

Litter cover after 2 years was estimated at 69 percent and considered to be unchanged from the second posttreatment survey. Average litter depth was 0.8 inches (2 cm) on this survey, indicating that litter depth apparently was not affected by treatment over the duration of the study.

LIVE GROUND COVER

Canopy coverage of live plants to a height of 1 ft (0.3 m) above the soil surface was recorded prior to logging and during the second and third posttreatment surveys, 1 and 2 years following harvest. Canopy coverage above 1 ft (0.3 m) does intercept rainfall, but its direct effect on soil protection is difficult to evaluate. Canopy coverage for this study was primarily restricted to graminoids (elk sedge and pinegrass), forbs (arrowleaf balsamroot, dogbane, heartleaf arnica, and several others), and small shrubs (ninebark, Scouler willow, spirea, and many others).

Prior to logging, live plant canopy cover averaged 29 percent, but had decreased to 8 percent when measured 1 year after the logging and fire. From visual observation, I attribute essentially all of this decrease to the fire. Conditions for plant regrowth during the first year were poor, as this was the driest winter on record in the Northwest. Most of the live vegetation remaining was elk sedge that had not burned.

The second year, live vegetation increased to cover 15 percent of the ground surface. Many forb seedlings and small shrubs, notably snowbrush ceanothus, that were not present the previous year sprouted during the spring and summer of 1978.

Soil Disturbance

Soil disturbance below the litter layer was evaluated by measuring areal coverage and depth of soil horizon mixing and erosion within the 1 m^2 plots.

SOIL MIXING

The mixing of soil horizons is relatively easy to determine in the field. When 0 horizons are incorporated with underlying A horizon material there is obvious disruption of A horizon structure, disaggregation, and a general sense of mechanical disturbance to the soil. A mixing of the A and subsoil horizons is less common, requiring deep churning of the soil, but the mixing is also readily recognizable. Soil mixing loosens soil particles and makes a soil more susceptible to erosion. Mixing also interferes with the normal vertical gradients of nutrient distribution in a soil and disrupts nutrient cycling processes.

Prior to logging 1 percent of the area evaluated was considered to exhibit some degree of soil mixing. This percentage included a total of 20 observations of mixing, eight of which were attributable to animal activity, such as game trails or pocket gopher casts. The other 12 cases of soil mixing were difficult to categorize as to cause. Most appeared to be related to a common ongoing erosion/deposition process on the slope, such as dry creep or sheet erosion, which resulted in mixing of litter with lithic soil grains. All soil mixing recorded in the pretreatment survey was shallow, less than 1 inch (2.5 cm) deep.

I recorded 62 separate soil mixing events during the first posttreatment survey. Total area disturbed by soil mixing was nearly 5 percent. Many soil mixing events recorded during the pretreatment survey were not observed after the treatment, presumably because fire destroyed the evidence. Twelve (19 percent) of the mixing occurrences were attributable to animals (pocket gophers and two game trails); 26 (42 percent) to direct mechanical disturbance caused by logging; and 24 events (39 percent) that I could not categorize. Most of these events again appeared to be related to shallow slope erosion/deposition processes. Average depth of soil mixing surveyed was 1½ inches (4 cm); deepest mixing was 4 inches (10 cm).

On the second postlogging survey, 61 soil mixing events were tallied. Several of the previously recorded mixing events became erosional events following the storm; however, there was considerable new mixing due to gophers. Nearly 5 percent of the total area remained in the soil mixing category. Seventeen events (33 percent) were caused by animals. Fifteen of these events were pocket gopher casts. Mechanical disturbance due to logging accounted for 24 events (47 percent), and the other 10 events (20 percent) were due to unknown causes.

On the final survey, there were 50 soil mixing events recorded, with 3 percent of the soil area disturbed. Animal activity accounted for 20 events (40 percent) of the disturbance, 19 events (38 percent) were attributed to mechanical effects of logging, and 11 events (22 percent) were of unknown origin. The following tabulation summarizes the data on soil disturbance by mixing caused by various agents:

Survey	Animals	Logging	Other	Percent area disturbed
	No. %	*No. %*	*No. %*	
Prelogging	8 (40)	— —	12 (60)	1
First postlogging	12 (19)	26 (42)	24 (39)	5
Second postlogging	17 (33)	24 (47)	10 (20)	5
Third postlogging	20 (40)	19 (38)	11 (22)	3

An increase in soil mixing caused by pocket gopher activity was one very notable trend after logging. Other researchers studying response of small mammals to logging in the same cutting unit found similar increases in pocket gopher casts, particularly in large openings created by the logging and the fire (personal communication, Dean E. Medin).

SOIL EROSION

Estimates of erosion were made within the boundaries of the 10.8 ft^2 (1 m^2) plots by measuring areal coverage and mean depth of depressions presumably resulting from rilling, deflation, or mechanical removal of soil during logging activities. Erosion volume was converted to a weight basis assuming a soil bulk density of 1.3 g/cm^3. Depressions resulting from stump and root burnout following the fire were not considered erosion. Deposition of soil from upslope erosion was only recognized on one plot and was not considered to be a gain. Permanent vertical reference points, such as erosion pins, would have been helpful in determining soil deposition and erosion from processes such as dry creep, that do not leave recognizable depressions; this oversight was not realized, however, until most erosion had taken place.

Natural erosion volumes were estimated on the basis of two different surveys: total erosion was measured during the prelogging survey and erosion volumes were measured on the 16 plots that were known to be undisturbed by logging and burning. The total erosion figure was not truly a rate since the timespan over which recognizable erosion took place is unknown. Rodent activity, known to have increased following logging, probably affected postlogging erosion rates on these plots, but can be roughly accounted for.

Based on the prelogging survey, natural erosion was 0.04 ton/acre (0.09 t/ha). Forty percent of this was attributable to two game trails running through the plots. The remaining 60 percent was attributed to surface erosion of hydrologic origin (small rills). Erosion events were recognized on five of 200 plots during this survey.

Erosion volume on the 16 undisturbed plots equalled 0.6 ton/acre (1.3 t/ha) during the second posttreatment survey following the rainstorm. No previous erosion was measured on these plots. I determined that 0.3 ton/acre (0.7 t/ha) could be attributed to sheet erosion from the storm and that 0.3 ton/acre (0.6 t/ha) was primarily caused by gopher damage. Based upon this small sample, there is an approximate order of magnitude difference in the natural erosion rate due to the influence of a single high intensity rainstorm.

The erosion measured during the first posttreatment survey conducted in May 1977, all plots included, was 0.85 ton/acre (1.9 t/ha). Essentially all of this erosion was caused by mechanical disturbance associated with the logging and occurred on 11 of the 200 plots surveyed. Erosion was due to gouging and scraping during felling and yarding operations. During this first posttreatment survey, no accelerated erosion was attributed to the fire.

Evidence of erosion increased dramatically during the second posttreatment survey in October 1977. Erosion was observed on 34 plots. The estimated weight of eroded materials was in excess of 6 tons/acre (14 t/ha). Of this 6 tons/acre, as mentioned above, 10 percent or 0.6 ton/acre was considered to be natural erosion occurring on undisturbed plots. The remaining erosion was partitioned by cause as follows: 2.5 tons/acre (5.6 t/ha) were attributed to mechanical disturbance accelerated by the storm; 2 tons/acre (4.5 t/ha) were attributed to sheet erosion on plots that were previously denuded by the fire; and the remaining 1.2 tons/acre (2.6 t/ha) were not attributed to any single cause. All of the erosion not attributed to a single cause (1.2 tons/acre) occurred on plots previously disturbed by fire or logging. Gopher damage on bare soil disturbed by the fire had occurred on many of the plots included in this final group. Figure 1 graphically presents the erosion-by-cause data 1 year after logging.

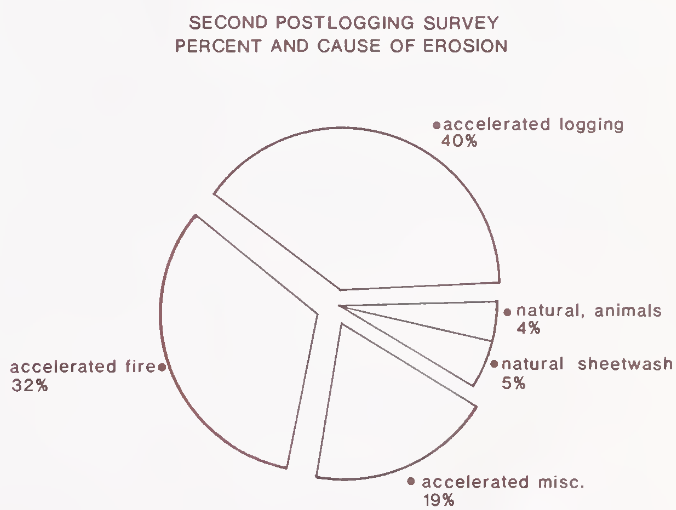

Figure 1.—Data on percentage of erosion by cause are presented in this figure. These data were gathered in October 1977, 1 year following logging and broadcast burning. Accelerated erosion is shown by the expanded sections of this pie diagram.

The percentage erosion attributed to various causes, such as logging, fire, and natural causes, remained essentially unchanged between the second and third posttreatment surveys (October 1977 to August 1978). The amount of erosion decreased from 6 tons/acre (14 t/ha) to 4 tons/acre (9 t/ha). This decrease was the result of 12 slightly eroded plots that stabilized during the third posttreatment survey. Two of the more severely eroded plots continued to lose soil material, and erosion estimates on these plots increased.

TOTAL AREA OF SOIL DISTURBED

The total area of soil disturbance attributable to the logging and slash disposal was 19 percent. Seventy-four percent of this disturbed area (14 percent of the total area) was caused by loss of litter, mainly due to the fire. Sixteen percent (3 percent of the total area) was due to soil mixing, generally resulting from mechanical disturbance during logging and to rodent activity. The remaining 10 percent (2 percent of the total area) was considered to be actively eroding due to the combined effects of logging and burning.

Dyrness (1967, 1972) published results of soil disturbance associated with skyline and balloon logging, two other yarding systems considered to cause relatively minor soil disturbance. Although our techniques of evaluation differ somewhat, our data can be compared and the results are similar. Dyrness (1967, 1972) described area of disturbance by classes as follows:

Undisturbed.—Litter still in place and no evidence of compaction.

Slightly disturbed.—Three conditions fit this class:

1. Litter removed and mineral soil exposed;
2. Mineral soil and litter intimately mixed;
3. Mineral soil deposited on top of litter.

Deeply disturbed.—Soil surface removed and subsoil exposed.

Compacted.

The following tabulation compares results of soil disturbance by helicopter logging shown in this study with results of soil disturbance by skyline and balloon logging (Dyrness 1967, 1972):

Classes	Skyline	Balloon	Helicopter
Undisturbed	63.6	78.1	81
Slightly disturbed	24.4	15.8	17
Deeply disturbed	4.7	2.6	2
Compacted	3.4	1.7	not evaluated

CONCLUSIONS

Clearcut logging with helicopter yarding appears to cause minimal onsite soils disturbance when compared with other, more conventional logging systems (Dyrness 1965, 1967). Accelerated erosion was found on 2 percent of the area, and volume estimates indicate a short-term increase of approximately one order of magnitude. Eroded areas appear to be healing 2 years after the treatment.

Broadcast burning of slash resulted in litter losses on approximately 14 percent of the total area. This contributed to the acceleration of erosion and also resulted in a loss of a valuable nutrient sink. Although many nutrients contained in litter may have remained on the site in ash, some nitrogen and sulfur have been lost through volatilization. Cations in the ash are quite mobile and leaching loss is likely. Other methods of slash disposal including jackpot burning will be evaluated in future studies at Silver Creek.

PUBLICATIONS CITED

Dyrness, C. T.
1965. Soil surface condition following tractor and high-lead logging in the Oregon Cascades. J. For. 63:272-275.

Dyrness, C. T.
1967. Soil surface conditions following skyline logging. USDA For. Serv. Res. Note PNW-55, 8 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

Dyrness, C. T.
1972. Soil surface conditions following balloon logging. USDA For. Serv. Res. Note PNW-182, 7 p. Pac. Northwest For. and Range Exp. Stn., Portland, Oreg.

Kidd, W. Joe, Jr.
1964. Probable return periods of rainstorms in central Idaho. USDA For. Serv. Res. Note INT-28, 8 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Meeuwig, R. O.
1970a. Infiltration and soil erosion as influenced by vegetation and soil in northern Utah. J. Range Manage. 23:185-188.

Meeuwig, R. O.
1970b. Sheet erosion on intermountain summer ranges. USDA For. Serv. Res. Pap. INT-85, 25 p. Intermt. For. and Range Exp. Stn., Ogden, Utah.

Megahan, Walter F., and W. J. Kidd.
1972. Effects of logging and logging roads on erosion and sediment deposition from steep terrain. J. For. 70(3):136-141.

Mersereau, R. C., and C. T. Dyrness.
1972. Accelerated mass wasting after logging and slash burning in western Oregon. J. Soil Water Conserv. 27(3):112-114.

Packer, P. E.
1963. Soil stability requirement for the Gallatin elk winter range. J. Wildl. Manage. 27:401-410.

The Intermountain Station, headquartered in Ogden, Utah, is one of eight regional experiment stations charged with providing scientific knowledge to help resource managers meet human needs and protect forest and range ecosystems.

The Intermountain Station includes the States of Montana, Idaho, Utah, Nevada, and western Wyoming. About 231 million acres, or 85 percent, of the land area in the Station territory are classified as forest and rangeland. These lands include grasslands, deserts, shrublands, alpine areas, and well-stocked forests. They supply fiber for forest industries; minerals for energy and industrial development; and water for domestic and industrial consumption. They also provide recreation opportunities for millions of visitors each year.

Field programs and research work units of the Station are maintained in:

Boise, Idaho

Bozeman, Montana (in cooperation with Montana State University)

Logan, Utah (in cooperation with Utah State University)

Missoula, Montana (in cooperation with the University of Montana)

Moscow, Idaho (in cooperation with the University of Idaho)

Provo, Utah (in cooperation with Brigham Young University)

Reno, Nevada (in cooperation with the University of Nevada)