# MICROSONIC DETECTION OF LANDSLIDES

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The microsonic activity (subaudible rock noise) that is recorded in a material can be used to evaluate the stability of slopes in the area. The method can be used in conjunction with other monitoring devices for more thorough monitoring of slope stability. The California Department of Transportation, through a series of research studies, has shown the feasibility of the technique. Currently, the method is used to provide information on activity of landslides, stability of cut slopes, and effectiveness of field corrections for stability problems. Several case histories illustrate uses of microsonic monitoring. The Porto Marina landslide was monitored to minimize the hazard and inconvenience to traffic on Calif-1. Monitoring of the Thornton Bluffs landslide illustrates the relationship of microsonic activity, slope indicators, and nail measurements. Newly constructed cut slopes have been monitored to determine potential for slope failures. Corrective measures for the American Canyon landslide were monitored to evaluate their effectiveness.

•THE California Department of Transportation is using subaudible rock noise (SARN) to monitor various types of slope stability problems. This technique together with other methods, such as use of slope indicators, measurement across cracks, and surveying of points, is available for monitoring. Each slope stability problem must be considered carefully to determine which monitoring method or combination of methods is most suitable. The case histories described in this paper illustrate some of the benefits that can be derived from SARN monitoring.

Interest by the department in the use of SARN to monitor the stability of slopes developed in 1962. A study by the University of California (1) that was done for the Transportation Laboratory of the department concluded that actively moving landslides generate subaudible rock noise and that equipment capable of detecting and recording these noises was available. These noises have been referred to as microsonic noises, acoustic emission, microseismic noises, and subaudible rock noise. The second phase of the department's investigation of SARN evaluated the practicality of using SARN recordings to monitor slope stability. Four conclusions were drawn from this study (2).

1. SARN rate reflects the stability of the immediate area.
2. Number of counts increases as stability decreases.
3. SARN rates should be considered as relative values rather than absolute numbers. Changes in SARN rates are significant for evaluating slope stability.
4. Improvement in equipment and field techniques was needed.

Subsequent study by the Transportation Laboratory has evaluated equipment for detecting and recording SARN and has modified the field techniques. The conclusions and recommendations contained in the final research report are as follows (3):

> The experience gained through equipment development and the data observed and analyzed both in the case histories included with this report and in ongoing projects indicate that subaudible rock noise (SARN) is directly related to instability.
>
> SARN rates do not appear to be absolute measurements of activity but rather provide a qualitative evaluation of stability, i.e., increases or decreases in SARN rates reflect decreases or increases in stability.

Given a site history and a SARN rate indicative of stability for the site, properly trained personnel can evaluate site stability by monitoring, and give a subjective decision as to the probability of failure at some time following the monitoring.

There is evidence that stability changes can be detected by SARN monitoring up to several weeks in advance of other forms of monitoring. Additional experience with this phenomenon should lead to further applications of SARN monitoring.

Care must be exercised in selecting and training personnel to make such evaluations. Proper equipment for monitoring is also mandatory.

Based on the experience and knowledge gained during this research, further use of SARN monitoring as a means of slope stability evaluation is recommended. Because these decisions are subjective rather than absolute, it is also recommended that only experienced personnel be utilized for stability evaluations.

As a result of experience gained while monitoring various slope stability problems, a mobile SARN laboratory has been built to improve on-site monitoring capability.

The case histories in this paper in which SARN has been used were chosen because they illustrate the more common applications to slope stability problems and because data obtained on these cases provide information about the capabilities of SARN as a monitoring technique.

## MONITORING LANDSLIDES

### Porto Marina Landslide

A slope above Calif-1 along the coast near Los Angeles began to fail in 1969. A report by Mearns (4) indicated that unusually heavy rains had preceded the developing failure. By the time the SARN monitoring crew arrived at the site, the slope was unstable and falling material had blocked 1 lane of the 4-lane highway. A large cantilevered house (Figure 1) was starting to slide toward the road. The traffic count at the time was 30,000 cars/day, and no good alternate route was available. The SARN monitoring was to be used to evaluate the stability of the slope and to minimize the hazard and the inconvenience to traffic using Calif-1. Monitoring began at 11:00 a.m. on February 20, 1969, and was described as follows by Mearns (4).

The first noise counts, although high, did not suggest imminent failure. However, at 1300 hours the count abruptly jumped to a dangerous level. Because of the extremely high noise count and measurable movement of up to ½ inch (12.7 mm.) across cracks in the driveway, District 07 maintenance personnel controlling traffic on the road below were told that the slope was considered dangerous. At 1352 hours they ordered Road 07-LA-1 closed as a safety measure.

Noise rate continued at a serious level until approximately 1600 hours on February 20, 1969. At approximately 1430 the noise was nearly continuous and a count was difficult to obtain. By 1700 hours the noise rate had dropped back to the pre-movement level. During this time period severe wrenching of the house occurred, most of the glass broke out and three of the front five caissons separated completely from the house and a fourth was badly damaged. No surveyed measurements were taken of this movement, however, the taped distance between one microphone location and the uppermost crack at the head of the slide increased from 18 to 23 feet (5.5 to 7 m.) and the elevation dropped nearly four feet (1.2 m.) with respect to the sewer line at the head of the slide.

At the toe of the slide small slumps of soil and rock occurred during the entire period of high activity. Also during this period, boulders of sheared material as large as 6 feet (1.8 m.) in diameter rolled down the slope and out as far as centerline of the highway. A few smaller fragments rolled across centerline.

The noise rate continued to decrease after 1700 hours and at approximately 2100 hours maintenance personnel were notified that the noise rate was at a nonhazardous level and the standby cleanup crew was sent home.

Monitoring was continued through 1600 hours on February 21, 1969, with no signs of increased activity and maintenance personnel were required only to keep people out of the hazardous area.

As heavy equipment for demolishing the house was moved into the area and began work, the noise rate jumped to the original noise level of February 20, 1969 and tape recordings were again started. These recordings were continued until the last microphone connection was broken by the work (approximately 2000 hours). At no time during the destruction of the house did the noise rate reach a hazardous level.

A plot of SARN counts per minute against time is shown in Figure 2. The high SARN rates correspond to the most intense slide activity. This plot also provides a way of determining whether the SARN rates are increasing or decreasing. This type of information was extremely useful for deciding when to close and when to open the road.

### Thornton Bluffs

A coastal area just south of San Francisco is subject to continuing erosion by the ocean. The bluffs, composed of poorly consolidated sands, silts, and clays, contain numerous slides. One of the slides overhangs an abandoned state highway right-of-way (Figure 3). The upper scarp traverses a subdivision cul-de-sac and affects several houses (Figure 4).

Several types of monitoring were applied to this site. In addition to SARN listening, slope indicators were read, and measurements across cracks in the cul-de-sac were made regularly. The monitoring provided information on the configuration and rate of movement of the slide and helped evaluate the hazard to residents of the area.

Plots of the results of 3 different types of monitoring are shown in Figure 5. This figure illustrates the correlation of the different monitoring techniques. In this particular case, increased SARN activity was noted in December 1973; increased rate of movement for the other monitoring was noted about 2 months later. In some cases, SARN appeared to indicate a change in stability earlier than some other monitoring systems.

## MONITORING CUT SLOPES

### Pacheco Pass

The first evaluation by the Transportation Laboratory of the use of SARN to monitor new cut slopes has been reported previously (3). Several slides had occurred on a highway relocation project in the Central Coast Ranges of California. As a result of these stability problems in the fractured and sheared sandstone and shale encountered on the project, several cut slopes were selected for SARN monitoring. Figure 6 shows the relationship between SARN rates and site conditions such as construction activity, rainfall, and a local slide. The highest count was obtained shortly after the slide had occurred. Figure 7 shows the local slide that occurred. The monitoring location was near the man standing beside the highway. The results of this study were encouraging enough to warrant further monitoring of cut slopes with the SARN method.

### Anderson Grade

The construction of a segment of I-5 in the Klamath Mountains of northern California was complicated by difficult alignment problems imposed by the rugged terrain. Five cuts over 100 ft (30.5 m) high had been designed in fractured and sheared, fine-grained metamorphic rock. The cut-slope angles would be steep, and presplit blasting would be required for some of the slopes to minimize the disturbance of the rock remaining in the cut face. SARN monitoring was begun in March of 1968 before construction. During construction, the slopes were monitored at approximately 1-month intervals. Monitoring was continued for several months after completion of the construction. SARN rates were low throughout the period of monitoring. No major slope failures occurred on any of the monitored slopes.

Figure 1. Porto Marina landslide.

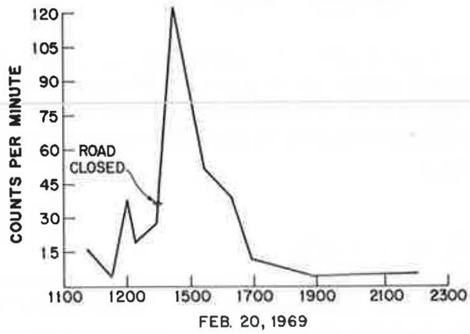



Figure 2. Subaudible rock noise counts recorded at a location in the Porto Marina landslide.

Figure 3. Thornton Bluffs landslide.

## MONITORING CORRECTIVE WORK IN AMERICAN CANYON

In 1968, during the construction of I-80, a large landslide developed in soft sedimentary rocks. The slide was located several miles (kilometers) northeast of Vallejo, California, and is referred to as the American Canyon slide. Initial efforts to correct the slide were not successful, and, in early 1969, SARN monitoring of the slide was begun.

Figure 4. Cracks in a cul-de-sac at head of Thornton Bluffs landslide.

Figure 5. Subaudible rock noise counts, nail point measurements, and slope indicator measurements taken at head of Thornton Bluffs landslide.

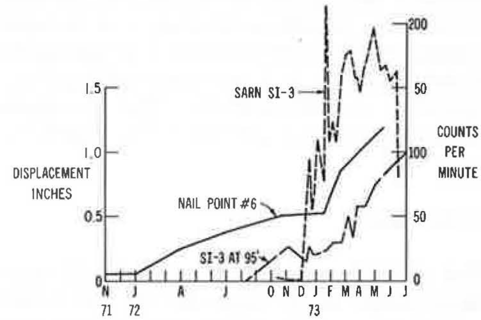



Figure 6. Subaudible rock noise counts recorded at station 46 near Pacheco Pass.

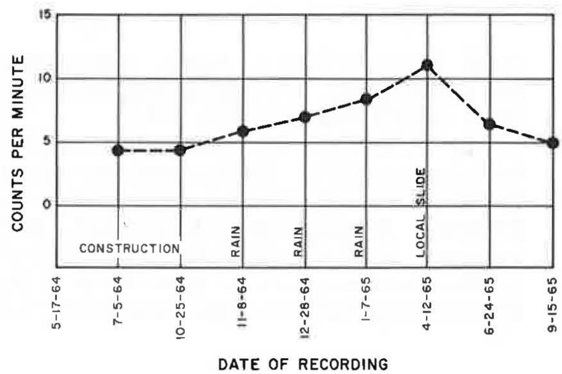



Figure 7. Small slide in cut slope at station 46 near Pacheco Pass.

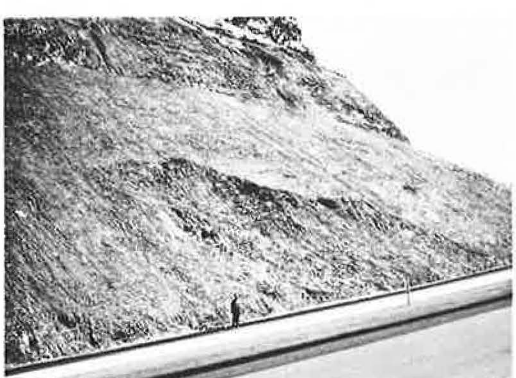
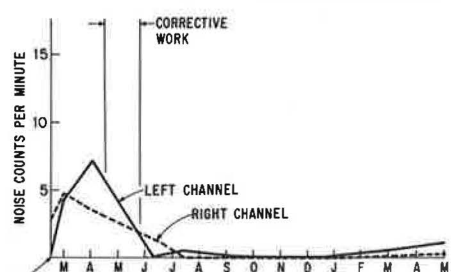


Figure 8. Subaudible rock noise counts recorded at station 483 in American Canyon.



Additional work to correct the slide included the installation of a series of 600- to 800-ft-long (183- to 244-m-long) horizontal drains to remove groundwater and the removal of 350,000 $yd^3$ (267 759 $m^3$) of material from the upper part of the slide. The SARN counts that were recorded at station 483 are shown in Figure 8. The SARN rate dropped steadily during the corrective work and remained low after the correction. This illustrates how SARN monitoring can be used to monitor the effectiveness of correction measures that are used on a slope stability problem. Left channel and right channel in Figure 8 refer to 2 separate microphones that were installed adjacent to each other and operated simultaneously. The correlation between the 2 records increases the confidence that can be placed in the SARN rates.

## SUMMARY

The case histories presented in this paper illustrate some of the uses that the California Department of Transportation has made of SARN monitoring. The method has provided useful information about the activity of landslides, the stability of cut slopes, and the effectiveness of corrective measures that are applied to slope stability problems.

## REFERENCES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3. R. Mearns and T. Hoover. Sub-Audible Rock Noise (SARN) as a Measure of Slope Stability. Transportation Laboratory, California Department of Transportation, Research Rept. CA-DOT-TL-2537-1-73-24, Aug. 1973.
4. R. Mearns. Sub-Audible Rock Noise in Random Samples. Materials and Research Department, California Division of Highways, May-June 1969, pp. 1-7.