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A Cooperative Geophysical Site Assessment at Mammoth Hot Springs, Yellowstone National Park

Mammoth Hot Springs has long been an area of development within Yellowstone National Park. The park's second superintendent, Philetus W. Norris, selected Mammoth as the permanent park headquarters in 1878 because of its

> ...[N]earness and accessibility throughout the year, through one of the...main entrances to the park to the nearest permanent settlements of whites and a military post, [because of its] remoteness from routes inviting Indian raids, and [its position as] a proper site of defense therefrom, and [because it provided] for ourselves [and our] saddle and other animals, good pasturage, water, and timber, as well as accessibility to the other prominent points of interest in the Park.*

In retrospect, Mammoth has proved to be an unfortunate choice for park headquarters. For example, the surface rock in the area is predominantly travertine. Because travertine is highly porous and susceptible to dissolution , subsurface cavities are likely present throughout the area. Collapse features, that form when subsurface water weakens overlying travertine, are commonly seen at the surface. Moreover, steeply dipping fractures are observed cutting horizontally bedded travertine deposits in vertical exposures. The area features active hot springs with new hot springs forming and some old hot springs becoming inactive. As a result, the area is unstable and historic buildings are occasionally threatened by the inconstant thermal features and subsidence.

Throughout Yellowstone National Park's history, the area's unique cultural and natural resources have generated a great deal of research activity by both park and outside researchers. This has resulted in substantial collections of natural resource specimens and cultural resource artifacts stored in overcrowded facilities and a lack of researcher workspace. Current storage conditions do not meet professional standards, and deficiencies include inadequate environmental controls, security, fire protection, and pest management.

To best serve researchers and the resource collections, the park requires a consolidated research and preservation facility for storage and exhibition of cultural and natural resource collections. The proposed facility, the "Yellowstone Heritage and Research Center," will be approximately 35,000 square feet in size and include storage and exhibit areas, wet and dry laboratories, and researcher workspaces.

Mammoth Hot Springs has been targeted as the preferred location so that the facility will be accessible to park staff and visiting researchers. Given the unstable nature of the area, the park is concerned about finding a secure site for this facility. Non-invasive subsurface investigations commonly employing one or more geophysical techniques were considered as a preliminary step in surveying the potential construction sites at Mammoth Hot Springs in order to limit the disturbance to the surroundings. In the best case, geophysical techniques can provide a picture of the subsurface with sufficient detail to locate subsurface cavities and large scale fractures or faults that are present in the area. The need for geophysical site characterization at Mammoth Hot Springs provided a unique opportunity for a cooperative study involving students at Montana Tech of the University of Montana and the National Park Service.

Field studies are often an integral part of geoscience curricula. At Montana Tech, much of the field experience is gained in a six-week-long summer field camp in which students are exposed to both geological and geophysical field methods. This camp is a required course for both geophysical and geological engineering majors at Montana Tech. Group projects are typically utilized to give students the experience of working with others. Furthermore, service-learning projects that combine elements of service to the community with academic learning are sought to enrich the field camp experience.

Preliminary testing in the spring of 1997 at Mammoth indicated that Ground-Penetrating Radar (GPR) would be useful for obtaining subsurface information in the area. This initial study showed that GPR penetration depths of over 15 meters were possible in the travertine at Mammoth Hot Springs. As a result of this preliminary study, Yellowstone National Park staff made arrangements to have students in the Montana Tech summer course perform a geophysical site assessment of one of the sites under consideration: the 1895 Mail Carrier's Cabin. The students had to provide a professional quality report to the park detailing the results of the survey at the end of the field course.

Of commonly used geophysical techniques, GPR has the potential for offering the greatest resolution in the subsurface. In ideal situations, objects separated by a few centimeters can be distinguished from one another. Moreover, GPR profiles can be quickly displayed and interpreted in the field.

In practice, GPR measurements are made by moving transmitting and receiving antennas (1MHz to 1 GHz) along the ground surface. At a particular position along the surface, the transmitter emits an electromagnetic wave into the ground. When this wave encounters a boundary between materials of differing electrical properties, some of the incident wave energy is reflected back to the surface. The energy returning to the surface is, in turn, recorded at the receiving antenna. The information recorded at one ground position is called a trace and reflected energy on the trace is observed as an increase in the signal amplitude that occurs at a particular time along the trace.

As the GPR system is moved along the ground surface, traces are recorded at regular intervals. When these traces are displayed side by side as a cross section, the size, shape, and depth of a reflecting object can be determined. Some common features that cause reflections in the subsurface include: changes in rock type, cavities, plastic and metal containers, pipes, changes in porosity, the water table, hydrocarbon plumes, and building foundations.

Unfortunately, the electrical conductivity of the subsurface limits the use of GPR. As conductivity increases, the depth of penetration decreases. In highly conductive, clay-rich soils, the effective depth of penetration of the electromagnetic waves may be less than a meter. Local geologic conditions govern which geophysical methods can be used at a given site.

GPR data collection by Montana Tech students at Mammoth Hot Springs was organized into task groups that variously surveyed profile lines, collected GPR profiles, and collected background information at Yellowstone National Park Research Library. Individual student tasks were changed at intervals to provide students with a variety of experiences. During data reduction and report preparation, students were organized into teams to complete various tasks such as map preparation, profile preparation, and survey data reduction.

The GPR survey at the Mail Carrier's Cabin site successfully detected numerous cultural features such as buried wires and pipes but did not show any large cavities that would preclude building at the site. The study, however, indicated that numerous fractures and small faults are present throughout the site. These fractures may be related to historical subsidence. Partly on the basis of this study, alternate sites are being considered for the proposed facility. A GPR evaluation of one of the alternate sites indicated that it would be a more secure building site.

Student evaluations of this project were overwhelmingly supportive. Students enjoyed the visit to Yellowstone National Park as well as the opportunity to contribute to a professional quality report that was going to be put to real use. Students welcomed the opportunity to practice their public relation skills while interacting with park personnel and visitors. This study provided Yellowstone National park personnel with information that proved useful for planning purposes for the siting of the proposed facility. Cooperative projects such as this one can provide important learning opportunities for college students while at the same time perform a useful service for the community.

Note

* Fifth Annual Report of the Superintendent of the Yellowstone National park, to the Secretary of the Interior, Washington, D.C., Government Printing Office, 1881, 23.

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