NEWSLETTER

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Extraordinary Solutions Featured at Saluda Dam

by Jeffrey M. Bair, Paul C. Rizzo Associates, Monroeville, PA (jeff.bair@rizzoassoc.com)

Extraordinary problems require out-of-the-ordinary solutions. When South Carolina Electric & Gas discovered that Saluda Dam could liquefy during an extreme seismic event, that is exactly what they faced — an extraordinary problem.

SCE&G's engineer — Paul C. Rizzo Associates, Inc. — determined that under the design seismic event, the existing semi-hydraulic fill dam constructed in the 1920s could liquefy, resulting in deformation and settlement of the crest on the order of 50 feet. These analyses were completed by 1999, and the design of remedial measures began immediately thereafter. Many options are available to reduce or mitigate liquefaction potential — ranging from sand drains to reduce potential pore pressure buildup to dynamic compaction, grouting and stone columns to densify the in-situ soils. Rizzo explored all available options in the search for a remedial "fix" for Saluda Dam. However, when the entire 1.5-mile-long, 200-foot-high embankment is

Topping out final section of RCC berm.

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USSD Conference, May 2006

Outstanding Program Planned for San Antonio

Thanks to an excellent response to the Call for Papers, an outstanding program is planned for the **26th USSD Annual Meeting and Conference**, to be held May 1-5, 2006, in San Antonio, Texas. The 2006 Conference theme is ***The Role of Dams in the 21st Century***.

Technical Sessions, organized by a Planning Committee chaired by **John W. France**, will feature the presentation of more than 60 papers on topics including dam safety and security, environmental issues, concrete and RCC dams,

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Durango Workshop and Field Tour Well Attended

Nearly 50 dam engineers traveled to Durango, Colorado, to attend the USSD Workshop on **Practical Seepage Considerations for Embankment Dams — The Design and Construction Perspective,** held on October 5. Organized by **John M. Cyganiewicz**, **John W. France** and **Debora J. Miller**, the Workshop featured sessions on remediation, design, construction and monitoring; and a panel discussion.

A Field Tour on October 6 featured the **Bureau of Reclamation**'s Animas-La Plata Project, including the Ridges Basin Dam construction site. Reclamation construction engineer Barry Longwell led the tour.¤

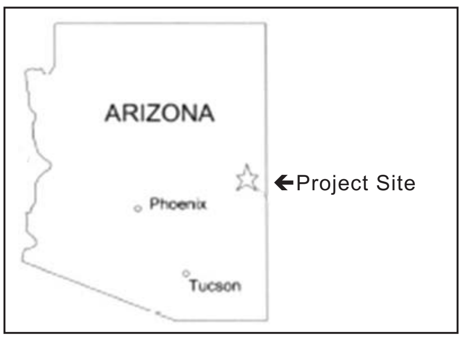
Additional Items of Interest

River Reservoir Dam

Mapping Seepage through Earthen Embankments

by Val Kofoed, Paul Rollins (prollins@willowstick.com) and Jerry Montgomery, Willowstick Technologies, Salt Lake City, Utah

Seepage of water through an earthen embankment suggests a number of possible scenarios, and none of them are good. At best, the reservoir owner is losing a valuable commodity. At worst, the seepage may be the precursor of dam failure. The first step in addressing a problem with seepage is as obvious as it is difficult: pinpointing its source. In the past, procedures for determining the exact location and nature of seepage points have been both costly and time consuming. Of course, when dam failure is imminent, there is much more than money and time at stake; the rapidity and efficiency with which engineers can locate the source of seepage may make the difference between a timely fix and catastrophe.



River Reservoir Dam is an arched earthen structure on the headwaters of the Little Colorado River. It is located about 15 miles southwest of Eagar, Arizona, and is owned and operated by Round Valley Water Users Association (RVWUA). In 1896 and based on very limited engineering, settlers constructed the dam using local materials and without a clay core. Due to recurring sloughing problems, the dam received significant modifications on at least four separate occasions. The embankment consists of clayey soils within a rock-fill shell, measuring 1,100 feet long, with a maximum height of approximately 70 feet and is founded upon basalt bedrock.

In 1996, additional rip-rap was installed to reduce the original slope of the upstream and downstream faces. A review of the early inspection reports revealed that the left abutment drain was constructed by using tabular rocks to create a box-shaped opening over the rock foundation. However, the contacts between these rocks were neither sealed nor grouted. There has been much speculation regarding the original purpose of this drain. Most investigators believe that it was constructed to carry away water that emerges from a perennial spring rumored to exist within the left abutment; it may also have been intended to function as a temporary outlet to the reservoir.

In late March 2004, an unusual amount of water was observed to be seeping from the left abutment weir box. This seepage contained significantly higher than normal silt content. The seepage path was thought to be related to the rumored spring, its associated clay pipe, and the tabular stone-box drainage system. Investigators feared the possibility of imminent dam failure. Emergency personnel were mobilized to the site to monitor and address the situation.

The RVWUA immediately contacted the State of Arizona, which agreed to fund the investigation and subsequent remediation work. RVWUA also enlisted the services of **Turner Collie & Braden, Inc.**, which contacted Willowstick Technologies. These two organizations worked together to assist RVWUA in investigating and resolving the rapidly deteriorating situation.

Investigative work was done using Willowstick's AquaTrack technology. The technology uses a low voltage, low amperage, audio-frequency electrical current to energize the groundwater or seepage in question. Electrodes are placed strategically in wells, springs or surface water so as to induce electricity to flow through the groundwater system of interest. Because groundwater is a conductor, the electrical current will follow the path of the groundwater between the electrodes. As it flows through the groundwater, the current creates a magnetic field. This magnetic field can be identified and surveyed from the surface using a highly sensitive and specially tuned magnetic receiver. The magnetic receiver measures the specific magnetic field, filters out interference and amplifies the signal. Repeated measurements are recorded over time to ensure consistent results.

The equipment used to measure the magnetic field includes three sensors oriented in orthogonal directions, a data logger used to collect, filter and process the sensor data, a Global Positioning System to locate and map the field measurements, and a Windows-based handheld computer to store the GPS and magnetic field data. This equipment is mounted on a surveyor's pole and can be hand-carried to each measuring station.

The instrument measures the voltage from each of the three sensors located at each measurement station. The measured values correspond to the strength of the magnetic field. For quality control, a base station is established within the survey area. The field strength at the base station is measured at the beginning, middle and end of each field day. This data is used to identify any changes in the background magnetic field, such as diurnal drift. The magnetic field measurements collected during the survey of the larger region of interest are later normalized to compensate for these effects. The quality of the data is also assured by examining the signal-to-noise ratio in real time, and fluctuations in the data due to natural and man-made phenomena are removed. The horizontal and vertical magnetic field magnitudes and directions can be measured to further define the groundwater or seepage system. The survey data is later normalized to show relative highs and lows in the magnetic field strength.

Taking readings from boat.

High relative field strengths correspond to higher current flows and represent an increased presence of groundwater.

For the River Reservoir Dam investigation, one electrode was installed in the lake, approximately 800 feet south of the western abutment, and a second was placed in the left abutment weir box, where the high silt content was observed (about 140 feet downstream of the dam crest). These two electrodes were connected by heavy gauge wire and linked to a 400Hz power generator. An electrical current was then induced between the two electrodes. A total of 107 magnetic measurements were taken on the upstream and downstream sides of the dam, as well as on the crest. Twenty additional measurements were taken from a boat in the reservoir. Upon completion of the fieldwork, the collected data was then sent back to the lab for interpretation. The measured magnetic field data were processed, contoured and correlated to other hydrogeologic information. This resulted in an enhanced definition of the extent and preferential flow paths of the seepage. The results of the survey pinpointed the area with the greatest leakage in both the horizontal and the vertical directions.

Using this data, maps of the preferential flow paths that existed between the reservoir and the left abutment weir box and its associated drainage system were produced. This information was integral to the comprehensive remedy developed by the geotechnical engineers at TCB. Willowstick personnel mobilized rapidly on short notice and performed the investigation work over a two-day period. Preliminary maps were generated on an overnight basis. The final report was presented within a couple of weeks from completion of the fieldwork.

The location of the leak was confirmed through dye tests performed immediately after the magnetic field survey. Three different fluorescent dyes were used for the tracer work, fluorescein (green), eosine (yellow), and rhodamine WT (red). The rhodamine was placed in the middle section of the dam near the old tabular-stone drain. The fluorescein was introduced at a point to the left of where the rhodamine was introduced and the eosine at a point to the right. Within eight minutes of its introduction, a substantial amount of rhodamine was observed downstream, confirming previous findings and indicating serious seepage problems.

Following this analysis and the subsequent ground proofing, the reservoir was drawn down to a level below the primary area of concern in order to implement temporary remedial measures in order to eliminate the risk of immediate failure. The temporary remediation of the dam has been completed and the funding for a more permanent fix is pending.¤

ASCE Geo-Institute Seeks USSD Input

The Geo-Institute is beginning an evaluation of its draft Standard on Inspection of Dams to determine if the Standard should be issued to provide a consensus document on inspection of dams.

USSD Members are invited to participate in this effort. For more information about the Standard, contact committee chair Richard Kummerie at rpkummerie@tectonicengineering.com or 845-534-5959, x222.¤

News of Members

Gannett Fleming, Inc. is celebrating its 90th anniversary this year. The firm is currently involved in the rehabilitation of New York City's historic Catskill System Dams, including Gilboa and Ashokan.

Lee C. Gerbig has formed his own consulting firm, Lee C. Gerbig, LLC. He lives in Avon, Indiana, and can be reached at leegerbig@indy.rr.com.

Milton E. Harr has moved from North Kingston, Rhode Island, to Longboat Key, Florida. Contact him at meharr@aol.com.

Hatch Acres announced its new name, effective August 1, 2005. The energy consulting firm, which acquired Acres Incorporated in June 2004, will market its services and execute new projects under the name Hatch Acres in Canada and the U.S. Overseas markets will continue to be served by Acres International Limited, an operating group of Hatch Acres.

Fred H. Kulhawy was recently named an honorary member of ASCE. He was recognized for his significant contribution in the areas of foundation engineering, geotechnical reliability applications, soil-structure interactions and soil and rock behavior. He was a professor for 29 years at Cornell University, and is now a private geotechnical consultant.

Eric J. Malvick is now with the Division of Dam Safety, California Department of Water Resources, in Sacramento. A former student at the University of California, Davis, he is a past recipient of the USSD Scholarship.

Joseph L. Schwenk has retired from the Corps of Engineers and is now affiliated with Alberici Constructors, Inc., St. Louis, Missouri.

James H. Weldon, Denver Water, and **Richard L. Wiltshire**, Bureau of Reclamation, recently gave a presentation, *Cheesman Dam — an Engineering Marvel*, at the Denver Public Library. A speaker series and photo exhibit commemorated a century of service for the Denver Water dam.¤