DESIGNING A DAM MONITORING SYSTEM

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by Craig Hewes

Leica Total Station TCRP 1202+

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In early 2017, winter storms filled and then overfilled reservoirs in California, USA, leading to the evacuation of hundreds of thousands of citizens near Lake Oroville, California's second largest manmade lake.

About 160 kilometres away, the Pardee and Camanche reservoirs also filled from the 2017 storms, reaching 103 per cent of capacity in March, but the dams were not overtopped, and releases were sustainable within the waterways.

Thanks to the installation of one of the nation's most advanced automated GNSS-based dam monitoring systems at these two facilities, along with other instrumentation improvements, East Bay Municipal Utility District (EBMUD) had the technology in place to **monitor crest elevations at these dams and dikes remotely** with improved temporal resolution. Having this type of data available is one more tool in an infrastructure owner's tool belt for monitoring the condition and performance of critical facilities.

Designing for Better Data

Consulting with Sensemetrics, a firm specialising in networked sensor applications based in San Diego, U.S.A., EBMUD designed and proposed a sophisticated monitoring system based on:

- 31 Leica GMX901+ GPS sensors.
- Four Leica GM10 GNSS reference stations.

Submitted By

Craig Hewes, PLS

Director of Structural Monitoring,
Leica Geosystems
Email: *craig.hewes@leicaus.com*

- A radio network consisting of 900 MHz mesh radios.
- 2.4 GHz repeaters and two radio towers.
- Leica GNSS Spider and GeoMoS software solutions.

The use of Geosystems receivers is important, according to Cory Baldwin, president of Sensemetrics: *"The GMX901+s are purpose-built for remote monitoring applications, with non-exposed, built-in antennas," he says. "They were my first choice here, because other vendors don't really have a good option for monitoring in this environment."*

Three of the GNSS reference station receivers are solar powered and one is powered by a 120v AC feed. All are securely fastened inside enclosures installed near the Leica AR20 antennas, which are mounted on concrete pedestals. **The network is largely autonomous, needing only occasional attention**. Data flow is through 900 MHz and 2.4 GHz spread spectrum radios into an existing microwave telemetry link to EBMUD's business intranet at its Oakland headquarters, where a server runs the Spider and GeoMos software necessary to process the GNSS data and results. The results are then presented through software customised by Sensemetrics.

Five of the GMX901+ sensors as well as four seismographs are installed on the Pardee Dam connected via fiberoptic cable directly to the microwave business intranet. These **instruments continuously monitor dam movement and report remotely**. Two of the GM10 reference stations were installed near and on either side of Pardee Dam and are connected to the fiberoptic line by 2.4 GHz radio connections.

Downstream from Pardee Dam, the Camanche Reservoir site consists of one large earth-filled dam and six dikes. The Camanche Reservoir is primarily used to control releases to downstream agencies and maintain flows for the salmon. Twenty-six GMX901+ sensors are installed around the reservoir, and these also monitor and report continuously.

A Complete Picture of Infrastructure Performance

The State of California Division of Safety of Dams (DSOD) requires semi-annual monitoring surveys. The new system provides accurate information more rapidly, reduces staff time spent on monitoring, and is capable of being tied into state-wide emergency and seismic monitoring systems as they emerge.

"EBMUD's infrastructure is spread out over a vast area and covers multiple counties," says Baldwin. *"In particular, the Pardee and Camanche sites are several hours away from main offices, and the semi-annual surveys [conducted previously] took over a week to complete. This new system provides more accurate data, more or less constantly, and, of course, reduces the time survey crews spend on this task. It's a big improvement, and it is performing beyond expectations."*

Baldwin says one important design goal was inter-connectivity with existing and future monitoring systems. The potential to automate and improve emergency responses to seismic events is a major advantage of monitoring networks. EBMUD now has more survey information immediately at its fingertips regarding structure performance than at any previous moment in the district's history.

"The GPS system at Pardee Dam now gives us a complete picture of the seasonal deformations due to thermal expansion and contraction of the concrete structure," says Steven J. Martin, survey supervisor for EBMUD. *"With the Camanche Reservoir portion of the GPS monitoring system, we are able to meet DSOD monitoring requirements without long trips out of town by the survey crew and to check for any possible deformations remotely in near real time."*

Automated Dam Monitoring in Action

A recent example of the benefits of automating a survey monitoring scheme comes from another EBMUD automated dam monitoring project on San Pablo Dam in California. In 2008 and 2009, the dam underwent a seismic improvement to buttress the toe of the dam to bedrock using a cement deep soil mixing process. Increased monitoring requirements from the DSOD, while working on an active dam, were met via an Automated Motorised Total Station System (AMTS), which has been running several times a day since that project was completed in 2009. EBMUD also has a program to visually inspect dams and reservoirs immediately after an earthquake to check for cracking or other visible damage as a quick ground truth.

After a 4.4 magnitude earthquake in January 2018 on the Hayward fault centred in Berkeley, less than 8 km from the San Pablo dam site, EBMUD geotechnical engineers were able to log in to the AMTS automated monitoring system to **review whether there had been any actual movement or slumping on the dam,** and they confirmed that there was no significant movement. This ability to have information immediately and at their fingertips has proven to be a huge asset in managing dam safety at EBMUD.

Figure 1. Pardee reservoir across the Mokelumne River, California