CUSTOMER STORY | 2019

# Comprehensive Monitoring of Victoria Dam

## Modern Monitoring of Victoria Dam Performed by Sri Lanka Authorities Using Trimble Monitoring Solutions

An automated monitoring system, optical total stations, GNSS receivers and other structural monitoring instrumentation continuously monitors Sri Lanka's tallest dam — providing a 360-degree view in real-time — of all dam movements.

## Solution

Trimble S9 total stations
Trimble NetR9 Ti-M GNSS receivers
Trimble DiNi digital level
Trimble 4D Control monitoring software

# overview

Victoria Dam is the tallest dam in Sri Lanka, located on the Mahaweli River and about 20 kilometers (12 miles) from the town of Teldeniya. A double-curvature concrete arch dam, it is vital to the area in terms of agricultural irrigation and the production of hydroelectric power. Construction of the dam started in 1978 and was completed in April 1985.

Location
TELDENIYA, SRI LANKA

## CHALLENGE

Due to the age of the dam and its importance to the infrastructure of the country, the Mahaweli Authority of Sri Lanka determined the dam's original monitoring system required a major upgrade. Authorities needed continuous monitoring capabilities to analyze the structural integrity of the dam, as well as to understand its behavior according to the dam's original design. The team investigated modern structural monitoring technology and ultimately selected Trimble sensors and Trimble 4D Control software to build a sophisticated motion monitoring instrumentation network.

### The crown jewel of Sri Lanka dams

Considered by many as the crown jewel of Mahaweli Development Projects, the Victoria Dam is built in a deep valley just above the Victoria Falls rapids and 300 meters (984 feet) below the point where the Hulu Ganga river meets the Mahaweli River. At the time of its original construction, the dam's funding, design and the technical expertise was provided by the United Kingdom. Then Prime Minister Margaret Thatcher was at the dam's ceremonial opening in 1985 along with then-president of Sri Lanka, J. R. Jayewardene.

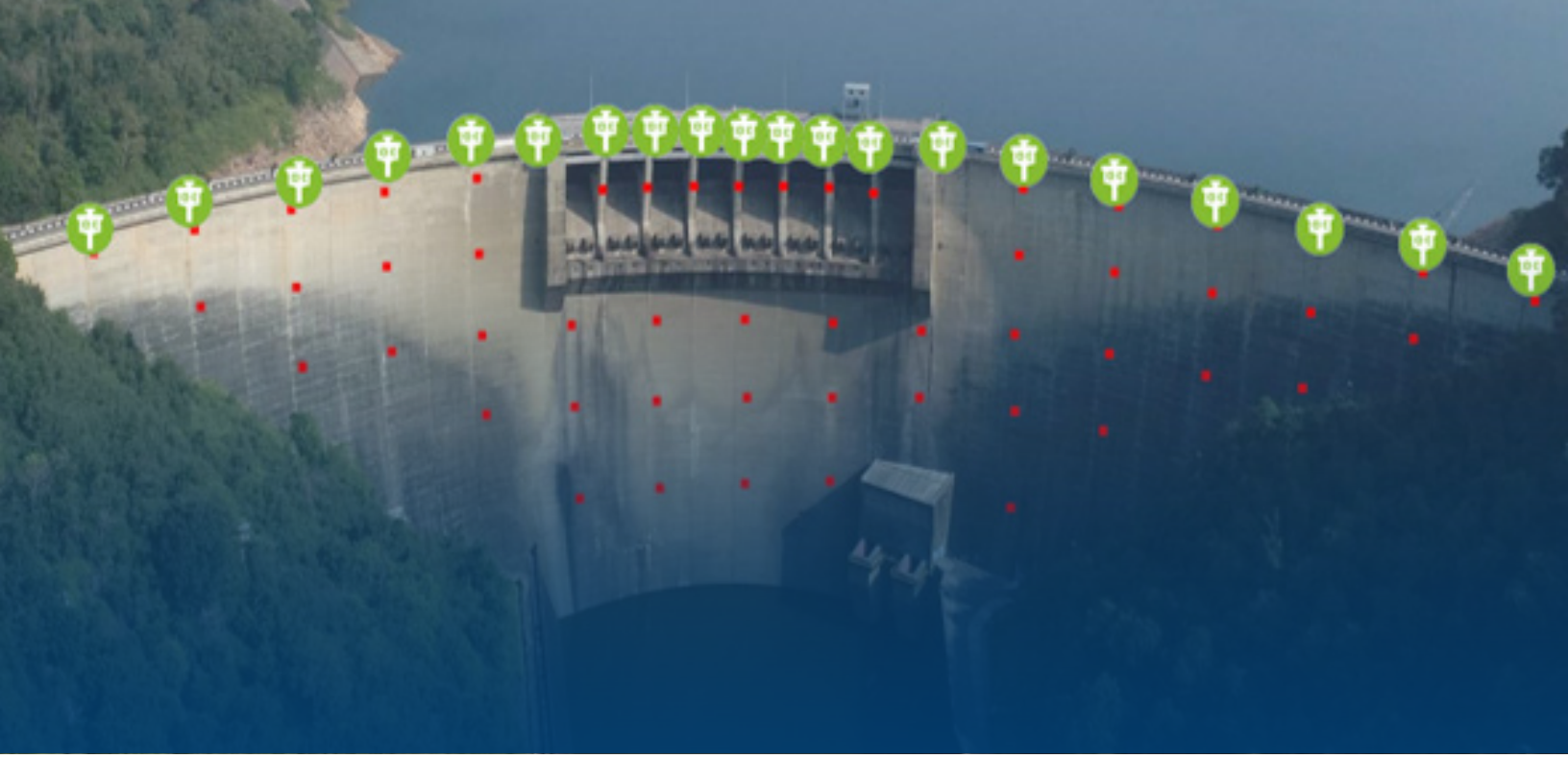
The dam is 520 meters long and 122 meters high (1,706 feet long by 400 feet high) and has a width of six meters (19 feet) at the crest and 25 meters (82 feet) at the base. Water from the dam is fed to a powerhouse via a 5,646 meter (18,523 foot) tunnel. From there, tanks feed three 70 megawatt, 12.5 kV turbines, which produce up to 780 gigawatt hours of electrical energy annually (roughly six percent of Sri Lanka's power). The dam creates the Victoria Reservoir which has a gross storage capacity of 722,000,000 cubic meters. (Source: Amazing Lanka).

The region where the dam is located has periods of extreme rainy seasons, which can dramatically impact reservoir water levels to potentially unsafe tolerances. When the dam was originally constructed, engineers installed a comprehensive monitoring system that included a geodetic system and instruments embedded into the dam's structure. Monitoring tasks were conducted manually, including the geotechnical sensors that were surveyed by staff every two weeks and the geodetic points, which were measured and recorded on an annual basis.

### Original monitoring equipment shows its age

Over the years, some of structure's original measurement equipment stopped working properly, parts became unserviceable and the accuracy of the data produced was compromised. Er. S.R.K. Aruppola, Director of Operation and Maintenance for Victoria Dam, explains the dam's conventional manual geodetic measurement processes were becoming tedious and dangerous to manage as the terrain is steep and slippery. Measuring and recording the dam's movement with these instruments was also prone to human error, requiring the team to fix each instrument on four different pillars and take multiple sets of readings at separate intervals. Adding concern, minor cracks in the dam were found in 1996.

After consulting with technology specialists, the dam's director and his team began designing a fully-automated, real-time geodetic system to replace the manual monitoring system. The new monitoring system is comprised of several components, including Trimble NetR9 Ti-M GNSS receivers and GNSS antennas, Trimble S9 robotic total stations, Trimble DiNi digital precise leveling instruments, automated water level reading systems and the integration of other geotechnical instrumentation. In addition to these components, all movement sensors were designed to connect to the core of the monitoring system — Trimble 4D Control monitoring software. Trimble 4D Control software collects, processes, visualizes and analyzes the data of all monitoring sensors installed at the Victoria Dam and populates the results in real-time through an intuitive web interface. The software also issues alarms automatically whenever the system detects movement outside of user determined, acceptable parameters and sends status reports at user defined intervals.



## Optical monitoring—setup of prisms and robotic total stations

*"We selected existing monitoring station pillars on opposing banks for the new total stations to make sure all parts of the dam wall could be monitored, even when the overflow gates are open. We couldn't risk not being able to obtain a reading due to cascading water."*

Because of the double curvature of the Victoria Dam wall and often rainy conditions in the area, installing the required monitoring instrumentation across the dam was quite challenging. To start, the team had to develop a safe method to install the instrumentation, which included the construction of a gantry-like system suspended from a crane. This setup allowed an engineer to reach the wall of the dam safely to install the components, even at its most concave shape. The team installed 72 monitoring prisms set across the dam wall and on the dam crest next to the overflow gates. Forty-eight of these prisms were placed at the same locations as the pre-existing survey targets, and 24 were added at new locations. In addition to the prisms at the dam, 40 prisms were installed on the left bank of the dam and 32 on the right bank.

During installation, the team also set up 64 millimeter (2.5 inch) prisms as part of the control network for the Trimble total stations, comprised of four points per station. The Trimble S9 total stations collect data measurements automatically for consistent and reliable data capture of all movement across the dam. Today, the total stations are scheduled to take a two-face observation of all prisms every three hours, which takes approximately 20 minutes. The collected data is then sent to Trimble 4D Control software for processing, analysis and visualization.

## GNSS and water level monitoring—setup of GNSS receivers and piezometers

To provide redundancy to prism monitoring and to monitor the stability of the control network, GNSS monitoring was integrated into the system. The team installed three Trimble NetR9 Ti-M GNSS receivers on the dam crest and one as a base station in the control center building. For integrated data processing, each GNSS antenna is co-located with a prism. All GNSS receivers on the dam crest transmit the observation data to the control center over Wi-Fi with a backup power source completing each GNSS station.

*"The Victoria Dam is a vital piece of Sri Lanka's infrastructure in terms of providing irrigation, electricity generation, and the sustainability and prosperity of the region. The new, automated monitoring system brings together all the data sources we need to focus on long-term structural stability of the dam and to study the behavior of the structure in accordance with its original design."*

Amongst other sensors, the team also incorporated vibrating wire piezometers and a wireless data logger system to automatically read water levels. The wireless data logger transmits readings from close to the center of the dam crest to the control center building where the server hosting the system's monitoring software is located. Currently, the GNSS processing interval is set to three hours, while the data logger of the piezometers sends new data sets once per hour.

# SOLUTION

## Bringing it all together—Trimble 4D Control monitoring software

The heart of the monitoring system is Trimble 4D Control monitoring software. Victoria Dam project leaders decided to install Trimble 4D Control on a server in the dam's control center. The software processes data from optical total stations, GNSS receivers, geotechnical and other types of sensors. The historic monitoring data was imported into the software to analyze the behavior of the dam since it was erected. The manually collected historic data, the new real-time raw data, as well as the processed results allow project engineers to apply additional, customized calculations to the sensor data.

In total, data from 479 sensors is pulled into the Trimble monitoring software. Because the data can be collected and correlated in one platform, today's dam engineers have a much better understanding of the structure's history and transitions over time.

*"With Trimble recorders, sensors and monitoring software, we now have greater confidence that we can spot any unexpected changes to the dam infrastructure and we can take steps to remediate issues to keep the dam functioning at optimal levels," said Er. Aruppola.*

# RESULTS

## Improved monitoring leads to enhanced analysis

With the implementation of an automated monitoring system, Victoria Dam engineers now have a much more comprehensive and accurate collection of movement data at their fingertips. The team can focus their efforts on detailed analysis, predicting future behavior and continually studying the behavior of the dam with the added security of the system's automated alarm system that alerts them to any changes to the dam exceeding set thresholds. The real-time, and now accurate, data allows the team to determine temperature and water level effects, and their influence on temporary movements, as well as permanent deformations. Among other observations made since the adoption of Trimble equipment, the team has noticed irreversible swelling of the concrete of the dam, which will continue to be observed.

*Commenting on the new monitoring system post-installation, Er. Arrupola observed, "Working with Trimble's automated, real-time geodetic GNSS monitoring data, combined with automated water level readings, has enabled us to establish a more complete and more accurate method for monitoring movement, reservoir crest levels and possible swelling of the Victoria Dam."*

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