DAM SAFETY & GEOTECHNICAL MONITORING, DATA DISSEMINATION & ALARMS

Sutron’s New Wireless & Master Stations Are Easily Integrated with Existing Piezometer Networks & Provide Communications via GOES, IRIDIUM®, GPRS/GSM & Spread Spectrum.

New Dam Safety Monitoring Systems and Upgraded /Expanded Existing Vibrating Wire Systems

Sutron’s state-of-the-art XPert Datalogger is the ideal base for dam performance monitoring when interfaced with any of several vibrating wire devices and multiplexers. XPerts, with built-in MODBUS protocol and unlimited sensor versatility, can also be used for reservoir pool and inflow/outflow monitoring.

Sutron also offers complete, multi-mode telemetry systems (GOES & Iridium® satellites, GSM/GPRS, PSTN/modem, all LOS radios and repeaters, IP-Accessible, hard-wire, Direct-Connect, etc.) and Base Station Software for recovering data, creating automated reports in any format required, posting data to the Web, sending alarms and alerts - all in real time.

Our latest Dam Monitoring asset is SutronWIN Real-Time Web Service for Hydro-Meteorological Data Collection & Dissemination. It provides Direct

Features

- Flood Control Dam Monitoring & Automated Data Acquisition using existing communications & instrumentation (vibrating wire) with new
- Sutron’s XPert Datalogger interfaces with existing Piezometers, Canary, Campbell Scientific Multiplexer/DSP Boards, Geocon 98020 Strong Motion Instruments, Crest Survey Monuments, Tilt Plates, Inclinometers, & other embankment instruments.
- The Results? Upgraded existing hard-wired networks & new wireless systems.
- Plus real-time data and remote status directly to your smart phone, laptop or web site.
- On-demand or on schedule automatic custom voice alerts/alarms, graphics, tabular formatting, reports...any way you want your data & in any format.
Case Study: Dam Data Acquisition & Alarm Reporting, Puerto Rico

The Puerto Rico Automated Dam Data Acquisition and Alarm Reporting System (ADDAARS) was designed to obtain, monitor and analyze, in real-time, critical safety parameters such as inflows, outflows, gate openings and lake elevations for 29 principal reservoirs.

Summary
This system allows dams to be operated more safely and emergency plans to be more effectively coordinated and implemented with the emergency management agencies.
ADDAARS provides information to decision makers in real-time through a combination of radio and satellite telemetry, microwave, fiber optic and Internet technology in order to:

- Improve the distribution and use of manpower
- Provide real-time data for safe dam and reservoir operation
- Reduce emergency response time
- Provide a precise and consistent data collection system.
- Provide the tools to monitor conditions of the dams and reservoirs in real-time at the emergency operation center and at the regional operations centers.

Equipment
Data collection platforms (DCP) collect data from sensors at each site and transmit values via satellite and radio.

Sensors
- Water level sensors
- Radar based sensors
- Submersible pressure gages
- Non-submersible (bubbler) pressure gages
- Pluviometers
- Tipping bucket rain gages
- Position sensors
- Shaft-encoders
- Integration with existing sensors (i.e. Modbus)
Hydropower & Dam Safety Monitoring

Dam Safety Monitoring

Process

- The DCP collects, stores, and prepares data for transmission via Satellite and Radio.
- The DCP manages all scheduling of sensor readings and organization of sensor data.
- The Satellite Transmitter receives data from the DCP and transmits it to the NOAA GOES East Satellite.
- Satellite communications are one-way from the station to the receive site.
- All scheduling of satellite transmissions is handled by the DCP and the satellite transmitter.
- After the DCP is programmed, nothing can be done during an event without reprogramming the DCP.
- Since all transmissions are scheduled, this is a near real-time system.
- During an event, the DCP will provide all the data needed.

Normal Conditions

- Data is collected and stored every 5 minutes.
- Data for every 15 minutes during the last 2 hours is provided to the satellite transmitter.
- Data is transmitted every 1 hour.
- Since the last 2 hours of data is transmitted every hour, each transmission contains 1 hour of fully redundant data.
- Data is received by central servers and stored in relational database management systems. Hydrologic database software with a graphical user interface is used to access the data.
- The system incorporates redundancy to maximize data availability under a wide range of hydrologic and meteorologic conditions.

Hydrologic Database Software

- Hydrologic database software is used......
  - to decode satellite and radio transmissions
  - to store the decoded values in a database
  - to display the data in both tabular and graphical format
  - to send alarms via beeper messages, email, fax or specialized programs
- A graphical user interface (GUI) is used for quick and efficient access to data from multiple stations and sensors.
- The hydrologic database software provides flexible tools to review satellite and radio data either independently or together.
- The database software also facilitates evaluation of station conditions and data quality, as well as provides a wide range of reports to present both summarized and detailed information in printed form.

Alarm Conditions

- Data is collected and stored every 5 minutes.
- Data for every 5 minutes is provided to the satellite transmitter.
- Data is transmitted every 5 minutes while the event lasts.
- Since only one value is transmitted, no redundancy occurs in alert mode.

Transmission Types

900 MHz Spread Spectrum Radios

- The radios do not require an FCC license to operate while VHF radios do require a license.
- The radios are subject to less interference when compared to VHF radio frequencies.
- They have the capability for 10/100 BaseT networking at 512 mbps.
- They have two network-routable serial ports.

Satellite

- More reliable in extreme events
- Minimal management during an event
- Near real-time system, events are scheduled... not triggered.

Radio

- True real-time system, events are triggered
- Two-way communication allows for better management of the station
- More susceptible to damage in extreme events.
**Hydropower & Dam Safety**

**Dam Safety Monitoring**

**Hydropower Services**
- Inflow Monitoring for Short Term Scheduling
- High Hazard Dam Warning Systems
- Water Use Optimization
- Input to Real-Time Models
- Inflow/Outflow Monitoring Systems
- Compliance Monitoring
- Instream Flow Requirements
- Ramp Rates
- Water Rights Monitoring
- Water Quality Monitoring
- Gate Control
- Geotechnical Monitoring Systems

**Hydropower/Dam Safety Customers**

| PacificCorp | Florida Power & Light |
| TVA | PG&E |
| Northeast Utilities | Southern California Edison |
| Millineum Power | Bureau of Reclamation H |
| Hatfield Hydro | Thunder Bay Power |
| So. New Hampshire Power | Consumer Power |
| US Army Corps of Engineers | American Power |
| Reliant Energy | Niagara Mohawk |
| Grant County, WA PUD | EWEB |

**Case Study: PacifiCorp**

**North Umpqua Hydroelectric Project**

**FERC Project No. 1927**

Compliance with Oregon Water Resources Department (OWRD) licensing regulations by monitoring flow in the network of canals withdrawing water from the North Umpqua River and its tributaries near Toketee Lake.

As one of the lowest-cost hydropower producers in the U.S., PacifiCorp generates 8,000 megawatts of energy for nearly 1.5 million customers in the Pacific Northwest.

On July 19th of 2000 PacifiCorp agreed to monitor flow in the network of canals withdrawing water from the North Umpqua River and its tributaries near Toketee Lake to assure water rights compliance.

Sutron received contracts for the first two phases of the project. The contract for the first phase, valued at $200,412, was completed in 2001.
The contract for the second phase of the project, valued at over $369,500, was awarded to Sutron in July 2002 (included with July 2002 bookings) to be completed by October 31, 2002. The contract for the third phase of the project, which will include real-time telemetry for all existing gauging stations, is expected in 2004.

In the first phase a set of four stream gauging stations were established on the main canals supplying water for generation. In the second phase an additional 15 monitoring stations will be added on the natural stream reaches adjacent to the canals and on the penstocks that feed the project generators. Data from all the sites will be brought to PacifiCorp’s Toketee Control Center where it will be available to system operators.

The system will produce daily water usage reports and compare water usage to minimum and maximum allowable flows.

The turnkey system is designed, built, installed, supported and maintained by Sutron. Sutron also provides PacifiCorp with the following:

- Hydrologic engineering services, stream gauging, installation of staff gauges, all data logging instrumentation and equipment, gauge houses
- Data reporting software and training of PacifiCorp employees for maintenance and operation.

**Requirements**

In 2000, PacifiCorp met with Oregon Water Resources Department (OWRD) representatives at the Toketee Control Center to review PacifiCorp’s schedule for bringing the North Umpqua Project into compliance with operating licenses that specify maximum diversion from each natural stream as well as minimum flows to be maintained in bypass reaches (natural streams) below project diversions. The resulting agreement stipulated installation of a gaging system to account for all project diversions and bypass flows. Discharge data from the canal gaging system and penstock flowmeters was to be reported to the District 15 Watermaster’s Office in Roseburg, Oregon, on a daily basis. Flow information from bypass reaches will be reported daily beginning in 2001.

The resulting project has two phases. Phase I provides for monitoring flows in canals (by datalogger) and penstocks (by ultrasonic flowmeters). Reports will be generated by operators who acquire data from the logger network and the penstock flowmeters. Phase 2, completed by October 31st of 2002, will add monitoring of bypass reaches and bring all of the data to the Toketee Control Center by means of a radio network. A computer system will allow operators to monitor flows in real-time and will automate report generation for OWRD. OWRD requirements:

- Gages will meet applicable United States Geological Survey (USGS) standards.
- Rating tables for each gage will be developed from current meter measurements over the range of expected canal flows.
- Each rating will be verified annually to ensure accuracy
- Discharge data from the canal gaging system and penstock flowmeters will be reported to the District 15 Watermaster daily beginning in 2001.
- Flow information from bypass reach USGS gages will also be reported daily beginning in 2002.
### The Problem

Because the area is mountainous with canal and river sites scattered over a 100 square miles, flow monitoring for North Umpqua presents challenges. Bypass reaches are in areas difficult to access, even on foot. Sites are often surrounded by tall trees, inhibiting communications and preventing use of solar panels for power. Access is primarily via dirt roads, barely passable in bad weather. Visiting each site daily requires heavy manpower (about 4 hours for a complete circuit). A water right or flow violation could go undetected for days. Viewing flow conditions in real-time is critical.

### The Solution - Phase 1

Monitoring canal and river flows requires sophisticated expertise so PacifiCorp asked the U.S. Geological Survey to recommend a vendor. Sutron Corporation, a designer/manufacturer/installer of turnkey remote monitoring systems, was recommended. Sutron and PacifiCorp agreed to focus on canal sites in 2001 (Phase I) and completion of the entire system by October of 2002. ODWR Phase I requirements will be met by placing permanent gaging stations near the downstream ends of major canals, using data loggers (without telemetry) that read flow directly by determining the relationship between flow depth and discharge rate and that store flow data.

Real-time flow data requires a communications network. PacifiCorp has in place a variety of hard-wire and fiber optic links and has conducted experiments with line-of-site radio. PacifiCorp's access rights to an existing radio repeater site at Cinnamon Butte to the east of the project area will be an integral part of the solution. A complete radio path survey to facilitate design of the communications network for Phase 2 was completed in September, 2001.

### The Solution - Phase 2

The Phase 1 monitoring system was in place by October 31, 2001 and the communications path survey to determine the exact combination of radios, repeaters, and other links needed to bring data back to the Control Center is finished. Next, the final communications system including data loggers and communications for the bypass reach sites will be implemented. The penstock flow meters will also be integrated into the telemetry network.

When the entire computer system and software have been incorporated, operators will access a computer that stores canal and stream gage ratings which are correctly updated if changes are indicated by the stream gaging program. Ratings will be used in real-time to convert the telemetered stream and canal stages to flow. Values of the stage readings and the flows will be stored in a relational database that limits storage time for telemetered stage values and computed flows to 6 months.

There will also be a process that automatically generates OWRD flow reports containing tables showing site-specific stage and flow measurements at a mutually-agreed-upon time of day and that stores this data on the system hard drive. A graphical man-machine interface (MMI) will aid operators in station setup and interpreting data. Trained personnel will use the MMI to change station characteristics as well as add or remove stations.

The primary operator display will resemble a spreadsheet that contains a list of system gaging points and the current stage and flow. The display will update in real time.

The table will update every 15 minutes (interval set by agreement with OWRD). Stations whose report times are more than 20 minutes old will be marked by yellowed time panels. Stations whose report times are more than 1 hour and 10 minutes old will be marked by red time panels. Yellow and red time panels will alert the operator to any problems with telemetry.

The table will also provide water right and low flow alerts. When flow exceeds the water right for the site, the flow value will be changed to blinking red and the amount of the alert will be presented in a separate "alert" window at the bottom of the table. Similarly, the system will warn if the flow drops below the specified minimum. The design will allow for multiple alerts (alerts at more than one site.)

### Summary and Conclusions

PacifiCorp’s real-time flow monitoring network will allow project operators to view the flow in system canals, bypass reaches and penstocks in real time as well as alert them when any violation of minimum flow requirements or water rights takes place. The system will use line-of-sight radio, fiber optic, and hard-wire communications technologies, data loggers, streamgaging stations, and ultrasonic flowmeters. It will save about four person-hours per day and greatly shorten response time to any flow change situation.
Integrating with Existing Dam Monitoring Networks

Sutron began working with New England District of the Army Corps of Engineers (NAE) in early 2005 on geotechnical applications. NAE has responsibility for 31 flood control dams in Connecticut, Massachusetts, New Hampshire and Vermont.

**NAE’s GOAL - Upgrade Existing Dam Monitoring Systems at 31 Flood Control Dams**

Sutron provided the following:
- Automated instrumentation system to reliably collect and transmit performance data
- System used the existing communications infrastructure (primarily GOES Satellite)
- System used as much of existing instrumentation (primarily vibrating wire piezometers) as possible

**Datalogger**

Sutron’s **XPERT DATALOGGER** Interfaces with Existing Geotechnical Instrumentation
- Piezometers, Canary MiniMux, Geocon 8020
- Strong motion instruments
- Crest survey monuments
- Tilt plates
- Inclinometers
- Other instruments to adequately monitor embankment performance
Integrating Sutron’s Xpert Datalogger & SatLink2 GOES Transmitter/Logger into an Existing Vibrating Wire System Using Sutron System Software

GOES SATELLITE DAM SAFETY MONITORING EXAMPLE:
XPERT & SATLINK INTEGRATED INTO EXISTING VIBRATING WIRE NETWORK PLUS ADDITIONAL NEW POLLING STATIONS
Sutron is the only GOES Transmitter Provider Who Can Guarantee 30 Day Repairs Turn-Around.

All other providers depend upon 3rd party manufacturers

Plus, Sutron’s GOES Transmitter Has a 3-Year Warranty.
Information on piezometer levels and other geotechnical parameters has traditionally been collected by hand or by ground-based radio or hardwire telemetry systems. Sutron Corporation has worked with the New England District, US Army Corps of Engineers (NAE) to develop alternative telemetry networks combining line-of-site radio, hard-wire, and GOES (Geostationary Operational Environmental Satellite) messaging.

NAE has responsibility for 31 flood control dams in Connecticut, Massachusetts, New Hampshire and Vermont. These dams control flood runoff in four major river basins in these states. All USACE dams are required to have a level of instrumentation that enables proper monitoring and evaluation of the structure under all operating conditions.

Geotechnical instrumentation at NAE dams consists of piezometers, seismic strong motion instruments, crest survey monuments, tilt plates, inclinometers, and other instruments as deemed necessary to adequately monitor embankment performance. Automated instrumentation systems are currently being installed at each dam to collect and transmit data from the piezometers, seepage measurement devices, pool level sensors and strong motion instruments to the NAE District office. These systems will improve the early warning of potentially critical embankment performance parameters. The GOES system is a key part of the telemetry.

System installations consist of two types:
- Upgrades to existing hard-wired systems
- New, automated wireless systems.

The master data collection station at each site is a programmable data logger. Sutron developed custom software for the loggers to support the necessary multiplexing equipment.

Automated data is sent from the master stations at each site via network modems and/or GOES transmissions. Data is decoded and streamed into an Oracle database, with automated tabular, graphical, and visual Dam Safety output products posted on the web.

The upgrades to the hard-wired systems consist of data logger and telemetry upgrades using existing vibrating-wire piezometers. The upgrades have the advantage of requiring only a single data logger with a multiplexer and wiring to each piezometer. The disadvantage is a greater incidence of lightning damage to equipment, vs. having more data loggers to maintain at wireless field stations. The new automated wireless systems at NAE are field stations with solar power and battery backup. These systems employ pressure transducers utilizing 4-20 ma output.

Use of GOES Satellite Transmissions in Dam Monitoring

GOES Dam Safety Monitoring

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Abstract

The New England District of the US Army Corps of Engineers (NAE) was a pioneer in adopting the Geostationary Operational Environmental Satellite (GOES) system for hydromet operations. NAE was one of the first districts to purchase a direct-readout ground station for GOES in the late 1970s.

The GOES system is a worldwide network of geostationary satellites parked in fixed positions over the equator. The satellites, primarily used for hurricane tracking and other weather-related activities, are also equipped with a data collection system (DCS) link. The DCS link allows licensed users to transmit environmental data through the GOES network to their own ground stations or to the central GOES ground station operated by the National Oceanic and Atmospheric Administration’s (NOAA’s) National Satellite Data Information Service (NESDIS) at Wallops Island, Virginia. The original GOES DCS link limited users to 100 bits per second (bps) data through assigned one-minute windows every four hours. Additional emergency data could be sent through two dedicated “random” channels by any user with no assigned time windows. The system has been improved over the years so that users can now transmit 300 bps data through 10-second windows every hour. The availability of hourly data has greatly increased the utility of the system. Hourly data is adequate for daily operations on many larger river systems.

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Piezometer Networks & GOES

A key element of earth-fill dam performance monitoring is an installed piezometer network. The purpose of the piezometer network is to allow the operating agency to monitor the piezometric surface within the toe embankment to ensure that the surface remains within the embankment and that piping does not occur.

The piezometer network is often installed during construction. Fifteen to thirty or more pressure transducers – typically based on vibrating wire technology – are buried in the embankment or suspended in small diameter bore holes within the embankment. The transducer cables can be terminated in individual locations at the borehole, or, in some instances all extended to a central location and terminated in a junction box.

Piezometer levels are not expected to change rapidly. Rapid change is exactly what is NOT expected. Thus the reading of the piezometer levels has traditionally been done by manual methods. A “readout box” can be attached to an individual sensor, or the box can be attached to a switch in the central junction box. Readings are then taken manually and recorded so that piezometric surface plots can be created.

The nature of the piezometer networks presents the greatest challenge in using GOES as a telemetry method. Virtually all NAE dams are equipped with GOES telemetry. Typical dams transmit the pool elevation and outlet discharge. GOES is used at streamgaging stations to transmit river stage and compute inflow discharges. Many sites are equipped with rain gages and other weather instrumentation. The traditional instruments used to make these measurements provide zero to five-volt DC outputs, switch closure outputs, and other standard outputs that are compatible with the telemetry devices used for GOES. The GOES telemetry devices, called Data Collection Platforms (DCPs) can automatically take readings from any of the common hydrologic instruments used for pool elevation, stream stage, and weather. Most DCPs do NOT incorporate the technology required to take readings from vibrating wire piezometers. The manufacturers of vibrating wire equipment usually use proprietary techniques to make pressure measurements, and provide proprietary readout boxes for use in making manual measurements. In addition, most DCPs are not designed for large numbers of inputs of one type. The limited bandwidth of the GOES system (300 bps and 10 seconds of time per transmission) means that most DCPs are designed with limits such as 8 analog sensors or some other fairly low limit. Special hardware and software techniques are required to read a vibrating wire network and incorporate the information into GOES transmissions.

A secondary issue related to the use of GOES is costs A single GOES DCP, along with the associated enclosure, antenna, solar panel or AC power supply, and battery can cost as much as $4,000. It is thus not practical to put individual DCPs at single transducers. Some type of network hardware is required.

Solving the Hardware Problem

Three types of hardware problems typically present:
1. Bringing signals from a large number of individual piezometers to a central location where the DCP is.
2. Interfacing the large number of sensor signals to a typical DCP that is not designed for large numbers of one type of input
3. Interfacing vibrating wire sensors to a typical DCP

The first problem, that of bringing the piezometer levels to a central location, is a function of the age of the dam being monitored. Older dams are equipped with vibrating wire sensors that are already wired to central locations. These older sites offer mixed benefits.

The wiring problem is already solved, but the long wires are often buried in shallow trenches and make excellent lightning antennas. Nearby lightning strikes can generate surge voltages in the signal cables. The surges are easily capable of burning out individual signal channels, or in some instances burning up complete data loggers and associated equipment.

Sites with individual sensors terminated at the top of bore holes offer a different challenge. Extending wires to each site is not desirable because of the lightning problem. Fiber optic links are feasible, but extending trenches over the toe embankment can be problematic, depending on what type of surface material is present, the slope, and other factors. The method chosen by NAE is to make use of low-cost ($300 to $500), license-free, spread-spectrum radio
modules. These modules can be placed in small housings atop individual bore holes and used to relay the piezometer signal to the central location, thus eliminating wires and most of the lightning-related problems.

The second problem has a dedicated hardware solution. The manufacturers of piezometer equipment offer hardware multiplexers that:

- Allow the user to wire large numbers (in increments of 16 – i.e. 16, 32, 48, etc.) of instruments to a single input/output (I/O) board
- Optionally contain the necessary hardware/software required to take readings from a vibrating wire sensor
- Provide data from the sensor network as either a serial digital output, analog output, or four-to-twenty-milliamp output

The use of a multiplexer requires programming capability within the DCP or the data logger that drives the DCP. The necessary programming is described in the next section.

The third problem, reading the signal from vibrating wires, has two solutions. The first solution is to incorporate more dedicated hardware. Multiplexers are available with a module that can “ping” vibrating wires and return the pressure value. The second solution is to make use of pressure transducers that offer standard zero to five volt or four-to-twenty-milliamp outputs that can be read by the DCP.

Figures 1 and 2 illustrate typical solutions for the hardware problems associated with using piezometers with GOES DCPs. Figure 1 illustrates a typical multiplexer solution as used with an existing vibrating wire network connected to a central location. Figure 2 illustrates the general structure of a network that makes use of spread-spectrum radio links to bring the piezometer data to the central location.

Note in both figures that the device labeled Satlink is the GOES DCP. It is connected to an antenna that is pointed at the GOES satellite. The device labeled XPerit is a data logger.

The data logger is required for data storage and to provide the necessary programmability to read the multiplexer and/or poll the individual piezometer sites using the spread-spectrum radios.

Transmitter, DCP & Software Issues

The type of DCP used must be considered carefully when deciding on which GOES Transmitter is appropriate for use with a piezometer network. Two general types of DCPs are offered.

The first type is a dedicated “OEM” transmitter. These DCPs typically offer no specific input/output capability. They are designed to be used as a general purpose output device for any manufacturer’s data logger. These DCPs accept a serial data stream as input and handle the work associated with creating a GOES message and transmitting it on time.

The second type is a combined data logger/transmitter. The combined units are capable of reading a variety of inputs – typically a number of analog voltages, a special serial interface called SDI-12, counters, and switches used for tipping bucket rain gages. Most also offer some type of serial interface. These DCPs can be connected directly to hydrologic instruments. They collect data on a schedule, maintain a log of values, and handle the GOES transmissions. Some offer programming capability so that the user can write special data handling software such as interfaces to serial instruments or custom averaging routines.

The piezometer-monitoring network developed by NAE uses a programmable data logger and DCP. The data loggers are programmable either in BASIC or C++. The programmability made it possible to incorporate the necessary software to schedule data collection on the multiplexer and also to poll data using the spread spectrum radios. The data logger is used to collect data and format the GOES messages. The DCP is used strictly for scheduling and sending the messages.

Two types of multiplexing hardware are used by NAE. One type combines the multiplexer with a module that is capable of reading vibrating wires. The other just uses the multiplexer to read analog or four-to-twenty milliamp signals from a network of sensors. The multiplexer/vibrating wire combination provides data as serial values from the vibrating wire interface module. The multiplexer by itself provides a four-to-twenty milliamp or analog voltage output. In either case, programming is required. The multiplexer must be controlled by the data logger in both cases. A software module is required that sends “clocking” signals to the multiplexer to tell it which piezometer it is to read. The clocking signal consists of a timed series of zero-to-five volt pulses. Typically one pulse means “read channel one”, two pulses means “read channel two”, and so on.

If the multiplexer is being used alone, then its output will be tied to a single analog or four-to-twenty-milliamp input on the data logger. A software module must be created to tell the data logger which sensor is connected at a particular time, and when and where to log the data. The logger typically “knows” how to take data from the logged values and create a GOES message.

When the vibrating wire interface module is used along with the multiplexer the data enters the logger through a serial port. The same clocking software can be used to set the multiplexer to a data channel. Different software is required to open a serial port and read the data provided by the vibrating wire module. Logging the vibrating wire data and sending the GOES message are the same.

For more information on Dam Safety Monitoring Systems, please contact Sutron Corporation at (703) 406-2800, email: sales@sutron.com, or on the web at www.sutron.com.