Appendix D
Automatic Data Acquisition Systems

D-1. General

The concept of remote, automatic monitoring of dams is a proven alternative to conventional manual monitoring systems typically installed in Corps dams. However, technologies are constantly being developed and evolving with time. Many are not appropriate for common needs nor are they reliable for various applications. Therefore, caution and professional judgment of individuals with dam monitoring experience is essential for designing and implementing automated systems on a case-by-case basis.

Automated monitoring systems have become very common in the industry since the early 1990s. It has been thoroughly developed and successfully implemented for several instruments such as piezometers and relative movement devices. It is currently considered the "state of practice" for the dam safety industry.

This document does not attempt to duplicate information available from other sources (see References at end of this appendix) nor does it present all information necessary for all system applications. The information presents some key considerations and prudent approaches for the discretionary use by dam safety professionals.

D-2. The Decision to Automate

Automating monitoring systems does not solve dam performance problems but is a tool that can enhance the evaluations. Automation comes with a cost in terms of economics as well as organizational expertise and process. In general, the justification for automating instruments should be based on the need for the advantages it offers. The features that are included in automated systems should be restricted to gaining the advantages that are needed rather than attempting to integrate more capability than is necessary. The consequence for overly sophisticated or complex systems can be greater incidence of malfunction and the forfeiture of critically essential information. There are also disadvantages, or limitations that must be considered in the decision process. Therefore, strong purpose is necessary to not only justify the initial system, but to assure the availability of the resources, expertise, and continued attention that will be necessary during the life of the system.

D-3. Advantages

Automated systems have proven to be extremely beneficial for identifying problems, defining the causes, and understanding the characteristic behavior of a dam in ways that were previously not possible with manually monitored systems. As a result, automated systems have reduced the need for dam safety modifications, justified needed action requiring priority attention and funding, reduced risk associated with lives and property downstream of high hazard dams, and accomplished other types of necessary dam safety efforts. Some of the more useful advantages of automated system are:

- Increased accuracy
- Increased frequency
- Consistency
- Supplement staff
- Remote acquisition, operation, diagnostics
- Timeliness of information
- Immediate data reduction

- Enables rapid data validation
- Alarms
- Compatibility with a other functions such as security, emergency response, etc.

D-4. Disadvantages

In addition to capital cost of the components of the system, there are some disadvantages that are characteristic of the technology and operation. The disadvantages may include, but are not limited to, the following:

- Vandalism
- Lightning
- Specialized Expertise
- Excess Data
- Harsh Environment Conditions
- Maintenance

Some or all of these could negatively impact any particular system application. Generally, the limitations can be accommodated if the advantages are important. Experience with addressing the negative impacts on automated systems has been gained by the Corps of Engineers as well as from other major dam owners in the industry. Advice on these matters should be pursued and implemented to enable the benefits of automation to improve dam performance monitoring.

D-5. Components

A rendering of a typical configuration of an automated system is shown in Figure D-1. An example of a remote monitor unit is shown in Figure D-2. Components of such a system would typically consist of sensors, data loggers, on-site computers, communications, power supplies all with the appropriate grounding and transient protection. The typical system is operated by software to acquire, reduce, store, and transmit data to a remote location for assessment. The sensing technologies can include electronics, acoustics, laser, GPS, and others. Communications can be cabling, radio, fiber optics, telephone, satellite, and others. Data can be downloaded by direct connections to hand-held devices or laptops and to personal computers via remote telemetry. Personal computers can be used in a stand-alone, or networked environment. The most appropriate configuration, combination of components and means of data transmission are functions of case-specific characteristics and needs determined by those professionals responsible for the performance assessment of dams.

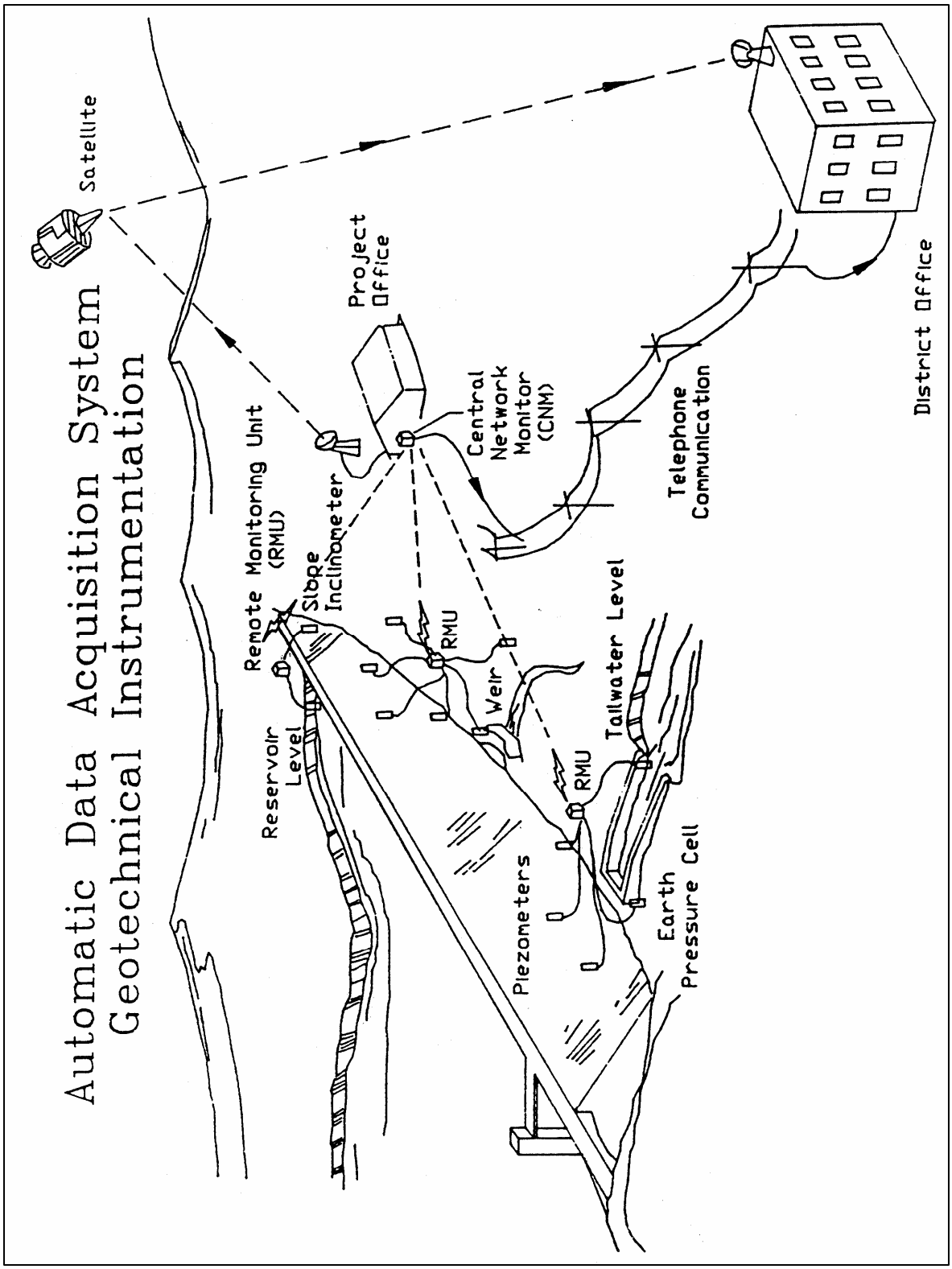

Figure D-1. Typical project automation plan

Figure D-2. Remote monitor unit in protective structure showing solar panel, pressure transducer, and portable computer

D-6. Technical Issues

When planning and designing automated systems, the dam safety professional should utilize a failure mode analysis technique (reference ER 1110-2-1156, Appendix H) to determine the most critical parameters to be monitored. This information will be used to locate the instrument and choose the appropriate sensor. The installation requirements will be a function of the instrument manufacturers' specifications and the dam construction process. Each system should include the following basic requirements as a minimum:

a. Each instrument should be capable of being read manually after automation or provide a manual redundant instrument.

b. Each instrument should be capable of being read electronically prior to entering the automated net.

c. The network monitor station should be able to collect, store, process, display, and produce a hard copy of the data at the project office, or other designated point on the dam site. This network monitor station should also be capable of performing a quality control check of instrument readings, responding to a preset threshold level, and having the capability of being queried from the district or other remote location.

d. A backup communication link to the district or manual access should be provided to assure availability of data.

e. The automated system should not relieve or replace the normal visual inspection schedule of the project features.

f. A backup power supply should be provided.

g. Appropriate grounding and transient protection should be provided.

h. The level of required maintenance and the associated level of expertise should be considered when planning and designing the system. Involve the O&M entity early in the process.

i. Vandalism protection should be designed.

j. Readily understood and easily supportable products should be opted for, avoiding proprietary software and hardware.

k. Compatibility of newly designed automation system with existing hardware, software, and organizational expertise and processes must be assured.

Under no circumstances should the entire responsibility of planning, design, installation, operation, and maintenance be given to a party other than to the safety professional of the dam. A thorough working knowledge of the system must be retained within the Corps organization. And final responsibility for the acquisition of reliable and meaningful data must remain with the Corps of Engineers. It is strongly recommended to make use of the Center for Automated Performance Monitoring of Dams for development and/or review of critical phases of system design and implementation.

D-7. Procurement

While it is always preferred to accomplish the more significant efforts in-house, it is recognized that contracting is often necessary to accomplish automated instrumentation. The sophisticated technologies of automated systems in conjunction with the importance of reliable information for dam safety assessments preclude the use of some popular procurement practices meant for more conventional work. Procurement of components and installation should not be done by prime dam construction contractors but by specialized

subcontractors with at least 5 years of specific, practical experience in monitoring and assessing dam performance. Avoid small business/low bid initiatives. Justify sole source and/or "brand name or equal" whenever necessary to assure compatibility, reliability, and compliance with specific dam safety requirements. Many of the major instrument manufacturers are on General Services Administration (GSA). Regardless of the method of procurement, insist on verifiable laboratory performance data for components, field calibration after installation, warranties, system-wide demonstration of performance, training, and a period of follow-on maintenance to monitor initial operation and make adjustments.

D-8. Data Acquisition and Management

Effective use of the automated system may influence the design or installation and also may require organizational processes to be modified. The data acquired from automated systems should be used for a variety of purposes, including: more accurate and timely dam performance analysis, assurance of data validity, assessment of instrument performance and system-wide health, established level and frequency of maintenance/recalibration, and archived for future reference.

To gain full advantage of the timely instrument data, it follows to also focus on commensurate timely performance assessments. In addition to instrument data, acquire, document and store other information that influences the performance analysis such as hydrologic and meterologic conditions. Instrument data should be formatted for rapid reduction and processing with software intended for dam performance assessments. Such software (WinIDP) is made available by HQUSACE through CEMVS-ED-G. Determine thresholds and engage alarms to draw immediate attention to conditions of concern. Integrate other pertinent electronic information such as cad overlays, GIS data, boring logs, hydrologic data, etc. to facilitate assessment and reporting of dam performance and condition. Additional information regarding data analyses and performance assessments can be found in EM 1110-2-1908 and ER 1110-2-1156.

In general, the operation of the monitoring system is based on the requirements defined by the dam safety professionals who are responsible for assessing the dam performance, and who should determine the frequency of data acquisition and the scenario of data processing. Periodical checking on system performance should be recommended to avoid prolonged periods of acquiring faulty information. Instrument data should be edited/masked to assure that only meaningful information is stored in a shared database. Excess information should be eliminated and that which is necessary for future reference should be archived. A database should be used that is compatible with all needs and intended uses of the information. Periodical reviewing of the process and the software will assure continued access and usability of the dam performance information.

D-9. Maintenance

Maintenance is necessary to assure reliable performance of the automated monitoring system. The level of maintenance can vary, depending on many factors, including: type of component/sensor, frequency of use, application, and environment. Maintenance can be minimized during the design phase by involving those that will be responsible for the operation and maintenance to assure compatibility with the level of expertise and the resource support planned for the system. The design can also specify the use of standardized products to facilitate compatibility with alternative manufacturers' products and ease of change out of malfunctioning components. Each system must have documentation that includes an operation and maintenance manual with troubleshooting guides, functional sketches, as-installed drawings, and recommended frequency of recalibration. There should be a supply of consumable replacement parts based on the designer and the installer recommendations. Additional guidance on the required level of maintenance can be acquired from users of similar systems.

D-10. References

Additional guidance is available from the following sources:

- EM 1110-2-1908, Instrumentation of Embankment Dams and Levees, 30 June 1995.

- General Guidelines for Automated Performance Monitoring of Dams, United States Society on Dams, October 2002.

- Corps-wide Center for Automated Performance Monitoring of Dams, CEMVS-ED-G.

- ETL 1110-2-316, Database for Automated Geotechnical Instrumentation, 15 November 1988.

- ER 1110-2-1156, Safety of Dams – Policy and Procedure, July 2003