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In This Issue . . .

Development of Standing Operating Procedures for Dams

Maintenance and Maintenance Management Practices

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***Cover photograph*:** SOPs shown in the Technical Service Center's SOP/EAP file room.

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DEVELOPMENT OF STANDING OPERATING PROCEDURES FOR DAMS

by: Charlie Swanson, P.E., Bureau of Reclamation, Technical Service Center, Instrumentation and Inspections Group, 86-68360

The Bureau of Reclamation (Reclamation) has over 245 high- and significant-hazard dam facilities under its jurisdiction, with 5 regional offices and 25 area offices. Reclamation uses the term "Standing Operating Procedures" (SOP) to indicate the operating document used at their dams. Reclamation requires SOPs for all of their high- and significant-hazard dam facilities (see Reclamation Manual Directives and Standards FAC 02-01, http://www.usbr.gov/recman/fac/fac02-01.pdf). The SOP is a "living document," which must be kept current by, at least, annual reviews and revisions.

The purpose of the SOP is to ensure that specific operating practices and procedures are documented and applied to each of Reclamation's high- and significant-hazard dams. The instructions contained in the SOP will permit personnel, knowledgeable in reservoir operations but unfamiliar with the conditions at a particular dam, to operate the dam and reservoir during emergency situations and at times when regular operating personnel cannot perform their normal duties. SOPs may also be written for other facilities (e.g., low-hazard dams, diversion dams, canals, pumping plants, pumping-generating plants, fish facilities, regulating reservoirs, etc.), but are not required.

This article provides general information about the subject content for dams only, covering chapters I through IV and related appendices. This article excludes the discussion of the Emergency Action Plan (EAP) and Communications Directory related references and documentation.

For general consistency, all SOPs for Reclamation dams should be organized similar to Reclamation's Standing Operating Procedures Guide for Dams, Reservoirs, and Power Facilities (SOP Guide), in that all Reclamation SOPs for dams will have chapters I through IV as follows:

Chapter I	General Information
Chapter II	Structural, Mechanical, and Electrical
Chapter III	Structural Behavior Instrumentation
Chapter IV	Reservoir Operations
Appendix A	Reservoir Operation Supporting Material
Appendix B	Forms
Appendix C	Drawings
Appendix D	Glossary and Definitions

SOPs reflect that each dam and their operation and maintenance (O&M) procedures are detailed. The SOP is a unique document for each dam, as no two dams are the same. In addition to dam operating personnel, the SOP is often used by many other offices, including regional and area offices, operating agencies, and the Technical Service Center (Denver). Sometimes copies are also provided to other agencies (i.e., U.S. Army Corps of Engineers (Corps) for flood control operations). The SOP includes operating procedures for the equipment (gates, valves, generators, etc.) and maintenance requirements for the dam, mechanical equipment, and electrical equipment.

Prior to the development of SOPs, the Designers' Operating Criteria (DOC) was the first document used at a facility that included O&M procedures. Information from the DOC was often used in developing the SOP, as the SOP was written based on actual O&M requirements for the dam. After a period of time of operation using the DOC, it was important to capture the operator's "institutional knowledge" and to include this information in the SOP.

Key operating personnel/supervisors and related Reclamation offices are responsible for reviewing the SOP to ensure all the information is current. Suggested changes to the SOP should be provided to the issuing (area/regional) office for revisions. Recommendations are sometimes made during onsite field examinations to revise the SOP, and these recommended revisions should be made in a timely manner.

Lessons Learned

- It is important to note that key information that was in the DOC and/or Design Summaries must be included in the SOP. When available, the DOC and Design Summaries become supporting documents that should be listed in chapter I, Section M (Supporting Documents). Pertinent information from the DOC should be included into the SOP so that all O&M information for the dam is in one (controlled) document. It is recommended that there should not be any references made in the SOP to the DOC or Design Summaries since this information should be included directly in the SOP.

  For example, information in one particular DOC included procedures for installing an intake structure bulkhead gate. It stated that if the upstream portion of the outlet works conduit ever needed to be unwatered (drained) for maintenance purposes, the bulkhead gate was stored at another dam in another region. This particular bulkhead was designed to be used at several dams, but only one bulkhead gate was manufactured. All pertinent information from the DOC and the existence of the bulkhead needed to be verified and the current location of the bulkhead updated in the SOP.

The details in the DOC provided information about who to contact if the bulkhead was needed, the equipment and services required for transporting it, installation procedures, removal procedures, and maintenance. This information was included in the SOP so that if the bulkhead was ever needed, the information was available in the SOP without having to search for the DOC. References to the DOC were then removed from the previous SOP.

- "Caution" and "Note" statements are often used in the SOP. To ensure that this information is more visible in the SOP, "Caution" and "Note" boxes (a single-cell table) can be used as shown below. Warning information could also be used similar to the Caution box by changing the heading. Examples of a "Caution" and "Note" box are shown below.

CAUTION
The forced-air ventilation system for the vault is required to be in operation at least 30 minutes before entering.

NOTE
The Ongoing Visual Inspection Checklist should be copied and used for all inspections, with any deficiencies noted on the form.

- Digital photographs of the dam and appurtenant features, equipment, and controls for equipment operations can be beneficial and should be included in the SOP. There is no standard as to where photographs are located in the SOP. The decision as to the location of photographs should be made by the Reclamation office having jurisdiction of the dam. Consider having the photographs included within the SOP section where the feature is discussed in the text. This can be done with word processing software.

- Drawings should be included in the SOP as a means of providing additional information to supplement the text. Drawings that are referenced in the text of the SOP should be included if available. Consider including drawings in appendix C of the SOP. A complete set of the construction drawings should not be included, but rather only drawings that represent the key features, mechanical equipment, installation, general electrical drawings, piping systems, etc. Note that any drawings provided in the SOP are not to be used for construction purposes.

Chapter I – General Information

Section headings (A. through N.) are typically included in chapter I. A brief description about each of these sections is provided below. More detailed information about each of these sections is discussed in the SOP Guide.

A. Purpose of the Project

Briefly identify the dam and reservoir, state the authorized purpose of the project, and note the benefits.

B. Directions and Access to the Dam and Reservoir

Identify primary and alternate routes to the dam or alternate means (helicopter, snowmobiles, 4-wheel drive, etc.) of traveling to the dam. Provide information about the locations of the nearest commercial and small aircraft airports.

C. Assignment of Responsibility

Clearly identify all areas of responsibility in the chain of command with respect to dam and reservoir O&M. A summary of typical maintenance/inspection duties should be included with frequency headings shown (e.g., Daily, Weekly, Monthly, Quarterly, Semiannually, Annually, Every 3 Years, Every 6 Years, As Necessary, etc.).

D. Attendance, Communications, and Warning Systems

1. Attendance

   Note the operating personnel's residence location and distance to the dam, and state his attendance at the dam—either full time, part time, or unattended. For part-time and unattended dams, provide the times and/or frequency of the site visits.

2. Communications

   Identify and describe primary and backup means of communication at the dam and provide the location of the communication equipment.

3. Warning Systems

   Briefly describe the warnings system(s) equipment installed at the dam. If no warning system equipment is installed, then state that "No warning system equipment is currently installed at the dam."

E. Cooperation with Other Agencies

Identify and briefly describe the relations between the operating organization and other agencies (e.g., National Weather Service, Corps, U.S. Geological Survey, Natural Resources Conservation Service (snow surveys), State and local governments, municipalities, water districts, etc.).

F. Data Reporting

Identify the usual data reports that are required as part of the O&M of the dam. Examples of data reports include, but are not limited to: weather, reservoir elevation, inflow, and discharge flow; visual inspections, facility examinations, structural behavior instrumentation readings, examination of inaccessible features, etc.

G. Operating Log

Include a statement of purpose for the Operating Log that is maintained at the dam site; and state the storage location of the Operating Log. A typical list of logbook entries should be provided in this section.

H. Public Safety and Health

Safety of the public is of primary concern; safety instructions and protection shall comply with all applicable regulations. Describe public use at or near the dam, distance to the nearest medical or law enforcement assistance, potential hazardous areas not discussed in Section I (Restricted Areas), safety equipment at the dam, and other pertinent information concerning public health or safety.

I. Restricted Areas

Identify all areas within or surrounding the dam and reservoir from which unauthorized persons are restricted and explain the purpose of the restrictions, barriers, and/or signs.

J. Emergency Management and Facility Security Plans

State in general terms the need for security regulations and plans for protecting the dam. Reference to the EAP should be made to address specific procedures in case of an emergency event.

K. Distribution of Standing Operating Procedures

The SOP must have a limited distribution, as these are controlled copies. At least one copy must be located at the dam. All controlled copies of the SOP should be distributed to other designated offices as deemed necessary by the issuing office. To ensure that all copies of the SOP are kept current, a record of their location must be maintained. The record should be kept in the SOP by including the Letter of Transmittal, showing the complete distribution list, and identifying the control number assigned to each office. This will ensure that revised pages are furnished to all official copyholders whenever revised instructions are distributed.

L. Revisions to Standing Operating Procedures

State which office will be authorized and responsible for issuing all revisions to the SOP. A record of all SOP revisions must be kept with the SOP. Clear and concise instructions for making the revisions should be included in the transmittal memo to avoid any confusion.

M. Supporting Documents

Examples of specific documents include, but are not limited to, contracts, Memoranda of Understanding, Memoranda of Agreement, Designers' Operating Criteria, Design Summaries, Examination Reports, Final Construction Reports, Oil Spill Prevention and Countermeasure Plans, Corps regulations, etc.

N. Reference Material

List all manuals, publications, bulletins, and other reports that may assist personnel in performing specific O&M duties at the dam.

Chapter II – Structural, Mechanical, and Electrical

The section headings for chapter II can vary depending on the features and equipment at the dam. The following example is provided to illustrate the possible section headings for a dam having multiple spillways and multiple outlet work structures. The section headings should include only the specific spillway and outlet structures.

A. Description of the Dam

In addition to the written description of the dam, the table shown below can be used to summarize the pertinent engineering data for the dam and appurtenant features. The table shown is an example for an embankment dam and should be revised if being used for concrete or composite dams.

Table II-1. Engineering Data for _____ Dam

Type of Dam	Zoned Earthfill	
Drainage Area:	_____ square miles	
Location	Approximately _____ miles (direction) of City, State Latitude: ___° ____' N Longitude: ___° ____' W	
Construction Period(s)	Original construction period, and any modifications	
Dam Dimensions	Structural Height	_____ feet
	Hydraulic Height	_____ feet
	Maximum Base Width	_____ feet
	Crest Length	_____ feet
	Crest Elevation	_____ feet
	Crest Width	_____ feet
Total Embankment Volume	Approximately _____ yd^3	
Total Capacity (maximum water surface)	_____ acre-feet	
Active Conservation (El. _____)	_____ acre-feet	
Surface Area – El. _____	_____ acres	
***Spillway**: Provide a brief description of the spillway, type (gated ungated), and location		
Crest Length	_____ feet	
Crest Elevation	_____ feet	
Capacity at Elevation _____ feet	_____ ft^3/s	
***Outlet Works**: Provide a brief description of the outlet works system and gates		
Capacity at Elevation _____ feet	_____ ft^3/s	

* Additional features (spillway, outlet works, dikes, diversion works, etc.) should be added to this table as needed.

B. O&M Instructions for Service Spillway (as applicable)[1]

1. Description
2. Operation
3. Maintenance
4. Spillway Gate Exercising and Testing[2]

C. O&M Instructions for Emergency Spillway (as applicable)[1]

1. Description
2. Operation
3. Maintenance

D. O&M Instructions for Fuse Plug Spillway (as applicable)[1]

1. Description
2. Operation
3. Maintenance

E. O&M Instructions for River Outlet Works (as applicable)[1]

1. Description
2. Operation
3. Maintenance
4. Gate Exercising and Testing

F. O&M Instructions for Canal Outlet Works (as applicable)[1]

1. Description
2. Operation
3. Maintenance
4. Gate Exercising and Testing

G. Electrical Systems and Equipment

1. Description
2. Operation
3. Maintenance

[1] Include/delete sections for specific spillway and outlet structures.
[2] Delete spillway gate exercising and testing if spillway is ungated.

H. Supervisory Control and Data Acquisition (SCADA)[3]

1. Description
2. Operation
3. Maintenance

I. Auxiliary Equipment[4]

1. Reservoir Level Gage

    a. Description
    b. Operation
    c. Maintenance

2. Emergency Generator(s)

    a. Description
    b. Operation
    c. Maintenance

3. Heating and Ventilation Systems

    a. Description
    b. Operation
    c. Maintenance

4. Sump Pump Units

    a. Description
    b. Operation
    c. Maintenance

5. Elevator

    a. Description
    b. Operation
    c. Maintenance

J. Dam Maintenance and Inspection

1. Maintenance
2. Inspection of Dam and Related Work
3. Inspection Following Earthquakes

[3] This example shows SCADA as its own section instead of under "Auxiliary Equipment."
[4] This is not meant to be a complete list of auxiliary equipment (delete or revise as necessary).

K. Safety Procedures

1. Hazardous Energy and Control Procedures
2. Logbook Entries
3. Operations Associated with Contractors or Non-Reclamation Personnel
4. Confined Spaces
5. Evacuation Procedures
6. Hand Tools and Portable Power Tools
7. Personal Protective Equipment
8. Ropes, Chains, and Accessories
9. Materials Handling, Storage, and Disposal
10. Equipment and Motor Vehicles

L. Protective Coating

1. Inspection
2. Maintenance

Chapter III – Structural Behavior Instrumentation

Structural behavior instrumentation at dams often varies based on the type of dam and types of instruments that are installed. In some cases, there could be some instruments that are "abandoned" and/or "on standby," in which case, **all** pertinent information about the instruments should still be included in the SOP.

The following is an example of subject headings that may be used in chapter III.

A. General

Describe the types and number of each type of structural behavior instrumentation installed at the dam. It is suggested that a list of all instruments installed at the dam is shown even if the instruments are abandoned, destroyed, on standby, etc. Also, include the total number of instruments installed whether they are currently being monitored or not to inform the users of the SOP of what instrumentation is at the dam and the current status of each instrument type.

B. Identification of Expected Data

This information is generally found in both the "Evaluation of Performance Monitoring" and the "Future Performance Monitoring" sections of the Comprehensive Review report. If the information regarding expected data readings change, the SOP should be revised to reflect the changes so that the SOP remains current. Sometimes a table of

expected readings is provided, usually when there are multiple instruments, or a brief statement is written to show the expected readings (typically for structural and embankment measurement points). This list of instruments is normally the same as those shown in section D (below).

1. Seepage Monitoring Points
2. Observation Wells (standby)
3. Porous-Tube Piezometers
4. Hydraulic Piezometers (abandoned)
5. Embankment Measurement Points
6. Structural Measurement Points

C. Responsibilities

1. Dam Operator/Operating Office
2. Area Office
3. Regional Office
4. Technical Service Center

D. Description of Each Type of Instrument

The instrumentation listed below is provided as an example of equipment installed at a dam. The author should also include a detailed description of instrumentation installations and references to applicable drawings

1. Seepage Monitoring Points
2. Observation Wells (Standby)
3. Porous-Tube Piezometers
4. Hydraulic Piezometers (Abandoned)
5. Embankment Measurement Points
6. Structural Measurement Points

Within each type of instrument description in this section, subsections should include the location(s), monitoring, and maintenance of each instrument. Regardless if the instrument is actively monitored, "standby," or "abandoned," it is helpful to know as much about the history of the instruments installed at the dam as possible. For example, a statement, such as, "Hydraulic piezometers have been abandoned in-place, but seepage problems could occur," should be expanded to include the location(s) of the piezometers.

E. Seismic Monitoring/Strong Motion Program

Some dams may have seismic monitoring equipment installed at or near the dam. When seismic monitoring equipment is installed and operational, a description of the instrument(s), location(s), and maintenance requirements should be provided.

When no seismic monitoring equipment is installed at the dam, a ground-motion sensor could be used to provide post-earthquake ground-shaking information. Knowing the location of the earthquake epicenter, the table contained in this section can be used to estimate if the dam site has experienced a horizontal ground acceleration of 0.05g or greater.

F. Schedule for Periodic Monitoring

This section is used to make reference to the Schedule for Periodic Monitoring (L-23), which provides information on the monitoring method and monitoring schedule at the dam.

Chapter IV – Reservoir Operations

Section headings (A. through N.) are typically included in chapter IV. A brief description about each of these sections is provided below. More detailed information about each of these sections is discussed in the SOP Guide.

A. Reservoir Capacity Allocations

The current reservoir capacity allocations information should be included in the SOP on an approved form. It is important to include the current area-capacity curves and tables in the appropriate appendix. The SOP should also mention that sediment accumulations, as detected by re-survey, may change the capacity allocations.

B. Design Flood Studies and Routings

The current reservoir inflow design flood (IDF) should be included in the SOP to give operating personnel some idea of the type and magnitude of a flood for which the dam, spillway, and outlet works are considered adequate. If available, a summary of the most recent probable maximum flood (PMF) should be included with a reference made in the report indicating where the information was obtained.

The IDF and/or PMF should show the date the described flood was approved for design or review purposes. The flood description should include volume, duration, and peak inflow. Describe the type of flood

(rain, snowmelt, or combination), the months of the year during which it can occur, and the assumed antecedent hydrologic conditions. This information would be helpful in supporting some operating procedures and for operating personnel evaluating a flood event. Include a statement indicating the resulting maximum reservoir water surface elevation and peak spillway and outlet works discharges.

C. General Filling Schedule and Release Procedures

Describe detailed filling and release procedures to accomplish the authorized and incidental objectives of the project. Explain when water is stored in the reservoir and all restrictions that exist on rates, quantities, and times for which water may be stored. Include factors governing reservoir releases for project purposes.

Indicate specific operating instructions, such as when releases are to be made, and list all established requirements for releases such as maintenance of streamflows (e.g., fish and wildlife benefits) and flood control options.

D. Inflow Forecasting

Provide detailed instructions on inflow forecasting and procedures for preparing, both preceding and during runoff months, periodic estimates of inflow volumes for the runoff season. Forecasting procedures are mostly for reservoirs having snowmelt inflow. In some exceptional cases, short-term inflow forecasting procedures may be appropriate for reservoirs having large watersheds and only rainfall runoff.

Instructions should be described in sufficient detail and completeness to enable designated personnel to be effective in estimating inflow and fully implementing the procedures. Describe procedures and criteria used by other agencies and instructions for operating personnel to procure and use such forecasts.

E. Flood Operating Criteria

Provide detailed information regarding dam and reservoir flood operating criteria and procedures to be followed preceding and during flood inflows, which are not appropriate to include in Sections C (Filling Schedule and Release Procedures) and D (Inflow Forecasting) of this chapter.

Describe established criteria for storage and release schedules preceding and during flood inflow periods (including established constraints for downstream flood control) as well as reservoir operating criteria needed for dam and public safety. Flood operating criteria and inflow forecasts

provide the basis for operating plans for routing of flood inflows. Safe channel capacities should be described for various reaches of the downstream river channel.

For structures with gated spillways, this section should provide specific detailed emergency operating instructions for operating personnel to use when communication outages are experienced during floods that require independent facility operation. Instructions should be presented in both narrative and graphical form (e.g., flood release chart, gate operating curve, etc.) to avoid possible misinterpretation of these important instructions.

If the reservoir has an authorized flood control function, references should be made to applicable Corps documents.

F. Special Reporting During Flood or High Water Conditions

This section could be omitted if it is sufficiently covered in the EAP, with a reference to the EAP. Reporting promptly and completely during floods and high-water periods is of high importance. Comprehensive instructions on reports required from personnel at the dam during these periods should be assembled in this section for ready reference. Instructions should establish when initial reports are to be made, who shall receive reports, data requirements, and reporting intervals.

Further reporting procedures will be established during the first report; if not, reporting intervals and data requirements for all reports should be established in the SOP.

G. Filling and Drawdown Limits

Describe all recorded special limits on rates and ranges of reservoir filling and drawdown that have been established because of landslides or other geologic conditions in the reservoir and for embankment dams because of stability requirements. Include a description and location of sinkholes or other unusual geologic formations.

The results of the reservoir evacuation study should be included in this section. This information is useful should an emergency evacuation be needed at the dam.

Include reasons for reservoir operating restrictions. Procedures for variances from the established operating requirements should be made on a case-by-case basis. If special limits have not been established, then make the statement that limits are not applicable.

H. Landslide Surveillance

Landslide surveillance procedures have been established for Reclamation projects. The procedures require the identification, annual examination, and preparation of data and/or data reporting of landslide areas by the regional geologist or designated representative. As a result of these and other examinations, operating procedures and appropriate schedules of landslide must be established for specific dams and reservoirs.

Include detailed information, such as locations of landslides or potential landslides that may be activated by drawdown, and include a map in the SOP appendix showing landslide locations.

Except for reporting procedures and reservoir operating instructions, all information and instructions related to landslides and landslide surveillance should be given in the SOP section. Inspection requirements relative to landslides should be described in SOP chapter I, Section F (Data Reporting) and referred to in this section. Reservoir operating requirements resulting from landslide conditions should be included in SOP chapter IV, Section G (Filling and Release Drawdown Limits).

Special instructions for O&M personnel may be developed as a result of the annual examination of landslide areas, and other information should include, but not be limited to: maintaining posted warning signs of landslide areas; identifying names and locations of persons and entities in established locations who would be affected by either slow or sudden movement of a critical landslide, and who could benefit from establishment and implementation of related emergency communication procedures; maintaining and observing landslide monitoring instruments; measuring landslide areas by land surveying; examining and reporting on critical landslide areas between annual examinations as directed by the regional geologist; adhering to special limitations on reservoir drawdown rate; and immediately reporting unusual landslide activity.

Landslide surveillance should describe landslide observations and measurements to be made following an earthquake and should refer personnel to the EAP for reporting procedures.

I. Preventing Oil Pollution of Water

Describe and identify operating personnel’s pollution abatement responsibilities to prevent or reduce further pollution, inventory and locations of possible oil and hazardous material sources, and sources of oil and hazardous substance cleanup.

At facilities where emergency plans for dealing with accidental pollution have been published, the SOP should include the plan or the document in which it is described, and the document should be referenced in this section. References should also be made to other pertinent documents containing information about temporary corrective measures to perform in the event of oil and/or hazardous material incidents and a reference made for contacting the National Response Center.

J. Fish and Wildlife Considerations

Provide reference to all contracts and agreements with other agencies for the benefit of fish and wildlife. Explain any requirements and how the agreements affect dam and reservoir operations. These requirements might include minimum water surface elevations, reservoir levels during specified periods of the year, and minimum reservoir release rates to meet downstream flow.

If applicable, include detailed information about the Memorandum of Understanding/Memorandum of Agreement with Federal, State, and/or local fish and game agencies.

K. Recreation Management Plan

State whether or not a recreation management plan has been established for the reservoir area. If a plan has been published, identify the agreement establishing the plan, the agency responsible for operating the plan, and how the plan affects reservoir operations.

L. Off-Road Vehicle Regulations

Identify regulations regarding off-road vehicle use for protecting public lands: identify the Federal Register issue establishing the regulations, indicate the agency responsible for operating the plan, and state if and how the plan affects reservoir operation or operating personnel responsibilities.

Maps designating roads and trails for off-road vehicle use, as well as maps indicating prohibited areas, should be included in the SOP appendix.

M. Hydropower Release Criteria (include if applicable)

This section may be useful when hydroelectric plants are non-Reclamation and operated by others. For reservoirs serving as forebays to hydroelectric plants, this section should state the basic criteria used in determining the time and quantity of hydropower releases and should indicate the relation of releases to other reservoir operating functions and criteria. When the only reservoir function is hydroelectric, the reservoir is one of several

interrelated reservoirs, or when operation is coordinated to maximize power generation consistent with other authorized project operation purposes, the criteria may be referenced here and included in chapter I, Section M (Supporting Documents).

Clearly state the reporting requirements, release range, and power demands before effecting sudden or large releases of water. Also describe warning signs, devices, etc., to alert people downstream of increased releases.

N. Operating Criteria for Other Functions (include if applicable)

Operating criteria for other reservoir functions not appropriately included in other SOP sections may be described here. Where appropriate, this section may include reviews of reservoir operating criteria for downstream pollution abatement, structure protection during periods of the year, and control of silt deposition in the reservoir.

Other sections that have been added in chapter IV by other Reclamation offices include:

- Water Rights
- Telemetry
- Cultural Resource Areas

If a section within chapter IV is not needed, sometimes it is best to state "Not applicable" or "No information is available at this time" rather than deleting the heading. The decision to keep the section heading or delete the heading should be made on a case-by-case basis.

Appendix A – Reservoir Operation Supporting Material

This appendix should include, but not be limited to, area-capacity tables and curves, discharge curves, discharge tables, etc.

Appendix B – Forms

This appendix should include common forms that are used for reporting information about operations/maintenance at the dam. Forms in the SOP generally include, but are not limited to: "Telephone Report of Water and Power Interruptions and Facility Failure," daily operations reports, sample pages of the Operating Log, structural behavior instrumentation data reporting forms, etc.

Appendix C – Drawings

Include drawings relating to the dam and appurtenant features. There is no need to include all design and specification drawings, as this would make the SOP large with extraneous drawings.

Appendix D – Glossary and Definitions

This appendix has been included by some regions and is to be included as deemed necessary.

Summary

In general, no two SOPs will be exactly the same, but there may be similarities. Each dam SOP is unique for many reasons/factors: location, operating entity, purpose, operating equipment, size, design, appurtenant structures, instrumentation, etc. Information in this article may be helpful whether developing a new SOP or updating the SOP as a complete republished document.

The following points should be considered when developing/revising an SOP:

- SCADA could be its own subject heading (see example) instead of being buried under another subject heading (i.e., Auxiliary Equipment, Miscellaneous Equipment, etc.)

- The SOP Guide showed Section B "O&M Instructions for Spillway, Outlet Works, and Other Appurtenances." After further examination, it may be better to discuss each outlet feature as a separate section as shown in the chapter II examples above. This can make it easier to find information about the particular feature at a dam.

- There are too many possibilities of features and equipment at dams to include them in this article. The SOP author(s) should use their best judgment when organizing the contents in each chapter. This applies mostly to chapter II.

- Information from the DOC should be incorporated into the SOP instead of making a reference to the DOC.

- Chapters II and III should be tailored to meet the requirements of the structures and equipment installed at the dam.

- Computers and word processing software now make it possible to embed digital photographs and other digital (tiff or jpeg) images into the document. Word processing software also makes it easier to update and maintain an SOP.

References

Assistant Commissioner - Engineering and Research, Technical Memorandum No. 3, Criteria and Guidelines for Evacuating Storage Reservoirs and Sizing Low Level Outlet Works.

Reclamation Manual FAC 02-01, Operating Practices and Procedures for High- and Significant-Hazard Dams (and other facilities, as applicable).

Standing Operating Procedures Guide for Dams, Reservoirs, and Power Facilities, dated August 1996, revised reprint June 2001.

MAINTENANCE AND MAINTENANCE MANAGEMENT PRACTICES

by: Stuart Hirai, MSCE, Bureau of Reclamation, Policy and Administration, Maintenance Services Division (84-57000)

A. What Defines "Maintenance"?

Maintenance is described as the act of keeping fixed assets in acceptable condition. It includes preventive maintenance, normal repairs, replacement of parts and structural components, and other activities needed to preserve the asset so that it continues to provide acceptable services and achieves it expected life. Maintenance excludes activities aimed at expanding the capacity of an asset or otherwise upgrading it to serve needs different from, or significantly greater than, those originally intended.

B. What is the "Theory of Maintenance"?

The theory of maintenance can be defined as any support process used to ensure the proper day-to-day operations of any facility or its associated substructure. However, you must also review those processes using various criteria, such as cost-benefit analysis, safety considerations, and operational savings.

I like to think that the Theory of Maintenance is a study of the processes, techniques, and philosophies currently available, which effectively extend the useful life of a facility or its components. It should ensure the delivery of services in a safe manner at the best possible cost, while using proper risk analysis of failure and assisting management in proper maintenance to operation scheduling.

The Theory of Maintenance continually changes due to the effects of deterioration, which is a dynamic process. As new technologies become available, a continuing evaluation must be effected to determine their role in meeting the ongoing variety of maintenance objectives.

Our conversation about the Theory of Maintenance needs a set of definitions of common terms so that we can communicate effectively *(these are not official definitions, just examples.)*:

1. Preventive maintenance
2. Predictive maintenance
3. Scheduled maintenance
4. Breakdown maintenance

5. Extraordinary maintenance
6. Emergency maintenance
7. Reliability centered maintenance
8. Proactive maintenance
9. Deferred Maintenance
10. Cyclic maintenance

1. Preventive Maintenance

Preventive maintenance is the routine planned activity in which periodic inspection, adjustments, cleaning, lubrication, replacement of parts, and minor repairs are performed, for which specialized training may not be required. This function consists of many checkpoint activities on items that, if disabled, would interfere with an essential operation of the installation, endanger life or property, or involve high cost or long lead time for replacement. Preventive maintenance is the cornerstone of any good maintenance program. A weak or nonexistent preventive maintenance program could result in much more emergency work and costly repairs.

2. Predictive Maintenance

Predictive maintenance refers to testing and inspection activities that involve the use of sophisticated diagnostic means to identify requirements. As an example, this may include ultrasonic testing, infrared photography, thermograph imagery, electrolyte testing, oil analysis, vibration/frequency analysis, etc.

3. Scheduled Maintenance

Schedule maintenance refers to any kind of maintenance that is scheduled on a cyclical basis and has a proven history of reliability. The timeframe is usually 1 year or intervals of time of less than 1 year.

4. Breakdown Maintenance

Breakdown maintenance refers to repairing noncritical components after they have been allowed to "run to failure." These components are not considered essential for safety or the delivery of services, and they do not impact the facility's operation.

5. Extraordinary Maintenance

Extraordinary maintenance is performed on an as-needed basis. Extraordinary maintenance includes repairs, rehabilitation, or improvements.

6. Emergency Maintenance

Emergency maintenance refers to performing unscheduled maintenance to restore critical services. Emergency maintenance impacts delivery of services, safety, structural components, function, and operability of a system. This kind of maintenance cannot be delayed.

7. Reliability-centered Maintenance

Reliability-centered maintenance is a philosophy that incorporates the most logical and cost-effective mix of breakdown maintenance, preventive maintenance, predictive maintenance, and proactive maintenance.

8. Proactive Maintenance

Proactive maintenance combines the principle of total quality management in order to identify the "root cause" of failures (reasons or circumstances causing failure or breakdown), such as defective parts, defective installation, improper operation or maintenance, or unsuitable design. After the "root cause" is determined, actions are taken to remove or change the circumstance that caused the failure in order to gain the expected life of other similar components.

9. Deferred Maintenance

Deferred maintenance refers to maintenance that was not performed when it should have been or when it was scheduled and which, therefore, has been put off or delayed to a future period.

10. Cyclic Maintenance

Cyclic maintenance is preventive maintenance that occurs on a periodic and scheduled cycle of greater than 1 year.

C. Asset Management

1. What is Asset Management?

In terms of physical asset management (as opposed to financial, fiscal, and economic), it is the management of physical assets in the form of using its replacement value of construction and then applying a financial process to derive its proposed life cycle costs. Performance metrics can be used to determine how the asset performs within a defined set of parameters.

2. What is a Life Cycle?

A life cycle is the amount of time a particular facility or component is designed to last. The life cycle of a facility can be extended through proper performance of maintenance. The costs involved include those for planning, designing, constructing, operating, maintaining, repairing, and replacing components throughout the life of the facility and will include retirement costs as well (figure 1).

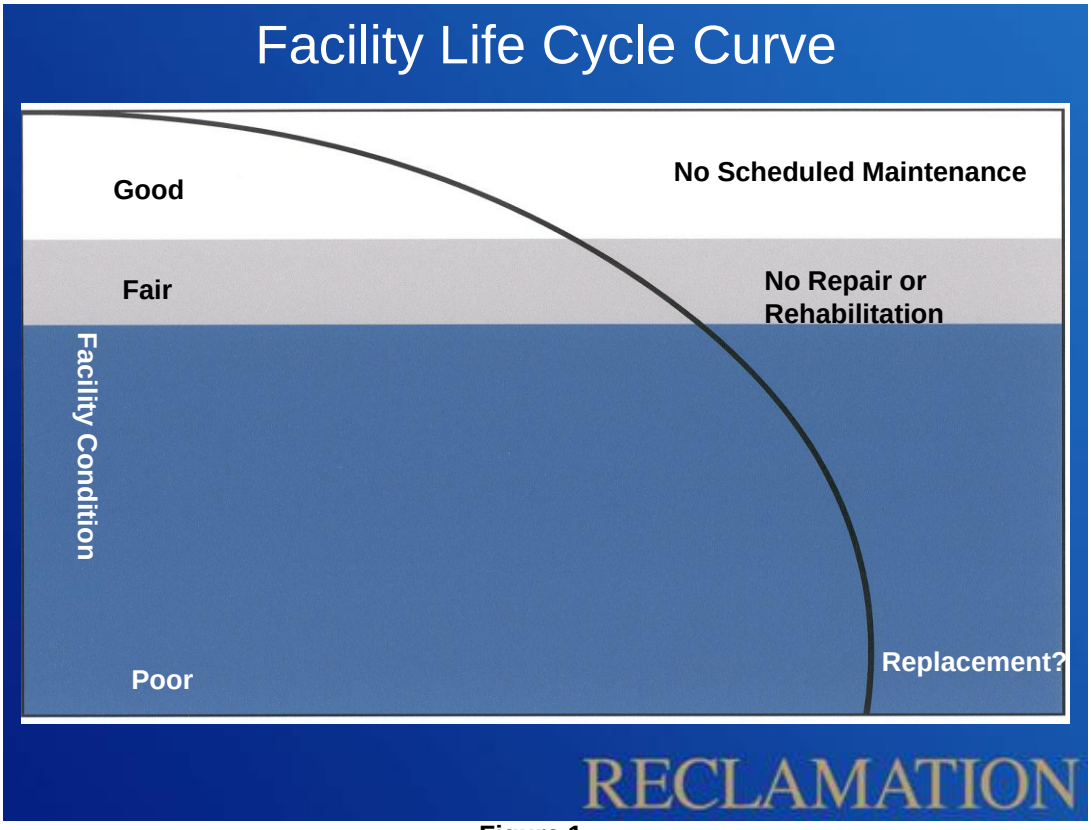

Figure 1

3. How can you use Asset Management in Evaluating Whether or not you have Enough Resources to Operate and Maintain a Facility?

"Based on experience and judgment, the Committee on Advanced Maintenance Concepts for Buildings (National Research Council) proposes that the appropriate level of maintenance and repair (M&R) spending should be, on average, in the range of 2 to 4 percent of current replacement value of the inventory." This means that if your inventory has a replacement value of $10 million, an appropriate level of M&R spending for buildings should be, on average, in the range of $200,000 to $400,000. If it isn't, this could explain your backlog in maintenance. As it turns out, the 2 to 4 percent seems to be the average used most often by facility personnel.

4. Condition Assessment Survey (Review of Operation and Maintenance) or Facility Reviews (Periodic Facility Reviews and Comprehensive Facility Reviews)

In order to evaluate the condition of facilities in your inventory, condition assessment surveys should be performed. The survey is an evaluation of the degree of accumulated deterioration of each component of any particular facility in the inventory and is used to schedule future maintenance. In Reclamation, the programs that closely resemble this kind of assessment is the Review of Operations and Maintenance program for facilities other than high- and significant-hazard dams and Facility Review Program – Periodic Facility Reviews (PFRs) and Comprehensive Facility Reviews for high- and significant-hazard dams. The review of operation and maintenance could also include reservoir sedimentation surveys.

5. Facility Life Cycle

Figure 1 shows the life cycle of a typical facility or component with no maintenance. Scheduled maintenance activity improves the quality and extends the life of the facility, but note that improvements will rarely return a facility or its components to their original condition (figure 2).

6. New Requirements in Reporting Deferred Maintenance on Reclamation Constructed Facilities (only applies to "reserved works")

Under the Statement of Federal Financial Accounting Standards No. 6 (SFFAS No. 6), all Federal agencies are to include deferred maintenance estimates in

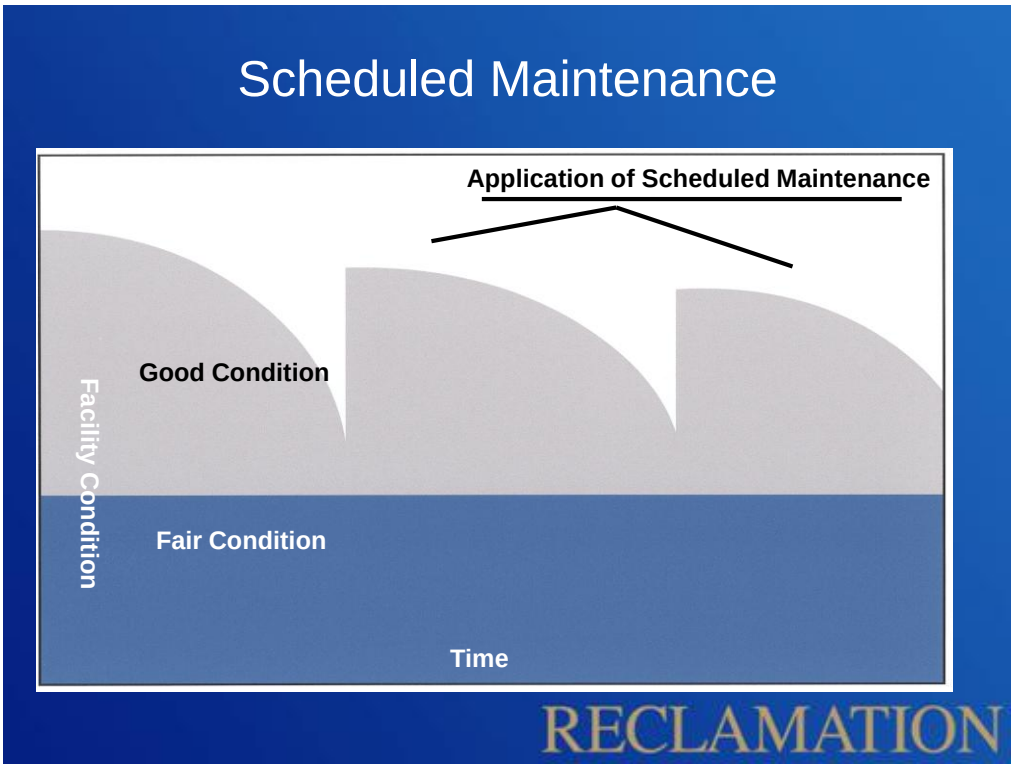

Figure 2

agency financial reports, which recommend using the life cycle costing method or condition assessments (the U.S. Department of the Interior [Interior] has since adopted the condition assessment methodology). Deferred maintenance is defined by SFFAS No. 6 as maintenance and repair "that was not performed when it should have been or when it was scheduled to be and which, therefore, was put off or delayed for a future period." Reclamation has been reporting deferred maintenance since 1998 using the applicable accounting standards developed by SFFAS No. 6 and adopted and modified by Interior.

7. Key Steps of a Proactive Maintenance Program

There are four key steps in a proactive maintenance program:

Identifying – Update inventory of facilities that have maintenance needs, conduct condition assessment surveys, tabulate work requests, determine preventive maintenance (PM) requirements, and establish performance criteria.

Planning – Generate annual work plans, including PM, prioritize rehabilitation and other projects, develop and justify budgets, and create plans for accomplishing work (contracting out or done in-house).

Performing – Execute PM schedule, accomplish work orders, perform rehabilitation and other projects, and record accomplishments.

Evaluating – Evaluate plans and accomplishments, review deferred maintenance, analyze performance, and make appropriate adjustments for the next cycle.

8. Industrial Comparisons

One way of determining how your organization compares with others is to perform benchmarking. Benchmarking is a process for measuring your organization's performance by category against those of other similar organizations that consistently distinguish themselves in similar categories.

Once the measurement has been made, benchmarking is a tool for setting appropriate measurable objectives for improvement:

Planning – Determine what to benchmark (cost to deliver water, maintain a component, etc.) and identify key performance variables (vehicle maintenance costs, etc.).

Action – Implement and monitor progress, measure results against known industrial statistics, and recalibrate benchmarks.

D. Annual Reviews by Operating Entity Personnel

Annual onsite inspections and meetings should be held to identify deficiencies in an operation and maintenance (O&M) program and to plan and prioritize future work. The results of the inspections should be reviewed and coordinated with managers, supervisory personnel, directors, water users and their representatives, and O&M personnel.

Tours (or field reviews) should be scheduled to examine systems/facilities for deficiencies. The success of the tour depends on how well it is planned and attended. It is beneficial to schedule the tour alternately during differing site/water conditions. For example, operational concerns or seepage problems along a canal alignment are best viewed with the canal watered to capacity. Excessive seepage and difficulty delivering water may determine the need for system evaluation. Delivery blocks can be isolated to determine their efficiencies. On the other hand, canal prism and structure concerns are better viewed when the system is dewatered.

Transportation should be provided, which allows the entire group to stay together so that discussions can be held while traveling to and from the project.

If tours cannot be conducted, photographs and slides can be used at meetings to show effectiveness of improvements and areas needing attention. Both the tours and meetings should point out current problems, accomplishments, and suggested future improvements. Agreements on the work required and schedules should be reached as a result of these reviews.

Additionally, in the interim time period between annual reviews, continual monitoring and surveillance by key operating personnel (dam operator, ditch rider, etc.) is also recommended to identify potential maintenance deficiencies. The ability to continue deliveries or minimize outages during routine or emergency operations needs to be considered. The availability of specialized equipment should be considered. Those items identified should then be addressed during the annual reviews with appropriate personnel.

These reviews, if properly conducted, identify deficiencies at an early stage and can be beneficial in the development of work plans and budgets. They can also help in establishing a good communication process among all involved O&M and administrative personnel.

1. Periodic Facility Reviews

Periodic facility reviews should be held to evaluate system conditions and to provide assurance that proper operation is sustained on a long-term basis to fulfill intended objectives of the project.

These reviews could be similar to Reclamation's comprehensive facility reviews for high- and significant-hazard dams or associated facility reviews of water distribution systems, which are held every 3–6 years by regional and Technical Service Center personnel.

The teams performing the examination should be experienced in operation and maintenance of water systems, facilities, and structures. For an independent overview, those conducting the reviews should not be directly involved in project operations. The reviews should include appurtenant portions of distribution systems and all dams, as well as equipment, operational, and management functions.

A report on each review is then prepared and copies are distributed to appropriate office heads and water user organizations. The report contains categorized recommendations that require corrective actions.

A more detailed discussion of general procedures and observations to be made during the facility reviews are provided within the Review of Operations and Maintenance Program Field Examination Guidelines (1991), Safety Evaluation of Existing Dams (reprint 1992), Guidelines for Safety Evaluation of Mechanical

Equipment (1992), and the Training Aids for Dam Safety. These guidelines provide details on the organization of the inspection program. Such observations can also be very beneficial to operating personnel during routine surveillance and by water user organizations during their annual reviews.

2. Comprehensive Facility Reviews

Comprehensive facility reviews, as conducted in Reclamation, are similar to the PFRs, but are more rigorous and intensive and include representatives from Reclamation's corporate office in Denver, Colorado.

The review should be made by representatives who are familiar with state-of-art practice and/or knowledge in the related technical field. They should have 10 years of experience in the related technical area and, where applicable, be licensed to ensure that they have not only extensive structural knowledge of dams but also be knowledgeable about any associated possibilities of deficiencies or any safety concerns. The reviews include site examinations, examinations of normally inaccessible features, and a report of findings. These reviews will be performed every 6 years and alternating every 3 years with the PFRs. As done with the PFRs, a report package is provided as documentation of the examination results.

Although not specifically part of these reviews, reservoir sediment surveys should be considered to establish a baseline so that survey frequencies can be determined.

E. Maintenance Management

Maintenance programs may take different forms and should be adapted to best fit an organization. A suggested procedure for development of a good maintenance program, from the Training Aids for Dam Safety, is given below. Operational aspects should also be considered in this process, and ultimately, O&M requirements should lead to the development of annual (or biennial, triennial) work plans and budgets.

Organizing a maintenance management program generally consists of the following steps:

Maintenance Management Systems – The procedures and details for establishment and implementation of a maintenance management system are given in "Guidelines for Manual Maintenance Management System for Water O&M Projects," which are provided within Water O&M Bulletin No. 138.

These guidelines provide the necessary information for developing a simple manual card file system, which may be appropriate for your particular facility/system. However, for those facility/systems that involve considerably more features, equipment, and associated data, or if more detailed reporting requirements are needed/desired, consideration should be given to the purchase of a computerized system (software-based database management program).

Computerized Maintenance Management System – With the complexity and extensive number of computerized maintenance management system (CMMS) programs available on the market today, choosing the one that best matches your needs can be a daunting task. In general, most CMMS programs are developed in a modular format, allowing the purchase of only the modules that meet your needs.

1. Work Order Management

To effectively manage a routine and corrective maintenance workload, a database management program must allow personnel to :

- Develop standard forms for recording work request and completion data
- Develop standard forms for recording and automating recurring task data (preventive maintenance)
- Create subtables for labor (employee identification and pay rate), crafts, account codes, and equipment that can be linked to active work orders
- Consolidate expenses accumulated on a work order to a particular piece of equipment for tracking historical costs
- Link/download data from one or more fuel dispensing stations to allow tracking of vehicle mileage and triggering of automated maintenance
- Link inventory parts usage to associated work orders
- Track labor, parts, and services expensed to a work order
- Schedule work for completion through the use of start and finish dates or equipment meter readings
- Create various reports for tracking work completion, listing backlogged work, or planning (scheduling) future work based on asset availability
- Track expenses in various formats through customized equipment expense reports

- Compare equipment expenses per period and exchange data with the Business Accounting Program

- Allow users the capability to archive completed work orders and restore them if necessary

2. Purchasing Management

Although the purchasing program need not be an integral part of the CMMS, it must have the capability to link purchase cost data to various work orders to allow tracking of the materials and service costs for each job. This link could be initiated automatically or manually.

To effectively manage both routine and special purchase activities, a database management program must allow personnel to:

- Develop standard forms for recording purchase request data

- Develop standard forms for recording purchase order data

- Create subtables for account codes, vendors, and inventory items that can be linked to active purchase orders

- Calculate total costs associated with multiple line items and automatically includes applicable taxes and shipping costs

- Provide for the approval of purchase orders based on the amount of the purchase

- Create various reports for tracking purchasing status and listing backordered purchases

- Track expenses in various formats through customized purchase order expense reports

- Change the active status of a purchase order based on the status of receiving some or all items.

- Compare purchase order expense per period and exchange data with the Business Accounting Program

- Use a bar code scanner to make the receiving function more efficient and accurate.

- Receive “credit invoices”

- Allow users the capability to archive completed work orders and restore them if necessary

3. Inventory and Spare Parts Management

Although the inventory management program need not be an integral part of the CMMS, it must have the capability to link inventory usage data to work orders to allow tracking the inventory usage for each job. This link could be initiated automatically or manually.

To effectively manage inventory usage, a database management program must allow personnel to:

- Develop standard forms for recording inventory data
- Develop standard forms for recording inventory activity
- Develop standard forms for performing physical inventory counts
- Create subtables for account codes, vendors, and inventory locations
- Track line item status with regard to minimum and maximum stock levels
- Create various reports for tracking inventory status, including stock levels and total inventory value at any point in time
- Create various reports for tracking inventory usage by type of activity
- Support annual and cycle counts by generating special count tables and forms
- Change the active status of an inventory item (stock or nonstock) dependent on usage level
- Use a bar code scanner to record inventory transactions and to facilitate the performance of cycle counts and physical inventories
- Reserve items of inventory for use with specific work orders
- Allow users the capability to archive completed work orders and restore them if necessary

4. Asset Management

Although an asset management program need not to be an integral part of your maintenance program, it can be a useful tool when integrated with a CMMS program.

To effectively manage assets, a database management program must allow personnel to:

- Develop standard forms for recording asset data
- Develop standard forms for recording asset activities
- Develop standard forms for performing asset inventory
- Create subtables for account codes, locations, and equipment types
- Track original cost, ongoing maintenance expenses and depreciation
- Create various management reports, including total asset value by location and asset depreciation value at any point in time
- Use a bar code and scanners to identify assets and to facilitate the performance of inventories
- Develop appropriate performance metrics by asset type

The program should contain various user access security provisions to protect critical data from being edited and deleted. In addition, program security should provide the ability to prevent user access (hide) to sensitive data such as employee salary or personal information. Programs that allow hiding unnecessary data from various data entry forms help simplify the data entry process.

5. Historical Heritage Assets

As project facilities, structures, and buildings get older, there is an ever-increasing demand to ensure designated assets are properly operated and maintained. This is just a reminder that designated properties considered as having historical value or significance are operated and maintained differently than nondesignated assets. Contact your local cultural resource specialist responsible for these assets to ensure proper O&M activities are being implemented.

F. Summary

A CMMS program must enable the user to perform the basic functions necessary to support your ongoing maintenance program. Simplicity and flexibility are key factors to consider when screening a CMMS program. The extent to which the program is "user friendly" is also a very important issue. Success in implementing a new maintenance management program is directly linked to how the program is received and used by the end users in the field. I recommend getting key end users involved in the screening process as well as establishing specific program needs with management and front level supervisors. Future upgrade ability of the program should also be considered; however, care should be taken to ensure you do not purchase a program that is so complex that it becomes difficult to use and manage. Sometimes less is more!

G. Conclusion

An organized maintenance management program is critical to sustained and successful operation of water systems (distribution systems and dams). The methods described are one way of accomplishing a program. Other similar programs may be more adaptable to your system/facility, and they should be considered when developing your O&M programs. The basic premise is that potential problems should be identified and dealt with before they occur, thus avoiding emergencies, safety hazards, and general deterioration.

H. Sources of Information

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I. Sources of Maintenance Management Technology

Applied Technology Publications, Inc.
1300 S. Grove Avenue, Suite 205, Barrington, IL *60010*
http://www.mt-online.com/selection
Phone: (847) 382-8100
Fax: (847) 304-8603

Maintenance Technology, The Magazine of Plant Equipment Maintenance and Reliability Management, An Applied Technology Publication

Public Works – City, County, and State
Public Works Journal Corporation
200 South Broad Street Ridgewood, NJ *07450*
http://www.pwmag.com/
Phone: (201) 445-5800
Fax: (201) 445-5170

Training Aids for Dam Safety (TADS)
The entire TADS series of modules (PDF) and videos (DVD) are available in a two-CD set that can be ordered at no cost from the Federal Emergency Management Agency.

Water Operation and Maintenance Bulletin
Mail Code 84-57000, PO Box 25007, Denver CO *80225*
http://www.usbr.gov/pps/WaterOandMBulletins

Mission

The mission of the Bureau of Reclamation is to manage, develop, and protect water and related resources in an environmentally and economically sound manner in the interest of the American public.

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