Current and Available Guidelines, Tools, and Resources for Dam Design, Evaluation, Remediation, Operation, and Maintenance

Resources from
Bureau of Reclamation

Jay N. Stateler
U.S. Department of the Interior
Bureau of Reclamation
Design Standards

- **Design Standard No. 1: General Design Standards** (September 2009; updated May 2012) [682 KB .pdf File]
  - Chapter 1: Preparing and Using Design Standards
  - Chapter 2: Design Standards Index

- **Design Standard No. 9: Buildings and Other Structures**
  - Chapter 8: Modification of Existing Buildings (January 2012) [337 KB .pdf File]
  - Chapter 13: Seismic Design (October 2012) [613 KB .pdf File]

- **Design Standard No. 13: Embankment Dams**
  - Chapter 1: General Design Standards (October 2011) [2.7 MB .pdf File]
  - Chapter 3: Foundation Surface Treatment (July 2012) [19.6 MB .pdf File]
  - Chapter 4: Static Stability Analysis (October 2011) [3.5 MB .pdf File]
  - Chapter 5: Protective Filters (November 2011) [16.7 MB .pdf File]
  - Chapter 8: Seepage (October 2011) [14.8 MB .pdf File]
  - Chapter 9: Static Deformation Analysis (November 2011) [7.6 MB .pdf File]
  - Chapter 10: Embankment Construction (May 2012) [4.5 MB .pdf File]
  - Chapter 12: Foundation and Earthen Materials Investigation (July 2012) [6.1 MB .pdf File]

- **Design Standard No. 14: Appurtenant Structures for Dams (Spillway and Outlet Works)**
  - Chapter 1: Introduction (November 2010; updated October 2011) [2.2 MB .pdf File]
  - Chapter 2: Hydrologic Considerations (November 2013) [3.6 MB .pdf File]
Bureau of Reclamation (BOR) Technical Service Center (TSC) Design Standards (DS)

- [http://www.usbr.gov/pmts/tech_services/engineering/design/index.html](http://www.usbr.gov/pmts/tech_services/engineering/design/index.html)

- **DS No. 1: General Design Standards**
  - Chap. 1: Preparing and Using Design Standards
  - Chap. 2: Design Standards Index

- **DS No. 2: Concrete Dams**
  - Chap. 1: Introduction
  - Chap. 2: Design Considerations
BOR TSC Design Standards (DS)

• DS No. 3: Water Conveyance Facilities, Fish Facilities, and Road and Bridges
  – Chap. 1: Open Channels
  – Chap. 2: Canal Structures and Canal Automation
  – Chap. 3: Diversion Dams and Headworks
  – Chap. 4: Tunnels, Shafts, and Caverns
  – Chap. 5: Fish Facilities
  – Chap. 6: Water Management
  – Chap. 7: Cross Drainage
  – Chap. 8: Pipelines and Pipe Distribution Systems
  – Chap. 9: Bridges and Roads
  – Chap. 11: General Hydraulic Considerations
  – Chap. 12: General Structural Considerations
  – Chap. 13: Safety Standards for Water Conveyance and Fish Facilities
BOR TSC Design Standards (DS)

- **DS No. 4: Electrical Apparatus and Systems**
  - Chap. 1: General Considerations for Power, Pumping, and Pumped Storage Plants
  - Chap. 2: Electrical Rotating Machinery
  - Chap. 3: Associated Electrical Equipment
  - Chap. 5: Switchyards and Substations
  - Chap. 6: Powerplant Control and Station-Service Equipment
  - Chap. 9: Grounding Methods

- **DS No. 5: Field Installation Procedures**
  - Chap. 2: Electrical Standards for Equipment Installation
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- **DS No. 6: Turbines and Pumps**
  - Chap. 1: Hydraulic Turbines
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- **DS No. 7: Valves, Gates, and Steel Conduits**
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  - Chap. 2: Closed Steel Conduits
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• **DS No. 8: Miscellaneous Mechanical Equipment**
  - Chap. 1: Handling Facilities and Shop Equipment
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  - Chap. 3: De-icing Systems
  - Chap. 4: Heating, Ventilating, and Cooling

• **DS No. 9: Buildings**
  - Chap. 1: General Structural Design Procedures and Standards
  - Chap. 2: Structural Design Data and Criteria
  - Chap. 3: Concrete Design and Details
  - Chap. 4: Steel Design and Details
  - Chap. 5: Architectural Details
  - Chap. 6: Timber Design Criteria
  - Chap. 7: Masonry Design Criteria
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• DS No. 9: Buildings (continued)
  – Chap. 8: Modification of Existing Structures
  – Chap. 9: Instrumentation and Monitoring
  – Chap. 10: Plant Structure Type
  – Chap. 11: Special Structural Materials
  – Chap. 12: Site Design
  – Chap. 13: Seismic Design
  – Chap. 14: Accessibility Design
  – Chap. 15: Design for Life Safety
  – Chap. 16: Security Assessment and Design Criteria for Buildings
  – Chap. 17: Special Structures
  – Chap. 18: Sustainable Design
BOR TSC Design Standards (DS)

- **DS No. 10: Transmission Structures**
  - Chap. 1: General
  - Chap. 2: Structures
  - Chap. 3: Foundations and Cable Trenches
  - Chap. 4: Site Development
  - Chap. 5: Oil Spill Containment
  - Chap. 6: Drawings

- **DS No. 12: Plant Testing**
  - Chap. 1: ASME PTC-18, Performance Test Code for Hydraulic Turbines and Pump-Turbines
  - Chap. 2: Field Generator, Motor, and Generator/Motor Tests
  - Chap. 3: NFPA 12, Carbon Dioxide Fire Extinguishing Equipment
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- DS No. 13: Embankment Dams
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- DS No. 13: Embankment Dams (continued)
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  - Chap. 16: Cutoff Walls
  - Chap. 17: Soil-Cement Slope Protection
  - Chap. 19: Geotextiles
  - Chap. 20: Geomembranes
  - Chap. 21: Dewatering
  - Chap. 22: Seismic Loading
BOR TSC Design Standards (DS)

- DS No. 13: Appurtenant Structures for Dams
  - Chap. 1: Introduction
  - Chap. 2: Hydrologic Considerations
  - Chap. 3: General Spillway Design Considerations
  - Chap. 4: General Outlet Works and Diversion Design Considerations
  - Chap. 5: Hydraulic Considerations for Spillways and Outlet Works
  - Chap. 6: Structural Considerations for Spillways and Outlet Works
  - Chap. 7: Mechanical/Electrical Considerations for Spillways and Outlet Works
Current information

Many topics are still under development

Older Design Standards have been pulled

Design Standards

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Best Practices in Dam and Levee Safety Risk Analysis

Best Practices and Risk Methodology

The Bureau of Reclamation has been using risk analysis as the primary support for dam safety decision-making for about 15 years, and has developed procedures to analyze risks for a multitude of potential failure modes. Manuals, guidelines, standards, and practical reference material on how to perform risk analysis for dam safety applications are lacking. The Best Practices Training Manual contains what are considered the “Best Practices” currently in use for estimating dam safety risks at the Bureau of Reclamation. Risk analysis at the Bureau of Reclamation has evolved over the years and will continue to evolve. Therefore, updates to this manual are planned in the future as significant improvements are developed.

From the outset of implementing risk analysis, Reclamation recognized that procedures and data available for dam safety risk analysis, while quantitative, do not provide precise numerical results. Therefore, this manual strives to present useful information, tools, and techniques, while stopping short of a “cookbook” approach. This allows the risk analyst(s) to use the proper balance of engineering judgment and calculations in estimating risks, and to understand “build the case” for what is influencing the risks the most. Thus, the numbers, while important, are less important than understanding and documenting what the major risk contributions are and why.

The Bureau of Reclamation conducts risk analysis at different levels, from screening level analyses performed by an individual (with peer review) during a Comprehensive Facility Review (CFR) to full blown facilitated team risk analyses, which include participation by field personnel. It is envisioned that the tools presented in this manual can be used for any level of risk analysis. The primary difference will be the level of detail to which the analyses are carried. These differences are noted where appropriate.

Contact for course information: Bill Fiedler (WFi@br.usbr.gov)

Best Practices Chapters

Please note that these documents are intended to serve as instruction material during the training course of the same name and should not be used as a stand-alone reference. In many cases, additional details should be sought from the available references or an experienced risk analyst.

Internal Erosion Tables

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## 26. Internal Erosion Risks

### Key Concepts

The number one cause of dam failures in the United States is from internal erosion of embankments (or their foundations). Unfortunately, this is a potential failure mode that cannot be completely analyzed using simplistic formulas or models. However, valuable information on dam and soil behavior is available to help in assessing internal erosion risks. The term “internal erosion” is used by Reclamation and USACE as a generic term to describe erosion of soil particles by water passing through a body of soil. Pipelines are often used generally in the literature, but actually refer to a specific internal erosion mechanism (described below).

It is recognized that risk estimating procedures, although qualitative, do not provide precise or accurate results. The nature of the risk evaluation should be advisory and not prescriptive. Furthermore, the results of such a procedure can be applied in decision making, rather than reliance on a “cookbook” numerical approach (Van Thoai, 1999). Thus, although the numbers are important, the more important aspects of a risk analysis are: (1) develop an improved understanding of the dam’s strengths, weaknesses, and potential failure modes; and (2) to "build the case" for the numbers that are presented and the resulting recommended action (or inaction). As such, one of the primary objectives of the risk assessment is to understand and "build the case" for the risk estimates that are developed and the resulting recommendations. Prior to the risk assessment, the risk team should review and discuss available information, and some analyses may be necessary (e.g., filter compatibility, internal instability, vertical or horizontal flow, etc.). The risk team should also review pertinent case histories. A few are summarized at the end of this chapter as a good starting point.

According to Sherard et al. (1965), “there remains a wide variety of opinion and practice among engineers working in the field. Many aspects of designing and constructing large earth dams will probably always belong to the group of engineering problems for which there are no universally accepted or universally correct procedures. In spite of advances in related technology, it is likely that the building of such dams will always remain an empirical process.” This assessment certainly applies to risk estimating procedures as well.
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http://www.usbr.gov/ssle/damsafety/Risk/methodology.html

Google is not the best approach for this
Best Practices in Dam and Levee Safety Risk Analysis

1: Risk Guidelines
2: Potential Failure Analysis
3: Qualitative and Semi-Quantitative Assessments
4: Building the Case
5: Basic Probability and Statistics
6: Seismic Hazard Analysis
7: Hydrologic Hazard Analysis
8: Water Level Exceedence Curves
9: Consequences of Flooding
10: Evaluating and Communicating Geological and Geotechnical Information for Use in Risk Assessments
11: Event Trees
12: Probabilistic Stability Analysis (Reliability Analysis)
Best Practices in Dam and Levee Safety Risk Analysis

13: Subjective Probability and Expert Elicitation
14: Reinforced Concrete Failure Mechanisms
15: Erosion of Rock and Soil
16: Flood Overtopping Failure of Dams and Levees
17: Seismic Spillway Pier Failure
18: Seismic Failure of Spillway/Retaining Walls
19: Risk Analysis for Concrete Buttress Dams
20: Risk Analysis for Concrete Gravity Structures
21: Risk Analysis for Concrete Arch Dams
22: Stagnation Pressure Failure of Spillway Chutes
23: Cavitation-Damage-Induced Failure of Spillways
24: Overtopping of Walls and Stilling Basin Failure
25: Levee Floodwalls
Best Practices in Dam and Levee Safety Risk Analysis

26: Internal Erosion Risks
27: Seismic Risks for Embankments
28: Landslide Risks
29: Seismic Failure of Spillway Radial Gates
30: Trunnion Friction Radial Gate Failure
31: Drum Gates and Other Gates
32: Probability of Failure of Mechanical and Electrical Systems on Dam Gates
33: Risk Estimates for Operational Failure
34: Construction Risks
35: Combining and Portraying Risks
36: Facilitating Risk Analyses
37: Practice Exercises
Dated (1983)

Does not cover risk considerations

Dam safety methodology and processes described are no longer used by USBR

There is some information that might be of interest regarding inspecting dams
Geared toward discussing new dams versus modifying existing dams
- Dated (1987)
- Does not cover risk considerations
- Dam safety methodology and processes described are no longer used by USBR
- Sample specifications are not in currently used CSI format
- Environmental rules and regulations out of date
- Filter criteria has been significantly updated
experimentation has been performed by the Corps of Engineers [30] and the Bureau of Reclamation [31]. Several somewhat different sets of criteria are given by these authorities. The following limits are recommended to satisfy filter stability criteria and to provide ample increase in permeability between base and filter. These criteria are satisfactory for use with filters of either natural sand and gravel or crushed rock and for filter gradations that are either uniform or graded:

\[
\frac{D_{15} \text{ of the filter}}{D_{15} \text{ of base material}} \geq 5, \text{ provided that the filter does not contain more than 5 percent of material finer than 0.074 mm (No. 200 sieve) after compaction.}
\]

\[
\frac{D_{15} \text{ of the filter}}{D_{85} \text{ of base material}} \leq 5.
\]

\[
\frac{D_{85} \text{ of the filter}}{\text{Maximum opening of pipe drain}} \geq 2.
\]

(4) Generally, the filter should be uniformly graded to provide adequate permeability and prevent segregation during processing, handling, and placing.

In the foregoing, \(D_{15}\) is the size at which 15 percent of the total soil particles are smaller; the percentage is by weight as determined by mechanical analysis. The \(D_{85}\) size is that at which 85 percent of the total soil particles are smaller. If more than one filter layer is required, the same criteria are followed; the finer filter is considered as the base material for selection of the gradation of the coarser
the use of shear-wave velocities derived from seismic surveys for seismic stability analyses.

The various geotechnical techniques and their implications are used for SEED Investigations follow:

1. Seismic Refraction and Reflection. This method measures layered compressional and ground-roll velocities. If there are any changes in the earth materials of a dam, a velocity anomaly will be generated. The ground-roll velocity approximate shear-wave velocity and can be used as a parameter in the determination of the dynamic response of an earth dam when shear-wave velocities are not available.

2. Seismic Shear-Wave Velocity Investigations. Shear waves are measured by downhole, cross-hole, and up-hole methods, using a standard refraction seismograph as the recorder. Shear-wave velocities are used as one of the key parameters in the determination of the dynamic response of an earth dam.

3. Radar Surveys. Radar surveys measure reflections from any interface that has a contrast in its complex dielectric properties. Radar is used to locate voids in concrete and behind tunnel walls, and to evaluate soils near the surface.

4. Resistivity Surveys. Resistivity surveys measure the electrical properties of soil and rock. Resistivity is primarily used to locate the phreatic surface through earth embankments.

The information obtained from the analysis of geologic issues is generally needed for the analysis of geotechnical issues. In some instances, the geologic analysis may indicate the need for additional geotechnical analysis, or it may, by itself, identify a dam safety deficiency. An example of such a case is a landslide hazard, which may necessitate the installation of an extensive landslide monitoring instrumentation and warning system and the modification of the SOP's for the dam.

13.16. Analyses of Geotechnical Issues. The analyses of geotechnical issues may include an evaluation of the available data, static stability analyses, seepage analyses, dynamic stability (deformation) analyses, and liquefaction analyses.

The performance of the structure under prior maximum loading conditions often provides a partial basis for assessment. The quality of performance is judged on the visual condition of the structure, as described in the Examination Report, and on available instrumentation records (Structural Behavior Report).

All available instrumentation data from the Structural Behavior Report and other sources are reviewed during the geotechnical evaluation. If no data or only limited data are available, a determination is made on whether additional instrumentation is required to assist in the potential dam safety problem.

An assessment of the structural stability and seepage-control integrity of the embankment and foundation under static loads is made for each dam. The extent of the assessment should vary in each case, depending on the following factors:

1. Visual condition of the embankment and foundation.
2. Operation and performance record.
3. Structural and hydraulic height of the embankment.
4. Embankment zoning and exterior slope structures.

(c) Seepage Stability Analyses. The seepage stability of the embankment and foundation should be assessed. This analysis focuses on such factors as increased seepage with time and the presence of sinkholes, cavities, and sandboils. Existing information and records are used in the evaluation. Seepage analyses of items like critical gradients, flow-net construction, and finite elements are performed as required if sufficient data are available. The seepage-control integrity of filters, drains, blankets, and transition-zone materials should also be assessed.
Figure 9-15.—Drop inlet spillway for a small dam. 103-D-1873.

Figure 10-2.—Typical free-flow conduit outlet works installations. 103-D-1837.
Dated (1987)

- Flood studies – no discussion of paleohydrology, little discussion of estimating flood frequencies
- Moving away from relative density testing of cohesionless soils
- Geosynthetics – no discussion
- Riprap sizing – new USBR design standard
- Filters – now modified ASTM C33
- Toe drains – no discussion of HDPE or PVC pipe
- Drilling methods, lab methods, foundation treatment methods, grouting details, concrete specs – all could be updated
Only one main issue to be aware of – temperature control in mass concrete was based on Hoover Dam studies and is out-dated

- Now (starting around 2000) cement is more finely ground for more rapid strength gain in high-rise building construction
- Heat rise would be more rapid than indicated in this manual

Otherwise, nothing wrong, but:
- Written with 1976 computer technology in mind
- Written without any risk-based design considerations
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Same list as for gravity dams

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Design Criteria for Concrete Arch and Gravity Dams

Office of Design and Construction
Engineering and Research Center
Denver, Colorado 80225

United States Department of the Interior
Bureau of Reclamation

1977 40 pages
Design Criteria for Concrete Arch and Gravity Dams

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Design Criteria for Concrete Arch and Gravity Dams

Office of Design and Construction
Engineering and Research Center
Denver, Colorado 80225

United States Department of the Interior
Bureau of Reclamation

1977
40 pages
Guide for Preliminary Design of Arch Dams

UNITED STATES DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

1966 29 pages
Technical Service Center
Materials Engineering and Research Lab

MERL Publications

MERL staff members not only possess unparalleled expertise in materials engineering and testing, they also share their expertise with others in Reclamation and throughout the engineering community. Here are a few of the widely regarded publications that MERL personnel have prepared over the years. All reports are in PDF format; those with no size listed are less than 5 MB.

- Creating a GIS System to Display Aggregate Quality Information, 2005 (13 MB)
- Developing NDT Methods to Evaluate Large Anchor Bolts, 2004
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- Guide to Protective Coatings: Inspection and Maintenance, 2002
- Linings for Irrigation Canals, 1976 (21 MB)
- New Recommendations for ASR Mitigation in Reclamation Concrete Construction
- Performance of Granular Soil Covers on Canals (REC-ERC-81-7), 1981
- Performance of Plastic Canal Linings (REC-ERC-84-1), 1984 (10.5 MB)
- Standard Specifications for Corrugated Polyethylene and Polyvinyl-Chloride Drainage Pipe — M-20, 1995
- Use of Geomembranes for Emergency Spillways, 1985
MERL Publications

MERL staff members not only possess unparalleled knowledge, but also share their expertise with others in Reclamation and the public. Among the widely regarded publications that MERL produces are:

- Creating a GIS System to Display Aggregate Sampling Zones
- Developing NDT Methods to Evaluate Laminated Laminate Composite Materials in Rail Track Components
- Guide to Concrete Repair, 1997 (9 MB)
- Guide to Protective Coatings: Inspection and Maintenance
- Linings for Irrigation Canals, 1976 (21 MB)
- New Recommendations for ASR Mitigation
- Performance of Granular Soil Covers on Concrete
- Performance of Plastic Canal Linings (RE-28659, 1995)
- Standard Specifications for Corrugated Plastic Drainage Pipe
- Use of Geomembranes for Emergency Spill Containment
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- Performance of Granular Soil Covers on Canals (REC-ERC-81-7), 1981
- Performance of Plastic Canal Linings (REC-ERC-84-1), 1984 (19.5 MB)
- Standard Specifications for Corrugated Polyethylene and Polyvinyl-Chloride Drainage Pipe — M-20, 1995
- Use of Geomembranes for Emergency Spillways, 1985
# CONCRETE MANUAL

A WATER RESOURCES TECHNICAL PUBLICATION

EIGHTH EDITION - REVISED

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

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Still a good reference

Some areas are dated:
- Newer technology
- Updated test procedures
- New and different admixtures, cement types, etc. now available

Fundamentals still okay
CONCRETE MANUAL

PART 2

A Water Resources Technical Publication

NINTH EDITION

U.S. DEPARTMENT OF THE INTERIOR
BUREAU OF RECLAMATION

1992
CONCRETE MANUAL

PART 2

A Water Resources Technical Publication

NINTH EDITION

1992

- Compilation of test procedures

- Since ASTM test procedures can and are more frequently updated, ASTM is the best source for the latest information regarding testing procedures

- Still a good reference, particularly for testing areas not currently addressed by ASTM test procedures
Still very useful and basically current
New Recommendations for ASR Mitigation in Reclamation Concrete Construction

Technical Services Center, Denver Colorado
Concrete

Aggregate Database

Summaries of aggregate quality evaluation test results are available for some of the aggregate sources tested by this facility.

Reclamation’s Materials Laboratory in Denver has had an international reputation for excellence in concrete technology for over 50 years. Reclamation has a concrete laboratory that includes aggregate processing and testing, cement testing, mixing room, fog room and environmental chambers, freezing and thawing equipment, sulfate attack, durability testing, chemistry, petrography, and many specialized test facilities. The concrete laboratory is complemented by complete structural testing capabilities including a 5,000,000 pound universal testing machine and vibration laboratory.

Concrete Quality Control Database

The group has developed a PC compatible database program for tracking project concrete mixture proportions, fresh and hardened concrete properties, and source data. The program assembles the data to produce user defined reports, tables and graphs.

Concrete Publications from MERL

- Guide to Concrete Repair, 1997 (9-MB pdf)
- New Recommendations for ASR Mitigation in Reclamation Concrete Construction (pdf)
- Concrete Rules of Thumb (pdf)

Useful Forms

- Field Exploration Concrete Coring Log Sheet for use with a standard 5’ long, 6” diameter, split tube core barrel. (pdf)
- Laboratory Concrete Break Sheet (pdf)
- Aggregate & Riprap Quality Evaluation Form (pdf)

Concrete Presentations

- RRCG Facing VID
# Concrete Mix Rules of Thumb

## Adding One Gallon of Water to One Cubic Yard of Freshly Mixed Concrete Will:

- Increase slump about one inch
- Decrease compressive strength about 200 to 300 psi
- Increase shrinkage potential about 10%
- Waste as much as 1/4 bag of cement

## If Freshly Mixed Concrete Temperature Increases 10 Degrees Fahrenheit:

- About 1 gallon of water per cubic yard maintains equal slump
- Air content decreases about 1%
- Compressive strength decreases about 150 to 200 psi

## If the Air Content of Freshly Mixed Concrete:

- Increases 1%, then compressive strength decreases about 5%
- Decreases 1%, then yield will decrease about 1/4 cubic foot per cubic yard
- Decreases 1%, then slump decreases about 1/2 inch
- Decreases 1%, then durability decreases about 10%
Reclamation – Technical Service Center
Materials Engineering and Research Lab (MERL)
www.usbr.gov/pmts/materials_lab/pubs/

Technical Service Center
Materials Engineering and Research Lab

MERL Publications

MERL staff members not only possess unparalleled expertise in materials engineering and testing, they also share their expertise with others in Reclamation and throughout the engineering community. Here are a few of the widely regarded publications that MERL personnel have prepared over the years. All reports are in PDF format; those with no size listed are less than 5 MB.

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- Performance of Plastic Canal Linings (REC-ERC-84-1), 1984 (19.5 MB)
- Standard Specifications for Corrugated Polyethylene and Polyvinyl-Chloride Drainage Pipe — M-20, 1995
- Use of Geomembranes for Emergency Spillways, 1985
• Still a good reference

• There have been a lot of advances regarding filters since 1998, so this is not an appropriate reference in this area

• Same issue regarding the discussions on investigations and mapping – technology has changed greatly since 1998

• On test procedures – defer to ASTM for latest
Google is very roundabout for this – go to MERL

• Compilation of test procedures

• Since ASTM test procedures can and are more frequently updated, ASTM is the best source for the latest information regarding testing procedures

• Still a good reference, particularly for testing areas not currently addressed by ASTM test procedures

Same as Concrete Manual – Part 2

Reclamation – Technical Service Center
Materials Engineering and Research Lab (MERL)
www.usbr.gov/pmts/materials_lab/pubs/

MERL Publications

- Creating a GIS System to Display Aggregate Quality Information, 2006 (13 MB)
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- Performance of Plastic Canal Linings (REC-ERC-84-1), 1984 (19.5 MB)
- Standard Specifications for Composite Polyethylene and Polyvinyl-Chloride Drainage Pipe — M-20, 1995
- Use of Geomembranes for Emergency Spillways, 1995
Technical Service Center
Embankment Dams and Geotechnical Engineering Groups

Rock Manual

The Rock Manual provides common technical information on properties of rocks, field and laboratory investigations, and testing of rocks used as foundations and materials for dams, tunnels, canals, and many other types of structures built for Reclamation. The Rock Manual consists of two parts:

Part 1, to be completed, will include chapters on the properties of rocks and general principles as well as stages of rock investigations.

Part 2, which is this website, provides the rock testing procedures Reclamation currently recommends. Please download the introduction to Part 2 (pdf) for disclaimers and an explanation of how to use these standards.

- Specialized Reclamation standards are presented when no such standard exists in the industry or when Reclamation requirements are such that none of the existing standards are applicable. Some of these are very detailed type standards developed under the original Rock Manual protocol. Reclamation-specific standards tend to be much more detailed than comparable ASTM standards.

- Rock testing resources are available under the ISRM Suggested Methods and the U.S. Army Corps of Engineers (USACE) Rock Testing Manual.
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ENGINEERING GEOLOGY FIELD MANUAL
SECOND EDITION
VOLUME II

U.S. Department of the Interior
Bureau of Reclamation
## Embankment Dam Instrumentation Manual

### Concrete Dam Instrumentation Manual


---

### Technical Service Center, Geotechnical Services

**Instrumentation and Inspections Group**

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EMBANKMENT DAM INSTRUMENTATION MANUAL

A WATER RESOURCES TECHNICAL PUBLICATION

UNITED STATES DEPARTMENT OF THE INTERIOR
Bureau of Reclamation

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WATER MEASUREMENT MANUAL

A WATER RESOURCES TECHNICAL PUBLICATION

A guide to effective water measurement practices for better water management

Table A7-4. Discharge of 90° V-notch weirs, in ft³/sec, computed from the formula \( Q = 2.49H^{1.48} \)

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U.S. Department of the Interior
Bureau of Reclamation
Water Measurement Manual

3rd edition, 1997
Revised reprint, 2001

The Water Measurement Manual is the official reference on irrigation water measurement for the Bureau of Reclamation and the U.S. Department of Agriculture. The manual is available in several formats:

- Hardbound - See How to Obtain the Water Measurement Manual
- Online
  - HTML format - individual sections are contained in small files that download quickly. An interactive index is provided.
  - Browse the Water Measurement Manual on the web - This is the best way to see high resolution figures and graphs. Click on individual images to view high resolution versions.
  - Download a self-extracting ZIP file to install the HTML version of the manual onto your PC or laptop [9 MB]
  - PDF format - this version of the manual is a single large file [3.2 MB]. This version does not include an index.
    - Browse the manual on the web (PDF format)
    - Download a ZIP file containing the PDF version of the manual that can be installed on your PC or laptop [3.2 MB]
The Water Measurement Manual - Bureau of Reclamation
www.usbr.gov/pmts/hydraulics_lab/pubs/wmm/

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Water Measurement Manual

Cover Page
... of this manual, please see Where to get the Water ...

13. Special Weirs
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More results from usbr.gov »

Water Measurement Manual - US Government Bookstore
bookstore.gpo.gov/products/sku/024-003-00186-4


www.idwr.idaho.gov/WaterManagement/WaterMeasurement/ ... continued demand for the Water Measurement Manual are responsible for ... The first edition of the Water Measurement Manual (1953) had a distribution of ...
Guidelines For Performing Foundation Investigations For Miscellaneous Structures
By: Interior Dept., Bureau of Reclamation
GPO Stock #: 024-003-00203-9 ISBN:
Provides guidance on geotechnical/geological investigation requirements for nonhydraulic and hydraulic structures.

Earth Manual, Part 1
By: Interior Dept., Bureau of Reclamation
GPO Stock #: 024-003-00183-0 ISBN:
3rd edition. Provides technical information on the field and laboratory investigations and construction control of soils used as foundations and materials for dams, canals, and other types of structures built for reclamation projects. Part...

Design of Small Dams
By: Interior Dept., Bureau of Reclamation
GPO Stock #: 024-003-00184-3 ISBN:
Discusses the architectural, design, engineering, ecological and environmental considerations in the construction and maintenance of small dams. Covers different dam types and dam safety, including flood control, along with detailed...

Colorado River Documents 2008 (Hardcover and DVD)
By: Interior Dept., Bureau of Reclamation
GPO Stock #: 024-003-00203-2 ISBN: 9780160061006
Discusses the history of the U.S. Bureau of Reclamation’s operation and management of the Colorado River on behalf of the Secretary of the Interior from 1975 through 2008. Details the political, legal, institutional, and other instruments...

Colorado River Documents, 2008 (DVD)
By: Interior Dept., Bureau of Reclamation
GPO Stock #: 024-003-00213-7 ISBN: 9780160084105
Discusses the history of the U.S. Bureau of Reclamation’s operation and management of the Colorado River on behalf of the Secretary of the Interior from 1975 through 2008. Details the political, legal, institutional, and other instruments...

Bureau of Reclamation’s Civilian Conservation Corps Legacy: 1933-1942
By: Interior Dept., Bureau of Reclamation
GPO Stock #: 024-003-00203-4 ISBN: 9780160082431
A comprehensive study focusing on the Bureau of Reclamation’s Civilian Conservation Corps (CCC) program. Includes a brief overview of the national CCC program and a description of Reclamation’s CCC program, followed by individual forms...
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<td>The Bureau of Reclamation: History Essays From the Centennial</td>
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Dams and Public Safety
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Discusses U.S. requirements and offers unparalleled, dam design and construction and dam safety issues of interest to consumers and engineers alike.

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Metric Manual
By: Interior Dept., Bureau of Reclamation


Price: $45.00
Bureau of Reclamation Resources

• Older – many cautions

• Older – some cautions
  – Design of Arch Dams (1977)
  – Concrete Dam Instrumentation Manual (1987)
Bureau of Reclamation Resources

• Current or basically current
  – Guide to Concrete Repair (1997)
  – Reclamation Design Standards (as currently posted)
Design Standards

- **Design Standard No. 1: General Design Standards** (September 2009; updated May 2012) (682 KB .pdf File)
  - Chapter 1: Preparing and Using Design Standards
  - Chapter 2: Design Standards Index

- **Design Standard No. 9: Buildings and Other Structures**
  - Chapter 8: Modification of Existing Buildings (January 2012) (337 KB .pdf File)
  - Chapter 13: Seismic Design (October 2012) (613 KB .pdf File)

- **Design Standard No. 13: Embankment Dams**
  - Chapter 1: General Design Standards (October 2011) (2.7 MB .pdf File)
  - Chapter 3: Foundation Surface Treatment (July 2012) (19.6 MB .pdf File)
  - Chapter 4: Static Stability Analysis (October 2011) (8.5 MB .pdf File)
  - Chapter 5: Protective Filters (November 2011) (16.7 MB .pdf File)
  - Chapter 8: Seepage (October 2011) (14.8 MB .pdf File)
  - Chapter 9: Static Deformation Analysis (November 2011) (7.6 MB .pdf File)
  - Chapter 10: Embankment Construction (May 2012) (4.5 MB .pdf File)

- **Design Standard No. 14: Appurtenant Structures for Dams (Spillway and Outlet Works)**
  - Chapter 1: Introduction (November 2010; updated October 2011) (2.2 MB .pdf File)
  - Chapter 2: Hydrologic Considerations (November 2013) (3.6 MB .pdf File)
Bureau of Reclamation Resources

• Current or basically current
  – Guide to Concrete Repair (1997)
  – Reclamation Design Standards (as currently posted)
  – Best Practices in Dam and Levee Dam Safety Risk Analysis
Best Practices in Dam and Levee Safety Risk Analysis

Best Practices and Risk Methodology

The Bureau of Reclamation has been using risk analysis as the primary support for dam safety decision-making for about 15 years, and has developed procedures to analyze risks for a multitude of potential failure modes. Manuals, guidelines, standards, and practical reference material on how to perform risk analysis for dam safety applications are lacking. The Best Practices Training Manual contains what are considered the “Best Practices” currently in use for estimating dam safety risks at the Bureau of Reclamation. Risk analysis at the Bureau of Reclamation has evolved over the years and will continue to evolve. Therefore, updates to this manual are planned in the future as significant improvements are developed.

From the outset of implementing risk analysis, Reclamation recognized that procedures and data available for dam safety risk analysis, while quantitative, do not provide precise numerical results. Therefore, this manual strives to present useful information, tools, and techniques, while stopping short of a “cookbook” approach. This allows the risk analysis to use the proper balance of engineering judgment and calculations in estimating risks, and to understand “build the case” for what is influencing the risks the most. Thus, the numbers, while important, are less important than understanding and documenting what the major risk contributions are and why.

The Bureau of Reclamation conducts risk analysis at different levels, from screening level analyses performed by an individual (with peer review) during a Comprehensive Facility Review (CFR) to full blown facilitated team risk analyses, which include participation by field personnel. It is envisioned that the tools presented in this manual can be used for any level of risk analysis. The primary difference will be the level of detail to which the analyses are carried. These differences are noted where appropriate.

Contact for course information: Bill Fiedler (WFielder@usbr.gov)

Best Practices Chapters

Please note that these documents are intended to serve as instruction material during the training course of the same name and should not be used as a stand-alone reference. In many cases, additional details should be sought from the available references or an experienced risk analyst.

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http://www.usbr.gov/ssle/damsafety/Risk/methodology.html
The End