# Forest Service Manual
# National Headquarters - Washington Office
# Washington, DC

## Forest Service Manual 7500 – Water Storage and Transmission

## Chapter 7520 - Dam Planning, Investigation, and Design

**Amendment:** 7500-2011-3

**Effective date:** May 13, 2011

**Duration:** This amendment is effective until superseded or removed.

**Approved by:** James M. Pena, Associate Deputy Chief, NFS

**Date approved:** May 11, 2011

**Responsible Staff:**

**Last Change:** 7510, Amendment 7500-2011-2

**Superseded Document(s):** 7520, Amendment 7500-2000-1, 9/11/2000

**Posting Instructions:** Amendments are numbered consecutively by title and calendar year. Post by document; remove the entire document and replace it with this amendment. Retain this transmittal as the first page(s) of this document. The last amendment to this title was 7500-2011-2 to FSM 7510.
**Digest:** Following is an explanation of the changes throughout the directive by section.

**7520:** Changes categorization of dams from A, B, C, and D and low, medium, and high hazard to low, significant, and high hazard potential classification throughout chapter. Recodes, reorganizes, and revises direction and makes minor technical and editorial changes throughout the chapter.

**7520.2:** Establishes code, caption, and adds cross-reference to 7502.

**7520.3:** Establishes code, and recodes to this section caption and policy statement previously set out in section 7521.03.

**7520.5:** Establishes code, caption "Definitions," and sets forth terminology specific to this chapter.

**7521:** Changes caption from "Scheduling" to "Scheduling of Dam Management and Engineering."

**7521. 03: Removes code, and recodes caption and policy statement to 7520.3.**

**7523.05: Removes code, caption, and obsolete terms.**

**7524 thru 7524.22:** Removes captions and direction and recodes to section 7525. Establishes captions and sets forth direction for "Review and Approval of Proposed Projects."

**7525 thru 7525.49:** Removes captions and direction and recodes to 7526. Recodes to this section captions and direction previously set out in section 7524.

**7525.43:** Changes caption from "Earthquake Design" to "Seismic Design" and revises direction.

**7526:** Establishes code and recodes to this section caption and direction previously set out in section 7525.

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## 7520.2 - Objectives

See FSM 7502.

## 7520.3 - Policy

Ensure that the design of dams is consistent with the applicable land management plan and applicable feasibility studies, environmental impact assessments, and site investigations.

## 7520.5 - Definitions

For additional definitions, see FSM 7505 and FSH 7509.11, section 05.

Design Storm. A specified amount of storm rainfall, described using the areal and temporal distribution of the rainfall and used to estimate a design discharge that is typically based on a specified recurrence period.

Design Earthquake. The magnitude of earthquake a dam is designed to resist without failing, represented by specification of the free-field ground motion that would be felt at the dam due to the seismic event that is used as the basis for earthquake-resistant design.

Design Maximum Credible Earthquake (MCE). The largest possible earthquake that could reasonably occur along recognized faults or within a particular seismic source.

Horizontal Acceleration. The acceleration horizontally at the point of consideration resulting from the design earthquake.

Incremental Damage Analysis. A comparative study of two floods of different magnitude that is used to quantify incremental increases in impacts on human life and property.

Probable Maximum Flood. The flood flow that may be expected from the most severe meteorological and hydrological conditions that are reasonably possible in the area.

Recurrence Period. The interval in which an event will occur once on average.

## 7521 - Scheduling of Dam Management and Engineering

Dam management includes coordination, budgeting, scheduling, planning, and project and construction management for dams. Dam engineering includes all aspects of design and project engineering for dams, including reviews. Schedule dam management and engineering to:

1. Design dams effectively and economically.

2. Ensure compliance with program objectives, environmental concerns, and public safety.

## 7522 - Design Records

Keep design records orderly and current to allow efficient review at any stage. Design records must be complete and understandable, since they may form the basis for later actions such as design changes, modification or addition of appurtenant works, investigation of structural deficiencies, periodic safety evaluations, hazard assessment, development and updating of an EAP, and possible litigation. Scope and detail of the design record will vary with the complexity and risk of the project.

Design-related correspondence must contain a full presentation of the pertinent facts and analysis and must document the selection of alternatives or other matters affecting the design.

Final design documentation must include a permanent record of the design analysis and decisions and an index to the design records.

## 7523 - Planning

In the planning stage, consider alternate sites and structural types to meet objectives, maximize use of on-site or local materials, and minimize project costs and social and environmental impacts (FSM 1950). Constraints may include minimum stream flow requirements, fish passage and protection measures, sluice gates to pass sediment downstream to protect and maintain channel and aquatic habitats, water rights, land management plan standards and guidelines, project funds, the dam's hazard potential classification, and environmental issues such as wetlands. The environmental analysis must consider these constraints as well as the benefits of reservoir storage. Consider flood storage for Forest Service-operated dams when the potential benefits exceed additional construction costs.

Gather data needed to plan the design and assess design alternatives from available maps, records, and site reconnaissance. Field surveys and geological and geotechnical foundation investigations may be necessary, depending on the complexity and risks of the project.

## 7524 - Review and Approval of Proposed Projects

Plans and designs for all new dams and modification or repair of existing dams on National Forest System lands must have written approval from the authorized officer prior to construction. Approval must be based on administrative (7524.1) and engineering (7524.2) review.

Coordinate with appropriate Federal and State agencies to ensure that:

1. Project plans are consistent with policies in FSM 7503.

2. Project plans include securing any needed water rights or permits from the State for water development or use (FSM 2540).

3. The project is consistent with the applicable land management plan.

4. Construction of the project can be effectively coordinated with other National Forest System activities in the area.

5. The emergency action plan (EAP) is prepared, when required, during the design phase (FSM 7515 and FSH 7509.11, ch. 50).

### 7524.1 - Environmental Review

Ensure that the scope and complexity of the environmental analysis (FSM 1950) and administrative work are appropriate and have been completed for each project. Protection and Mitigation measures should be developed pursuant to authority granted via FLPMA (FSM 2710 and FSM 2720) and the Federal Power Act (FSM 2770) and to protect fish and wildlife habitat (FSM 2630).

### 7524.2 - Engineering Review of Dam Designs

The regional director of Engineering shall review and approve the designs for dams to be operated by the Forest Service or the holder of a special use authorization. The scope of engineering review of a dam design varies with the complexity, extent, and hazard potential classification of the dam, as well as the level of involvement of a Federal or State dam safety agency. See FSM 7504 for additional direction on design review and approval.

### 7524.21 - Independent Engineering Review

All dams with a high or significant hazard potential classification must have an independent engineering review conducted by a qualified engineer (FSM 7505) not directly involved in the design process. Independent engineering reviews of dams operated by the holder of a special use authorization may be conducted by qualified Forest Service engineers, Federal and or State agencies, or professional engineering consultants not employed by the primary design firm.

### 7524.22 - Design Approval

Designs of new dams and rehabilitation of dams with a high or significant hazard potential classification must be accomplished by a qualified engineer with professional experience consistent with the requirements for analyzing the size of the structure and the hazard potential classification involved.

Plans and specifications for new dams and rehabilitation of dams operated by the holder of a special use authorization must be approved in writing by the regional director of Engineering before construction commences. The approval documentation must contain any terms and conditions for project implementation. Design changes made after the initial review or during construction must be submitted to the regional director of Engineering for written approval at least 3 days prior to implementation.

Designs submitted for dams to be operated by the holder of a special use authorization must be prepared and signed or stamped by a licensed engineer with professional experience consistent

with the requirements for analyzing the size of the structure and the hazard potential classification involved.

### 7525 - General Design Standards

The level of design detail increases from preliminary to final design and with increasing size, value, and hazard potential classification of the structure. The level of detail of the geological and geotechnical investigation, design, design reports, and drawings must be adequate to construct the dam within acceptable safety parameters for its size and hazard potential classification. Utilize current U. S. Army Corps of Engineers or Bureau of Reclamation standards and procedures for dams in planning, investigating, and designing dams on National Forest System lands.

Appropriate design standards for tailings dams include "Design and Evaluation of Tailings Dams," EPA 530-R-94-038, and State of Idaho Rule 37.03.05. Federal or other State agencies with jurisdiction or overlapping jurisdiction may impose additional or more stringent standards for tailings dams on National Forest System lands.

### 7525.1 - Hydrology and Flood Routings

At a minimum, utilize standards and procedures established by the Bureau or Reclamation, U.S. Army Corps of Engineers, or Natural Resources Conservation Service for determining the design storm event and sizing the spillway. Any appropriate Federal and State standards may be used case by case. Conduct site-specific evaluations to develop the inflow design hydrographs.

### 7525.11 - Incremental Damage Analysis

Incremental damage is the additional damage resulting from flooding with overtopping dam failure versus flooding without overtopping dam failure. Perform an incremental damage analysis to determine flood damage and potential loss of life resulting from the sudden release of water stored in the reservoir.

In addition to flows from the reservoir, consider flows from tributaries downstream from the reservoir up to the point where no further significant incremental damage would occur.

### 7525.2 - Hazard Assessment

Determine the hazard potential classification of a dam (high, significant, or low, according to FSM 7512.1) based on flood damage from a breach of the dam in clear weather up to a point downstream from the dam where the flood is contained within the 100-year flood channel. In conducting a hazard assessment, consider the reservoir full to the crest of the uncontrolled spillway, and consider and document reasonably foreseeable downstream development as well as existing development. Calculate the time required for complete breach to occur for the type of dam and size of the dam using generally accepted methods.

## 7525.3 - Spillway Sizing

### 7525.31 - Spillway Sizing Standards

In general, size the spillway so that it can accommodate the inflow design flood shown in exhibit 01. An inflow design flood that is smaller than the applicable inflow design flood listed below is acceptable if the results of an incremental damage analysis show that failure of the dam would cause insignificant incremental damage to property and no additional threat to human life (7525.32).

**7525.31 – Exhibit 01**

**Required Inflow Design Flood for New Dams and Dam Modifications**

| Hazard Potential Classification | Inflow Design Flood |
|---|---|
| HIGH | PMF* |
| SIGNIFICANT | 1/2 PMF |
| LOW | 100-YEAR RP** |

* Probable maximum flood.
** Recurrence period.

### 7525.32 - Exceptions to Spillway Sizing Standards

The discharge produced during the failure of dams with small reservoirs is often less than the expected discharge for the probable maximum flood (PMF). For these dams, the inflow design flood generally should not exceed the peak discharge resulting from a dam failure because any additional consequences resulting from larger flood events can be attributed to natural flooding. Include an appropriate freeboard value based on the potential for waves, wave run-up, future dam settlement, and future dam maintenance to ensure the dam safely withstands the selected inflow design flood.

An inflow design flood that is smaller than the applicable inflow design flood in 7525.31, exhibit 01, is acceptable if the results of an incremental damage analysis show that failure of the dam would cause insignificant incremental damage to property and no additional threat to human life. Utilize "Federal Guidelines for Dam Safety: Selecting and Accommodating Inflow Design Floods for Dams," April 2004, as amended, in making this determination.

In determining whether an exception to spillway sizing standards is appropriate, consider the level of flood protection provided by the dam for populations downstream. In sizing the spillway, consider local site conditions, such as the potential for debris in the watershed, the orientation and potential for plugging of the spillway, and any other factors that affect safe operation of the spillway. Under no circumstances should the spillway capacity be reduced below the applicable minimum threshold in exhibit 01.

### 7525.32 – Exhibit 01

**Minimum Spillway Capacity**
**For Incremental Damage Analysis**

| Hazard Potential Classification | Inflow Design Flood | Minimum Spillway Capacity |
|---|---|---|
| High | PMF* | 1/2 PMF |
| Significant | 1/2 PMF | 100-Year RP** |
| Low | 100-Year RP | 50-Year RP |

* Probable maximum flood.
** Recurrence period.

Existing dams which can accommodate at least 75 percent of the inflow design flood do not need to be modified to increase spillway capacity to the minimum requirements in 7525.32, exhibit 01, until the dams undergo major reconstruction.

New spillways will be located in a manner that does not prevent ground access to the dam or its appurtenances and affords maximum exposure to sunshine during the shortest day of the year. If an existing spillway is blocked by ice or snow during the winter months, determine the angle of the sun at that location during the shortest day of the year and remove all obstructions, such as vegetation or boulders, of the sun at that angle.

## 7525.4 - Investigation and Design Criteria

Apply the site investigation and design criteria in 7525.41 through 7525.48 to new dams, enlargement/improvement of existing dams, and for dams considered structurally unsafe. Any variance from these criteria must have prior written approval from the regional director of Engineering.

## 7525.41 - Site Investigations

Investigate and test a potential dam site to the extent appropriate for the size and hazard potential classification of the dam and for possible geological features that influence the risk of dam failure. Consult with an experienced professional engineer and a geologist to formulate an appropriate geotechnical and geological investigation of potential dam sites.

## 7525.42 - Structural Stability

Current structural guidelines for dams developed by the U. S. Army Corps of Engineers and the Bureau of Reclamation may be used in designing side slopes made of earth for dams with a low hazard potential classification. Analyze the embankment stability for dams with a significant or high hazard potential classification to ensure that all pertinent static and dynamic loading conditions will not exceed allowable shearing stresses in the embankment or foundation. Ensure that the factors for safety and allowable shear stresses used in the design are appropriate for the construction and operating conditions for the dam.

## 7525.43 - Seismic Design

Determine the design earthquake for new dams and dams undergoing major modifications based on the dams' hazard potential classification, as shown below:

| Hazard Potential Classification | Annual Exceedance Probability | Recurrence Period in Years* | Exceedance Probability in 50 years |
|---|---|---|---|
| Low | $2 \times 10^{-3}$ | 500 | 10% |
| Significant | $4 \times 10^{-4}$ | 2,500 | 2% |
| High | $2 \times 10^{-4}$ | 5,000 or MCE** | 1% |

* Multiply the recurrence period in years by 0.75 to obtain the design earthquake recurrence period for existing dams. For example, for a dam with a low hazard potential classification, 500 years x 0.75 = a 375-year design earthquake recurrence period.

** Use of the 5000 year event or maximum credible earthquake (MCE) is left to the discretion of the regional director of Engineering. Establish ground motion associated with the MCE using a deterministic approach.

In determining the design earthquake, consider earthquake-related issues such as fault displacement; foundation and soil liquefaction; cracking potential; structural, abutment, and slope stability; overtopping effects; and required defensive measures, such as an emergency action plan (EAP).
Conservative simplified methods that have become accepted engineering practices may be used in determining the design earthquake.

Dams may be exempted from an in-depth seismic analysis if all the following conditions are met:

1. The dam and foundation materials are not subject to liquefaction and do not include sensitive clays.

2. The dam is compacted to at least 95 percent of laboratory maximum dry density (ASTM D 698) or has a relative density of more than 75 percent.

3. The slopes of the dam are 3H:1V or flatter, or the phreatic line is below the downstream toe of the embankment.

4. The peak horizontal acceleration at the base of the dam is no more than 0.30g.

5. The static safety factors for all dam components and appurtenances that could trigger a dam failure or lead to a loss of crest elevation (that is, slides that are not shallow or surficial) during an earthquake are greater than 1.5 under static loading and pore pressure conditions expected immediately prior to an earthquake.

6. The freeboard at the time of an earthquake is at least 3 to 5 percent of the embankment height and not less than 3 feet, and there are no critical appurtenant features that would be harmed by small movements of the embankment.

### 7525.44 - Geosynthetics

Generally, the use of natural materials, such as native or quarried soil and rock, is preferable in constructing a dam. Access to a dam may be difficult, significantly increasing the cost of repairs or reconstruction. In these circumstances, geosynthetics offer a relatively low-cost option for embankment reinforcement, seepage protection, filtering, and material separation. Given the uniqueness of most dam sites and the potential for failure if a geosynthetic is incorrectly designed or installed, use of any geosynthetics requires prior written approval from the regional director of Engineering.

### 7525.45 - Outlet Works

The following criteria apply, unless a dam is specifically exempted from them in writing by the regional director of Engineering:

1. All new or replacement outlets for dams with a high hazard potential classification must be at least 30 inches in diameter. When selecting appropriate diameter, consider the potential for plugging and ease of inspection.

2. All new or reconstructed dams with a high hazard potential classification must have outlet works capable of lowering 75 percent of the normal pool elevation within 20 to 30 days. Base the appropriate time frame for drawdown on identified hazards, site-specific conditions, and dam design. In cases where upstream slope failure is a concern, the drawdown rate may not exceed one foot per day. The time frame for drawdown must have prior written approval from the regional director of Engineering.

3. Unless specifically approved by the regional director of Engineering, corrugated metal pipe may not be used in any dam.

### 7525.46 - Flashboards

Flashboards may not be used in spillways unless approved in writing by the regional director of Engineering. The regional director of Engineering must consider spillway capacity and increased surcharge in reviewing requests to use flashboards in spillways.

### 7525.47 - Access

Consider access for future operation and maintenance and emergency management during the design phase.

### 7525.48 - Instrumentation

Depending on the size, hazard potential classification, and design of the dam and foundation conditions, consider installing an instrumentation system to observe changing conditions in the foundation, embankment, and abutments during construction, initial reservoir filling, and operation. Instrumentation may include items such as reservoir staff gauges, weirs, flumes, piezometers, survey monuments, and remote sensing systems.

### 7525.49 - Additional Design Items

In addition to the criteria in FSM 7525.41 through 7525.48, consider the following in dam design:

1. Conservation pools;

2. Sediment storage;

3. Wave action on the freeboard above the maximum pool elevation achieved during the inflow design flood;

4. Wave, slope, spillway, and internal erosion protection;

5. Fish passage structures; and

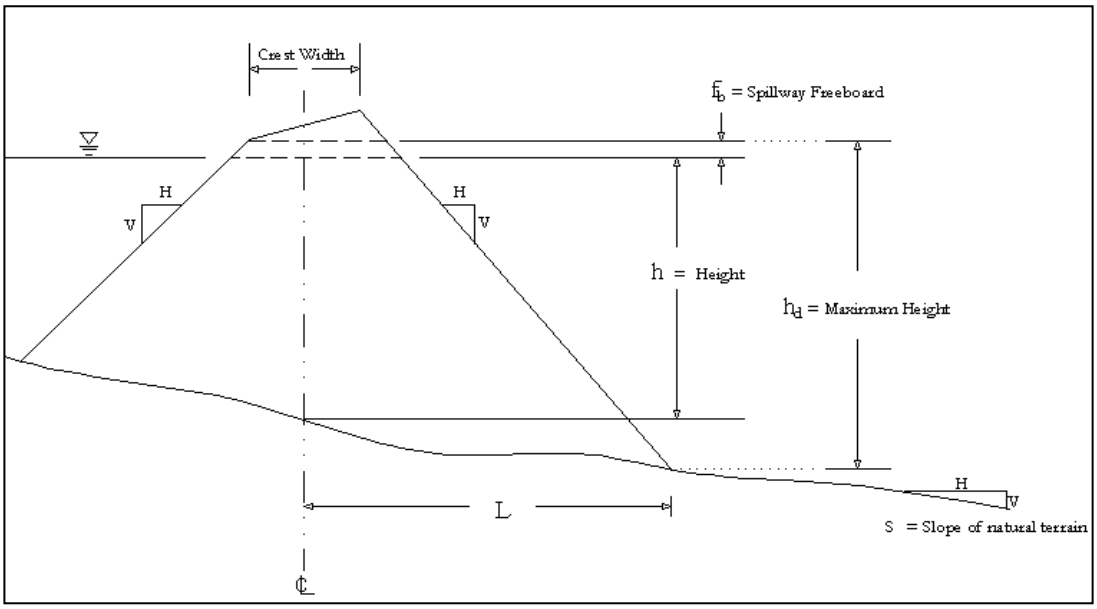
6. Added embankment height to compensate for settlement.

7. Bypass flow requirements.

The crest width (W) for earth dams must be at least 10 feet and must increase in width based on dam height (H), or $W = (H + 35) \div 5$. The crest width for earth dams over 100 feet high must be at least 28 feet.

For existing dams, dam height is measured by using the slope of the downstream channel and the height of the dam at the downstream toe by extrapolating the measured height to the longitudinal centerline of the dam. The formula for determining the vertical height of existing dams is h = hd-fb-s x L where h = height, hd = height of the dam from the downstream toe, fb = freeboard, s = slope of the natural surface of the ground downstream from the dam, and L = measured or computed horizontal distance between the downstream toe and the longitudinal centerline of the dam figure 1.

**Figure 1. Calculating dam height.**




## 7526 - Channel Planning, Investigation, and Design

See FSH 7509.11, section 82, for direction on channel planning, investigation, and design.

## 7527 - Acquisition of Dams by the Forest Service

1. Before a dam is acquired voluntarily, such as through land acquisition or exchange:

   a. Ensure that the owner provides a hazard assessment and a current operation and maintenance (O&M) inspection.

   b. Ensure that the decisionmaking process is informed by an engineering study.

   At a minimum, the engineering study must:

   (1) Identify hazards to downstream life and property and potential hazards if future development occurs;

(2) Include an inspection report prepared by a qualified engineer that documents any deficiencies in the dam, associated risks, recommendations for their remediation, and estimated cost of repairs; and

(3) If a decision is made to acquire the dam, include a life cycle cost analysis performed by a qualified engineer that identifies the long-term cost of operating and maintaining the dam.

c. Document the long-term benefits and liabilities to the Forest Service from the acquisition.

d. Ensure that any deficiencies identified by the qualified engineer in the inspection report that adversely affect operation of the dam or public safety or endanger property downstream are repaired or require the dam to be decommissioned or breached in accordance with applicable Forest Service standards.

e. Immediate breach or drawdown may be inappropriate for tailings dams. Consult with environmental engineering specialists and geotechnical engineers regarding mitigation of hazards present at these sites.

2. If a dam is acquired involuntarily, such as by abandonment, ensure that ownership has vested in the United States (FSM 2716.4). In addition, at a minimum:

a. Ensure that the dam is inspected by a qualified engineer.

b. Consult the local Office of the General Counsel regarding minimizing liability of the United States in connection with the dam and identification of potentially responsible parties who may be held accountable for expenses associated with the dam.