VII. TABULATED SUMMARY

COMPARATIVE LIMITING CRITERIA FOR DAMS AND APPURTENANCES

<table>
<tr><th>DESIGN ITEM</th><th>S.C.S.
(SOIL CONSERVATION SERVICE)</th><th colspan="3">C.O.E.
(CORPS OF ENGINEERS)</th><th colspan="3">U.S.B.R
(BUREAU OF RECLAMATION DIV. DAM SAFETY)</th><th colspan="3">B.L.M.
(BUREAU OF LAND MANAGEMENT)</th><th>F.S.
(FOREST SERVICE)</th></tr>
<tr><td>I. Structure Classification</td><td>Class of Dams</td><td>Category</td><td>Loss of Life (Extent of Development)</td><td>Economic Loss (Extent of Development)</td><td>Classification</td><td>Anticipated Loss of Life</td><td>Economic Loss</td><td>Hazard Category</td><td>Potential for Loss of Human Life</td><td>Potential for Property Damage</td><td></td></tr>
<tr><td>A. Hazard Classification</td><td>(a) Dams located in rural or agricultural areas where failure may damage farm buildings, agricultural land, or township and country roads.*</td><td>Low</td><td>None expected (No permanent structures for human habitation)</td><td>Minimal (Undeveloped to occassional structures or agriculture)</td><td>Low</td><td>0</td><td>Minimal (Undeveloped agriculture, occasional uninhabited structures or minimal outstanding natural resources.</td><td>LOW</td><td>No known potential for loss of human life if the dam should fail.</td><td>No known potential for significant property damage if the dam should fail.</td><td>1. Low Hazard. This applies to dams built in undeveloped areas where failure would result in minor economic loss and damage would be limited to undeveloped or agricultural lands, and improvements are not planned in the foreseeable future. Loss of life would be unlikely.</td></tr>
<tr><td></td><td>(b) Dams located in predominately rural or agricultural areas where failure may damage isolated homes, main highways or minor railroads or cause interruption of use or service of relatively important public utilities.*</td><td>Significant</td><td>Few (No urban developments and no more than a small number of inhabitable structures)</td><td>Appreciable (Notable agriculture, industry or structures)</td><td>Significant</td><td>1-6</td><td>Appreciable (Rural area with notable agriculture, industry, or worksites, or outstanding natural resources).</td><td>SIGNIFICANT</td><td>Little potential for loss of human life if the dam should fail.</td><td>Potential for significant property damage if the dam should fail.</td><td>2. Moderate Hazard. This applies to dams built in areas where failure would result in appreciable economic loss with damage limited to improvements, such as commercial and industrial structures, public utilities and transportation systems, and serious environomental damage. No urban development and no more than a small number of habitable structures are involved. Loss of life would be unlikely.</td></tr>
<tr><td></td><td>(c) Dams located where failure may cause loss of life, serious damage to homes, industrial and commercial buildings, important public utilities, main highways, or railroads.</td><td>High</td><td>More than few</td><td>Excessive (Extensive community, industry or agriculture)</td><td>High</td><td>More than 6</td><td>Excessive (Urban area including extensive community, industry, agriculture, or outstanding natural resources).</td><td>HIGH</td><td>Potential for loss of at least one human life if the dam should fail.</td><td>Potential for large amount of property damage if the dam should fail.</td><td>3. High Hazard. This applies to dams built in areas where failure would likely result in loss of life or economic loss would be excessive. Generally this would involve urban or community type development with more than a small number of habitable structures.</td></tr>
<tr><td></td><td>*Note: Breach analysis is used to evaluate potential damages.</td><td colspan="3"></td><td colspan="3"></td><td colspan="3">Dams are classified for hazard based on the potential for loss of life and property downstream from the structure. Structures less than 6 feet high, regardless of impounding capacity and structures with impounding capacity of less than 15 acre-feet, regardless of height, are exempt from hazard classification. All other dams must be classified for potential hazard. The hazard class is based on the amount of development that might be reasonably expected to occur during the life of the structure as well as upon the degree of existing development.</td><td></td></tr>
<tr><td>B. Size Classification</td><td>*None</td><td colspan="3"><table><tr><td>Category</td><td colspan="2">Impoundment</td></tr><tr><td></td><td>Storage (Ac-Ft)</td><td>Height (Ft)</td></tr><tr><td>Small</td><td>< 1000 & ≥ 50</td><td>< 40 & ≥ 25</td></tr><tr><td>Intermediate</td><td>≥ 1000 & < 50,000</td><td>≥ 40 & < 100</td></tr><tr><td>Large</td><td>≥ 50,000</td><td>≥ 100</td></tr></table></td><td colspan="3">None</td><td colspan="3"><table><tr><td>Size</td><td>Hydraulic Height (feet)</td><td>Maximum Storage (Ac-feet)</td></tr><tr><td>Minor</td><td>6 to 25</td><td>15 to 50</td></tr><tr><td>Small</td><td>25 to 40</td><td>50 to 1,000</td></tr><tr><td>Intermediate</td><td>40 to 100</td><td>1,000 to 50,000</td></tr><tr><td>Large</td><td>> 100</td><td>> 50,000</td></tr></table></td><td><table><tr><td>Admin. Class</td><td>Height (ft)</td><td></td><td>Storage (ft)</td></tr><tr><td>A</td><td>≥ 100</td><td>or</td><td>≥ 50,000</td></tr><tr><td>B</td><td>< 100 & ≥ 40</td><td>or</td><td>< 50,000 & ≥ 1000</td></tr><tr><td>C</td><td>< 40 & ≥ 25</td><td>or</td><td>< 1000 & ≥ 1000</td></tr><tr><td>D</td><td>< 25</td><td>and</td><td>< 50</td></tr></table></td></tr>
<tr><td>Comment:</td><td>*Class (a) dams less that 35 ft. high and with a product of storage times height less than 3000 are covered under less stringent criteria not included in this comparison (PS 378).</td><td colspan="3">All COE dams are considered high hazard for design. The above hazard and size classification is for existing dams only and is for dam safety purposes.</td><td colspan="3">All USBR dams are considered high hazard for design. The above hazard classification is for existing dams only and is for dam safety purposes.</td><td colspan="3">The size classification of the dam is determined by either the hydraulic height or the detention/impoundment capacity of the dam, whichever yields the larger size category.</td><td></td></tr>
<tr><td>II. Hydrology
A. Precipitation</td><td>NOAA Atlas 2, Vol. IV; NWS-HMR's #38, 49, 51, & 52; 1967 PMP study on Rio Grande Valley (in NM).</td><td colspan="3">Same as SCS plus site specific PMP's furnished by NWS; upcoming HMR 55; Standard Project Precipitation (EM1110-2-1411).</td><td colspan="3" rowspan="4">NOAA Atlas 2 for specific frequency floods for certain sites; NWS-HMR's #36, 43, 49, 51, 52, 55 for PMP in appraisal and feasibility level studies. Site specific adaptations for final design.
PMF Storm - Runoff determined using a constant loss rate based on soils and underlying geology.
Other Storms - Runoff and hydrographs for events in the probability range are determined from stream flow records when they are available. For larger storms runoff is determined using an initial loss plus a constant loss rate based on same parameters as above.
Snowmelt is also a frequent consideration for both PMF and other storms, because many USBR dams control large drainage areas where runoff from snowmelt or rainfall on snow is a significant factor.
Hydrograph duration is a function of rainfall duration and loss characteristics, and lag based on the basin characteristics.
Service spillways provide the primary flood discharge capability at USBR structures and, in most cases, are the only spillway used. They are designed to discharge the total inflow design hydrograph in combination with other outlet works facilities as applicable. (Principal spillways, as such, are not applicable to USBR structures).
Emergency Spillway:
Provided only for protection of dam from overtopping. Not intended to operate except in emergency where other systems (auxiliary spillway, outlet works, etc.) have failed to operate.</td><td colspan="3">Same as SCS</td><td>No specifics used, similar to SCS. See below.</td></tr>
<tr><td>B. Runoff & Hydrographs</td><td>SCS Curve Number procedure & SCS unit hydrographs (NEH 4 & special NM studies).</td><td colspan="3">Regionalized Snyder Unit Hydrograph; coefficient based on actual reproduced runoff events.</td><td colspan="3">Same as SCS</td><td>No specific criteria developed. Typically use SCS criteria for runoff volume and USBR Design of Small Dams for hydrographs.</td></tr>
<tr><td>C. Principal Spillways
1. Storm Duration for Design</td><td>24-hr. or 10-day whichever is more critical when routed (in NM).</td><td colspan="3">A Standard Project Flood (SPF) is used. Duration varies from 6 hr. to 72 hr. and depends on the storm size and the project.</td><td colspan="3">6-hour</td><td>No separate criteria for duration or flow rates. Separate criteria not used for principal and emergency spillways. FSM Section 7531.2.</td></tr>
<tr><td>2. Frequency & Capacity Before Emergency Spillway Operates

(See footnote on sheet 2 of 5).</td><td><table><tr><td>Class of Dam</td><td>Purpose of Dam</td><td>Product of Storage X Effective Height</td><td>Existing or Planned Upstream Dams</td><td colspan="2">Precipitation Data for Maximum Frequency 1/ of Use of E.S. Types:</td></tr><tr><td></td><td></td><td></td><td></td><td>Earth</td><td>Vegetated</td></tr><tr><td>(a)</td><td>single 2/ irrig. only</td><td>< 30,000</td><td>None</td><td>1/2 design life</td><td>1/2 design life</td></tr><tr><td></td><td></td><td>> 30,000</td><td></td><td>3/4 design life</td><td>3/4 design life</td></tr><tr><td></td><td>single or multiple 4/</td><td>< 30,000</td><td>None</td><td>P_{50}</td><td>P_{25} 3/</td></tr><tr><td></td><td></td><td>> 30,000</td><td></td><td>$\frac{1}{2}(P_{50}+P_{100})$</td><td>$\frac{1}{2}(P_{25}+P_{50})$</td></tr><tr><td></td><td></td><td>all</td><td>any 5/</td><td>P_{100}</td><td>P_{50}</td></tr><tr><td>(b)</td><td>single or multiple</td><td>all</td><td>none or any</td><td>P_{100}</td><td>P_{50}</td></tr><tr><td>(c)</td><td>single or multiple</td><td>all</td><td>none or any</td><td>P_{100}</td><td>P_{100}</td></tr></table></td><td colspan="3">No specific frequency assigned to SPF but is in excess of 100 yr. event (typically 40-60% of PMF). (Principal Spillway does not operate). May release through outlet conduit (water supply purpose).

Emergency spillway operates for PMF event only. Crest of emergency spillway is set at SPF elevation or other design floods determined appropriate for the specific site.</td><td colspan="3">1. Major Dams. All detention structures greater than 25 ft. in hydraulic height, or impounding more than 50 acre-feet (includes small, intermediate, and large size dams as defined in Table IV), and all retention dams impounding more than 15 acre-feet, regardless of height (includes minor, small, intermediate, and large size dams).

a. Reservoir Capacity. The design capacity must be sufficient to meet the use requirements after making appropriate allowances for evaporation losses, seepage losses, and loss of reservoir volume due to sedimentation (see BLM Manual Section 7317).
i. Retention dams must be designed with the storage capacity at the spillway elevation such that the project objectives are met for the design life. (Refer to Table 1 for design criteria).
ii. Retention dams with outlet structures should have the entrance elevation of the outlet structure at least 3 feet below the spillway elevation. Outlet structures installed in a retention reservoir must be flood routed. The outlet should be of sufficient size to route at least a 5-year frequency, 6-hour duration rain with no flow through the emergency spillway.</td><td>7531.33 - Spillway Protection. Limit the frequency of use of unlined earth and vegetated spillways to once in 50 years. Provide a lined spillway capable of handling up to 50 year frequency flood to limit use of and protect unlined spillways.</td></tr>
</table>

ITEM	S.C.S.	C.O.E.	U.S.B.R.	B.L.M.	F.S.

S.C.S. (footnotes, continued)

1/ Precipitation amounts by return periods in years. In some areas direct runoff amounts determined by figure 2-1 and 2-2 or procedures in chapter 21, NEH-4 should be used in lieu of precipitation data.

2/ Applies to irrigation dams on ephemeral streams in areas where the annual rainfall is less than 25 inches.

3/ The minimum criteria are to be increased from P_{25} to P_{100} for a ramp spillway.

4/ Class (a) dam involving industrial or municipal water are to be designed with a minimum criteria equivalent to that of class (b).

5/ Applies when the upstream dam is located so that its failure could endanger the lower dam.

B.L.M. (continued)

iii. Dention structures must be designed following the design criteria in Table I so that sufficient dead storage (storage area below outlet structure entrance) is provided to accommodate anticipated sediment, and the storage capacity between the outlet structure entrance and spillway elevation is such that the design storm can be safely flood routed through the structure.

2. Minor Dams. (All detention dams less than 25 feet in hydraulic height, and impounding less than 50 acre-feet, and all retention dams impounding less than 15 acre-feet).

a. Reservoir Capacity. Retention dams must be designed so that the storage capacity at the spillway elevation is approximately the same as the total runoff from the design storm plus the sediment yield. The design storm should be the frequency shown in Table I, for a 6-hour duration rainstorm. The sediment storage should be that shown in Table I. Judgement must be used when good, natural spillways exist at a different elevation.

TABLE I
DESIGN CRITERIA GUIDE

Type of Structure	Minimum Inflow Design Flood Frequency	Minimum Sediment Storage yrs.
A. Retention & Detention Reservoirs (less than 50 acre-feet)	25-yr.	15-yr.
B. Retention & Detention Reservoirs (more than 50 acre-feet)	50-yr.	30-yr.

D. Emergency Spillways

1. Storm Duration for Design

S.C.S.: A minimum of 6-hr. or the Time of Concentration (Tc) whichever is greater.

C.O.E.: Duration varies from 6 to 72 hr.

U.S.B.R.: Emergency Spillway:

Provided only for protection of dam from overtopping. Not intended to operate except in emergency where other systems (auxiliary spillway, outlet works, etc.) have failed to operate.

Auxiliary Spillway:

Used in combination with service spillway and/or flood outlet works designed to operate less frequently than service spillway. Probability of operation is 1 percent or less for any given year. Thus designed to lower standards than service spillway.

B.L.M.: 6-hour

F.S.: No specific criteria for duration. Typically use SCS criteria and USBR Design of Small Dams.

2. Frequency & Capacity

S.C.S.:

Precipitation Data for 1/

Class of Dam	Product of Storage X Effective	Existing or Planned Upstream Dams	Emergency Spillway Hydrograph	Freeboard Hydrograph
(a) 2/	< 30,000	None	P_{100}	P_{100} + 0.12($PMP-P_{100}$)
	> 30,000	None	P_{100} + 0.06($PMP-P_{100}$)	P_{100} + 0.26($PMP-P_{100}$)
	all	any 3/	P_{100} + 0.12($PMP-P_{100}$)	P_{100} + 0.40($PMP-P_{100}$)
(b)	all	None or any	P_{100} + 0.12($PMP-P_{100}$)	P_{100} + 0.40($PMP-P_{100}$)
(c)	all	None or any	P_{100} + 0.26($PMP-P_{100}$)	PMP

1/ P_{100} - Precipitation for 100-year return period. PMP = Probable maximum precipitation.

2/ Dams involving industrial or municipal water are to use minimum criteria equivalent to that of class (b).

3/ Applies when the upstream dam is located so that its failure could endanger the lower dam.

Note: If Tc > 6 hr. the precipitation amounts are to be increased by the values in the applicable NWS references.

C.O.E.: No frequency assigned. Spillway designed to pass PMF with a minimum of 3 ft. freeboard below top of dam.

RECOMMENDED SPILLWAY DESIGN FLOODS

Hazard	size	*Spillway Design Flood (SDF)
Low	Small	50 to 100-yr frequency
	Intermediate	100-yr to 1/2 PMF
	Large	1/2 PMF to PMF
Significant	Small	100-yr. to 1/2 PMF
	Intermediate	1/2 PMF to PMF
	Large	PMF
High	Small	1/2 PMF to PMF
	Intermediate	PMF
	Large	PMF

*The recommended design floods in this column represent the magnitude of the spillway design flood (SDF), which is intended to represent the largest flood that need be considered in the evaluation of a given project, regardless of whether a spillway is provided; i.e., a given project should be capable of safely passing the appropriate SDF. Where a range of SDF is indicated, the magnitude that most closely relates to the involved risk should be selected.

B.L.M.:

TABLE II
DAM SPILLWAY CAPACITY*
Spillway Design Flood (SDF) Capacity Required for Each Size Category of Retention and Detention Dams

Hazard Class of Dam	Minor	Small	Intermediate	Large
LOW	25-50 yr.	50-100 yr.	100 yr.-½ PMF	½PMF-PMF
SIGNIFICANT	50-100 yr.	100 yr.	100 yr.-½ PMF	½PMF-PMF
HIGH	100 yr.	100 yr.-½	½PMF-PMF	PMF

*U.S. Army Corps of Engineers, Recommended Guidelines for Safety Inspections of Dam

The above criteria should be used to design the dam's spillway or emergency overflow. The spillway should pass the desired volume of floodwater without serious structural damage to the dam. For flood routing, the worst-case assumption is that the reservoir is filled, that any outlet works are not operational, and that the entire additional volume of water is routed through the emergency spillway or overflow.

The recommended design floods in Table II represent the magnitude of the spillway design flood (SDF), which is intended to represent the largest flood that need be considered in the evaluation of the safety of a given project. Where a range of SDF is indicated, the magnitude that most closely relates to the involved risk should be selected. (These are based on 6-hour duration storms.)

F.S.:

RECOMMENDED SPILLWAY DESIGN FLOOD

Hazard Potential	Size Class	Spillway Design Flood
Low	A	½ PMF to PMF
	B	100 yr. to ½ PMF
	C	50 yr. to 100 yr.
Moderate	A	PMF
	B	½ PMF to PMF
	C	100 yr. to ½ PMF
High	A	PMF
	B	PMF
	C	½ PMF to PMF
	D	100 yr. to ½ PMF

III. Sedimentation

A. Required Sediment Storage

S.C.S.: Provide design floodwater storage capacity afer loss of volume from sedimentation.

SCS procedures (TR-12 & NEH-3) and MUSLE.

The volume of required sediment storage is that predicted for the economic life of the structure used in the project justification (100 yrs., 50 yrs., etc). Maximum legislative limitation is 12,500 Ac-ft.

C.O.E.: Provide design capacity after loss of volume from sedimentation. Sediment quantities are based and computed on actual measurements where available. Procedures have varied from project to project.

U.S.B.R.: Sufficient storage space is provided such that the required active capacity of the reservoir is still available at the end of the economic life of the reservoir. USBR has specific criteria and procedures of its own.

B.L.M.: Provide design capacity after loss of volume from sedimentation.

Use BLM procedure, Manual 7317.

F.S.: Provide for a sediment pool to compensate for the volume of sediment expected to accumulate during the design life of the reservoir.

IV. Hydraulics

A. Principal Spillways

1. capacity

S.C.S.: Frequently restricted to regulate flows to the levels assumed for downstream benefits and project formulation; otherwise full pipe flow is used.

Minimum capacity is as required to reduce the floodwater pool to 15% of the maximum floodwater pool in 10 days or less

C.O.E.: As a minimum, low level discharge facilities will be sized to reduce the pool, within a period of four months, to the higher of the following pool levels: (a) a pool level that is within 20 feet of the pre-project "full channel" elevation, or (b) a pool level which will result in an amount of storage in the reservoir that is 10 percent of that at the beginning pool level. The beginning pool level for drawdown will be assigned at spillway crest for uncontrolled spillways and at top of spillway gates for controlled spillways. Inflow into the lake during the drawdown period will be developed by obtaining the average flow for each month of the year. The drawdown period inflow will then be assumed equivalent to the average flow of the highest consecutive four-month period.

U.S.B.R.: USBR does not use the conventional SCS Principal Spillway for their project purposes.
30" minimum for free flow outlet works - limit free flow cross section to 75 percent of pipe area. Normally use cast-in-place conduits with continuous reinforcement through joints.

No minimum capacity requirements. Depends on location or reservoir and if major damage or lost lives is a factor whether the releases are limited to channel capacity.

Maximum unit discharge for open chutes is usually limited to 500 cfs/ft of width.

B.L.M.: Drawdown time for detention dams must also be considered, as required by State law.

F.S.: For a flood control dam, provide spillway capacity to empty the flood pool in 10 days or less. A smaller spillway may be used if it is needed to limit flood damage downstream from the dam or to comply with legal requirements. When a smaller spillway is used, take measures to offset damage that may result from prolonged storage or outflow.

<table>
<tr><th>ITEM</th><th>S.C.S.</th><th>C.O.E.</th><th>U.S.B.R.</th><th>B.L.M.</th><th>F.S.</th></tr>
<tr><td>2. Crest of low-or single-stage elevation</td><td>At the sediment pool or other permanent pool (recreation, etc.).</td><td></td><td>At the top of the active conservation or top of flood control pool.</td><td>At the sediment pool or other permanent pool (recreation, etc) Must be at least 3 feet below crest of Emergency Spillway.</td><td></td></tr>
<tr><td>3. Routing</td><td>If 80% or more of the retarded floodwater volume is not emptied in 10 days begin routing at the 10-day drawdown elev. from a routed PSH. If 80% or more is emptied begin routing at the filled (end of life) sediment pool or permanent pool whichever is higher.</td><td>Begin at the top of the sediment pool or top of conservation pool.</td><td>Begin at the top of the active conservation pool or elevation where the starting inflow is equal to outflow - whichever is higher. Inflow design flood series generally includes an anticedent flood.</td><td></td><td>Start routing of the spillway design flood for flood control dams at the elevation of the water surface that would exist after 10 days of drawdown from the flood pool.

For a reservoir without a flood pool, start routing of the spillway design flood at the lowest uncontrolled spillway crest elevation.</td></tr>
<tr><td>4. Risers</td><td>Weir or pipe control for single stage risers. Orifice control also employed for two stage risers. Special design configuration is required if the conduit velocity exceeds 30 fps, or for conduits greater than 48". Model studies normally required if velocity > 50 fps.
Standard riser designs available.</td><td></td><td>Glory hole spillways are designed for throat control at maximum water surface, unless earlier throat control is needed for limiting downstream releases.</td><td></td><td></td></tr>
<tr><td>5. Minimum Conduit Sizes:</td><td><table>
<tr><th>Class Dam</th><th>Fill Height</th><th>on yielding foundation</th><th>on non-yielding foundation</th></tr>
<tr><td>RCP: (a)</td><td>all*
< 50'
> 50'</td><td>30"
18"
24"</td><td>-
18"
24"</td></tr>
<tr><td>(b)</td><td>all*
all</td><td>30"
24"</td><td>24"</td></tr>
<tr><td>(c)</td><td>all</td><td>30"</td><td>24"</td></tr>
</table>
*Unless a joint extension safety margin > 1.5" is provided in which case the smaller sizes can be used.
CMP or WSP may be used for single purpose class (a) dams with a product of storage times height less than 10,000 when the height of fill is less than 25 ft. and the pipe is structurally adequate and watertight. In this case the minimum diameter is 18".</td><td>36" minimum.</td><td>Conduit size is not limited to dam classification. Usually try to go to tunnels when embankment exceeds 150 feet over conduit.</td><td>Major dams - 18" minimum
Minor dams - none</td><td>24" minimum</td></tr>
<tr><td>6. Outlet Structures</td><td>The outlet structures are to adequately dissipate energy and be stable.
Standard designs available.</td><td>The outlet structures are to adequately dissipate energy and be stable.</td><td>The outlet structures are to adequately dissipate energy and be stable.</td><td></td><td>The outlet structures are to adequately dissipate energy and be stable.
Proportioning of earth channels and the estimation of the capabilities of natural channels should be based on full consideration of:
1. The erodibility of materials in banks and stream bottom, bank stability, suspended sediment load, bedload and natural stream morphology.
2. The effects on the natural stream regime of changes in alinement, grade, suspended load, quantity of flow and duration of flow.
The proportioning of lined channels should be based on the determination of the most economical and feasible combination of grade and cross-section.
The lower value of "n" should be used in flow computations intended to analyze channel stability. The upper value of "n" should be used in flow computations intended to analyze channel capacity.</td></tr>
<tr><td>7. Outlet Channels
a. Capacity</td><td>Must be stable for the principal spillway design release rate using the "aged" Mannings "n" value for the site conditions.</td><td></td><td></td><td></td><td></td></tr>
<tr><td>b. Stability (earth)</td><td>Design to be non-aggrading and non-degrading using the appropriate methods in TR-25.
i. allowable velocity
ii. tractive force
iii. tractive power
iv. Sediment transport</td><td></td><td>Degradation is taken into consideration with respect to life of dam. Stilling basin floors are lowered to allow the degradation, otherwise special protection such as riprap, afterbays, etc., are used.</td><td></td><td></td></tr>
<tr><td>c. Linings</td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>i. Concrete, reinforced</td><td>min. thickness = 6", V < 10 fps
" " = 7", V > 10 fps</td><td></td><td>No criteria on dam structures or for concrete channels downstream from basin.</td><td></td><td></td></tr>
<tr><td>ii. Riprap size & gradation</td><td>Design to provide protection against degradation and local scour. NHCRP Report 108, USBR Monograph No. 25 and TR-59 are often used. Draft criteria is being developed. Thickness is usually 1.5 to 2 times maximum size. Filter beddings are usually 6" to 1 ft. thick.</td><td>Design to prevent erosion. Specific COE guides and criteria are used.</td><td>Usually use a 3-foot riprap thickness in outlet channels; however, Monograph No. 25 is used as a guide. Filter is usually one half of the riprap thickness.</td><td>None specific.</td><td>None specific.</td></tr>
<tr><td>B. Emergency spillway
1. Minimum capacity</td><td>Must pass the routed freeboard storm identified by the precipitation in Section II.D.2, Emergency Spillway Frequency and Capacity, with reservoir at the top of dam.</td><td>Must pass the routed freeboard storm identified by a proportion of the PMP in Section II.D.2, Emergency Spillway frequency and capacity with reservoir 3 feet below the top of dam.</td><td>Will operate only if all other systems fail to operate properly. The other systems are already proportioned to pass the PMP. Depth is limited and based on erosion potential.</td><td>Not specifically proportioned as to capacity. Provide only to protect dam from overtopping. Not intended to operate except in an emergency when other systems (auxiliary spillway, outlet works, etc.) have failed.</td><td>Must pass the routed freeboard storm identified by a proportion of the PMP in Section II.D.2., Emergency Spillway Capacity with reservoir at top of dam.</td></tr>
<tr><td>2. Crest elevation</td><td>Crest Elevation is set at the elevation of the routed principal spillway storm identified by the precipitation in Section II.C.2., Principal Spillway Frequency and Capacity.</td><td>Crest elevation is set at the elevation of the Standard Project Flood (SPF) or other design floods determined appropriate for the specific site.</td><td>Crest elevation is set above maximum water surface from normal flood routings. Usually located above the influence of any wave action at the maximum water surface.</td><td>Crest elevation of auxiliary spillway is set at 1% frequency level (100 year precipitation) above the service spillway. Crest of the emergency spillway is set higher than the auxiliary but determined on a site by site basis.</td><td>Crest elevation of unlined emergency spillway is set at 2% frequency level (50 year precipitation). Lining is required for floods up to the 50 year flood.</td></tr>
<tr><td>3. Routing</td><td>Routing begins at the highest elevation associated with 1) the lowest ungated outlet, 2) sediment storage, 3) significant base flow water surface or 4) water surface after the 10 day drawdown of the principal spillway hydrograph.</td><td>Routing begins after 5 days drawdown of the SPF.</td><td>Routing begins at the normal reservoir water surface; however, with the other specific spillway systems not operating.</td><td></td><td></td></tr>
<tr><td>4. Types
a. Closed Conduit</td><td>Conduit must have a minimum width to height ratio of 0.75 to 1 but not more than 1.33 to 1.
<table>
<tr><th>Class of Dam</th><th>Drainage Area, sq.-mi.</th><th>Minimum cross-sectional area conduit, sq. ft.</th></tr>
<tr><td>(a)</td><td>all</td><td>12</td></tr>
<tr><td>(b),(c)</td><td>< 10
> 10</td><td>20
*40</td></tr>
</table>
*(30 w/o std, 2-way covered risers)</td><td>Varies</td><td>No specific classifications.</td><td></td><td></td></tr>
</table>

<table>
<tr><th>ITEM</th><th>S.C.S.</th><th>C.O.E.</th><th>U.S.B.R.</th><th>B.L.M.</th><th>F.S.</th></tr>
<tr><td>b. <u>Open Channel</u></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>i. <u>Structural</u></td><td>Minimum depth is 3'; sidewalls must be to top of dam; may be hydraulically proportioned for 2/3 maximum required capacity.</td><td></td><td></td><td></td><td></td></tr>
<tr><td>ii. <u>Earth or Vegetated</u></td><td>Minimum depth is 3'; divider dikes required for each 200' in width; exit channel must be supercritical for discharges above 25% of the design discharge; exit channel slope need not be steeper than S=0.04.

Minimum bulk lengths in the direction of flow are required and are a function of the volume of flow through the spillway per unit width and plasticity of soil. (Using SCS Technical Release No. 52)
Exit channel velocities must be shown shown stable during passage of the ESH (using SCS Technical Release No. 25 and Technical Release No. 60) where failure may allow flow to impinge on the toe of the dam.
Vegetation is established wherever possible for improved allowable velocities.

Riprap is used on and near the crest and other areas to reduce local erosion.</td><td></td><td>Soil erodability is considered based on duration and what can be tolerated. Usually limit depth of flow to 10 ft. maximum and if possible limit velocity to 7 fps in erosive materials.

Vegetation is used where enough moisture is available to sustain growth.

Riprap is used on and near the crest structure to reduce erosion.</td><td>A 20' Level Control section is required. Exit channel slopes must equal or exceed S=0.03.

<u>Minor dams</u> - The spillway must be capable of handling the peak discharge from the design storm. The surcharge storage may be considered in determining the spillway size, but the spillway should be no less than 25 feet in width unless a good natural spillway exists.
<u>Major dams</u> - The spillway for a dam is often a cut section through existing material near one end of the dam. Spillways should not be located on erosive materials that will wash out in a few years or pose an expensive maintenance problem. When a dam must be constructed at a site where a stable spillway section in natural earth material cannot be obtained consider using mechanical outlet works, such as a drop inlet pipe, a chute, or an open drop spillway. Seeding or riprapping the spillway should be performed where necessary.

The designer must consider that the mean annual inflow is the average amount to be received every year over a given number of years. The probability of excessive rainfall has to be considered when setting the emergency spillway elevation. If an earth spillway is used frequently, <u>it will wash out</u> or, at the very least, require excessive maintenance. Secondly, the reservoir may have water in storage when inflow is received. Considering these factors, the emergency spillway could be set at an elevation that will give additional reservoir storage of up to 50% of the mean annual inflow. The exact elevation of the emergency spillway depends on the available spillway site, runoff potential of the site, and emergency spillway site erosive characteristics.

The spillway must be capable of handling the peak discharge from the design storm, as outlined in Table I, without serious spillway degradation. For those structures that meet the criteria for size and hazard classification as outlined in Tables III and IV, Table II must be used to select the storm design of a spillway. The surchage storage may be used when calculating spillway widths.

The spillway should be designed for velocities that will not erode the spillway materials, and for a maximum flow depth of 2 feet, but the spillway width should not be less than 25 feet.</td><td>Design open-channel spillways to conform to the criteria for channel design as set forth in FSM 7540. Spillways may be designed for subcritical flow throughout or for supercritical flow in the exit channel. Supercritical flow in the exit channel is preferred.

Unlined spillways must be able to pass the design discharge without erosion damage to the crest of the spillway. When the design velocity cannot be kept to a nonerosive value, lining is required.

No specific criteria, it is left up to the design engineer.</td></tr>
<tr><td>V. <u>Structural Design</u></td><td></td><td></td><td></td><td></td><td></td></tr>
<tr><td>A. <u>Reinforced Concrete</u></td><td>ACI-318 is used except that fy=40 ksi is used for grades 40, 50 & 60 reinforcing steel. A load factor 1.8 is used for all positive loads. fc = 0.4 f'c and fs = 20 ksi are used in working stress design. SF = 1.5 commonly used for floating and sliding analysis.</td><td>Varies</td><td>The same criteria as SCS is used except that the Load factor = 1.7 and Percent steel is limited to 0.375 P_b in strength design.

fc = 0.45 f'c and fs = 24 ksi are used in working stress design.

Different safety factors are used for concrete structures depending on the type of structure and load condition.</td><td>Varies</td><td></td></tr>
<tr><td>B. <u>Reinforced Concrete Pipe</u></td><td>The minimum load assumption is 12 ft. of earth fill. Projecting conduit condition is a required assumption for earth dams.

SF for AWWA C 300 is 1.33 with a 0.01" crack in 3 edge bearing.

SF for AWWA C 301 is 1.00 with a 0.001" crack in 3 edge bearing.</td><td></td><td>Reinforced concrete pipe is generally not used in dams. When AWWA C300 is used elsewhere individual structural analysis is made using Olanders Method, a Load factor of 1.8, fy = 33,000 psi for the cylinder and fy = 40,000 psi for the reinforcement

When AWWA C301 is used a stress design method is used.</td><td>Bedding and compaction of outlet structure must be select backfill, compacted to 95% maximum density (AASHTO T-99). In addition, concrete pipe must be supported in a concrete cradle.</td><td>No specific criteria, it is left up to the design engineer.</td></tr>
<tr><td>C. <u>Corrugated Metal Pipe & Welded Steel Pipe</u></td><td>A corrosion investigation is required.

Used only in class (a) dams with a storage times height less than 10,000 and fill heights less than 25 ft. Maximum diameter in dams is 18"; Fed. Spec. WW-P405 is used for CMP and Manual M-11 is used for WSP.</td><td></td><td>Not used in dams. Elsewhere Fed. Spec. WW-P405 is used for CMP and AWWA C200 and Manual M-11 is used for WSP.</td><td>A soil test should be performed to determine "years to perforation" to aid in the selection of the conduit type and any necessary coating to extend the life of the conduit</td><td>Corrugated metal pipe is not used in dams. The use of welded steel pipe is up to the designer; accepted standards are used for this.</td></tr>
<tr><td>VI. <u>Earth Embankment</u>
A. <u>Height</u></td><td>The top of dam is set at the greater of the routed FBH or ESH plus that needed for wave action and post construction settlement.</td><td>The top of dam is set at the routed PMF plus the greater of the following:
1. 3' (min) freeboard
2. post construction settlement + wave runup
3. 3% of embankment height (Seismic Zones 2 and 3 only)</td><td>Top of dam excluding camber, crown and crest surfacing is set at the reservoir level obtained by routing the inflow design flood plus the following:
1. Reservoir wind setup and wave runup (3' min.)
2. Post construction setting and
3. Provision for frost and desiccation cracking.
4. Effects of possible malfunction of spillway or outlet works.
5. Allowance for crest deformation due to seismic effects if deformation is greater than the difference between the normal watersurface and the top of dam as determined by other considerations.</td><td><u>Minor Dams</u> - Freeboard. The freeboard between the spillway elevation and elevation of the dam crest must be a minimum of 3 feet, unless otherwise required by State law.

<u>Major Dams</u> - Freeboard. The minimum freeboard between the crest of the dam and maximum high waterline (flow depth in spillway)must be 3 feet, unless otherwise required by State law.</td><td>The top of dam is set at the design storm elevation plus wave action.</td></tr>
<tr><td>B. <u>Floodwater Storage</u></td><td>Maximum by legislation is 12,500 Ac-ft.</td><td>Varies - no specific limit</td><td>No specific limit.</td><td>No specific limit</td><td>No specific limit.</td></tr>
<tr><td>C. <u>Top Width</u></td><td><table>
<tr><th rowspan="2">Total Height of Embankment (H) (feet)</th><th colspan="2">Min. Top Width (feet)*</th></tr>
<tr><th>Single Purpose, Floodwater Retarding</th><th>All Other</th></tr>
<tr><td>< 14'</td><td>8</td><td>8</td></tr>
<tr><td>15-19</td><td>10</td><td>10</td></tr>
<tr><td>20-24</td><td>12</td><td>12</td></tr>
<tr><td>25-34</td><td>14</td><td>14</td></tr>
<tr><td>35-95</td><td>14</td><td>$\frac{H + 35}{5}$</td></tr>
<tr><td>95+</td><td>16</td><td>26</td></tr>
</table>
*If used for public roadway minimum the width is 16 ft. for 1-way traffic and 26 ft. for 2-way traffic.</td><td>Varies - depends on other uses of top of dam (road, etc.)</td><td>30 feet minimum required in most cases. It may be increased to accommodate highways; and may be decreased for low, homogeneous dikes which provide freeboard only.</td><td>12 ft. minimum</td><td>For dams up to 100 feet in height, the minimum top width required is 10 feet, but not less than:
$W = \frac{H + 35}{5}$

Minimum top width required for dams over 100 feet in height is 28 feet.</td></tr>
</table>

ITEM	S.C.S.	C.O.E.	U.S.B.R.	B.L.M.	F.S.

D. Slope Stability

S.C.S.

a. Use ICES-LEASE or STABL (incl. RANDOM & WEDGE)
b. Min. seismic coefficient by special study or TM-809-10 NAVFAC P-355 AFM 88-3

Loading Condition	Class Dam	Strength Parameters: Condition	Strength Parameters: Test	Min. Factor of Safety: w/o seismic Force 1/	Min. Factor of Safety: w/seismic Force 2/
End of Construction	all	w/excess pore press w/o excess pore press	UU CD(orCU)	1.4 2/	NA
Steady Seepage from Highest Principal Spwy. crest	all	Emb. only; w/o seismic:	CD(orCU)	1.4	1.0
		w/seismic, use the more limiting of:	CU or CD(or$\overline{CU}$)	1.5	1.0
		Found. included; use the more limiting of:	CU or CD(or$\overline{CU}$)	1.5	1.1
Sudden Drawdown, Complete and/or partial	all	Emb. only; use the lowest from a composite strength envelope of:	CU and CD(orCU)	1.3 3/	NA
		Found. included; use the more limiting of:	CU or CD(or$\overline{CU}$)		

1/ Factor of safety for an infinite slope analysis is to exceed 1.0 for class (a) and 1.1 for classes (b) & (c)

2/ A factor of 1.3 may be used where limiting failure surface is entirely within embankment

3/ A factor of 1.2 may be used where limiting failure surface is entirely within the embankment

C.O.E.

a. Same as SCS

b. Same as SCS

Minimum Factors of Safety 1/

Case No.	Design Criteria	Minimum Factor of Safety	Shear Strength	Remarks
I	End of Construction	1.3 2/	Q or S 3/	Upstream and downstream slopes
II	Sudden drawdown from maximum pool	1.0 4/	R, S	Upstream slope only. Use composite envelope. See fig. 4
III	Sudden drawdown from spillway crest or top of gates	1.2 4/	R, S	Upstream slope only. Use composite envelope. See fig. 4
IV	Partial pool with steady seepage	1.5	$\frac{R+S}{2}$ for R<S, S for R>S	Upstream slope only. Use intermediate envelope. See fig. 5
V	Steady Seepage with maximum storage pool	1.5	$\frac{R+S}{2}$ for R<S,	Downstream slope only. Use intermediate envelope. See fig. 5
VI	Steady Seepage with surcharge pool	1.4	S for R>S	
VII	Earthquake (Clases I, IV and V with seismic loading)	1.0	5/	Upstream and downstream slopes

1/ Not applicable to embankments on clay shale foundations.

2/ For embankments over 50 ft. high on relatively weak foundations use minimum factor of safety of 1.4.

3/ In zones where no excess pore water pressures are anticipated, use S strength.

4/ The safety factor should not be less than 1.5 when drawdown rate and pore water pressures develop from flow nets (Appendix III) are used in stability analyses.

5/ Use shear strength for case analyzed without earthquake except that it is not necessary to analyze sudden drawdown for earthquake effects.

6/ Q≡UU; R≡CU; S≡CD.

U.S.B.R.

a. Limit equilibrium method of Spencer using USBR version of SSTABl by Wright.

b. Seismic coefficients not used in stability analysis procedure - displacement is estimated by Newmark's procedure.

	Safety Factors
End of Construction Embankment Soils: UU for clays and silts w/no drainage. CD for drained conditions Foundation Soils: UU for clays and most silts CD for sands, gravels, and permeable silts. CD for over-consolidated clays and clay shales - residual shear strengths if shear deformation has occurred in the past - Thixotropic strength gain may be investigated to modify residual strengths.	(a) Pore Pressures in dam and foundation. 1.3 for effective stress analysis with laboratory determination of pore pressure and monitoring during construction. 1.5 for total stress or effective stress analysis and no field monitoring of pore pressures. (b) Pore pressures in embankment only 1.3 - Either effective or total stress analysis.
High Level Steady State CD for embankment and foundation soils. See remarks under End of Construction state for residual shear strength consideration.	1.5
Rapid Drawdown CD (or $\overline{CU}$) for embankment materials (depending on permeability of material). CD (or $\overline{CU}$) for foundation soils. Rate of loading in Test is Extremely Critical for over consolidated Clays and Clay Shales	1.3 for drawdown from either normal or maximum water surface.

B.L.M.

Slopes. The upstream slopes must not be steeper than 3:1 and the downstream slope must not be steeper than 2:1.

Minor Dams - Compaction. Semicompaction is required as a minimum. Semicompaction means that compaction obtained by placing the embankment material by scraper type equipment in approximately horizontal layers, 6 inches in thickness, and distributing the equipment travel over the entire width of the embankment so as to obtain uniform compaction while placing the material.

For dams which will impound more than 15 acre-feet of water and for all dams where failure would present a hazard to life or property, compaction to 95 percent of maximum density as obtained by AASHTO T-99 is required.

Semicompacted fill heights may be increased by 10 percent to offset settlement.

Major Dams - Compaction. All embankments over 25 feet and any dams with outlet structures must be compacted (watered and rolled) to 95 percent maximum density (AASHTO T-99).

Minor Dams - Cutoff Trench. Cutoff trenches should extend into an impervious layer but be no less than 3 feet in depth. The minimum bottom width of the trench must be 12 feet with 1:1 side slope.

F.S.

Embankment Cross-Section. Design the fill zoning plan and the cross-sectional shape of the dam to ensure that the dam and its foundation will remain stable under any condition of loading and internal seepage that may reasonably be expected to develop during the life of the structure. Stability analyses and settlement analyses will be:

1. Performed by methods conforming to accepted engineering practice.
2. Based on realistic assumption of applied conditions.
3. Based on data obtained from competent investigations and the testing of representative samples of materials.

E. Seepage Control

S.C.S.

Site specific, but typically includes:

a. foundation cutoff trenches
b. embankment drains for steady seepage or embankment crack interception
c. blanket drains or toe drains
d. reservoir blankets
e. grouting of surface cracks in rock or rock formations.

C.O.E.

Site specific; similar to SCS.

U.S.B.R.

Site specific, but typically includes:

a. Foundation cutoff trenches
b. Toe drains (and relief wells if needed)
c. Treatment of surface cracks in rock foundations
d. Grouting of permeable (secondary) rock foundations
e. Vertical and horizontal internal drainage zones in the embankment.

B.L.M.

Major Dams - Cutoff Trench. Cutoff trenches should extend into an impervious layer, but must not be less than 3 feet in depth. The trench must extend to a depth that will erase all traces of top soil, shrinkage cracks, root channels, and organic debris. Where the dam is underlain by pervious materials, the trench must be keyed into an imprevious stratum, or to a depth below the ground surface of one-half the height of the dam embankment, whichever is less. The cutoff trench must have a minimum bottom width of 12 feet and minimum side slopes of 1 to 1.

Toe Drains. Toe drains should be incorporated into the design where appropriate, based on embankment and foundation materials.

F.S.

Include such embankment and foundation drains and associated filters as are needed to:

a. Prevent the uncontrolled emergence of water on the downstream slope of the dam.
b. Reduce or neuturalize seepage pressures to prevent failure by piping or heaving.
c. Reduce pore pressures in confined foundation strata.
d. Prevent saturation of zones where shear strength is critical to the stability of the structure.
e. Ensure safe interception and disposal of water from zones that are susceptible to cracking resulting from differential settlement.

When embankments or foundations contain materials that are susceptible to internal erosion or cracking caused by settlement, drainage filters should be provided at all critical discharge faces.

Where adequate quantities of free draining, coarse materials are available, internal drainage needs may often be met by zoning of fill within the dam. When suitable drain fill materials are not available near the site:

a. Drains may be waived for moderate- and low-hazard class D dams so long as the design risk is acceptable and accounted for in the maintenance plan.
b. For all other classes of dams, suitable materials must be imported.

F. Foundation Design

S.C.S.

Site specific, but typically includes:

a. Inplace densities generally in the order of 90% or greater of standard proctor density.
b. Settlement and collapse upon wetting analysis.
c. Strength and stability analysis in conjunction with the compacted fill.
d. Treatment of embankment cracking potential caused by excessive or differential settlement (or collapse in excess of about 5%) by removal, recompaction, foundation drainage, or embankment drains or conbinations of these.