DEPARTMENT FOR NATURAL RESOURCES AND ENVIRONMENTAL PROTECTION
Department for Environmental Protection
Division of Water
(401 KAR 4:030)

RELATES TO: KRS 151.250
PURSUANT TO: KRS 151.125, 224.033(17), 224.045-(6)(b), 13.082
SUPERSEDES: DOW-Rg-2
NECESSITY AND FUNCTION: This regulation is necessary to establish minimum design criteria for dams and associated structures constructed in Kentucky.

Section 1. This regulation applies to all dams as defined by KRS 151.100 and to all other impounding obstructions which might create a hazard to life or property.

Section 2. Except as modified in this regulation, the procedures outlined by the latest edition of "Design of Small Dams" (Second Edition, 1973), available from the U.S. Government Printing Office and the Bureau of Reclamation, herein filed by reference, shall be the minimum criteria.

Section 3. The Division of Water Engineering Memorandum No. 5 outlined as follows: Section A. Definitions; Section B. Structure Classification; Section C. Hydrologic Criteria; Section D. Sediment Storage; Section E. Principal Spillways; Section F. Emergency Spillways; Section G. Earth Embankments; and Section E. Utilities Under Embankments; is hereby incorporated by reference and made a part of this regulation as if fully set out herein. Copies are available from the Division of Water upon request.

Section 4. Structure types not generally used in Kentucky, i.e., gravity, buttress, steel, timber, etc., will be considered on an individual basis and reviewed in accord with prevailing practices that are currently accepted by the engineering profession.

Section 5. In all cases the safety of the structure, the water and/or other material impounded therein, property and human life will be the principal governing factors. Under no circumstances will the proposed use of the structure and its contents, or the cost of providing an unquestionably safe structure be allowed to assume precedence over the possible hazard involved.

Section 6. Structures which are to be repaired or reconstructed must be made to conform to the criteria established by this regulation.

Section 7. Each of the following stated criteria indicates whether the limit is a maximum or minimum limit and is not to be construed as being satisfactory design criteria at all sites. Professional judgment, state laws and regulations, investigations, or analysis may dictate more conservative criteria.

Section 8. (1) Approval of all plans and specifications shall be divided into two (2) distinct parts:

(a) Issuance of a construction permit pursuant to KRS 151.250 shall constitute approval of the final engineering documents to allow construction to be started; and

(b) Final written approval by the department upon receipt of the "as-built" plans and specifications will constitute approval to impound.

(2) No approval to impound water and/or other material is implied or is in any way granted until the "as-built" plans and specifications have been approved, an on-site inspection has been made, and a written statement of approval issued. It is recommended that the owner and/or his engineer contact this division before initiation of final design for a pre-design conference.

Section 9. All plans and specifications submitted for consideration must bear the seal and signature of the responsible engineer as defined in KRS 322.010 (2), except officers and employees of the United States Government while engaged in engineering for the government. Each sheet of the drawings shall bear the seal and signature of the engineer or engineers responsible for its preparation.

Section 10. All structures, other-than Class A as defined in Engineering Memorandum No. 5 (2-1-75) shall have a complete sub-surface investigation and soil analysis submitted as an integral part of the drawings.

Section 11. (1) Elevation area capacity data and elevation discharge data must be submitted as a part of the plans for each structure. This elevation area capacity data shall give the area and capacities from the elevation of the lowest point in the impoundment area to at least the elevation at the top of the dam. When the configuration of the structure will not allow the elevation discharge relationship to be developed by methods accepted as standard by the engineering profession, the structure must provide the storage necessary to contain the entire storm runoff without probable damage to the structure or creating an unacceptable hazard to life or property.

(2) When this required basic information is furnished by the responsible design engineer, the Division of Water will upon request assist the engineering in preparing the floodroutings required by Engineering Memorandum No. 5.

(3) In the event that the elevation area capacity data is not furnished or the floodroutings show that insufficient floodwater storage has been provided, the plans will be returned to the design engineer without being approved.

Section 12. All information concerning elevations shall refer to mean sea level and the use of assumed elevations for any purpose is prohibited. Should an error in either the horizontal control or vertical control become known during construction, the necessary information to correct the distances and the elevations shall be referred to on the first sheet of the "as-built" drawings or referred to in the index. Clearly marked reference points and bench marks shall be maintained at the job site by the responsible engineer until final written approval is received.

Section 13. Unless waived in writing by the department, no structure shall be approved unless a positive means is provided to pass water through the structure in sufficient quantity to satisfy the needs of downstream users and to empty the reservoir within a reasonable length of time. Conditions considered in determining downstream water requirements and required minimum time to empty the impoundment shall be determined by the responsible engineer and referred to on the drawings.

Section 14. Construction supervision and inspection must be performed by or under the direction of the design engineer. Unless otherwise directed by the department the engineer shall submit monthly progress reports on forms to be supplied by the department. Copies of all testing reports shall be submitted with the progress reports.

Section 15. All "as-built" documents shall be submitted by the responsible engineer in the form of permanent type drawings of a standard and uniform size. Variations in size will be permitted for federal agencies in order that they may use their standard drawings. Drawings that do not conform to standard practices or drawings that are not easily legible will not be accepted.

Section 16. Because of the department's statutory duty to review federal projects for the Commonwealth under KRS 151.220, the United States Army Corps of Engineers is exempt from the provisions of this regulation and KRS 151.250.

ADOPTED: March 12, 1975
RECEIVED BY LRC: March 13, 1975 at 2:31 p.m.

DOW/CP-021
Revised 10/80

DEPARTMENT FOR NATURAL RESOURCES AND ENVIRONMENTAL PROTECTION
Department for Environmental Protection

Division of Water
(401 KAR 4:040)

RELATES TO: KRS 151.250
PURSUANT TO: KRS l5l.l25, 224.033(17), 224.045(6)(b), 13.082
SUPERSEDES: DOW-Rg-3
NECESSITY AND FUNCTION: This regulation is necessary to exempt certain dams, embankments, levees, dikes, bridges, fills, and other stream obstructions proposed in conjunction with surface and deep mining from the provisions of KRS Chapter 151 to avoid duplication of effort within the Department for Natural Resources and Environmental Protection.

Section 1. As a part of the routine processing of application for permits for surface mining and the surface effects of deep mining, the engineering staff of the Division of Permits, Bureau of Surface Mining Reclamation and Enforcement, reviews all designs for dams, embankments, levees, dikes, bridges, fills, and other stream obstructions proposed in conjunction with surface or deep mining and, whereas a substantial number of such dams, embankments, levees, dikes, bridges, fills, and other stream obstructions are of such a size, type, and location as to present no potential hazard to life and/or property; this regulation exempts from the provision of KRS 151.250 all such dams, etc., as described above, except those dams which come within the hazard classification contained in Division of Water Engineering Memorandum No. 5 (2-1-75), and those obstructions as described, which, in the professional judgment of the Division of Permits engineering staff, present a potential hazard to life and/or property. Copies of Engineering Memorandum No. 5 (2-1-75) are available upon request from the Division of Water.

Section 2. Certified, "as-built" engineering plans for all dams which impound or divert water and/or other material and which (i) are twenty-five (25) feet or more in height or (ii) have an impounding capacity of fifty (50) acre-feet or more at the lowest point on the top of the dam must be forwarded by the Division of Permits to the Division of Water for inclusion in the Dam Safety Program required by KRS 151.295(c). Height is measured from the natural bed of the stream or watercourse at the downstream toe of the barrier to the low point in the top of the dam.

ADOPTED March 12, 1975
RECEIVED BY LRC: March 13, 1975, at 2:31 p.m.

Department for Natural Resources and Environmental Protection
Division of Water
Engineering Memorandum No. 5

SECTION A - DEFINITIONS

A spillway is an open or closed channel, or both, used convey water from a reservoir. It may contain gates, either manually or automatically controlled, to regulate discharge of water.

The principal spillway is the ungated spillway designed convey the water from the retarding pool at release rates established for the structure.

The emergency spillway of a dam is the spillway designed convey water in excess of that impounded for flood control or other beneficial purposes.

The retarding pool is the reservoir space allotted to the temporary impoundment of floodwater. Its upper limit is the elevation of the crest of the emergency spillway.

Retarding storage is the volume in the retarding pool.

The sediment pool is the reservoir space allotted to the accumulation of submerged sediment during the life of the structure.

The sediment storage is the volume allocated to total sediment accumulation.

The sediment pool elevation is the elevation of the surface the anticipated sediment accumulation at the dam.

An earth spillway is an unvegetated open channel spillway in earth materials.

A vegetated spillway is a vegetated open channel spillway in earth materials.

A ramp spillway is a vegetated spillway constructed on the downstream face of an earth dam.

A rock spillway is an open channel spillway in durable rock materials.

A control-section in an open channel spillway is that section where accelerated flow passes through critical depth.

The inlet channel of an emergency spillway is the channel upstream from the control section.

The exit channel of an emergency spillway is that portion of the channel downstream from the control section which conducts the flow safely to a point where it may be released without jeopardizing the integrity of the structure.

The emergency spillway-hydrograph is that hydrograph used to establish the minimum design dimensions of the emergency spillway.

The freeboard hydrograph is the hydrograph used to establish the minimum elevation of the top of the dam.

Joint extensibility is the length of a pipe joint measured from the center of the gasket to the point of flare of the bell ring or collar when the joint is engaged.

Joint gap is the longitudinal dimension between the end face of the spigot end of a pipe joint and the corresponding face of the bell end of the connecting pipe. It does not include the beveled portions designed for sealing compounds.

The rotation capacity of a pipe joint is the maximum angular deflection possible for the joint without binding or loss of watertightness.

The maximum possible high water is the maximum elevation of the water surface that might be attained either above or below the structure, which may be attributed to structure.

The height of the embankment is the distance in feet measured from the natural bed of the stream or watercourse at the downstream toe of the barrier to the low point in the top of the dam.

SECTION B - STRUCTURE CLASSIFICATIONS

SECTION B - STRUCTURE CLASSIFICATION

In determining structure classification, a number of factors must be considered. Consideration must be given to the damage that might occur to existing and future developments downstream resulting from a sudden breach of the earth embankment and the structures themselves. The effect of failure on public confidence is an important factor. State and local regulations and the responsibility of the involved public agencies must be recognized. The stability of the spillway materials, the physical characteristics of the site and valley downstream, and the relationship of the site to industrial and residential areas all have a bearing on the amount of potential damage in the event of a failure.

Structure classification is determined by the above conditions. It is not determined by the criteria selected for design.

1. CLASS OF STRUCTURES

The following broad classes of structures are established to permit the association of criteria with the damage that might result from a sudden major breach of the structure.

A. Class (A) - Low Hazard

This classification may be applied for structures located such that failure would cause loss of the structure itself but little or no additional damage to other property. Such structures will generally be located in rural or agricultural areas where failure may damage farm buildings other than residences, agricultural lands, or county roads.

B. Class (B) - Moderate Hazard

This classification may be applied for structures located such that failure may cause significant damage to property and project operation, but loss of human life is not envisioned. Such structures will generally be located in predominantly rural agricultural areas where failures may damage isolated homes, main highways or major railroads, or cause interruption of use or service of relatively important public utilities.

C. Class (C) - High Hazard

This classification must be applied for structures located such that failure may cause loss of life, or serious damage to houses, industrial or commercial buildings, important public utilities, main highways or major railroads. This classification must be used if failure would cause probable loss of human life.

The responsible engineer shall determine the classification of the proposed structure after considering the characteristics of the valley below the site and probable future development. Establishment of minimum criteria does not preclude provisions for greater safety when deemed necessary in the judgment of the engineer. Considerations other than those mentioned in the above classifications may make it desirable to exceed the established minimum criteria. A statement of the classification established by the responsible engineer shall be clearly shown on the first sheet of the plans.

II. STRUCTURES IN SERIES

When structures are spaced so that the failure of an upper structure could endanger the safety of a lower structure, the possibility of a multiple failure must be considered assigning the structure classification of the upstream structure.

Additional safety can be provided in either structure by (1) increasing the retarding storage and/or (2) increasing the emergency spillway capacity.

SECTION C - HYDROLOGIC CRITERIA

SECTION C - HYDROLOGIC CRITERIA

I. RUNOFF

Procedures for hydrologic design as contained in the USDA Soil Conservation Service National Engineering Handbook, Section 4 "Hydrology" will be accepted. Copies of this publication are available from the U. S. Government printing office.

The specific references for runoff determination are found in Chapter 10. All runoff volumes for design purposes will be based on Antecedent Moisture Condition II or greater. Chapter 21 contains hydrologic procedures for determining principal spillway capacities, retarding storage, and emergency spillway and freeboard hydrographs.

A. Structures in Series

For the design of a lower structure in a series, if the total drainage area above a lower structure exceeds 10 square miles and Section B-II of this memorandum applies, it is necessary to apply two sets of storms for development of both the emergency spillway and the freeboard hydrographs.

The first set of design storms will be selected for the development of the uncontrolled drainage area above a lower structure. The dimensions of the emergency spillway for a lower structure under this condition will be determined by reservoir routings of hydrographs developed for each storm.

The second set of design storms will be selected for the entire drainage area above the lower structure. Each design storm rainfall is determined by using this area in the areal adjustment of rainfall amounts. These design storm durations are determined by using the time of concentration of this area assuming no upper structures are in place. The design storm hydrographs will be routed through the emergency spillways of the upstream structures and the outflow routed to the lower structure and combined with the hydrograph for the uncontrolled area. The dimensions of the emergency spillway for a lower structure under this condition will also be determined by reservoir routings of the hydrographs developed for each storm.

The design storm imposing the most severe flow condition at the lower structure will be used.

II. PRINCIPAL SPILLWAY

The retarding storage and associated principal spillway discharge will be such that the emergency spillway will not operate more frequently than indicated in Table F-I, Section B, Emergency Spillways. The inflow hydrograph or the minimum runoff volume for developing the balance between principal spillway capacity and retarding storage will be determined by procedures in Chapter 21, Section 4, SCS National Engineering Handbook. In areas where streamflow records can be regionalized and transposed to ungaged watersheds (based on the volume-duration-probability analyses), the Division of Water will authorize the use of these data for developing the principal spillway capacity and retarding storage. When other streamflow data are used, sufficient documentation must be prepared to show how these values were determined.

In the determination of the retarding storage and the principal spillway capacity, it is assumed that the initial reservoir stage is at the crest of the principal spillway.

III. EMERGENCY SPILLWAY

The emergency spillway hydrograph will be routed through the reservoir starting with a water surface at the elevation of the principal spillway inlet or at the water surface elevation after 10 days of drawdown, whichever is higher. The 10-day drawdown will be computed from the maximum water surface elevation which would be attained during the passage of the minimum principal spillway design runoff for that class of structure.

IV. FREEBOARD

The freeboard hydrograph for class (A) and (B) structures will be routed through the reservoir starting at the same water surface elevation as for the emergency spillway hydrograph. The routing of the freeboard hydrograph for class (C) structures may be started at the crest of the principal spillway.

V. MINIMUM HYDROLOGIC CRITERIA

Minimum hydrologic criteria are established for the development of each hydrograph as follows:

Emergency Spillway Hydrograph

Class (A) $P_A = P_{100}$
Class (B) $P_B = P_{100} + 0.12 \times (PMP - P_{100})$
Class (C) $P_C = P_{100} + 0.26 \times (PMP - P_{100})$

Freeboard Hydrograph

Class (A) $P_A = P_{100} + 0.12 \times (PMP - P_{100})$
Class (B) $P_B = P_{100} + 0.40 \times (PMP - P_{100})$
Class (C) $P_C = PMP$

in which P denotes 6-hour design rainfall, P_{100} refers to 6-hour, 100-year precipitation, and PMP represents 6-hour Probable Maximum Precipitation.

The above values may be obtained from the "Rainfall Frequency Atlas of the United States for Durations from 30 Minutes to 24 Hours and Return Periods from 1 to 100 Years", Technical Paper No. 40, Weather Bureau, U. S. Department of Commerce, Washington, D. C., and "Two To Ten-Day Precipitation For Return Periods of 2 To 100 Years In Contiguous United States", Technical Paper No. 49, Weather Bureau, U. S. Department of Commerce, Washington, D. C. These values may also be found in Division of Water, Kentucky Department for Natural Resources and Environmental Protection, Engineering Memorandum No. 2, "Rainfall Frequency Values for Kentucky."

When hydrographs are required for drainage areas with times of concentration in excess of 6 hours, the above must be modified to reflect the appropriate storm period.

<u>The establishment of the above criteria does not eliminate the need for sound engineering judgment but only establishes the lowest limit of design considered acceptable</u>.

It is the responsibility of the design engineer to classify the structure and to determine if the design requirements are in excess of the minimum.

SECTION D - SEDIMENT STORAGE

Where the primary purpose is floodwater retardation or water storage or combination thereof, reservoirs are normally designed on the basis of a 50 to 100-year useful life. In order to assure full effectiveness, capacity must be provided in the reservoir to offset depletion due to sediment accumulation for a period equal to its design life.

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SECTION E - PRINCIPAL SPILLWAYS

SECTION E - PRINCIPAL SPILLWAYS

All component parts of the principal spillway except attached gates and trash racks will be of equal durability. The structural design criteria and detailing of such spillways will conform to recognized standards and codes of practice.

I. CAPACITY OF PRINCIPAL SPILLWAYS

The required capacity of the principal spillway depends on (1) the benefits that accrue to the reduction of the discharge rate, (2) damages that may result from prolonged storage in the retarding pool, (3) damages that may result from prolonged outflow, (4) the possibility of occurrence of significant runoff from two or more consecutive storm events within the time required to empty the retarding pool, and (5) limitations in water rights or other legal requirements.

It is desirable that the retarding pool be emptied in ten (10) days or less. It may be assumed that this requirement has been met if eighty (80) percent of the maximum volume of retarding storage has been evacuated in the ten (10) day period. The use of a longer period must be justified by an appraisal of the considerations listed above.

The discharge through gated outlets will not be considered in determining the emptying time of the retarding pool *unless* a specific reservoir operation plan has been approved and included in the plans.

II. ELEVATION OF PRINCIPAL SPILLWAYS

The crest of a single stage principal spillway will be placed at the elevation of the 50-year sediment pool except where a higher elevation is justified. For a two stage principal spillway, the crest of the lower inlet will be set at the same elevation as for a single stage structure. When a period greater than 50 years has been used for evaluation, it is recognized that structural changes may be necessary to make the structure function effectively during the latter part of its life.

For dry dams, the riser will be designed to permit design discharge at the 50-year sediment pool elevation with provisions for discharging water at lower elevations to satisfy the functional requirements of the structure. Flood routings must start at or above the anticipated elevation of the 50-year sediment pool.

When water is stored for beneficial use, the elevation of the lowest ungated inlet of the principal spillway will be determined by the volume, area, or depth of water required for the planned purpose or purposes in addition to the anticipated sediment storage during the design life.

III. DESIGN OF PRINCIPAL SPILLWAYS

A. Layout

The barrel of drop inlets should be straight in alignment when viewed in plan. Any required changes in alignment will be accomplished by angle changes at joints which do not exceed five degrees or by special elbows having a radius equal to or greater than the diameter or width of the conduit. Thrust blocks of adequate strength will be provided where special pipe elbows are used. They will be designed to distribute the thrust, due to change in direction, for the maximum possible discharge.

Drop inlet barrels will be installed with sufficient camber to insure free drainage to the outlet of all parts of the barrel at the time of construction and under the maximum anticipated foundation consolidation.

B. Conduits

All conduits under an earth embankment must support the external loads imposed with an adequate factor of safety. They must withstand the internal hydraulic pressures without leakage under full external load and settlement. They must convey water at the design velocity without damage to the interior surface of the conduit.

Principal spillway conduits under earth dams must be designed to support fill heights greater than the original constructed height where there is a reasonable possibility that it may become desirable to raise the embankment height at a later date to incorporate additional storage.

Principal spillway conduits are to be of reinforced concrete pipe, cast-in-place reinforced concrete, or ductile iron pipe, unless corrugated steel or welded steel pipe is used in accordance with subsection III-B-2, which follows:

1. Rigid Pipe

Rigid drop inlet barrels will be designed as positive projecting conduits. For reinforced Concrete Water Pipe Steel Cylinder Type, Prestressed, meeting specification AWWA C-301, the 3-edge bearing strength at the first 0.001 inch crack will be used in the design analysis with a factor of safety of at least one.

For reinforced Concrete Water Pipe - Steel Cylinder Type - Not Prestressed meeting specification AWWA C-300, for Reinforced Concrete Water Pipe - Non-cylinder Type - Not Prestressed meeting specification AWWA C-302, and other types of reinforced concrete pipe, the

3-edge bearing strength at the first 0.01 inch crack will be used in the design analysis with a factor of safety of at least 1.33.

Ductile Iron Pipe may be used as a principal spillway conduit under certain conditions. Fill heights and foundation conditions require special considerations such that each use will be checked on an individual basis. Cradling or encasement in concrete may be required in most instances.

Elliptical or other systems of reinforcement requiring special orientation of pipe sections are not permitted in pipe drop inlet barrels.

Reinforced concrete pipe, with or without cradles, will be designed to support at least 12 feet of earth fill above the pipe at all points along the conduit.

These safety factors are for uniform conditions. They should be increased if the strength and compressibility of the foundation are not reasonably uniform.

a. Minimum Inside Diameters on Yielding Foundations.

Class (A) dams: The minimum diameter of the principal spillway barrel will be 30 inches except:

(1) Where a joint extension safety margin of 1.5 inches is used, in which case the minimum diameter is to be 18 inches for fill heights up to 50 feet and 24 inches for greater heights.

(2) Where the drop inlet is designed hydraulically in such a way that the flow in the barrel under all possible conditions of discharge and foundation consolidation is positively known to be open channel flow with the water surface in the conduit subject to atmospheric pressure only, in which case the minimum diameter will be 18 inches.

(3) Where corrugated metal pipe is used the principal spillway must be designed in accordance with conditions presented in Section III-B-2 below.

Class (B) dams: The minimum diameter of the principal spillway barrel will be 30 inches, except where a joint extension safety margin of 1.5 inches is used, in which case the minimum diameter will be 24 inches.

Class (C) dams: The minimum diameter of the principal spillway barrel will be 30 inches.

b. Minimum Inside Diameter on Rock Foundations

Class (A) , (B) , and (C) dams: The minimum diameter of the barrel of reinforced-concrete pressure pipe drop inlets for class (1) dams is to be 18 inches for heights up to 50 feet and 24 inches for heights greater than 50 feet, and 24 inches for all class (B) and (C) dams. The barrel and cradle or bedding are to rest directly on firm bedrock thick enough so that there is essentially no foundation consolidation under the barrel. Under these conditions the cradle under the pipe need not be articulated.

2. Corrugated Metal Pipe and Welded Steel Pipe

Principal spillways of corrugated metal pipe or welded steel pipe may be used for class (A) dams under the following conditions, all of which must be met:

a. The minimum diameter of the barrel will be 18 inches.

b. The height of fill over the pipe will be less than 25 feet.

c. Corrugated steel pipe is to be close riveted, asbestos treated, and asphalt coated, with watertight connecting bands. The minimum gage is to be that specified for 35 feet of fill over the pipe.

d. Welded steel pipe conduits are to conform to ASTM specifications A53, A120, A135, A139, or A134 and are be structurally designed as rigid pipe. A joint extension safety margin of 1.5 inches is to be provided for conduits on yielding foundations. Welded pipe is to be protected by an approved exterior coating.

e. Joints between lengths of corrugated steel or welded steel pipe, other than welded joints, are to electrically bridged on the outside of the pipe with insulated copper wire, #6 AWG or larger, securely attach to uncoated pipe metal at both sides of the joint. The requirement applies whether or not the cathodic protection is completed by the installation of anodes, etc. The wire should have a tough, waterproof insulation designed for direct burial, with a rating of at least 600 volts. Bare wire and exposed pipe metal at the points of connection are to be thoroughly coated with a coating equivalent the original pipe coating to prevent the entry of moisture.

f. Soil investigations for resistivity and pH of the subgrade and backfill materials to be adjacent to the conduit are to be made if corrugated steel or welded steel pipe is to be used. The resistivity measurements are to be made on saturated samples.

g. Cathodic protection is to be provided for welded steel pipe conduits according to approved engineering criteria.

h. Cathodic protection meeting the above requirements is to be provided for corrugated steel pipe in soil whose resistivity in a saturated condition is less than 4000 ohms/cm^3 or whose pH is lower than 5.0.

i. If cathodic protection for corrugated steel or welded steel pipe is not required according to the above criteria and is not installed during construction of the dam, pipe-to-soil potentials are to be measured within the first two (2) years after construction when the soil around the conduit is estimated to be at its normal post-construction moisture content, and cathodic protection is to be installed if such measurements indicate it is needed.

C. JOINTS

Conduit joints will be designed and constructed to remain water tight under maximum anticipated hydrostatic head and maximum probable conditions of joint opening including the effects of joint rotation and a margin of safety where required.

The required joint extensibility is equal to the unit horizontal strain in the earth adjacent to the barrel, multiplied by the length (in inches) of the section of barrel between joints, plus the extension (in inches) due to calculated joint rotation, plus a margin of safety if required. A margin of safety of 0.5 inch is recommended. The required joint extensibility, plus the maximum permissible joint gap equals the required joint length.

The calculation of the required joint extensibility for any particular dam and spillway depends, among other things, on the evaluation of the maximum potential foundation consolidation under the spillway barrel. For Classes (B) and (C) dams, the consolidation will be estimated from adequate foundation borings and samples, soil mechanics laboratory tests and engineering analysis.

For those Class (A) dams where undisturbed foundation samples are not taken for other purposes, approximate procedures based on soil classification and experience will be used for estimating foundation consolidation. When AWWA C-302 or other types of reinforced concrete pipe are used, they will have rubber to steel joints.

Only joints incorporating a round rubber gasket set in a positive groove which will prevent its displacement from either internal or external pressure under the maximum designed joint extensibility will be used on precast concrete pipe drop inlet barrels.

Articulation of the barrel will be provided at each joint in the barrel and at the junction of the barrel and the inlet (riser). Concrete bedding for pipe drop inlets need not be articulated: cradles will be articulated when on yielding foundations.

D. Anti-Seep Collars

All conduits through earth embankments, foundations, and abutments will be provided with anti-seep collars.

The minimum number of anti-seep collars will be determined by the size of collars and the length of that portion of the conduit which lies in the saturated zone of earth embankment.

The following criteria will be used to determine the size and number of anti-seep collars.

Let V = the vertical projection and minimum horizontal projection of the anti-seep collar in feet.

L = Length in feet of that portion of the barrel of a drop inlet or culvert lying within the zone of saturation, measured from the downstream side of the riser to the toe drain, or point where phreatic line intercepts the conduit.

n = Number of anti-seep collars.

The length of the line of seepage is defined as the distance along the line of contact between the earth embankment and the barrel and the anti-seep collars from the upstream end of the barrel to the point of intersection of the barrel and the phreatic line. The ratio of the length of the line of seepage ($L + 2 n V$) to L will not be less than 1.15.

Anti-seep collars should be equally spaced, except where necessary to avoid pipe joints, along that portion of the barrel within the saturated zone at distances of not more than 25 feet.

In the absence of positive evidence to the contrary (for purposes of computing anti-seep collar requirements) the location of the phreatic line in the earth dam embankment will be estimated on the assumption that the foundation of the embankment is impervious or that it is fully saturated.

E. Cantilever - Outlets

The invert of cantilever outlets of pipe drop inlets or culverts at its lower end will be at least one foot above the tailwater elevation of the downstream channel at maximum discharge.

Cantilever outlets will be supported on bents or piers and will extend a minimum of eight feet beyond the bents or piers. The bents will be located downstream from the intersection of the downstream slope of the earth dam embankment with the grade line of the channel below the dam. They will extend below the lowest elevation anticipated in the scour hole.

In determining the depth of the stilling basin, full consideration must be given to the total energy to be dissipated. The stilling basin will be excavated when soil conditions at the downstream end of the cantilever outlet indicate that a stilling basin will not be readily formed without extensive erosion of channel banks or the embankment.

Adequate safeguards must be taken to insure that the seepage forces into the stilling basin will not result in a piping failure.

F. Trash Racks

Trash racks will be designed and built to provide positive protection against clogging of the spillway at any point. The average velocity of flow through a clean trash rack will not exceed two feet per second with the water elevation in the reservoir five feet above the top of the trash rack or at the crest of the emergency spillway whichever is lower. Velocity will be computed on the basis of the net area of opening through the rack.

For dry dams, a trash rack may be used in lieu of a ported concrete riser. The principal spillway trash rack will extend sufficiently above the anticipated sediment elevation at the inlet to provide full design flow through the spillway with velocities through the net area of the trash rack above the sediment elevation not in excess of two feet per second when the water surface in the reservoir is five feet above the top of the trash rack.

G. Anti-Vortex Device

All closed conduit principal spillways designed for pressure flow will have an adequate anti-vortex device.

H. Drawdown Facilities

The necessary drawdown facility for any dam may be made an integral part of the principal spillway structure if the principal spillway configuration warrants, but in no case will the drawdown facility be allowed to be valved on the downstream side of the embankment. This precludes in any case a wet line under pressure through the embankment.

This above stated requirement will be waived in the case of a water supply line through the dam but provision must be made for a positive shutoff on the upstream side of the structure.

Department for Natural Resources and Environmental Protection
Division of Water
Engineering Memorandum No. 5

SECTION F - EMERGENCY SPILLWAYS

SECTION F - EMERGENCY SPILLWAYS

Emergency spillways are provided to convey large flows safely past an earth embankment. They are usually open channels excavated in earth or rock or constructed of compacted embankment or reinforced concrete.

An emergency spillway must be provided for each structure, unless the principal spillway is large enough to pass the routed freeboard hydrograph discharge and the trash that comes to it. A conduit type principal spillway having a barrel with a cross-sectional area of 36 square feet or more, an inlet which will not clog, and an elbow designed to facilitate the passage of trash, is a minimum size and design that may be utilized without an emergency spillway. If a principal spillway of this type and size is not provided, danger from clogging requires the use of an emergency spillway regardless of the volume of storage provided.

A single uncontrolled open channel spillway may be used for all purposes provided it is designed to accommodate all discharges, including the freeboard storm, without damage to the structure. However, a positive means to drain the lake must also be provided unless waived in writing by the Director.

I. SPILLWAY REQUIREMENTS

A. Capacity of Emergency Spillways

Emergency spillways will be proportioned so that they will pass the emergency spillway hydrograph at the safe velocity determined for the site. They will have sufficient capacity to pass the freeboard hydrograph with the water surface in the reservoir at or below the elevation of the settled height of the dam. When the principal spillway is of the size and design that requires the use of an emergency spillway, the capacity of the emergency spillway will not be less than that determined from

$$Q = 230 \times A^{0.5}$$

where Q is the spillway capacity in cubic feet per second and A is the drainage area in square miles but in no case shall a Q of less than 200 cfs be used.

B. Elevation of the Crest of the Emergency Spillway

The minimum crest elevation of the emergency spillway depends on the frequency of operation selected for the specific site. The minimum retarding storage volume and the associated principal spillway discharge will be such that the emergency spillway discharge will not occur during the routing of the runoff from any duration storm of the selected frequency.

C. Hydraulic Design

The relationship between the water surface elevation in the reservoir and the discharge through the emergency spillway will be evaluated by computing the head losses in the inlet channel upstream of the control section, or if a control section is not used, by computing the water surface profile through the full length of the spillway.

Manning's formula will be used to evaluate friction losses and determine velocities. Policy on the selection of the "n" values is given in the discussion of the various types of emergency spillways.

II. VEGETATED AND EARTH EMERGENCY SPILLWAYS

Vegetated and earth emergency spillways are open channels and usually consist of an inlet channel, a control section, and an exit channel (see Section A - Definitions). Subcritical flow exists in the inlet channel and the flow is normally supercritical in the exit channel.

Vegetated emergency spillways are usually trapezoidal in the cross-section and are protected from damaging erosion by a grass cover. They are adapted to sites where a vigorous grass growth can be sustained by normal maintenance without irrigation.

Earth spillways are used in those areas where vegetative growth cannot be maintained. They are similar to vegetated spillways but are designed for lower permissible velocities and less frequent use. Normally they will require more maintenance after a flow occurs.

Earth and vegetated emergency spillways are designed on the basis that some erosion or scour may be permissible if its occurrence is infrequent, if maintenance facilities are provided, and if damage from a severe storm, as represented by the freeboard inflow hydrograph, will not endanger the structure.

A Manning's "n" of 0.040 will be used for determining the velocity and capacity in vegetated spillways. Permissible velocities in earth spillways will be based on an “n” value of 0.020 but the capacity of earth spillways will be based on an appraisal of the roughness condition at the site.

A. <u>Layout</u>

Emergency spillways should be located away from the dam site whenever possible. Topographic saddles generally make good sites.

The layout and profile of vegetated or earth spillways should provide a maximum bulk of material to provide safety against breaching of the spillway during the passage of the freeboard hydrograph. This can be accomplished by the proper selection of the location and layout of the spillway. A long, non-deepened inlet section will provide more bulk but has the disadvantage of requiring a higher stage in the reservoir for any given discharge. The exit channel should be as long as reasonably practical with just sufficient slope to meet hydraulic design requirements. The characteristics and layering of the materials on which the spillway is built must be considered in estimating the volume required to prevent breaching.

The inlet channel will be level for a minimum distance of 30 feet upstream from the control section. This level part of the inlet channel will be the same width as the exit channel, and its centerline will be straight and coincident with the centerline of the exit channel. A curved centerline is permissible in the inlet channel upstream from the level section, but it must be tangent to the centerline of the level section.

The centerline of the exit channel will be straight and perpendicular to the control section for a distance equal to at least one-half of the maximum base width of the dam. Curvature may be introduced below this point if it is certain that the flowing water will not impinge on the dam should the channel fail at the curve.

When a control section is utilized, the grade of the exit channel should be sufficient to insure supercritical flow for all discharges equal to or greater than 25 percent of the maximum discharge through the emergency spillway during the passage of the emergency spillway hydrograph. However, the slope in the exit channel need not exceed 4 percent (s=0.04 ft/ft) to meet this requirement.

The spillway discharge may be conducted by an exit channel to a point some distance above the stable grade of the natural stream channel. When this is done, the discharge is allowed to spread naturally over the existing topography and find its way to the channel downstream. This layout involves no consideration of velocities beyond the exit channel and during spillway discharge there may be considerable erosion on those reaches not designed on a permissible velocity basis.

Another approach is to construct a channel from the end of the exit channel to stable grade below. In this case, the lower constructed channel may be designed with higher velocities than are permissible in the exit channel proper. This assumes that erosion in the lower, well defined, improved channel may be less damaging than that occurring where the discharge is permitted to meander over the natural relief in reaching stable grade.

In both layouts erosion will occur wherever the permissible velocities are exceeded and maintenance will be required to protect the integrity of the spillway.

1. Special Precautions for Class (C) Structures

Special consideration must be given to the layout of spillways on human hazard structures to assure that the spillway will not breach under the most extreme conditions of flow. The length of the exit channel should be increased to the maximum extent possible so that the area most subject to erosion is at a considerable distance from the dam. Within the limitations of the site, the profile of the spillway will be such that a maximum bulk of material is provided.

It is preferable that the flow be confined without the use of levees, but when they are necessary they will be high enough so that they will not be overtopped during the passage of the freeboard hydrograph. Levees will be constructed of erosion resistant materials and will be compacted to the degree necessary to develop this resistance. They will have a toe width not less than 12 feet and, if not protected with riprap, have side slopes not steeper than 3 horizontal to 1 vertical. When constructed on foundations subject to piping or undermining, they will be keyed into the foundation with a compacted core having a width not less than the top width of the levee and sufficient depth to reach sound material, or at least equal to the height of the levee.

Where the bulk or quality of the material in the spillway may be questionable, it may be desirable to provide a crest control structure at the control section. The purpose of this structure is to stabilize the crest of the emergency spillway for at least the period equal to the passage of the freeboard hydrograph. It is subject to eventual failure if the exit channel is not properly maintained.

Consideration should also be given to the reduction of the duration of flow through the emergency spillway by raising the elevation of the crest of the emergency spillway, thereby increasing the volume of storage in the retarding pool. An alternate or complementary procedure is to increase the capacity of the principal spillway by means of a two stage inlet of sufficient size to have an appreciable effect on the outflow hydrograph of the reservoir.

B. Frequency of Use of Earth and Vegetated Emergency Spillways

Table F-I gives the permissible frequency of use of earth and vegetated emergency spillways. For earth spillways, it refers to sites where peak flow of short duration may be expected, and where erosion resistant soils and moderate slopes exist. When vegetated spillways are used, the sites must have these same characteristics, and in addition, conditions must be such that vigorous vegetation can be maintained without irrigation.

TABLE F-1
ALLOWABLE FREQUENCY OF USE OF EMERGENCY SPILLWAYS

Emergency Spillway Maximum Frequency of Use			
Class of Structure	Earth Once In	Vegetated Once In	Rock Once In
(A)	50 years	25 years	10 years
(B)	100 years	50 years	25 years
(C)	100 years	100 years	50 years

When conditions are less favorable, spillways must be designed for less frequent use by (1) raising the elevation of their crest, (2) providing a second stage of greater capacity to the principal spillway, or (3) increasing the capacity of the principal spillway.

The maintenance required for the emergency spillway will be increased as the flow frequency and duration increases. Good design requires balancing the spillway maintenance cost against the increased cost of modifying the other elements of the dam to reduce the flow frequency.

C. Permissible Velocity in Vegetated Earth Emergency Spillways

The maximum velocity limitations given below for vegetated or earth emergency spillways apply to the exit channel. They must not be exceeded from the control section to a point where (1) the distance from the control section is at least equal to one-half the maximum base width of the embankment and (2) a channel failure might cause the flow to impinge on the toe of the dam. The velocity limitations are based on the capacity required by routing the emergency spillway hydrograph and the assumption that uniform flow conditions exist in the exit channel. When the spillway is of the minimum capacity as determined by $Q=230 \cdot A^{0.5}$, the velocity limitation will only apply to the lesser flow that would be developed by routing the emergency spillway hydrograph.

1. Vegetated Emergency Spillways

When the anticipated average use of a vegetated emergency spillway is more frequent than once in 50 years, the maximum permissible velocity will be in accordance with the values given in Table F-II. The values may be increased 10 percent when the anticipated average use is not more frequent than once in 50 years or 25 percent when the anticipated average use is not more than once in 100 years.

The values given will be the upper limit for all grasses. Values for grasses or grass mixtures will be determined by comparison with the values shown, with due consideration given to the growth characteristics and density attained in the local area by the species under consideration.

Where bona fide studies or investigations have been made to determine the permissible velocity for a specific soil, and site, these values may be used in lieu of those shown in Table F-II.

TABLE F-II

PERMISSIBLE VELOCITIES FOR VEGETATED ARTS SPILLWAYS

Grasses or Grass Mixtures		
Soil Type	Slope	Permissible Velocity
Erosion Resistant	0 - 5% 5 - 10%	8.0 fps 7.0 fps
Easily Eroded	0 - 5% 5 - 10%	6.0 fps 5.0 fps

a. Ramp Spillways

The use of ramp spillways is prohibited.

2. Earth Emergency Spillway

The permissible velocity in earth spillways will be chosen after due consideration of the soils involved, the frequency of use of the spillway and other pertinent factors. Table F-III is taken from Fortier and Scobey's study, "Permissible Canal Velocities After Aging", and may be helpful in determining this velocity. The values given for non-cohesive soils are quite applicable and should not be exceeded unless bona fide studies have demonstrated that higher velocities are permissible. The table is not strictly applicable for cohesive soils since it applies to canal beds that are seasoned (perhaps permitting higher velocities) and subject to continuous flow and under conditions where erosion damage cannot be tolerated (requiring lower velocities).

TABLE F-III

PERMISSIBLE CANAL VELOCITIES AFTER AGING*

Original Material Excavated	Feet/Second
Fine sand, non-colloidal	1.50**
Sandy loam, non-colloidal	1.75
Silt loam, non-colloidal	2.00
Alluvial silts, non-colloidal	2.00
Ordinary firm loam	2.50
Volcanic ash	2.50
Fine gravel	2.50
Stiff clay, very colloidal	3.75
Graded, loam to cobbles, non-colloidal	3.75
Alluvial silts, colloidal	3.75
Graded silt to cobbles, colloidal	4.00
Coarse gravel, non-colloidal	4.00
Cobbles and shingles	5.00
Shale and hardpans	6.00

* Recommended in 1926 by Special Committee on Irrigation Research, American Society of Civil Engineers.
** Values shown apply to clear water, no detritus.

On easily erodible soils, consideration should be given to the use of mechanical control on the spillway crest to maintain the elevation and position of the control section.

III. ROCK EMERGENCY SPILLWAYS

Some of the principles used for the layout of earth emergency spillways are applicable to rock emergency spillways. Allowable average frequency of use and permissible velocities must be ascertained for the specific site based on a knowledge of the hardness, condition, durability, and structure of the rock formation. An individual appraisal is necessary to determine the proper roughness coefficient, “n”. In the absence of a complete investigation and a written recommendation to design the spillway as a rock spillway, the material shall be considered earth. A note showing the engineer's recommendation and bearing his seal and signature shall be a part of the plans. Table F-I gives the permissible frequency of use of rock emergency spillways.

IV. STRUCTURAL EMERGENCY SPILLWAYS

Chutes or drops, when used for emergency spillways, will be designed in accordance with the principles set forth in SCS National Engineering Handbook, Section 5, "Hydraulics", Section 11, "Drop Spillways", and Section 14, "Chute Spillways".

All structural concrete shall be designed by a registered professional engineer and shall conform to the latest accepted design codes.

V. WATER SURFACE PROFILE

The design engineer shall compute a complete water surface profile for both the emergency spillway storm and freeboard storm, to include an energy grade line, between the upstream and downstream normal flow depths. This profile shall be a part of the plans and be of such detail as to delineate the required information.

SECTION G - EARTH EMBANKMENTS

I. HEIGHT

The earth embankment will be high enough to prevent overtopping with the most severe of the following conditions: (1) the passage of the freeboard hydrograph or (2) the passage of the emergency spillway hydrograph, plus the necessary freeboard required by the site for frost conditions or wave action.

II. TOP WIDTH

The top width of earth embankments will not be less than the value given by the following equation:

$$W = \frac{H + 35}{5}$$

where H = Height of embankment in feet.
W = Minimum top width of embankment in feet.

III. WAVE EROSION PROTECTION

The earth embankment will be riprapped or other wave protection provided over the full range in stage between the lowest drawdown elevation and at least a few feet above the full normal pond elevation.

SECTION H - UTILITIES UNDER EMBANKMENTS

Existing pipelines, cables and conduits of a wide variety of sizes, materials and functions are frequently encountered at dam sites. These conduits usually are located at shallow depth in flood plain. They constitute a hazard to the safety of the dam and must be (1) relocated away from the site or (2) reconstructed or modified to provide the durability, strength and flexibility equal in all respects to the principal spillway designed for the site.

Every reasonable effort should be made to have such conduits, cables, and pipelines removed from the site. Most utilities and industries will want their facility removed from the site for easy maintenance. Only as a last resort and under the limitations imposed will conduits be permitted to remain under an earth dam embankment.

Conduits permitted to remain under any part of the embankment below the crest of the emergency spillway must be (1) provided with anti-seep collars when the location of the pipe creates a piping potential, (2) properly articulated on all yielding foundations, (3) encased in concrete or otherwise treated to insure durability and strength equal to that of the principal spillway, and (4) made absolutely watertight against leakage either into or out of the pipe.

Enclosure of the conduit, cable or pipeline within another conduit which meets the requirements of this section and which is positively sealed at the upstream end to prevent seepage into the enclosing conduit is acceptable. Such an enclosing conduit will extend the full distance through which the conduit being enclosed is beneath the embankment.