IOWA DEPARTMENT OF NATURAL RESOURCES

Technical Bulletin No. 16

DESIGN CRITERIA AND GUIDELINES FOR IOWA DAMS

December, 1990

IOWA DEPARTMENT OF NATURAL RESOURCES
TECHNICAL BULLETIN NUMBER 16

FLOODPLAIN MANAGEMENT PROGRAM DESIGN CRITERIA AND GUIDELINES FOR IOWA DAMS*

* Adopted by reference 567—72.3(1)”a”, Iowa Administrative Code

CHAPTER I
INTRODUCTION

The purpose of this bulletin is to set forth technical design criteria and guidelines that the Department of Natural Resources will use in reviewing applications to obtain a permit for construction, operation and maintenance or modification of a dam. Other requirements which must be met in order to secure such a permit are outlined in the Iowa Administrative Code under agency number 567. Several chapters of the department's administrative rules in 567 Iowa Administrative Code concern the construction, operation and maintenance of dams as follows:

> Chapter 70 contains definitions of terms used in other chapters.
>
> Chapters 50, 51 and 52 concern water permits which must be obtained to authorize storage of water in surface impoundments.
>
> Chapter 71 explains when approval is required in order to construct, modify, operate and maintain dams.
>
> Chapter 72 lists criteria for approval of dam projects.
>
> Chapter 73 concerns operational procedures for dams, fluctuation of water levels in impoundments, abandonment and removal of dams, inspections of dam sites and dams, and designation of unsafe dams. Chapter 73 applies to all dams whose dimensions or effects exceed the regulatory thresholds in Chapter 71.

Copies of the department's administrative rules may be obtained from the Records Center, Department of Natural Resources, 502 E 9th St, Des Moines IA 50319, upon request.

The above-described rules should be consulted when planning to construct or modify a dam, change the operation or use of a dam, or abandon or remove a dam. This bulletin is part of the above-described rules and is intended for use in conjunction with them. The chapters entitled "Hazard Classifications" and "Lands, Easements, Rights-of-Way" are substantively identical to rules published in the Iowa Administrative Code. These non- technical criteria are repeated in this bulletin for the convenience of the user.

Minimum requirements in this bulletin are labeled as "guidelines" or "criteria" depending on the frequency with which they are likely to be relevant to the safety of a particular type of structure. The distinction between criteria and guidelines is not intended to be rigid. When the applicability of a criterion or guideline to a particular project is not clear to the design engineer, the engineer should consult the department. Any permit issued by the department must explain the reasons for waiving conformity with a criterion or guideline determined to be applicable to the type of structure proposed.

Adoption and Amendment of Bulletin #16. This bulletin has been adopted as part of the department's administrative rules. Pursuant to Section 17A.6(3), Code of Iowa, this bulletin is not published in the Iowa Administrative Code but copies will be made available to the public upon request at no more than the cost of reproduction.

This bulletin may be amended from time to time by rulemaking proceedings. Amended editions of this bulletin will be identified in Chapter 72 of the department's rules by reference to the year and month that the new, superseding edition becomes effective. The user should obtain a copy of current departmental rules as published in the Iowa Administrative Code and compare the edition date on the cover page of this bulletin with the edition date identified in the rules.

CHAPTER II
HAZARD CLASSIFICATION[1]

Dams shall be assigned a hazard class based on the potential consequences of failure. Anticipated future land and impoundment use shall be considered in the determination of hazard class. The criteria in this chapter shall be used to determine hazard class regardless of the methodology used in engineering design of a dam. The hazard class shall determine the design requirements of the structure as outlined in this bulletin. The hazard class shall be evaluated using the following criteria.

A) Low Hazard. Structures located in areas where damages from a failure would be limited to loss of the dam, loss of livestock, damages to farm out-buildings, agricultural lands, and lesser used roads, and where loss of human life is considered unlikely.

[1] This chapter is substantively identical to 567-72.3(2)"a", Iowa Administrative Code.

B) Moderate Hazard. Structures located in areas where failure may damage isolated homes or cabins, industrial or commercial buildings, moderately traveled roads or railroads, interrupt major utility services, but without substantial risk of loss of human life.

   In addition, structures where the dam and its impoundment are of themselves of public importance, such as dams associated with public water supply systems, industrial water supply or public recreation, or which are an integral feature of a private development complex, shall be considered moderate hazard for design and regulatory purposes unless a higher hazard class is warranted by downstream conditions.

C) High Hazard. Structures located in areas where failure may create a serious threat of loss of human life or result in serious damage to residential, industrial or commercial areas, important public utilities, public buildings, or major transportation facilities.

D) Multiple Dams. Where failure of a dam could contribute to failure of a downstream dam or dams, the minimum hazard class of the dam shall not be less than that of any such downstream structure.

CHAPTER III
DESIGN FLOODS

A dam will be required to safely accommodate or pass certain minimum flood events. Routings of the flood hydrograph through the impoundment should begin at an elevation no lower than the normal operating level. The magnitude or frequency of the required flood discharges will vary with the hazard classification, size, and drainage area of the project.

A) Freeboard Design Flood
   The specified freeboard design flood represents the greatest flood the dam must be designed to accommodate. The flood must be passed without overtopping of the dam and endangering its safety or the dam must be designed to withstand such overflow. Some erosion damage in earth emergency spillways will be tolerated, provided the safety of the dam would not be compromised.

   For dams with emergency spillways, the top of dam elevation after settlement shall not be less than the highest peak pool elevation reached during the freeboard design flood. For dams without an emergency spillway, the top of dam elevation shall be two feet higher than the peak flood elevation expected to occur during passage of the freeboard design flood, unless it is specifically designed to withstand the overflow.

   In the following circumstances, the indicated freeboard design flood will be used:

   1) All high hazard dams: the probable maximum flood (PMF).

   2) All moderate hazard dams, and low hazard dams classified as major structures: one-half (0.5) of the probable maximum flood (a flood hydrograph produced by multiplying the ordinates of the PMF hydrograph by a factor of 0.5).

   3) Low hazard dams not classified as major structures:

      a. Where the height of the emergency spillway crest* measured above the elevation of the channel bottom at the centerline of the dam (in feet) multiplied by the total storage volume (in acre-feet) to the emergency spillway crest elevation* is between 3,000 and 30,000, the flood shall correspond to the rainfall calculated from the following formula developed by the USDA Soil Conservation Service.

         Rainfall = P100 + 0.12 (PMP – P100)

      b. Where the height of the emergency spillway crest* measured above the elevation of the channel bottom at the centerline of the dam (in feet) multiplied by the total storage volume (in acre-feet) to the emergency spillway crest elevation* is less than 3,000, the flood shall be that resulting from the 50- year, 24-hour precipitation.

B) Principal Spillway Design Floods and Discharge Capacity
   The principal spillway is normally a concrete or metal conduit or structure which conveys water

through or around the dam. Its size and discharge capacity are governed primarily by the following factors: the need to control flood discharges downstream from the dam, and the need to limit both the depth to which floodwaters are impounded and the length of time for which they are impounded. Related to these factors is the need to limit the frequency of operation of emergency spillways.

Except where special considerations must be addressed, the criteria listed below shall apply to the design of principal spillways. The design floods indicated must be passed by the principal spillway without need for operation of an emergency spillway.

1) Design Floods
   a. High hazard dams – the 100- year flood.

   b. Moderate hazard dams – the 50- year flood.

   c. Low hazard dams with drainage areas of 250 acres or more – the 25-year flood.

   d. Low hazard dams with drainage areas less than 250 acres – the 10-year flood.

2) The spillway discharge capacity shall be sufficient to evacuate at least 80% of the volume of water temporarily stored during the principal spillway design flood within 10 days.

   Where this cannot be accomplished, the emergency spillway and freeboard design flood routings shall be made beginning with the impoundment level at the 10-day drawdown elevation.

3) For dams with emergency spillways of structural concrete or which are excavated into sound rock, a higher frequency of use, and therefore a lower principal spillway design flood, may be permitted if flood control or dam safety would not be adversely affected.

*For dams without emergency spillways, the storage volume and height shall be determined by measuring to the top of dam elevation.

C) Rainfall Depth and Distribution
   Precipitation values for various frequency storm events: 10, 25, 50, 100-year and PMP are contained in the Iowa Department of Agriculture and Land Stewardship publication, Climatology of Iowa Series #2, Revised, Iowa Rainfall Frequencies by Paul Waite. Ten-day rainfall amounts are contained in the National Weather Service publication, Technical Paper No. 49.

   Some acceptable methods of distributing the rainfall in Iowa are found in the USDA Soil Conservation Service publication, TR-60, Earth Dams and Reservoirs; and the Illinois State Water Survey publication, Time Distribution of Rainfall In Heavy Storms by FA Huff.

D) Rainfall Losses
   Conservative loss rates (interception, infiltration, etc.) and antecedent moisture conditions should be used in computing rainfall excess. Also, when applicable, snowmelt runoff rates should be estimated.

   The Soil Conservation Service (SCS) weighted curve number method is acceptable for determining rainfall losses and is explained in National Engineering Handbook Section 4 Hydrology, SCS, 1972.

E) Storm Duration
   Criteria and guidelines for developing design storms from rainfall events are as follows:

   1) The critical duration storm or the storm which results in the highest water level in the impoundment, shall be used in determining the freeboard design flood for a high hazard dam.
   2) Six hour storms are recommended for determining the freeboard design flood for dams designated in paragraphs A (2) and A (3)”a” of this chapter except where the time of concentration exceeds six hours. The 24-hour storm is recommended for dams designated in paragraph A (3)”b” of this chapter.
   3) Twenty-four hour (24-hour) or 10-day storms are recommended for developing principal spillway design floods.

CHAPTER IV
HYDRAULIC & STRUCTURAL CRITERIA AND GUIDELINES FOR SPILLWAYS

The following criteria and guidelines are design considerations which will be used by the department to insure that spillway structures are capable of functioning safely and efficiently and of resisting the forces to which they may be exposed during the life of the structure.

A) Spillways should be designed to operate safely for the life of the structure and at the discharges and pressures which would be experienced under all normal or flood flow conditions including the freeboard design flood.

B) Anti-seepage collars or other means of piping and seepage control (e.g., drainage diaphragms), anti-vortex devices, trash racks or other inlet debris control measures, and outlet stilling basins should be provided for all conduits unless evidence can be presented establishing they are not necessary.

C) For dams where a conduit is proposed to serve as the principal spillway, suggested minimum sizes of the principal spillway conduit for the indicated type of structure are as follows:

    1) High hazard dams and moderate dams classed as major structures – 36-inch inside diameter.
    2) Moderate hazard dams not classed as major structures and low hazard dams, which are classed as major structures – 24 inch inside diameter.
    3) Low hazard dams not classed as major structures but which have drainage areas of 250 acres or more – 18-inch inside diameter.
    4) Low hazard dams with drainage areas under 250 acres – 12-inch inside diameter.

    These minimum sizes are applicable to dams with emergency spillways or which are designed for overtopping only. For dams without emergency spillways, substantially larger conduit sizes with special provisions against plugging will normally be required.

D) Drop inlets (risers) should have an inlet cross-sectional area at least 1.5 times that of the conduit and should be constructed of comparable materials.

E) Conduits and risers should be of sufficient strength and have adequate joints to withstand all anticipated external and internal pressures without damage or leakage, with provisions made for vertical settlement. Conduits should be cambered where significant settlement of the overlying embankment is anticipated. Articulated or bell joints should be provided as necessary to accommodate the maximum elongation estimated to occur during the life of the structure. Risers must be designed to counteract buoyant forces.

F) Corrugated metal pipe conduits and risers should be close riveted with watertight connecting bands and should be fiber bonded, asphalt coated, or given equivalent protection. Cathodic protection shall be provided in corrosive soils. Corrugated metal pipe (CMP) conduits are not recommended for high hazard dams, moderate hazard dams classed as major structures, or where the height of earth fill over the conduit exceeds 25 feet.

G) Concrete conduit and drop inlet (riser) design using precast pipe sections should specify reinforced concrete pressure pipe.

H) Open concrete spillways, concrete box conduits, and concrete flumes or chutes should have longitudinal curbs or raised joints which will prevent contact by normal flows with the construction joint between the floor and wall slabs. Seepage barriers, drainage blankets and drains should be installed where needed to maintain hydraulic flow integrity through the structure and to accommodate anticipated settlement or elongation in the longitudinal or transverse directions.

I) Emergency spillways should be capable of safely conveying excess flood flows around or through the dam. They should not operate except at floods greater than the principal spillway design flood.

J) Earth emergency spillways should be subject to the following minimum requirements at the control section:
    1) Minimum bottom width – 10 feet.
    2) On major structures, minimum depth – 3 feet. On other structures, minimum depth –

2 feet. (Elevation of top of dam minus elevation of emergency spillway crest.)

3) The profile through the emergency spillway should be horizontal for at least 30 feet through the crest control section.
4) Exit channel slopes should not be less than 1% or greater than 10%, but should provide for maintaining critical depth control at the crest.

K) For dams where substantial erosion in the emergency spillway would pose the risk of a dam failure, the flow velocities during the freeboard design flood should be non-erosive. Where such erosion would pose no substantial risk of failure, the flow velocities should be non-erosive at the discharge which occurs when flow through the control section is at 30% of the maximum depth. On vegetated spillways, the non-erosive velocity should be determined assuming the vegetation is well established.

L) Emergency spillways should be constructed in undisturbed soil wherever possible. Where no viable alternative is available, they may be constructed on fill as a ramp spillway.

M) Smooth transitions in horizontal and vertical alignment should be provided at and between the inlet, the control at the crest and the outlet sections of emergency spillways.

N) All spillways should discharge a safe distance from the toe of the dam, and the inlets and outlets should be so located and aligned as to minimize risk of erosion damage to the dam or of damage to downstream buildings, roads, dams or other structures.

O) An adequate energy dissipation structure (stilling basin) or an alternative acceptable method should be incorporated at the outlet of all structural spillways. On major structures, uplift analysis and arching requirements should be considered.

CHAPTER V
EMBANKMENTS

The earth embankment of a dam should be designed and built according to the following criteria and guidelines.

A) Foreslopes and Backslopes. Embankments should be built of suitable materials and with stable slopes. Foreslopes should not be steeper than 3:1 (horizontal to vertical) in till or loess soils below the permanent water level. Above the permanent water level, foreslopes should not be steeper than 2.5:1 in till soil or 3:1 in loess soil. Backslopes should not be steeper than 2.5:1 in till soils or 3:1 in loess soils. Steeper foreslopes or backslopes may be used if justified by soil tests and stability analysis.

B) Settlement Allowance. A minimum vertical settlement allowance of five percent of the depth of fill should be provided unless a lesser amount is justified by soil tests.

C) Top Width. The minimum embankment top width should be 14 feet for dams 25 feet high or higher. As a rule of thumb, the top width could be reduced by two feet for every five feet of reduction in the height of the dam to a minimum width of eight feet. The top width of dams with roads across the crest should be consistent with normal roadway design practices, including roadway and shoulders.

D) Core Trench. Core trenches should be located approximately along the centerline (axis) of the earth fill. It should be continuous across the base of the fill extending into and up the side slopes of the dam abutments to normal reservoir level. The core trench should be excavated to a minimum depth of five feet or until a suitable base material is reached. The base width should be that which will accommodate excavating equipment, but not less than eight feet. The side slopes of the core trench should not be steeper than 1:1, regardless of depth or width of base. Impervious material shall be used in backfilling the core trench.

E) Wave Erosion Protection. On the upstream face of the dam, a horizontal bench or berm at least 10 feet wide usually should be provided at the normal pool elevation to limit damage from wave erosion. On larger impoundments, riprap or other physical means of protection should be considered whether or not the berm is provided.

F) Site Preparation. All vegetation, sod, stumps, and large roots should be removed from the embankment site, and the ground surface scarified to provide bond with the earth fill. Overhanging banks, pits, or holes should be sloped and graded so slopes do not exceed 1:1, and any other sharp discontinuities in the ground surface shall be smoothed. Special consideration should be given to the removal of sandy or mucky deposits unless otherwise provided for in the design.

In till soils, topsoil should be saved and placed as a surface layer over the finished embankment to provide an adequate seed base in establishing vegetation.

G) Fill. Fill material should be clean earth containing no appreciable amounts of vegetation, large rock, frozen material or other foreign substances. Fill should not be placed on a frozen foundation or in freezing weather.

Moisture content of the fill should be sufficient to assure adequate compaction. A moisture content slightly higher than optimum is recommended. An above optimum moisture content is desirable from the standpoint of providing a more plastic embankment capable of resisting greater differential settlement without experiencing potentially hazardous cracking. Unless otherwise specified after soil testing, fill should be placed in horizontal lifts not exceeding eight inches extending over the entire fill area and compacted by not less than four overlapping passes by sheepsfoot or rubber tired rollers. Smooth steel rollers or passes by caterpillar tracks are not considered adequate for compaction of earth-fill dams. The surface of the fill should be scarified or roughened if sufficient time elapses between lifts for a crust to develop.

Backfill adjacent to spillway structures and anti-seep collars should be carefully placed and compacted by hand equipment. Heavy equipment shall not pass over conduit structures until two feet of compacted earth cover is in place.

H) Drains. Internal seepage control drains are recommended for all dams and are normally required on major structures unless soils investigation finds they are not needed. Drains should be capable of preventing saturation of the downstream portion of the embankment by intercepting any seepage through the fill or the foundation and any seepage along structural spillways or conduits.

If springs are encountered during site preparation, drains should be provided to allow a controlled outlet.

I) Seeding. As soon as possible after earth fill for the embankment is completed, the embankment and any other exposed areas should be seeded. Mulch or other means of erosion control can be placed as part of seeding and maintained until vegetation is established. Grass or vegetative species selected for use should be appropriate for the soils and conditions expected at the site. Crown vetch is generally not acceptable for dam embankments or emergency spillways.

J) Riprap. Riprap shall be designed for its expected use and anticipated water velocities. All riprap should be placed on a properly designed bedding unless the gradation of the underlying base material is such that it will not infiltrate through the riprap, or an acceptable filter fabric is used.

K) Groins. Where the embankment foreslopes and backslopes intersect the natural or modified abutment slopes, appropriate groin design and erosion control recommendations should be provided.

Embankments composed of concrete, rock, or other materials, as associated with gravity, rockfill and arch dams, designed in accordance with standards by the Army Corps of Engineers, USDA Soil Conservation Service, or the US Bureau of Reclamation are generally acceptable. These types of dams are not normally constructed in Iowa.

CHAPTER VI
SPECIAL REQUIREMENTS FOR MAJOR DAM STRUCTURES

Because of the size, public importance, or potential hazard of a major dam structure, a higher level of investigation, design and assurance of proper construction is needed. A major dam structure is defined as a dam meeting any of the following criteria.

1. Any high hazard dam.
2. Any moderate hazard dam with a permanent storage exceeding one hundred (100) acre-feet or a total of permanent and temporary storage exceeding two hundred fifty (250) acre-feet at the top of the dam elevation.
3. Any dam, including low hazard dams, where the height of the emergency spillway crest measured above the elevation of the channel bottom at the

centerline of the dam (in feet) multiplied by the total storage volume (in acre-feet) to the emergency spillway crest elevation exceeds 30,000. For dams without emergency spillways, these measurements shall be taken to the top of dam elevation.

As a condition of permit approval, the following items will be required for major dam structures.

A) A soils and foundation investigation shall be made which includes the evaluation of slope stability requirements, anticipated vertical settlement and horizontal elongation, seepage and under-seepage potential, whether cathodic protection is needed for metal pipes, and proper construction practices for the soil types and conditions encountered. Stability evaluation shall include end of construction, steady state seepage and sudden drawdown conditions.

B) Anticipated sedimentation rates and their impact on the life and usefulness of the impoundment shall be investigated. Sediment storage shall be provided in the volume necessary for continuation of design uses of the impoundment throughout its design life.

C) A gated low level outlet shall be provided which is capable of draining at least 50 percent of the permanent storage behind the dam within a reasonable length of time. The pipe conduits shall be designed so that negative pressures will not occur at any point along the system.

D) In order to assess the degree of threat to life and property located downstream of the dam, a dam breach analysis may be required. The analysis will be made to determine the most adverse failure condition and the resulting peak outflows and water surface elevations downstream of the dam following failure of the dam during the freeboard design storm.

E) Construction shall be inspected by an engineer registered under Chapter 114 of the Code of Iowa or by a trained inspector under the supervision of the engineer. The engineer shall prepare and certify as-built plans after completion and a report detailing any unusual circumstances encountered during construction and submit them to the Department of Natural Resources, ATTN: Flood Plains.

F) The applicant, as a condition of the permit, shall submit an annual maintenance and inspection report. The report shall describe maintenance work done since the previous annual report, describe any deficiencies observed in the dam or appurtenant structures, detail the remedial measures necessary and the method and time the applicant proposes to correct the deficiencies found. If there is a change in the land use downstream of the dam, this change should be noted on the annual maintenance and inspection report. The applicant may also be required to provide additional inspections and reports by an engineer or other qualified personnel.

CHAPTER VII
SPECIFICATIONS

When detailed project specifications are prepared, they should include the following information.

A) The general provisions which specify the rights, duties, and responsibilities of the owner, applicant, applicant's engineer, and builder or contractor, and the prescribed order of the work.

B) The technical provisions which describe approved work methods, equipment, materials and desired end results.

C) Special provisions as may be required which describe those technical details that are not usually contained in standard technical provisions.

CHAPTER VIII
DAM BREACH ANALYSIS

A) In some cases, it will be necessary to evaluate the consequences of a dam failure to verify hazard classification or adequacy of design. A special case of dam breach analysis will involve failure or improper operation of flood control gates or other structures.

B) Where such evaluations are made by the department's staff, the necessary data will be obtained from topographic maps or other available information. If that information is not adequate, the applicant may be required to obtain additional downstream survey data.

C) Prediction of the downstream consequences of a hypothetical dam breach requires several component steps: development of the impoundment inflow hydrograph; routing the hydrograph through the impoundment; selecting failure conditions for the structure; calculating the outflow hydrograph from the failed structure; and modeling movement of the flood wave downstream to determine travel time, inundated areas, maximum water surface elevations, etc.

D) The criteria, methodology, and computer programs developed by the US Corps of Engineers, the National Weather Service, the USDA Soil Conservation Service, and the US Geological Survey for simulating a hypothetical dam failure are, in general, acceptable.

CHAPTER IX
OPERATING PLAN

For any dam with gates or other moveable structures which must operate or be operated during times of flood or to provide a minimum downstream release rate, a written operating plan shall be prepared. Development of such a plan is considered part of the design process. The following shall be addressed in preparation of the operating plan.

A) Responsibility
No operating plan can be expected to work properly unless it can be assured the necessary personnel will be present to operate the equipment, or, in the case of automatic equipment, to monitor it and insure it is functioning properly.

The plan shall identify who is responsible for operating and monitoring the equipment and provide means to assure the necessary personnel are present when needed.

B) Operating Circumstances
The circumstances under which operation must occur shall be clearly defined, and a means provided to insure that operating personnel are present when necessary.

C) Method of Operation
The means and methods by which operation is to be conducted shall be clearly defined. Included shall be such items as rates and sequences for opening or closure of gates, pool level vs. gate setting tables, etc., as required.

The operating plan shall allow for safe passage of all floods up to and including the freeboard design flood. Flood discharges through the dam greater than the design peak flood inflows into the impoundment shall not be permitted. In design and analysis, due consideration shall be given to the potential impacts of the operating procedure on both downstream and poolside lands.

The plan should also address low flow situations and should specify a minimum release rate and how it will be provided and maintained.

Consideration shall also be given to and allowance made for the possible failure of or malfunctioning of the equipment.

D) Discharge Measurement
A means shall be provided to determine the discharge through the control structures, especially where operation is to maintain a minimum downstream flow. Control setting vs. discharge tables, streamflow gages or other means of obtaining discharge readings shall be provided. The settings of control structures shall be easily read.

CHAPTER X
LANDS, EASEMENTS, RIGHTS-OF-WAY*

The determination of lands, easements, and rights-of-way required for the construction, operation and maintenance of a dam project are considered part of the design process. An application for approval of a dam project shall include information showing the nature and extent of lands, easements, and rights-of-way, which the applicant has acquired or proposes to acquire for the project. Acquisition of lands, easements or rights-of-way for construction, operation, and maintenance of a dam project shall be consistent with the following criteria.

A) Ownership or perpetual easements shall be obtained for the area to be occupied by the dam embankment, spillways and appurtenant structures, and the permanent or maximum normal pool.

B) Ownership or easements shall be obtained for temporary flooding of areas which would be inundated by the flood pool up to the top of dam elevation and for spillway discharge areas.

C) Easements covering areas affected by temporary flooding or spillway discharges shall include provisions prohibiting the erection and usage of structures for human habitation or commercial purposes without prior approval by the Department of Natural Resources.

D) In locating the site of a dam and in obtaining easements and rights-of-way, consideration should be given to the impacts which changes in land use downstream of a dam and adjacent to the impoundment could have on the hazard class of the dam, the operation of the dam, and the potential liability of the dam owner.

E) The applicant may be required to acquire control over lands downstream from the dam as necessary to prevent downstream development which would affect the hazard class of the dam.

*This chapter is substantively identical to 567—72.3(2)"b", Iowa Administrative Code.

CHAPTER XI
HYDROLOGIC & HYDRAULIC DESIGN REFERENCES

General

Handbook of Applied Hydrology by Ven Te Chow, McGraw-Hill Book Company, 1964.
Handbook of Applied Hydraulics by David and Sorensen, McGraw-Hill Book Company, 1969.
Handbook of Hydraulics by King and Brater, McGraw-Hill Book Company, 1963.
Water Resources Engineering by Linsley and Franzini, McGraw-Hill Book Company, 1963.

US Department of Interior, Bureau of Reclamation

Design of Arch Dams, 1977.
Design of Gravity Dams, 1976.
Design of Small Canal Structures, 1974; Revised Reprint, 1978.
Design of Small Dams, 2nd Edition, 1973; Revised Reprint, 1977.
Discharge Coefficients for Irregular Overfall Spillways, Engineering Monograph No. 9, 1952.
Hydraulic Design of Stilling Basins and Energy Dissipators, Engineering Monograph No. 25, 1978.
Unitgraph Procedures, 1965.

Interim Guidelines for Preparing Inundation Maps for Areas Downstream of Bureau of Reclamation Dams.

Corps of Engineers

Engineering Manuals (EM):
EM 1110-2-1411 Standard Project Flood Determinations.
EM 1110-2-1602 Hydraulic Design of Reservoir Outlet Structures.
EM 1110-2-1603 Hydraulic Design of Spillways.
EM 1110-2-1908 Instrumentation of Earth and Rockfill Dams.
EM 1110-2-2200 Gravity Dam Design.
EM 1110-2-2300 Earth and Rockfill Dams General Design and Construction Considerations.
EM 1110-2-50 Low Level Discharge Facilities for Drawdown of Impoundments.
EM 1110-2-1450 Hydrologic Frequency Estimates.
ETL 1110-2-221 Wave Runup and Wind Setup on Reservoir Embankments.

Mining Enforcement and Safety Administration

Engineering and Design Manual, Coal Refuse Disposal Facilities, 1975.

Soil Conservation Service

National Engineering Handbook
Section 4 – Hydrology
Section 5 – Hydraulics
Section 11 – Drop Spillways
TR-39 Hydraulics of Broad-Crested Spillway
TR-48 Computer Program for Project Formulation-Structure Site Analysis "DAMS-2"
TR-49 Criteria for the Hydraulic Design of Impact Basins
TR-52 A Guide for Design and Layout of Earth Emergency Spillways
TR-55 Urban Hydrology for Small Watersheds
TR-59 Hydraulic Design of Riprap Gradient Control Structures
TR-60 Earth Dams and Reservoirs
TR-61 Computer Program for Water Surface Profiles
TR-66 Simplified Dam Breach Routing Procedure
DN-8 Entrance Head Losses in Drop-Inlet Spillways
SMN-1 Tentative Guides for Determining the Gradation of Filter Materials

National Weather Service

Technical Paper No. 40 – Rainfall Frequency Atlas of the United States (for Duration from 30 minutes to

24 hours and Return Periods from 1 to 100 years), 1961.

Technical Paper No. 49 – Two to Ten Day Precipitation for Return Periods of 2 to 100 Years in the Contiguous United States, 1964.

Hydrometeorological Report No. 51 – Probable Maximum Precipitation Estimates, United States East of the 105th Meridian, June 1978.

DAMBRK: NWS Dam-Break Flood Forecasting Model, November 1979.

Illinois State Water Supply

Precipitation Relations for Use in Dam Safety Project by Floyd Huff, 1980.

Time Distribution of Rainfall in Heavy Storms by Floyd Huff, 1967.

Iowa Department of Agriculture and Land Stewardship

Climatology of Iowa Series #2, Revised, Iowa Rainfall Frequencies by Paul Waite, 1988.

Climatology of Iowa Series No. 3 – Iowa's Greatest 24-Hour Precipitation and Related Storm Data by Paul Waite and Paul Jaeger, 1981.

United States Geological Survey

Bulletin No. 7 – Drainage Areas of Iowa Streams by O.J. Larimer, Reprinted, March 1974.

Bulletin No. 12 – Floods in Iowa, A Comparative Study of Regional Flood Frequency Methods by Oscar G. Lara, 1974.

Water Resources Investigation Report 87- 4132 – Method for Estimating The Magnitude and Frequency of Floods at Ungaged Sites on Unregulated Rural Stream In Iowa, by Oscar G. Lara, 1987.

Federal Highway Administration

Hydraulic Engineering Circulars:

HEC No. 10 – Capacity Charts for the Hydraulic Design of Highway Culverts, November 1972.

HEC No. 11 – Use of Riprap for Bank Protection, June 1967.

HEC No. 13 – Hydraulic Design of Improved Inlets for Culverts, August 1972.

HEC No. 14 – Hydraulic Design of Energy Dissipater for Culverts and Channels, December 1975.

HEC No. 15 – Design of Stable Channels with Flexible Linings, October 1975

Hydraulic Design Series No. 1 – Hydraulics of Bridge Waterways, 2nd Edition, 1970.

Hydraulic Design Series No. 3 – Design Charts for Open Channel Flow, 1973.

Hydraulic Design Series No. 4 – Design of Roadside Drainage Channels, 1965.

Hydraulic Design Series No. 5 – Design of Highway Culverts, September 1985.

Agricultural Research Service

The SAF Stilling Basin, 1959.

Hydraulics of Closed Conduit Spillways, Parts I – XVII.